SCOTTISH NATURAL HERITAGE

# COMMISSIONED REPORT

## Commissioned Report No. 001

# Evaluating the ecological and conservation status of freshwater fish communities in the United Kingdom

(ROAME No. F01AC6)

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# COMMISSIONED REPORT Summary

## Evaluating the ecological and conservation status of freshwater fish communities in the United Kingdom

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Contractor: P S Maitland, Fish Conservation Centre, Haddington


### Background

This project was initiated to investigate the inter-relationships between SERCON (System for Evaluating Rivers for Conservation) and the Water Framework Directive (WFD) in relation to fish. Many of the ideas which have been developed for SERCON over the last decade are highly relevant to the proposals being considered for the WFD and a major theme of the present report is the potentially valuable relationship between the two.

The provision of adequate data concerning fish populations to meet the requirements of the WFD presents a number of logistic and other difficulties. As fish are generally confined by catchment boundaries, the WFD task of 'river basin characterisation' suggests that defining fish distribution with respect to standard Hydrometric Areas (which comprise single catchments or groups of catchments) is a useful approach.

### Main findings

The present assessment of the naturalness of fish communities, used in SERCON, was fully revised, giving a more detailed method of assessing this aspect of conservation status. An essential basis for this revision was information from existing databases on the current distribution of native freshwater fish species in the UK in relation to Hydrometric Areas. The status and distribution of established alien species, both those foreign to the UK and those believed to have been transferred by humans outwith the areas to which they are native, was also related to Hydrometric Areas.

A literature review considered past studies with analytical approaches to the assessment of freshwater fish communities, particularly those relevant to the requirements of SERCON and the WFD.

The requirements of the WFD in relation to fish communities were considered in relation to assessing status, surveillance monitoring and measuring 'sustainable reproductive success', and proposals are made on WFD assessments of species composition, abundance and age classes.

Assessing species composition given adequate data on habitat and those species of fish native to the catchment is straightforward. However, the effect that alien fish species might have in determining ecological status has yet to be determined.

Measurements of the abundance of fish can range from relatively easy (electrofishing in small streams) to very difficult or expensive (sonar or mark-recapture in large shallow lakes). In some cases measures of relative abundance may be the best option.

Though the analysis of age classes is usually straightforward, their interpretation is likely to be difficult because of the large number of natural factors which can be involved. Recruitment of new generations is the most important aspect and this should be highlighted in any method of assessing status.



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# 1 INTRODUCTION

This project was initiated following discussions regarding the potentially valuable inter-relationships between SERCON (System for Evaluating Rivers for Conservation) and the Water Framework Directive (WFD) – particularly, in the present context, in relation to fish. Many of the ideas which have been developed for SERCON over the last decade (Boon *et al.* 1994, 1996, 1997, 2002) are highly relevant to the proposals being considered for the WFD, and a major theme of the present report is the relationship between the two. Recently, a new consultation document has been issued by the Scottish Environment Protection Agency (SEPA) on behalf of the Scottish Executive, focusing on the WFD Technical Annexes II and V, which set out how the condition of the aquatic environment will be assessed, monitored and classified. This report (SEPA 2002) is considered further below.

Although the provision of adequate data concerning fish populations to meet the requirements of the WFD presents a number of logistic and other difficulties, the end product should make the effort worthwhile. As well as being at the top of the trophic pyramid in many fresh waters, fish are a valuable element in the economy of many areas and the important contribution of fisheries to the rural economy is now recognised (MAFF 2000; Everard *et al.* 2002). As many fish are relatively catchment-bound, the requirement of the WFD to characterise river basins suggests that the use of Hydrometric Areas as a means of defining fish distribution is a useful approach to take and the one adopted in this report.

## 2 OBJECTIVES

The principal objectives and methods are those proposed in Annex A of the tender document, taking into account the following points.

- Information from existing databases to be used as a basis for establishing the current distribution of all native freshwater species presently established in the UK in relation to standard Hydrometric Areas.
- The status and distribution of established alien species, both those foreign to the UK and those believed to have been transferred by humans outwith the areas to which they are native, also to be related to Hydrometric Areas.
- The literature review to consider studies with analytical approaches to the assessment of freshwater fish communities, particularly those relevant to the requirements of SERCON and the WFD.
- The present assessment of the Naturalness of fish communities used in SERCON to be fully revised giving a more accurate and sophisticated assessment of this aspect of conservation status.
- The requirements of the WFD in relation to fish communities to be considered in relation to assessing status, surveillance monitoring and measuring 'sustainable reproductive success' and proposals to be put forward relevant to the requirements of the Directive in these areas.

# 3 LITERATURE REVIEW

A literature search of relevant publications has reviewed studies with various approaches to the assessment of freshwater fish communities which are relevant to the requirements of SERCON and the WFD. These involve a number of issues which are outlined below.

## 3.1 Fish and habitat

In an examination of fish assemblage structure in 29 streams in Brittany, Oberdorff & Porcher (1992) found that catchment area, stream gradient and distance from source were significantly correlated with species richness. In all streams, the addition of species occurred with no longitudinal displacement. The total density of fish decreased significantly with increasing stream size, but no correlation was found between total biomass and catchment area. Headwaters were characterised by short-lived, solitary and nocturnal-feeding species, whereas downstream sites were typified by long-lived, schooling, diurnal-feeding species. The temporal variation in individual species density showed an upstream-downstream gradient with the highest variation upstream. The species responsible for this variation were mostly small benthic ones which are relatively difficult to sample; thus the greater variation in upstream areas could be due to problems with sampling efficiency.

The variation in fish assemblage structure was examined by Oberdorff *et al.* (1993) in various rivers in the basin of the River Seine. Factor analysis was used to identify similarities among samples and species and to show ichthyological changes along an upstream/downstream gradient. Fish species richness was correlated with catchment area and distance from source. Species richness increased with river size, the pattern being consistent with the River Continuum Concept (Vannote *et al.* 1980).

Studies on 15 sections of streams in Austria by Jungwirth *et al.* (1993) demonstrated the importance of river bed structure to fish communities. For example, reduced spatial heterogeneity due to river straightening resulted in decreasing number of fish species, density and biomass. The variance of maximum depths (VMD) used as a measure of habitat structure showed a highly significant correlation with the number (NFS) and diversity (DFS) of fish species. The validity of this VMD/NFS model was demonstrated after a restoration project on a channelised section of the Melk River and in subsequent studies (Jungwirth *et al.* 1995).

The relationships between habitat features and biomass and density of brown trout populations were studied in 33 sections of the Neste d'Aure river and three of its tributaries by Barand *et al.* (1993). The data were used to test the Habitat Quality Index (Binns & Eiserman 1979) which did not appear to be a good method of assessing the biomass of brown trout here. Total biomass was significantly related to altitude, cover, maximum summer temperature, conductivity, mean bottom velocity, mean depth and width/depth ratio. Total density was related to the same variables, with the exception of mean depth and the inclusion of stream gradient and width.

Relationships between fish and their habitat were studied by DeJalon *et al.* (1996) in streams in the Spanish Pyrenees. Instream Flow Incremental Methodology (IFIM) was adapted to analyse the fish habitat in these streams and parameters were developed that measured the particular characteristics of these streams, taking into account the habitat needs of the main developmental stages (fry, juveniles, adults, spawners). The results show that fish abundance increases along the river continuum, indicating that the habitat carrying capacity increases downstream. The water depth and rock surfaces appeared to be the main factors limiting the capacity of a stream to provide refuges.

In order to assess fish assemblage attributes which are sensitive to river alterations, Thomas *et al.* (1998) compared 23 fish assemblage parameters between 74 slightly disturbed and 133 strongly disturbed sites in the basin of the River Seine. They found that eight parameters were important in showing that fish assemblages are sensitive to river alterations. However, the results also indicated the difficulty of choosing parameters to develop an index based on fish communities, especially because of the poor species richness and low functional diversity of the ichthyofauna of the River Seine.

## 3.2 Indices

One of the earliest models used to calculate fish standing stocks in lakes was the Morphoedaphic Index (MEI) developed by Ryder (1965). This model caused some controversy and much discussion (Ryder 1970) and led to the development of other models which used different indices but had the same objective – for example, the TP-Fish Production model of Downing *et al.* (1990) and Downing & Plante (1993).

Binns & Eiserman (1979) developed two multiple regression models to augment costly field surveys of fish standing stocks in Wyoming. They referred to each of these models as a Habitat Quality Index (HQI). However, although successful locally, application of this model in other parts of the United States was only modestly successful in predicting fish biomass, for incompletely understood reasons. Leiner (1996) concluded that the low predictive power of these models '*probably indicates that it is limited to the geographic area of field measurement origin*'. The lesson here is that any biotic index which is transferred from one geographic area to another should be tested thoroughly before general use.

A major issue for the management of aquatic habitats is the availability of sensitive methods for the assessment of environmental degradation. In order to quantify the extent of resource degradation due to human disturbances, a fish-based index, the Index of Biotic Integrity (IBI) has been used throughout North America (Fausch *et al.* 1984, 1990; Leonard & Orth 1986, Karr 1991) and, more recently, in some parts of Europe (Oberdorff & Hughes 1992), Africa (Hugueny *et al.* 1996), Asia (Ganasan & Hughes 1998) and Australia (Harris & Silveira 1999). The IBI is based on the assumption that fish assemblage attributes change in characteristic fashion with stream degradation. Other, similar, approaches to the analysis and classification of fish assemblages have been attempted by a variety of workers in various countries (Hughes & Noss 1992; Hughes *et al.* 1998) and in different habitats – eg estuaries (Deegan *et al.* 1997).

Oberdorff & Porcher (1994) analysed the impact of fish farm effluents on fish assemblages in several streams in Brittany and found, downstream from fish farms, an increase in both density and biomass of most species, extirpation of sensitive ones (bullhead) and appearance of pollution tolerant (roach) and exotic species (rainbow trout). A modified IBI was used and compared with chemical variables to illustrate how this index can be applied to quantify disturbances of the quality of stream water by fish farm effluents. This IBI, based on 10 fish assemblage attributes, showed close agreement with these chemical measurements.

Harris (1995) reviewed the use of fish in ecological assessments and concluded that the Index of Biological Integrity can be used as a predictive model of aquatic environmental quality. The IBI is claimed to be '*a quantitative biological tool with a strong ecological foundation that integrates attributes from several levels of ecosystem organisation … its robustness, flexibility and sensitivity can cope effectively with the low diversity of the Australian fish fauna and the dominance of ecological generalists.*'

Orth (1995) used Physical Habitat Simulation (PHABSIM) analyses for common warm-water fish to show that the weighted usable area for these fish is either insensitive or maximised at low flows. The analyses indicated that the production and yield of fish were strongly dependent on the bottom-up influence of benthic invertebrate prey, whose productivity, in turn, may be reduced by decreases in flow during the growing season.

The relationships between mesohabitats, fish communities and IBI metrics, the latter adapted to the Meuse River, were studied by Didier & Kestemont (1996). Dividing the river into three mesohabitats (riffles, runs and pools), it was found that salmonids showed a high correlation with runs and cyprinids with pools. It was concluded that accurate sampling of fish populations in rivers requires that the full range of mesohabitats in each is properly sampled.

Also in the River Meuse, Didier (1997) describes the development of a fish-based index BIFI (Biotic Index of Fish Integrity) to assess the ecological quality of lotic ecosystems. The index, which is based on three categories of metrics (species richness, water quality and habitat) is believed to be applicable to other rivers in the same ecoregion. However the author stresses the need for '*more accurate sampling methodologies (representative of the local ichthyofauna) and metrics independent of sampling biases*'.

A multivariate model to relate hydrological, chemical and biological parameters to salmonid biomass in Italian Alpine rivers was developed by Annoni *et al*. (1997). A variety of river data were collected and Principal Component Analysis was used to identify the relevant parameters. The best regression model used only six parameters which explained 89% of the variation in fish biomass and it was concluded that it is possible to simplify habitat quality evaluation using a subset of environmental parameters.

Cao *et al.* (1998) examined the effects of excluding rare species on comparisons of species richness. This led to a serious underestimation of the differences in species richness among sites in terms of both absolute numbers and species loss percentages. They concluded that deleting rare species can damage the sensitivity of community-based methods to detect ecological changes – rare species are critical for bioassessment.

In South Africa, Kleynhans (1999) is developing a Fish Assembly Integrity Index (FAII) based on fish species expected to be present in river segments with homogeneous habitat. It was concluded from initial work that the index '*provides a broad, synoptic estimation of the biological integrity of a river but further refinement of the technique is required*'.

In Belgium, Belpaire *et al*. (2000) used an Index of Biotic Integrity (IBI) to assess the status of fish communities in 104 standing waters and 757 sites in running waters. Scores for standing waters were substantially different from running waters and only 18.5% of waters were considered to satisfy the basic ecological demands. It was concluded that the IBI is a valuable tool to assess the ecological quality of water bodies for the WFD.

Schmutz *et al.* (2000) have proposed a multi-level concept for fish-based assessment (MuLFA) of the ecological integrity of running waters designed for large-scale monitoring programmes such as required for the WFD. The principle of MuLFA is based on an assessment of the deviation from undisturbed reference conditions. Reference conditions have to be compiled for every distinct river type using historical fish and abiotic data, present river-type-specific reference sites and reference models. The final assessment procedure compares the assessment reach with the reference conditions using a five-tiered scheme and assigning that reach to the level of highest coincidence. The benefit of MuLFA is claimed to be its potential for consistent sensitivity to low and high dose human alterations and its adaptability to all river types.

Fish were among the key criteria used in Austria by Chovanec *et al.* (2000) to assess the ecological integrity of running waters. A classification was developed based on the assessment of individual criteria by means of a comparison between a river-type-specific reference state and the current conditions. This approach, which has been laid down in the Austrian Standard M 6232 '*Guidelines for the ecological study and assessment of rivers*', also meets the general requirements for the classification of ecological status of running waters as described in the EC WFD.

As a framework for environmental assessment, Oberdorff *et al.* (2001) developed a probabilistic model characterising fish assemblages in French rivers, believing that fish assemblages are of particular interest because of their ability to integrate environmental variability at different spatial levels. Their approach used information available from fish assemblages to establish an index through the use of the '*reference condition approach*' which involves testing a fish assemblage exposed to a particular stress against a reference condition that is unexposed to such a stress.

For a variety of reasons and especially in those areas where most waters are polluted or otherwise affected by human influences, it is important to identify not only those waters which have current ecological value, but also those with high ecological potential, regardless of their present condition. In Flanders, Wils *et al.* (1994) developed a system to evaluate the present as well as the potential ecological values of streams and rivers. This evaluation was based on a number of morphological characteristics, on water quality and on aquatic communities. The final result was a countrywide ecological evaluation map of each river basin to be available to policy makers in order to assist river restoration and conservation projects.

The species composition, community structure, trophic composition, abundance and biomass were investigated by Kesminas & Virbickas (2000) in 60 Lithuanian streams. From the analyses of these data, four main types of fish community were identified – brooks, streams, medium and large rivers. The Index of Biotic Integrity (Karr *et al.* 1986) was modified for Lithuanian conditions and nine metrics in three categories (species composition, abundance and biomass, trophic composition and fish condition) were chosen for the study. The analyses indicated that it was possible to classify river fish communities into six integrity classes – excellent, good, fair, poor, very poor and fishless). Whilst brooks and streams mainly showed intact conditions, medium and large rivers were significantly more degraded.

Length/weight relationships were used by Vila-Gispert *et al.* (2000) as a simple method to test differences in condition among several populations of Mediterranean Barbel *Barbus meridionalis* and to examine possible correlations between fish condition and ecological factors. Significant differences in condition among populations were evident, '*which could imply differences in habitat characteristics*' and that fish condition may be a good indicator of habitat quality in stream ecosystems.

## 3.3 Monitoring

The EIFAC symposium on methodologies for the survey, monitoring and appraisal of fishery resources in lakes and large rivers (EIFAC 1974) had five main objectives: (a) review present methods used in sampling the fish populations of lakes and large rivers, (b) define terms for methodology, (c) assess sampling gear and data to establish the characteristics of, and changes in, fish populations, (d) assess new or improved methods available for sampling, and (e) formulate a long-term programme of research on these problems.

In order to develop comparable methods of sampling fish, a study was initiated with the objective of developing and intercalibrating methods used in freshwater fish studies in Nordic countries (Appelberg *et al.* 1995). A new type of multi-mesh gill net was developed and comparative studies with other nets have shown that these new nets better describe the actual population structure for several fish species. Additionally, in relation to the ageing of fish, it was found that differences between laboratories can be reduced by intercalibration.

Using monthly echo-sounding estimates of fish numbers, Elliott *et al.* (1996) found changes in the population densities of pelagic salmonids in Windermere in relation to lake enrichment, with a decline in the numbers of Arctic charr and an increase in brown trout. They concluded that it was important to continue with the monitoring programme and thus ensure that there is advance warning of any marked changes in charr stocks.

Variations in the growth patterns of pike, chub and roach were studied by Przybylski (1996) along the upper Warta River, where human impact (mostly pollution) has influenced longitudinal zonation of the fish assemblages. Significant differences were found in the length/weight relationships of both chub and roach but not pike. All three species grew better in the zone where the Index of Relative Abundance (which relates the dominance of a species to its maximum abundance in a river system) achieved its highest value, suggesting that this index may be a good indicator to monitor '*habitat quality*'.

In a study of the River Rhine, aimed at developing river ecosystem indicators, Lorenz *et al.* (1997) studied theoretical concepts describing natural rivers. These included zonation, stream hydraulics, river continuum, nutrient spiralling, serial discontinuity, flood pulses, riverine productivity and catchment hierarchy. They concluded that the design, implementation and ecological assessment of monitoring programmes should reflect an integrated spatial view – which means they should be measured at a catchment scale.

Harper *et al.* (2000) have pointed out that '*River management in the UK has seen the development of a series of quality assessment methodologies with little integration between them.*' They indicate that methods which assess habitat structure in a biologically meaningful way offer the best approach to integrating measures of the effects of physical and chemical processes on the river environment, and believe that simultaneous measurement of surface flow types and habitat structures show clear links which could form the first stage in the development of a rapid, cost-effective measure of ecological integrity in rivers in the UK.

## 3.4 General

The River Loire is one of the largest rivers in Europe with a total length of 1,012km and a catchment of 117,482km$^2$. In spite of dams in the upper reaches and nuclear power plants in its middle reaches, Arrignon (1988) found that the distribution of the 51 species of fish in the river was in accordance with the typical fish zonation of western Europe.

Badino *et al*. (1991) showed that in the alpine rivers of western Europe, river fish community structure in stretches unaffected by humans is closely related to local physical and chemical conditions whereas in polluted or heavily modified stretches the distribution of fish species does not correspond to potential zonation. Although benthic invertebrates are commonly used as bio-indicators, sometimes fish are better indicators since they are normally high-order consumers and often reflect the responses of the entire trophic structure to environmental stress.

The microhabitat preferences of 0+ juvenile fish in the River Lee were found by Pilcher & Copp (1997) to be influenced by channel width, depth and distance from the bank. Analyses of data using Canonical Correspondence Analysis and habitat profiles indicated that the rheophilous species (eg barbel and brown trout) preferred features characteristic of upstream channels, whereas the more ubiquitous (eg perch) and limnophilous fish (eg tench and pike) preferred habitats in the downstream channelised stretches.

An analysis of French freshwater fish communities (Keith 1998) reviewed the contribution made by studies in biogeography, palaeontology, archaeology, ecology and history. The outcome was a list of reference communities in the main catchments of France, thus defining a reference state and making it possible to compare the current state of species distribution with this reference state, in order to measure the impact of natural and anthropogenic factors on communities over the last 5,000 years.

Gassner & Wanzenboeck (1999) have emphasised the importance of defining ecological baseline states for fish communities if the objective is to evaluate ecological integrity. In Austria, five lakes were selected in order to reconstruct the native fish communities: this was done from historical documents dating from 1500 to 1940. The potential fish species of these lakes were then classified according to their ecological requirements and finally 16 ecological parameters were used to develop the assessments of ecological integrity.

An investigation by Muhar *et al*. (2000) of the 52 largest Austrian rivers with catchments larger than 500m$^2$ (excluding the River Danube) provided a national estimate of the ecological status of Austria's rivers. Emphasis was placed on evaluation criteria (morphology, instream structures, river corridor, lateral connectivity and hydrological regime) which could be compared with original conditions. This evaluation of 5,000km of river identified the remaining stretches of high habitat quality and those affected by human activities. These investigations help to fulfil the requirements of the EC WFD by helping to delineate and characterise reference sites of different river types.

Girvan *et al*. (2001) surveyed the fish species diversity in selected lakes in Northern Ireland as a first step in implementing the WFD. The objective was to survey the four main WFD fish requirements (composition, abundance, biomass and age structure) in lakes considered to have high water quality across a range of geomorphological types in order to obtain baseline data against which other lakes can be compared. Species diversity was low but no lakes were found to be fishless and most lakes had three or more species present. There appeared to be little correlation between the fish populations and basic physical and chemical lake characters. It was concluded that '*the fishing techniques developed were efficient at covering all lake zones and capturing a wide range of fish species*'.

Factors affecting species richness and component patterns in native fish faunas in 30 streams in the middle basin of the River Guadiana were studied by Corbacho & Sanchez (2001). They found that (a) species richness increased with stream length and catchment area, (b) native species numbers declined as anthropogenic factors increased (the reverse being true for alien species), (c) the two main negative factors affecting different parts of the streams were channelisation in the lower reaches and dams in the upper reaches, (d) the length of pristine streams was the main factor predicting native species richness, and (e) native fish faunas of small isolated streams were more vulnerable than those of larger streams. '*Fish communities appear to be a sensitive indicator of … environmental degradation*' and therefore useful in monitoring.

The integrity of a small anthropogenically influenced urban stream system in south-western Germany was studied by Siligato & Bohmer (2002). The fish assemblage was abnormal with several site-specific fish species missing but non-site-specific species were relatively common. Highest species diversity was recorded downstream of the main migration barrier, while upstream only a few species were present. In general, there was a shift to ubiquitous and limnophilic species as well as to those more tolerant of pollution. The assessment system used was '*based on the similarity of the potential natural and the actually established fish assemblage as demanded by the Water Framework Directive of the European Union for the evaluation of the ecological status of a fish assemblage in a stream*'.

# 4 FISH FAUNA OF GREAT BRITAIN AND IRELAND

An up-to-date check list of all freshwater fish known to be established or to have occurred in the past in Great Britain and Ireland has been prepared, based on recent revisions by Kottelat (1997) and Maitland (2000a) (Table 1). This includes both native and established alien species. In addition, as a prerequisite to the discussions below concerning naturalness and fish habitats, information is also presented concerning which species are considered native to different countries of the UK (Table 2) and to major freshwater habitats (Table 3). As in other countries in Europe (Persat & Keith 1997), the decision as to whether some species are native or alien is sometimes a difficult one and is discussed further below.

The main geographic units used in the present context for the distribution of freshwater fish within the UK are the standard Hydrometric Areas (Figure 1) and some important details of these are given in Table 4. As an aid to understanding the availability of habitat in each Hydrometric Area, and some of the implications for adequate monitoring, the numbers of lakes and rivers have also been included in Table 4. Note that there is a coincidence in the numbering of Hydrometric Areas in Great Britain and those in Ireland.

A wide variety of records of fish distribution is available from a range of sources, both published and unpublished. Information from existing databases (Maitland 1969, 1972a, 1992, 2000b, 2001), record centres and literature (eg Kurz & Costello 1999) was used as a basis for establishing the current distribution of all freshwater species presently known to be established in the UK (Maitland & Campbell 1992) in relation to standard Hydrometric Areas (Table 5a–f) and is also available in map form (examples are given in Figures 2a and 2b). These data form an important basis for a revised SERCON Fish Naturalness assessment, but are also useful for analysing fish assemblages (Scott & Hall 1997) in relation to the WFD.

## 4.1 Native fish species

The indigenous freshwater fish fauna of the UK can be divided into two groups according to their origin: (1) those fish which can live in both salt and fresh water, known as euryhaline species; (2) those fish which can live only in fresh water, known as stenohaline species.

For most parts of the British Isles, the history of its freshwater fish began during the final stages of the last Ice Age, about 13,000–15,000 years ago, when the great ice cap that had covered all of Scotland and all but the most southern parts of England, Wales and Ireland was melting and retreating northwards. At that time, and for about the next 3,000 years, a land connection existed between England and the Continent, from just north of the River Humber southwards to the River Thames. Both humans and much of our terrestrial wildlife recolonised the country, sterilised by the ice cap, via this land bridge. Through it flowed rivers which were either tributaries of the River Rhine, or at least shared a common floodplain with this large continental river, giving them a shared fish fauna.

As the ice melted, euryhaline fish were able to follow the coastline northwards and colonise any new ice-free fresh waters that were accessible from the sea. Surviving ice dams must have provided refuge lakes for many of these colonisers for a period until they melted. Stenohaline species, on the other hand, being unable to move round the coasts, were restricted to the English tributaries of Continental rivers and survived successfully in this ice free refugium until the final retreat of the ice. The number of euryhaline species is not great, therefore the number of species originally native to northern England, Wales, Scotland and Ireland is comparatively small. Also, the comparatively short length of time that the land bridge with the Continent existed did not allow a full representation of the north-west European fish fauna to reach Britain, while later introductions from Europe and elsewhere were selective and not comprehensive. Thus the present freshwater fauna of the British Isles is an impoverished one (40 native species) when compared with that of north-west Europe (ca 80 species) and Europe as a whole (ca 215 species).

Much of the present day distribution of freshwater fish in the British Isles is the result of re-distribution by humans, intentional and otherwise. However, some natural re-distribution must have taken place also as a result of post-glacial changes in land levels, melting of ice dams and by river capture – though the latter would probably only have affected those stenohaline species living in fast-flowing headwaters, such as minnows, stone loach and bullhead. Presumably at times, some great natural catastrophes must have taken place, such as flooding on a massive scale, resulting in the formation of temporary lakes which might have allowed the colonisation of hitherto isolated river systems across low watersheds. Transfers by birds and waterspouts may also have been important from time to time.

## 4.2 Alien fish species

In recent years, humans have certainly been the main agents of re-distribution (Maitland 1987). They imported several fish as food from the Continent, such as carp, and translocated several native species within the British Isles, presumably for the same reason. By tradition, the clergy in particular have been held responsible for much of the re-distribution of fish which were kept in small ponds, moats and lakes, where they could easily be gathered, assuring a dependable supply of fish for Fridays. Humans have also introduced and re-distributed fish for sport, particularly those fish which provide both sport and food, such as brown and rainbow trout, brook charr, grayling, pike, carp, tench and pikeperch. As an indirect result of developing sport fisheries, several other species have become widely re-distributed too.

The role of alien species in relation to SERCON Naturalness and WFD status class has been discussed with a number of people. There seems to be general agreement that the presence of one or more established alien species is certainly not 'natural' and is likely to affect the WFD status class in a detrimental way. However, the WFD is largely concerned with changes to the hydromorphological or physico-chemical features of waters which have affected ecological status and not with biological aspects which have been changed directly by human interference (eg introduction of alien species – plants, invertebrates or fish, including parasites and disease). Unfortunately, although there are many waters with established populations of alien fish species, only in a few cases have they been studied. Thus it is generally not possible to prove that introduced species have had any impact. In those which have, alien species have often been shown to bring about ecological changes – sometimes major ones (Maitland 1972b; Adams & Maitland 1998, 2001). Such impacts may go well beyond effects on the indigenous fish community. The most logical assumption is that alien populations do change the nature of pristine communities, and thus the Precautionary Principle seems the wisest option as far as determining impact is concerned. In particular, it is important that the role of alien species within Protected Areas (SEPA 2002) is clarified. Protected Areas under the WFD are those designated under EC legislation (eg SACs).

Thus the question of alien species needs to be resolved in relation to the WFD and to the assessment of the 'status' of individual aquatic systems. Further discussion is required on this topic within Scotland and comment and advice is needed from the European Union if this is to be resolved in a standard way across member states. The SERCON system for evaluating the conservation value of rivers (Boon *et al*. 1996), discussed further below, downgrades sites where alien species are established. Two recent reviews are highly relevant (IUCN 2001; Adams & Maitland 2001) and provide useful background information on this topic. A preliminary assessment, indicating which species are believed to be native to each of the four countries of the UK is given in Table 2. In view of the varying opinions as to the origin of freshwater fish in different parts of the UK (Went 1950; Maitland 1969; Jones 1972; Wheeler 1974, 1977; Adams & Maitland 2001) it is probably unrealistic to attempt to refine this assessment any further (ie to geographic regions within each country) but the subject is discussed further below.

The status and distribution of established alien species, both those foreign to the UK and those believed to have been transferred within the UK by man outwith the areas to which they are native, has also been related to Hydrometric Areas (Table 5). Worthy of note is that 26% of the fish fauna of England is now alien. The figure for Scotland, if one includes 'alien species' introduced from England, is currently 38%.

## 4.3 Fish assemblages

In assessing how freshwater fish species are associated with each other and with various types of water, the approach previously explored by Maitland (1979, 1980, 1990) may be useful. Synecological studies of animal and plant communities appear to confirm that a critical definition of discrete communities is not possible – rather that a continuum exists along which there are important, probably stable, nodes which can be described in detail (Maitland 1966, 1979; Vannote *et al*. 1980). The method of Association Analysis proposed by Fager (1957) has proved useful in the past for various groups of invertebrates and appears also to have some value for fish species which do form natural associations with particular habitats (Mahon 1984). An example is given in Figure 3, where each fish species is linked to that with which it is most highly associated, the relevant values being indicated between the species concerned. From this diagram, five main associations of native fish species may be identified, as follows:

(a) Original marine invaders, many now largely isolated in fresh water and including brook lamprey, brown trout, Arctic charr, powan, nine-spined stickleback and three-spined stickleback, as well as pollan and vendace (not included in this analysis).

(b) Current diadromous species, including river lamprey, sea lamprey, sturgeon, allis shad, twaite shad, smelt, eel, Atlantic salmon, sea trout and flounder.

(c) Running water (lotic) species, including dace, chub, gudgeon, minnow, stone loach, grayling, bullhead and ruffe.

(d) Standing water (lentic) species, including common bream, rudd, roach, tench, perch and pike.

(e) Estuarine (transitional water) species which make incursions into fresh water including, as well as various species which are largely marine, sea bass, thick-lipped grey mullet, thin-lipped grey mullet, and common goby, as well as golden grey mullet (not included in this analysis).

However, in developing techniques for assessing the naturalness of fish communities and reference conditions for fish in running waters in the UK it is impossible to ignore the effects of history and geomorphology. As discussed above, probably the most important event in the evolution of the UK's environment over the last 30,000 years was the last ice age, after which there was a relatively easy colonisation of fresh waters from the sea by those fish species with marine affinities, followed by a slow natural dispersal and an increasingly faster rate of transfers by humans of other, purely freshwater, species from the south. Additionally, alien species from abroad have been introduced. All of this has resulted in somewhat of a north/south divide (and, to a lesser extent, an east/west one) in the distribution of species and the composition of fish communities in Great Britain (and certain differences between Great Britain and Ireland). The situation is more complex than a single dividing line on the map, but it is certainly true to say that the fish communities in the north and on islands have many fewer species than comparable systems in the south.

**Rivers**

Typical northern running waters in the north of Scotland like the Rivers Naver, Thurso and Helmsdale have only about six or seven species of freshwater fish, whereas comparable waters in southern Scotland, for example the Rivers Nith, Annan and Tweed, have 16–19 species. Further south still, in England, the Rivers Severn, Avon and Thames may have 25–30 species. In terms of species composition, many of the northern communities have probably remained the same for thousands of years and are relatively stable, whereas those in the south have changed substantially over the last two centuries due to human impacts and continue to do so with introductions by anglers and others. Each new introduction can produce instability in its new community and threaten rare native species, as studies of the River Endrick have shown in recent years (Maitland 1966; Doughty & Maitland 1994).

The essence of this, in the present context, is that in the south the greater range of species available allows great flexibility in the variation and structure of fish communities from, say, salmonid to cyprinid, in relation to habitat type. In the north, however, where there are virtually no cyprinids, such a range is impossible and the communities, in a range of types of water body, and though just as natural (and certainly more pristine), are less diverse. This is one of the major reasons for requiring a detailed inventory of fish species in relation to catchments and so a tabulation of species presence/absence against standard Hydrometric Areas (Table 5) is important.

One of the problems of classifying rivers in relation to their native fish communities is this natural variation in the zoogeography of fish species. General attempts to classify running waters have been of two kinds: first, the division of systems into definable zones (from source to mouth), and second, the separation of river systems into definable types. Each type of classification presents its own problems.

Various schemes of zonation for running waters have been devised (Hawkes 1975) and one common method of differentiating zones in rivers is the distribution of common fish species (Hughes & Gammon 1987). Such schemes, originally described for European rivers by Thienemann (1925), were unsuccessfully adapted for the British Isles by Carpenter (1928). A similar, but more elaborate, scheme was developed by Huet (1946, 1959) for Europe and this has been adopted as part of the CORINE Biotope classification (Devillers *et al*. 1991), a standardised classification of both freshwater and terrestrial ecosystems. The main categories of rivers are: rivulets, trout zone, grayling zone, barbel zone and bream zone.

| **Thienemann (1925)** | **Carpenter (1928)** | **Huet (1959)** | **Corine (1991)** |
|---|---|---|---|
| Springs | Head stream | – | Rivulets |
| Trout zone | Trout beck | Trout zone | Trout zone |
| Grayling zone | Minnow reach | Grayling zone | Grayling zone |
| Barbel zone | Upper lowland reach | Barbel zone | Barbel zone |
| Bream zone | Lower lowland reach | Bream zone | Bream zone |
| Brackish zone | – | – | – |

For the zoogeographic reasons outlined above, these schemes do not work in northern Britain, where grayling, barbel and bream and several other stenohaline fish species are absent – thus an alternative classification scheme is required. In essence, if the native fish fauna of the UK is to be adequately reflected, then this may need geographic sub-units to reflect the varying zoogeography. Such a classification, using the same geographic units (A–E) presently used in SERCON (Boon *et al*. 1996), might be as follows:

| REGION | SOURCE WATERS | HEAD WATERS | MIDDLE (LOTIC) REACHES | LOWER (LENTIC) REACHES | TRANSITIONAL WATERS |
|---|---|---|---|---|---|
| **A.** | No fish | Brown trout | Atlantic salmon<br>Brown trout | 3-spined stickleback<br>Brown trout<br>Flounder | Common goby<br>Sea trout<br>Flounder |
| **B.** | No fish | Brown trout | Atlantic salmon<br>Minnow<br>Stone loach | 3-spined stickleback<br>River lamprey<br>Pike<br>Sea lamprey | Common goby<br>Smelt<br>River lamprey<br>Sea trout |
| **C.** | No fish | Brown trout<br>Bullhead | Atlantic salmon<br>Minnow<br>Loach<br>Grayling | 3-spined stickleback<br>Lampreys<br>Roach<br>Perch | Common goby<br>Smelt<br>River lamprey<br>Thick-lipped mullet |
| **D.** | No fish | Brown trout<br>Bullhead | Gudgeon<br>Bleak<br>Barbel<br>Dace<br>Grayling | Common bream<br>Chub<br>Roach<br>Rudd<br>Tench<br>Ruffe & Perch | Sea bass<br>Common goby<br>River lamprey<br>Thick-lipped mullet |
| **E.** | No fish | Brown trout<br>Bullhead | Gudgeon<br>Bleak<br>Barbel<br>Dace<br>Grayling | Silver bream<br>Common bream<br>Chub<br>Roach<br>Rudd<br>Tench<br>Ruffe & Perch | Sea bass<br>Common goby<br>River lamprey<br>Thick-lipped mullet |

***Note:*** This scheme indicates for each of the main habitats from source to mouth in river systems in each geographic area of the UK (Figure 4), the species which characterise that habitat. It considers only those species which are native to each geographic area concerned and most typical for the reaches indicated. Thus, brown trout may occur in many waters in the south of the UK but, unlike northern Britain, are not the most diagnostic species there and thus not listed. Ubiquitous species such as eel are not included in the scheme, nor are rare species such as allis and twaite shad, vendace, powan, pollan, thin-lipped grey mullet, golden grey mullet nor vagrants such as sturgeon or houting.

In practice, however, a more accurate procedure would be to consider the actual distribution within each Hydrometric Area (see below).

**Lakes**

As with running waters, in developing techniques for assessing naturalness and reference conditions for fish in standing waters in the United Kingdom (UK) it is impossible to ignore the effects of history and geomorphology. Fish communities in lakes in the north of Scotland and on islands have many fewer species than comparable systems in the south. Thus, for example, typical northern standing waters, such as Lochs Stack, Shin and Calder have only six or seven native species whilst Lochs Ken, Lomond and St Mary's Loch in the south of Scotland have nine (Ken) to 15 (Lomond). In the south of England, several additional native species (eg silver bream) are available to increase the community complexity. Most of the northern communities have remained stable for thousands of years, whereas those in the south have changed substantially over the last two centuries. Each new introduction can produce instability in its new community, as studies of Loch Lomond have shown in recent years (Adams & Maitland 1998, 2001).

The fish communities of these lake types in Europe may broadly be described as follows:

| LAKE TYPE | FISH CHARACTERISTICS |
|---|---|
| Dystrophic | Sometimes no species, always very few |
| Oligotrophic | Few species, dominated by salmonids and sometimes coregonids |
| Mesotrophic | More species, sometimes dominated by percids and cyprinids |
| Eutrophic | Usually a wide range of species, but often dominated by cyprinids |

However, as in rivers, because cyprinids (and to a lesser extent percids) are virtually absent from northern Britain, such community classifications are inadequate and special systems have to be devised to meet these particular circumstances.

Thus, as in rivers, and for the zoogeographic reasons outlined above, previous schemes for the classification of lakes in relation to fish do not work in northern Britain, where common bream, roach, ruffe and other southern species are absent – thus an alternative classification scheme is required. In essence, if the native fish fauna of the UK is to be adequately reflected, then this may need geographic sub-units such as Hydrometric Areas, or groupings of Hydrometric Areas, to reflect the varying zoogeography.

In looking objectively at the range of fish communities found in Great Britain and Ireland it is possible to detect a broad range of types ranging from high altitude streams and lakes where conditions are so extreme that there are no fish to lowland conditions with easy connections to the sea where estuarine species may occur. Where a water body is naturally fishless (eg because it is ephemeral, or climatic conditions are too rigorous), then other means must be used to assess its status.

# 5 RIVER CONSERVATION STATUS

## 5.1 Evaluation using SERCON

SERCON (System for Evaluating Rivers for Conservation) is a broad-based technique for river evaluation, designed to be applied with greater consistency than present methods, and to provide a simple way of communicating technical information to decision makers (Boon *et al*. 1996, 1997). SERCON Version 1 evaluates data on 35 attributes, grouped within six conservation criteria – Physical Diversity, Naturalness, Representativeness, Rarity, Species Richness and Special Features. Attributes concerning fish feature in all but the first of these. Assessments of Representativeness are based on geographic information on the observed complement of fish species found in a river compared to that expected in different geographic zones of the UK. Tables are provided to show which native species are expected in each zone. Scores for Naturalness (attribute 'NA 9' in SERCON) are derived from the proportion of alien to native species. SERCON Version 2 combines the fish Representativeness and Naturalness criteria into a single Naturalness criterion.

This way of evaluating 'departure from naturalness' is highly relevant to the concept of 'ecological status' adopted in the EC WFD and the revision of SERCON Fish Naturalness, proposed below, should be very useful in that context, as well as to SERCON itself. Based on the information available for Hydrometric Areas, it should give a more accurate and sophisticated assessment of this aspect of conservation status.

## 5.2 Proposed revision of SERCON NA 9: Fish

The proposed revision of the existing SERCON scheme for assessing Fish Naturalness is as follows.

NA 9. Fish

Question: How natural is the complement of native fish?

Naturalness of the fish community of an Evaluated Corridor Section (ECS) can be determined by first assessing if the ECS is largely lentic (Le) or lotic (Lo), or both (LL) and then obtaining a complete list of fish species established there. This list should then be checked against the known list for the Hydrometric Area in which the ECS lies (Table 5a–f). This indicates which species are present in and which are native (Le, Lo, LL) or perhaps present but alien (A, At, As) to that Hydrometric Area. Only those native species expected to occur in the main ECS habitat(s) (Table 3) should be used in scoring and if the ECS is inaccessible to fish migrating upstream from the sea, such species should be deleted from the expected native list. Score modifiers are based on the presence of alien fish species.

(i) Calculate the SERCON score for NA 9 (based on the above specifications)

| SCORE | DESCRIPTION |
|---|---|
| 0 | 0% of expected native list present. |
| 1 | >0–20% of expected native list present. |
| 2 | >20–40% of expected native list present. |
| 3 | >40–60% of expected native list present. |
| 4 | >60–80% of expected native list present. |
| 5 | >80–100% of expected native list present. |

(ii) Modify the SERCON score for NA 9 as follows:

Subtract 1 when 1 alien species is established (or stocked regularly) or
Subtract 2 when 2 or more alien species are established (or stocked regularly)

Score 5 for waters which are naturally fishless – for example because they dry out from time to time, because they freeze solid or become anaerobic under ice in winter, or because of high altitudes and corresponding low average temperatures fish are unable to grow sufficiently to survive.

***Note:*** The SERCON scoring above combines native species positively and alien species negatively in the one score. In the suggestions below for scoring WFD species composition, the scoring systems for native and alien species are separate because there is not yet any clear resolution regarding the latter in assessing WFD status – '*… where introductions have become established without causing ecologically significant changes … it would seem appropriate to regard them as a minor impact.*' (SEPA 2002).

# 6 ASSESSMENTS OF FISH COMMUNITIES UNDER THE WATER FRAMEWORK DIRECTIVE

## 6.1 Relationships between freshwater habitats and fish communities

The British Isles are renowned for the great variety of landscapes they contain within a relatively small land area. This quality reflects the wide range of basic conditions fundamental to the evolution of contrasting land forms: high and low ground, hard and soft rocks, rich and poor soils, high and low rainfall, a highly convoluted coastline and a history of various intensive land uses. It follows therefore that there is also a wide variety of natural freshwater habitats, to which must be added the considerable number of artificial water bodies such as the canal networks in the lowlands and numerous reservoirs of all shapes and sizes, mostly in the uplands.

In the British Isles, the range of natural freshwater habitats encompasses the high lochs of the Central Highlands of Scotland at around 900m in altitude, with their clear nutrient-poor waters, ice-free for less than half the year; the large, deep and elongated, glaciated lake basins of upland areas in Scotland and north-west England, with their relatively nutrient-poor (oligotrophic) waters; the shallow biologically rich (eutrophic) limestone loughs of Ireland; the acid peat-stained pools, the source of upland streams; the swift-flowing chalk and marl streams of southern England and parts of Ireland with clear water and dense vegetation; the turbid lower reaches of large rivers, whose systems include tributaries of various characteristics, but whose original nature is now largely masked by the run-off from agricultural land and the discharge of domestic and industrial effluents; the many estuaries, large and small, with full ranges of salinity from fresh to salt water; the less common habitats such as the mildly saline water bodies impounded by storm beaches around the coast, and the immense variety of ponds, ditches and marshy pools throughout the country.

The most important qualities of freshwater habitats that, in theory, dictate the density and species composition of the fish present are water velocity, level of dissolved oxygen, summer temperatures and the level of chemical, and therefore biological, richness and degree of pollution. Many of the large rivers which rise in upland areas gradually progress from being fast flowing and oligotrophic to slow flowing and eutrophic. There are many classic examples on the Continent (eg the Rivers Rhine and Gironde) where the species composition of the fish fauna is closely related to the habitat provided by each particular section of the river. However, as discussed above, in the British Isles, with its short rivers, its impoverished fauna and flora and specialised history of fish colonisation, re-distributions and introductions, this type of correlation is only approximate.

However, there are some features and relationships characteristic of the communities found in fresh waters in the British Isles. Though there are some base-rich uplands, in mountainous regions generally the mainly hard insoluble rocks and poor soils mean that the acid waters of their streams and lakes are poor in the minerals required to promote growth and can therefore only support a low level of biological productivity. Their invertebrate life is poor in species and dominated by insects. These habitats, though, favour salmonid fish, and Atlantic salmon, brown trout and Arctic charr thrive in the cool, clean, well oxygenated waters and clean silt-free gravels which are important for the survival of their eggs and young stages. Such habitats are the most vulnerable to the impact of 'acid rain' as they have insufficient buffering capacity to neutralise the acids being deposited from the atmosphere. Some coarse fish also inhabit such waters but they seldom dominate the salmonids, for most cyprinid species do not tolerate the rather impoverished habitats or low summer temperatures.

At the other extreme there are typical lowland river systems flowing over soluble base-rich strata and influenced by run-off from the rich agricultural soils in the catchment. This results in high pH 'alkaline' waters and a biologically rich, eutrophic, environment. The often turbid waters (chalk streams being an exception) of these systems usually support much aquatic vegetation and a rich and diverse invertebrate fauna with molluscs and crustaceans as important members. Being at a low altitude, the relatively high summer water temperatures provide the conditions essential to so many cyprinid fish species for successful ova hatching and fry survival. Such habitats suit most members of the carp family and many other stenohaline fish. However, where these (especially pike) are absent, salmonid fish will thrive as long as there are tributaries with good spawning and nursery areas to provide an adequate recruitment to maintain their populations further downstream.

## 6.2 Fish community classification

TThe requirements of the WFD in relation to fish mean that much more information than is presently available on the distribution and ecology of fish communities in the UK, together with adequate data on the numbers, growth and age structure of native species in different parts of the country, is going to be an essential preliminary step before attempting to assess status in relation to fish. Unless detailed studies of the fish populations have been carried out (eg Shafi & Maitland 1971a, b) it will be impossible to carry out accurate and objective WFD assessments. In practice, for the great majority of water bodies such information is not available and many initial assessments may have to rely on expert judgement rather than hard facts.

The European Union already recognises two categories of waters in relation to fish. These are specified in Council Directive 78/659/EEC of 18 July 1978 on the quality of fresh waters needing protection or improvement in order to support fish life and are defined as:

- Salmonid waters – 'waters which support or become capable of supporting fish belonging to species such as salmon (*Salmo salar*), trout (*Salmo trutta*), grayling (*Thymallus thymallus*) and whitefish (*Coregonus*)'.
- Cyprinid waters – 'waters which support or become capable of supporting fish belonging to the cyprinids (*Cyprinidae*), or other species such as pike (*Esox lucius*), perch (*Perca fluviatilis*) and eel (*Anguilla anguilla*)'.

Member states were obliged to designate waters into these two categories and set values for a range of physical and chemical parameters, as specified in the Directive.

Two concepts used by the WFD in relation to fish are 'type-specific communities' and 'type-specific disturbance sensitive species'. Adequate definitions for these concepts are awaited from other groups involved in the WFD where various typologies are being produced. (P.J. Boon, personal communication) and though the typologies presented in this report (see below) may be useful in helping to develop expected associations of species within Hydrometric Areas, they will probably not be used as additional typologies under the WFD.

A broad classification of types of freshwater bodies which, apart from longitude, incorporates the '*obligatory factors for sub-dividing surface water categories into types*' (SEPA 2002) – altitude, depth (for lakes), geology and size – has previously been used as a basis for developing ideas concerning synoptic limnology and analysis of freshwater bodies in the UK (Maitland 1979; Maitland & Morgan (1997). Its structure is as follows:

| **GEOLOGY (rock & soil)** | **SIZE (area/depth)** | **ALTITUDE (& latitude)** | **FISH (community)** | **DIVERSITY (species)** |
|---|---|---|---|---|
| POOREST | SMALLEST | HIGHEST | PERHAPS NONE | |
| dystrophic & oligotrophic systems | shallow pools & trickles | cooler waters often frozen | stenothermic species (eg Salmonidae) may dominate | very low<br>low |
| mesotrophic systems | | | | medium |
| eutrophic & hypertrophic systems | deeper lakes & rivers | warmer waters rarely frozen | eurythermic species (eg Cyprinidae) may dominate | high<br>medium |
| RICHEST | LARGEST | LOWEST | SOME BRACKISH | |

This concept, close to that required by the WFD to categorise surface water body types, was further developed by Maitland *et al.* (1981) in an analysis of all water bodies in Shetland (Maitland *et al.* 1975; Maitland & East 1976; George & Maitland 1984; Maitland & Britton 1985), then the Tayside Region (Maitland *et al.* 1981) and subsequently the Inner Hebrides (Maitland & Holden, 1983). As an example, the results for Tayside Region, summarised in Tables 6a and b, if taken in conjunction with Table 4, give a good idea of the task which might be involved in any detailed coverage of fresh waters in the UK. Physico-chemical and biological data are available for a stratified subsample of Shetland and Tayside waters and are perhaps worthy of analysis in relation to the requirements of the WFD.

A preliminary classification of lake types has been carried out in Northern Ireland (Rippey *et al.* 2001). There are 1,668 lakes there, most of which are small with only eight larger than 1km$^2$. A preliminary classification of 566 of these lakes based on four major descriptors – altitude, geology, size and alkalinity gave seven lake types. Work is in progress to see if these types relate to the biological communities, including fish.

The document recently produced by SEPA (2002) clarifies much of the WFD in relation to waters in Scotland and establishes what needs to be done towards meeting WFD requirements. In relation to fish, the relevant quality elements for ecological status classification in different categories of surface water are, for both rivers and lochs: composition (of the fish community), abundance (of each species) and age structure (of each species). '*For good ecological status in river, loch and transitional water bodies, no more than slight changes are permitted to the fish quality elements as a result of impacts on the hydromorphological or physico-chemical quality elements.*'

## 6.3 Ecological status

As a first stage in establishing the ecological status of surface waters, the WFD has proposed the use of a number of ecoregions which have been defined for Europe by Illies (1978), and which places Great Britain in one (No 18) and Ireland in another (No 17). Thus the UK is divided between two separate ecoregions. There is clearly variation within ecoregions and the WFD deals with this by adopting a classification of water body types (ecotypes) based on physico-chemical descriptors.

The definitions of status class in the WFD are as follows:

(a) **High status** – *'There are no, or only very minor, anthropogenic alterations to the values of the physico-chemical and hydromorphological quality elements for the surface water body type from those normally associated with that type under undisturbed conditions. The values of the biological quality elements for the surface water body reflect those normally associated with that type under undisturbed conditions, and show no, or only very minor, evidence of distortion.'*

(b) **Good status** – *'The values of the biological quality elements for the surface water body type show low levels of distortion resulting from human activity, but deviate only slightly from those normally associated with the surface water body type under undisturbed conditions.'*

(c) **Moderate status** – *'The values of the biological quality elements for the surface water body type deviate moderately from those normally associated with the surface water body type under undisturbed conditions. The values show moderate signs of distortion resulting from human activity and are significantly more disturbed than under conditions of good status.'*

(d) **Poor status** – *'Waters showing evidence of major alterations to the values of the biological quality elements for the surface water body type and in which the relevant biological communities deviate substantially from those normally associated with the surface water body type under undisturbed conditions.'*

(e) **Bad status** – *'Waters showing evidence of severe alterations to the values of the biological quality elements for the surface water body type and in which large portions of the relevant biological communities normally associated with the surface water body type under undisturbed conditions are absent.'*

All of these categories would appear to occur in the UK.

In relation to fish, the more detailed definitions of High, Good and Moderate status in the WFD are:

| **High status** | **Good status** | **Moderate status** |
|---|---|---|
| Species composition and abundance correspond totally or nearly to undisturbed conditions<br><br>All the type-specific disturbance-sensitive species are present | There are slight changes in species composition and abundance from the type-specific communities attributable to anthropogenic impacts on physico-chemical and hydromorphological quality elements | The composition and abundance of fish species differ moderately from the type-specific communities attributable to anthropogenic impacts on physico-chemical or hydro-morphological quality elements |
| The age structure of the fish communities show little sign of anthropogenic disturbance and are not indicative of a failure in the reproduction or development of any particular species | The age structures of the fish communities show signs of disturbance attributable to anthropogenic impacts on physico-chemical or hydromorphological quality elements, and, in a few instances, are indicative of a failure in the reproduction or development of a particular species, to the extent that some age classes may be missing | The age structure of the fish communities shows major signs of anthropogenic disturbance, to the extent that a moderate proportion of the type specific species are absent or of very low abundance |

These requirements mean that a thorough knowledge and classification of native fish communities in the UK, together with ecological information on the numbers, growth and age structure of individual species in each water, is an essential preliminary step before attempting to meet the assessment requirements of the WFD.

As well as designing a programme which meets the requirements of the Directive it should be remembered that consideration should be given to other options which measure the health of fish populations and which would identify problems not picked up by the WFD metrics or analyses and sometimes give early warning of problems within fish populations. A major change in behaviour, for example, is one such factor (Hartmann 1982).

## 6.4 Assessment of ecological status

Many of the objectives proposed in the WFD parallel those already developed in SERCON (Boon *et al.* 1994, 1996, 1997, 2002) and it is worth considering a scheme based on this experience. In trying to develop a workable WFD scheme, there are several aspects related to the assessment of the status of water bodies as far as their fish communities are concerned and the following five approaches are worthy of consideration, given that some changes to the assessment criteria may well be necessary in the light of adequate testing.

As in SERCON, as a preliminary to such assessments, basic data must be available for consideration so that a proper comparison between the expected and the observed fish assemblages can be carried out.

(a) Data on local fish habitat, especially substrate in relation to hydrology (ie lentic/lotic).

(b) Current information on the assemblage of fish in the stretch of water concerned.

(c) A list of those fish species considered to be native to the catchment concerned (see Table 5).

(d) Information on accessibility from the sea to the water (ie natural/artificial barriers).

### (i) Species composition

***Historical evidence for the loss of native species due to human activities***

There are many waters where past human activities have eliminated some or all of the original complement of native fish species. Often, the human impact has gone, but because of the relatively poor powers of dispersal of most fish the previous community has never been restored. There are many causes of such losses (eg pollution, acidification, eutrophication, abstraction, barriers to migration, etc.) and numerous examples of depauperate fish communities have resulted as a consequence.

The ecological status of a fish population in relation to historic loss could be assessed as follows:

| ASSESSMENT | WFD STATUS | SCORE |
|---|---|---|
| a. No loss of native species* | High | 5 |
| b. Loss of up to 25% | Good | 4 |
| c. Loss of >25–50% | Moderate | 3 |
| d. Loss of >50–75% | Poor | 2 |
| e. Loss of >75% | Bad | 1 |

***Note** that the WFD does allow high status to be achieved when conditions are not quite pristine: 'nearly to undisturbed'. However such flexibility does not pertain here when the loss of even one species implies a major change.

The assessment is effectively achieved by calculating the number of native species found divided by the number of expected native species, expressed as a percentage. Contrasting examples would be Loch Eck which has retained all of its native species (thus Score 5: High ecological fish status), Rostherne Mere which has lost one species (Smelt) (thus Score 4: Good ecological fish status) and Loch Valley which is fishless due to acidification (thus Score 1: Bad ecological fish status).

### *Presence of alien fish species established in the fish community*

The general conservation consensus around the world is that, after habitat destruction and loss, the introduction of alien fish species is one of the greatest hazards facing many freshwater fish communities. In extreme cases – for example, certain rivers in California – alien species now make up the entire fish communities. The first thing to know in any assessment is just what alien species are present, how many of them there are and how well established they are. In the absence of any other information, it can be assumed that they do affect the status of the water body concerned.

The status of a fish population in relation to the presence of alien fish species could be assessed as follows:

| ASSESSMENT | WFD STATUS | SCORE |
|---|---|---|
| a. No aliens* | High | 5 |
| b. Up to 25% of species are aliens | Good | 4 |
| c. >25–50% of species are aliens | Moderate | 3 |
| d. >50–75% of species are aliens | Poor | 2 |
| e. >75% of species are aliens | Bad | 1 |

***Note*** that the WFD does allow high status to be achieved when conditions are not quite pristine: 'nearly to undisturbed'. However such flexibility does not pertain here when the establishment of even one alien species may imply major changes.

The assessment is effectively achieved by calculating the number of alien species found divided by the total number of species present, expressed as a percentage. Contrasting examples would be Loch Eck and Red Tarn, where there are no alien species (thus Score 5: High ecological fish status), Llyn Tegid where there are several alien species (thus Score 4: Good ecological fish status), Loch Lomond where more than 25% of the fish species are aliens (thus Score 3: Moderate fish status), Lower Loch Erne (Rosell 2001) where more than 50% of the fish species are aliens (thus Score 2: Poor ecological fish status), and Lough Lea (Girvan *et al.* 2001) where all the fish species can be regarded as aliens (thus Score 1: Bad ecological fish status).

The species composition in Lower Lough Erne (Rosell 2001) has changed dramatically in recent years because of the introduction of alien species. Yet the WFD status in relation to native species composition, as determined by the method proposed above is Good, since only one species (Arctic charr) has become extinct (though another, pollan, is apparently nearing extinction). However, the WFD status in relation to alien species is Poor, since 57% of the whole community are alien species. However, the SERCON approach, outlined above, would give a score of 3 (Moderate) which is probably a more realistic score for the present status of this water body.

### (ii) Abundance

***Impact of human activities on native fish populations***

As well as completely eliminating fish species from a water body, human activities can affect fish populations in many other ways, changing the abundance and biology of individual or all native species and affecting the nature of the fish community as a whole. Examples might include elimination of a species from part of a water body (due to pollution), a high incidence of disease due to poor water quality, loss of spawning due to shoreline destruction, etc.

The status of each native fish species in a population in relation to the effect of human impact on abundance could be assessed as follows:

| ASSESSMENT | WFD STATUS | SCORE |
|---|---|---|
| a. No impact: Population >80% of expected mean density* | High | 5 |
| b. Slight impact Population >60–80% of expected mean density* | Good | 4 |
| c. Medium impact Population >40–60% of expected mean density* | Moderate | 3 |
| d. Major impact Population >20–40% of expected mean density* | Poor | 2 |
| e. Severe impact Population ≤20% of expected mean density* | Bad | 1 |

* 'expected mean density' = the abundance corresponding to '*totally or nearly totally to undisturbed conditions*'.

The score for the whole water body would be the mean of the scores for each native species.

At the moment, the scores for each assessment are rather arbitrary and these may need to be adjusted in the light of real data for each species and perhaps for each water for natural variations in population size are sometimes large. Contrasting examples would be Loch Eck, where the numbers of all native species are believed to be normal (thus Score 5: High ecological status), Bassenthwaite Lake where numbers of vendace and possibly other native species have declined (thus Score 2: Poor ecological status) and Loch Maree where stocks of sea trout and Atlantic salmon have declined dramatically (thus Score 1: Bad ecological status).

### (iii) Decline in fish population size

***Biological responses to anthropogenic stresses***

Before fish populations dwindle and eventually become extinct, they exhibit various features which indicate they are under pressure. A significant reduction in numbers or a changing age class structure are clearly important in this context and considered above and below respectively. Other signs of stress and population deterioration could include a higher than normal number of (a) deformities (Oberdorff & Hughes 1992; Ganasan & Hughes 1998) (b) parasites (Hellawell 1986) or (c) diseases (Bucke *et al.* 1979), but a lower than normal (d) condition factor (Pitcher & Hart 1982) or (e) growth rate (Hellawell 1986). It would clearly be of value to record appropriate parameters during routine monitoring if these are going to give early warning signals that the population is under stress. Prior indications that this is the case could be important for managers and, if a species eventually disappears, previous data would be available which might explain its eventual demise. For example, although the ultimate extinction of the vendace in the Mill Loch at Lochmaben is thought to be primarily due to eutrophication, it was observed before it disappeared that the population was suffering from a high incidence of the parasitic fish louse *Argulus*. This parasite may well have been the final pressure which eliminated the vendace.

The status of the population of each native species could be assessed as follows:

| ASSESSMENT | WFD STATUS | SCORE |
|---|---|---|
| a. Population mean for all stress factors within 50% of the norm | High | 5 |
| b. Population mean for 1 stress factor greater than 50% of norm | Good | 4 |
| c. Population mean for 2 stress factors greater than 50% of norm | Moderate | 3 |
| d. Population mean for 3 stress factors greater than 50% of norm | Poor | 2 |
| e. Population mean for >3 stress factors greater than 50% of norm | Bad | 1 |

The score for the whole water body would be the mean of the scores for all type-sensitive species.

This assessment is not an essential requirement of the WFD, but has great value in giving an early indication of serious health problems within a fish population which are likely to affect the other aspects of WFD assessment in the future. Note that the actual stress factors proposed and how they are measured requires further consideration and elaboration. Contrasting examples would be Loch Eck, where all fish stocks are apparently unstressed (thus Score 5: High ecological fish status), Lough Scolban (Girvan *et al*. 2001), where at least two of the five species present are carrying a high parasite burden (notably *Argulus* and *Diplostomum*) (thus Score 4: Good ecological fish status) and Loch Maree, where returning sea trout are thin (low condition factor) and carrying high burdens of sea lice (thus Score 3: Moderate ecological fish status).

### (iv) Age classes

***Status of age structure of native fish populations***

The age structure of fish populations can have considerable natural variation due to weather, population densities, parasite load and other natural features (see below). However, other, anthropogenic, factors can significantly affect age structure without necessarily eliminating the species. Because of different habitat preferences and tolerances between young and old, one part of the population may be eliminated by short-term pollution or other impacts. For example, the classic effect of acidification is to reduce or eliminate recruitment to the population, thus leaving a largely ageing population (Rosseland *et al*. 1980; Harvey 1982).

The status of the population of each native species in relation to its age structure could be assessed as follows:

| ASSESSMENT | WFD STATUS | SCORE |
|---|---|---|
| a. Completely normal age structure: All expected age classes present within 50% of expected % means | High | 5 |
| b. Slight change in age structure: >75 (but less than 100)% of age classes present within 50% of expected % means | Good | 4 |
| c. Significant change in age structure: >50–75% of age classes present within 50% of expected % means | Moderate | 3 |
| d. Major change in age structure: >25–50% of age classes present within 50% of expected % means | Poor | 2 |
| e. Severe change in age structure: ≤25% of age classes present within 50% of expected % means | Bad | 1 |

* 'expected % means' = the means corresponding to '*totally or nearly totally to undisturbed conditions*'.

The score for the whole water body would be the mean of the scores for all native species.

The age class composition should be considered on a percentage basis, thus allowing simple comparisons from one sample to another. Note that the percentages proposed are arbitrary and may require further consideration and modification in the light of experience. Contrasting examples would be Loch Eck, where all species apparently have a normal age structure (thus Score 5: High ecological fish status) and Loch Doon where native salmonids (brown trout and Arctic charr) have suffered reduced recruitment due to acidification (thus Score 3: Moderate ecological fish status).

'Completely normal' would imply that a range of age classes compatible with the life expectancy of each species (see Table 7) was present, and that, in most populations, there was a substantial proportion of young fish present. Severe abnormalities would be indicated by the complete loss of a high proportion of age classes – of particular concern would be the absence of young fish. In this context, perhaps a weighting factor could be introduced to give populations with a high proportion of young fish a higher status than those with a high proportion of old fish (indicating recruitment failure).

### (v) Integrated assessment of ecological status

In any final assessment of the ecological status of a water body in relation to fish, a scoring system, such as that indicated above, could be used for the individual criteria. By combining scores from all the criteria and calculating the mean score, an ultimate WFD status assessment for the water body can be achieved.

As an example, Loch Eck would score very highly under such a scheme, scoring 5 for all criteria, and is therefore undoubtedly of High ecological fish status.

However, this issue will require further discussion when all assessments (plants, invertebrates and fish) are combined to produce the ultimate WFD status. There will then need to be some decision as to whether a low score in any category would bring the overall assessment down to a lower ecological status band. For example, if a water body scored high for all elements but one, but that one scored very low, where would the overall score be fixed?

## 6.5 Provisional assessment of rivers and lakes using expert judgement

In view of the extreme paucity of all the data required to make such assessments of status, it may be necessary in the first instance, in order to meet some of the time schedules required under the WFD, to carry out initial estimates subjectively. Below are some examples from Scotland which may provide a starting point for a discussion of this interim approach.

### High status

Loch Eck – original pristine fish community intact, with no alien species; disturbance-sensitive species (powan, Atlantic salmon, Arctic charr) present; age structure (of those species examined) normal.

River Dee (Grampian) – original pristine fish community intact, with no alien species; disturbance-sensitive species (Atlantic salmon) present; age structure (of those species examined) normal.

Other examples – Loch Einich.

### Good status

Loch Awe – Original fish species still present, but recent additions include roach and dace (introduced by anglers) and rainbow trout (escapes from fish cages). Type-sensitive species (Atlantic salmon and Arctic charr) still present, but growth of the latter affected by presence of regular food from fish cages.

River Cree – Original fish species still present; disturbance-sensitive species (Atlantic salmon and smelt) still present, but the former eliminated from some upper reaches by acidification, the latter affected in the lower reaches by pollution, engineering works and fishing.

Other examples – River Annan.

### Moderate status

Loch Doon – Original fish species still present, including disturbance-sensitive species (Atlantic salmon and Arctic charr). However, number of Salmon reduced due to hydro-scheme, and numbers and growth of brown trout and Arctic charr affected by acidification and losses due to hydro-scheme.

River Dee (Kirkcudbright) – Most of original fish species still present, except eel and smelt, which have been eliminated by a hydro-scheme. One disturbance-sensitive species (Atlantic salmon) still present, but numbers probably reduced by hydro-schemes and acidification in upper reaches.

Other examples – Loch Grannoch.

**Poor status**

Loch Leven – Original fish community changed significantly by the loss of disturbance-sensitive species (Atlantic salmon and Arctic charr) and migratory species (sea trout and eel) due to river obstructions and changed loch levels. Heavy stocking with rainbow trout and intensive angling.

River Clyde – Original fish community changed significantly with the loss of disturbance-sensitive species (Atlantic salmon and smelt) and migratory species (sea trout and eel) due to severe pollution in the lower reaches. Some (eg Atlantic salmon), but not all (eg smelt), of these species are returning because of improved water quality. Several alien species (eg barbel, dace and grayling) are well established.

Other examples – Mill Loch (Lochmaben).

**Bad status**

Loch Valley – Original fish community (brown trout only) eliminated due to acidification.

River Garry (Perthshire) – Complete loss of fish communities (Atlantic salmon, brown trout, eel, minnow) in upper reaches due to hydro-engineering.

Other examples – Loch Ruskie, River Leven (Fife).

## 6.6 Assessment of sensitive species

Clearly each species of fish has evolved to be able to thrive within a particular set of environmental conditions, though some species have a wider range of tolerance than others in relation to some parameters. In general it is true to say, as indicated above, that most salmonid fish require low temperatures, high oxygen, good water quality and coarse substrates (usually with few weeds) for reproduction. In contrast, most cyprinid fish and several other taxa require higher temperatures (to maintain growth), are able to thrive in conditions of lower oxygen and poorer water quality and live mainly in habitats with silted substrates and often weedy conditions. In the UK, the impact of human activities (including the effect of climate change) has been to move the conditions in most fresh waters towards those favoured by cyprinids, to the detriment of salmonids and other native species.

Table 8 provides an assessment of the sensitivity of fish species now (or previously) known to occur in the UK to the main human impacts observed at present. The general picture is that many sensitive native species, especially salmonids, are declining in status (some are extinct), whilst many, more tolerant, cyprinid species, together with several aliens, are increasing. Acidification, increasing temperatures, hydro and other dams threaten salmonids in the uplands, which is their stronghold, whilst eutrophication, mild pollution, and increasing temperatures actually favour many cyprinids in the lowlands to the detriment of salmonids there.

## 6.7 Assessment of sustainable reproductive success

Sustainable reproductive success is assumed to mean that, within a population, reproduction and recruitment are always sufficient to maintain a population indefinitely in the water concerned. As well as measuring the size of a population over a number of years, a useful way to look at annual success is to consider age structure. Examples from the literature indicate that the age structure of populations can be quite variable even within a single species and so, to some extent, the population of each fish species in each water needs to be considered on its own. However, on a broader front, there is significant evidence that for many species climatic factors can have a major effect on recruitment across quite wide geographic areas, giving perhaps very strong or very weak year classes in particular years.

The life expectancy of each species is also an important factor here, as, with inadequate recruitment, short-lived species could disappear within a few years whilst populations of long-lived species could last much longer, a point also considered by Rosell (2001). Thus, as a pointer to monitoring frequency and other considerations, the relationship between life expectancy and fish size is worth examining (Table 8, Figure 5). The clear implication is that populations of short-lived species need to be monitored much more frequently than long-lived ones.

A wide variety of factors can affect the age structure of a fish population. A prerequisite to understanding any age structure is to have some knowledge of life expectancy in the species concerned together with local factors which may be affecting reproduction and recruitment. Some examples of factors (natural and anthropogenic) affecting population age structure are as follows.

(a) **Climate – missing year classes:** The success of many fish species is very dependent on weather at different critical times of the year. For southern species (especially cyprinids), warm weather during the reproductive and growing season is essential, whereas for northern species (especially salmonids), relatively low temperatures are favoured at these times. Thus common carp in northern parts of the UK are only able to breed successfully during warm summers, which allow the young to grow sufficiently to survive the winter. Typically, such northern populations have age classes missing for the cooler years.

(b) **Climate – successful year classes:** Le Cren (1958) and Le Cren *et al.* (1977) found that the numbers of perch hatched successfully in Windermere in 1959 was particularly large compared to the years before and after. This successful 1959 year-class dominated not only Windermere but many other British populations of perch for several years and could easily be distinguished in the age structure of the population. Often there are differences in the growth rate of year classes within a population and between-year fluctuations within populations may be largely the result of summer temperature differences. Le Cren (1958) found that some 66% of the variation in the yearly growth of perch in Windermere could be accounted for by temperatures above 14°C in the growing period.

(c) **Population size:** growth and stunting: Apart from temperature, other factors which were found to control the growth of Windermere perch include the negative effect of density. Craig (1980) has also suggested that the type of food available to fish is important and that perch achieved a faster growth from a diet of fish than from invertebrates. Other workers have stressed the role of intraspecific competition within strong year-classes and the effect of cannibalism (Persson 1983a, b).

(d) **Parasites and disease:** Diseases can cause massive changes to the age structure of fish populations. The perch population of Windermere, which has been studied for several decades, suffered a massive mortality in the 1970s (Bucke *et al.* 1979). It was estimated that more than 98% of the population (well over one million fish) were killed by '*perch disease*' which was specific to perch and no other species in the lake seemed to be affected. The causal agent was never fully identified and several year classes were almost eliminated at the time. Subsequently, the same disease took hold in other British lakes (eg Loch Leven) and caused massive mortalities.

(e) **Acidification:** One of the most characteristic effects of acidification on fish is the failure of recruitment of new age classes into the population (Harvey, 1982; Rosseland *et al*. 1980) This is manifest in an altered age structure and reduced population size, with decreased intra-specific competition for food and increased growth and/or condition of survivors. The average age and size of fish increases because there are lower numbers – mainly of larger, older fish. However, with no recruitment the stock eventually dies out. A good example of an intermediate stage in this sequence was found with brown trout and Arctic charr at Loch Doon (Maitland *et al*. 1991).

(f) **Pollution:** Serious pollution may completely eliminate a fish population, which, when it recovers, is likely to be dominated by young age classes. With short-lived fish (eg minnows and three-spined sticklebacks) this effect is likely to disappear within a few years. However with longer-lived species (eg perch and pike) the dominance by the first few age classes to be produced after pollution has gone may continue for a decade or more.

(g) **Migration barriers:** Temporary barriers to migration, whether natural or artificial, may prevent anadromous fish species from spawning in waters upstream of the barrier. Thus one or more age classes may be absent for the years when any barrier was effective.

(h) **Overexploitation:** The role of fisheries can also be important in influencing recruitment to a fish population. However, in this context, it should be noted that fisheries appear to be a special case for '*although fishing inevitably changes the abundance of the fish and shellfish species in a water body to some extent.' (SEPA 2002) '… what matters ecologically is that the changes in abundance do not*:

- *pose a risk to the viability of the exploited species by significantly reducing its ability to reproduce; or*
- *adversely affect the condition of other aquatic animals and plants which depend in some way upon the abundance of the exploited species.*

*If a fishery met these conditions, it would be compatible with 'high status.'*

The main conclusion from the above brief review is that, although studies of the age structure of fish populations can reveal much about the success or otherwise of previous year-classes, the results must be interpreted with caution and experience. In particular, it is important to distinguish between natural and human agents which could be responsible for any unusual features identified, and also to take into account the life expectancy of any species involved (Table 7).

## 6.8 Fish and surveillance monitoring

The detailed and accurate monitoring of fish populations is notoriously difficult and expensive to carry out, especially in large rivers and lakes. Considerable work on methodology, especially on non-destructive methods, is still required. It is clear that, whilst national statistics may be available for some species (eg Atlantic salmon) from catch data and fish counters, the number of waters for which regular and detailed population data could be available will be limited by resources. For this reason, relative data on numbers combined with information on age frequency may be the most attractive option to implement WFD criteria. Occasionally, it may be possible to monitor some species using water screening systems associated with public water supplies (Maitland 1985) or power stations (Maitland *et al*. 1980, 1984; Maitland 1998).

The main objectives defined by the WFD for monitoring programmes (SEPA 2002) are: (a) to check that the environmental risk assessments correctly identify all water bodies at risk of failing to achieve the WFD objectives, (b) to enable the status of those water bodies to be established, and (c) to assess the effectiveness of the measures taken to achieve the environmental objectives.

SEPA intends to review existing monitoring in Scotland and a preliminary assessment of fish monitoring, to which the author contributed (SEPA 2001), has already been carried out. It is planned to establish new monitoring networks by adapting and building on existing networks. Presumably any scheme developed will take into account the statement on common standards for monitoring designated sites, produced by JNCC (1997).

The pros and cons of assessing abundance as opposed to relative abundance must be carefully assessed before embarking on any long-term monitoring programme. In some situations, adequate quantitative data can be achieved for a reasonable amount of effort and the study of young salmonids in small streams or adult salmonids passing through fish counters are good examples. In other cases, notably the study of fish in large rivers or lakes, the effort required is disproportionate to the value of the data obtained and would be considered by many to be a waste of resources. Here, relative abundance using standard fishing effort should be enough to produce adequate data to make the required WFD assessments.

# 7 CONCLUSIONS

It is clear from the literature review of relevant studies of fish and fish habitat assessment methods that considerable research has been carried out in this field in a number of countries. Both physical (Bain *et al.* 1988) and chemical (Alabaster & Lloyd 1982; Fozzard *et al.* 1999) parameters have been used widely in developing various indices, as well as metrics from the fish populations themselves (Doledec *et al.* 1999; Angermeier *et al.* 2000). An important objective in such studies has been to obtain reliable information on the environmental requirements of fish (Mann 1996). Several studies have emphasised the importance of understanding the importance and role of alien fish species within native communities (Minckley & Deacon 1991; Gido & Brown 1999; Adams & Maitland 2001). There is a notable concentration on running rather than standing waters. However, it is clear that, even where different workers have found value in a particular index developed by other workers elsewhere, they have had to modify it to their own fish communities and types of water body. The Index of Biotic Integrity is one of the most widely explored indices, but one of the difficulties that workers trying to use it have found is the difficulty of applying it to waters where the fish species complex is very simple (Leonard & Orth 1986; Schrader 1989) – as in much of the north and west of the UK.

This would perhaps imply that, even within the UK, because of considerable geographic variation, there are difficulties. Thus the most useful approach to develop, in the first instance at least, is a simple, very broad-based system, which can be applied to any water or fish community. However, for each fresh water of importance, whatever system is adopted, it is essential that a database of reliable information is available, or established over future years, and that assessments are carried out by those with appropriate expertise.

One further review which could usefully be carried out to provide background data for the development of WFD objectives is a comprehensive analysis of the physical, chemical and biological requirements of all freshwater fish which occur in the UK. Although some work has been done in this direction for a few species (Maitland 1979; Ranta & Lindstrom 1990; Crisp 1996), much more is needed to provide a comprehensive review. Some of the necessary studies in this area have recently been initiated by the Environment Agency (Carvalho *et al.* 2002).

Although the literature offers several indices which are purported to be valuable tools for WFD assessments, in the initial years it seems unnecessary to introduce the use of complex metrics and indices when simpler methods may be applied to an already complex process, fraught with logistic difficulties and high staff requirements. Given agreement on typology and reference conditions for fish in each river basin (equivalent to one or a number of Hydrometric Areas), the basic information required to meet the requirements of the WFD is:

- Composition – a list of the species present in each water
- Abundance – the numbers, or relative numbers, in each water
- Age structure – the composition by age of the population of each species

However, as indicated above, in the development of sampling and monitoring methodologies, as well as collecting the minimum information to meet the above (number of species, number per unit area or effort, individual ages), it would be worth collecting additional basic information, from individual fish – notably length and weight, but also some measure of deformities, parasites and disease.

It is clear from this review that lack of adequate data on fish and fish habitat from a wide range of waters in the UK is a major stumbling block in the development and testing of useful WFD methodologies for assessing status and subsequently monitoring this. In addition, the wide differences in native fish communities in the UK, especially from north to south but to a lesser extent from east to west, make if difficult to produce a unified system for the two ecoregions concerned.

Some of the arguments in developing sophisticated systems for assessment require sequential decision making whereas at the moment, attempts are being made to develop everything at the same time (Owen *et al.* 2002). There is much proposed, ongoing and unpublished work developing various strands of the WFD requirements – for example, on fish assessment methods (NI-RoI Technical Advisory Group 2002) and systems for determining the ecological quality of rivers (McCavana 2002). An important issue to be resolved early on in the process is the typology of fresh waters. Here, experience and data from early work on synoptic limnology (Maitland 1979) should prove helpful. Once this has been done, the sequence might be:

(a) Produce lists of type-specific and of disturbance-sensitive species

(b) From the limited available data, test proposals for assessing status

(c) Modify proposals after tests

(d) Collect comprehensive data from relevant waters

(e) Test proposals further and finalise methodology

Such a sequence is very similar to that which took place in the development of SERCON, which has clearly much to offer to those producing assessment systems for the WFD. A revision of SERCON NA9 is proposed in this report together with modifications of the SERCON method as proposed WFD assessment tools.

As far as reference conditions are concerned, it would seem relatively straightforward to set these for fish in areas which have been relatively unaffected by human influences, especially the introduction of alien species. Such waters are found mainly in the north and west of the UK, especially the islands. Elsewhere, uncertainty of the natural distribution of species native to the UK makes assessment difficult and decisions must be made on this in order to take the subject of reference conditions forward as far as fish are concerned. There would appear to be four main options here:

- Accept the present distribution of UK native species as *'natural'* and only transfers outside this in the future as *'alien'*.
- Accept national (England, Northern Ireland, Scotland, Wales) boundaries (Table 2) as the limits for those species where it is fairly certain that they reached a new country through transfers by humans (eg grayling in Scotland).
- Accept a scheme which defines *'natural'* distribution by Hydrometric Area, based on the historic record and expert judgement.
- Accept the supposed natural distribution of stenohaline species as that believed to have occurred shortly after the last ice age, with every occurrence outside that boundary being *'alien'*.

None of these options is entirely satisfactory but the most reasonable would appear to be boundary definitions by Hydrometric Area or by country.

A valuable discussion on alien fish species and the WFD has been given by Rosell (2001) who notes that '*Throughout history, fish populations in Ireland have been affected by man-made introductions … and changes in water quality … It could be said that introductions have been the more important of these factors because, in Ireland, the native fauna is depauperate and successive introductions … must have had significant effects on the resident biota*.' He concludes that, since it will be impossible to return this lough to its pristine state, '*It will be much more practicable to set objectives for an assemblage of fish populations that reflects the current mix of species, their relative abundances and current patterns of exploitation*.'

The guidance given by SEPA (2002) to interpreting the WFD makes it clear that reference conditions must represent a state of '*no, or only very minor*' changes to a water body's quality elements as a result of human activities. '*The provision to accommodate minor changes is important. Water bodies do not have to be restored to their reference conditions*'. Later, the guidance states that '*Introductions of plant and animal species can also change pristine conditions. However, where introductions have become established without causing ecologically significant changes to the native plants and animals, it would seem appropriate to regard them as a minor impact. If not, achieving good ecological status could become impractical because of the enormous difficulty in removing species once they have become established*.' Apart from the fact that there have been very few studies examining the impact of introductions (Adams & Maitland 2001), this would seem to be a case of '*bending the rules*' to avoid an admission that many waters in the UK will fail to achieve good status because of the extensive introductions which have taken place to date. For example, we know that the introduction of ruffe to Loch Lomond has caused major '*ecologically significant changes*' there (Adams & Maitland 1998). Thus, even with the above relaxed interpretation of the WFD, this means that Loch Lomond can never achieve good status. For most waters with alien species we have no such data.

Finally, the importance of setting realistic fish community objectives for each water must be given serious consideration. These will '*…define objectives for the structure and function of the … fish community, and identify environmental and other issues that have the potential to prevent achievement of these objectives*.' (Eshenroder *et al.* 1995). They will also help to define a unified objective for the many management activities occurring within the catchment and thus bring together those managing and those using the resource.

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# 10 TABLES

**Table 1 Check list of UK freshwater fish.**

| COMMON NAME | SCIENTIFIC NAME |
|---|---|
| River lamprey | *Lampetra fluviatilis* (Linnaeus 1758) |
| Brook lamprey | *Lampetra planeri* (Bloch 1784) |
| Sea lamprey | *Petromyzon marinus* Linnaeus 1758 |
| Common sturgeon | *Acipenser sturio* Linnaeus 1758 |
| Eel | *Anguilla anguilla* (Linnaeus 1758) |
| Allis shad | *Alosa alosa* (Linnaeus 1758) |
| Twaite shad | *Alosa fallax* (Lacepede 1803) |
| Silver bream | *Abramis bjoerkna* (Linnaeus 1758) |
| Common bream | *Abramis brama* (Linnaeus 1758) |
| Bleak | *Alburnus alburnus* (Linnaeus 1758) |
| Barbel | *Barbus barbus* (Linnaeus 1758) |
| Goldfish* | *Carassius auratus* (Linnaeus 1758) |
| Crucian carp* | *Carassius carassius* (Linnaeus 1758) |
| Common carp* | *Cyprinus carpio* Linnaeus 1758 |
| Gudgeon | *Gobio gobio* (Linnaeus 1758) |
| Sunbleak* | *Leucaspius delineatus* (Heckel 1843) |
| Chub | *Leuciscus cephalus* (Linnaeus 1758) |
| Orfe* | *Leuciscus idus* (Linnaeus 1758) |
| Dace | *Leuciscus leuciscus* (Linnaeus 1758) |
| Minnow | *Phoxinus phoxinus* (Linnaeus 1758) |
| False harlequin* | *Pseudorasbora parva* (Temminck & Schlegel 1842) |
| Bitterling* | *Rhodeus sericeus* (Bloch 1782) |
| Roach | *Rutilus rutilus* (Linnaeus 1758) |
| Rudd | *Scardinius erythrophthalmus* (Linnaeus 1758) |
| Tench | *Tinca tinca* (Linnaeus 1758) |
| Spined loach | *Cobitis taenia* Linnaeus 1758 |
| Stone loach | *Barbatula barbatula* (Linnaeus 1758) |
| Black bullhead* | *Ameiurus melas* (Rafinesque 1820) |
| Wels catfish* | *Silurus glanis* Linnaeus 1758 |
| Pike | *Esox lucius* Linnaeus 1758 |
| Smelt | *Osmerus eperlanus* (Linnaeus 1758) |
| Vendace | *Coregonus albula* (Linnaeus 1758) |
| Pollan | *Coregonus autumnalis* (Pallas 1776) |

**Table 1** *(continued)*

| COMMON NAME | SCIENTIFIC NAME |
|---|---|
| Powan | Coregonus lavaretus (Linnaeus 1758) |
| Houting | Coregonus oxyrinchus (Linnaeus 1758) |
| Rainbow trout* | *Oncorhynchus mykiss* (Walbaum 1792) |
| Atlantic salmon | *Salmo salar* Linnaeus 1758 |
| Brown trout | *Salmo trutta* Linnaeus 1758 |
| Arctic charr | *Salvelinus alpinus* (Linnaeus 1758) |
| Brook charr* | *Salvelinus fontinalis* (Mitchill 1814) |
| Grayling | *Thymallus thymallus* (Linnaeus 1758) |
| Burbot | *Lota lota* (Linnaeus 1758) |
| Thick-lipped grey mullet | *Chelon labrosus* Risso 1826 |
| Golden grey mullet | *Liza aurata* (Risso 1810) |
| Thin-lipped grey mullet | *Liza ramada* (Risso 1826) |
| Three-spined stickleback | *Gasterosteus aculeatus* Linnaeus 1758 |
| Nine-spined stickleback | *Pungitius pungitius* (Linnaeus 1758) |
| Bullhead | *Cottus gobio* Linnaeus 1758 |
| Sea bass | *Dicentrarchus labrax* (Linnaeus 1758) |
| Rock bass* | *Ambloplites rupestris* (Rafinesque 1817) |
| Pumpkinseed* | *Lepomis gibbosus* (Linnaeus 1758) |
| Largemouth bass* | *Micropterus salmoides* (Lacepede 1802) |
| Ruffe | *Gymnocephalus cernuus* (Linnaeus 1758) |
| Perch | *Perca fluviatilis* Linnaeus 1758 |
| Pikeperch* | *Sander lucioperca* (Linnaeus 1758) |
| Common goby | *Pomatoschistus microps* (Kroyer 1838) |
| Flounder | *Platichthys flesus* (Linnaeus 1758) |

***Note:*** those marked * are regarded as aliens.

**Table 2 An assessment of which freshwater fish species are native (+) or alien (–) to each UK country**

| | ENGLAND | WALES | SCOTLAND | N IRELAND |
|---|---|---|---|---|
| River lamprey | + | + | + | + |
| Brook lamprey | + | + | + | + |
| Sea lamprey | + | + | + | + |
| Common sturgeon | + | + | + | + |
| Eel | + | + | + | + |
| Allis shad | + | + | + | + |
| Twaite shad | + | + | + | + |
| Silver bream | + | – | – | – |
| Common bream | + | – | – | – |
| Bleak | + | – | – | – |
| Barbel | + | – | – | – |
| Goldfish | – | – | – | – |
| Crucian carp | – | – | – | – |
| Common carp | – | – | – | – |
| Gudgeon | + | – | – | – |
| Sunbleak | – | – | – | – |
| Chub | + | – | – | – |
| Orfe | – | – | – | – |
| Dace | – | – | – | – |
| Minnow | + | + | + | + |
| False harlequin | – | – | – | – |
| Bitterling | – | – | – | – |
| Roach | + | + | + | – |
| Rudd | + | + | – | – |
| Tench | + | – | – | – |
| Spined loach | + | – | – | – |
| Stone loach | + | + | + | – |
| Black bullhead | – | – | – | – |
| Wels catfish | – | – | – | – |
| Pike | + | + | + | + |
| Smelt | + | + | + | + |
| Vendace | + | – | + | – |
| Pollan | – | – | – | + |
| Powan | + | + | + | – |
| Houting | + | – | – | – |

**Table 2** *(continued)*

| | ENGLAND | WALES | SCOTLAND | N IRELAND |
|---|---|---|---|---|
| Rainbow trout | – | – | – | – |
| Atlantic salmon | + | + | + | + |
| Brown trout | + | + | + | + |
| Arctic charr | + | + | + | + |
| Brook charr | – | – | – | – |
| Grayling | + | + | – | – |
| Burbot | + | – | – | – |
| Thick-lipped grey mullet | + | + | + | + |
| Golden grey mullet | + | + | + | + |
| Thin-lipped grey mullet | + | + | + | + |
| Three-spined stickleback | + | + | + | + |
| Nine-spined stickleback | + | + | + | + |
| Bullhead | + | + | – | – |
| Sea bass | + | + | + | + |
| Rock bass | – | – | – | – |
| Pumpkinseed | – | – | – | – |
| Largemouth bass | – | – | – | – |
| Ruffe | + | – | – | – |
| Perch | + | + | + | + |
| Pikeperch | – | – | – | – |
| Common goby | + | + | + | + |
| Flounder | + | + | + | + |
| | | | | |
| **TOTAL NATIVE SPECIES** | **40** | **27** | **26** | **23** |

**Table 3 The occurrence of freshwater fish within the main habitat types in the British Isles**

| | RIVER (LOTIC) | RIVER (LENTIC) | TRANSITIONAL (ESTUARINE) | LAKE |
|---|---|---|---|---|
| River lamprey | + | ++ | + | + |
| Brook lamprey | ++ | ++ | – | + |
| Sea lamprey | + | ++ | + | + |
| Common sturgeon | – | – | ++ | – |
| Eel | ++ | ++ | ++ | ++ |
| Allis shad | + | ++ | +++ | – |
| Twaite shad | + | ++ | +++ | + |
| Silver bream | – | ++ | – | ++ |
| Common bream | – | ++ | – | ++ |
| Bleak | – | ++ | – | + |
| Barbel | ++ | ++ | – | – |
| Goldfish | – | + | – | ++ |
| Crucian carp | – | ++ | – | ++ |
| Common carp | – | ++ | – | ++ |
| Gudgeon | ++ | ++ | – | + |
| Sunbleak | – | ++ | – | ++ |
| Chub | ++ | ++ | – | + |
| Orfe | ++ | ++ | – | ++ |
| Dace | ++ | ++ | – | + |
| Minnow | ++ | ++ | – | ++ |
| False harlequin | – | ++ | – | ++ |
| Bitterling | – | ++ | – | ++ |
| Roach | – | ++ | – | ++ |
| Rudd | – | ++ | – | ++ |
| Tench | – | ++ | – | ++ |
| Spined loach | – | ++ | – | – |
| Stone loach | ++ | + | – | + |
| Black bullhead | – | + | – | ++ |
| Wels catfish | – | + | – | ++ |
| Pike | – | ++ | – | ++ |
| Sparling | – | – | ++ | – |
| Vendace | – | – | – | ++ |
| Pollan | – | – | – | ++ |
| Powan | – | – | – | ++ |
| Houting | – | – | ++ | – |

**Table 3** *(continued)*

| | RIVER (LOTIC) | RIVER (LENTIC) | TRANSITIONAL (ESTUARINE) | LAKE |
|---|---|---|---|---|
| Rainbow trout | – | + | – | ++ |
| Atlantic salmon | ++ | + | + | + |
| Brown trout | ++ | + | + | ++ |
| Arctic charr | – | – | – | ++ |
| Brook charr | ++ | + | – | + |
| Grayling | ++ | + | – | – |
| Burbot | – | ++ | – | + |
| Thick-lipped grey mullet | – | – | ++ | – |
| Golden grey mullet | – | – | ++ | – |
| Thin-lipped grey mullet | – | – | ++ | – |
| Three-spined stickleback | – | ++ | + | ++ |
| Nine-spined stickleback | – | ++ | + | ++ |
| Bullhead | ++ | + | – | – |
| Sea bass | – | – | ++ | – |
| Rock bass | – | + | – | ++ |
| Pumpkinseed | – | + | – | ++ |
| Largemouth bass | – | + | – | ++ |
| Ruffe | – | ++ | – | ++ |
| Perch | – | ++ | – | ++ |
| Pikeperch | – | ++ | – | ++ |
| Common goby | – | – | ++ | – |
| Flounder | – | + | ++ | + |
| | | | | |
| **TOTAL SPECIES** | **18** | **44** | **18** | **42** |

***Note:*** ++ = favoured habitat; + = less favoured habitat; – rarely occurs here.

**Table 4 Details of the area, the numbers of lakes and the numbers of river systems and streams (after Smith & Lyle 1979) in each Hydrometric Area in the UK**

| NO | NAME | AREA (km²) | NO OF LAKES (Area km²) | | | NO BY STREAM ORDER Systems | | Streams | |
|---|---|---|---|---|---|---|---|---|---|
| | | | <1 | 1–4 | >4 | 1–2 | 3–5 | 1–2 | 3–5 |
| 1. | Wicks Gp | 877 | 18 | 1 | 0 | 7 | 4 | 60 | 6 |
| 2. | Helmsdale Gp | 1372 | 48 | 6 | 0 | 6 | 4 | 111 | 6 |
| 3. | Shin Gp | 1909 | 70 | 6 | 1 | 10 | 3 | 181 | 11 |
| 4. | Conon Gp | 2173 | 76 | 7 | 5 | 6 | 3 | 99 | 5 |
| 5. | Beauly | 1075 | 43 | 2 | 3 | 2 | 1 | 46 | 4 |
| 6. | Ness | 1993 | 75 | 5 | 6 | 0 | 1 | 74 | 4 |
| 7. | Findhorn Gp | 1821 | 28 | 1 | 1 | 3 | 2 | 59 | 4 |
| 8. | Spey | 2988 | 34 | 3 | 0 | 0 | 1 | 88 | 6 |
| 9. | Deveron Gp | 1454 | 0 | 0 | 0 | 7 | 1 | 30 | 1 |
| 10. | Ythan Gp | 1415 | 8 | 1 | 0 | 9 | 1 | 32 | 1 |
| 11. | Don (Grampian) | 1336 | 0 | 0 | 0 | 0 | 1 | 26 | 1 |
| 12. | Dee (Grampian) | 2117 | 16 | 2 | 0 | 0 | 1 | 53 | 3 |
| 13. | Esk Gp | 2027 | 15 | 0 | 0 | 8 | 2 | 46 | 4 |
| 14. | Firth of Tay Gp | 1070 | 10 | 0 | 0 | 9 | 0 | 15 | 0 |
| 15. | Tay | 5081 | 83 | 9 | 6 | 0 | 1 | 150 | 9 |
| 16. | Earn | 976 | 12 | 2 | 1 | 0 | 1 | 23 | 1 |
| 17. | Firth of Forth Gp | 1444 | 47 | 1 | 1 | 8 | 1 | 19 | 1 |
| 18. | Forth | 1627 | 30 | 6 | 2 | 3 | 1 | 46 | 5 |
| 19. | Almond Gp | 915 | 18 | 3 | 0 | 1 | 2 | 16 | 2 |
| 20. | Tyne (Lothian) Gp | 673 | 5 | 0 | 0 | 4 | 0 | 9 | 0 |
| 21. | Tweed | 6366 | 15 | 3 | 0 | 3 | 2 | 116 | 12 |
| 22. | Coquet Gp | 2052 | 19 | 0 | 0 | 8 | 3 | 52 | 3 |
| 23. | Tyne (Northumberland) | 2916 | 19 | 0 | 1 | 0 | 1 | 86 | 4 |
| 24. | Wear | 1197 | 7 | 0 | 0 | 1 | 1 | 32 | 1 |
| 25. | Tees Gp | 2238 | 17 | 1 | 0 | 9 | 1 | 82 | 3 |
| 26. | Hull Gp | 2125 | 9 | 0 | 0 | 9 | 3 | 51 | 3 |
| 27. | Ouse (Yorkshire) | 11366 | 158 | 0 | 0 | 6 | 5 | 309 | 25 |
| 28. | Trent | 10436 | 128 | 5 | 0 | 2 | 1 | 104 | 9 |
| 29. | Ancholme Gp | 1905 | 17 | 0 | 0 | 14 | 0 | 31 | 0 |
| 30. | Witham & Steeping | 3366 | 25 | 0 | 0 | 1 | 1 | 24 | 1 |
| 31. | Welland | 1601 | 16 | 1 | 0 | 0 | 1 | 19 | 3 |
| 32. | Nene | 2369 | 42 | 1 | 0 | 0 | 1 | 24 | 1 |
| 33. | Great Ouse | 8582 | 65 | 0 | 1 | 2 | 1 | 72 | 6 |

**Table 4** *(continued)*

| NO | NAME | AREA ($km^2$) | NO OF LAKES (Area $km^2$) | | | NO BY STREAM ORDER Systems | | Streams | |
|---|---|---|---|---|---|---|---|---|---|
| | | | <1 | 1–4 | >4 | 1–2 | 3–5 | 1–2 | 3–5 |
| 34. | Norfolk Rivers Gp | 3694 | 52 | 0 | 0 | 4 | 3 | 46 | 3 |
| 35. | East Suffolk Rivers | 1600 | 4 | 0 | 0 | 13 | 0 | 20 | 0 |
| 36. | Stour (Essex & Suffolk) | 1043 | 2 | 0 | 0 | 1 | 1 | 10 | 1 |
| 37. | Essex Rivers Gp | 3149 | 28 | 1 | 1 | 15 | 2 | 62 | 2 |
| 38. | Lee | 1419 | 32 | 1 | 0 | 0 | 1 | 23 | 1 |
| 39. | Thames | 10942 | 192 | 4 | 0 | 0 | 2 | 170 | 10 |
| 40. | Kent Rivers Gp | 4784 | 72 | 1 | 0 | 6 | 4 | 147 | 11 |
| 41. | Sussex Rivers Gp | 3086 | 39 | 0 | 0 | 7 | 5 | 134 | 11 |
| 42. | Hampshire Rivers Gp | 2735 | 21 | 0 | 0 | 20 | 1 | 40 | 1 |
| 43. | Avon and Stour | 2974 | 12 | 0 | 0 | 1 | 2 | 69 | 5 |
| 44. | Frome Gp | 1324 | 11 | 0 | 0 | 8 | 2 | 41 | 2 |
| 45. | Exe Gp | 2253 | 4 | 0 | 0 | 6 | 3 | 109 | 6 |
| 46. | Dart Gp | 1512 | 10 | 0 | 0 | 9 | 2 | 79 | 2 |
| 47. | Tamar Gp | 1820 | 6 | 0 | 0 | 10 | 2 | 91 | 5 |
| 48. | Fal Gp | 1559 | 14 | 1 | 0 | 40 | 2 | 76 | 2 |
| 49. | Camel Gp | 1249 | 4 | 0 | 0 | 25 | 1 | 73 | 1 |
| 50. | Taw & Torridge | 2146 | 6 | 0 | 0 | 6 | 2 | 106 | 7 |
| 51. | East Lyn Gp | 528 | 3 | 0 | 0 | 9 | 1 | 27 | 1 |
| 52. | Somerset Rivers Gp | 2761 | 16 | 1 | 0 | 11 | 3 | 127 | 7 |
| 53. | Avon (Bristol) | 2220 | 10 | 0 | 1 | 1 | 1 | 32 | 1 |
| 54. | Severn | 11421 | 108 | 2 | 1 | 10 | 2 | 186 | 11 |
| 55. | Wye (Hereford) | 41184 | 16 | 3 | 0 | 1 | 1 | 117 | 6 |
| 56. | Usk | 1741 | 12 | 3 | 0 | 4 | 1 | 51 | 3 |
| 57. | Taff (Glamorgan) Gp | 926 | 14 | 1 | 0 | 2 | 1 | 26 | 1 |
| 58. | Mid Glamorgan Gp | 1028 | 7 | 0 | 0 | 6 | 2 | 44 | 2 |
| 59. | Loughor Gp | 861 | 10 | 0 | 0 | 8 | 2 | 32 | 2 |
| 60. | Towy | 2048 | 6 | 1 | 0 | 7 | 2 | 86 | 7 |
| 61. | Cleddau Gp | 1481 | 7 | 1 | 0 | 25 | 2 | 53 | 2 |
| 62. | Teifi | 1027 | 8 | 0 | 0 | 0 | 3 | 41 | 1 |
| 63. | Ystwyth Gp | 846 | 23 | 1 | 0 | 10 | 1 | 29 | 1 |
| 64. | Dyfi Gp | 1343 | 19 | 0 | 0 | 8 | 3 | 66 | 5 |
| 65. | Glasslyn Gp | 1317 | 33 | 0 | 1 | 14 | 1 | 51 | 1 |
| 66. | Conway & Clwyd | 1503 | 27 | 0 | 0 | 3 | 2 | 49 | 4 |
| 67. | Dee (Cheshire) | 2117 | 23 | 2 | 1 | 1 | 1 | 48 | 4 |

**Table 4** *(continued)*

| NO | NAME | AREA (km²) | NO OF LAKES (Area km²) | | | NO BY STREAM ORDER Systems | | Streams | |
|---|---|---|---|---|---|---|---|---|---|
| | | | <1 | 1–4 | >4 | 1–2 | 3–5 | 1–2 | 3–5 |
| 68. | Cheshire Rivers Gp | 1886 | 4 | 0 | 0 | 4 | 1 | 38 | 3 |
| 69. | Mersey & Irwell | 2687 | 93 | 0 | 0 | 3 | 1 | 55 | 5 |
| 70. | Douglas Gp | 618 | 13 | 0 | 0 | 2 | 0 | 8 | 0 |
| 71. | Ribble | 1488 | 35 | 1 | 0 | 0 | 1 | 46 | 5 |
| 72. | Wyre & Lune | 1648 | 13 | 0 | 0 | 3 | 2 | 61 | 5 |
| 73. | Kent Gp | 1202 | 29 | 1 | 2 | 4 | 2 | 26 | 2 |
| 74. | Esk (Cumbria) Gp | 914 | 11 | 0 | 2 | 10 | 0 | 27 | 0 |
| 75. | Derwent (Cumbria) Gp | 1219 | 9 | 3 | 2 | 4 | 1 | 34 | 1 |
| 76. | Eden (Cumbria) | 2397 | 15 | 1 | 1 | 0 | 1 | 69 | 5 |
| 77. | Esk (Dumfries) | 1363 | 2 | 0 | 0 | 2 | 1 | 45 | 1 |
| 78. | Annan | 960 | 9 | 0 | 0 | 0 | 1 | 26 | 1 |
| 79. | Nith | 1480 | 14 | 0 | 0 | 2 | 1 | 36 | 1 |
| 80. | Dee (Galloway) | 1527 | 37 | 1 | 2 | 6 | 2 | 53 | 4 |
| 81. | Cree Gp | 2047 | 42 | 0 | 0 | 15 | 2 | 52 | 2 |
| 82. | Doon Gp | 1078 | 27 | 0 | 1 | 1 | 3 | 36 | 3 |
| 83. | Irvine & Ayr | 1515 | 26 | 0 | 0 | 6 | 3 | 60 | 5 |
| 84. | Clyde | 3040 | 85 | 3 | 0 | 1 | 3 | 84 | 5 |
| 85. | Leven (Strathclyde) | 814 | 17 | 2 | 0 | 2 | 1 | 50 | 4 |
| 86. | Firth of Clyde Gp | 861 | 26 | 1 | 1 | 25 | 2 | 52 | 2 |
| 87. | Fyne Gp | 720 | 17 | 2 | 0 | 19 | 2 | 72 | 2 |
| 88. | Add Gp | 808 | 73 | 2 | 0 | 15 | 2 | 74 | 2 |
| 89. | Awe and Etive | 1391 | 53 | 3 | 0 | 10 | 1 | 70 | 3 |
| 90. | Loch Linnhe Gp | 1177 | 37 | 1 | 1 | 25 | 1 | 60 | 1 |
| 91. | Lochy (Highlands) | 1327 | 26 | 3 | 4 | 0 | 1 | 52 | 3 |
| 92. | Loch Shiel Gp | 1153 | 53 | 2 | 1 | 30 | 2 | 88 | 2 |
| 93. | Loch Alsh Gp | 1679 | 84 | 2 | 1 | 33 | 2 | 77 | 2 |
| 94. | Loch Maree Gp | 1061 | 101 | 8 | 1 | 25 | 2 | 84 | 2 |
| 95. | Laxford Gp | 2196 | 380 | 15 | 3 | 45 | 9 | 226 | 9 |
| 96. | Naver Gp | 1958 | 189 | 4 | 3 | 25 | 5 | 167 | 9 |
| 97. | Thurso Gp | 912 | 52 | 2 | 0 | 9 | 1 | 51 | 3 |
| 101. | Isle of Wight | 381 | 1 | 0 | 0 | 9 | 0 | 12 | 0 |
| 102. | Anglesey | 714 | 17 | 1 | 0 | 13 | 0 | 27 | 0 |
| 103. | Isle of Man | 572 | 4 | 0 | 0 | 7 | 1 | 23 | 1 |
| 104. | Kintyre Gp | 2163 | 126 | 2 | 0 | 79 | 1 | 197 | 1 |

**Table 4** *(continued)*

| NO | NAME | AREA (km$^2$) | NO OF LAKES (Area km$^2$) | | | NO BY STREAM ORDER Systems | | Streams | |
|---|---|---|---|---|---|---|---|---|---|
| | | | <1 | 1–4 | >4 | 1–2 | 3–5 | 1–2 | 3–5 |
| 105. | Inner Hebrides | 2508 | 142 | 3 | 1 | 113 | 1 | 194 | 1 |
| 106. | Outer Hebrides | 2733 | 1067 | 16 | 3 | 127 | 5 | 182 | 5 |
| 107. | Orkneys | 698 | 41 | 5 | 2 | 11 | 0 | 13 | 0 |
| 108. | Shetlands | 1279 | 193 | 2 | 0 | 147 | 4 | 294 | 4 |

| NO | NAME | AREA (km$^2$) | NO OF LAKES (Area km$^2$) | | | NO BY STREAM ORDER Systems | | Streams | |
|---|---|---|---|---|---|---|---|---|---|
| | | | <1 | 1–4 | >4 | 1–2 | 3–5 | 1–2 | 3–5 |
| 1. | Foyle* | 2840 | | | | | | | |
| 2. | Faughan-Roc | 891 | | | | | | | |
| 3. | Bann* | 5732 | | | | | | | |
| 4. | Bush | 925 | | | | | | | |
| 5. | Lagan-Quoile | 1966 | | | | | | | |
| 6. | Newry-Dee | 909 | | | | | | | |
| 26. | Shannon, Upper | 6 | | | | | | | |
| 35. | Drowes | 110 | | | | | | | |
| 36. | Erne* | 4202 | | | | | | | |
| 39. | Skeoge | 16 | | | | | | | |
| 40. | Lough Foyle | 6 | | | | | | | |

***Note:*** No equivalent data on the numbers of lakes and streams in Ireland were available for this report.

**Table 5 Occurrence of fish species in Hydrometric Areas, organised mainly by country in the UK**

| **Explanatory Key:** |
|---|
| LL = Native, found in both lentic and lotic habitats |
| Le = Native, found mainly in lentic habitats |
| Lo = Native, found mainly in lotic habitats |
| A = Alien species, originating from outside the UK |
| At = Alien species translocated from elsewhere in the UK |
| As = Alien species maintained by stocking |
| Tr = Occurring mainly in transitional or coastal waters |
| ~ = Not recorded |

**Table 5a Fish species by Hydrometric Area – mainly Scotland East**

| FISH SPECIES | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 107 | 108 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| River lamprey | ~ | ~ | ~ | LL | ~ | ~ | ~ | LL | LL | ~ | LL | ~ | LL | LL | LL | LL | LL | LL | LL | LL | LL | ~ | ~ |
| Brook lamprey | ~ | ~ | ~ | LL | ~ | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | ~ | ~ |
| Sea lamprey | ~ | ~ | ~ | LL | ~ | ~ | ~ | LL | LL | ~ | ~ | LL | LL | LL | LL | LL | LL | LL | ~ | ~ | LL | ~ | ~ |
| Common sturgeon | ~ | ~ | Tr | Tr | ~ | Tr | ~ | ~ | Tr | Tr | ~ | ~ | Tr | ~ | Tr | ~ | ~ | Tr | Tr | Tr | Tr | ~ | ~ |
| Eel | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL |
| Allis shad | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | Tr | Tr | Tr | Tr | Tr | Tr | ~ | Tr | ~ | Tr |
| Twaite shad | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | Tr | ~ | ~ | ~ | ~ | Tr | ~ | Tr | ~ | Tr | ~ | ~ | Tr | ~ | Tr |
| Silver bream | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Common bream | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Bleak | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Barbel | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Goldfish | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Crucian carp | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | A | ~ | ~ | ~ | ~ | A | ~ | ~ | ~ | ~ | ~ | A | ~ | ~ |
| Common carp | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | A | ~ | ~ | ~ | ~ | ~ | A | ~ | ~ | ~ | A | A | ~ | ~ |
| Gudgeon | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | At | ~ | ~ | At | ~ | ~ | ~ | ~ | ~ | ~ | At | ~ | ~ |
| Sunbleak | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Chub | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Orfe | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | A | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Dace | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | At | ~ | ~ | At | ~ | ~ |
| Minnow | ~ | ~ | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | ~ | ~ |
| False harlequin | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Bitterling | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Roach | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | Le | ~ | ~ | ~ | Le | Le | Le | Le | Le | Le | Le | Le | Le | ~ | ~ |
| Rudd | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Tench | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | At | ~ | ~ | ~ | At | At | At | ~ | ~ | At | At | At | ~ | ~ |
| Spined loach | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Stone loach | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | At | ~ |
| Black bullhead | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Wels catfish | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Pike | ~ | ~ | ~ | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | ~ | ~ |
| Smelt | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | Tr | Tr | ~ | Tr | Tr | Tr | ~ | ~ | ~ | ~ |
| Vendace | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Pollan | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Powan | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Houting | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |

**Table 5a** *(continued)*

| FISH SPECIES | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 107 | 108 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rainbow trout | As | As | As | As | As | As | As | As | As | As | As | As | As | As | As | As | As | As | As | As | As | As | As |
| Atlantic salmon | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo |
| Brown trout | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo |
| Arctic charr | ~ | La | La | La | La | La | La | La | ~ | ~ | ~ | La | La | ~ | La | La | La | La | ~ | ~ | La | La | La |
| Brook charr | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | A | A | A | ~ | A | ~ | ~ | ~ | ~ | ~ |
| Grayling | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | At | At | At | At | At | ~ | At | ~ | ~ |
| Burbot | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Thick-lipped grey mullet | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | Tr | ~ | Tr | Tr | ~ | Tr | ~ | ~ | ~ | ~ |
| Golden grey mullet | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Thin-lipped grey mullet | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| 3-spined stickleback | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL |
| 9-spined stickleback | ~ | ~ | ~ | LL | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | LL | LL | ~ | ~ | ~ | ~ |
| Bullhead | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | At | ~ | At | ~ | At | ~ | ~ |
| Sea bass | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | Tr | ~ | ~ | ~ | Tr | ~ | Tr | Tr | Tr | Tr | Tr | Tr | ~ | ~ |
| Rock bass | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Pumpkinseed | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Largemouth bass | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Ruffe | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Perch | ~ | ~ | ~ | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | ~ | ~ |
| Pikeperch | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Common goby | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | Tr | Tr | Tr | Tr | Tr | Tr | Tr | Tr | Tr | ~ | ~ |
| Flounder | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL |

**Table 5b Fish species by Hydrometric Area – mainly Scotland West**

| FISH SPECIES | 77 | 78 | 79 | 80 | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 | 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 104 | 105 | 106 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| River lamprey | LL | LL | LL | ~ | LL | ~ | LL | LL | LL | ~ | ~ | ~ | ~ | ~ | ~ | LL | ~ | ~ | ~ | ~ | ~ | LL | ~ | ~ |
| Brook lamprey | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | ~ | ~ | ~ | LL | ~ | ~ | ~ | ~ | ~ | LL | ~ |
| Sea lamprey | LL | LL | LL | LL | LL | LL | ~ | LL | LL | LL | LL | LL | LL | LL | LL | ~ | ~ | ~ | LL | ~ | ~ | ~ | ~ | ~ |
| Common sturgeon | ~ | Tr | Tr | ~ | ~ | ~ | ~ | ~ | Tr | Tr | Tr | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | Tr | ~ | Tr |
| Eel | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL |
| Allis shad | Tr | Tr | Tr | Tr | Tr | Tr | ~ | ~ | ~ | ~ | ~ | ~ | ~ | Tr | ~ | Tr | ~ | ~ | ~ | ~ | ~ | ~ | Tr | ~ |
| Twaite shad | Tr | Tr | Tr | Tr | Tr | Tr | ~ | ~ | ~ | ~ | Tr | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Silver bream | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Common bream | ~ | At | ~ | ~ | ~ | ~ | ~ | At | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Bleak | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Barbel | ~ | ~ | ~ | ~ | ~ | ~ | ~ | At | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Goldfish | ~ | ~ | ~ | ~ | ~ | ~ | ~ | A | ~ | A | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Crucian carp | ~ | ~ | ~ | ~ | A | ~ | ~ | A | A | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Common carp | A | A | ~ | A | A | ~ | ~ | A | A | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Gudgeon | ~ | At | At | ~ | At | ~ | At | At | At | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Sunbleak | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Chub | At | At | ~ | ~ | At | ~ | ~ | At | At | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Orfe | ~ | A | ~ | ~ | ~ | ~ | ~ | A | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Dace | ~ | ~ | ~ | At | ~ | ~ | ~ | At | At | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Minnow | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | ~ | ~ |
| False harlequin | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Bitterling | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Roach | Le | Le | Le | Le | Le | ~ | Le | Le | Le | ~ | Le | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Rudd | ~ | At | ~ | At | At | At | ~ | At | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Tench | At | At | At | At | At | At | ~ | At | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Spined loach | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Stone loach | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | ~ | ~ | ~ | ~ | ~ | Lo | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Black bullhead | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Wels catfish | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Pike | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Smelt | Tr | Tr | Tr | Tr | LL | Tr | Tr | Tr | Tr | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Vendace | ~ | La | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Pollan | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Powan | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | La | La | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Houting | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |

**Table 5b** *(continued)*

| FISH SPECIES | 77 | 78 | 79 | 80 | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 | 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 104 | 105 | 106 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rainbow trout | As | As | As | As | As | As | As | As | As | As | As | As | As | As | As | As | As | As | As | As | As | As | ~ | As |
| Atlantic salmon | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo |
| Brown trout | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL |
| Arctic charr | ~ | ~ | ~ | La | La | La | ~ | ~ | ~ | La | La | La | La | La | La | La | La | La | La | La | La | La | La | La |
| Brook charr | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Grayling | ~ | At | At | ~ | ~ | ~ | At | At | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Burbot | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Thick-lipped grey mullet | Tr | ~ | ~ | Tr | Tr | Tr | ~ | Tr | Tr | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Golden grey mullet | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Thin-lipped grey mullet | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| 3-spined stickleback | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL |
| 9-spined stickleback | ~ | ~ | LL | ~ | LL | ~ | ~ | LL | LL | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | LL | LL | LL |
| Bullhead | ~ | ~ | ~ | ~ | ~ | ~ | ~ | At | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Sea bass | Tr | ~ | ~ | Tr | Tr | ~ | ~ | Tr | Tr | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | Tr | ~ | ~ | ~ | ~ |
| Rock bass | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Pumpkinseed | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Largemouth bass | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Ruffe | ~ | ~ | ~ | ~ | ~ | ~ | ~ | At | At | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Perch | Le | Le | Le | Le | Le | Le | Le | Le | Le | ~ | ~ | ~ | Le | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | Le | ~ | ~ |
| Pikeperch | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Common goby | ~ | Tr | ~ | ~ | Tr | ~ | ~ | Tr | Tr | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | Tr | ~ | Tr |
| Flounder | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | ~ | LL | LL | ~ | LL | LL | LL | LL | LL | LL |

**Table 5c Fish species by Hydrometric Area – mainly England East**

| FISH SPECIES | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| River lamprey | LL | ~ | LL | LL | ~ | LL | LL | LL | LL | LL | LL | LL | LL | LL | ~ | LL | ~ | LL | LL | LL | LL | LL |
| Brook lamprey | LL | LL | LL | LL | ~ | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL |
| Sea lamprey | LL | LL | LL | LL | ~ | LL | ~ | ~ | ~ | ~ | ~ | ~ | LL | LL | LL | LL | ~ | LL | ~ | ~ | LL | ~ |
| Common sturgeon | ~ | ~ | Tr | ~ | ~ | ~ | Tr | ~ | ~ | ~ | Tr | Tr | Tr | Tr | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Eel | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL |
| Allis shad | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | Tr | ~ | ~ | ~ | ~ | Tr | ~ |
| Twaite shad | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | Tr | Tr | ~ | Tr | ~ | ~ | ~ | Tr | Tr | Tr |
| Silver bream | ~ | ~ | ~ | ~ | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | ~ | Le |
| Common bream | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le |
| Bleak | ~ | ~ | ~ | ~ | Le | Le | Le | Le | Le | Le | Le | Le | ~ | ~ | ~ | Le | Le | Le | Le | Le | Le | Le |
| Barbel | ~ | Lo | Lo | Lo | Lo | Lo | Lo | ~ | Lo | Lo | Lo | Lo | Lo | ~ | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo |
| Goldfish | A | A | ~ | ~ | ~ | A | A | A | A | ~ | ~ | A | A | A | A | A | A | A | A | A | A | ~ |
| Crucian carp | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | ~ |
| Common carp | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A |
| Gudgeon | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL |
| Sunbleak | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | A | ~ |
| Chub | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N |
| Orfe | ~ | ~ | ~ | ~ | A | A | A | ~ | A | ~ | A | A | A | A | A | A | A | A | A | ~ | A | ~ |
| Dace | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL |
| Minnow | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL |
| False harlequin | ~ | ~ | ~ | ~ | ~ | ~ | A | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | A | ~ | ~ | A | ~ |
| Bitterling | ~ | ~ | ~ | ~ | ~ | A | ~ | ~ | ~ | ~ | ~ | A | ~ | ~ | ~ | ~ | ~ | A | ~ | ~ | ~ | ~ |
| Roach | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le |
| Rudd | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le |
| Tench | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le |
| Spined loach | ~ | ~ | ~ | ~ | ~ | ~ | Lo | Lo | Lo | Lo | Lo | Lo | Lo | ~ | Lo | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Stone loach | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo |
| Black bullhead | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Wels catfish | ~ | ~ | ~ | ~ | ~ | A | A | A | A | A | A | A | A | A | ~ | A | A | A | A | A | ~ | ~ |
| Pike | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le |
| Smelt | ~ | Tr | Tr | ~ | Tr | ~ | Tr | Tr | Tr | Tr | Tr | Tr | Tr | Tr | Tr | Tr | ~ | Tr | Tr | ~ | ~ | ~ |
| Vendace | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Pollan | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Powan | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Houting | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |

**Table 5c** *(continued)*

| FISH SPECIES | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rainbow trout | As | As | As | As | As | As | As | As | As | As | As | As | As | As | As | As | As | As | As | As | As | As |
| Atlantic salmon | Lo | Lo | Lo | Lo | Lo | Lo | Lo | ~ | ~ | ~ | ~ | Lo | ~ | Lo | Lo | Lo | ~ | Lo | Lo | ~ | Lo | Lo |
| Brown trout | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL |
| Arctic charr | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Brook charr | A | ~ | ~ | ~ | ~ | A | ~ | ~ | A | ~ | ~ | A | A | ~ | ~ | ~ | ~ | ~ | ~ | A | ~ | ~ |
| Grayling | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo |
| Burbot | ~ | ~ | ~ | ~ | ~ | Le | Le | ~ | Le | ~ | ~ | Le | Le | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Thick-lipped grey mullet | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | Tr | Tr | ~ | ~ | Tr | ~ | ~ | ~ |
| Golden grey mullet | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Thin-lipped grey mullet | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | Tr | Tr | ~ | ~ | ~ |
| 3-spined stickleback | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL |
| 9-spined stickleback | ~ | ~ | LL | ~ | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL |
| Bullhead | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo |
| Sea bass | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | Tr | Tr | Tr | Tr | ~ | Tr | ~ | ~ | Tr | ~ |
| Rock bass | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | A | ~ | ~ | ~ | ~ |
| Pumpkinseed | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | A | ~ | ~ | ~ | ~ | ~ | A | A | A | ~ | ~ |
| Largemouth bass | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | A | ~ | A | ~ | ~ |
| Ruffe | ~ | ~ | ~ | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | ~ | ~ | ~ |
| Perch | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le |
| Pikeperch | ~ | ~ | ~ | ~ | ~ | ~ | A | ~ | ~ | A | A | A | ~ | A | A | A | A | A | ~ | A | ~ | ~ |
| Common goby | ~ | ~ | ~ | ~ | ~ | ~ | ~ | Tr | ~ | ~ | Tr | Tr | Tr | Tr | Tr | Tr | ~ | ~ | Tr | Tr | ~ | ~ |
| Flounder | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL |

**Table 5d  Fish species by Hydrometric Area – mainly England West**

| FISH SPECIES | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 | 77 | 101 | 103 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| River lamprey | LL | LL | ~ | LL | LL | LL | ~ | LL | LL | ~ | LL | ~ | ~ | ~ | ~ | LL | LL | ~ | LL | LL | LL | ~ | ~ |
| Brook lamprey | LL | LL | LL | LL | LL | LL | ~ | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL |
| Sea lamprey | LL | LL | LL | LL | LL | LL | LL | LL | ~ | ~ | LL | ~ | ~ | ~ | ~ | ~ | LL | ~ | LL | LL | LL | ~ | LL |
| Common sturgeon | ~ | ~ | ~ | ~ | Tr | Tr | ~ | ~ | ~ | ~ | Tr | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Eel | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL |
| Allis shad | Tr | Tr | Tr | Tr | Tr | Tr | Tr | Tr | ~ | ~ | Tr | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | Tr | ~ |
| Twaite shad | Tr | Tr | Tr | Tr | Tr | Tr | Tr | Tr | Tr | ~ | Tr | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | Tr | Tr |
| Silver bream | Le | Le | ~ | ~ | ~ | ~ | ~ | ~ | ~ | Le | Le | Le | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Common bream | Le | Le | Le | Le | Le | Le | Le | ~ | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le |
| Bleak | ~ | Le | Le | ~ | ~ | ~ | ~ | ~ | Le | Le | Le | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Barbel | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | Lo | Lo | Lo | Lo | Lo | Lo | Lo | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Goldfish | ~ | ~ | ~ | A | A | A | ~ | ~ | ~ | ~ | A | A | A | ~ | ~ | ~ | A | ~ | ~ | ~ | ~ | A | ~ |
| Crucian carp | ~ | A | ~ | A | A | A | ~ | ~ | A | A | A | A | A | A | A | A | A | ~ | A | A | ~ | A | ~ |
| Common carp | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | ~ |
| Gudgeon | Le | Le | Le | Le | Le | Le | Le | ~ | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | ~ | Le | ~ | Le | Le |
| Sunbleak | ~ | A | ~ | ~ | ~ | ~ | ~ | ~ | A | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Chub | Le | Le | ~ | ~ | ~ | ~ | ~ | ~ | Le | Le | Le | Le | Le | Le | Le | Le | Le | ~ | ~ | Le | Le | ~ | ~ |
| Orfe | A | A | A | ~ | A | ~ | ~ | ~ | ~ | ~ | A | A | A | A | A | A | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Dace | LL | LL | ~ | LL | ~ | LL | LL | ~ | LL | LL | LL | LL | LL | LL | LL | LL | LL | ~ | LL | LL | LL | LL | ~ |
| Minnow | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | ~ | LL |
| False harlequin | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Bitterling | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | A | A | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Roach | Le | Le | Le | Le | Le | Le | Le | ~ | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le |
| Rudd | Le | Le | Le | ~ | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | ~ | ~ | Le | ~ |
| Tench | Le | Le | Le | Le | Le | Le | Le | ~ | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | ~ |
| Spined loach | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Stone loach | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | ~ |
| Black bullhead | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | A | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Wels catfish | ~ | ~ | A | ~ | ~ | ~ | ~ | ~ | A | ~ | A | A | A | ~ | ~ | A | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Pike | Le | Le | Le | ~ | Le | ~ | ~ | ~ | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le |
| Smelt | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | Tr | ~ | ~ | Tr | ~ | ~ | ~ | ~ | Tr | ~ | ~ |
| Vendace | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | La | ~ | ~ | ~ | ~ |
| Pollan | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Powan | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | La | ~ | ~ | ~ |
| Houting | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |

**Table 5d** *(continued)*

| FISH SPECIES | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 | 77 | 101 | 103 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rainbow trout | As | As | As | As | As | As | As | As | As | As | As | As | As | As | As | As | As | As | As | As | As | As | As |
| Atlantic salmon | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | ~ | Lo |
| Brown rout | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL |
| Arctic charr | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | La | La | La | ~ | ~ | ~ | ~ |
| Brook charr | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | A | ~ | ~ | A | A | ~ | ~ | ~ | A | ~ | ~ | ~ | ~ | ~ | ~ |
| Grayling | Lo | Lo | ~ | Lo | Lo | Lo | ~ | ~ | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | ~ | ~ | ~ | Lo | ~ | ~ | ~ |
| Burbot | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Thick-lipped grey mullet | ~ | ~ | ~ | N | N | N | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Golden grey mullet | ~ | ~ | ~ | N | N | N | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Thin-lipped grey mullet | ~ | ~ | ~ | N | N | N | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| 3-spined stickleback | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL |
| 9-spined stickleback | ~ | ~ | LL | ~ | ~ | ~ | ~ | ~ | LL | LL | LL | LL | LL | ~ | LL | LL | ~ | ~ | ~ | ~ | ~ | LL | LL |
| Bullhead | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | ~ | N | N | N | N | ~ |
| Sea Bass | ~ | ~ | Tr | Tr | Tr | Tr | Tr | ~ | ~ | ~ | Tr | ~ | ~ | ~ | ~ | ~ | Tr | ~ | ~ | Tr | ~ | ~ | ~ |
| Rock Bass | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Pumpkinseed | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | A | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Largemouth bass | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Ruffe | ~ | ~ | ~ | ~ | ~ | Le | ~ | ~ | Le | ~ | Le | Le | Le | Le | Le | Le | Le | ~ | Le | ~ | ~ | ~ | ~ |
| Perch | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le |
| Pikeperch | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | A | ~ | A | A | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Common goby | ~ | ~ | ~ | ~ | Tr | Tr | ~ | ~ | ~ | ~ | Tr | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Flounder | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | ~ | LL |

**Table 5e Fish species by Hydrometric Area – mainly Wales**

| FISH SPECIES | 54 | 55 | 56 | 57 | 58 | 59 | 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 102 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| River lamprey | LL | LL | LL | ~ | LL | LL | LL | LL | LL | ~ | LL | ~ | LL | LL | LL |
| Brook lamprey | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL |
| Sea lamprey | LL | LL | ~ | ~ | ~ | LL | LL | ~ | LL | ~ | LL | LL | LL | LL | ~ |
| Common sturgeon | Tr | Tr | Tr | Tr | Tr | Tr | Tr | Tr | Tr | Tr | Tr | Tr | Tr | Tr | Tr |
| Eel | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL |
| Allis shad | TrLo | TrLo | TrLo | ~ | ~ | Tr | TrLo | Tr | Tr | ~ | Tr | ~ | ~ | Tr | ~ |
| Twaite shad | TrLo | TrLo | TrLo | Tr | ~ | Tr | TrLo | Tr | Tr | ~ | Tr | ~ | ~ | Tr | ~ |
| Silver bream | At | At | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Common bream | At | At | At | At | At | At | At | At | At | At | At | At | At | At | At |
| Bleak | At | At | At | At | At | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Barbel | At | At | At | At | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | At | ~ |
| Goldfish | A | ~ | A | A | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Crucian carp | A | A | A | A | A | A | A | A | ~ | ~ | A | A | A | A | A |
| Common carp | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A |
| Gudgeon | At | At | At | At | At | At | At | At | ~ | ~ | ~ | At | At | At | At |
| Sunbleak | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Chub | At | At | At | At | ~ | ~ | ~ | ~ | ~ | ~ | ~ | At | At | At | ~ |
| Orfe | A | ~ | A | A | ~ | A | ~ | ~ | ~ | ~ | ~ | ~ | A | A | A |
| Dace | At | At | At | At | At | At | ~ | ~ | ~ | ~ | ~ | ~ | ~ | At | ~ |
| Minnow | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL |
| False harlequin | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Bitterling | A | A | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | A | ~ |
| Roach | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le |
| Rudd | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le |
| Tench | At | At | At | At | At | At | At | At | At | At | At | At | At | At | At |
| Spined loach | Lo | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Stone loach | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | ~ |
| Black bullhead | A | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Wels catfish | A | A | ~ | ~ | ~ | A | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | A |
| Pike | Le | Le | Le | Le | Le | Le | Le | Le | Le | ~ | Le | Le | Le | Le | Le |
| Smelt | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | Tr | Tr | ~ |
| Vendace | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Pollan | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Powan | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | La | ~ |
| Houting | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |

**Table 5e** *(continued)*

| FISH SPECIES | 54 | 55 | 56 | 57 | 58 | 59 | 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 102 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rainbow trout | As | As | As | As | As | As | As | As | As | As | As | As | As | As | ~ |
| Atlantic salmon | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo |
| Brown trout | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL |
| Arctic charr | At | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | La | La | At | ~ | ~ |
| Brook charr | A | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | A | ~ | A | A | A |
| Grayling | Lo | Lo | Lo | Lo | ~ | ~ | Lo | ~ | ~ | ~ | ~ | Lo | ~ | Lo | ~ |
| Burbot | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Thick-lipped grey mullet | ~ | ~ | ~ | ~ | Tr | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Golden grey mullet | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | Tr |
| Thin-lipped grey mullet | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| 3-spined stickleback | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL |
| 9-spined stickleback | LL | ~ | ~ | LL | LL | LL | LL | LL | ~ | ~ | LL | ~ | LL | LL | LL |
| Bullhead | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo | ~ | ~ | Lo | Lo | Lo | ~ |
| Sea bass | ~ | ~ | ~ | ~ | ~ | Tr | Tr | Tr | Tr | Tr | Tr | Tr | Tr | ~ | ~ |
| Rock bass | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Pumpkinseed | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Largemouth bass | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Ruffe | At | ~ | At | At | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | At | ~ |
| Perch | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le | Le |
| Pikeperch | A | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Common goby | Tr | Tr | ~ | ~ | ~ | Tr | ~ | Tr | ~ | ~ | Tr | Tr | ~ | ~ | Tr |
| Flounder | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL | LL |

**Table 5f Fish species by Hydrometric Area – mainly Northern Ireland**

| FISH SPECIES | 1 | 2 | 3 | 4 | 5 | 6 | 35 | 36 |
|---|---|---|---|---|---|---|---|---|
| River lamprey | ~ | ~ | LL | ~ | LL | ~ | ~ | ~ |
| Brook lamprey | LL | LL | LL | LL | LL | LL | LL | LL |
| Sea lamprey | ~ | LL | LL | ~ | LL | ~ | ~ | ~ |
| Common sturgeon | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Eel | LL | LL | LL | LL | LL | LL | ~ | ~ |
| Allis shad | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Twaite shad | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Silver bream | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Common bream | At | At | At | ~ | At | At | At | At |
| Bleak | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Barbel | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Goldfish | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Crucian carp | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Common carp | ~ | A | A | ~ | A | ~ | ~ | ~ |
| Gudgeon | At | At | At | ~ | At | At | At | At |
| Sunbleak | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Chub | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Orfe | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Dace | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Minnow | At | At | At | At | At | At | At | At |
| Bitterling | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Roach | At | At | At | ~ | At | At | At | At |
| Rudd | At | At | At | ~ | At | At | At | At |
| Tench | ~ | At | At | ~ | At | ~ | At | At |
| Spined loach | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Stone loach | At | At | At | At | At | At | At | At |
| Black bullhead | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Wels catfish | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Pike | Le | Le | Le | ~ | Le | Le | Le | Le |
| Smelt | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Vendace | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Pollan | ~ | ~ | La | ~ | ~ | ~ | ~ | La |
| Powan | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Houting | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Rainbow trout | As | As | As | As | As | As | As | As |

**Table 5f** *(continued)*

| FISH SPECIES | 1 | 2 | 3 | 4 | 5 | 6 | 35 | 36 |
|---|---|---|---|---|---|---|---|---|
| Atlantic salmon | Lo | Lo | Lo | Lo | Lo | Lo | Lo | Lo |
| Brown trout | LL | LL | LL | LL | LL | LL | LL | LL |
| Arctic charr | ~ | ~ | ~ | ~ | ~ | ~ | La | ~ |
| Brook charr | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Grayling | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Burbot | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Thick-lipped grey mullet | Tr | ~ | Tr | ~ | Tr | Tr | ~ | ~ |
| Golden grey mullet | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Thin-lipped grey mullet | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| 3-spined stickleback | LL | LL | LL | LL | LL | LL | LL | LL |
| 9-spined stickleback | ~ | ~ | LL | ~ | LL | LL | LL | ~ |
| Bullhead | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Sea bass | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Rock bass | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Pumpkinseed | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Largemouth bass | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Ruffe | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Perch | At | At | At | ~ | At | At | At | At |
| Pikeperch | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Common goby | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| Flounder | LL | LL | LL | LL | LL | LL | ~ | ~ |

**Table 6a The numbers of running water segments in the Tayside Region**

| GEOLOGY | STREAM ORDER | ALTITUDE IN METRES ASL | | | | TOTALS |
|---|---|---|---|---|---|---|
| | | <15 | 15–183 | >183–610 | >610 | |
| BASE POOR | 1 | 0 | 116 | 2615 | 747 | 3478 |
| | 2 | 0 | 86 | 1211 | 222 | 1519 |
| | 3 | 0 | 34 | 595 | 47 | 676 |
| | 4 | 0 | 21 | 226 | 2 | 249 |
| | 5 | 0 | 11 | 61 | 0 | 72 |
| | 6 | 0 | 0 | 0 | 0 | 0 |
| | 7 | 0 | 0 | 0 | 0 | 0 |
| | 8 | 0 | 0 | 0 | 0 | 0 |
| **Total** | | **0** | **268** | **4708** | **1018** | **5994** |
| INTERMEDIATE | 1 | 0 | 4 | 8 | 1 | 13 |
| | 2 | 0 | 38 | 122 | 9 | 169 |
| | 3 | 0 | 73 | 135 | 2 | 210 |
| | 4 | 0 | 143 | 148 | 0 | 291 |
| | 5 | 42 | 146 | 111 | 0 | 299 |
| | 6 | 8 | 93 | 0 | 0 | 101 |
| | 7 | 0 | 29 | 0 | 0 | 29 |
| | 8 | 11 | 23 | 0 | 0 | 34 |
| **Total** | | **61** | **549** | **524** | **12** | **1146** |
| BASE RICH | 1 | 79 | 974 | 800 | 39 | 1892 |
| | 2 | 60 | 419 | 287 | 6 | 782 |
| | 3 | 20 | 253 | 78 | 0 | 351 |
| | 4 | 7 | 105 | 26 | 0 | 351 |
| | 5 | 0 | 14 | 0 | 0 | 14 |
| | 6 | 0 | 0 | 0 | 0 | 0 |
| | 7 | 0 | 0 | 0 | 0 | 0 |
| | 8 | 0 | 0 | 0 | 0 | 0 |
| **Total** | | **166** | **1765** | **1201** | **45** | **3177** |
| **TOTALS** | | **227** | **2582** | **6433** | **1075** | **10317** |

**Table 6b The numbers of standing waters in the Tayside Region.**

| GEOLOGY | AREA HECTARES | ALTITUDE IN METRES ASL | | | | TOTALS |
|---|---|---|---|---|---|---|
| | | **<15** | **15–183** | **>183–610** | **>610** | |
| BASE POOR | 0–1 | 0 | 26 | 131 | 55 | 212 |
| | >1–25 | 0 | 8 | 83 | 13 | 104 |
| | >25–100 | 0 | 3 | 9 | 1 | 13 |
| | >100–400 | 0 | 0 | 7 | 0 | 7 |
| | >400 | 0 | 0 | 3 | 0 | 3 |
| **Total** | | **0** | **37** | **233** | **69** | **339** |
| INTERMEDIATE | 0–1 | 0 | 8 | 6 | 0 | 14 |
| | >1–25 | 0 | 5 | 7 | 2 | 14 |
| | >25–100 | 0 | 3 | 2 | 0 | 5 |
| | >100–400 | 0 | 0 | 3 | 0 | 3 |
| | >400 | 0 | 2 | 1 | 0 | 3 |
| **Total** | | **0** | **18** | **19** | **2** | **39** |
| BASE RICH | 0–1 | 29 | 345 | 30 | 0 | 404 |
| | >1–25 | 13 | 90 | 29 | 0 | 132 |
| | >25–100 | 0 | 5 | 5 | 0 | 10 |
| | >100–400 | 0 | 0 | 0 | 0 | 0 |
| | >400 | 0 | 1 | 0 | 0 | 1 |
| **Total** | | **42** | **441** | **64** | **0** | **547** |
| **TOTALS** | | **42** | **496** | **316** | **71** | **925** |

**Table 7 Average life expectancy and length of freshwater fish found in the UK. Data from Maitland (2000a)**

| FISH SPECIES | AVERAGE LIFE EXPECTANCY (YEARS) | AVERAGE FORK LENGTH (CM) |
|---|---|---|
| River lamprey | 5–7 | 30–35 |
| Brook lamprey | 6–7 | 12–15 |
| Sea lamprey | 7–9 | 50–70 |
| Common sturgeon | 20–50 | 150–250 |
| Eel | 10–20 | 40–90 |
| Allis shad | 4–8 | 30–50 |
| Twaite shad | 5–9 | 25–40 |
| Silver bream | 5–10 | 20–30 |
| Common bream | 6–12 | 30–50 |
| Bleak | 4–8 | 12–15 |
| Barbel | 8–16 | 25–75 |
| Goldfish | 8–15 | 15–35 |
| Crucian carp | 8–15 | 20–45 |
| Common carp | 10–30 | 25–75 |
| Gudgeon | 5–8 | 10–15 |
| Sunbleak | 4–6 | 5–9 |
| Chub | 5–10 | 30–50 |
| Orfe | 5–10 | 35–50 |
| Dace | 4–8 | 15–25 |
| Minnow | 3–5 | 6–10 |
| False harlequin | 2–5 | 4–6 |
| Bitterling | 3–5 | 5–8 |
| Roach | 4–8 | 20–35 |
| Rudd | 4–8 | 15–30 |
| Tench | 10–20 | 20–40 |
| Spined loach | 3–5 | 8–10 |
| Stone loach | 4–6 | 8–12 |
| Black bullhead | 6–12 | 20–30 |
| Wels catfish | 15–25 | 100–200 |
| Pike | 10–15 | 30–120 |
| Smelt | 2–5 | 10–20 |
| Vendace | 3–7 | 15–25 |
| Pollan | 4–9 | 30–35 |
| Powan | 4–9 | 25–40 |

**Table 7** *(continued)*

| FISH SPECIES | AVERAGE LIFE EXPECTANCY (YEARS) | AVERAGE FORK LENGTH (CM) |
|---|---|---|
| Houting | 4–9 | 25–40 |
| Rainbow trout | 3–6 | 25–45 |
| Atlantic salmon | 4–9 | 40–100 |
| Brown trout | 8–20 | 15–50 |
| Arctic charr | 6–12 | 15–40 |
| Brook charr | 5–9 | 20–35 |
| Grayling | 7–10 | 25–35 |
| Burbot | 10–15 | 30–50 |
| Thick-lipped grey mullet | 8–10 | 30–50 |
| Golden grey mullet | 6–8 | 20–35 |
| Thin-lipped grey mullet | 8–10 | 25–40 |
| Three-spined stickleback | 2–3 | 4–8 |
| Nine-spined stickleback | 2–3 | 5–7 |
| Bullhead | 3–5 | 10–15 |
| Sea Bass | 15–25 | 40–70 |
| Rock Bass | 5–9 | 15–20 |
| Pumpkinseed | 4–8 | 12–15 |
| Largemouth bass | 8–12 | 20–40 |
| Ruffe | 3–5 | 10–15 |
| Perch | 8–12 | 20–35 |
| Pikeperch | 10–15 | 30–70 |
| Common goby | 1–2 | 3–6 |
| Flounder | 5–10 | 20–30 |

**Table 8 An assessment of the 'sensitivity' of freshwater fish found in the UK**

| FISH SPECIES | SENSITIVITY FACTOR | ORIGIN | NOTES |
|---|---|---|---|
| River lamprey | +++ | Native | Declining, due to pollution and habitat loss |
| Brook lamprey | ++ | Native | Declining, due to pollution and habitat loss |
| Sea lamprey | ++++ | Native | Declining, due to pollution and habitat loss |
| Common sturgeon | +++++ | Native | Declining, a vagrant almost extinct now in the UK |
| Eel | + | Native | Declining, reasons unclear, perhaps overfishing |
| Allis shad | ++++ | Native | Declining, no breeding stocks left in the UK |
| Twaite shad | +++ | Native | Declining, few breeding stocks left in UK |
| Silver bream | ++ | Native | Increasing, though slight, due to stocking |
| Common bream | + | Native | Increasing, due to stocking |
| Bleak | ++ | Native | Increasing, though only slightly, due to stocking |
| Barbel | ++ | Native | Increasing, dispersing significantly due to stocking |
| Goldfish | + | Alien | Increasing, though only slightly, due to stocking |
| Crucian carp | + | Alien | Increasing, due to stocking |
| Common carp | + | Alien | Increasing, due to stocking |
| Gudgeon | + | Native | Increasing, due to stocking |
| Sunbleak | + | Alien | Increasing, established recently; dispersing in the UK |
| Chub | + | Native | Increasing, due to stocking |
| Orfe | + | Alien | Increasing, though only slightly, due to stocking |
| Dace | + | Native | Increasing, due to stocking |
| Minnow | + | Native | Increasing, due to stocking and natural dispersal |
| False harlequin | + | Alien | Increasing, established recently; dispersing in the UK |
| Bitterling | ++ | Alien | Increasing, but slow due to specialised life cycle |
| Roach | + | Native | Increasing, due to stocking |
| Rudd | + | Native | Increasing, due to stocking |
| Tench | + | Native | Increasing, due to stocking |
| Spined loach | +++ | Native | Steady, little change from its original distribution |
| Stone loach | ++ | Native | Increasing, due to stocking and natural dispersal |
| Black bullhead | + | Alien | Increasing, established relatively recently |
| Wels catfish | + | Alien | Increasing, recent dispersal due to stocking |
| Pike | ++ | Native | Increasing, due to natural dispersal |
| Smelt | ++++ | Native | Declining, many stocks lost over the last century |
| Vendace | +++++ | Native | Declining, extinct now in Scotland |
| Pollan | +++++ | Native | Declining, possibly extinct now in some loughs |
| Powan | +++++ | Native | Increasing, due to successful translocations |
| Houting | +++++ | Native | Declining, a vagrant extinct now in the UK |

**Table 8** *(continued)*

| FISH SPECIES | SENSITIVITY FACTOR | ORIGIN | NOTES |
|---|---|---|---|
| Rainbow trout | ++ | Alien | Increasing, maintained largely by regular stocking |
| Atlantic salmon | +++++ | Native | Declining, due to various factors |
| Brown trout | +++ | Native | Declining, due to acidfication and other factors |
| Arctic charr | +++++ | Native | Declining, several stocks lost over the last century |
| Brook charr | +++ | Alien | Steady, a few established populations, some stocking |
| Grayling | +++ | Native | Increasing, due to stocking in new rivers |
| Burbot | +++++ | Native | Declining, extinct now in the UK |
| Thick–lipped grey mullet | ++ | Native | Steady, little information |
| Golden grey mullet | +++ | Native | Steady, little information |
| Thin–lipped grey mullet | ++ | Native | Steady, little information |
| Three–spined stickleback | + | Native | Steady, a widespread species |
| Nine-spined stickleback | +++ | Native | Declining, sporadic distribution, some stocks extinct |
| Bullhead | ++ | Native | Increasing, due to stocking in new rivers |
| Sea bass | ++ | Native | Declining, due to overfishing and other factors |
| Rock bass | + | Alien | Steady, only one population ever known |
| Pumpkinseed | + | Alien | Steady, several populations known for many years |
| Largemouth bass | + | Alien | Steady, only a few populations ever known |
| Ruffe | + | Native | Increasing, due to stocking in Wales and Scotland |
| Perch | + | Native | Steady, little apparent change in recent years |
| Pikeperch | + | Alien | Increasing, recent dispersal due to stocking |
| Common goby | + | Native | Steady, little information |
| Flounder | ++ | Native | Steady, a widespread species |

***Note:*** + = very tolerant species; +++ = sensitive to some impacts; +++++ = sensitive to many impacts.

# 11 FIGURES

## Figure 1 The Hydrometric Areas of Great Britain and Ireland

**Figure 2a Fish distribution by Hydrometric Area (• = +ve; ○ = -ve)**

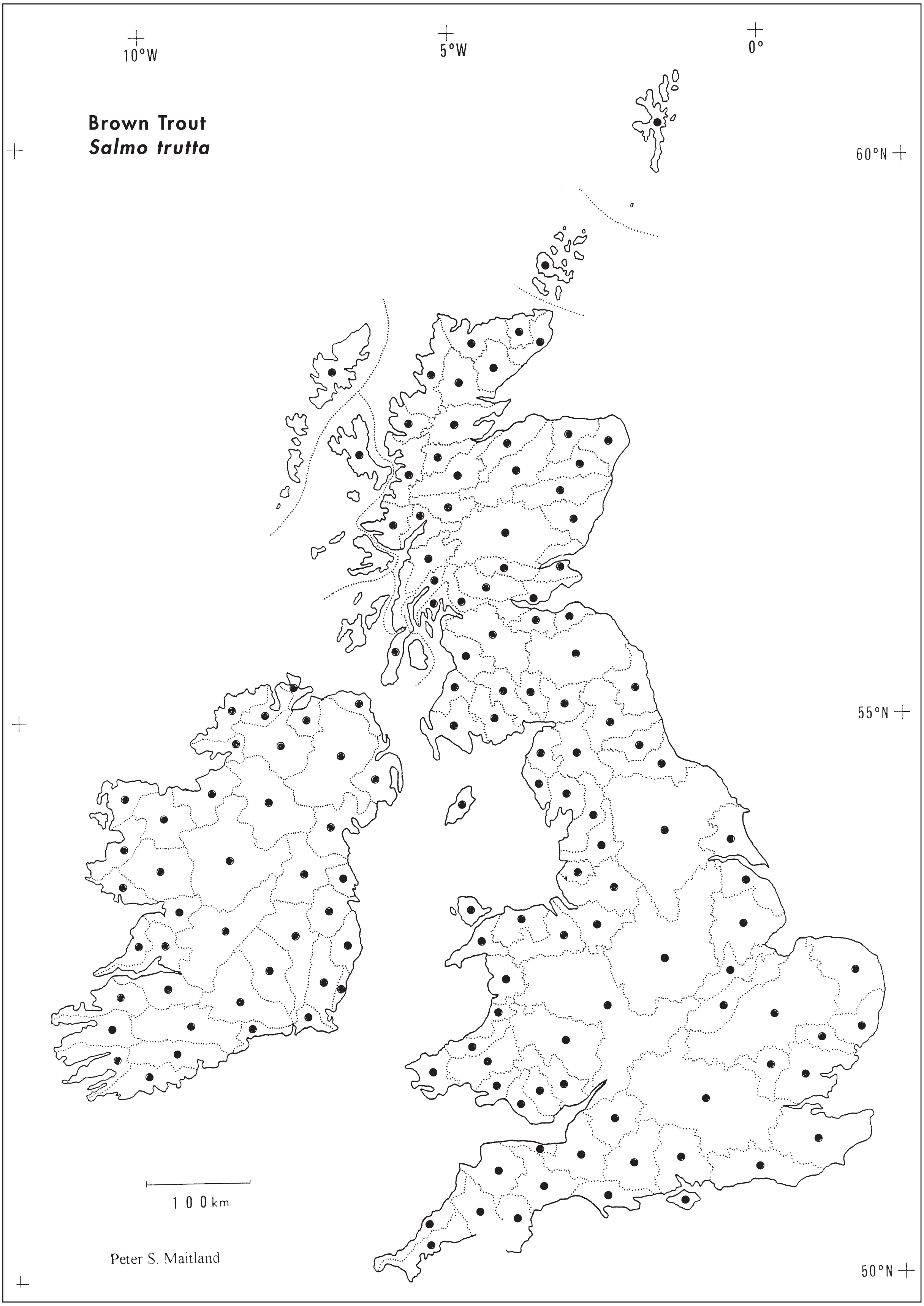


**Figure 2b Fish distribution by Hydrometric Area (• = +ve; ○ = -ve)**

**Figure 3 Association diagram of freshwater fish species in Scotland calculated using data from 103 sites (Fagar 1957). Each species is linked to the two others with which it is most commonly associated (numbers represent percentages of possible maximum associations). Some species are not included because of their rarity.**

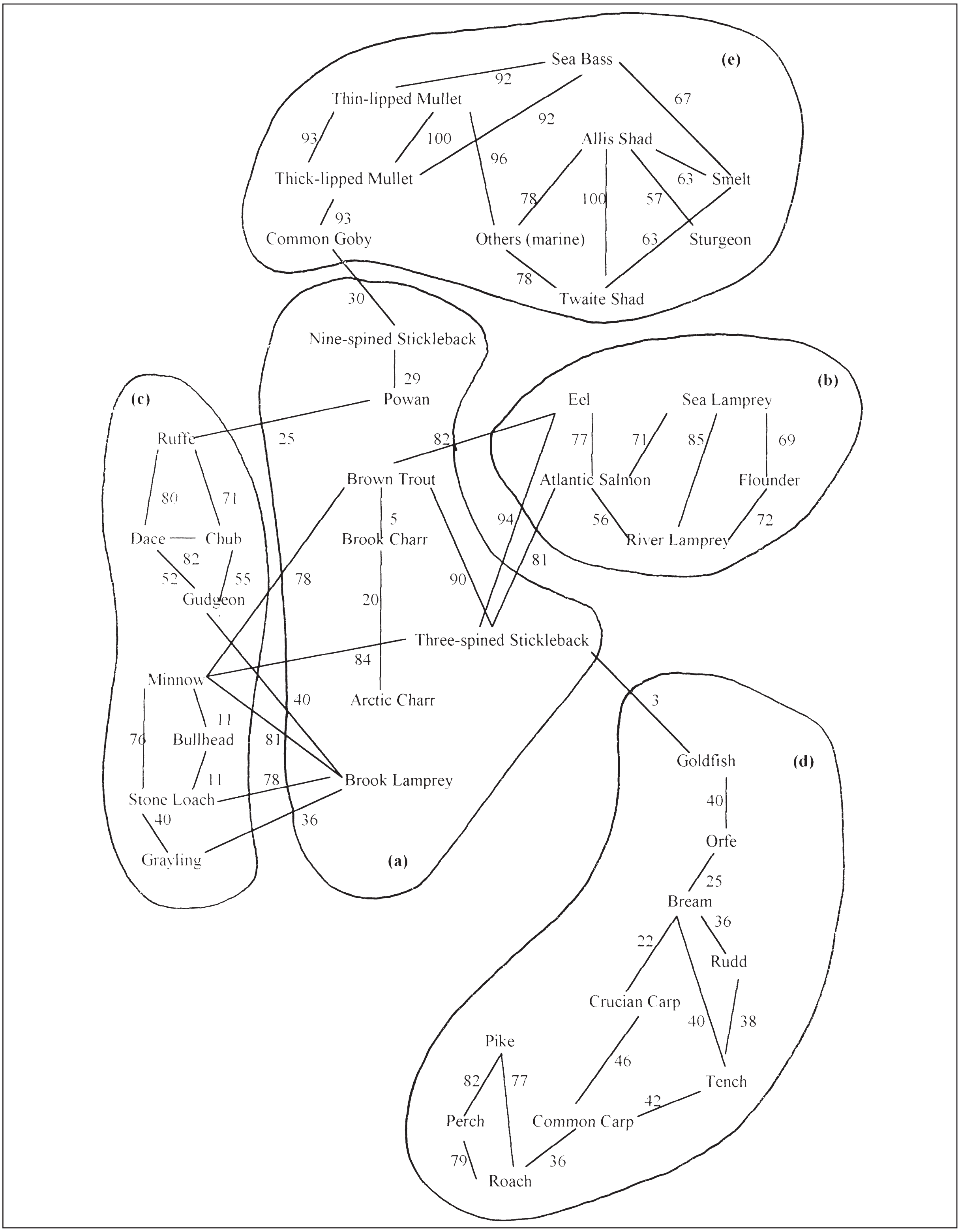


**Figure 4 The division of the UK into five regions (A–E) within which the presence of certain freshwater fish species may be predicted**

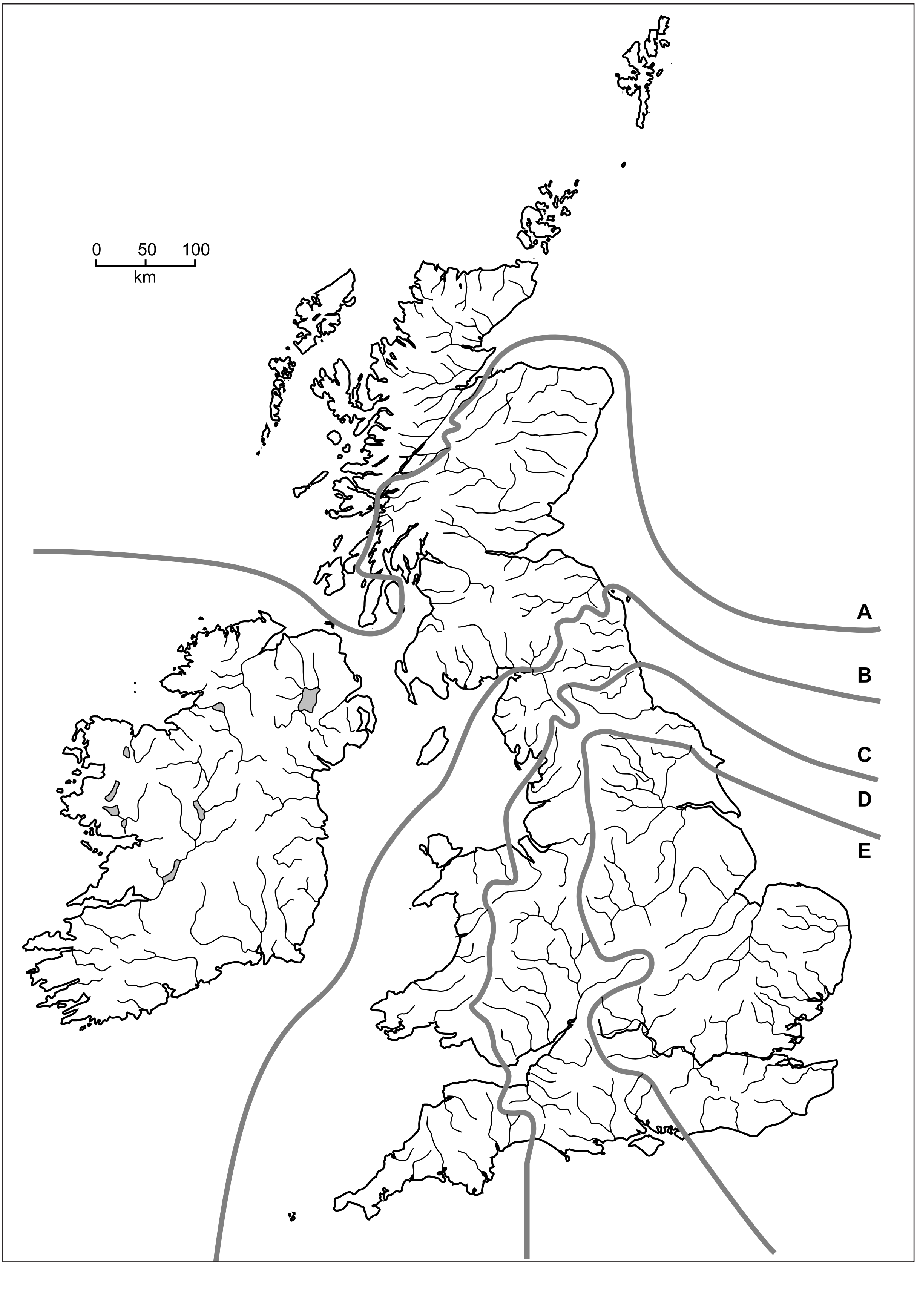
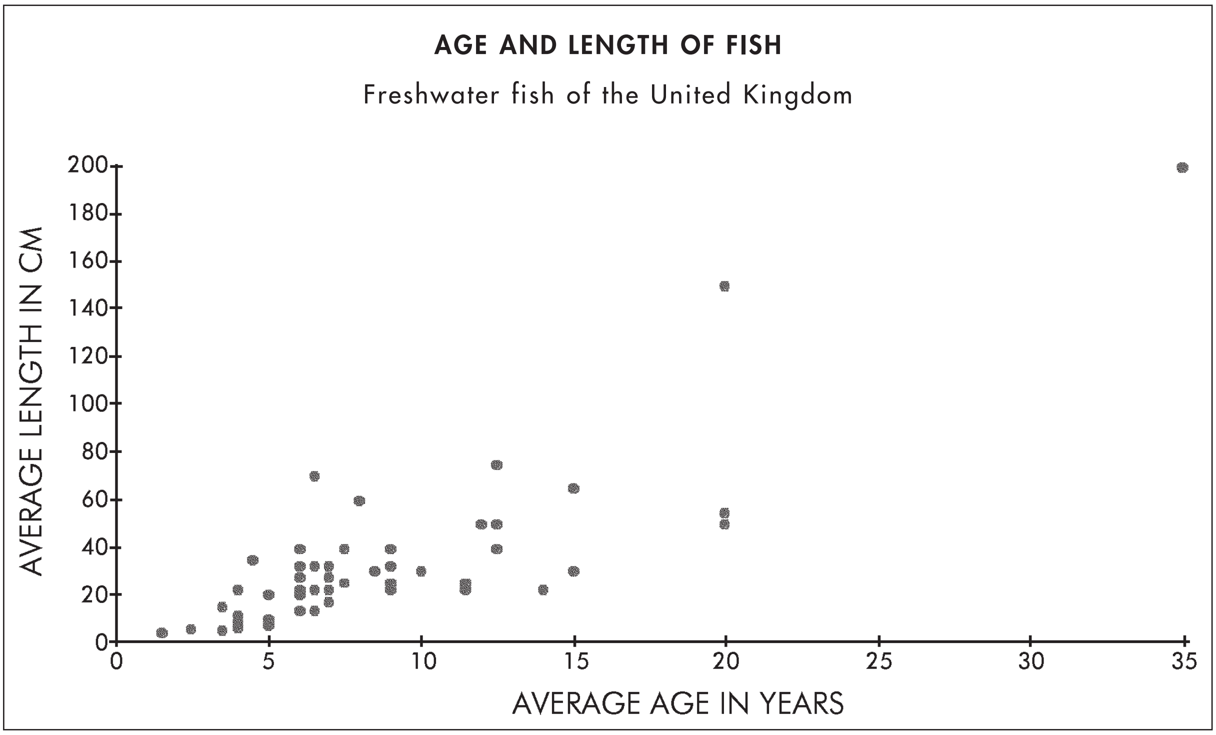


**Figure 5 Relationship between age and length in freshwater fish species established in the UK.**



# APPENDIX

## Evaluating the Ecological and Conservation Status of Freshwater Fish Communities

***A workshop arranged by Scottish Natural Heritage and the Scotland and Northern Ireland Forum for Environmental Research (SNIFFER) on Tuesday 11 March 2003 at SEPA, Riccarton, Edinburgh***

### POST-PROJECT WORKSHOP REPORT

***Attendees:***

| | |
|---|---|
| Phil Boon (PB) | SNH (Meeting chair) |
| Peter Maitland (PM) | Fish Conservation Centre |
| Colin Bean (CB) | SNH |
| Tristan Hatton-Ellis (TH) | Countryside Council for Wales (CCW) |
| David Fraser (DF) | English Nature (EN) |
| Willie Duncan (WD) | Scottish Environment Protection Agency (SEPA) |
| Robin Guthrie (RG) | SEPA |
| Ian Fozzard (IF) | SEPA |
| Brian Clelland (BC) | SEPA |
| Alan Starkie (AS) | Environment Agency (EA) |
| Rick North (RNor) | EA |
| Ross Gardiner (RGa) | Fisheries Research Services (FRS), Pitlochry |
| Ian Cowx (IC) | University of Hull |
| Richard Noble (RN) | University of Hull |
| Alastair Stephen (ASt) | Scottish & Southern Energy |
| Ian Winfield (IW) | Centre for Ecology and Hydrology (CEH), Windermere |
| Ronald Campbell (RC) | Tweed Foundation |
| Colin Bull (CBu) | Forth Fishery Foundation |
| Rebecca Badger (RB) | SNIFFER |
| Hilary Anderson (HA) | Scottish Fisheries Coordination Centre (SFCC) |
| Alison Gilmour (AG) | Joint Nature Conservation Committee (JNCC) (Minutes) |

***Objectives:***

The aim of the workshop was to discuss the results of a project entitled 'Evaluating the Ecological and Conservation Status of Freshwater Fish Communities in the United Kingdom'. This work was commissioned by Scottish Natural Heritage with additional funding provided by the Joint Nature Conservation Committee. The project had a dual purpose: developing a more detailed approach to fish conservation evaluation using SERCON (System for Evaluating Rivers for Conservation), and extending the method for use in Water Framework Directive assessments.

***Workshop Programme:***

The main part of the programme comprised five short presentations from Peter Maitland (Fish Conservation Centre) who carried out the project on behalf of SNH and the JNCC, interspersed with workshop discussions.

## 1. Fish and the Water Framework Directive (presentation by Willie Duncan)

**Key Points:**

1.1 The assessment of fish communities plays a role in two of the technical tasks under the WFD: River Basin Characterisation (Annex II) and Classification and Monitoring (Annex V).

1.2 Surface water bodies will be classified into one of five status classes under the WFD: high status, good status, moderate status, poor status and bad status. By 2015 all water bodies must achieve 'good status' ***and*** there must be no deterioration in status class.

1.3 Classification and Monitoring divides into the following types:

- Operational monitoring
- Surveillance monitoring
- Investigative monitoring

1.4 Operational monitoring will be used to:

- establish water body status
- validate risk assessments
- assess the effectiveness of the River Basin Programmes of Measures
- drive investment programmes

1.5 Operational monitoring will be based upon the biological element that is the most sensitive to any particular pressure for a water body. There is therefore the opportunity to omit the assessment of fish under operational monitoring as other biological elements may be more sensitive. Examples of pressures for which assessment of the fish community may be useful include habitat destruction, acidification and toxic pollution.

1.6 Fish assessments must be included in surveillance monitoring for the WFD. Surveillance monitoring will be used to supplement and validate risk assessments and to assess the effects of long-term changes, eg climate change, on a water body.

1.7 Keys questions to be resolved for the monitoring of fish for WFD purposes include the following:

- Which anthropogenic pressures are fish most sensitive to?
- Which aspect of fish ecology is affected by the pressure?
- What do we measure?
- What is the risk of misclassification?
    - Fish variability
    - Measuring variability
- What aspect of fish ecology will provide the most robust classification results?

## 2. Fish conservation assessment using SERCON (presentation by Peter Maitland)

**Workshop Discussion:**

2.1 Concern was raised that a field survey may not give a true estimate of all the fish species present at a site, and that this may reduce the SERCON score resulting in a poor site assessment. TH illustrated this point with some examples:

**Llyn Tegid:** has 16 native species. However, some (eg stickleback, rudd, brook lamprey) are rarely seen; others cannot be reliably caught using standard methods (eg eel, bullhead) or are seasonal (eg salmon). Meanwhile, perch, ruffe, roach, grayling, trout, pike and gwyniad could perhaps be caught reliably. Thus, of the 16 species at the site, perhaps only half could be monitored reliably using species richness without excessive effort.

**Afon Seiont, Snowdonia:** has a species-poor community made up of salmon, brown and sea trout, eel and lamprey. Lamprey and eel are present but only patchily due to the limited availability of suitable habitat, and may not be effectively sampled by standard electrofishing. The water body is therefore defined by only two species – salmon and trout, each of which represents 50% of the species richness. Even with all four species recorded there are fewer species than quality bands, so the highest SERCON score would be impossible to obtain.

PM responded by highlighting the flexibility within the scoring system in that SERCON scores relate to a banded percentage. (ie 5 = >80–100%, 4 = >60–80%, etc. of the expected native list present.) This allows a surveyor to miss some species while sampling, without altering the SERCON score itself. Furthermore as with most ecological assessments, the SERCON score would not be based solely on one sampling occasion, thus reducing the possibility of mis-recording the true complement of fish species at a site.

2.2 Concern was also raised over the comparison of the observed and expected species lists. TH mentioned that if the historic fish community were not well known, the expected species list may not be a reliable guide. Standing water bodies in particular tend to show a highly vicarious pattern of fish distribution, depending on local features and chance colonisation. PM stressed that the list of fish species by Hydrometric Area (tables 5a–5f) has been compiled using the best available current information. If, however, additional local knowledge exists, due to lengthy historical survey records, this should be used to improve the 'expected' fish species list for a SERCON assessment.

2.3 IW asked whether the score modification of 'Subtract 2 when two or more alien species are established (or stocked regularly)' is a feature of other attributes scored within SERCON. PM stated that it was. Capping the subtraction at 2 is a sensible approach, as it reflects the downgrading of the site due to aliens (or stocking) without reducing the score completely to zero.

2.4 CBu queried whether or not the scoring used any additions for positive features, such as the presence of rare fish species. PM stated that this is accounted for elsewhere within the SERCON scoring system in the 'Rarity' criteria. RA 1 and RA 4 can be used to assess sites according to the presence of EC Habitats Directive species within the assemblage.

2.5 The issue of 'naturally fishless' waters was discussed. The current method suggests that these sites should automatically score 5. PB opened this up for debate. TH made the point that there were many naturally fishless lakes where brown trout had been introduced in Victorian times and it is now often very difficult to distinguish these as such due to a lack of historical records. He also stated that lakes where fish were present but have since become fishless (for various reasons) are fairly common in Wales. Again, it is difficult to assess which lakes fall into this category and which fall into the 'naturally fishless' category without long-term survey records for these sites. Following discussion, it was generally agreed that naturally fishless waters should score 5.

## 3. Assessing the 'ecological status' of fish assemblages: (1) Species composition (presentation by Peter Maitland)

*Question:* How should we incorporate alien species into any scoring system for Water Framework Directive purposes?

**Workshop Discussion:**

3.1 IC stated that the FAME project has eliminated the effects of biological degradation from its assessments, so alien species are not accounted for. This is due to the fact that it is impossible to improve a water body which has aliens present, without going so far as draining the system completely (obviously impractical). However most people thought that the impacts of alien species cannot simply be ignored and should be incorporated into the scoring system in some way. TH suggested that as many aliens are associated with stressed or disturbed conditions they might, in some cases, be discouraged simply by improving the habitat quality (eg by reducing nutrient inputs).

3.2 WD stated that a UK TAG group has been set up to look at the issue of alien species and the WFD, and fish will be included in their discussions. Their key questions to answer will be:

– What does the presence of alien species mean to a water body?
– What, if anything, should be done about it?

Article 4(5) of the WFD allows the opportunity to follow less stringent environmental objectives for water bodies where it would be infeasible or disproportionately expensive to meet the full objectives. However, certain conditions must be met if this option is taken; ie there should be no possibility of introducing remedial measures and there should be no further deterioration in the ecological status of the affected water body.

3.3 PB stated that the REFCOND guidance from Brussels suggests that where alien species have a significant ecological impact, the ecological status of the water body should be reduced. This raised the question; *Should* ***all*** *water bodies be down-graded for the impacts of alien species, even if the impacts vary greatly in their severity between water bodies?*

3.4 PM went on to say that the degree of impact from alien species may vary from location to location, and perhaps this should be taken into account when classifying water body status. Some examples were given:

– PB raised the issue of Lough Erne where zebra mussels turn over the entire volume of the lake every two weeks, increasing water clarity. Although some see this as a positive impact, zebra mussels clearly detract from the natrualness of the lake.

– Zander have been present in the River Severn since the 1960s. They only appear in small numbers and behave much like a native pike population would, therefore there has been little impact on the native fish population.

– Conversely, zander are also present in Coombe Abbey Lake, and here the ecological impact has been considerable. Although there may have been other contributory factors causing the changes in the native fish population of the lake, the presence of zander has had an impact and should be included in any assessment of ecological status.

– DF stated that many SACs in England support 'put and take' trout fisheries. As this has a potentially reversible impact on resident fish populations, should the ecological status of such water bodies be down-graded?

*Perhaps a sliding scale should be incorporated into the status classification, in order to reflect differing degrees of impacts from alien fish species.*

3.5 PB was concerned that if water bodies were classified at good or even high status despite the presence of alien species, the wrong message would come across. Alien species are not desirable, and even if complete eradication is not possible, steps should be taken at least to prevent their further spread. This suggests that their presence should be taken into account in some way when assessing ecological status. PB suggested that if water bodies were to be classified as being at good ecological status despite the presence of alien species, perhaps this could be clearly indicated (eg by using an asterisk against the classification class).

3.6 BC stated that it would be undesirable to down-grade a large number of sites if nothing can be done to improve their status. For example, if some water bodies are classified as 'moderate' due to the presence of alien species, but nothing can be done to remove them, it would be difficult to reach the objective of all water bodies attaining 'good status' by 2015.

## 4. Assessing the 'ecological status' of fish assemblages: (2) Fish abundance (presentation by Peter Maitland)

**Workshop Discussion:**

4.1 Recording fish abundance is more complicated than species composition, but this additional component adds value to the data, eg if alien species are present, their impact on the native fish population may be assessed in greater detail with information on fish abundance.

4.2 Relative abundance would be a more cost-effective measurement than absolute abundance, and would be suitable for WFD purposes, particularly as the WFD status classifications are based on a comparative system: ie change from 'reference condition'. However, relative abundance would be required for reference condition status, against which the other status classes can be compared.

4.3 RN stated that FAME models backwards from site data in order to achieve data for 'reference conditions'. However, in order to do this, there must be a robust and predictive relationship between species abundance and the impact. FAME is currently running a number of models to test this predictive response for a number of different impacts.

4.4 TH stated that there may not always be a decline in abundance due to impact, but an increase, eg eutrophication may increase fish abundance due to improved feeding conditions. Furthermore, the relationship may be non-linear, eg charr may increase in mean size and abundance with mild eutrophication, but then decline rapidly with increasing eutrophication due to the loss of suitable spawning substrate. For operational monitoring other biological elements should be sampled, eg phytoplankton and diatoms, as they would be the more sensitive indicators for this impact. WD stressed the need to assess which aspects of fish monitoring are robust and reliable enough to use for WFD purposes, and the need to assess for which impacts fish will be the most sensitive indicator. Surveillance monitoring methods for fish will also be required in order to classify water bodies in terms of ecological status.

4.5 IC mentioned that there are European CEN standards for both riverine and lake fish survey. It may be useful to refer to these.

## 5. Assessing the 'ecological status' of fish assemblages: (3) Age structure and sustainable reproductive success (presentation by Peter Maitland)

**Workshop Discussion:**

5.1 PM began by stating that recruitment is an important part of assessing fish populations but there are uncertainties involved due to natural fluctuations in strong/weak year classes. For example, one strong year class may dominate a population for a number of years, therefore requiring long-term survey records in order to gain a full assessment of the dynamics of the population over time. Furthermore, the importance of distinguishing the effects of anthropogenic impacts from those of natural change complicates any assessment.

5.2 RN stated that the FAME project will use a 'proportional stock density' approach, ie the proportion of juveniles compared with the rest of the population. A site with good juvenile recruitment would record a high proportional stock density. (An important factor in this approach is to know at what age in a population fish are reaching maturity.) A site with high proportional stock density for a number of consecutive years demonstrates its 'recruitment strength' and should equate to 'high status'.

5.3 TH showed support for this approach, noting that it would be particularly beneficial for species that are relatively short-lived. CBu added that information on the presence/ absence of certain species of fry would be more valuable than population abundances, as this is indicative of the reproductive status of the population.

## 6. Integrated assessment for the ecological status of fish communities (presentation by Peter Maitland)

PM suggested that an integrated assessment of the ecological status of fish communities could include the three components: species composition, species abundance and age structure, possibly weighted (2:1:1 respectively) to have varying degrees of influence on the final assessment score. He also suggested that additional basic information (such as deformities, parasites, disease and growth rate) could be easily collated while carrying out surveys.

**Workshop Discussion:**

6.1 **Normative definitions of ecological status classifications:** IF highlighted the fact that the WFD states (in Annex V) that for fish, only anthropogenic impacts on physico-chemical and hydromorphological quality elements can result in a downgrading from anything less than 'high status' (see Annex I). This suggests that the impacts of alien fish species cannot be considered in any downgrading other than from 'high status' to 'good status'.

6.2 It is important to note that there are differences in fish survey programmes across the UK, both spatially and temporally. For example, the EA undertakes a comprehensive salmon sampling programme across England and Wales, whereas in Scotland, fisheries surveys have historically been confined to those rivers and lochs with commercially valuable salmon populations. WD highlighted the importance of building on the current survey network for WFD purposes. However, if the current survey network contains significant gaps or is otherwise inadequate then steps must be taken to resolve these issues.

6.3 **Weighting of components:** FAME is unlikely to weight the different components of composition, abundance and age structure, and may not even integrate these into an overall assessment. IC mentioned that species composition had emerged from FAME as the factor which most reliably reflects the ecological status of a fish community. This would support PM's suggestion of a higher weighting for species composition if this option were to be pursued. No further conclusion was reached on this issue as it was generally agreed that it was too early to be giving much consideration to weighting.

6.4 **Additional parameters:** It was suggested that these should be quite limited due to pressures on sampling time and resources within the agencies. PM stated that factors such as deformities, obvious parasites and disease, which can be easily noted whilst on site, should be recorded, provided that they do not materially increase the work load. Furthermore, these are early-warning indicators of stress, which may provide valuable information about a population for little extra effort.

6.5 PM suggested that comparisons should be made between 'condition assessments' of SACs under the Habitats Directive and ecological status assessments made under the WFD. However, PB cautioned against expecting a perfect match for sites assessed as being in 'favourable condition' and those at good ecological status. Although this may often occur, there would certainly be examples of SACs at good ecological status but in 'unfavourable condition'. For example, CB pointed out that many lakes with coregonids contain alien species; this could lead to them being classified as 'unfavourable' even if their status under the WFD were deemed to be 'good'.

6.6 The importance was recognised of developing an overall fish assessment method which results in a score that is comparable to the scores for macroinvertebrates and macrophytes. This is particularly important as the overall status class for a water body will default to the lowest class of all the biological elements. IC stated that the European **Sta**ndardisation of **R**iver Classifications (STAR) project is developing a framework for calibrating different biological survey results against ecological quality classifications for the WFD. This should provide some guidance for ensuring that comparable assessments are developed for the different biological elements.

## Annex I

### Extract from WFD Annex V, Table 1.2.1: Definitions for high, good and moderate ecological status in rivers

***Element – Fish fauna***

#### High status

Species composition and abundance correspond totally or nearly totally to undisturbed conditions.

All the type-specific disturbance-sensitive species are present.

The age structures of the fish communities show little sign of anthropogenic disturbance and are not indicative of a failure in the reproduction or development of any particular species.

#### Good status

There are slight changes in species composition and abundance from the type-specific communities *attributable to anthropogenic impacts on physicochemical and hydromorphological quality elements*.

The age structures of the fish communities show signs of disturbance *attributable to anthropogenic impacts on physico-chemical or hydromorphological quality elements*, and, in a few instances, are indicative of a failure in the reproduction or development of a particular species, to the extent that some age classes may be missing.

#### Moderate status

The composition and abundance of fish species differ moderately from the type-specific communities *attributable to anthropogenic impacts on physico-chemical or hydromorphological quality elements.*

The age structure of the fish communities shows major signs of anthropogenic disturbance, to the extent that a moderate proportion of the type-specific species are absent or of very low abundance.

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