THE WATER FRAMEWORK DIRECTIVE: USING FISH AS A MANAGEMENT TOOL

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ABSTRACT

Many countries, including Ireland, were ill-prepared for the requirements of the Water Framework Directive (WFD) regarding the use of fish as a biological element. Examination of archival data proved uninformative. Details of species composition, distribution and density were fragmented and non-standard. No monitoring programme or strategic stock assessment existed, and information of the type required by the WFD was not available. This paper describes the research undertaken in Ireland since 2000 to deliver standardised WFD survey methods and protocols with which to create essential WFD-compliant data on fish communities in rivers, lakes and transitional waters. Three research projects, one in each surface water category, are discussed, as are initial developments towards fish-classification schemes, surveillance monitoring, and participation and advances in the intercalibration process.

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INTRODUCTION

The Water Framework Directive (WFD; 2000/60/EC; European Parliament and Council 2000) and its transposing legislation (Statutory Instrument No. 722 of 2003; Government of Ireland 2003) require an evaluation of ecosystem quality in rivers, lakes and transitional waters, based on a variety of 'quality elements', including fish. Three key attributes of the fish community—species composition, abundance and age structure (Annex V)—must be included in the scheme(s) for freshwater fish classification in order to be WFD compliant. The classification must be based on an evaluation of current status of the fish community relative to the value at reference conditions—the ecological quality ratio (EQR)—for the various rivers, lakes and transitional waters. Guidance on establishing reference conditions and on the assessment of ecological status leading to the overall ecological classification of waterbodies for the WFD is provided (European Parliament and Council 2000; Wallin *et al.* 2005). Classification schemes created or used by each member state, in particular the interpretation of 'good ecological status', shall be harmonised using the EQR values to ensure consistency across all EU states, and this must be achieved through an intercalibration process.

It appears to have been assumed that much more was known about fish communities than was actually known and that some form of ecological monitoring of this element was in place in European rivers, lakes and transitional waters. Alas, whilst some countries had schemes in place or at an advanced stage of development, mostly based on the Index of Biological Integrity (IBI) developed for rivers in the US (Karr 1981), many did not; nor did they have the necessary basic information available with which to develop such a classification.

Therefore, it was necessary for each member state to evaluate all available information on fish and, for freshwater habitats, to select material that contained inter alia the essential details on species composition, abundance and age structure (for transitional waters information on age is not required). As specified elsewhere for freshwater (Champ 2000; Kelly *et al.* 2007a), there is no established practice of systematic monitoring of fish stocks using standard procedures in Irish fresh or estuarine waters. It was immediately evident that appropriate material for the WFD was not available in Ireland. Therefore, the initial priority was to generate the necessary data for rivers, lakes and transitional waters in compliance with requirements of the WFD using the standard sampling procedures and methods proposed by the European Committee for Standardization (CEN), where applicable. The development of the necessary classification schemes could then be progressed.

The following account provides a synopsis of the work completed to date in Ireland for the fisheries aspects of the WFD. Current advances have been made possible principally through the mechanism of specifically funded projects in respect of rivers, lakes and transitional waters;

further progress has been achieved with the commencement of the surveillance-monitoring (SM) programme and through participation in the intercalibration process.

CONSIDERATION OF FISH COMMUNITIES IN IRISH WATERS

Guidance on ecological classification and EQRs is provided in WFD Common Implementation Strategy guidance document no. 13 (European Commission 2003). A prerequisite for any fish-based, WFD-compliant classification scheme for Ireland is the consideration of the composition and origins of the unique ichtyofauna of this island (ecoregion 17) in order to define 'reference conditions' in terms of the fish community. Went and Kennedy (1976) compiled a *List of Irish fishes*, containing an outline of the various fish species reported from fresh and marine waters of this island at that time. The species occurring in Irish freshwaters today are given in Table 1, and discussions on the origins and distribution of these species are presented in Kelly *et al.* (2007b; 2008). The Irish Specimen Fish Committee (ISFC) has had occasion to amend the list of species available to anglers due to the recent colonisation of Irish inshore coastal waters by

Table 1—List of freshwater fish species of Ireland.

Common name	*Scientific name*	*Status*	
Group 1			
River lamprey	*Lampetra fluviatilis* (Linnaeus 1758)	W	A
Brook lamprey	*Lampetra planeri* (Bloch 1784)	L	C/R
Sea lamprey	*Petromyzon marinus* (Linnaeus 1758)	L	C/R
Killarney shad	*Alosa fallax killarnensis* (Regan 1916)	L	R
Atlantic salmon	*Salmo salar* Linnaeus 1758	W	A
Brown trout/sea trout	*Salmo trutta* Linnaeus 1758	W	A
Rainbow trout	*Oncorhynchus mykiss* (Walbaum 1792)	L	R
Arctic char	*Salvelinus alpinus* (Linnaeus 1758)	L	R
Pollan	*Coregonus autumnalis* (Pallas 1776)	L	R
Pike	*Esox lucius* Linnaeus 1758	W	A
Carp	*Cyprinus carpio* Linnaeus 1758	L	C
Gudgeon	*Gobio gobio* (Linnaeus 1758)	W	A
Tench	*Tinca tinca* (Linnaeus 1758)	L	C
Bream	*Abramis brama* (Linnaeus 1758)	W	A
Minnow	*Phoxinus phoxinus* (Linnaeus 1758)	W	A
Rudd	*Scardinius erythrophthalmus* (Linnaeus 1758)	W	C
Roach	*Rutilus rutilus* (Linnaeus 1758)	W	C
Dace	*Leuciscus leuciscus* (Linnaeus 1758)	L	R
Chub	*Leuciscus cephalus* (Linnaeus 1758)	L	R
Stoneloach	*Noemacheilus barbatulus* (Linnaeus 1758)	W	A
European eel	*Anguilla anguilla* (Linnaeus 1758)	W	A
Three-spined stickleback	*Gasterosteus aculeatus* Linnaeus 1758	W	A
Ten-spined stickleback	*Pungitius pungitius* (Linnaeus 1758)	L	C
Perch	*Perca fluviatilis* Linnaeus 1758	W	A
Group 2			
Twaite shad	*Alosa fallax* (Lacépède 1803)	L	R
Smelt	*Osmerus eperlanus* (Linnaeus 1758)	L	R
Group 3			
Allis shad	*Alosa alosa* (Linnaeus 1758)	L	R
Sturgeon	*Acipenser sturio* (Linnaeus 1758)	L	R
Flounder	*Platichthys flesus* (Linnaeus 1758)	W	C

Group 1 = species that spend their entire life or the major part thereof in freshwater.
Group 2 = species that enter freshwater to spawn near the upstream limit of tidal influence.
Group 3 = species that may enter freshwater for variable periods but principally occur in marine or estuarine waters.
Native species are in bold type; A = abundant; C = common; L = local; R = rare; W = widespread.

golden grey mullet (*Liza aurata*) and gilthead bream (*Sparus aurata*) (Fahy *et al.* 2005; ISFC 2005; 2006).

IRISH FRESHWATER FISH

Ireland has a depauperate freshwater fish community (only 29 species) compared with the rest of Europe (FAME CONSORTIUM 2004) and with Britain (Maitland and Campbell 1992). Trout, salmon and eel are ubiquitous in Ireland and occur in all waters to which they have been able to gain access. Irish freshwaters contain only eleven truly native fish species, comprising four salmonids, European eel, one shad, two sticklebacks and three lampreys. Therefore, the native fish community of Irish freshwaters, in the absence of anthropogenic influence, is one dominated by salmonids, including at some lake sites the glacial relicts Arctic char (*Salvelinus alpinus*) and pollan (*Coregonus autumnalis*).

The Irish fish fauna and the development of an ecological quality index

High species richness is an advantage in the development of a biological quality index (e.g. IBI; Karr 1981); however, Joy and Death (2000) successfully correlated a limited fish species composition with habitat quality. It is considered possible that the different tolerances displayed by the various elements of the Irish ichthyofauna to physico-chemical and environmental pressures could facilitate the development of an index, despite the restricted species variability (Kelly *et al.* 2007b).

Developments in Ireland towards delivery of fish-classification schemes for the WFD

Since 2000 considerable progress has been achieved in respect of the fish communities in Irish rivers, lakes and transitional waters and of the various requirements of the WFD. Resources were provided under the EU Environmental Research, Technological Development and Innovation (ERTDI) Programme 2000–2006 (Kelly *et al.* 2007b) for river fish investigations; the lakes research was facilitated through the INTERREG IIIa programme, which funded the North South Shared Aquatic Resources (NS SHARE) project.

More recently, the Marine Ecological Tools for Reference, Intercalibration and Classification (METRIC) project, financed through the Science, Technology, Research and Innovation for the Environment (STRIVE) Programme 2007–2013, was designed to support the Irish role in the EU intercalibration process for the assessment of ecological quality and to implement the WFD in transitional and coastal (TraC) waters (Cusack *et al.* 2008). The initiation of the WFD national monitoring programme (EPA 2006), and specifically SM for fish, has resulted in the expansion of the project-generated data sets and facilitated further understanding of the complexities involved in this demanding process.

Implementation of the WFD in Ireland has progressed in close cooperation with environmental and fisheries agencies in the adjoining jurisdictions through the aforementioned NS SHARE project, the North–South Technical Advisory Group, the UK Technical Advisory Group and the UK–Republic of Ireland WFD Marine Task Team. Progress has also been achieved internationally through the intercalibration process in which Ireland (north and south) and Great Britain are participating with Scandinavian countries through the Northern Geographical Intercalibration Group (NGIG) for both rivers and lakes (Jepsen and Pont 2007). Ireland participates with Belgium, Denmark, France, Germany, the Netherlands, Norway, Portugal, Spain and the Basque Region, Sweden and the UK in the North-East Atlantic Geographical Intercalibration Group (NEA-GIG) with respect to TraC waters.

MONITORING FOR THE WFD

In accordance with legislation (Statutory Instrument No. 722 of 2003), the Environmental Protection Agency (EPA) specified the monitoring that was to take place, as well as the locations of the monitoring. The national programme was scheduled to commence in 2007 and thereafter to proceed on a three-year rolling basis, with the first phase due for completion in 2009 (EPA 2006). The Irish legislation specifies that all ecological elements must be monitored at all locations identified for SM. The Central Fisheries Board (CFB), the national semi-state agency with primary responsibility for freshwater and certain marine fishes, was assigned the responsibility of delivering the fish-monitoring requirements for the WFD. Specific exchequer resources were allocated to facilitate this work. The CFB, together with the Regional Fisheries Boards, the agencies responsible for protection, management and development of fisheries at regional level, is carrying out the SM programme for fish, working in close association with angling clubs and riparian and fishery owners. Interim reports are posted on the CFB's WFD website as this work progresses (CFB 2009a).

RIVER (LOTIC) FISH COMMUNITIES

THE RELATIONSHIP BETWEEN FISH STOCKS AND THE EPA QUALITY RATING (Q-VALUE)

Fish-stock assessment specifically for the WFD commenced in 2001 when funding became available through the ERTDI 2000-MS-4-M1 project to investigate the relationship between river fish stocks, EPA ecological quality ratings (Q-values), environmental factors and the degree of eutrophication.

The species composition, number and age structure of fish populations that occur in any river varies from location to location (spatial), as well as seasonally and annually (temporal). A variety of physical, chemical and biological factors influence this variability (Huet 1959; Hynes 1970; Karr 1981; Fausch *et al.* 1984; 1990). Using the river quality rating scheme, the EPA found that there was a pronounced deterioration in water quality over many years, with particular implications for survival of the salmonid fish community (McGarrigle 1998; Champ 2000). Unfortunately, quantitative fish data were not available, and it was considered desirable for the purpose of the WFD to demonstrate a relationship, independently of hydromorphological and river-habitat influences, between the fish community and water quality.

Therefore, the primary aims of the study were to assess the impact of water quality on fish stocks in rivers, as evidenced by the EPA's Q-value rating; to establish if a relationship exists between fish and quality ratings by investigating fish species composition and abundance at sites of varying Q-values (Q1 to Q5); to assess the feasibility of using fish assemblages as biological indicators of water quality in Irish rivers; and to develop a predictive model for fish based on Q-values that would have application in the context of the WFD (Kelly *et al.* 2007b).

Fish-stock assessment

Electric fishing has proven to be the most comprehensive and effective single method for collecting fish in streams (Barbour *et al.* 1999), and this was the method of choice for rivers in this project. The technique complied with CEN guidance for fish-stock assessment in wadable rivers (CEN 2003). Fish stocks were only assessed in wadable stretches (depth < 0.7m) or where the depth was < 1.5m (electric fishing by boat). A draft protocol was compiled (Kelly 2001), setting out the methodology for electric-fishing surveys in rivers and specifying the ancillary information to be collected, in order to satisfy obligatory WFD requirements.

The 2000-MS-4-M1 study compiled information on fish populations at over 500 locations in first- to sixth-order streams. Investigations were therefore mostly conducted in small to medium rivers across the full range of Q-values at elevations ranging from 4.2 to 263m. Only ten sites were streams of order five or six.

Fish and river water quality

The study established that there is a relationship between fish community composition and water-quality rating (Q-values). Non-salmonids dominate the fish community at poor-quality sites (Q2–3) but decrease to < 10% of the fish population at high-quality sites (Q4–5 and Q5), whereas salmonids dominate the community at high-quality sites and decrease to < 20% at poor-quality sites (Kelly *et al.* 2007b). It was statistically possible to separate a number of fish groups in relation to Q-values. These authors demonstrated that three metrics—percentage composition of total salmonids, percentage composition of 1+ salmonids and older, and abundance of salmonids 1+ and older—statistically segregated fish into five Q-value groups. A fourth metric, abundance of 1+ salmon and older, successfully separated the high/good and good/moderate boundaries for the WFD. Separation of the good/moderate boundary (Q4/Q3–4) is particularly important, but this segregation is only applicable to locations downstream of impassable barriers to which salmon have access.

Predicting fish community from water quality

Through the use of the fish community data generated by the project, a predictive model was developed, using the reference-condition approach, for fish in rivers (Kelly *et al.* 2007b). All sites achieving a Q-value of Q4–5 and Q5 were considered high-quality or possible reference sites. Two models were developed: one for sites with barriers present downstream (includes sites without barriers); and one for sites without barriers present downstream. The latter model assessment indicated the percentage of sites assigned correctly to the bio-groups and showed that the distribution of reference-site scores was similar to many published RIVPACS (River Invertebrate Prediction and Classification System) and AUSRIVAS (Australian River Assessment System) models produced in the UK, Australia and New Zealand using fish and invertebrates (Smith *et al.* 1999; Wright *et al.* 2000; Joy and Death 2002; 2003), suggesting that the model produced for the project is robust and up to the standard of other similar models in use worldwide.

Whilst the correlation with Q-value scores was strong and positive, there was no significant difference between the reference sites and the Q3–4 sites. Also, the analyses showed that the strongest influence on the fish community at any location was the presence of a barrier downstream, and a number of reference sites may be influenced by restricted fish passage, possibly negating their reference status (Kelly *et al.* 2007b).

Project database

The project delivered an extensive and immensely valuable database for river habitats, incorporating physical and environmental factors and fish community composition. Though this database is comprehensive, the authors recommend that it should be expanded; nonetheless, it provides the foundation on which to develop a WFD-compliant classification tool for Irish rivers. The database was also scrutinised further to check more thoroughly for pressures on fish, such as barriers downstream, abstraction impacts, drainage, forestry, urbanisation and intensive agriculture. Physico-chemistry and other biological elements are influenced entirely by the catchment area upstream, whereas fish communities reflect pressures downstream and upstream. Consultations were held with fishery colleagues using site photographs showing in-stream and riparian habitat to obtain consensus on actual status (expert opinion) based on fish community, as against ecological status based on macroinvertebrates, as was previously the case. These details were then submitted to the National Technical Coordination Group for inclusion in and development of the draft river basin management plans (RBMPs). Thus, the database is particularly valuable nationally, and it was also provided, following reformatting, for incorporation and testing in models developed in Sweden (VIX) and Finland (FIFI), and for combination with similar material from across Europe for further testing of an International Common Metric (ICM) (Jepsen and Pont 2007).

MONITORING RIVERS FOR WFD

The EPA monitoring programme (EPA 2006) identifies all river locations in Ireland at which monitoring is to take place, and the first three-year cycle of monitoring was scheduled to commence in 2007 and to be completed in 2009. Unfortunately, it was not possible to initiate the river fish monitoring in 2007. Consequently, this challenging task was rescheduled by the CFB for completion within two years. SM of river fish communities commenced in 2008, for which specific resources were allocated by the exchequer through the Department of Communications and Natural Resources.

In 2008 climatic factors—frequent heavy rain and floods—hampered the sampling programme; however, fish surveys were completed at 83 river sites. The data, having been compiled in the appropriate format, have been submitted for analysis in the intercalibration process. A further 100 SM river sites are scheduled for examination in 2009, and this will complete the entire programme planned for 2007–9.

LAKES (LENTIC) FISH COMMUNITIES

NS SHARE FISH IN LAKES PROJECT

Implementation of the WFD on the island of Ireland provided the opportunity for cooperation, North and South, on the sustainable management of the shared aquatic resource. A specific project, the NS SHARE project, was set up to deliver the objectives of the WFD within the NS SHARE river basin district (RBD) between August 2004 and December 2008.

An important part of the NS SHARE project was the development of ecological-classification tools for lake fish populations, conducted through the Fish in Lakes (FIL) project. As project partners, the primary Fisheries Agencies in both jurisdictions (North and South) cooperated in the execution and delivery of this specific part of the NS SHARE project, thereby ensuring standardisation of methodologies and uniformity of approach throughout ecoregion 17, having particular regard to the unique aspects of fish population assemblages therein.

As was the case for river data, archival information on fish stocks in lakes was fragmented and dated, and did not comply with the compulsory requirements of the WFD (Annex V). Again, no national monitoring programme existed. The NS SHARE project provided the opportunity to generate data of sufficient quality for baseline reporting and ground truthing for some of the waters located in the NS SHARE portion of ecoregion 17. Sampling procedures for fish in lakes were reviewed (Kelly *et al.* 2006), and a suite of methods for assessing fish stocks were tested in lakes of varying typologies (Kelly *et al.* 2007a). New European standards for fish sampling in lakes (CEN 2005a; 2005b) ultimately determined the sampling protocol and methodology developed in the course of this project (Kelly *et al.* 2008). The developed technique was then applied in 2006 to initiate the lakes-monitoring programme in both jurisdictions, as required by

the WFD. In total, the project created fish data sets for 83 lakes (53 in the Republic of Ireland and 30 in Northern Ireland), ranging in size from 3 to 2,253ha.

Assessment of lake fish stock using WFD-compliant methods

Following the review and testing of lake fish-survey methods, statistical analysis showed it was possible to reduce the gill-netting effort (Kelly *et al.* 2007a). Because of high stock densities and concerns about damage to fish, particularly in managed salmonid fisheries and in lakes with glacial relict fish communities, a standard sampling protocol for surveying lakes was established in which the multi-mesh, stratified gill-netting procedure in the European standard protocols (CEN 2005b) was reduced by 50% (Kelly *et al.* 2007a). Under this protocol, paired fyke nets are used to supplement the gill-netting effort, and in high-alkalinity lakes the netting effort is supplemented with gill nets of larger mesh size (60–75mm knot to knot).

Bathymetric maps

Depth contours were used wherever they were available (Taylor *et al.* 2006), and bathymetric surveys were carried out in lakes where details of the depth contours were required. Bathymetry maps were generated for 51 lakes in the NS SHARE area (Kelly *et al.* 2008).

Environmental variables

Environmental variables were collected from the middle of each lake during the fish-stock survey. Winter water samples were collected, and total P (TP) and alkalinity data from these results were substituted for summer/autumn values for these parameters. Fish, environmental and abiotic data for all the lakes were compiled into a single 'metrics' table. Maximum TP was the only pressure indicator available, and trophic status was allocated according to a modified Organisation for Economic Co-operation and Development classification.

Species composition, distribution, abundance and richness

Overall, a total of seventeen species of fish and two types of hybrids were recorded from the 83 lakes (sea trout are treated as a separate 'species' of trout). Eels were the most common species, followed by perch, brown trout, pike, roach, roach × bream hybrid, bream, char, three-spined stickleback and salmon. Rudd, sea trout, gudgeon, roach × rudd hybrid, tench, flounder, minnow, rainbow trout and pollan were present in less than 10% of the lakes surveyed. Species-distribution maps, an analysis of species richness and trophic status, details of species distribution by depth, and age and growth analyses are presented in Kelly *et al.* (2008).

Many fish species have been introduced to Irish waterbodies over the past 700 years, and are now naturalised in many waters, but they continue to appear in new catchments due to illegal translocation (Kelly *et al.* 2008). In the geographical area of the NS SHARE RBD, covering the north-west, the north and the north-central midlands, the native species depict a north-south and west-east spread, whereas non-native, introduced cyprinid species occur in just a few lakes in the north-west but are more plentiful and widely distributed in lakes to the east and south. Pike was discovered outside the previously known area of its distribution, in a cluster of small lakes in south Donegal; perch also occurred in some of these, and roach was present in two. Trout populations, previously known to occur in these lakes, have been displaced by the introduced species since the 1980s.

Fish in Lakes tool

The classification tool for fish in lakes follows a predictive multimetric approach (Kelly *et al.* 2008). The traditional multimetric approach combines indicators, or metrics, reflecting elements of biological integrity (e.g. percentage of piscivore species), into a single index value; however, the classification tool for fish in lakes deviates from this approach. The individual metrics were not scored and combined in the manner employed by Karr (1981). Instead, classification rules were developed for each fish type, and each lake was then allocated to an ecological quality class using discriminant analysis. A metric is defined as 'a characteristic (attribute) of the biota that changes in some predictable way with increases in human disturbance' (CEN 2004). Details of the tool development are provided in Kelly *et al.* (2008).

Survey results from the 77 lakes were assigned to ecological-status classes using the FIL tool; 15 lakes were classified as high, 37 as good, 16 as moderate, 4 as poor and 5 as bad (Kelly *et al.* 2008). The ecological status of the lakes reflected a geographical trend from high and good in the north-west (less-populated, mountainous area) to poor and bad in the east and south-east (moderately populated, agricultural, calcareous lowland) (Fig. 1). The FIL tool identified 11 reference lakes on the basis of having no, or only very minor,

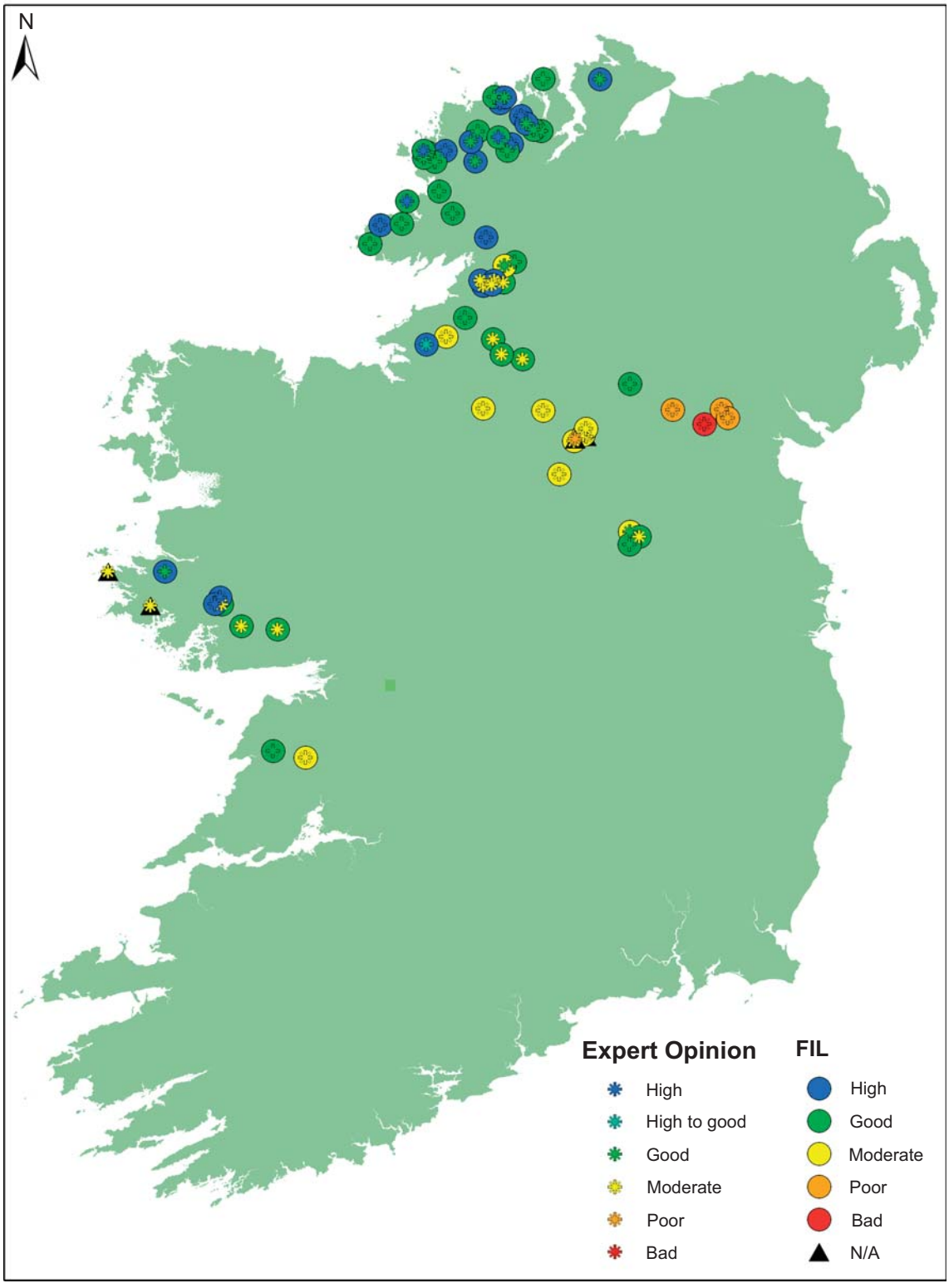

Fig. 1—Distribution of lakes surveyed in NS SHARE project, and subsequent additions resulting from surveillance monitoring in 2007 and 2008.

Table 2—Reference conditions for Irish lakes depending on temporal baseline and fish community, according to expert opinion as defined in Kelly *et al*. (2008).

Period	*Fish community*
Immediately post-glacial	Naturally colonised species only, all with euryhaline ancestry. These are salmon, trout, char, shads*, pollan**, eel, sticklebacks, smelt***, flounder**** and lampreys.
Latter end of twelfth century to 1900	Pike, perch and cyprinids introduced at various times since 1160. Precise dates unknown for most species. Carp and tench repeatedly imported during seventeenth century. In this period cyprinids were restricted to local sites and generally did not impact on other fish. Pike, perch, rudd and bream were widespread and naturalised (in lowland systems) by 1900. Roach and dace released into Munster Blackwater in 1889 and confined to that system until 1950, except for transfer of roach to two enclosed waters in Northern Ireland.
1900 to 1950	Roach stocked into pond in Co. Tyrone in 1905 and to single site in the Erne system in the 1930s. These escaped to Erne system *c.*1960, spread throughout that system and translocated into the Neagh–Bann system, Shannon, Lough Corrib and many other waters from 1970s onwards. Char disappeared from L. Neagh and L. Erne at beginning of this period. Last records of char from L. Owel and L. Ennell are from 1925.
1950	Native fish species, including char and brown trout (including distinct trout varieties), dominated stocks. Pollan present in commercially viable fisheries—L. Neagh, Lower L. Erne and Shannon lakes (L. Derg and L. Ree). Small population subsequently discovered in L. Allen in 2006. Roach widely distributed post-1970; also dace, but to a lesser degree. State management of inland fisheries commenced in 1951 in Republic of Ireland (Inland Fisheries Trust) and in 1960s in Northern Ireland (Department of Agriculture and Rural Development) for recreation and tourism revenue generation. Agricultural soils were nutrient deficient in 1950; soil testing and planned programme of soil fertilisation had just commenced. Most of Ireland's forest area has been established since 1950. Major land-drainage schemes came into effect, mostly from 1950 onwards, following Arterial Drainage Act 1945 (Republic of Ireland) and Drainage Act 1947 (Northern Ireland). Also hydropower developments (Shannon 1929; Liffey 1943; Erne 1950; Lee 1957).
2000	Post-2000, only lakes in Donegal, west Mayo, west Galway and west and south-west Kerry, and isolated, upland lakes elsewhere, remain free of non-native species. Lakes in this grouping are generally restricted to low-alkalinity typology. Char disappeared post-1970 from various lakes, including Cloonsneachta, Gortglass, Naback, Corrib and Conn. Chub was released into River Inny, Co. Westmeath, in 2001.

* Only one lake population in Ireland (L. Leane; Killarney shad).

** Pollan known to occur only in L. Neagh, Lower L. Erne, L. Derg and L. Ree; population discovered in L. Allen in 2006. This species is not expected elsewhere in Ireland.

*** No lake populations in Ireland; this species occurs in a few estuaries only.

**** Flounder occur in some lakes some distance from the sea, e.g. L. Leane and L. Neagh.

physico-chemical and hydromorphological pressures. When non-native fish species are added as a pressure, only 4 lakes remain in reference state if a post-glacial reference condition is applied. Zoogeographic factors restrict the scope of classification schemes for Irish rivers and lakes based on fish assemblages. Therefore, when considering the selection of appropriate reference conditions, it may be necessary to segregate lakes spatially because some parts of ecoregion 17 remain free of non-native fish introductions. Proposals regarding reference conditions are presented in Table 2.

The FIL tool classified the group of lakes in south Donegal referred to above as being of high and good quality (Fig. 1). Clearly, this is erroneous (European Commission 2003) as the fish community in these lakes has been dramatically changed in terms of replacement of native trout by pike, perch and roach in the recent past. The lakes, misclassified by the FIL tool, were reclassified based on expert opinion, and the resulting classification was provided to the WFD National Technical Coordination Group for inclusion in the draft RBMPs.

SURVEILLANCE MONITORING OF LAKES 2007 AND 2008

SM of lakes for the NS SHARE programme commenced in 2006, when 53 lakes were surveyed in total. During 2007 it was possible to sample only 15 lakes. In 2008 a total of 31 lakes (32 waterbodies, Lough Corrib being split into two) were monitored. Of these, 6 were repeat surveys, thus providing a better baseline for and understanding of their fish communities. Sampling of 26 lakes was planned for 2009 (20 new and 6 that have previously been surveyed with the WFD protocol). Very large numbers of fish were sampled and processed in the course of these surveys. Preliminary reports were placed on the CFB's WFD website (CFB 2009a), together with an end-of-year report. The geographical distribution of the 93 lakes in the data set in 2008, together with an indication of the species-richness encountered in each lake, is presented in Fig. 2.

TRANSITIONAL AND COASTAL WATERS

In the period 2000–6 the CFB, working with the seven Regional Fisheries Boards, initiated a national programme dedicated to the compilation of a baseline on fish species composition and abundance in transitional waters. Initially, the aim was to investigate the status of important angling species, such as flounder, bass and mullet (Fahy *et al.* 2000). The CFB had also been commissioned, by the National Parks and Wildlife Service (NPWS) within the Department of Environment, Heritage and Local Government, to investigate the status of shad, smelt and lamprey, which, along with salmon, constitute fish species of significance in the context of the Habitats Directive (92/43/EEC) (King and Linnane 2004; King and Roche 2008). Irish legislation (Statutory Instrument No. 94 of 1997; Government of Ireland 1997) places an obligation on fisheries, jointly with the NPWS, to carry out surveillance on species listed in Annex II of the Habitats Directive. In the course of these surveys, inventories of non-target fish species have been compiled. Such information is relevant to monitoring for the WFD. The data collected in the early studies provide essential information on fish communities and species abundance (obligatory requirements) in transitional waters for the WFD.

SAMPLING METHODS FOR FISH IN TRANSITIONAL WATERS

When the CFB commenced its estuarine sampling programme in 2000, beach seining was the sole sampling strategy employed. Subsequently, the sampling approach was expanded, and various fish-capture techniques were tested, including seine netting, gill netting, fyke netting and beam trawling (CFB 2009b).

METRIC PROJECT

In 2006 the CFB, in conjunction with the Marine Institute, undertook an additional series of fish investigations in transitional waters through the METRIC project. The study was designed to develop protocols and metrics for phytoplankton, higher plants, benthic invertebrates and fish for implementing the WFD in Irish TraC waters. The CFB undertook the fish component, which was specifically designed to generate and contribute data to the NEA-GIG intercalibration exercise and to contribute to the development of fish metrics being coordinated by the Belgian and UK fish teams (Cusack *et al.* 2008).

Fish-stock surveys were carried out in seventeen previously unsampled transitional waterbodies (CFB 2009b) as part of the METRIC project. Seine nets and fyke nets were the main fish-capture methods used, but the project demonstrated the value of including beam trawls as an additional sampling apparatus. The METRIC

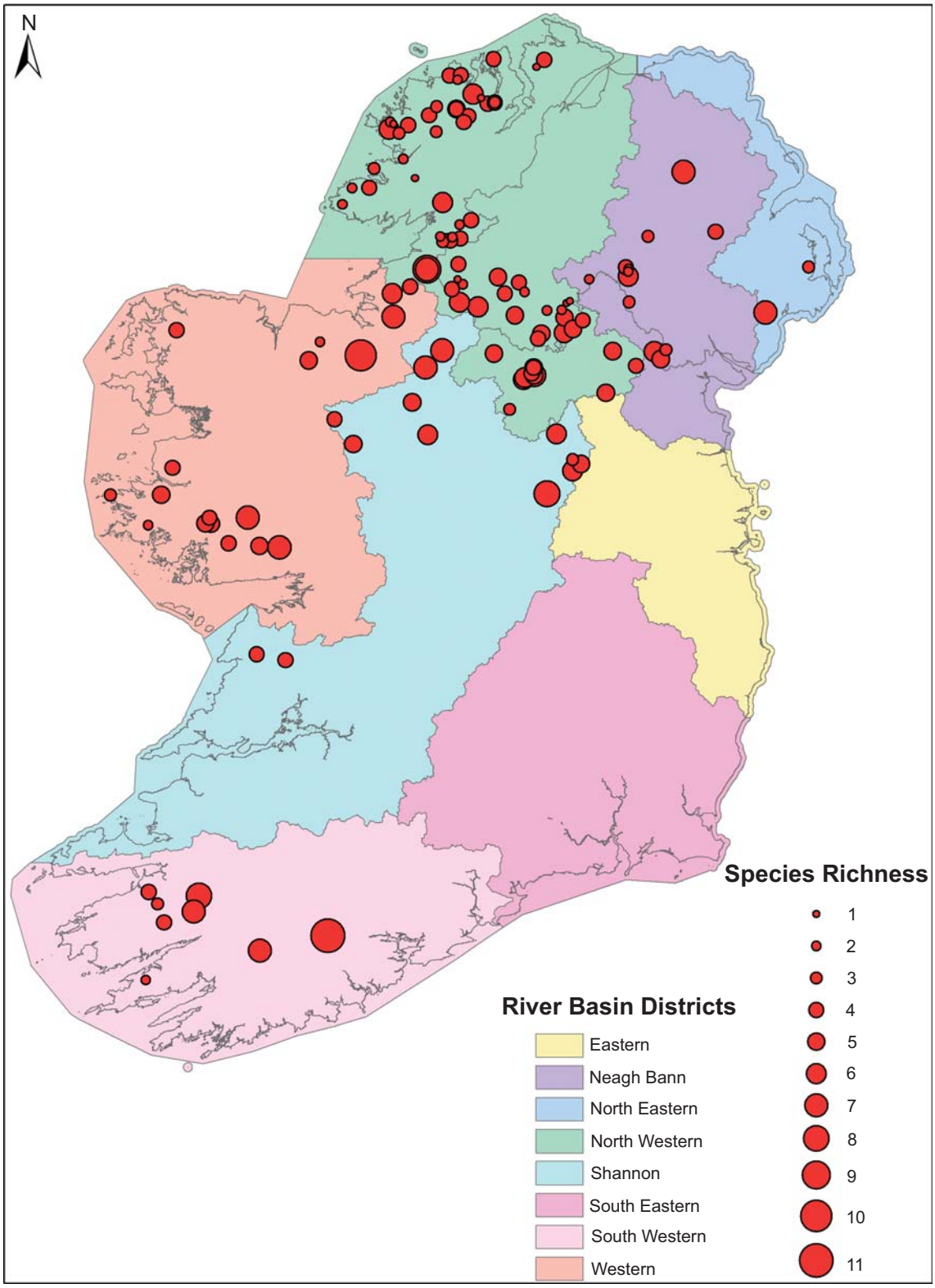

Fig. 2—Fish species richness in Irish lakes studied for WFD, 2005 to 2008.

project demonstrated inter alia the value of using a suite of fishing gear (e.g. seine nets, fyke nets and beam trawls) in a multi-method approach: the range of sampling gear added to the taxa-diversity listings of many of the estuaries studied; it demonstrated the suitability of different sampling gear to sample different habitats; and it highlighted the need for 'fit-for-purpose' sampling of estuarine areas with different habitat characteristics. The survey method is designed to sample fish in a series of littoral and open water sites characteristic of the estuary under study. Nets are set in all tidal conditions, depending on the nature of the site and the flow conditions, as some sites are only accessible at particular stages of the tide.

The METRIC project doubled the number of estuaries for which the requisite data are now available, greatly expanding the national database (CFB 2009b).

WFD MONITORING IN TRANSITIONAL WATERS

The extent of individual Irish estuaries was delineated by the EPA, showing that many of the larger estuaries have been segmented into 'waterbodies', and an SM schedule was compiled (EPA 2006). Monitoring commenced in autumn 2007 when the series of waterbodies comprising the Suir–Nore–Barrow–Waterford Harbour estuary complex was surveyed by the CFB, in collaboration with the Southern Regional Fisheries Board (CFB 2008). The logistics of survey timing, site selection and sampling gears were consistent with protocols developed by the NEA-GIG, of which the CFB is a member (CFB 2009a). The WFD requires the collection of information on the composition and abundance of fish species in transitional waters, as well as reporting on the status of indicator species. Of particular significance in this latter category are the diadromous or migratory fish species, such as eel, salmon, sea trout, lamprey and shad. The waterbodies surveyed in 2007 comprise part of the series of Special Areas of Conservation (SACs) designated nationally for salmon, lamprey and shad. During the present survey eels were regularly taken in fyke nets, and smelt, considered an indicator of good water quality, were regularly taken in beach seines. The nursery function of the estuary was clearly indicated by the profusion of juvenile and immature fish of a range of species taken within the various waters surveyed, including flounder, pollack, mullet and bass in sizeable numbers at particular sites (CFB 2008).

In 2008, with the assistance of the Regional Fisheries Boards, the CFB surveyed 42 transitional waters: 65 fish species were encountered, and 66,000 fish were recorded. The sampling apparatus used in transitional waters is not overly damaging to the fish captured, the majority of which can be returned relatively unharmed to the water. All available material compiled to date on Irish estuaries by the Central and Regional Fisheries Boards has been delivered in the appropriate format to the intercalibration process.

INTERCALIBRATION

RIVERS

A European Fish Index (EFI) was developed in 2004 within the EU research and development project FAME (Development, Evaluation and Implementation of a Standardised Fish-based Assessment Method for the Ecological Status of European Rivers), which is based on the concept of the IBI (Karr 1981). FAME was a project under the fifth Framework Programme, and it consisted of a consortium of researchers from twelve countries (Austria, Belgium, France, Germany, Greece, Lithuania, Poland, Portugal, Spain, Sweden, the Netherlands and the UK; FAME CONSORTIUM 2004). However, the fish community in Ireland is depauperate relative to Britain and even more so relative to the European mainland; consequently, a single pan-European classification scheme may not be possible. Initial application of the EFI in Ireland (ecoregion 17) as part of the NS SHARE project was found to be problematic (Kelly *et al.* in preparation), and this has since been shown to be the case elsewhere (Jepsen and Pont 2007). It is considered unlikely that the Environmental Agency (EA) in Britain will adopt the EFI as the classification tool for UK rivers, but will rely instead on a modification of a scheme for river fish classification currently being completed. The EA is developing a new, WFD-compliant Fisheries Classification Scheme 2 (FCS2) model, and a new desk project (WFD68) has been initiated through the Scotland and Northern Ireland Forum for Environmental Research to prepare and process the river fish data for a new tool for river fish classification for the Republic of Ireland, Northern Ireland and Scotland, based on the EA's FCS2 model. Several delegates at the third River Fish Intercalibration Meeting, held in March 2007 in Rotterdam, the Netherlands, expressed the opinion that salmonids (mostly trout) weighted the EFI excessively towards good status whilst the presence of other species downgraded the status, which presents significant problems where cyprinids and other

species (or non-salmonids) are native. The EFI project has now been extended to encompass all of Europe (Schmutz 2007), and it is hoped that the new model (EFI+) will be refined to resolve these difficulties.

The Irish river fish database was also provided for processing in Swedish and Finnish models as part of a pilot regional (NGIG) intercalibration exercise (Beier *et al.* 2007). The database was again amended following the River Fish Intercalibration Meeting in 2008, and additional pressure data, including barrier data, were calculated. The new data from the 2008 fish-monitoring programme have been added to this database, and have been delivered to the NGIG for further testing in regional models (Swedish and Finnish) to check the more comprehensive database for regional intercalibration and to evaluate these models for possible application in ecoregion 17. An amended database has also been forwarded to CEMAGREF for inclusion and testing in the development of the common intercalibration metric (CIM), through the EFI+ project.

LAKES

The NS SHARE programme was especially beneficial in assisting both jurisdictions in ecoregion 17 to create an extremely valuable database of fish in lakes, most of these lakes having never been previously surveyed. The joint database was expanded in the Republic of Ireland by the WFD fish-monitoring programme, and it currently contains the essential information for 120 lakes (130 fishing occasions). All lake typologies are represented in the database, but several typologies are populated by too few examples (Fig. 3). Likewise, within each typology, gaps exist in the trophic-status classes—some classes have no lakes, and others have few.

The fish-classification tool for lakes currently in place, the FIL tool, whilst compliant with many of the WFD requirements, is not based on reference fish communities, and this is a critical aspect of the EQR on which lake classification is to be based. The tool needs to be further developed to make it compliant in this important respect. However, statistical methods used in the FCS2 model for rivers might also have application in lakes. It has been proposed that research should be progressed in this area using data sets from the Republic of Ireland, Northern Ireland and Scotland, thereby providing a possible alternative to the current lakes model.

The combined Republic of Ireland/Northern Ireland lakes database has been prepared and submitted for analysis in the Swedish (EQR8) and Finnish (EQR4) models as part of the NGIG regional intercalibration exercise. The current ecoregion 17 data set is significant in the context of current research as it is now amongst the largest WFD-compliant data sets available in Europe. The material for the NGIG study is also being prepared for submission to CEMAGREF for inclusion in the EU CIM-development process.

TRANSITIONAL WATERS

The intercalibration process for transitional waters has been centred on the standardisation of fish-sampling methods and the development of a standard operating protocol with regard to their use.

In October 2006, as part of the METRIC programme, representatives from five member states participated in a fish-sampling workshop convened by the CFB at locations in Co. Donegal. Further comparative work for beach seines and fyke nets took place at Newport, Co.

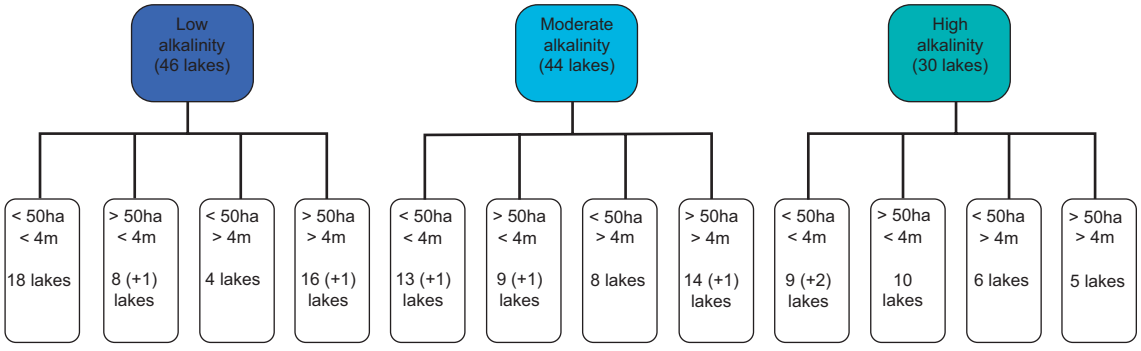

Fig. 3—Classification of lakes surveyed in ecoregion 17 according to typology (from NS SHARE project and from surveillance monitoring in 2007 and 2008); number in brackets indicates a repeat survey.

Mayo. The CFB also participated in a second sampling-gear intercalibration exercise, hosted by France in the Gironde estuary in September 2007, and this exercise contributed to streamlining the Irish SM exercise in October 2007 (CFB 2009b).

These workshops and comparative exercises proved particularly informative. Sampling apparatus of similar type (seines, fykes, beam trawls) used by different countries showed inconsistencies in mesh size, net length, net design and weights of lead ropes. However, similar length ranges were recorded between nets for the most common fish species within each gear type. Species composition was, in general, relatively similar, both between and across the three gear types (Cusack *et al.* 2008). The need for standardisation of sampling over a tidal cycle was identified.

The considerable amount of data compiled during the METRIC project and thereafter in the CFB national SM programme (2007 and 2008) was submitted to the Northern Ireland Environment Agency (NIEA). This material is being formatted in 2009 to develop a classification tool, using the IBI approach, broadly based on that developed for South African waters (Harrison and Whitfield 2004). The EA in the UK developed a suite of metrics (Coates *et al.* 2007) for EQR calculation in transitional waterbodies that has also been used in the Republic of Ireland. The combined data sets were also shared with EU partners in the NEA-GIG forum, and they were used for cross-referencing and intercalibration in the British and Belgian metric systems designed to generate EQRs. This transnational approach was developed to investigate the feasibility of a single suite of metrics for EQR calculation.

CONCLUSIONS

The three main research projects discussed above developed WFD-compliant sampling protocols, using, where applicable, prescribed (CEN) standard methods, for each of the surface water categories—rivers, lakes and transitional waters. In each category these projects also initiated baseline investigations using standard techniques (suites of capture apparatus used in lakes and estuaries) for fish capture that are comparable with methodologies and protocols being used in similar circumstances elsewhere in Europe.

Using the sampling methods and protocols developed, the research projects completed to date for rivers, lakes and transitional waters have generated comprehensive databases for each of the three surface water categories. These data sets are important at national, regional and European level in the context of the draft RBMPs, contributing to the development of ecological-classification tools for fish and facilitating the intercalibration process. The rivers and lakes databases are amongst the largest currently available in Europe.

The fish and water-quality study (2000-MS-4-M1) established that there is a relationship between fish community composition and water-quality rating (Q-values). It was statistically possible to separate a number of fish groups in relation to Q-values, and a predictive model was developed, using the reference-condition approach, for fish in rivers. Whilst the correlation with Q-values was strong and positive, there was no significant difference between the reference sites and the Q3–4 sites. The influence of barriers is thought to be responsible for the lack of differentiation in the river fish model. Therefore, more precise information is required on the effect of artificial barriers on migrating fish species, i.e. whether passage is totally prevented or only restricted for some or all species. Sites were reclassified based on hydromorphological features, using expert opinion as against EPA quality ratings, prior to inclusion in the draft RBMPs. The database is valuable nationally at regional intercalibration-group level (NGIG), and it also useful for the development of an ICM.

The NS SHARE project provided important, good-quality baseline data for lakes located in the north-western and northern portion of ecoregion 17. A standard sampling protocol for surveying lakes was established in which the CEN standard for the multi-mesh gill-netting procedure was reduced by 50%.

The technique was then applied in 2006 to initiate the lakes-monitoring programme in both jurisdictions, as required by the WFD. A number of species, including pike, perch and roach, were discovered outside their previously known area of distribution. These species had displaced native trout stocks in these waters. These impacts of translocation have been shown to be especially damaging, and they downgrade the ecological status of the waters affected. Comprehensive details on fish species distribution, community composition and species richness are now available for 130 lakes.

The FIL classification tool follows a predictive multimetric approach. In this instance classification rules were developed for each fish type, and lakes were allocated to ecological-quality

class using discriminant analysis. Although further development, testing and validation of the FIL classification tool is necessary, the analysis by Kelly *et al.* (2008) provides a platform on which to build a WFD-compliant classification tool. Additional data are required to improve the model, particularly data relating to reference lakes, but also data on other lake types and status classes; SM is contributing data to this process. However, SM is unlikely to provide sufficient data, and selective targeting of additional lakes is thought to be necessary. It was only possible to use one pressure—eutrophication as evidenced by TP—and great reliance is placed on few actual measurements of this critical parameter. The model also requires modification to capture significant change in the fish community due to biological pressures.

The current models are a 'first shot' in a development process. Therefore, a possibility exists to further develop the fish-classification schemes for Irish rivers and lakes to provide national classification tools; however, this would require resolution of the specific funding allocation. Currently, the main emphasis for rivers and lakes is placed on testing classification models developed in the UK and at regional level (Sweden and Finland) using the Irish data sets to validate their potential for use in ecoregion 17. Ireland is also contributing significantly to the intercalibration process and to the development of a CIM through the EFI+ project.

Ireland is currently working on the development of national, WFD-compliant fish-classification schemes for rivers, lakes and transitional waters. Preliminary efforts have been completed in respect of schemes for rivers and lakes, but these need additional development to fully qualify. A fish-classification scheme specifically for transitional waters in the Republic of Ireland and Northern Ireland is currently being developed by the NIEA. The equipment-intercalibration exercises for transitional waters proved immensely informative and highlighted the need for standardisation in the construction and application of sampling apparatus.

Whilst much has been achieved, it is evident that sampling methodologies need further refinement, that data sets need to be expanded and that a meaningful interpretation of 'reference condition' for fish in Ireland has to be decided in order to facilitate completion of the classification tools based on EQRs and to achieve the desired degree of harmonisation. These tasks and finalisation of the intercalibration process present the principal challenges that need to be resolved in order to enable satisfactory delivery of fish as a quality element for the WFD.

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