CONSERVATION OF FRESHWATER FISH IN THE BRITISH ISLES

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ABSTRACT

1. Due to recent glaciation, temperate fish communities are much less diverse than those of the tropics and even in the British Isles there is a marked reduction in species from south to north. Human impact has destroyed fish habitat on a wide scale and many hundreds of populations have disappeared over the last two centuries.

2. The recorded freshwater fish fauna of the British Isles is made up of 13 introduced and 42 native species. Of the latter, two are extinct and eight are threatened in various ways. In addition there are several distinct stocks of common native species and a number of important fish communities which may be under threat.

3. Protection for British fish exists mainly through legislation and protected sites of various designations. The legislation is inadequate in some respects and very few of the protected sites were actually established for their fish interest. Nevertheless, in Great Britain, 37 species of fish occur in National Nature Reserves.

4. The main conservation options for managing freshwater fish resources are habitat restoration, stock transfer to new sites, captive breeding and cryopreservation. The first two of these are regarded as the most useful for the long-term conservation of threatened species. Improved legislation would also help, especially in relation to preventing the import and transfer of potentially harmful species.

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

1. INTRODUCTION

It is clear that in many countries public support for the conservation movement has strengthened and broadened substantially over the last decade. Natural habitats like meadows and mountains, forests and seashores, rivers and lakes as well as wildlife like trees and flowers, butterflies and bees, birds and mammals are all topics of popular interest and concern, but fish - until recently - appear not to be. Fortunately, a number of reviews of the needs of fish conservation in several countries have started to appear in recent years (e.g. Maitland 1974, 1979, 1990, Paepke 1981, Johnson & Rinne 1982, Almaca 1983, McDowall 1983).

Fish are difficult to observe in the wild and so do not have a popular following comparable to field botanists or ornithologists. Instead of being warm and feathery or furry (like birds or bats) they are cold and wet. The public see fish most commonly as dead objects on a fishmonger's slab or served up in batter with chips. Yet there is a substantial interest in living fish among some groups of people. There are now reputed to be 4 million anglers in Great Britain alone but, sadly, their main concern is with the species they wish to catch. Indeed, some anglers do harm in a number of ways, such as moving fish around the country and introducing them as predators or competitors to waters containing rare species (Maitland 1987a). Another major interest group in fish is aquarists but, unfortunately, the great majority of these are uninterested in native temperate fish and are concerned mainly with exotic, often tropical, species (Maitland & Evans 1986).

It is a surprising fact that, world-wide, fish are the most abundant and yet, overall, the least known of the vertebrate classes. About 30,000 species have been described so far and it is likely that the eventual total will indicate that three in every five vertebrate species are fish. Every year, about one hundred new species are described so the final total of species must be well over 30,000. They live in virtually all kinds of aquatic habitat and have developed a wide variety of fascinating form and function.

Fish occur in both marine and freshwater environments, but although fresh waters occupy only a minute fraction of the earth's surface, it has been estimated that one-third of all fish belong to primary freshwater species, mainly carps, characins and catfishes. Because of the fragile nature of freshwater habitats and the pressure which they are under in all parts of the world from human activities, it is this sector of the fish fauna which is under greatest threat.

1.1 Temperate fish communities

For complex geological, climatic and other reasons there are enormous differences between the fish faunas of different parts of the world. This is true for marine fish but it is especially so for freshwater fish where isolation has tended to emphasise the role of historical events. There is a very evident decrease in the general abundance and diversity of fish from the poles to the tropics but the most striking and important differences are among the major continents of the world and even between major river basins in some continents. Unfortunately, progress in fish conservation in different parts of the world bears little relation to the relative importance of the indigenous fish communities there.

Within temperate areas, many fish are relative newcomers to the rivers and lakes they presently inhabit. This is because, at the height of the last Ice Age, only the southern parts of modern north temperate regions were not covered by the great ice cap and thus possessed open waters and fish. As the ice cap retreated north, new virgin lakes and rivers were opened up and gradually fish colonised these. They managed to do so in several ways - by migration around the coast and into new river systems (only possible for euryhaline species able to live in both fresh and sea water), by accident (the connection of watersheds during storms and land movements), by whirlwinds (Elsom 1988) sucking up water (and fish), by egg attachment to waterfowl and by intentional and unintentional introductions by humans. The last is by far the most important method at the moment - for fish distribution is continually changing and many species are still on the advance north from their original preglacial strongholds in the south.

Consequently, like many other groups of organisms, most temperate areas have far fewer fish species than equivalent parts of the tropics, largely because of the impact of past ice ages. Within all north temperate zones these is a distinct north-south trend with perhaps only a few species in the north increasing to a few hundred in the south (e.g. in the British Isles, Shetland has less than 10 species of freshwater fish, whereas southern England has over 40). However, unlike most other groups of organisms, many fish - because of their poor powers of dispersal - are still dispersing northwards and are likely to continue to do so for hundreds of years.

There are certain characteristics of freshwater fish (and some other aquatic organisms) which are especially relevant to the structure of their communities and to their conservation (Table 1). Their habitats are discrete and thus fish are contained within particular bounds. This leads to the differentiation of many independent populations with individual stock characteristics developed since their isolation. It should be noted that this is true even of migratory species; here, even though there is substantial mixing of stocks in the sea, the strong homing instinct has meant that there is a marked tendency for genetic isolation.

Because each population is confined to a single (often small) aquatic system, within which there is usually significant water movement, the entire population is vulnerable to the effects of pollution, disease, etc. Thus for a species the number of separate populations is usually of far greater importance than the number of individuals. Migrations are a feature of the life cycles of many fish and at these times they may be particularly vulnerable. In particular, in diadromous riverine species, the whole population has to pass through the lower section of its river to and from the sea. If this section is polluted, obstructed or subject to heavy predation the entire populations of several species may disappear leaving the upstream community permanently impoverished. This is the situation with several rivers in the British Isles at the moment and such communities may only have about 50 per cent of their previous species complement.

The nature of the life cycles of large slow-growing species (which are easily fished out over their long life-span) and smaller short-lived species (where virtually the whole population may be catchable at one time) means that they are vulnerable to fishing pressures and can be fished to extinction. Because they are confined to discrete systems, all the life cycle requirements for a species must be found within that system. Where this is not the case, species are either migratory or do not establish permanent populations.

Although all of the fish species endangered in the British Isles occur in other countries, many British populations have been isolated for at least 10,000 years and have developed distinct gene pools during that period (Ryman 1981). In some countries, where they are less rare, they are valuable commercially. The importance of conserving this resource for the future in virtually all continents and countries is clearly imperative (Maitland 1977).

1.2 Dangers to fish

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.

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). More research is needed on this important topic. Eutrophication is sometimes thought of as a mild form of pollution whilst the recent acidification from atmospheric pollution of many waters in Scandinavia and elsewhere (Maitland *et al.* 1987) has shown that even waters far away from urbanisation are not necessarily safe.

The impact of various forms of land use on many species of fish can be considerable. 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.

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 (Smith 1972)) to a more or less stable relationship of recruitment and cropping (ideally on a maximum sustainable yield basis) which exists in many old-established fisheries (e.g. that for Brown Trout *Salmo trutta* in Loch Leven (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).

1.3 Fish introductions

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. 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 has 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 *Esox lucius* 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 *Coregonus lavaretus* whose eggs it eats in large numbers.

Perhaps even more surprising than this move within Britain is the enormous move that the Ruffe has recently made from Europe to North America (Maitland & East 1989). In 1987, several Ruffe were found in the St. Louis River where it enters Lake Superior. Subsequent research showed that it is now well established in this part of the lake. It is believed that the original fish were brought accidentally from Europe in the ballast water of seagoing freighters travelling from one of the large rivers of Europe to the Great Lakes. The Great Lakes Fishery Commission is actively trying to introduce legislation which will force such ships to change their ballast water in mid-ocean or treat it to stop any further exotic organisms entering North America in this way.

It is now accepted that the numerous stocks of Atlantic Salmon *Salmo salar* in Scotland and other parts of Europe and eastern North America have been largely separated since the last Ice age and now have some genetic individuality (Ryman 1981). In Scotland, there are about 400 individual rivers with Salmon populations (Maitland 1984, Maitland 1992). For decades, many of these rivers have been subject to indiscriminate stocking which was rarely needed and has practically never been demonstrated to have done any good. Fortunately, this stocking was rarely carried out on a large scale and often native stock from the river in question was used as broodstock. Over the last decade, however, Salmon farming using sea cages has burgeoned in Scotland and annual production in the 1990s is expected to reach 40,000 tonnes which will be about 40 times the catch of wild fish.

One of the features of Salmon farming is that the industry has imported a number of strains of Salmon from abroad (especially Norway). These are being cross-bred with Scottish stocks to develop a domestic race of Salmon with characteristics desired by the industry (fast growth, disease resistance, placid nature, etc.) but unlikely to be advantageous in the wild. There is strong evidence that farmed salmonids are much less fit in the wild than native fish (Maitland 1984). However, farmed fish are being introduced into the wild so frequently and in such large numbers (either intentionally through stocking or unintentionally through escapes and accidents) that there is considerable concern that they may establish themselves and upset the genetic integrity and local adaptation of native stock. For example, a single accidental escape of 1.6 million Salmon fry into one small west-coast river is recorded and there have been numerous other incidents. Already, an appreciable proportion of the adult Salmon appearing in some rivers has originated in farms.

Many introductions of foreign species have been unsuccessful (Table 3).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 *Salvelinus alpinus* populations), (4) finds a 'vacant niche' within the community, which means that it adapts to resources that are ot 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.

Nilsson (1985) also outlines the complex sequence of events which have taken place in Lake Storsjon, where problems arose when the native Brown Trout and Arctic Charr declined because of hydro-electric developments. The American Lake Charr *Salvelinus namaycush* was introduced to the lake as was the crustacean *Mysis relicta*. Initially the Lake Charr did well but then declined as overgrazing of the *Mysis* took place. However, another fish, the Smelt *Osmerus eperlanus* was introduced successfully and there is now an apparently stable and important food chain in the lake comprising American Lake Charr-Smelt-*Mysis* which are all introduced species.

Magnuson (1976) points out that lake faunas are similar in many ways to those of islands - they are isolated, small and relatively young. Thus theories developed for the population dynamics of island populations (McArthur & Wilson 1963) should be relevant to lakes. The number of species in a lake may be the result of equilibrium between rates of immigration of new species and extinction of old ones. The number of species in small isolated lakes would be lower than in large more complex lakes or those more exposed to new species. Instability in species structure would be higher in the latter. The influence of immigration on species structure would be greater in smaller and simpler habitats than larger and more complex ones. Thus human activities in moving fish can increase instability and add greater uncertainty or "chance" into the results of fishery management plans. "Attempts to retain more natural rates of species exchange among lakes may reduce instability and increase predictability in fisheries management" (Magnuson 1976).

In many instances, the introduction of fish for angling is preceded by poisoning out any native stock. Anney (1984) described the application of liquid derris (5% rotenone) to an upland pond in England to eradicate Perch *Perca fluviatilis* there. Brown Trout and Rainbow Trout were introduced within three months and grew well. The conclusion is that the use of rotenone was fully justified and piscicides are quite widely used in the British Isles to eliminate native fish in favour of introduced species.

The great majority of the fish introductions into Great Britain and fish transfers within Britain have been related to angling and it is important that the national angling bodies adopt a more responsible and rational attitude to their activities. One extreme stance has been outlined by Tombleson (1972) who advocates national coarse fish rearing on farms for stocking. He points out that there is no other form of animal husbandry where stock selection and cross breeding is not carried out with great effect. 'The successful management of a good quality coarse fishery is simply another form of animal husbandry.' He also says 'the artificial fertilisation of fisheries will become important in years to come' and that fish production could be increased five-fold by such means.

1.4 Habitat loss

Thus fish face a number of problems, some of them common to other forms of wildlife, others more particular to fish. In addition, there has been habitat loss on an enormous scale, right across the wide range of aquatic habitats which occur in the British Isles (Table 4). 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 of Great Britain. The Rivers Clyde in Scotland and Thames in England are good examples of rivers which formerly had rich and diverse fish populations of some 20-30 species but which eventually became completely fishless in the lower reaches. In recent years, these waters were totally devoid of oxygen and comprised a lethal mixture of various industrial chemicals (Maitland 1987b). Fortunately (see Section 4.1), both rivers are now recovering.

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.

2. EXISTING STATUS

2.1 British freshwater fish

Of the 55 species of fish found in fresh waters in the British Isles (Table 5), none is endemic, three occur only as vagrants and 13 species have been introduced by humans (Table 6). Many of the 42 indigenous species are common and widespread, but several are declining or very restricted in distribution. Most waters contain some fish but a few do not and these include acidic peat pools and acidified waters, grossly polluted waters, high altitude waters and those which dry out periodically.

The indigenous fish species of the British Isles may be classified as: (1) those with a migratory marine propensity, i.e. mostly euryhaline (Table 6), though some are now 'landlocked', (2) those which appear to have mechanisms of dispersal and have moved extensively beyond their original catchments, and (3) those with poor powers of dispersal which are still largely confined to their original catchments.

In the British Isles, and, as discussed above, in north temperate areas in general, the number of fish species decreases from north to south (Maitland 1974, 1977); in mainland Britain, many species are confined to the south and east of the country and only a few are confined to the north and west. Some species are well distributed over most of the country and are found in both standing and running waters, e.g. Atlantic Salmon, Brown Trout (including its anadromous form, the Sea Trout), Pike, Minnow, Roach, Eel, Three-spined Stickleback and Perch (Table 7). Others have a mainly southern distribution and a tendency to occur in standing or very slow-flowing waters (e.g. Crucian Carp, Tench, Bream, Silver Bream, Rudd and Chub) or in running waters (e.g. Sea Lamprey, River Lamprey, Brook Lamprey, Grayling, Gudgeon, Bleak, Dace, Stone Loach, Ruffe, Bullhead and Flounder).

Wheeler & Maitland (1973) have given an account of the species of freshwater fish known to have been introduced to the British Isles. More than 20 species have been liberated at various times, but of these only 13 seem to have been successful and established viable populations. Several species have not survived (Table 3). Two tropical species (*Poecilia reticulata* and *Tilapia* sp) were temporarily successful in waters warmed by heated effluents, but all of these populations seem now to have disappeared.

Various methods have been developed for the objective assessment of the conservation status of plant and animal species. The major classification system used internationally for assessing the status of threat to each fish species is that adopted and developed by the International Union for the Conservation of Nature and Natural Resources (IUCN). The Red Data Book Categories are used by IUCN to indicate the degree of threat to individual species in their wild habitats. Below are given formal definitions of the categories together with additional information and examples to clarify and interpret them in relation to fish (Maitland 1986) for use in this report.

EXTINCT. This category is used only for species which are no longer known to exist in the wild after repeated searches of the type localities and other known or likely places. As interpreted by IUCN, this includes species which are extinct in the wild but surviving in captivity.

ENDANGERED. This category is defined as including taxa in danger of extinction and whose survival is unlikely if the causal factors continue operating. It includes taxa whose numbers have been reduced to a critical level or whose habitats have been so drastically reduced that they are deemed to be in immediate danger of extinction. It may also cover species with populations so critically small that a breeding collapse due to lack of genetic diversity becomes a possibility, whether or not they are threatened by human activities. An example would be a species reduced to *ca.* 100 specimens occurring in one inaccessible lake remote from humanthreats, but where one adverse event (e.g. a land-slide) could remove the whole population. In the case of fish, unlike most plants and other vertebrates, the actual numbers of individuals in the population are less important than the numbers of sites. This is because fish are often so confined within their habitat that one incident (e.g. a poisoning) could destroy every fish present. Thus in theory it would be much safer to have, say, 1,000 fish in each of 10 lakes than 100,000 or more in one lake.

VULNERABLE. These are taxa believed likely to move into the Endangered category in the near future if the causal factors continue operating. Included here are taxa of which most or all of the populations are decreasing because of over-exploitation, extensive destruction of habitat or other environmental disturbance, as well as taxa with populations which have been seriously depleted and whose ultimate security is not yet assured, and those taxa with populations which are still abundant but are under threat from serious adverse factors throughout their range.

RARE. This includes taxa with small world populations which are not at present Endangered or Vulnerable but are at risk. These taxa are usually localised within restricted geographical areas or habitats or are thinly scattered over a more extensive range.

INDETERMINATE. This includes taxa thought to be Extinct, Endangered, Vulnerable or Rare but where there is not enough information to say which of these four categories is appropriate.

The objective of the present classification is to consider the status of each species in the British Isles as a whole and not specifically in any one geographic region. Thus a species could well be endangered or even extinct in one part of the country, but still not be under any significant threat in the British Isles as a whole. The criteria used to classify the conservation status of fish species are outlined in Table 9.

The taxa concerned must be indigenous to the British Isles. They are likely to be more important if they are quite distinct taxonomically and not just members of a close species group. Concern about status will be greater the more restricted the geographic area and habitat of the species concerned. Species with sensitive features of their biology (e.g. Sturgeon, with slow maturation and large adult size) or ecology (e.g. Allis Shad, which needs to migrate through stretches of water where they are particularly vulnerable to pollution or exploitation) are much more likely to be in danger. The populations of such species have shown significant declines through most of their ranges and are therefore especially threatened.

Though many of the data are subjective and based on the best information available at the time of writing, the analysis itself is an objective one and valid for each species. Species introduced successfully into the British Isles (see Table 6) are not regarded as important in conservation terms and therefore not considered further. Perhaps surprisingly, in view of the enormous decline in the numbers and distribution of many species, none is yet extinct in Europe (though two have disappeared from the British Isles). Distinctly threatened species (endangered or vulnerable) are characteristically those fish belonging to very defined taxonomic units of restricted geographic range, which appear to be particularly sensitive to one or more human threats and whose populations or range have undergone significant decline which seems likely to continue.

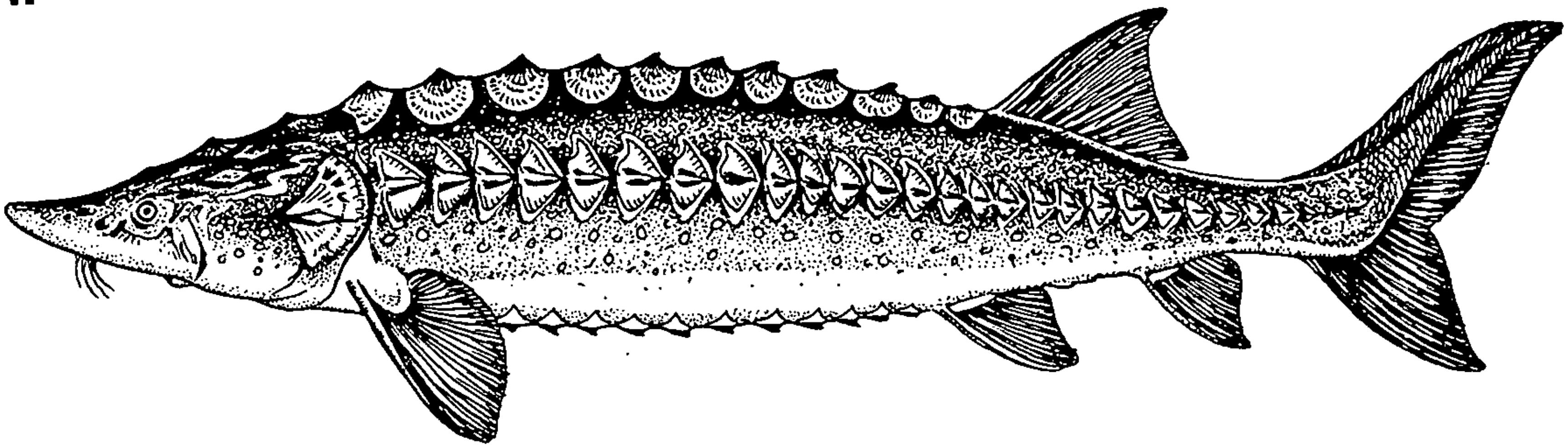
Taking the above criteria into account and using the available data on the origin, dispersion and number of populations (Table 9) an assessment of the present conservation status of all species in the British Isles has been made, using the key in Table 10. From this analysis, 10 species are deemed to be extinct or threatened in the British Isles (i.e. categories I, A, B and C in Table 9) and much of the content of this report is related to the plight of these fish. The major sites and geographic areas for these species are shown in Figure 1.

2.2 Threatened species

Each of the freshwater fish species most threatened in the British Isles (Table 11) is dealt with below in a standard fashion in which the major features of its ecology and status, including angling interest (National Anglers' Council 1991) are highlighted. The conservation measures proposed as necessary for each species are considered later in the report (section 5).

The conservation status of each species under various different assessments (together with the appropriate abbreviation) is listed below. These are: IUCN criteria, as defined above (IUCN 1990); the Bern Convention (BERN), where threatened species can be listed in Appendix II or III (Maitland 1986); the GB Wildlife and Countryside Act (WACA), where threatened species can be listed under Schedule 5; and the present assessment for the British Isles, following the guidelines discussed above (Tables 9 and 10).

1.



1. *Acipenser sturio* Linnaeus 1758 ACIPENSERIDAE

Sturgeon (Baltic Sturgeon)

IUCN: End
BERN: II
WACA: -
BRIS: I

Size. This enormous fish is really only a vagrant to fresh waters in the British Isles since it never breeds here. It regularly grows to lengths of 1-2 m and has been known to reach 3 m or more, with weights well over 200 kg. One of the largest specimens ever recorded was 3.45 m in length and weighed 320 kg. The females usually grow to a larger size than the males. There are no angling records though specimens are occasionally angled accidentally. In July 1933 an angler fishing for Salmon in the River Towy in Wales foul-hooked a huge Sturgeon. The fish eventually beached itself. It was 2.79 m in length, 1.49 m in girth and weighed 196 kg.

Distribution. The original distribution of this magnificent fish was much wider than at present. In the sea it occurred along the entire coastline of Europe from the North Cape to the Baltic, Mediterranean and Black Seas. A similar species occurs along the Atlantic coast of North America. The Common Sturgeon is no longer common and is much scarcer now and occurring only occasionally in our seas and breeding in only a few European rivers, notably the Gironde, Guadalquivir and lower Danube. Usually a few are caught each year off British coasts by commercial netsmen, but only very occasionally now does one ever venture into fresh water here.

Habitat. The adults favour the lower reaches of large rivers for spawning and the young remain here for some time before descending to the sea. Here many of them apparently stay in the nearby coastal waters, though others obviously do move about for considerable distances to be caught many hundreds of miles away. They appear to live mainly over soft sandy or muddy bottoms to which their feeding mechanism is adapted.

Reproduction. After a number of years in the sea, the maturing adults stop feeding and move back to their natal rivers. They enter these in the early spring and move upstream to the spawning grounds which take the form of pools where the water is deep (several metres) and flows over a gravel bed. After spawning, the adult fish (in poor condition for they have not fed since leaving the sea) drop back down to salt water and start to feed again, many of them dying during the journey.

The actual spawning takes place in early summer and the dark coloured sticky eggs, about 2-2.5 mm in diameter, are laid over the gravel to which they adhere. Females can produce from 800,000-2,400,000 eggs each, depending on size. These hatch in about 3-6 days at water temperatures of some 12-18°C.

Growth. Growth is fairly rapid after hatching though it does depend to some extent on local conditions. Most fish reach at least 10 cm by the end of their first year and many may reach twice this length. Some start to move down to the sea after this time but most others stay on for another one, sometimes two, years. In the sea growth is steady and fish are usually at least a metre in length when they first start to mature at about 8-12 years of age.

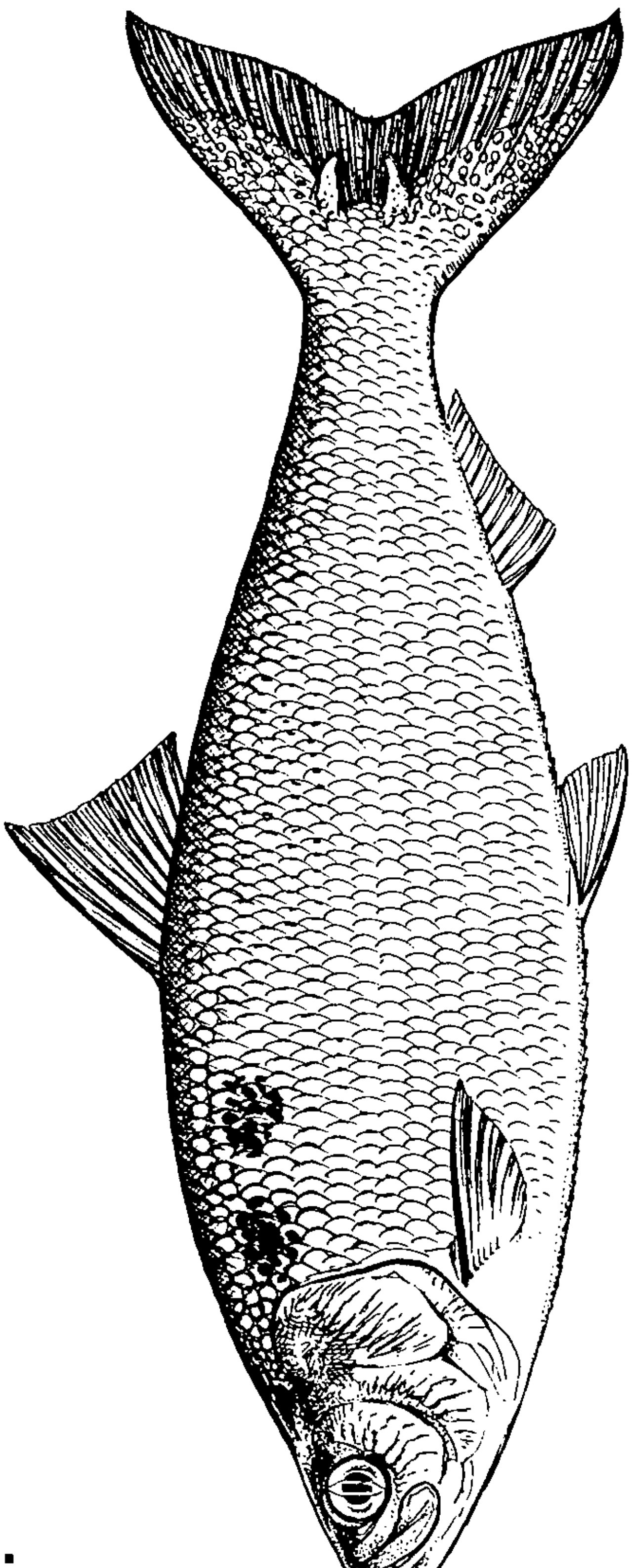
Food. Young Sturgeon feed mainly on bottom invertebrates in rivers, especially midge larvae and other insects, worms, crustaceans and molluscs. In the sea they feed on larger worms (including polychaetes), crustaceans and molluscs but also take some fish - especially sandeels and gobies

Status. Now a rare vagrant around the British Isles, it is endangered throughout its range and is included in Appendix I of the Convention of International Trade in Endangered Species (CITES).

Threats. Overfishing in the lower reaches of its spawning rivers; obstruction of river migration by pollution, dams and weirs; habitat destruction of spawning and nursery areas by pollution and engineering works.

Value. The Sturgeon is of little value in the British Isles. By tradition, any caught are supposed to be offered to the reigning monarch but they are rarely accepted. Occasionally they appear on fishmonger's slabs for curiosity value. On the continent of Europe, however, the flesh of the Sturgeon is highly prized and even more so its roe which is processed to make caviare, an extremely valuable commodity supplied to high class restaurants all over the world. The pursuit of this and other species of sturgeon for their valuable roes has been one of the main reasons for the decline in the numbers of all species in recent years. However, the development of Sturgeon farms in France and elsewhere, though primarily for the commercial production of caviare, may help in the conservation of this species if the farms are managed wisely. Such farms may help by reducing the need to catch fish from the wild and by releasing young stock from wild parents back into the wild again.

References. Almada-Villela (1988), Baeza (1975), Harkness & Dymond (1961), Letaconnoux (1961), Maitland (1972, 1979), Paba (1988), Pavlov *et al.* (1985), Rochard *et al.* (1990), Sokolov & Tsepkin (1982), Trouvery *et al.* (1984), Wheeler *et al.* (1975)



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2. Alosa alosa (Linnaeus 1758) **CLUPEIDAE**

Allis Shad (Bony Horseman, King of the Herring, May Fish)

IUCN: Vul
BERN: III
WACA: +
BRIS: A

Size. This is the larger of the two British shad and commonly grows to a length of about 30-50 cm, exceptionally to some 70 cm. The present British rod-caught record weighed 2.166 kg and was caught off Chesil Beach in Dorset in 1977.

Distribution. This fish is found along the coasts of western Europe from southern Norway to Spain and in the Mediterranean eastwards to northern Italy. It occurs mainly in shallow coastal waters and estuaries but during the spawning migration it penetrates the lower reaches of larger rivers. It has suffered considerably from pollution, overfishing and river obstructions and is now a rare fish over most of its range.

Habitat. Coastal waters as adults; large estuaries as juveniles; upper estuaries and large rivers for spawning.

Reproduction. Mature fish run up from the estuaries into rivers during late spring, thus giving it the name of May Fish in some areas. In some of the larger European rivers it has been known to ascend upstream for several hundred kilometres. Shoals of fish accumulate in suitable pools and spawning takes place there at night. Afterwards the spent adults drop downstream to the sea again, many of them to die there.

The clear eggs (about 4.4 mm in diameter) fall to the bottom and remain there in crevices until they hatch some 4-8 days later. The fry are about 10 mm on hatching but rapidly grow to 8-14 cm after one year. By this time many of them have descended to the sea and the remainder follow during their second year. The adults mature after 3-4 years at about 30-40 cm when they start the spawning migration again.

Growth. Little is known about the growth of this species, but available data would indicate that it is similar to that of the Twaite Shad.

Food. The food of the young fish is mainly bottom-living river invertebrates, especially midge larvae and crustaceans. The adults too, feeding in salt water, rely largely on invertebrates, especially planktonic crustaceans (e.g. calanoids and euphausids), but also eat small fish.

Status. A rare and vulnerable species which is much less common than formerly over its whole range. Although previously believed to breed in the Severn and other rivers (Table 12) there is now no known spawning site. However, recent evidence suggests that there may be one in the Solway area.

Threats. Obstruction of river migration by pollution, dams and weirs; habitat destruction of spawning areas by pollution and engineering works; overfishing in estuaries.

Value. Though this fish is highly esteemed for the table in several countries, there are few fisheries for it nowadays, largely because it is so rare. However, opinions on its culinary virtues are not universally high and it has been described as "a plebian fish excluded from all reputable banquets", and (in Northern Ireland) as "the bony horseman". Like many large anadromous species it is particularly vulnerable during the spawning migration both to local fisheries and to the hazards of pollution and obstructions so common now in the large European rivers in which the species was once abundant. It is finally being given special protection in several countries in Europe, and hopefully may recover in at least parts of its former range.

References. Aprahamian (1981), Aprahamian & Aprahamian (1990), Boisneau *et al.* (1985), Cazemier (1988), Maitland (1977), Mennesson-Boisneau *et al.* (1986), Wheeler *et al.* (1975)

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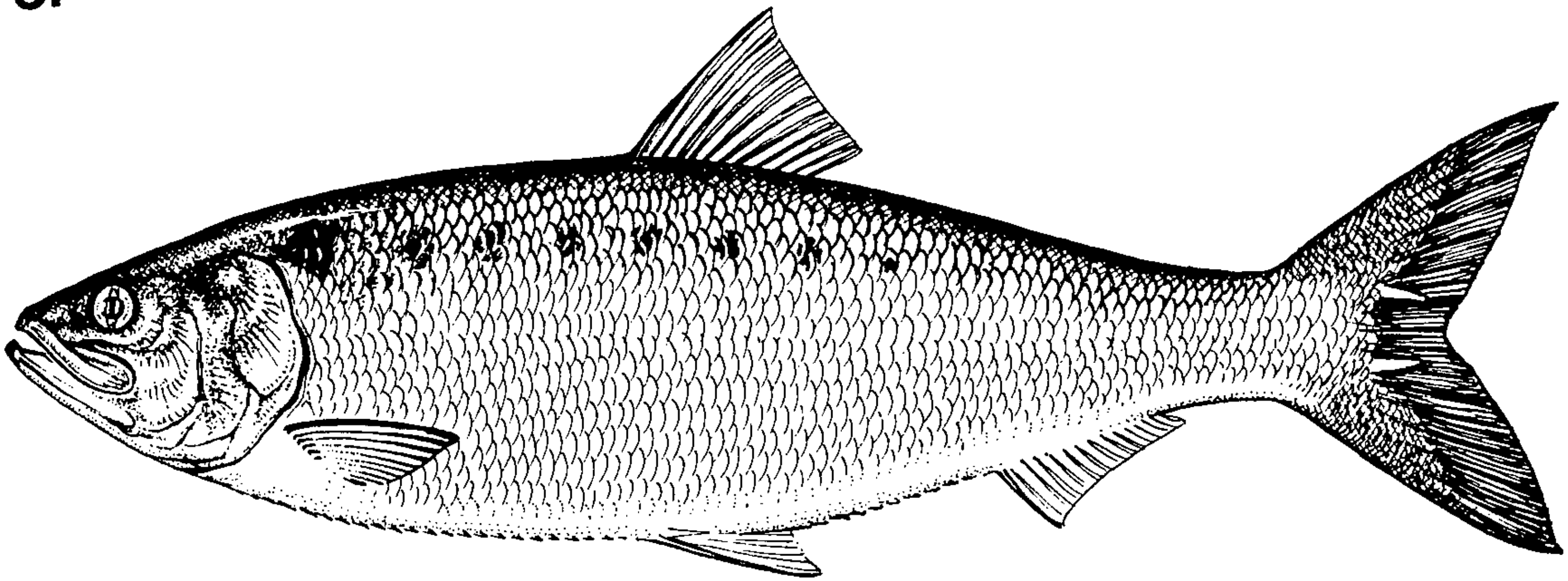

3. Alosa fallax (Lacepede 1803) **CLUPEIDAE**

Twaite Shad (Bony Horseman, Goureen, May Fish, Queen of the Herring)

IUCN: Vul
BERN: III
WACA: -
BRIS: A

Size. Though both are large herring-like fishes, the Twaite Shad is normally rather smaller than the Allis Shad, adult fish usually averaging some 25-40 cm with a maximum of about 55 cm. The British rod-caught record stands at 1.417 kg for two fish - one caught in 1949 near Deal in Kent and the other in 1954 near Torbay in Devon. The most recent notable catch was a fish of 1.247 kg caught in 1978 at Garlieston in the Solway Firth. The Irish record stands at 0.907 kg for a fish caught near St. Mullins in 1985.

Distribution. The Twaite Shad occurs along most of the west coast of Europe, from southern Norway to the eastern Mediterranean Sea and in the lower reaches of the large accessible rivers along these coasts. There are a number of extremely interesting non-migratory populations of this fish in a few of the larger European lakes such as Como, Garda, Iseo, Lugano and Maggiore. In the British Isles, Lough Leane in Killarney has such a population which appears to have been isolated here for thousands of years (Table 13). It is known as the Goureen and was given subspecific recognition by Regan in 1916 as *Alosa fallax killarnensis*. This fish is rather smaller than its marine based relatives and rarely grows longer than about 25 cm.

Habitat. With the exception of these isolated populations in large lakes, the normal habitat of this species is the sea - especially coastal waters off the southwest coast of northern Europe. It has been collected at depths down to 100 m but it normally occurs in water much shallower than this. The eggs and young are found in the lower reaches of large slow-flowing unpolluted rivers where there is easy access from the sea.

Reproduction. At maturity, the adult fish stop feeding and gather in the estuaries of these rivers in early summer (April and May), thereafter moving upstream to spawn in mid-June in the stretches above the influence of high tide. Usually the males move upstream first, but they are soon joined by the females and spawning takes place in flowing water over stones and gravel among which the eggs sink. The females, depending on their individual size, each produce about 75,000-200,000 eggs. The eggs take about 4-6 days to hatch and the young drop quickly downstream in the current to the quieter waters of the upper estuary where they start to feed and grow. Small 0+ Shad are found on the screens of the power stations in the Severn Estuary. The non-migratory populations seem to spawn in or in the vicinity of large rivers entering the lakes and the young soon find their way into the lake.

Growth. Growth in the first year is fairly rapid and they can reach some 5 cm in 6 months and 10-15 cm after one year. Thereafter, growth is steady and most fish reach about 20-25 cm after 2 years and 25-30 cm after 3 years. The males start to mature after three years and are therefore spawning with older and larger females at first. The females themselves do not start to mature until they are about 5 years old. Full size is usually reached at 8-10 years of age and some fish may live (and grow slowly) for several years beyond this.

Food. The young fish feed mainly on invertebrates, especially estuarine zooplankton, but as they grow they take larger crustaceans of various types (e.g. shrimps and mysids) and also small fish. Adults feed to an appreciable extent on other fish, especially the young of other members of their own family such as Sprat and Herring.

Status. It has stopped breeding at most of its previous sites in the British Isles (Table 12) and is now much rarer than formerly throughout its range. Only a few spawning populations are known (e.g. the Rivers Severn and Usk), but there are probably others (e.g. in the Solway).

Threats. Obstruction of river migration by pollution, weirs and dams. Habitat destruction of spawning and nursery areas by pollution and engineering works. Overfishing.

Value. Though it is now much less common than formerly, the species is still fished commercially in some parts of Europe with various types of nets, especially in estuaries during the start of the spawning migration. Some of the catch is smoked before sale. The species is also angled for seasonally in some rivers which still have a reasonable run of fish (e.g. the Rivers Wye and Severn). A fish of 450 g is considered a good specimen. The Goureen is sometimes taken by rod and line in Lough Leane.

References. Aprahamian (1981, 1985), Aprahamian & Aprahamian (1990), Bracken & Kennedy (1967), Claridge & Gardner (1978), Henderson *et al.* (1984), Kennedy (1981), O'Maoileidigh *et al.* (1988), Trewavas (1938).

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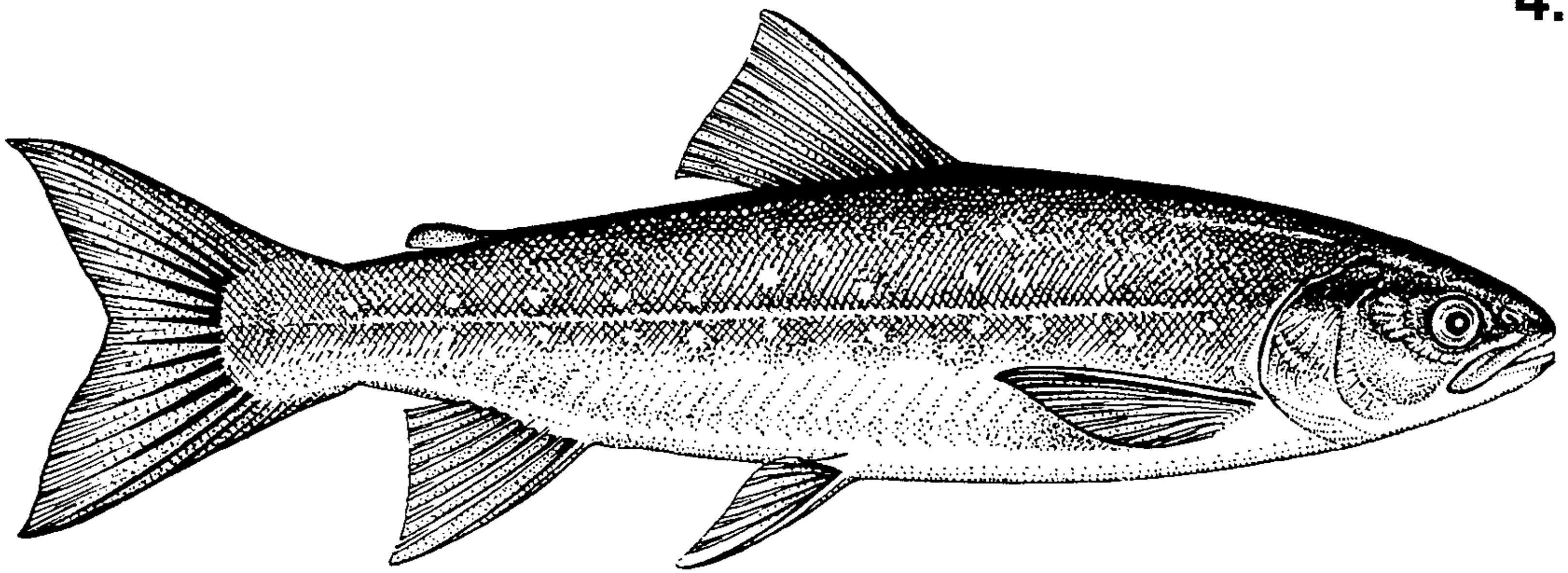

3. Salvelinus alpinus (Linnaeus 1758) **SALMONIDAE**

Arctic Charr (Cuddy, Red-bellied Trout, Red Waimb)

IUCN: -
BERN: -
WACA: -
BRIS: C

The spellings of 'Char' or 'Charr' are both acceptable. However, the latter - derived from the Gaelic *tarr* meaning belly (one Gaelic name for the Charr is *Tarr-dhearg*, meaning red bellied; the Welsh equivalent is *Torgoch*, meaning red belly) - is more authentic.

Size. The adults are usually rather small, typically about 20-25 cm in length (85-170 g), but in some lakes they may reach over 35 cm and 600 g. Some exceptionally large Charr have been recorded recently from the vicinity of floating fish farm cages where their diet is boosted by waste food pellets. The record fish for a number of years was from Loch Insh; then a new record was established by a fish weighing 1.502 kg, caught in 1985 in Loch Earn in Scotland. The present British rod-caught record is for a fish weighing over 3 kg, caught in 1990 in Loch Ericht.

Distribution. The Arctic Charr is a holarctic species occurring all round the northern hemisphere and in the northern parts of its range forms mixed non-anadromous and anadromous populations (comparable to Brown and Sea Trout) where the sea-going Charr can reach a large size. In the British Isles all populations are non-anadromous.

Habitat. In the British Isles, Arctic Charr are mainly found in large deep oligotrophic lakes lying in glaciated basins. However, there are also populations in shallow biologically rich habitats, as is common in Ireland. In Scotland, of 85 Charr lochs investigated, 43 (52%) had an average depth of 15 m and 7 (8%) less than 5 m. There are no true river populations in the British Isles, but they are found in streams connecting Charr lakes and at times some fish move into or are washed over dams and weirs into flowing water.

Reproduction. Spawning normally takes place from late September to December, but in one site (Windermere), one part of the population spawns in the autumn, the other in the spring. So little research has been carried out on Charr in the British Isles that there may well be other localities where there are both autumn and spring spawners. In lakes, spawning takes place over gravel and stones, normally in fairly shallow water near the shore or on a submerged reef.

The spawning behaviour is typically salmonid and the female excavates a redd in the gravel by turning on her side and sweeping her tail fin up and down. This is done within a territory that a mature male is defending. Data on fecundity from one population in a Scottish loch suggested that a fish of 250 g would produce 400-600 eggs. The eggs are amber in colour and 4-5 mm in diameter.

Growth. Most Charr populations are dominated by fish of 3-5 years and the maximum age is usually 7-10 years. In Loch Rannoch, where it has been shown recently that there are two races of Charr - one a benthic form, the other pelagic in habit - the growth of the pelagic form is fastest initially, but after the fourth year the benthic form starts to grow faster and most of the larger Charr belong to this group.

Food. They are by no means entirely pelagic. Of 15 Scottish Charr populations investigated, six were found to be feeding exclusively on planktonic crustaceans, while in a further six lochs these food organisms dominated or co-dominated along with benthic organisms. In three, Charr were found to be feeding almost exclusively on benthic invertebrates. Some Charr are piscivorous and in one loch eat not only adult Sticklebacks but also eat Stickleback eggs. Here, these two species are the only fish present - one of the few sites in the British Isles where Charr exist in the absence of Trout.

Status. The number of populations in Europe has declined substantially. In the British Isles, although many populations in the north west of Scotland and Ireland seem relatively secure, there has been a steady loss of stocks further south (Table 14).

Threats. The main threats are from acidification, eutrophication and overfishing. There is an increasing interest in Charr farming and this will give rise to problems. Charr are preyed on by other fish, principally large ferox Brown Trout, with which they normally coexist, and Pike and Perch which may eliminate them from a water.

Value. Charr have been exploited relatively little in the British Isles. The English Lake District fish have been caught for centuries; elsewhere, they seem only to have been harvested at spawning time, when they are most vulnerable. Few anglers fished for Charr until recently, but due to the pressures on other species, Charr are becoming increasingly regarded as an attractive alternative quarry.

References. Andersen *et al.* (1984), Andrews & Lear (1956), Avondhu (1951), Barbour (1984), Barbour & Einarsson (1987), Campbell (1979), Campbell (1982, 1984), Frost (1977), Frost & Kipling (1980), Gardner *et al.* (1988), Hardie (1940), Henriksen (1977), Kipling (1984), Maitland *et al.* (1984), Moore (1975a,b), Walker *et al.* (1988), Went (1971).

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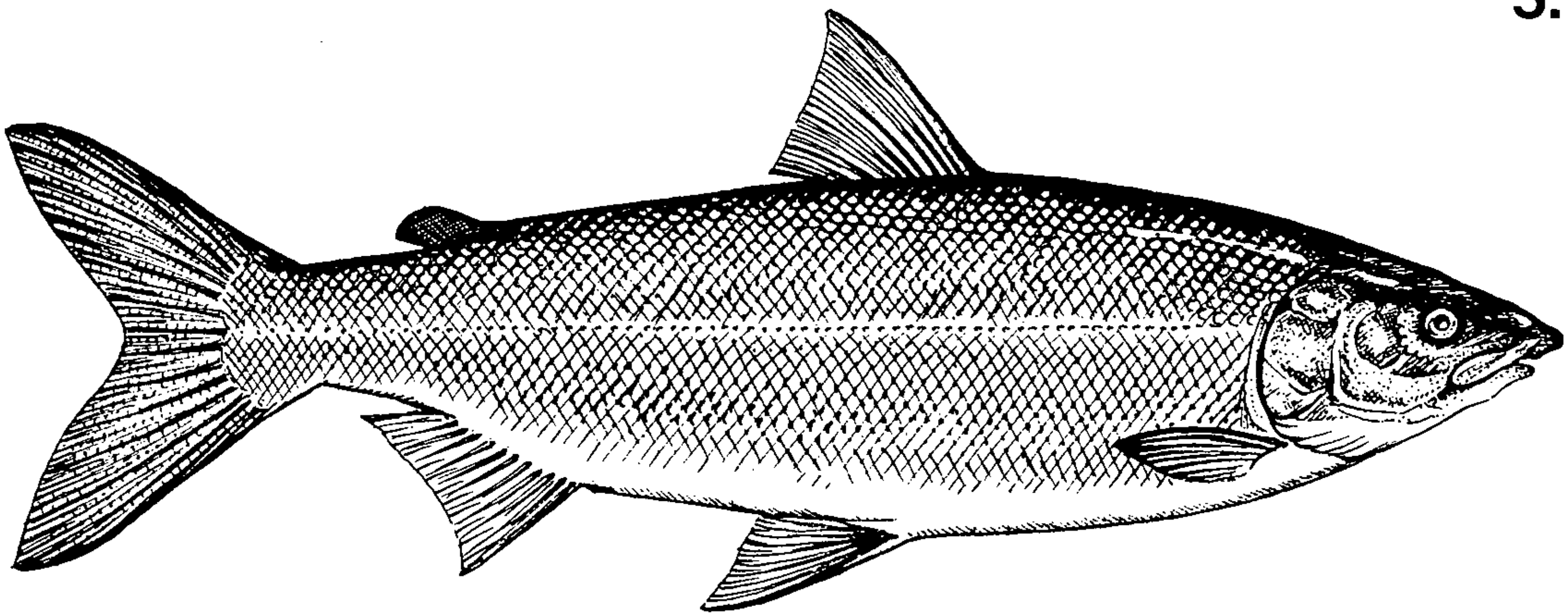

5. Coregonus oxyrinchus (Linnaeus 1758) **COREGONIDAE**

Houting (Hautin, Sea Whitefish)

IUCN: End
BERN: III
WACA: -
Extinct BRIS: I

Size. The normal adult length is some 25-35 cm but fish of up to 50 cm, weighing over 2 kg, have been recorded. There are no angling records for this species in the British Isles.

Distribution. Though some other species do go into brackish water in the Baltic this is the only truly anadromous whitefish in European waters. Its numbers have undergone a severe decline during this century, probably as a result of overfishing and the impact of pollution and barriers in most of the rivers in which it was formerly abundant such as the Rhine, Weser and Elbe. It is primarily a fish of the eastern North Sea and especially the Baltic where it was at one time abundant but now occurs in only a few rivers.

In the British Isles it, like the Sturgeon, has only been known as a vagrant, but at one time it was taken quite regularly along the south-east coast of England and occasionally in estuaries there such as those of the Colne and Medway. With the great reduction in numbers in its breeding areas its distribution has contracted and no specimens have been seen in Great Britain for many decades.

Habitat. The Houting is typically a coastal/estuarine species and rarely occurs in the open sea. Thus the low salinity waters of the Baltic suit it perfectly. Here it occurs in a unique assembly of freshwater and marine fishes which are able to form a brackish water community halfway between their respective normal chemical environments. Thus, as well as Houting, these waters contain Roach and Perch on the one hand and Cod and Plaice on the other.

Reproduction. The Houting has never been known to spawn in the British Isles and so can really only be regarded as a vagrant here. In those areas of the North Sea further east where it still occurs shoals assemble each autumn at the mouths of rivers and move upstream to spawn. This takes place from October to December over gravel in running water when the yellow eggs (2.9 mm in diameter) are produced. These sink to the bottom and, being slightly adhesive, attach themselves to the small stones there, often falling between the crevices where they are protected from predators of various kinds.

Growth. Little is known about the age and growth of this species. The young appear to move downstream into brackish water and spend most of their lives there only returning to fresh water when they are mature and ready to spawn.

Food. The food virtually throughout life consists almost entirely of zooplankton of various kinds, especially crustaceans such as copepods and small shrimps. Larger fish, though they do rely to some extent on benthic invertebrates, again feed mainly on crustaceans.

Status. Now extremely rare and endangered throughout its range. Extinct in many places, including the British Isles.

Threats. Obstruction of river migration by pollution, dams and weirs; overfishing in estuaries and lower reaches of rivers; habitat destruction of spawning and nursery areas by pollution and engineering works.

Value. Though once a valuable commercial species which was caught in large numbers in drift nets and traps, especially in upper estuaries and the lower reaches of rivers during the spawning run, the numbers of this species are now so reduced that it is only fished in a few places around the Baltic Sea.

References. Berg (1965), Cazemier (1988), Day (1880, 1887), Maitland (1970, 1972, 1979), Svardson (1957).

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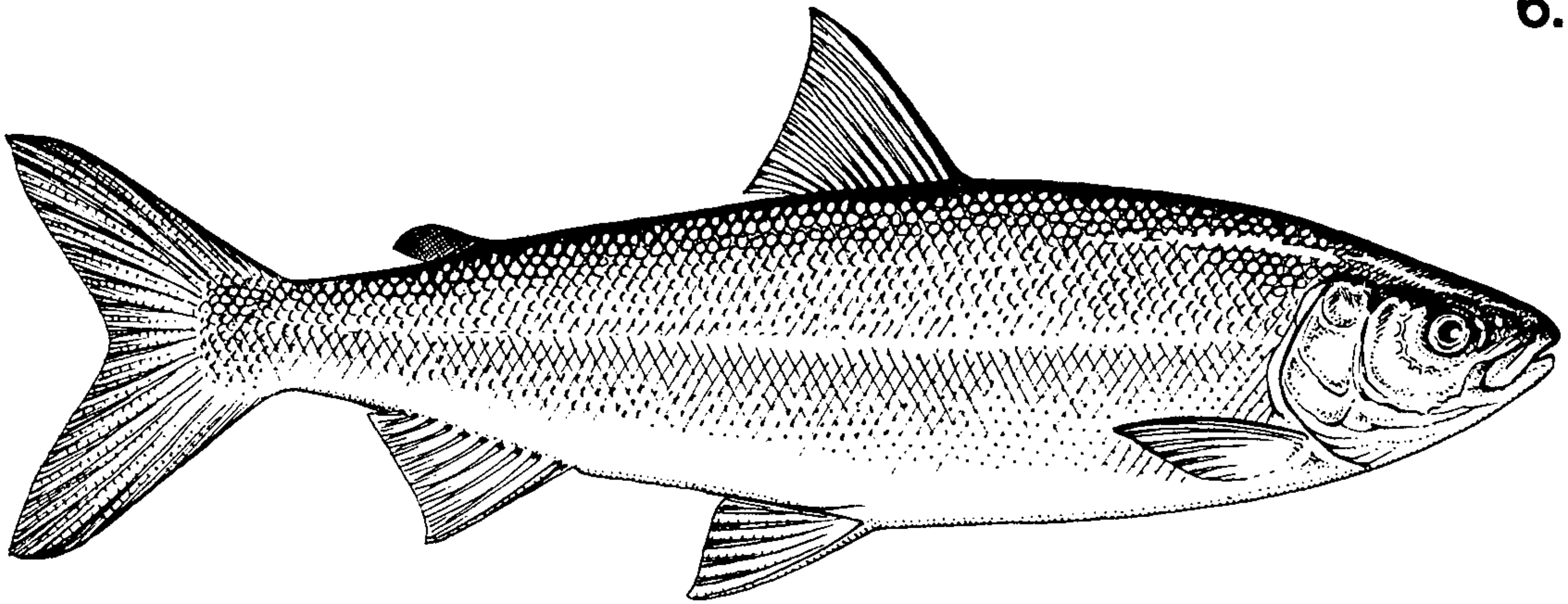

6. Coregonus lavaretus (Linnaeus 1758) **COREGONIDAE**

Powan (Freshwater Herring, Guiniad, Gwyniad, Schelly, Skelly)

IUCN: -
BERN: III
WACA: +
BRIS: B

Of the three common names used for this species in the British Isles, Powan has precedence over Gwyniad and Schelly. The species was first described as *Coregonus clupeoides clupeoides* from Scottish specimens, the southern forms being subsequently given the names of *Coregonus clupeoides pennantii* (Gwyniad) and *Coregonus clupeoides stigmaticus* (Schelly).

Size. The adult size of Powan is normally 30-35 cm (300-400 g), but in some European lakes fish up to 70 cm (8 kg) have been recorded. The present British rod-caught record is for a fish of 950 g caught in 1986 in Haweswater (Cumbria). It is now illegal to catch this species in Great Britain without a permit; these used to be dealt with by the Nature Conservancy Council but are now administered by its successor bodies in England, Wales and Scotland.

Distribution. The Powan is widespread across much of north west Russia, Finland and Sweden. It occurs also in several other countries (Norway, Switzerland, Germany, Poland and France) but only in certain areas - usually in mountainous alpine lakes. In the British Isles it is a relatively rare fish with local distribution (Table 13). It occurs in Lochs Lomond and Eck in Scotland, in Ullswater, Haweswater and Red Tarn in England (where it is known locally as Schelly) and in Llyn Tegid in Wales (called here the Gwyniad).

Habitat. Typically, Powan occur in relatively large deep lakes with clear well-oxygenated water. During daylight outside the breeding season adult fish stay in relatively deep water - on the bottom if they are in the littoral areas or at depths of

20-30 m if in deeper water. At dusk they rise into shallower water, often coming right up to the surface and in to the edge in littoral areas. At dawn a reverse migration takes place. Occasionally, fish occur in rivers associated with lakes. For example, there is a record of Gwyniad in the River Dee downstream from Llyn Tegid.

Reproduction. Near spawning time the fish move much nearer to the shores of the lake and shoal over the sublittoral areas. At these times they may be washed ashore and stranded, sometimes in considerable numbers. In Ullswater large numbers of Schelly were washed ashore in 1966 and 1967 after strong winds.

Spawning takes place during winter, usually starting in late December and finishing in early February. At dusk the adult males come on to the spawning grounds, which are characteristically gravelly shallows on headlands or offshore reefs. They shoal there in large numbers and spawn with ripe females which move in each night. The fertilised eggs fall to the bottom and lodge between crevices among stones and gravel. The eggs are 2-3 mm in diameter and pale yellow in colour. The fecundity of the females varies with size, but is usually 2,000-11,000. Very large females may have up to 24,000 eggs. Incubation takes about 90-100 days (340-420 day-degrees) at winter temperatures, the optimum temperature being some 6°C or less.

Growth. The young are some 9-11 mm at hatching and have a small yolk sac. However, they are strong swimmers and immediately move off into the pelagic areas where they spend much of the rest of their lives. Growth is variable but in favourable lakes the young can reach lengths of 10-12 cm after one year and 15-20 cm after two. After two years they may start to mature and usually have an adult length of 25-35 cm at 3-5 years of age. Most fish die after 6 or 7 years, but some live to 9 years.

Food. Powan feed mainly on plankton (especially crustaceans) when they are young. As they grow they start to feed more on bottom invertebrates (e.g. midge larvae, molluscs), though still relying a great deal on plankton during the summer months. At spawning time, many of them eat considerable numbers of their own eggs. In Llyn Tegid, Gwyniad concentrate on bottom fauna from December to July, changing to midwater and surface feeding during the rest of the year.

Status. The species has declined in several parts of Europe. In Great Britain the six known populations are still extant, though very vulnerable (Table 13).

Threats. The main concern arises from eutrophication, pollution and the introduction of new species of fish.

Value. The Powan is an important commercial species in most of the countries in which it occurs - Great Britain being the exception to this. It is caught in traps, seine nets and gill nets and is especially vulnerable at spawning time when it migrates and masses on spawning grounds in great numbers. In Great Britain it has no commercial or sporting significance. During both World Wars, however, it was fished commercially in Lochs Lomond and Eck and several hundred thousand fish were taken at this time.

References. Anonymous (1883), Ausen (1976), Bagenal (1966, 1970), Brown & Scott (1987), Dabrowski *et al.* (1984), Ellison (1966), Ellison & Cooper (1967), Ferguson (1974), Fuller & Scott (1976), Gervers (1954), Haram & Jones (1971), Maitland (1967, 1969, 1970, 1980, 1982), Maitland & Lyle (1990), Nicholas & Jones (1959), Roberts *et al.* (1970), Scott (1975), Slack *et al.* (1957).

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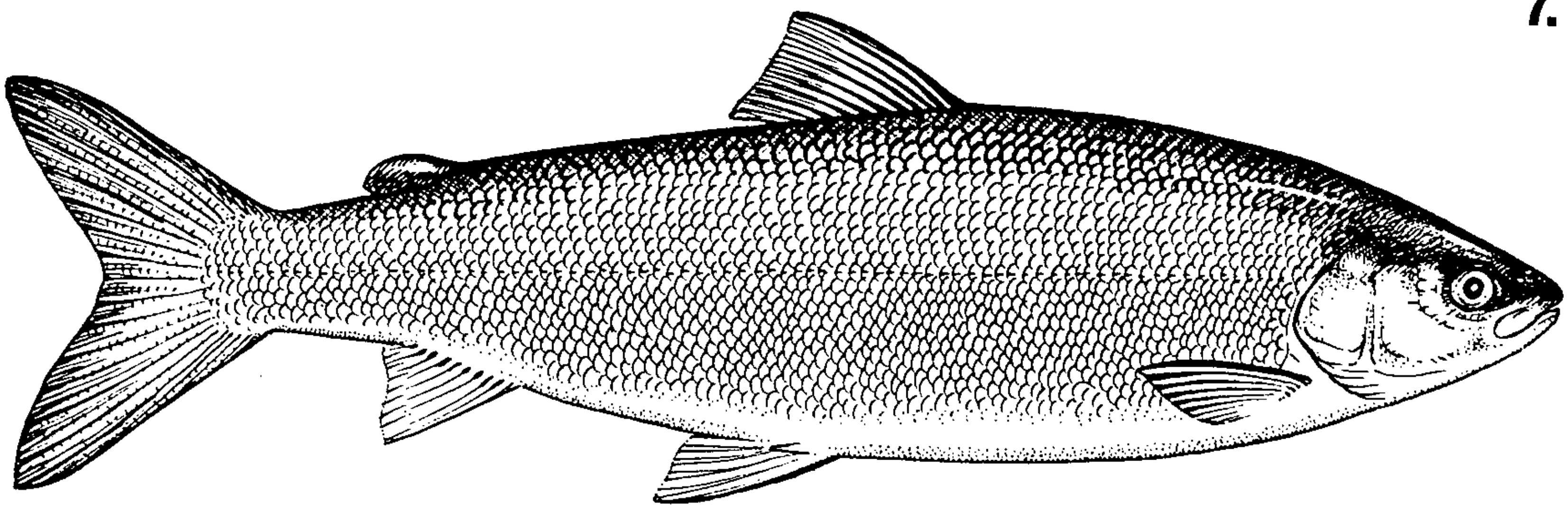

7. *Coregonus autumnalis* (Pallas 1776) **COREGONIDAE**

Pollan (Arctic Cisco, Cunn, Omul)

IUCN: -
BERN: III
WACA: -
BRIS: B

Up until a few years ago, the taxonomic status of this species was uncertain. Gasowska (1964), studying the detail of the bones of the Pollan, suggested that it was *Coregonus autumnalis* - which is found nowhere else in western Europe and otherwise occurs only in eastern Europe, Asia and western North America. This finding was not fully accepted until electrophoretic techniques showed that the Pollan does indeed appear to be the same fish as the Arctic Cisco, *Coregonus autumnalis* (Ferguson *et al.* 1978).

Size. In Ireland, the Pollan usually reaches an adult size of some 30-35 cm (350-450 g), though occasionally larger specimens are recorded. There is no British rod-caught record at the moment, this category standing open. In Canada, fish as long as 46 cm (1.4 kg) have been recorded, but weights of up to 2.5 kg have been reported from Siberia.

Distribution. The Pollan occurs in coastal areas and in the lower reaches of arctic rivers in north eastern Europe, Asia and north western North America - from the White Sea to Alaska and the North West Territories. Its occurrence in Ireland is surprising and well outside the rest of its world range. There are no logical explanations for its occurrence there. It is found in five large lakes (Table 13): Lough Neagh, upper and lower Lough Erne, and the Shannon lakes - Lough Ree and Lough Derg.

Habitat. Although it is anadromous throughout most of its northern range, the Irish populations are all non-migratory and purely freshwater. However, for a few years after the establishment of a power station creating a barrier on the short River Erne, between lower Lough Erne and the estuary, Pollan were taken in Salmon nets fished in the estuary and an examination of these fish showed that their rate of growth increased in the estuary where invertebrates (especially *Crangon*) dominated their diet. This incident would suggest that Pollan still retain the potential to become, at least locally, an anadromous species. All the lakes in which it occurs are large and relatively clean and deep - although Lough Neagh has undergone considerable eutrophication in recent years.

Reproduction. Spawning takes place in the lake, over beds of gravel and stones in relatively shallow water. As with other members of the family at spawning, the eggs fall down into spaces between the stones. The fecundity of the Irish fish is somewhat uncertain, but probably some 2,000-8,000 eggs per female. However, some of the larger females in Canada have been recorded as carrying over 90,000 eggs. The eggs are about 2 mm in diameter and yellowish in colour.

Growth. The young hatch about March with a small yolk sac, but are immediately pelagic. They grow to a length of about 10-12 cm in the first year and 15-20 cm after two years, when they start to mature. They are fully adult at 3-4 years of age when they are mostly 25-30 cm. They normally live for 5-7 years, but occasionally to 9 or 10 years.

Food. After the yolk sac is absorbed, the young fish feed on small zooplankton and later on larger zooplankton, especially crustaceans supplemented by other larger invertebrates which appear in the water column, such as midge larvae and pupae. They start to feed on bottom invertebrates as they get older, including the semi-pelagic crustacean *Mysis*, which occurs in these Irish lakes, sometimes in abundance. At spawning time they may eat large numbers of their own eggs.

Status. There is no evidence of any decline worldwide. All known populations in the British Isles are still extant but there are only five of these. Moreover, there have been no records from Upper Lough Erne this century and even its continued existence in Lower Lough Erne is in some doubt; there are no recent records from Lough Ree (A Ferguson, personal communication).

Threats. Eutrophication; overfishing; introduction of alien fish species or diseases.

Value. The Pollan is the only member of the family for which there is an important permanent commercial fishery in the British Isles. This has taken place for many years in Lough Neagh, and to a lesser extent in the other Irish loughs, and Pollan are regularly for sale in the Belfast and some of the other Irish fish markets. Some were even exported to northern England. They are caught mainly by seine and gill nets. The Pollan is of no sporting importance in Ireland. In both Siberia and Canada, this species is an important commercial species and fished extensively by native people, especially during the summer spawning migration from the sea.

References. Ferguson *et al.* (1978), Gasowska (1964), McPhail (1966), Twomey (1956), Wilson (1983, 1984), Wilson & Pitcher (1983,1984).

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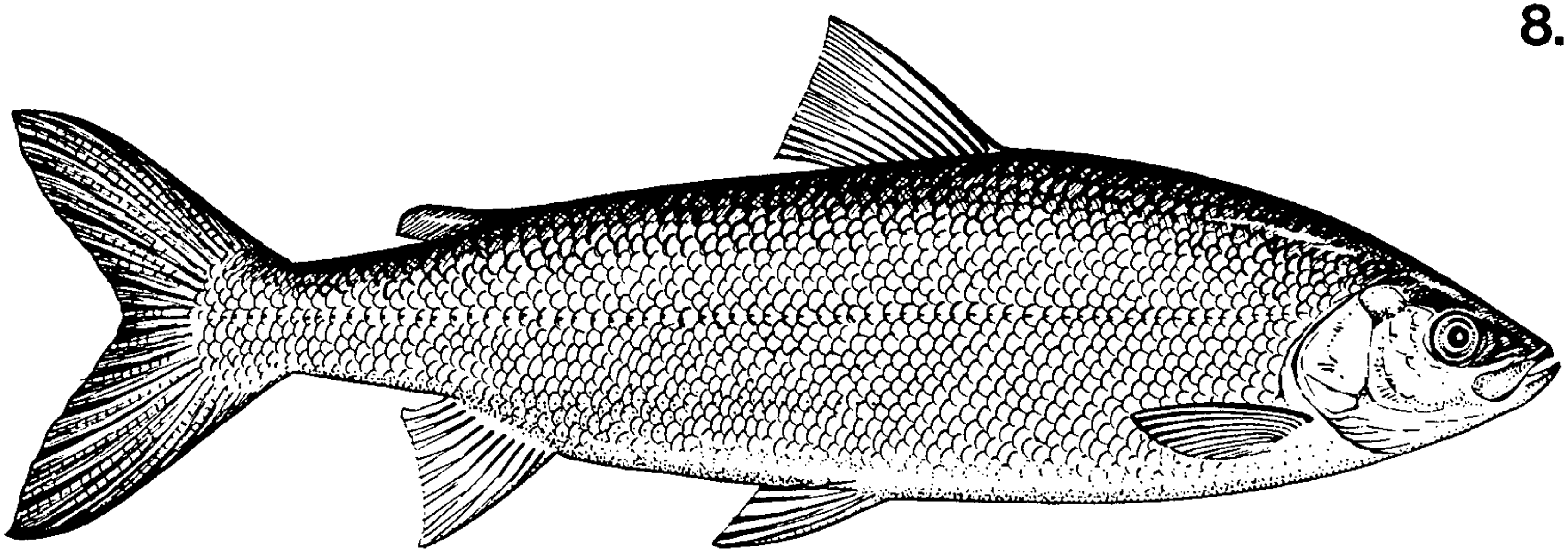


8. *Coregonus albula* (Linnaeus 1758) **COREGONIDAE**

Vendace (Cisco)

IUCN: -
BERN: III
WACA: +
BRIS: A

Size. The Vendace is normally regarded as a small to medium-sized fish, but its size is variable between populations, some of which can be quite stunted with fish maturing in their first year at 10-12 cm. The normal adult size is 20-25 cm (100-150 gm), but in some European lakes it may reach a length of 35 cm (500 gm). It is very rarely seen by anglers, due to the fact that it never takes bait - being very much a plankton feeder. It is now illegal to capture it without a permit.

Distribution. The Vendace occurs in north-west Europe, from northern Scandinavia and north-west Russia in the north to Bavaria further south and from the English Lake District in the west to western Russia in the east. Though it is mainly a lake species, some populations also occur in the Baltic Sea, migrating to fresh water to spawn. In the British Isles it has been known from only four lakes (Table 13): two in Scotland (where it is called the Lochmaben Vendace and was formerly described as a distinct species and subspecies - *Coregonus vandesius vandesius*), and two in England (the Cumberland Vendace - *Coregonus vandesius gracilior*).

Habitat. The Vendace seems to occur in lakes of any size from a hectare or so upwards. These lakes are often quite rich and are rarely very oligotrophic. Depth seems to be not too important, though probably several metres is needed to give freedom from summer heat stress and oxygen lack as well as winter kill. Strong competition and/or predation from Pike, Perch and other fish is probably very harmful unless a good deep, open water niche is available. The Vendace is a delicate pelagic fish which lives mainly in shoals in the open water offshore areas among the plankton. It remains in deeper (dimly lit) water during the day rising to the surface at dusk to feed, then descending at dawn.

Reproduction. Spawning is over gravelly/stony shores during winter, usually late November into December, though the actual timing varies from site to site (and from year to year) by a week or so. The mature males gather early on the spawning areas and as females ripen they join the males and spawn together in mid-water, the fertilised eggs dropping down into crevices among stones and gravel. The fecundity varies with size, and ranges from 1,500 to 5,000 eggs per adult female. The eggs are 1.5-1.8 mm in diameter and yellowish in colour. The incubation period varies with temperature, but is normally 90-120 days at 1-4°C.

Growth. The young possess a small yolk sac on hatching, but, like other whitefish, they are free and able swimmers immediately. They are 7-9 mm in length but soon start to grow rapidly as the surface waters of their lake warm up and zooplankton becomes available. At the end of the first year they reach a length of 8-10 cm. After two years they may be 14-18 cm, at which time many are mature and growth slows, so that most adults only reach some 20-25 cm, even after 5 or 6 years, which is the normal length of life.

Food. After absorbing their yolk sac over the first few days of life, the Vendace fry start to feed on small plankton (mainly crustaceans), and zooplankton forms their main diet throughout life. They may supplement it from time to time with benthic animals in the water column (e.g. midge larvae and pupae) or terrestrial insects which are trapped on the surface, and some eggs may be eaten at spawning time.

Status. The species has declined across its range. The population in the Castle Loch, Lochmaben is certainly extinct and none has been recorded since shortly after a new sewage works was opened there in 1911. The species was thought also to be extinct in the Mill Loch, Lochmaben but specimens were caught there in 1966 and in subsequent years. However, none has been seen for more than a decade and it seems likely that the species is now extinct there too. In Cumbria the species occurs in larger waters - Bassenthwaite Lake and Derwentwater - and though it may be secure there in the short term, this is at present Britain's rarest freshwater fish and its status is of urgent concern.

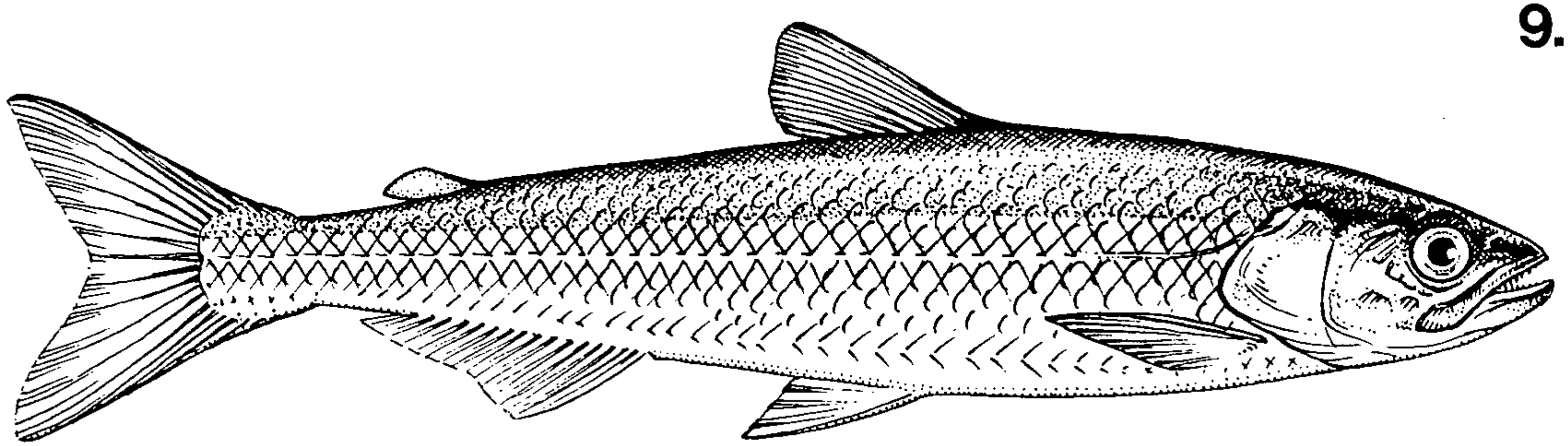
Threats. Eutrophication and the introduction of alien fish species and diseases seem to be the major threats.

Value. The Vendace is an important commercial species in some parts of Europe where it is caught mainly in gill nets, but sometimes in traps and seine nets where there are migrations at spawning time. It is sometimes smoked and small specimens may even be eaten raw.

The species is so rare in the British Isles that it has no commercial or sporting value. However, in times past it was an important fish at Lochmaben, where an annual festival was arranged each summer by two local 'Vendace Clubs', during which Vendace were caught in fine gill nets and then cooked and eaten outdoors while athletic contests took place.

References. Aass (1972), Dembinski (1971), Jurvelius *et al.* (1988), Maitland (1966a, 1966b, 1967, 1970, 1982).

9.



9. Osmerus eperlanus (Linnaeus 1758) **OSMERIDAE**

Smelt (Sparling)

IUCN: -
BERN: III
WACA: -
BRIS: B

Size. The Smelt, or Sparling as it is called in Scotland, is a small to medium sized fish whose adult size varies greatly according to habitat. The normal range in length is 10-20 cm but the fish can sometimes reach 30 cm. A fish about 15 cm long weighs some 30 g. In general, fish from non-migratory freshwater populations are much smaller than those which have lived in the sea. The present British rod-caught record stands at 191 g for a Smelt caught near Fleetwood in 1981. There is no Irish record.

Distribution. The Smelt occurs from southern Norway around the western coast of Europe (including the Baltic Sea) to north west Spain. It occurs in coastal waters and estuaries and migrates into large clean rivers at spawning time. The species is tolerant of wide salinity changes and there are several non-migratory purely freshwater populations in large freshwater lakes in Finland, Sweden and Norway. The Romans were supposed to have cultivated Smelt in freshwater ponds. The sole freshwater population in the British Isles, in Rostherne Mere in Cheshire (Table 13), became extinct many decades ago in the 1920s, probably due to eutrophication.

Habitat. This fish clearly favours clean estuaries except at spawning time and though it has the salinity tolerance noted above it is apparently very susceptible to pollution and perhaps other stresses created by humans. Many estuaries which formerly had large populations lost them as pollution increased.

Reproduction. On reaching maturity, adults migrate up the estuaries and into the lower reaches of rivers in March and

April. Usually the run in each river occupies only a few days, but during that time the spawning activity becomes furious and the sticky eggs attach themselves to everything on the river bed - gravel, stones, weed and sticks. Sometimes the river level drops subsequently and leaves many eggs stranded to dry out. The adults are very vulnerable to all kinds of predators at this time and occasionally become so excited during the actual spawning that they swim right out of the water and strand themselves on dry land.

Each female lays about 10,000-40,000 pale yellow eggs (0.9 mm in diameter) and these hatch in about 20-35 days according to the local temperature. The eggs are often laid in quite fast flowing water and the young are swept quickly down into the upper estuary where they start to feed. Though there is considerable mortality among the adults during spawning, many do manage to return to the sea where they recover to grow further and spawn again in subsequent years. Lake populations of this species spawn in or near the mouths of rivers entering the lake or along suitable shores.

Growth. Growth is a very variable process in this species according to local conditions. In suitable estuaries the young may reach 10 cm by the end of the first year and some 15 cm by the third year which is usually when they start to breed. They may live for several years beyond this, reaching lengths of about 20 cm at 6 years of age. The males are usually smaller than the females and average weights are about 28 and 36 g respectively.

Food. Smelt fry are very small at first and feed on minute zooplankton, probably mainly protozoans and rotifers. As they grow they take larger planktonic crustaceans and some bottom animals and eventually they become quite voracious predators taking larger crustaceans (shrimps and mysids) and young fish such as Sprat, Herring, Whiting and gobies.

Status. The Smelt was once a common species in the British Isles and occurred in most larger rivers from the Clyde and Tay southwards (Table 15). Over the last century, the species has gone into decline and has disappeared from many rivers - mainly as a result of pollution and overfishing. The only notable exception to this is the River Thames where, although it did disappear for many decades, fish have returned naturally as pollution decreased. There is now a strong population there. More recently, Smelt have started returning to the Forth Estuary, where they have not been seen for over 20 years.

Threats. Pollution and overfishing; obstruction of migration by pollution, dams and weirs; habitat destruction of spawning and nursery areas by pollution and engineering works.

Value. There are still several commercial fisheries in the British Isles which rely mainly on the vulnerability of Smelt during the short spawning run to catch them (sometimes in enormous numbers) in traps and nets. Only two populations are known to remain in Scotland, yet both are the subject of fisheries. On the River Cree in some years up to six tonnes of Smelt are taken from the spawning run - probably a high percentage of the population there and undoubtedly a threat to its existence. In some parts of Europe they are caught in the estuaries in drift nets and trawls and they are sold either fresh or smoked.

References. Abrosov & Agapov (1957), Banks (1970), Belyanina (1969), Ellison & Chubb (1968), Hutchinson (1983a,b), Jilek *et al.* (1979), Naesje *et al.* (1987).

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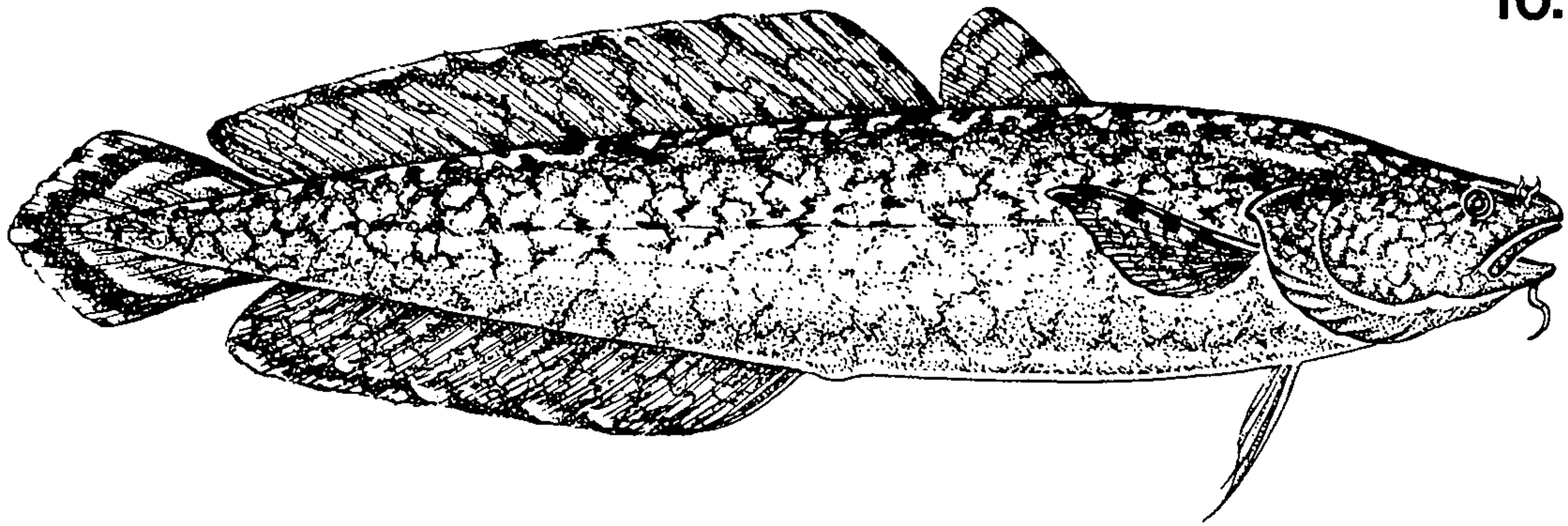

10. *Lota lota* (Linnaeus 1758) **GADIDAE**

Burbot (Barbolt, Coney Fish, Eel Pout, Freshwater Cod, Ling)

IUCN: -
BERN: III
WACA: +
Extinct **BRIS:** I

Size. Adult Burbot are usually some 30-60 cm in length, but in parts of Europe and North America may grow up to 120 cm in length and 32 kg in weight. In England, most of the Burbot caught in past years were some 30-50 cm and 1-3.6 kg in weight. There is no rod-caught record, for the species is probably extinct now and it would also be illegal to catch it without a permit.

Distribution. The Burbot has a northern circumpolar distribution and is found in clean lakes and rivers throughout much of northern, west and central Europe and in northern Asia and North America. In the British Isles, its original distribution was restricted to the larger rivers of eastern England from County Durham south to the Great Ouse system (Table 16), where the last one was recorded in 1972. It has not been seen in this country since then, in spite of a keen watch being maintained.

Habitat. Burbot require clean well-oxygenated water with an oxygen level of 5-7 $mg.l^{-1}$ - rather less than the requirements of Trout, Minnow, Stone Loach and Bullhead with which they often coexist. They are bottom dwelling fish, spending the day in concealment under stones, overhanging banks etc., emerging in the evening to forage for food. However, they will take food items which happen to come close enough in daylight.

Reproduction. Spawning takes place during the colder part of the year from November to March, when the water temperatures are from 0.5-4.0°C. Local spawning migrations may take place into suitable spawning habitats - usually shallow water 2-3 m deep with a clean substrate of sand or gravel. Male Burbot are usually first in the area and when the females arrive, spawning (which always occurs at night) is a communal process, up to 20 or so individuals forming a writhing ball and releasing eggs and milt. The fertilised eggs (some 1.2-1.8 mm in diameter) are pale yellow and semi-pelagic. The females are very fecund, each laying about 500,000 eggs per kg of body weight. Some 200 day-degrees are required for hatching, so that at normal winter temperatures a period of 40-70 days is involved, However, at a steady temperature of 4.4°C the eggs hatch in 30-35 days. In European waters the young fry usually appear in the spring.

Growth. Young Burbot grow rapidly, attaining a length of 9-12 cm within the first year and 22-23 cm by the end of the second. They start to become mature at about 32-34 cm, the males usually maturing for the first time when they are 3+ years of age and the females at 4+. They normally live for 10-15 years.

Food. Young Burbot feed on invertebrates, especially molluscs, crustaceans (e.g. water lice and small crayfish) and insect larvae, whereas older fish eat other fish and fish spawn, crayfish and frogs. Some authorities regard the presence of Burbot in salmonid waters as very damaging and one in fact goes so far as to advise that they should be eradicated altogether in the nursery reaches of Salmon rivers - a factor that should be taken into account should any attempts be made to re-introduce the Burbot to the British Isles.

Status. It has declined over parts of its range and is now believed to be extinct in the British Isles.

Threats. Pollution, habitat alteration and overfishing are believed to be the main threats.

Value. Burbot are popular with ice anglers in Scandinavia and North America but usually not regarded as a top class sporting fish elsewhere. They are the basis of several important commercial fisheries in Europe and North America, based on nets, traps and night lines. In England, they were at one time so plentiful in fenland rivers that as well as being sold in large numbers at local markets they were sometimes used to feed pigs.

References. Anonymous (1987), Bailey (1972), Clemens (1951a,b), Hinkens & Cochrane (1988), Lawler (1963), Marlborough (1970).

2.3 Rare and unusual races

More and more attention is being paid by ecologists and conservationists to the importance of the stock concept. Because of the isolation of many freshwater systems and the strong homing instinct at spawning time in migratory fish species many populations in the British Isles appear to have have evolved a stock individuality over the last few thousand years. In some species (e.g. Atlantic Salmon and Brown Trout) it is likely that this is being substantially interfered with due to indiscriminate stocking or other careless management practices. However, there are still important stocks of these and several other species which are of particular note and worthy of special conservation measures.

Thus, as well as rare species, rare or unusual stocks of fish also deserve conservation attention. Several of these are considered below (Table 17), but it is likely that there may be others which will be found worthy of attention once further research has been carried out on the stock individuality of other freshwater fish species in the British Isles.

The River Lamprey is quite widespread and common in many running waters in the British Isles south of the Great Glen. However, in the Loch Lomond catchment there is a unique population (Maitland 1980) which differs in many respects from all others. Instead of migrating to the sea to feed on fish after metamorphosis, the stock of River Lampreys in the River Endrick migrates downstream in the spring to Loch Lomond where it feeds intensively on Powan. In the autumn, it stops feeding and migrates back into the River Endrick where it spawns in the spring. As well as having these different ecological characteristics, this stock is quite different morphologically from other River Lampreys (Morris 1989): the Lomond stock are smaller, have larger oral discs, snouts and eyes and very much darker pigmentation than lampreys from other waters. There are also significant differences in body proportions and in the mean numbers of myomeres and teeth. These differences may result from both genetic isolation and the short freshwater feeding stage in Loch Lomond. Morris (1989) has suggested that this form may represent the intermediate stage between the parasitic and the non-parasitic forms in the *Lampetra fluviatilis/Lampetra planeri* species pair.

The Brook Lamprey is the most widespread of the three lamprey species in the British Isles, and because it does not migrate to the sea there are many more individual isolated stocks than is the case with the Sea Lamprey or the River Lamprey. Though the Brook Lamprey is clearly the smallest species at full maturity, it is the largest at metamorphosis (after which it does not feed) and most adults are in the range 110-170 mm. However, there is one isolated population on the Isle of Skye which matures at a very much smaller size (80-90 mm) than anywhere else in the British Isles. This feature, together with the fact that this is the only known breeding population of lampreys on any Scottish island, makes this particular stock worthy of note. Further research is needed to determine fully the distribution of lampreys in the Hebrides and the individuality of this particular population.

The Brown Trout was formerly regarded as just one of several species of trout in the British Isles and about 50 species have been described throughout the Brown Trout's range. However, recent studies have indicated that all these fish belong to just one variable species - *Salmo trutta*. Nevertheless there is no doubt that substantial stock individuality exists within this species, though undoubtedly some stocks have been lost due to pollution and other factors including mismanagement by anglers. Some clearly defined stocks do exist such as as Ferox (*Salmo trutta ferox*), Gillaroo (*Salmo trutta stomachicus*) and Sonaghan (*Salmo trutta nigripinnis*) which live together in Lough Melvin in Ireland. Ferguson & Mason (1981) have shown that these stocks are genetically distinct and though living together in the same water spawn separately in different parts of the system, thus continuing and reinforcing reproductive isolation. Other important stocks occur in some of the remoter parts of Scotland (Stephen 1984). It is essential that all such stocks are clearly identified and protected from the careless stocking procedures which have been practised by fishery managers in the past.

Unusual stocks of the widespread and common Three-spined Stickleback have been found in the Outer Hebrides by Campbell (1985). These fish, referred to as *anomalus* morphs, do not possess pelvic spines or pelvic girdle and have a variable number of dorsal spines. Four populations of these spine-deficient sticklebacks are now known from peatland lochs in North Uist and at least one of these stocks is made up wholly of the *anomalus* morph. In one population, some individuals have no spines at all - dorsal, pelvic or ventral. This morph occurs only rarely throughout the world range of the Three-spined Stickleback but other populations have been recorded along the Pacific coast of North America (Bell 1974). Breeding experiments carried out by Campbell (1985) suggest that spine deficiency is not a recessive, easily masked, characteristic and that these stocks of *anomalus* are probably quite stable genetically.

2.4 Rare and unusual communities

With a wide variety of freshwater habitats and 42 indigenous fish species of varied distribution there is potential for a considerable range of fish communities in the British Isles which are worthy of conservation measures. Many of the original communities have been eliminated by pollution or habitat destruction and others have been altered by the introduction of foreign species. However, there are still valuable communities left, reflecting pristineness, simplicity, diversity, uniqueness and classical community structures. In addition, there are many freshwater habitats which have no fish and are of conservation importance (for invertebrate communities or other factors) because of this.

Naturally, the communities in all the waters with populations of threatened species are of special interest and importance. The value of several of these is further enhanced by the combination of various other native species, as discussed below. The question of how to identify such sites has been considered by Maitland (1985) (Table 18).

Original pristine fish communities are under substantial threat - indeed there are probably very few left now. However, there are a fair number of rivers and lakes with classical oligotrophic native fish communities, especially in northern and western Scotland (Table 19). Good examples of standing waters are Langavat in Lewis and Loch Hope in Sutherland with their original euryhaline communities of Atlantic Salmon, Brown Trout (including a migratory Sea Trout component), Arctic Charr, Eel and Three-spined Stickleback. A good running water example is the River Skealtar which has Atlantic Salmon, Brown Trout, Eel, Three- and Ten-spined Sticklebacks, Common Goby, Thick-lipped Mullet and Flounder.

There are many waters in the British Isles which naturally have very simple communities - sometimes with only one species present. Small streams or lakes in which only Brown Trout or Three-spined Sticklebacks occur are common in some coastal or highland areas and thus are not rare or unusual in themselves. However, some simple communities are of special interest and one such is Loch Meallt in Skye where the only fish present are Arctic Charr and Three-spined Sticklebacks (Campbell 1982, 1984). These species interact with each other in various ways and this site is of substantial conservation interest.

Some of the larger waters in the British Isles have a very diverse array of fish species which make up extremely interesting and complex communities. Southern lowland rivers are prominent here, notably the Rivers Avon, Great Ouse, Severn and Thames (Table 19). The larger lake communities are less complex, but notable diversity occurs in Llyn Tegid, Loch Lomond, Loughs Corrib and Erne (Table 19). All these waters contain almost full representations of the original stenohaline fishes although these are now well mixed with later introductions. Such communities should be kept under observation and if possible safeguarded.

Other waters can be of particular interest because of unusual, sometimes unique, combinations of species. This is especially true where threatened species or unusual races are involved. Good examples of this are Loch Eck and Haweswater, the only two sites in the British Isles where Arctic Charr and Powan occur together, Loch Lomond where Powan are found with River Lamprey and Llyn Tegid where Powan (Gwyniad) occur with Grayling. Lough Leane's uniqueness in having a freshwater population of Twaite Shad (Goureen) is further enhanced by the presence there of Arctic Charr.

In giving full consideration to the importance of any site, intactness is of importance. As just noted, Loch Eck and Haweswater are the only sites in the British Isles with both Arctic Charr and Powan. However, whilst the integrity of Haweswater has been substantially compromised by the fact that it has been dammed and is now a fluctuating water supply reservoir, Loch Eck is relatively intact. In addition, Loch Eck has the full range of British salmonid species including the migratory Atlantic Salmon and Sea Trout, neither of which occur in Haweswater. Loch Eck is clearly the more important site in conservation terms.

Provisional lists of some important fish communities in the British Isles have been tabulated (Table 19). It should be remembered that while none of the native fish species is endemic - for they all occur elsewhere in north-western Europe - they have mostly been isolated from their common stock since the end of the last ice age and some have developed into distinct local races. This differs, say, from the great majority of our native birds whose populations are, in the main, continuous with those of mainland Europe.

As discussed above, the main human pressures on native fish communities are those resulting from exploitation, pollution, loss of habitat and the irresponsible re-distribution of disruptive fish species from other parts of the country. In recent years there has been a marked trend in the British Isles away from natural mixed fish populations towards artificially maintained unstable stocks of a few species for sporting and commercial interests. However, it should be noted that all ten of the threatened fish species considered above were once of commercial importance in the British Isles (Table 20) and, in a few places, some still are.

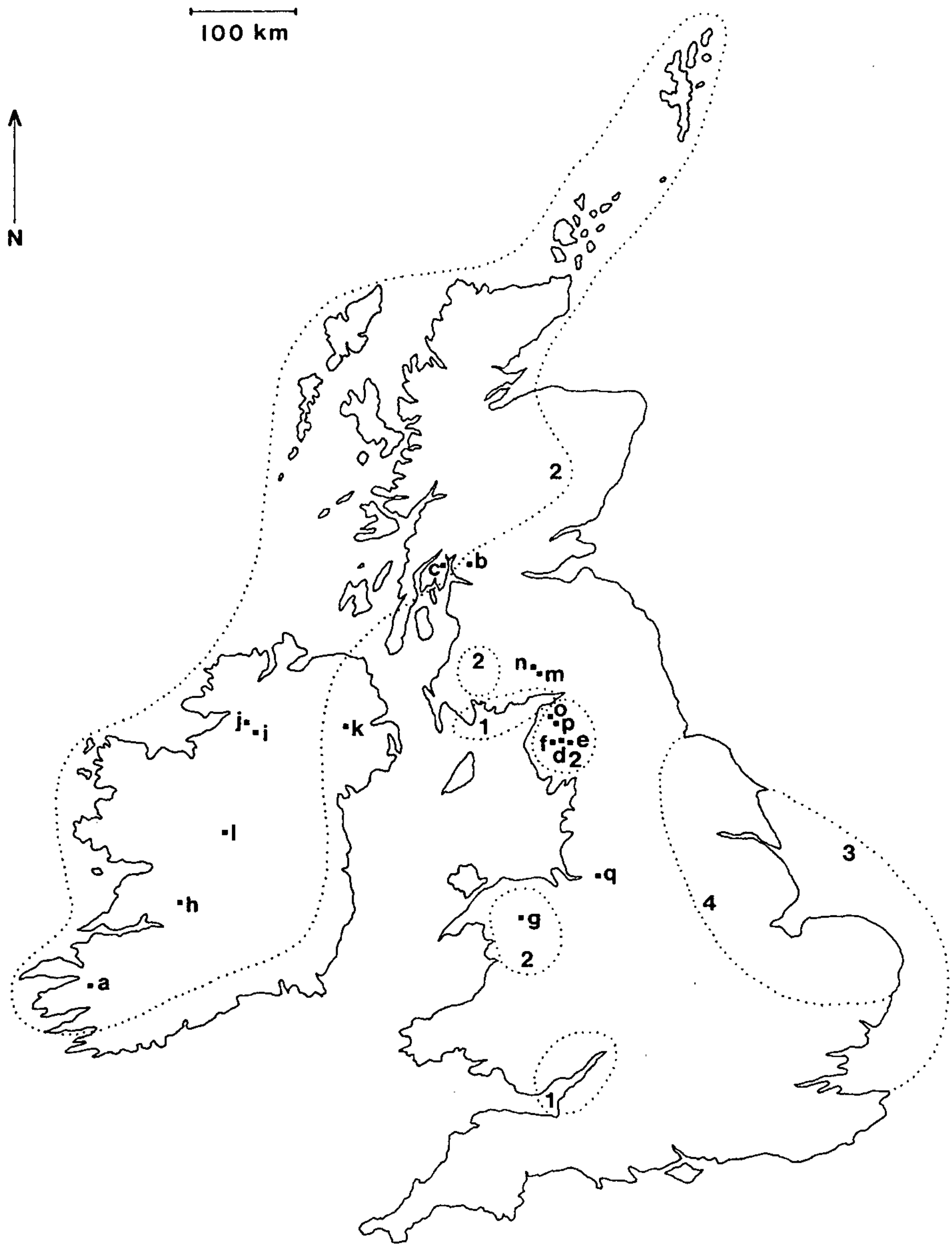

Figure 1. Areas in the British Isles of importance (now or in the past) for threatened fish: 1. Shad; 2. Arctic Charr; 3. Houting; 4. Burbot. The following lakes (see Table 13) are also marked: a. Lough Leane, b. Loch Lomond, c. Loch Eck, d. Ullswater, e. Haweswater, f. Red Tarn, g. Llyn Tegid, h. Lough Derg, i. Upper Lough Erne, j. Lower Lough Erne, k. Lough Neagh, l. Lough Ree, m. Castle Loch, n. Mill Loch, o. Derwentwater, p. Bassenthwaite Lake, q. Rostherne Mere.

3. EXISTING PROTECTION

Freshwater fish in the British Isles are protected in a variety of ways which may vary in the five different countries involved (i.e. England and Wales, Scotland, Northern Ireland and the Republic of Ireland). The two main forms of protection are through the creation of protected sites of one kind or another (usually known as nature reserves or sites (or areas) of special scientific interest) and a number of individual pieces of legislation. Most of the latter are concerned with fish species of sporting or commercial interest but a notable exception is the Wildlife and Countryside Act. Statutory protection of freshwater flora and fauna in Britain has recently been reviewed by Boon *et al.* (1992).

In Great Britain, the major review of nature conservation was 'A Nature Conservation Review', published by the Nature Conservancy Council (Ratcliffe 1977). In this extensive document there is a list of key conservation sites in Great Britain (the list of key sites has recently been revised by the Nature Conservancy Council, but the revision has not yet been published). The open water section contains details of 99 freshwater sites, mostly selected according to physical, chemical, botanical and ornithological criteria. In only 48 cases are fish referred to in the site description and in only a few cases were they part of the reason for site selection. These sites were:the Mill Loch (for Vendace), Loch Lomond (for Powan and high species diversity), Red Tarn (for Powan [Schelly]) and Rostherne Mere (for Smelt). In Ireland a major review of the status of wildlife (covering both Northern Ireland and the Republic of Ireland) is currently in progress (Whilde, personal communication).

3.1 National Nature Reserves

Of the 235 National Nature Reserves (NNRs) in Great Britain (Nature Conservancy Council 1990), 75% contain fresh waters but just over 20% of these have no fish (Lyle & Maitland

1992). Among the fish species found in the reserves with fresh water are 37 of the 55 freshwater species recorded from Great Britain. The majority of the fish found, however, are those most common in Great Britain and only three of the ten species under greatest threat (Maitland & Lyle 1991) occur in NNRs.

There are many fewer nature reserves in Ireland and none have been established because of their fish communities. In Northern Ireland, National Nature Reserves can be declared under legislation paralleling that In Great Britain. In the Republic of Ireland, Amenity Areas and Nature Reserves can be established under the Planning and Wildlife Acts. However, Amenity Areas (of which there are very few so far), designated under the Planning Act, have no implications for fish conservation.

3.2 Sites of Special Scientific Interest

Published guidelines are now available for the selection of biological Sites of Special Scientific Interest - SSSIs (Nature Conservancy Council 1989). The primary criteria used are: size, diversity, naturalness, rarity, fragility and typicalness. The guidelines for fresh waters divide habitats into three groups - standing waters, lowland ditch systems and running waters. Habitat division thereafter relies mainly on aquatic vegetation, though it is implied that guidelines for animal communities will be developed at a later date. The role of SSSIs in the conservation of rivers has been reviewed by Boon (1991).

The guidelines for various species groups include a short section on freshwater and estuarine fish. Because many water bodies now contain fish which have been introduced it is stated that where historical records are sparse or absent it may be extremely difficult to determine whether a population or community should be classed as 'natural'. For this reason, diversity does not provide a valid criterion for selecting SSSIs and it would only be in exceptional circumstances (e.g.

extreme isolation or high research potential) that SSSI selection on community grounds would be applicable.

The guidelines do allow site selection on grounds of isolated populations or rare species and give examples of ecotypic or genetically distinctive fish populations which are worthy of selection. These include populations of Arctic Charr in Wales, England and southern Scotland and also certain genetically distinct 'races' elsewhere in Scotland, possible post-glacial relict races of Brown Trout in northern Scotland and spine deficient Three-spined Sticklebacks in the Outer Hebrides.

Nationally rare species for which all breeding sites would qualify for selection are Allis Shad, Twaite Shad, Powan (known locally in England as Schelly and in Wales as Gwyniad), Vendace and Burbot. A nationally uncommon species for which some sites qualify for selection is the Smelt. It is already the case, that several existing SSSIs have been selected entirely or largely because of the importance of their stocks of rare fish (e.g. Bassenthwaite Lake, Mill Loch, Loch Doon) and these are thus given some protection by this designation. However, there has been no national review of the occurrence of freshwater fish communities in the large number of other SSSIs in Great Britain, which have been selected for a wide variety of reasons. Such a review, of all sites containing open water, might be extremely rewarding and an important advance for fish conservation.

A recent review of fish distribution in Scotland (Maitland 1992a) has resulted in a database within which all such information can be stored in the future. It is hoped to extend this programme to England and Wales and eventually to Ireland to parallel an earlier study for the British Isles (Maitland 1972) and also to build up national registers of important stocks, comparable to those available for other countries (e.g. Finland: Koljonen & Kallio-Nyberg 1991; Kallio-Nyberg & Koljonen 1991).

In Northern Ireland, Areas of Special Scientific Interest can be established under legislation paralleling that in Great Britain.

Under the Wildlife and Countryside Act, the owners of SSSIs are notified by the Nature Conservancy Council (or its successor bodies: English Nature, the Countryside Council for Wales and Scottish Natural Heritage) of 'Potentially Damaging Operations' which could endanger or destroy the interest of the site. In cases where the site has been notified for its freshwater interest the list would include those operations that might damage the fish community. Before such operations can be carried out the owners of sites have to advise NCC in writing of their intentions; negotiations may then follow to see if a compromise can be reached.

3.3 Other protected areas

There are many local nature reserves in various categories throughout the Britain and Ireland, and, as with National Nature Reserves, a considerable proportion of these contain aquatic habitats and fish communities. In general, relatively little is known about the fish within these reserves.

The Royal Society for the Protection of Birds and the Wildfowl and Wetlands Trust own many reserves throughout Great Britain whose primary importance is their bird life. Many of these reserves contain fresh waters but there has been no systematic study of their fish populations which are often an essential food resource for specific birds (e.g. divers, grebes, herons and sawbill ducks) of interest.

In England and Wales the national body with responsibility for coordinating the work of the many County Naturalists' Trusts is the Royal Society for Nature Conservation. However, each trust has its own list of reserves and there is no no overall assessment of their aquatic or fish potential for conservation.

In Scotland, apart from a few local nature reserves run by District or Regional Councils (e.g. Aberlady Bay Reserve in East Lothian) most nature reserves other than NNRs have been established by the Scottish Wildlife Trust. A useful reserves handbook for these is available (Scottish Wildlife Trust 1990) and is updated each year. An analysis of the aquatic interest of the 80 reserves included in the 1990 list shows that though 93% of the reserves have water bodies of one kind or another, relatively little is known about their fish. In only a few cases (11%) are fish mentioned in the description of the reserve and none of them was selected for the importance of fish.

In Northern Ireland, various reserves have been created (though none specifically for fish) by the Department of the Environment, the Royal Society for the Protection of Birds, the Ulster Trust for Nature Conservation and the Wetlands and Wildfowl Trust.

In the Republic of Ireland, reserves (again, none specifically for fish) have been established by the National Parks and Wildlife Service, the Irish Wildbird Conservancy and a few private trusts.

3.4 Legislation

Some protection is currently available for threatened fish in Britain and Ireland. Statutory protection given to freshwater flora and fauna in Britain has been discussed by Boon *et al.* (1992). In Great Britain, the Wildlife and Countryside Act (1981) affords protection to listed endangered species and there are now four fish species so listed - Allis Shad, Powan (Whitefish), Vendace and Burbot. This Act also lists several foreign fish species (e.g. Danube Catfish *Silurus glanis*, Pikeperch *Stizostedion lucioperca*) which must not be allowed to escape further to the wild or be deliberately redistributed without a licence to do so. However, there is no ban on the translocation of disruptive native species: the recent introduction and rapid establishment of the Ruffe *Gymnocephalus cernua* in Loch Lomond (Maitland & East 1989) is an example of this type of problem.

In Great Britain there are several pieces of essentially fisheries legislation which protect freshwater fish and their environment (Maitland 1987a). However, most of these relate directly to the fishery and farming interests of Atlantic Salmon and Brown and Rainbow Trout and may only incidentally help rare species. The Diseases of Fish Act allows the control of the importation or distribution of any fish thought to constitute a health hazard to native stocks. The Import of Live Fish Acts are of some help but unfortunately have a major loophole in that many potentially damaging species can readily be introduced as ornamental species. Thus theoretically, the Import of Live Fish (Scotland) Act could be used to ban all future imports of fish not native to Scotland, if felt to pose a threat to native fish, but in practice, most species can be imported under the guise of 'ornamental fish for aquaria or ponds'.

In Northern Ireland, the Department of Agriculture (under the Prohibition of Introduction of Fish Order) can prohibit the introduction of any species of fish into any water where it considered that this would be detrimental to the existing fishery. This Order also includes the names of several 'undesirable' fish species which are banned from Northern Ireland (e.g. Pink Salmon *Oncorhynchus gorbuscha*, Grayling *Thymallus thymallus*, Largemouth Bass *Micropterus salmoides*). Also available is the Diseases of Fish Act which controls the importation or distribution of any species, dead or alive, which may be considered to constitute a health hazard to Northern Ireland's fish stocks.

Site protection in Northern Ireland may be obtained under the Nature Conservation, Amenity, Lands and Wildlife Orders (which parallel the Wildlife and Countryside Act) administered by the

Conservation Service of the Countryside and Wildlife Branch of the Department of the Environment. As in Great Britain, owners of NNRs or ASSIs must give prior notice of any proposed activities which could damage the interest of the site.

In the Republic of Ireland, most freshwater fish legislation is aimed at its conservation as an exploitable resource rather than as an element of the native fauna. However, some of the current legislation is potentially effective in a more general way, for example, the importation of all coldwater fish and their eggs (into any part of Ireland) is prohibited (except under licence). A licence is also required for the transportation of live fish within the Irish Republic. The use of live bait (the source of many introductions) is banned.

In addition to legislation within Britain and Ireland there is also some important relevant international legislation - notably the Bern Convention and the EC Directive on 'The Conservation of Natural and Semi-Natural Habitats and of Wild Fauna and Flora (Boon *et al.* 1992).

The appendices of the Bern Convention (The Convention on the Conservation of European Wildlife and Natural Habitat) list species which are given protection. Following a report by Maitland (1986), fish were added to these appendices. Appendix II (species given full protection) now includes four fish species, none of which occur in the British Isles. Appendix III (species partially protected) includes 118 fish species, several of which occur (or occurred) in the British Isles, including Sturgeon, Allis Shad, Twaite Shad, Houting, Powan, Pollan and Vendace. A recent report to the Council of Europe (Maitland 1991) includes a recommendation for Appendix IV of the Bern Convention, which sets down prohibited means of killing capture or exploitation of the fish species listed in Appendix III.

The EC Directive has two Annexes concerned with species protection. Annex IV lists species which must be given full protection (this includes Sturgeon and Houting). Annex V lists species whose exploitation must be subject to management (this includes Twaite Shad).

4. CONSERVATION OPTIONS

The general conclusion from the above review of existing protection given to most native fish species in the British Isles is that it is generally inadequate both in terms of the establishment of appropriate reserves and of legislation. The exception relates to fish of angling importance which are given substantial protection both in the water and through available legislation. Even here, however, the situation is not entirely satisfactory, especially in Scotland. In general, throughout the British Isles, virtually no reserves have been established primarily for native fish conservation. In Great Britain, the main legislation other than that relating to fisheries is the Wildlife & Countryside Act. This is paralleled in Northern Ireland by appropriate Orders. In the Republic of Ireland, the Wildlife Act does not cover fish.

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 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.

4.1 Habitat restoration

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. In many cases, potentially unique stocks have completely disappeared (Table 21). 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 through which successful fish conservation will be achieved.

There have been enormous advances in pollution control in the British Isles over the last few decades and a number of the worst rivers are now much cleaner. Thus, 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, many freshwater and estuarine species have returned to the lower Thames which now supports a diverse community, not unlike its original one. It should be pointed out here, in relation to the discussion on monitoring below, that fish screens at various power stations along the river, although they do kill fish, have helped in monitoring the return of fish. Rehabilitation of the River Clyde has been rather slower. However, salmonid fish are conclusive evidence of high water quality and the return of the Atlantic Salmon *Salmo salar* to this river after an absence of more than 100 years is a tribute to decades of work by the local river purification board (Maitland 1987b).

However, the recent river quality survey by the National River Authority in England and Wales has shown that, in contrast to the situation in Scotland, there has been a general drop in water quality in many catchments and there is clearly no room for complacency.

An lake example from abroad is Lake Trummen in Sweden which 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.

Many fresh waters in Scandinavia, North America and the British Isles have lost their fish populations over the last three decades because of acidification, and altogether many thousands of individual stocks have disappeared (Haines 1981; Maitland *et al.* 1987). Various ways of ameliorating the impact of acid precipitation have been investigated, most of them involving the addition of 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 the Great Britain, various attempts at liming to ameliorate freshwater acidification have been attempted, most notable among which has been the work at Loch Dee (Burns *et al.* 1984) and later at Loch Fleet (Howells & Brown 1986), where the former healthy population of Brown Trout started to decline during the 1950s and became extinct during the 1970s (Maitland *et al.* 1987). In 1984, at Loch Fleet, 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 amounts of aluminium in the water decreased. Adult fish were introduced to the system in 1986 and these subsequently spawned successfully.

This experiment verified the earlier work of others, but though successful it is temporary (it is likely that further lime will have to be added to the catchment by the end of the century) and very expensive. In addition, liming often creates other ecological problems (e.g. damage to acidophilous vegetation) and it is by no means a complete solution to acidification (Woodin & Skiba 1990). Thus, though providing a possible short-term answer to the acidification problems affecting important local stocks of fish, e.g. the Arctic Charr at Loch Doon (Maitland *et al.* 1991), it does not provide a satisfactory long-term form of habitat restoration.

There are many others examples of habitat restoration to both running and standing waters. These include the reinstatement of spawning gravels, the restoration of meanders where rivers have been canalised, the provision of more compensation water where over-abstraction has taken place, etc. However, very few of these examples relate directly to the restoration of threatened fish populations *per se*. The types of habitat 'improvement' carried out by many anglers (e.g. deepening of pools, clearance of riparian trees, etc.) are really to help angling rather than the aquatic habitat.

4.2 Stock transfer

This can be done without any threat to the existing stocks, but it is important that certain criteria are taken into account in relation to any translocation proposal (Table 22). 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 hatching the eggs in a hatchery and introducing the young at various stages of development (Maitland & Lyle 1990).

One of the most urgent of these projects being undertaken in the British Isles at present concerns the Vendace. As noted elsewhere (Maitland & Lyle 1991), this species formerly occurred in two lochs in Scotland and two in England. Unfortunately, the two Scottish lochs are both very small; in one of them the Vendace disappeared at the turn of this century when a sewage effluent was led into the loch and in the other it appears to have become extinct from various pressures over the last decade. The objective of current work on this species is to identify suitable waters in which new populations may be established and initiate these over the next few years.

A similar procedure is at present under way with the Powan. There are only six populations of this species in the whole of Great Britain - two in Scotland, three in England and one in Wales. The largest population is probably in Loch Lomond and in recent years adult fish have been netted here from the spawning grounds in January and stripped to obtain many thousands of fertilised eggs. These have been hatched indoors and the young released into two lochs, both in the Loch Lomond catchment and previously selected as suitable for new populations, following the criteria outlined in Table 22. Sampling in 1991 showed that the fry introduced to one of these sites have grown extremely well and could be expected to spawn in January 1992.

The Arctic Charr occurs in only a few lakes in Wales, about ten in England but many more in Ireland and Scotland - particularly in the north and west. However, it has disappeared from several of its previous waters in England and

Ireland; in southern Scotland, where there were previously at least five populations, only one remains, in Loch Doon (Maitland *et al.* 1991). The system here is under threat from increasing acidification and current work aims at safeguarding the stock by creating new populations. Thus, eggs were collected from spawning adults in the autumns of 1986-90. These were taken to hatcheries and after hatching the alevins were introduced to a large reservoir in the Scottish Borders. In addition, adults and some reared young were introduced to a neighbouring reservoir during the same period (Maitland & Lyle 1990). There is already evidence that fry in the former water have survived and grown well, whilst young from a successful spawning in the second reservoir have been recovered in the outflow.

In the longer term it is hoped that all the other rare species will be involved in the project and that even the extinct Burbot may be restored to British waters by obtaining stock from waters elsewhere in Europe and re-introducing this attractive fish to some of its former sites. Proposals by the authors for this have already been included in the recovery plans collated by Whitten (1990) for endangered species in Britain. International co-operation around the North Sea - by protecting adults in the sea and in the few rivers in which they still breed, may also favour the restoration of Sturgeon and Houting to their previous numbers, so that they may both become common visitors to our shores.

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. One of the most difficult aspects of the programme to date has been to locate sites, which are suitable ecologically, geographically and where the owner is sympathetic to the proposals. A common problem is that a suitable site is already being used as a fishery. Considerable effort has already been devoted to this problem - so far without much success. It is important that 10-15 lake sites are located over the next few years and several different possibilities are presently being explored. One potential option may be sites within NNRs.

There are well over 200 National Nature Reserves in Great Britain and most of these contain fresh waters of one kind or another (Lyle & Maitland 1992). Clearly, where the interest of the NNR relates specifically to a freshwater body then there would rarely be any question of introducing any species there, however threatened. However, many of the fresh waters on reserves are incidental to the main interest of the reserve and could be potentially valuable sites for rare fish. Indeed, in some cases the establishment of such fish could enhance the quality of a reserve, not only because of the rarity of the fish but because of some contribution by the fish to local ecology. An example, involving a common species, occurred a number of years ago when Roach *Rutilus rutilus* were introduced to Morton Lochs NNR specifically to act as a food source for fish-eating birds there. However, it is clear that careful consultation with the statutory conservation agencies is needed in order to explore the possibility of fish introductions to NNRs - unless the species concerned had once existed there, when the case could be considered to be very strong.

4.3 Captive breeding

Captive breeding is widely used throughout the world for a variety of endangered animals, including fish (Maitland & Evans 1986). However, for most 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. Captive breeding in the long-term does not seem appropriate to any of the freshwater fish species at present under threat in the British Isles.

However, short-term captive breeding involving only one generation does have some advantages for a number of species and has already been carried out in the present project with Arctic Charr. It is especially relevant where translocations are desirable but it is difficult to obtain reasonable numbers of eggs or young 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 inbreeding and loss of genetic diversity it should not be carried out for more than one generation from the wild stock.

4.4 Cryopreservation

Modern techniques for rapid freezing of gametes to very low temperatures have proved successful for a variety of animals, including fish (Stoss & Refstie 1983). 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 eggs, no successful method of 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 would be worthwhile giving consideration to saving at least some of its genetic material through the cryopreservation of sperm. When it is possible to preserve female gametes in a similar way, the technique will have obvious possibilities in relation to the short-term conservation of a wide variety of fish species.

5. CONSERVATION ACTION

It can be seen from the above that a number of conservation options exist for each of the threatened species of fish in the British Isles. The conservation action proposed here varies considerably among the ten species concerned and is controlled by a number of constraints including their varying status and ecology, as well as logistics and finance. The relevant action procedures which seem feasible are discussed below and summarised in Table 23. Proposals for three of the species (Powan, Vendace and Burbot), prepared by the authors are included in the recovery programme produced by Whitten (1990).

5.1 Habitat management and restoration

This procedure is not relevant to Sturgeon and Houting, which have never bred in the British Isles, nor in the short-term to Burbot, which is now extinct. However, habitat management is of major importance to the remaining species. It is essential that a number of waters, both running and standing, are given high priority in this context both by the national conservation and the pollution control agencies. Clear management policies for such sites should be formulated soon. Obviously, priority should 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.

Habitat management is also of importance in relation to any new stocks which are initiated from translocation experiments. Thus the sites proposed in Table 24 should also be viewed in relation to overall habitat management proposals.

Thus the restoration of habitats from which important stocks have disappeared may be a much more difficult and expensive procedure and in some cases may not be considered worthwhile if effective alternative measures (see below) can be achieved. The most important examples are outlined in Table 21. Restoration of any of them would initially seem both difficult and expensive but should at least be considered.

5.2 Translocations

Translocation proposals for threatened fish species in the British Isles are summarised in Table 24 and considered below. One of the most realistic ways to safeguard vulnerable stocks of several of these is to initiate new populations in the near future. In general, such 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 the guidelines given in Table 22.

Since both **Sturgeon** and **Houting** have never bred in the British Isles, introductions here are not really relevant. Action elsewhere in Europe, however, should be supported fully.

Allis Shad. The status of this species is still uncertain, but it has certainly declined substantially over the last century and no certain spawning sites in the British Isles are known. There is strong evidence that the Severn and Solway estuaries are important to the species and efforts are being made at the moment to identify spawning sites in rivers there. No specific suggestions for translocations are relevant at the moment.

Twaite Shad. This species is more common than the Allis Shad and there are still spawning populations in the Rivers Severn, Usk and Wye (Aprahamian & Aprahamian, 1990); there is also one in the Solway area which requires further investigation. The unique landlocked stock in Lough Leane is under significant threat and translocation of stock to one or more appropriate loughs in the Killarney area would seem fully justified.

Arctic Charr. The status of this species in Great Britain is now fairly well known, and it seems relatively secure in its major stronghold - northwest Scotland (Maitland *et al.* 1984). However, it is threatened and declining elsewhere in its range

- southern Scotland, Cumbria and Wales - and it is believed that measures should be taken in each of these areas to establish stocks as a safeguard procedure. An initial programme has been carried out with the threatened Loch Doon population to restore it to waters (Megget and Talla Reservoirs) in the catchment of a loch where it is now extinct (St. Mary's Loch), and further introductions could replace the stocks lost in Galloway (Lochs Grannoch and Dungeon) and in Fife (Loch Leven). In addition, there has been some success in Wales where stocks from Llyn Peris, threatened by the activities of a new pumped-storage scheme there have been successfully established in Llyn Dulyn and Llyn Ffynnon Llugwy. There is a rapidly increasing interest in the exploitation of Arctic Charr by both fishing (angling and commercial) and farming interests. A number of new threats arise here, foremost among which must be the danger to the genetic integrity of existing populations of Arctic Charr, almost all of which have been isolated from each other since the last ice age.

Powan. This species exists in only six sites in Great Britain and it is certainly threatened at some of these. Translocations are seen as an important strategy for this fish and eventually it would be ideal to have an additional 1-3 'back-up' populations for each of the three site groupings: Gwyniad (Wales), Schelly (England), Powan (Scotland). As previously noted, preliminary work was undertaken at Loch Lomond from which stock has been transferred to Loch Sloy and Carron Valley Reservoir. This work should continue and other sites for the species are being urgently required.

Pollan. This species occurs in only five loughs in Ireland, and nowhere else in western Europe. These sites, however, are all very large and the situation seems reasonably secure. However, it would seem a reasonable safeguard to have at least two additional 'back-up' populations for each of the three site groupings in the Neagh, Erne and Shannon catchments.

Vendace. Of the four populations previously known in Great Britain, two are extinct. Thus this is probably the most threatened of the British fish, and translocation is seen as the major strategy for its survival. Eventually it would be ideal to have an additional 1-3 'back-up' populations for the Cumbrian sites (Bassenthwaite Lake and Derwentwater) and also to re-establish the species at suitable sites in Scotland, where some preliminary work to replace the extinct populations (originally at Lochmaben) was carried out.

Smelt. This species has declined in Great Britain and it has disappeared from many rivers and from the only site (Rostherne Mere) where there was a landlocked population. Several populations still remain in England (Howes & Kirk 1991), but there is only one left in Wales and only three (out of at least eleven) in Scotland. It is proposed that at least two appropriate rivers (one in Wales and one in Scotland) be selected for translocation experiments with this species. The technique of stripping fish and hatching eggs has already been developed during the present project.

Burbot. It is believed that this fish is extinct now in Great Britain and for this reason there is no immediate urgency for conservation here. Only if a stock of Burbot was shown still to exist in Great Britain would any immediate action be undertaken. There are several populations on the Continent and it seems reasonable to consider whether there should eventually be a programme to reintroduce it from there to one or more of its former habitats in eastern England. A precedent has already been set by the Nature Conservancy Council in the programme to re-introduce the Sea Eagle from Norway to the island of Rum (Love 1983). However, any such proposal would have to be prepared carefully and require the backing of the National Rivers Authority and angling groups. Thus, as far as this species is concerned, translocation can be the only strategy if it is to be re-established in Great Britain. Eventually it would seem ideal to have several populations restored to their original sites. This would involve a carefully considered and executed programme bringing in fertilised eggs, screened for disease, from continental Europe, rearing this to maturity at a suitable hatchery, stripping and eventually producing substantial numbers of fry to release at preselected sites. Some preliminary work has already been carried out by one of the authors on rearing Burbot (from North America) from fry to adult. The full programme is a substantial one.

5.3 Cryopreservation

For the reasons explained above, cryopreservation does not seem to be a realistic option for any of the threatened British species at the moment. However, this is an active research area of considerable relevance to fish conservation and as such support should be given to it.

5.4 Legislation

Sturgeon, Allis Shad, Twaite Shad, Powan, Pollan, Vendace and Houting have already been given some protection under the Bern Convention (Appendix III). The draft EC Habitat and Species Directive proposes protection for Sturgeon, Allis Shad, Twaite Shad, Powan, Vendace and Houting. Allis Shad, Powan (Whitefish), Vendace and Burbot are listed under the Wildlife and Countryside Act (Schedule 5). All fish are given substantial protection in England & Wales by the National Rivers Authority in relation to capture and to threats from translocated competitors or predators. In Scotland this is not so and there is an urgent need to revise the situation here so that all species of fish are given better protection. Also needed is some form of catchment to catchment control to prevent harmful translocations - either deliberately or from ignorance (often the case when live bait is disposed of). In this respect, public awareness needs to be improved. In addition, the import of foreign fish is an area of concern and tighter legislation is needed here so that harmful temperate species (which may predate, compete with, transfer disease or parasites to native fish) cannot gain entry to the British Isles.

Some years ago, the International Council for the Exploration of the Sea adopted a code of practice to reduce the risks of adverse effects arising from the introduction of non-indigenous marine species (ICES 1973). A similar code was adopted for inland waters by the European Inland Fisheries Advisory Commission and recently the American Fisheries Society and the International Council for the Conservation of Nature and Natural Resources have issued positive statements on the question of introductions and transfers. There have also been a number of positive proposals from individual scientists (e.g. Ryder & Kerr 1984).

Most of the fish introductions which take place within the British Isles are transfers from hatcheries or other waters within these islands. Such transfers are rarely needed, except in the case of 'put-and-take' fisheries, and can be potentially damaging. In general it should be illegal to introduce any fish into a water body without a permit from a national controlling authority. At the moment, such control is operable in England and Wales (through the National Rivers Authority) but not within Scotland because of inadequate legislation.

The great majority of the fish introductions into and within the British Isles have been related to angling and it is important that the national angling bodies adopt a more rational and responsible attitude to their activities.

There are obvious potential dangers also from temperate fish which are brought into this country and sold for aquaria or ponds. At present it is possible to purchase a variety of Eurasian and North American species through the aquarium and pond trade; a number of these could establish themselves here and pose a threat to native stocks. Examples are the North American Black Bullhead *Ictalurus melas* and Brown Bullhead

Ictalurus nebulosus, both already established elsewhere in Europe.

In spite of existing legislation there are still potential dangers from disease introduced with ornamental fish. The bulk of these fish are of tropical origin and destined for private indoor aquaria; there is probably very little risk here. However, with temperate species there are definite disease and parasite risks associated with their introduction and both fish and parasites could become established in the wild - as is already the case with the Largemouth Bass in southern England (Maitland & Price 1969). Moreover, even if the host fish was unable to establish a permanent population in the wild, a parasite might might well do so by transferring to native species.

One other loophole in the legislation which potentially allows even prohibited species (and their parasites) into the country lies with the problems of identification. Thus it has been suggested that Rainbow Trout could accidentally become mixed with batches of ornamental species imported regularly from Denmark and so bring in diseases which could prove a major threat to salmonid farming in the British Isles. The question of the identification of imported batches of fish is a very critical one for there is little point in having legislation banning the import of certain fish if the controlling authorities are actually unable to carry out accurate identifications.

Thus further controls would seem to be needed. These might include some or all of the measures proposed by Maitland (1990) and outlined in Table 25.

5.5 Research

The biology of rare species in the British Isles has recently been reviewed (Maitland & Lyle 1991); only the major gaps in knowledge are discussed below and summarised in Table 23.

Sturgeon. No major research is proposed on this species which is the subject of several research and management projects in Europe (Rochard *et al.* 1990). However, in view of its conservation status, a more formal procedure for recording full details of the specimens taken by commercial fishermen and others should be implemented.

Allis Shad. Some information from continental Europe is available on this species, but virtually no research has been carried out in the British Isles. In view of its rarity and threatened status, the stock in the Solway Firth seems to be an especially important one and merits substantial further investigation.

Twaite Shad. This species has been studied in the Severn area by Aprahamian (1981) and information is available from studies elsewhere in Europe. In view of its rarity and threatened status as well as its coincidence with Allis Shad there, the stock in the Solway Firth seems to be an especially important one and also merits substantial further investigation.

Arctic Charr. This species has been well studied in a number of localities both in the British Isles and elsewhere in its range. However, further research is required, especially in Scotland (Maitland *et al.* 1984) to determine the number of stocks as yet unrecorded and to establish the population status and genetic individuality of major populations.

Houting. No major research is proposed on this species. Some information is available from the literature in Europe. However, in view of its conservation status, some publicity and a more formal procedure for recording any specimens which might be taken accidentally by commercial fishermen and others should be implemented (presumably through the Scottish Office Agriculture and Fisheries Department and the Ministry of Agriculture, Fisheries and Food in England and Wales).

Powan. Some ecological/biological information is now available for all six populations. Further work is necessary to cover areas not yet studied (parasites, inter-relations with habitat and other species, etc.) and to investigate the ecology and biology of any new, translocated, populations.

Pollan. This species has been well studied in Lough Neagh but relatively little in the other Irish localities - though some data are available. Its status and ecology in the Erne and Shannon loughs merit further scientific research.

Vendace. Some ecological/biological information is available for the Bassenthwaite population and for that formerly in the Mill Loch. Some further work is necessary to cover topics not yet studied (parasites, inter-relations with habitat and other species, etc.) and to investigate the ecology and biology of any new, translocated, populations.

Smelt. This fish has been relatively little studied in the British Isles but there is substantial literature from continental Europe. Some work has been done on its ecology in the River Cree, Scotland (Hutchinson & Mills 1987). Further work needs to be carried out particularly in assessing the status of all remaining populations and their stock individuality - especially in relation to spawning sites and behaviour.

Burbot. Considerable ecological/biological information is available for this species from the literature. Since it is extinct now in the British Isles, no research is envisaged at the moment, other than perhaps an ecological assessment of the suitability of various systems, which previously held stocks, for possible translocation attempts.

5.6 Monitoring

It is believed that all populations which are sufficiently worthy of conservation must be monitored adequately - at the very least to prove from time to time that they still exist. Ideally, the system used, though it may not be quantitative, should at least be standardised so that comparisons can be made in time, and also perhaps in space in some cases. However, monitoring programmes of this type can be expensive, in terms of both time and finance and any monitoring programme must be designed to keep both of these to a minimum.

Some basic monitoring proposals for all the stocks at present believed to be important are summarised in Table 26. In some cases it is possible to take advantage of local circumstances which make monitoring relatively easy. In others, special methods and monitoring programmes must be set up. These are not outlined in detail as each site needs to be reviewed and considered on its merits. There is a particular need to investigate the various possible methods of monitoring, especially ones which are non-damaging (to fish), cheap and routine to carry out, and which thus could become part of the duties of local wardening or volunteer conservation staff.

In addition to monitoring stocks of major conservation significance it is also of importance to carry out regular reviews of the distribution and status of all fish species in the British Isles (Maitland 1972, Maitland 1992a) and maintain registers of all valuable stocks (Koljonen & Kallio-Nyberg 1991; Kallio-Nyberg & Koljonen 1991).

5.7 Assessing status

Several difficulties arise in assessing the degree of threat to a species and there are substantial anomalies in the conclusions which can be reached using different methods and also in comparing various groups of plants and animals. The method used in this study is an objective one which stresses the importance of the number of individual stocks of a species and whether or not these stocks are increasing or decreasing.

Of the ten fish species regarded as under threat, two (Houting and Burbot) have already gone from the British Isles, although the latter is still listed under Schedule 5 of the Wildlife and Countryside Act. Three of the others are also listed (Allis Shad, Powan [Whitefish] and Vendace) but the four eligible members (Sturgeon, Twaite Shad, Houting and Smelt) of the remaining five are not. This is perhaps surprising, especially in view of the fact that the Sturgeon, for example, is regarded as endangered world-wide (IUCN 1990). The five populations of Pollan in Ireland are the only ones in the whole of western Europe, but the species is not included in any of the Schedules of the Wildlife (Northern Ireland) Order 1985.

It is of some interest to compare the conservation status of these fish species, which are not included in Schedule 5 of the Wildlife and Countryside Act, with other animals which are. For example, the least threatened of the ten fish species reviewed above is the Arctic Charr which, though in decline, still has *ca.* 200 populations in the British Isles. In comparison, the Crested Newt *Triturus cristatus*, which is listed under Schedule 5, is also supposed to be in decline, but is estimated still to occur at some 18,000 sites in Great Britain (Whitten 1990). However, the main reason for this species being in Schedule 5 is that Great Britain has responsibilities, under European legislation, for the protection of this particular species. The Smelt, which has declined substantially in recent years, is still fished commercially at several of the *ca.*20 remaining sites. The Pipistrelle Bat *Pipistrellus pipistrellus*, however, included in Schedule 5, is regarded as vulnerable in Great Britain and in Europe, yet in Britain alone there are thousands of breeding colonies of this common species.

Fortunately, there is provision within the existing legislation for a five-yearly review of schedules by the successor bodies of the Nature Conservancy Council. This process allows new species to be added or species not at risk deleted. However, one problem related to conserving fish compared with other organisms is that many more species are exploited commercially or by anglers. Often, completely different methods of capture and exploitation are used in different countries and species regarded as important in one country are ignored in another. Attitudes and legislation in relation to fish conservation and stock management vary widely across Europe.

5.8 Other countries

The general picture 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. Here, an Endangered Species Act (which includes many fish species) became law in 1973 and has been updated several times since. The Act is implemented within the United States by the US Fish and Wildlife Service and the three main areas of emphasis are in listing the species under threat, protecting the habitats concerned and active management to recover populations which have undergone serious decline (Williams 1981). There is active conservation management for threatened fish species, some of this being carried out in premises designed for this purpose, such as the Dexter National Fish hatchery in New Mexico, established in 1974. 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, in addition to studying their ecological requirements. 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.

However, in the last few years more and more attention has been given to fish conservation internationally and several symposia have recently been devoted to this topic - e.g. Maitland (1987c), Le Cren (1990). Several reviews of the conservation status and needs of freshwater fish in large geographic areas have been prepared (e.g. Maitland 1986, 1992b, Pollard *et al.* 1990, Skelton 1990, Williams & Miller 1990) and it is hoped that these initiatives will lead to practical conservation management schemes to save threatened fish species and restore important habitats on a world-wide basis.

6. CONCLUSIONS

The general conclusion reached from this 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 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. There is a clear need for further action in fish conservation management and the proposals arising from this review have been summarised in Table 27.

Future scenarios are inevitably speculative, but if present trends continue, without any special measures for rare fish, then at least some of the following can be expected:

(a) Further rare species will disappear from the British Isles, the most threatened at present being Allis Shad and Vendace.

(b) The decline in other species (e.g. Arctic Charr) will continue, especially if the farming of this fish proceeds without controls.

(c) Some common southern species (e.g. Pike, Dace, Perch, Ruffe) will continue to disperse north and may destroy native communities there.

(d) Rare genetic races of some common species (e.g. Brown Trout) will disappear.

(e) Pristine communities will be replaced by mixed ones of common, often introduced, species.

(f) The genetic base and diversity of some common species (e.g. Atlantic Salmon, Brown Trout) will be damaged by indiscriminate stocking and release or escapes from fish farms.

(g) Fish will continue to be ignored by many conservation agencies.

(h) Without regular reviews of fish distribution and registers of important stocks many changes will not be noticed until it is too late to take action.

An alternative scenario, based on some of the more positive research and management activities taking place or proposed, is more optimistic and some or all of the following may be hoped for:

(a) No further species will be lost, and indeed extinct species like the Burbot may be reintroduced successfully from mainland Europe to selected waters in England.

(b) The future of species at present under threat will be secured by positive habitat restoration and the establishment of new additional safeguard populations.

(c) Further research will define criteria for the management of fish habitats and anticipate the impact of new threats (e.g. climate change). It will also identify more clearly the status of populations of unusual races and stocks of common species.

(d) Legislation will be introduced to control the movement and stocking of fish, especially into areas and waters where they do not occur.

(e) The status of fish will be taken into account when reviewing the establishment and management of National Nature Reserves, SSSIs and other designated areas.

(f) Important populations will be regularly monitored so that management decisions can be taken to conserve any stocks showing decline.

(g) There will be much greater awareness by the public and by conservation agencies of freshwater fish and their conservation needs.

(h) Regular reviews of fish distribution and status will be carried out in parallel with the maintenance of registers of important stocks.

The proposals put forward in this review are presented in outline only. The major suggestions are summarised in Table 27. Though the conservation of fish has been sadly neglected in the past in the British Isles (and in most other parts of the world), the authors believe that the present suggestions, if implemented, will substantially advance the cause of freshwater fish conservation. There is every reason to hope that, 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, commercial and aesthetic purposes.

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Table 1. Some characteristics of freshwater fish populations 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 2. A summary of the main pressures facing freshwater fish and their habitats in temperate areas.

	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. Temperate fish species which are known to have been introduced to waters in the British Isles (after Wheeler & Maitland 1973) but have never become established.

Huchen *Hucho hucho* (Linnaeus 1758)

Cutthroat Trout *Oncorhynchus clarki* Richardson 1836

American Lake Charr *Salvelinus namaycush* (Walbaum 1792)

Dolly Varden *Salvelinus malma* (Walbaum 1792)

Mudminnow *Umbra krameri* (Walbaum 1792)

Brown Bullhead *Ictalurus nebulosus* (Le Sueur 1819)

Smallmouth Bass *Micropterus dolomieu* Lacepede 1802

Walleye *Stizostedium vitreum* (Mitchill 1818)

Table 4. A simple diagrammatic classification of fish habitats in the British Isles. 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 5. Check list of the freshwater fishes of the British Isles.

LAMPREYS Family PETROMYZONIDAE
Sea Lamprey *Petromyzon marinus* Linnaeus 1758
River Lamprey *Lampetra fluviatilis* (Linnaeus 1758)
Brook Lamprey *Lampetra planeri* (Bloch 1784)

STURGEON Family ACIPENSERIDAE
Common Sturgeon *Acipenser sturio* Linnaeus 1758

SHADS Family CLUPEIDAE
Allis Shad *Alosa alosa* (Linnaeus 1758)
Twaite Shad *Alosa fallax* (Lacepede 1803)

SALMON, TROUT AND CHARR Family SALMONIDAE
Atlantic Salmon *Salmo salar* Linnaeus 1758
Brown Trout *Salmo trutta* Linnaeus 1758
Rainbow Trout *Oncorhynchus mykiss* (Walbaum 1792)
Pink Salmon *Oncorhynchus gorbuscha* (Walbaum 1792)
Arctic Charr *Salvelinus alpinus* (Linnaeus 1758)
Brook Charr *Salvelinus fontinalis* (Mitchill 1815)

WHITEFISH Family COREGONIDAE
Houting *Coregonus oxyrinchus* (Linnaeus 1758)
Powan *Coregonus lavaretus* (Linnaeus 1758)
Pollan *Coregonus autumnalis* (Pallas 1776)
Vendace *Coregonus albula* (Linnaeus 1758)

GRAYLING Family THYMALLIDAE
Grayling *Thymallus thymallus* (Linnaeus 1758)

SMELT Family OSMERIDAE
Smelt *Osmerus eperlanus* (Linnaeus 1758)

PIKE Family ESOCIDAE
Pike *Esox lucius* Linnaeus 1758

CARP Family CYPRINIDAE
Common Carp *Cyprinus carpio* Linnaeus 1758
Crucian Carp *Carassius carassius* (Linnaeus 1758)
Goldfish *Carassius auratus* (Linnaeus 1758)
Barbel *Barbus barbus* (Linnaeus 1758)
Gudgeon *Gobio gobio* (Linnaeus 1758)
Tench *Tinca tinca* (Linnaeus 1758)
Silver Bream *Blicca bjoerkna* (Linnaeus 1758)
Common Bream *Abramis brama* (Linnaeus 1758)
Bleak *Alburnus alburnus* (Linnaeus 1758)
Minnow *Phoxinus phoxinus* (Linnaeus 1758)
Bitterling *Rhodeus sericeus* (Bloch 1782)
Rudd *Scardinius erythrophthalmus* (Linnaeus 1758)
Roach *Rutilus rutilus* (Linnaeus 1758)
Chub *Leuciscus cephalus* (Linnaeus 1758)
Orfe *Leuciscus idus* (Linnaeus 1758)
Dace *Leuciscus leuciscus* (Linnaeus 1758)

LOACH Family COBITIDAE
Spined Loach *Cobitis taenia* Linnaeus 1758
Stone Loach *Noemacheilus barbatulus* (Linnaeus 1758)

CATFISH Family SILURIDAE
Danube Catfish *Silurus glanis* Linnaeus 1758

EELS Family ANGUILLIDAE
European Eel *Anguilla anguilla* (Linnaeus 1758)

STICKLEBACKS Family GASTEROSTEIDAE
Three-spined Stickleback *Gasterosteus aculeatus* Linnaeus 1758
Ten-spined Stickleback *Pungitius pungitius* (Linnaeus 1758)

COD Family GADIDAE
Burbot *Lota lota* (Linnaeus 1758)

BASS Family SERRANIDAE
Sea Bass *Dicentrarchus labrax* (Linnaeus 1758)

SUNFISH Family CENTRARCHIDAE
Largemouth Bass *Micropterus salmoides* (Lacepede 1802)
Pumpkinseed *Lepomis gibbosus* (Linnaeus 1758)
Rock Bass *Ambloplites rupestris* (Rafinesque-Schmaltz 1817)

PERCH Family PERCIDAE
Perch *Perca fluviatilis* Linnaeus 1758
Ruffe *Gymnocephalus cernua* (Linnaeus 1758)
Pikeperch *Stizostedion lucioperca* (Linnaeus 1758)

GOBIES Family GOBIIDAE
Common Goby *Pomatoschistus microps* (Kroyer 1840)

MULLETS Family MUGILIDAE
Thick-lipped Mullet *Chelon labrosus* (Risso 1826)
Thin-lipped Mullet *Liza ramada* (Risso 1826)
Golden Mullet *Liza aurata* (Risso 1810)

SCULPINS Family COTTIDAE
Bullhead *Cottus gobio* Linnaeus 1758

FLATFISH Family PLEURONECTIDAE
Flounder *Platichthys flesus* (Linnaeus 1758)

Table 6. The origins of the freshwater fish fauna of the British Isles.

INDIGENOUS SPECIES		INTRODUCED SPECIES	
1. Via the sea	2. Via land bridge	1. From Europe	2. From N America
(Euryhaline)	(Stenohaline)		
Sea Lamprey	Grayling	Common Carp	Rainbow Trout
River Lamprey	Pike	Crucian Carp	Pink Salmon
Brook Lamprey	Barbel	Goldfish	Brook Charr
Sturgeon	Gudgeon	Bitterling	Largemouth Bass
Allis Shad	Tench	Orfe	Pumpkinseed
Twaite Shad	Silver Bream	Danube Catfish	Rock Bass
Atlantic Salmon	Common Bream	Pikeperch	
Trout	Bleak		
Arctic Charr	Minnow		
Houting	Rudd		
Powan	Roach		
Pollan	Chub		
Vendace	Dace		
Smelt	Spined Loach		
Eel	Stone Loach		
3-sp Stickleback	Burbot		
10-sp Stickleback	Perch		
Sea Bass	Ruffe		
Common Goby	Bullhead		
Thick-l Mullet			
Thin-l Mullet			
Golden Mullet			
Flounder			

Table 7. Occurrence of fish by habitat in the British Isles.
Note: ++ = common; + = uncommon; * = occasional examples.

COMMON NAME	SEA	ESTUARY	RIVER	LAKE
Sea Lamprey	++	++	++	*
River Lamprey	+	++	++	*
Brook Lamprey			++	+
Sturgeon	++	+	*	
Allis Shad	++	++	+	
Twaite Shad	++	++	+	
Atlantic Salmon	++	++	++	+
Brown Trout	++	++	++	++
Rainbow Trout		*	+	++
Pink Salmon	*	*		
Arctic Charr			*	++
Brook Charr			+	++
Houting	++	++		
Powan			*	++
Pollan		*	*	++
Vendace				++
Grayling			++	*
Smelt	+	++	+	*
Pike			+	++
Carp			+	++
Crucian Carp				++
Goldfish				++
Barbel			++	
Gudgeon			++	
Tench			+	++
Silver Bream			+	++
Bream			++	++
Bleak			++	
Minnow			++	++
Bitterling			++	+
Rudd			+	++
Roach			+	++
Chub			++	+
Orfe			++	++
Dace			++	*
Spined Loach			++	
Stone Loach			++	*
Danube Catfish				++
Eel	++	++	++	++
Three-spined Stickleback	+	++	++	++
Ten-spined Stickleback		+	++	++
Burbot			++	
Sea Bass	++	++		
Largemouth Bass				+
Pumpkinseed				+
Rock Bass				+
Perch			+	++
Ruffe			++	++
Pikeperch			+	+
Common Goby	+	++		
Thick-lipped Mullet	++	++		
Thin-lipped Mullet	++	++		
Golden Mullet	++	++		
Bullhead			++	*
Flounder	++	++	+	+

Table 8. Scottish freshwater fish and their occurrence at different times since the last Ice Age.

ORIGINAL COLONISERS	LAND BRIDGE	INTRODUCTIONS		
Euryhaline sp	By 1790	By 1880	By 1970	By 1990
Sturgeon	Pike	Brook Charr	Rainbow Trout	Ruffe
Sea Lamprey	Roach	Grayling	Pink Salmon	
River Lamprey	Stone Loach	Tench	Common Carp	
Brook Lamprey	Perch	Common Bream	Goldfish	
Allis Shad	Minnow	Chub	Gudgeon	
Twaite Shad		Crucian Carp	Rudd	
Atlantic Salmon			Orfe	
Trout			Dace	
Arctic Charr			Bullhead	
Powan				
Vendace				
Smelt				
Eel				
3-sp Stickleback				
10-sp Stickleback				
Sea Bass				
Common Goby				
Thick-l Mullet				
Thin-l Mullet				
Golden Mullet				
Flounder				

Table 9. Conservation assessment of freshwater fishes in the British Isles. Note: Origin: M = Marine (euryhaline), S = Stenohaline, F = Foreign (introduced); Stocks: V = Vagrant; Status: see Table 10.

SPECIES	ORIGIN	DISPERSAL	STOCKS	STATUS
Sea Lamprey	M	-ve	>30	D
River Lamprey	M	-ve	>30	D
Brook Lamprey	M	-ve	>30	D
Sturgeon	M	-ve	V	I
Allis Shad	M	-ve	<10	A
Twaite Shad	M	-ve	<10	A
Atlantic Salmon	M	-ve	>30	D
Brown Trout	M	-ve	>30	D
Rainbow Trout	F	+ve	<10	E
Pink Salmon	F	-ve	V	E
Arctic Charr	M	-ve	>30	C
Brook Charr	F	+ve	<10	E
Houting	M	-ve	V	I
Powan	M	-ve	<10	B
Pollan	M	-ve	<10	B
Vendace	M	-ve	<10	A
Grayling	S	+ve	>30	E
Smelt	M	-ve	<30	B
Pike	S	+ve	>30	E
Carp	F	+ve	>30	E
Crucian Carp	F	+ve	>30	E
Goldfish	F	+ve	>30	E
Barbel	S	+ve	>30	E
Gudgeon	S	+ve	>30	E
Tench	S	+ve	>30	E
Silver Bream	S	-ve	>30	E
Bream	S	+ve	>30	E
Bleak	S	-ve	>30	E
Minnow	S	+ve	>30	E
Bitterling	F	+ve	<30	E
Rudd	S	+ve	>30	E
Roach	S	+ve	>30	E
Chub	S	+ve	>30	E
Orfe	F	+ve	<30	E
Dace	S	+ve	>30	E
Spined Loach	S	-ve	>30	D
Stone Loach	S	+ve	>30	E
Danube Catfish	F	+ve	<10	E
Eel	M	+ve	>30	E
Three-spined Stickleback	M	+ve	>30	E
Ten-spined Stickleback	M	-ve	>30	E
Burbot	S	-ve	0	I
Sea Bass	M	-ve	>30	D
Largemouth Bass	F	-ve	<30	E
Pumpkinseed	F	+ve	<30	E
Rock Bass	F	-ve	<30	E
Perch	S	+ve	>30	E
Ruffe	S	+ve	>30	E
Pikeperch	F	+ve	>30	E
Common Goby	M	-ve	>30	E
Thick-lipped Mullet	M	-ve	>30	E
Thin-lipped Mullet	M	-ve	>30	E
Golden Mullet	M	-ve	>30	E
Bullhead	S	+ve	>30	E
Flounder	M	+ve	>30	E

Table 10. Key to assess conservation priority of fish species.

1.	Native	2.
	Introduced	6.
2.	Species no longer occurs or does not breed here	I.
	Species still occurs and breeds	3.
3.	Less than 5 discrete breeding stocks	A.
	5-10 discrete breeding stocks	B.
	11-30 discrete breeding stocks	4a.
	More than 30 breeding stocks	4b.
4a.	Number of stocks declining	5a.
	Number of stocks stable or increasing	5b.
4b.	Number of stocks declining	5b.
	Number of stocks stable or increasing	5c.
5a.	Major threats to many existing stocks	A.
	No major threats to existing stocks	B.
5b.	Major threats to many existing stocks	C.
	No major threats to existing stocks	D.
5c.	Major threats to many existing stocks	D.
	No major threats to existing stocks	E.
6.	Endangered internationally	I.
	Not endangered internationally	E.

I. International action needed.

A. Urgent conservation action needed now.

B. A conservation management plan should be implemented soon.

C. A conservation management plan should be prepared.

D. A conservation management plan should be considered.

E. No immediate action needed.

Table 11. The rarer species of native freshwater fish in the British Isles.

FISH	OCCURRENCE
Sturgeon *Acipenser sturio*	An increasingly rare vagrant around all coasts.
Allis Shad *Alosa alosa*	Now uncommon around our coasts. No certain breeding sites.
Twaite Shad *Alosa fallax*	Less common than formerly around all coasts. Breeds in only a few rivers. Land-locked race in Lough Leane (Killarney).
Arctic Charr *Salvelinus alpinus*	Fewer populations than formerly. Many in Scotland & Ireland, a few in Wales & England.
Houting *Coregonus oxyrinchus*	An former vagrant around our coasts. Now extinct in the British Isles.
Powan *Coregonus lavaretus*	Only six populations altogether. Two in Scotland, three in England, one in Wales.
Pollan *Coregonus autumnalis*	Only five populations in large Irish loughs.
Vendace *Coregonus albula*	Only two populations left (in England). Two others (in Scotland) extinct this century.
Smelt *Osmerus eperlanus*	Much less common than formerly in most estuaries. Far fewer breeding stocks left. The single landlocked population now extinct.
Burbot *Lota lota*	Formerly in only a few rivers in eastern England. Now extinct in the British Isles.

Table 12. Physical data for some of the rivers in Great Britain in whose waters or estuaries Allis Shad and Twaite Shad have been recorded. As indicated in the text, very few spawning sites are known. Data refer to the lowest gauging site on each river.

RIVER	SITE	CATCHMENT (KM^2)	MEAN FLOW ($M^3.S^{-1}$)	MIN FLOW ($M^3.S^{-1}$)
ALLIS SHAD				
Cree	Newton Stewart	368	15.1	0.4
Loughor	Tit-y-dail	46	1.9	0.2
Ouse	Skelton	3315	48.1	7.0
Severn	How Bridge	9895	104.3	12.3
Thames	Kingston	9948	66.9	0.7
Tweed	Norham	4390	76.7	9.9
Tywi	Nantgaredig	1090	38.2	1.5
Usk	Chain Bridge	912	27.7	2.7
Wye	Redbrook	4010	71.2	5.2
TWAITE SHAD				
Axe	Whitford	289	5.0	0.6
Cree	Newton Stewart	368	15.1	0.4
Dart	Austine Bridge	248	11.0	0.7
Dyfi	Dyfi Bridge	471	22.5	0.8
Dysynni	Pont-y-garth	75	4.3	0.3
Exe	Thorverton	601	15.9	0.7
Forth	Craigforth	1036	47.9	3.6
Loughor	Tit-y-dail	46	1.9	0.2
Severn	How Bridge	9895	104.3	12.3
Taff	Tongwynlais	487	28.1	4.4
Teign	Preston	380	9.4	0.5
Thames	Kingston	9948	66.9	0.7
Tywi	Nantgaredig	1090	38.2	1.5
Usk	Chain Bridge	912	27.7	2.7
Wye	Redbrook	4010	71.2	5.2

Table 13. Physical data for lakes in which Twaite Shad, Powan, Pollan, Vendace and Smelt have been recorded in the British Isles.

SITE	ALTITUDE (M)	SURFACE AREA (HA)	MAX DEPTH (M)	1990 STATUS
TWAITE SHAD (Goureen)				
Lough Leane	20	2000	67	+ve
POWAN (Schelly, Gwyniad)				
Loch Lomond	8	7040	198	+ve
Loch Eck	9	458	42	+ve
Ullswater	145	894	63	+ve
Haweswater	241	390	57	+ve
Red Tarn	713	10	25	+ve
Llyn Tegid	163	160	42	+ve
POLLAN				
Lough Derg	33	12691	36	+ve
Upper L Erne	45	3385	27	+ve
Lower L Erne	44	11137	69	+ve
Lough Neagh	15	39627	31	+ve
Lough Ree	37	15540	32	+ve
VENDACE				
Castle Loch	42	78	6	-ve
Mill Loch	52	13	17	-ve
Derwentwater	75	530	22	+ve
Bassenthwaite L	68	535	21	+ve
SMELT				
Rostherne Mere	21	49	31	-ve

Table 14. Physical data for lakes in which Arctic Charr has been recorded in Wales, England and southern Scotland.

SITE	ALTITUDE (M)	SURFACE AREA (HA)	MAX DEPTH (M)	1990 STATUS
WALES				
Llyn Bodlyn	381	15	-	+ve
Llyn Cwellyn	141	76	37	+ve
Llyn Dulyn	533	13	58	+ve
Llyn Ffynnon Llugwy	534	13	-	+ve
Llyn Padarn	104	135	29	+ve
Llyn Peris	105	60	35	-ve
ENGLAND				
Buttermere	101	94	29	+ve
Coniston Water	44	491	56	+ve
Crummock Water	98	252	44	+ve
Derwentwater	75	535	22	-ve
Ennerdale Water	112	300	42	+ve
Haweswater	241	391	57	+ve
Loweswater	121	64	16	-ve
Thirlmere	179	327	46	+ve
Ullswater	145	894	63	-ve
Wastwater	61	291	76	+ve
Windermere	39	1476	64	+ve
SOUTHERN SCOTLAND				
Loch Doon	215	911	40	+ve
Loch Dungeon	305	36	29	-ve
Loch Eck	9	458	42	+ve
Loch Grannoch	211	120	21	-ve
Loch Leven	107	1331	26	-ve
Loch Spallander	210	40	-	-ve
St Mary's Loch	247	257	34	-ve

Table 15. Physical data for the major rivers in whose waters or estuaries Smelt have been recorded in Great Britain. The data refer to the lowest gauging site on each river. The stocks in those rivers marked * are still exploited by a commercial fishery.

RIVER	SITE	CATCHMENT (KM^2)	MEAN FLOW ($M^3.S^{-1}$)	MIN FLOW ($M^3.S^{-1}$)	1990 STATUS
Annan	Brydekirk	925	27.0	1.9	-ve
Blackwater	Appleford Br	139	1.2	0.2	+ve
Conwy	Cwm Llanerch	345	17.6	0.7	+ve
Cree*	Newton Stewart	368	15.1	0.4	+ve
Crouch	Wickford	72	0.3	0.1	+ve
Dee	Manley Hall	1019	30.9	3.1	+ve
Esk	Netherby	842	24.3	2.3	+ve
Forth	Craigforth	1036	47.9	3.6	+ve[1]
Frome	East Stocke	414	6.7	1.3	+ve
Girvan	Robstone	246	6.3	0.3	-ve
Great Ouse	Denver Complex	3430	15.6	11.6	+ve
Medway	Teston	1256	11.1	0.6	+ve
Nene	Orton	1634	9.3	0.5	+ve
Nith	Friars Carse	799	25.7	1.5	-ve
Piddle	Baggs Mill	183	2.4	0.4	+ve
Stinchar	Balnowlart	341	10.6	0.3	-ve
Tamar	Gunnislake	917	22.7	0.8	+ve
Tay*	Balathie	4587	158.1	14.7	+ve
Thames	Kingston	9948	66.9	0.7	+ve
Trent	North Muskham	8231	90.9	19.4	+ve
Urr	Dalbeattie	199	5.7	0.1	-ve
Waveney*	Needham Mill	370	1.8	0.3	+ve
Welland	Tallington	717	4.4	0.6	+ve
Witham	Claypole Mill	232	1.4	0.2	+ve

[1] This population has only just started to return (1989) after an absence of over 20 years.

Table 16. Physical data for the major rivers in whose waters Burbot have been recorded in Great Britain. The data refer to the lowest gauging site on each river.

RIVER	SITE	CATCHMENT (KM^2)	MEAN FLOW ($M^3.S^{-1}$)	MIN FLOW ($M^3.S^{-1}$)	1990 STATUS
Bure	Harstead Mill	313	2.2	0.7	-ve
Cam	Bottisham	803	3.6	0.6	-ve
Derwent	Stamford Bridge	1634	16.4	3.8	-ve
Esk	Sleights	308	3.5	0.3	-ve
Great Ouse	Denver Complex	3430	15.6	11.6	-ve
Hull	Hempholme	378	3.8	0.5	-ve
Little Ouse	Thetford Staunch	699	3.0	0.4	-ve
Ouse	Skelton	3315	48.1	7.0	-ve
Rye	Ness	239	3.8	0.7	-ve
Swale	Crakehill	1363	20.5	2.7	-ve
Thet	Red Bridge	145	0.9	0.1	-ve
Trent	North Muskham	8231	90.9	19.4	-ve
Waveney	Needham Mill	370	1.8	0.3	-ve
Wharfe	Flint Mill Weir	759	17.3	1.0	-ve
Witham	Claypole Mill	232	1.4	0.2	-ve
Wissey	Northwold	275	1.9	0.3	-ve
Yare	Colney	232	1.4	0.2	-ve

Table 17. Notable sites in the British Isles for unusual or rare races of the commoner fish species.

SPECIES	SITE
River Lamprey	Loch Lomond/River Endrick
Brook Lamprey	Loch Cill Chroisd
Brown Trout	Lough Melvin
	Loch Crocach
Three-spined Stickleback	Loch a Bharpa
	Loch Bee
	Loch Grogarry

Table 18. Summary of the procedure for the selection of important sites for freshwater fish in the British Isles (after Maitland 1985).

QUESTION	ANSWER	CHECK
1. Does the site have fish?	Yes No	2 A
2. Is there sufficient information?	Yes No	3 B
3. Are there rare species?	Yes No	C* 4
4. Are there any unusual races?	Yes No	C* 5
5. Are any stocks pristine?	Yes No	C* 6
6. Are unusual species combinations present?	Yes No	C* 7
7. Is diversity high relative to the number of local native species	Yes No	C* D
8. Is the site a particularly useful representative, locally or nationally, of a particular type of aquatic habitat or fish community?	Yes No	A D

COMMENTS

A. If it is naturally fishless, or particularly representative, then it is of potential value and further attention should be given to its plants, invertebrates, amphibians and birds to see if they are of interest.

B. Routine survey procedures should be carried out to assess the status of the fish community.

C. The site should be considered as an important one and notified accordingly.

D. The site is probably not of importance as far as freshwater fish are concerned.

* The case for conservation is strengthened if C is reached by more than one route. Thus, for example, because Loch Lomond is relevant under five categories, its conservation value is extremely high.

Table 19. Some examples of important fish communities in the British Isles. Those marke * are also important for threatened species.

SITE	VALUE	COMMENTS
ENGLAND & WALES		
River Avon	high diversity	several examples
River Great Ouse	high diversity	several examples
Haweswater*	unusual combination	degraded site
River Severn*	high diversity	several examples
Llyn Tegid*	high diversity	unique site
IRELAND		
Lough Corrib	high diversity	several examples
Lough Erne	high diversity	several examples
Lough Leane	unusual combination	unique site
Lough Melvin	local trout races	unique site
SCOTLAND		
Loch Eck	unique combination	unique site
Loch Hope	classical oligotrophic	several examples
Langavat	classical oligotrophic	several examples
Loch Lomond	high diversity unique combination	unique site
Loch Meallt	very simple	unique site
River Skealtar	classical oligotrophic	several examples

Table 20. The economic importance of threatened freshwater fish: a summary of previous and present values in the British Isles and elsewhere.

SPECIES	BRITISH ISLES		ELSEWHERE	
	Previous	Present	Previous	Present
Sturgeon	Occasional catches in estuaries & coast	Virtually none	Substantial catches	Small catches
Allis Shad	Catches in a few large rivers	None	Substantial catches	Small catches
Twaite Shad	Catches in some large rivers	Angled in Usk & Wye	Substantial catches	Small catches
Arctic Charr	Catches in several lakes	Angled in some lakes	Substantial catches	Large catches
Houting	Occasional coastal catches	None	Substantial catches	Small catches
Powan	Wartime in Lochs Eck & Lomond	None	Substantial catches	Large catches
Pollan	Regular catches	Regular catches	Regular catches	Regular catches
Vendace	Small catches in Castle & Mill Lochs	None	Substantial catches	Large catches
Smelt	Substantial estuarine fisheries	Reduced fisheries	Substantial catches	Large catches
Burbot	Regular catches in several rivers	None	Regular catches	Reduced catches

Table 21. Examples of waters, important for fish in the past, where habitat restoration for these fish could be considered.

WATER	PROBLEM	LIKELY CAUSE
River Severn	Allis Shad extinct	river engineering
River Thames	Twaite Shad extinct	pollution
Loch Grannoch	Charr extinct	acidification
Loch Dungeon	Charr extinct	acidification
Loch Doon	Charr vulnerable	acidification
Lough Neagh	Charr extinct Pollan vulnerable	eutrophication
Mill Loch	Vendace extinct	eutrophication
Castle Loch	Vendace extinct	eutrophication
River Forth	Smelt vulnerable	pollution
Rostherne Mere	Smelt extinct	eutrophication
River Derwent	Burbot extinct	pollution
River Waveney	Burbot extinct	pollution

Table 22. Important criteria concerning the translocation of threatened species to create new populations.

1. The translocation activities must pose no threat to the parent stock.

2. The introduction proposals must pose no threat to the ecology or scientific interest of the introduction site.

3. The introduction site must be ecologically suitable. In general, sites from which the species concerned has disappeared should be considered unsuitable unless the causal factors have ameliorated.

4. Ideally, the introduction site should be in the same catchment, or the same geographic region as the parent stock; or in the same geographic region as a former stock, now extinct.

5. Permission must be obtained from riparian owners or relevant legal authorities, where appropriate.

6. Stock may be transferred as eggs, fry, juveniles or adults, but the latter may pose a threat to the parent stock.

7. Special consideration should be given to the genetic integrity of the stock to be translocated. Once the stock has been defined, maximum genetic diversity should be sought by selecting material widely in space and time. When transferring fish or stripping adults to obtain fertilised eggs at least 30 adults of each sex should be used whereever possible.

8. Consideration must be given to avoiding the transfer of undesirable diseases or parasites. Most of these can be avoided by taking eggs only from the parent stock and checking for disease before the eggs or the resulting fry are introduced.

9. Notes of each translocation experiment should be kept and details published where relevant.

10. The fate of the translocated stock should be monitored.

Table 23. Summary of present proposals for the conservation management of threatened freshwater fish in the British Isles. Note: 1. Habitat restoration/management, 2. Translocation, 3. Cryopreservation, 4. legislation, 5. Monitoring, 6. Research.

SPECIES	1.	2.	3.	4.	5.	6.
Sturgeon	-	-	-	-	+	-
Allis Shad	+	+	-	+	+++	+++
Twaite Shad	+	+	-	+	+	++
Arctic Charr	+	++	-	+	+	+
Houting	-	-	-	-	-	-
Powan	-	+	-	+	+	+
Pollan	+	++	-	+	+	++
Vendace	+	+++	-	+	+++	++
Smelt	+	+	-	+	+	+
Burbot	+	+	-	+	-	-

Note: + = important

++ = urgent

+++ = very urgent

Table 24. Translocation proposals for threatened fish stocks in the British Isles with the objective of creating safeguard populations for the original stocks. See also Table 23.

SPECIES	SITE	NUMBER OF NEW SITES	LOCATION
Goureen	L Leane	2	Killarney
Arctic Charr	L Doon	2	Borders reservoirs
Powan	L Lomond	2	Lomond catchment
Powan	L Eck	2	Argyll
Schelly	Ullswater	2	Cumbria
Schelly	Red Tarn	2	Cumbria
Gwyniad	L Tegid	2	North Wales
Pollan	L Neagh	1	Northern Ireland
Pollan	L Erne	1	Erne catchment
Pollan	L Derg	1	Shannon catchment
Vendace	Derwentwater	4	Cumbria & Scotland
Vendace	Bassenthwaite L	4	Cumbria & Scotland
Smelt	R Cree	1	R Annan
Smelt	R Conwy	1	R Dee
Burbot	Europe	2	Yorkshire/East Anglia

Table 25. Recommendations for further controls on the importation of potentially damaging temperate fish.

1. A complete ban on the import of all temperate fish specified on a 'black list'. These would effectively be all temperate species which it is felt could establish in the wild in the British Isles and cause ecological problems here. The only exclusions might be fish brought into the country under special permit for research or other specific purposes.

2. More rigorous quarantine checks on disease and parasites of temperate fish being imported from abroad.

3. Better expertise within the controlling authority in relation to fish identification. The logistic problems which this might impose could perhaps be overcome by restricting the point of entry for temperate fish into the country to two or three places only.

4. A complete ban on the import of all fish species native to or already established in the British Isles, unless under special licence.

Table 26. General monitoring proposals for threatened fish stocks in the British Isles. Detailed methodology must be worked out for each site.

SPECIES	SITE	FREQUENCY IN YEARS	POSSIBLE METHOD	IDEAL MONTH
Goureen	L Leane	3	A	May
Arctic Charr		3	A	Oct
Powan	L Lomond	3	A	Jan
River Lamprey		3	B	Mar
Powan	L Eck	3	A	Jan
Arctic Charr		3	A	Oct
Schelly	Ullswater	3	A	Dec
Schelly	Haweswater	1	C	Dec
Arctic Charr		1	C	Oct
Schelly	Red Tarn	5	A	Jun
Gwyniad	L Tegid	3	A	Dec
Pollan	L Neagh	3	D	Dec
Pollan	Upper L Erne	3	A	Dec
Pollan	Lower L Erne	3	A	Dec
Pollan	L Ree	3	A	Dec
Pollan	L Derg	3	A	Dec
Vendace	Derwentwater	2	A	Dec
Vendace	Bassenthwaite L	2	A	Dec
Smelt	R Cree	2	E	Mar
Smelt	R Conwy	2	E	Mar

Note: A = gill netting, B = traps, C = screens, D = commercial catch, E = egg counts

Table 27. Summary of main conservation management proposals for threatened freshwater fish in the British Isles.

1. Further legislation to control import of potentially disruptive fish.

2. Further controls on the movement and release of fish within the British Isles, especially required for Scotland.

3. Improved fishery management and a complete ban on live baiting.

4. Active conservation management is needed for seven species within the British Isles (Allis Shad, Twaite Shad, Arctic Charr, Powan, Vendace, Pollan and Smelt).

5. International support should be given to the conservation of three other species in Europe (Sturgeon, Houting and Burbot).

6. Management plans should be established for all major sites of threatened species.

7. Habitat restoration and management should be the major long-term objective, but is often slow and expensive in the short-term.

8. Translocation of threatened stocks to create new safeguard populations is an important measure, perhaps vital in the short-term (e.g. Vendace) and valuable in the long-term.

9. Regular monitoring of existing and of new sites is essential.

10. Research is still required on a number of species and is especially urgent for some species (e.g. Allis Shad).

11. Substantial resources are required to implement the proposals, which must involve several different organisations in the British Isles.

12. Once safeguarded, there is no reason to discourage wise renewable use of any stocks (e.g. for angling, commercial exploitation).

13. As well as legislation and active conservation management there should be an active programme to educate the public (especially anglers) about the value of our native fishes.

14. There must in the future be regular reviews of the distribution and status of freshwater fish and also the development and maintenance of registers of important stocks.

APPENDIX

PRACTICAL CONSERVATION MEASURES AND RESEARCH

1. INTRODUCTION

Throughout the period of the project, practical measures were undertaken on six species of freshwater fish for which there is currently some concern. In the case of Allis Shad, Twaite Shad and Smelt, these studies were investigative ones to clarify the status of rare or endangered populations in southwest Scotland. More positive steps were taken for Arctic Charr, Powan and Vendace, by attempting to create new safeguard populations by translocation. For the latter, hatching and holding facilities were established at the Institute of Freshwater Ecology station at Penicuik, the Fish Conservation Centre at Stirling and at Megget Reservoir in the Borders Region.

The background information leading to the selection of these species for study is given in the main report. The work carried out on each is described briefly below.

2. ALLIS AND TWAITE SHAD

Adults of both these species are inadvertently caught by salmon stake-net fishermen along the Solway coast. Collections of shad were taken from six sites (Figure A1a and Table A1) in 1989, 1990 and 1991 to investigate their current status in this area. Concurrent enquiries were made locally but these failed to produce any positive information on shads, most particularly whether they entered local river systems to spawn. The dates and locations of capture are given in Tables A1 and A2 which show that these fish are most commonly caught at sites 2, 3 and 4. Many of the fish caught were in ripe condition for spawning and some fishermen reported that occasional fish caught in previous years were spilling eggs.

There is insufficient information as yet to come to conclusions on the status of shads in the area except to be certain that both species are there regularly throughout their spawning period. Although Twaite Shad is found in a few other parts of the British Isles, this is the only known locality where Allis Shad occur regularly and in some numbers. The specimens obtained during the study are being examined for length, weight, sex, age, growth, food and fecundity. It is clear that the area (especially the Cree estuary) is important for both species, but that a more intensive research project will be needed in the future to further the study and conservation of these rare fish.

3. ARCTIC CHARR

The Arctic Charr in Loch Doon is the only surviving population of several formerly known to occur in southwest Scotland. Recent studies have indicated that this population is threatened by acidification. Consequently, in an effort to save this stock, steps were taken to introduce it to Megget and Talla Reservoirs (Figure A1a) in an attempt to start new populations there.

In Loch Doon, Arctic Charr spawn in early October along many parts of the stony shore. Regular visits were made in October from 1986 to 1990 when fish were netted and stripped of eggs. The eggs were fertilised immediately and transported as soon as possible to the hatcheries where incubation rates and mortalities were recorded. Soon after hatching, alevins were introduced to Megget Reservoir each January. Small numbers of adult fish (from those taken in the nets) were transported alive to Talla Reservoir and released there. Details of the numbers of fish and eggs taken, and of alevins and adults introduced are given in Table A3. A few hundred alevins were held at IFE and FCC for rearing; at both places some reached maturity. Those at IFE were stripped and alevins from these eggs were taken to Megget Reservoir. Those at FCC spawned naturally in gravels provided in the pond there.

Thus only alevins have been introduced to Megget Reservoir and only adults (plus a few 0+ fish in 1987) have been introduced to Talla Reservoir. It will be some years before the success of these introductions can be confirmed. At Megget Reservoir a low intensity trapping programme during the summer of 1991 proved negative, but a single angling return in that year claimed a Charr. At Talla Reservoir, two 0+ Charr were caught on the screens below the reservoir in 1990 and further young were reported in 1991. Thus some natural spawning by the introduced fish has been successful there.

4. POWAN

There are increasing pressures on this species in Loch Lomond (e.g. the introduction of Ruffe) which have raised concern over its status there. Consequently, translocation attempts have been made, similar to those for Arctic Charr, to create two new safeguard populations - in Loch Sloy Reservoir and Carron Valley Reservoir, both of which are within the Loch Lomond catchment (Figure A1a).

Spawning adults were collected by netting in Loch Lomond on a known spawning ground around the Ross Isles in January of 1988, 1989 and 1990. Some adults were transferred directly to Loch Sloy in 1988. Eggs collected and fertilised on site were taken to hatcheries at IFE and FCC. In April of each year, freshly hatched (i.e. unfed) fry were taken to Loch Sloy and (in 1989 and 1990) to Carron Reservoir. In addition, small numbers of fry were placed in a pool at the base of the Sloy dam. Details of the numbers of fish and eggs collected and the numbers introduced are given in Table A4.

Small numbers of eggs and fry had been introduced to Loch SLoy some years prior to this project, but netting for Powan in January 1988 proved negative. However, a netting survey there in June 1991 confirmed the presence of Powan, when 21 adult fish of varying ages and sizes were caught. Preliminary age analysis indicates that these are the survivors of both adult and fry introductions there. There is no evidence as yet of breeding success at this site. Netting in the dam pool has indicated that there has been some survival there also.

It will be some years before a check can be made on the success of the introductions to Carron Valley Reservoir. Small numbers of fry were retained for rearing at FCC in 1989 and it is hoped that these will mature and spawn in January 1993.

5. VENDACE

Following its demise at the only two Scottish sites at Lochmaben, this species is currently Britain's rarest and most threatened freshwater fish; positive action is required if the remaining two stocks in Cumbria are to be safeguarded. As a preliminary trial, a similar approach to that described for Arctic Charr and Powan, involving translocation, was undertaken with the population in Bassenthwaite Lake.

Adult Vendace were netted in December 1988 and 1989 on probable spawning grounds in Bassenthwaite Lake, just offshore at Broadness. Eggs were collected and fertilised on site and then transferred to the IFE and FCC hatcheries. There was no survival from the 1989 batch, but unfed fry from the 1988 batches were introduced that year to a small pond (the North Pond) in Doune Ponds Reserve and to Loch Earn. Details of the numbers of fish eggs and fry are given in Table A5.

The survival of any Vendace at Doune North Pond must be in serious doubt due to the subsequent discovery there of Pike and Perch - despite a negative check for any fish prior to the introduction. At Loch Earn, even if the initial introduction has been successful, it will be many years before the population would be large enough to be easily detectable. Small numbers of fish were retained in 1988 for rearing at FCC and these spawned naturally over trays of gravel in the rearing pond in December 1991. No attempt was made to save these eggs but is hoped that the spawning will be repeated in 1992 when eggs will be retained for rearing.

6. SMELT

Several populations of Smelt have disappeared from the Solway area over the last few decades and the only one remaining is that in the River Cree and its estuary (Figures A1a and A1b). This stock is very vulnerable at its regular spawning site in the upper estuary (i.e. upper site in Figure A1b) and there has been recent concern over the numbers removed by commercial netting there. In order to gain experience in handling eggs and fry, the collection of eggs from this stock was proposed.

Preliminary success had been achieved in 1985 when good samples of eggs were obtained at the upper site (Figure A1b) and hatched indoors. However, in spite of local contacts (briefed to keep watch for the spawning run in March) and regular site visits, there was no evidence of spawning in 1988 or 1989. However, in March 1990 an extended examination of the river bed revealed that considerable spawning had taken place - but downstream of the supposed traditional upper site. Consequently, in March 1991 an intensive and repeated inspection was maintained over the whole of the available spawning substrate. This revealed the early presence of some eggs and subsequently spawning was witnessed on 14 and 15 March, coincident with high tides. Eggs were found at both the upper and lower sites and collections of eggs and adult fish (69 specimens) were made at the upper site for further study.

This spawning run was considered small in relation to those reported some years ago and apparently no commercial fishing was carried out in 1991 (though it was subsequently discovered that small catches had been made in 1989 and 1990). There is little doubt that the present Smelt population is under threat and the spawning grounds are under consideration as an SSSI.

7. DISCUSSION

These translocations were carried out on a small experimental scale, but the expertise gained will now allow much larger numbers of eggs and fish to be handled successfully, thus ensuring greater likelihood of success as well as improving the chances of maintaining the genetic diversity of the new stocks concerned.

An outstanding problem in this exercise has been the difficulty of obtaining suitable sites for the creation of new fish populations. The combination of adequate size, ecological suitability, absence of fish predators, owner permission and freedom from problems created by fishery management (e.g. stocking) occurs very rarely. So far, mostly reservoirs have been used because they are large managed waters with restricted access and semi-artificial fish populations. Less success has been achieved in obtaining the use of smaller water (e.g. large ponds) which would be suitable for the interim rearing of stock.

As well as the practical transfer work, the research involved is at present in preparation as a series of papers. The preliminary titles of these are listed below.

8. PROPOSED PAPERS

1. Collection and incubation of the eggs of Arctic Charr *Salvelinus alpinus*, Powan *Coregonus lavaretus*, Vendace *Coregonus albula* and Smelt *Osmerus eperlanus*.

2. Preliminary studies of Allis Shad *Alosa alosa* and Twaite Shad *Alosa fallax* in the Solway Firth.

3. Some aspects of the biology of the Smelt *Osmerus eperlanus* in Scotland.

4. Notes on the biology of an introduced population of Powan *Coregonus lavaretus* in Loch Sloy.

Figure A1. Locations of the sites involved in the practical fish conservation work.

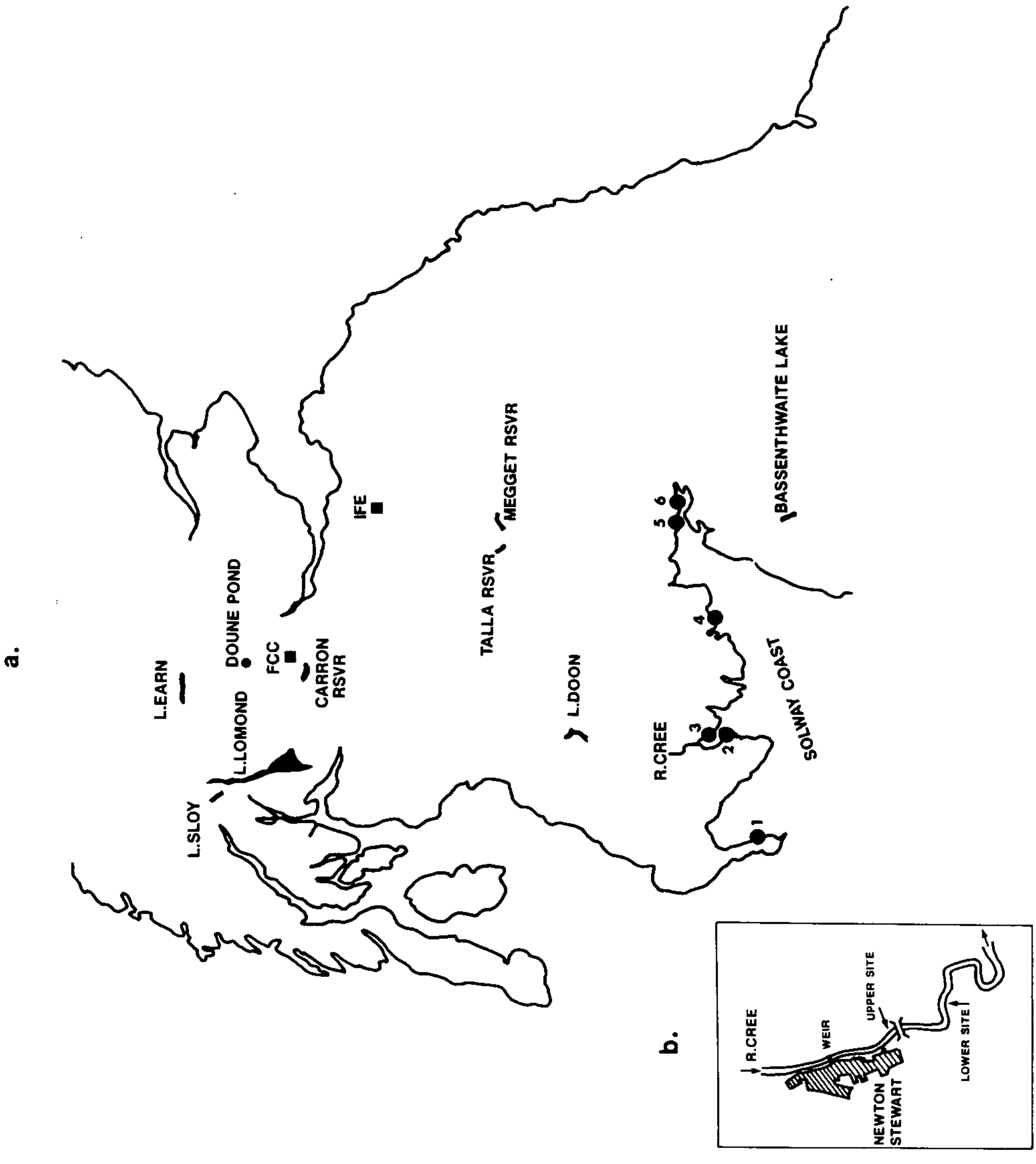

Table A1. Details of Allis Shad collections from six sites (see Figure A1a) on the Solway Coast in 1989, 1990 and 1991.

SITE	APRIL		MAY		JUNE		JULY		AUGUST		SEPTEMBER		ANNUAL		TOTALS
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	
1989															
1	-	-	-	-	1	-	3	-	-	1	-	-	4	1	5
2	-	-	1	2	2	-	4	3	-	-	-	-	7	5	12
3	-	-	-	-	-	-	-	1	-	-	-	-	-	1	1
4	-	-	6	-	2	-	1	-	-	-	-	-	9	-	9
5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
	0	**0**	**7**	**2**	**5**	**0**	**8**	**4**	**0**	**1**	**0**	**0**	**20**	**7**	**27**
1990															
1	-	-	1	-	-	-	-	-	-	-	-	-	1	-	1
2	-	-	7	5	2	2	-	-	-	-	-	-	9	7	16
3	-	-	4	-	-	-	1	-	-	-	-	-	5	-	5
4	-	-	-	-	2	-	2	-	-	-	-	-	4	-	4
5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
	0	**0**	**12**	**5**	**4**	**2**	**3**	**0**	**0**	**0**	**0**	**0**	**19**	**7**	**26**
1991															
1	-	-	-	-	1	-	-	-	-	-	-	-	1	-	1
2	1	1	2	2	1	-	-	-	-	-	-	-	4	3	7
3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
4	-	-	1	1	1	3	1	1	1	2	-	-	4	7	11
5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
	1	**1**	**3**	**3**	**3**	**3**	**1**	**1**	**1**	**2**	**0**	**0**	**9**	**10**	**19**
MONTHLY	1	1	22	10	12	5	12	5	1	3	0	0	48	24	
TOTALS	2		32		17		17		4		0				72

		SITE	3-YEAR TOTAL
Mr T Davidson	Drummore	1	7
Mr A Reid	Innerwell	2	35
Mr W Davidson)	Carsluith	3	6
" ")	Portling	4	24
Mr M Panzak	Annan	5	0
Mr J Woodman	Annan	6	0
			72

Table A2. Details of Twaite Shad collections from six sites (see Figure A1a) on the Solway Coast in 1989, 1990 and 1991

SITE	APRIL		MAY		JUNE		JULY		AUGUST		SEPTEMBER		ANNUAL		TOTALS
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	
1989															
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
2	-	-	-	4	1	2	1	-	-	1	-	-	2	7	9
3	-	-	1	1	-	3	-	1	-	-	-	-	1	5	6
4	-	-	-	1	2	2	-	-	-	1	-	1	2	5	7
5	-	-	-	-	-	-	-	-	1	-	-	-	1	-	1
6	-	-	-	1	-	1	1	-	-	3	-	-	1	5	6
	0	0	1	7	3	8	2	1	1	5	0	1	7	22	29
1990															
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
2	-	-	-	1	-	3	-	-	-	-	-	-	-	4	4
3	-	-	-	-	-	1	-	-	-	1	-	-	-	2+3*	5*
4	-	-	-	1	-	4	1	-	-	1	-	-	1	6	7
5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
	0	0	0	2	0	8	1	0	0	2	0	0	1	15	16
1991															
1	-	-	-	-	-	1	-	-	-	-	-	-	-	1	1
2	-	-	-	-	3	1	-	-	-	-	-	-	3	1	4
3	-	-	-	1	1	2	-	-	-	1	-	-	1	4	5
4	1	1	1	3	-	1	1	1	-	-	-	-	3	6	9
5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
6	-	-	-	1	-	-	-	-	-	-	-	-	-	1	1
	1	1	1	5	4	5	1	1	0	1	0	0	7	13	20
MONTHLY	1	1	2	14	7	21	4	2	1	8	0	1	15	50	
TOTALS	2		16		28		6		9		1		(+3)		65

* Note: 3 additional females collected from this site had no catch date

SITE	3-YEAR TOTAL
1	1
2	17
3	16
4	23
5	1
6	7
	65

Table A3. Details of Arctic Charr transfers from Loch Doon to Megget and Talla reservoirs

WINTER	LOCH DOON No. Charr caught	LOCH DOON No. females stripped	LOCH DOON Initial No. Eggs	MEGGET No. Alevins Introduced	TALLA No. adults introduced
1986/87	21	3	ca 1000	-	40 (+ 31 fry)
1987/88	221	31	14,550	3607	78
1988/89	189	43	16,920	6319	9
1989/90	48	2	274	98	4
1990/91	224	23	9,808	8284	-
TOTALS	703	102	42,552	18308	131 (+ 31 fry)

Table A4. Details of Powan transfers from Loch Lomond to Loch Sloy reservoir, Sloy dam pool, and Carron Valley reservoir.

	LOCH LOMOND			SLOY			CARRON
				RESERVOIR		POOL	
Year	No. Powan Caught	No. females stripped	Initial No. eggs	No alevins introduced	No. adults	No. alevins	No. alevins
1988	178	5	12,705	6,003	85	500	-
1989	240	8	22,100 (estimate)	2,430	-	250	2,750
1990	288	9	25,760	3,794	-	250	10,373
TOTALS	706	22	60,565	12,227	85	1000	13,123

Table A5. Details of Vendace transfers from Bassenthwaite Lake to Doune Ponds Reserve and Loch Earn

	BASSENTHWAITE LAKE			DOUNE POND	LOCH EARN
	No vendace caught	No. females stripped	Initial No. eggs	No. alevins introduced	No. alevins introduced
1988	14	3	14,500 (estimate)	1991	8379
1989	25	1	not counted no survival	-	-