# Development of an Estuarine Classification Scheme for the Water Framework Directive

**R&D Technical Report E1-131/TR**

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## Phase 1&2 - Transitional Fish Component

R&D Technical Report E1-131/TR

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Website: www.environment-agency.gov.uk

ISBN 1 84432 262 9



**Dissemination Status**
Internal: Released to Regions
External: Publicly Available

**Statement of Use**
This document provides guidance to Environment Agency staff, research contractors and external agencies on the development of a classification scheme to meet the requirements of the Water Framework Directive (WFD), European Council Directive 2000/60/EC.

**Keywords**
European estuaries; fish community; fish guilds; classification; ecological status; Water Framework Directive.

**Research Contractor**
This document was produced under R&D Project E1-131 by:
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Abbeywood, London, SE2 9AQ
Tel: 020 8310 5500 Fax: 020 8311 9778

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The Environment Agency's Project Manager for R&D project E1-131 was:
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# EXECUTIVE SUMMARY

The Water Framework Directive (WFD) is to establish a framework for the protection of inland surface waters, transitional waters, coastal waters, and groundwater (European Council Directive 2000/60/EC). A key objective of the WFD is to protect, enhance, and restore all bodies of surface water, including 'Transitional Waters' (estuaries), with the aim of achieving good surface water status by 2015.

The WFD will also introduce for the first time an international commitment to assess the ecological status of transitional waters, for which fish communities are a key biological monitoring component. Within Transitional Waters five biological quality elements are to be assessed (WFD CIS 2.7, 2003). These are phytoplankton, macro-algae, angiosperms, benthic invertebrates & fish (European Council Directive, 2000). The fish quality element is to be assessed by taking account of the composition and abundance of the fish fauna.

This report describes the first two stages of the three Phase development of the Estuarine Fish Community Index (EFCI) and forms part of a study to develop a fish-based estuarine classification scheme in support of the WFD.

The EFCI described here is an ecologically based method that combines both structural and functional attributes of estuarine fish communities and integrates these to provide both a robust and sensitive method for assessing the ecological condition of estuarine systems. It is also conceptually simple, the metrics are easily measured and the overall index is straightforward and rapid to calculate.

The EFCI is also an effective communication tool for converting ecological information into an easily understood format for managers, policy makers, and the general public as a whole.

# 1. INTRODUCTION

Fish communities can be described according to a number of characteristics. They can be defined in terms of species composition and the number of taxonomic units present, the diversity of the assemblage, the abundance of individuals among the species, the biomass of the individuals and the distribution of the biomass throughout the assemblage. In addition to a taxonomic approach, other approaches such as functional guilds (e.g. trophic structure) can be used to describe community structure (Krebbs, 1985; Elliott & Dewailly, 1995; Elliott *et al*., 2002a).

Trends in one of more of these community attributes can be used to monitor the ecological functioning and 'health' of a particular ecosystem (Whitfield & Elliott, 2002). Environmental stress or degradation can also be measured by comparing one or more community traits with the 'normal' or 'natural' condition derived from a number of sites and populations (Elliott *et al*., 2002a).

More integrated measures of estuarine condition have used an approach that combines a number of fish community attributes into a single multi-metric index (e.g. Miller *et al*., 1988; Deegan *et al*., 1997; Harrison *et al*., 2000; USEPA, 2000; Goethals *et al*., 2002).

In order to gain insight into the fish faunal assemblages within an estuary, a range of monitoring techniques and sampling strategies have been developed (Elliott *et al*., 2002c). Environment Agency, Thames Region has established a monitoring programme based upon the recovery of the Thames Estuary, with the initial monitoring work based upon power station fish impingement surveys (Wheeler, 1979; Attrill *et al.,* 1998; Kirk *et al.,* 2002).

However, with the decommissioning of the Thames power stations and the need to address the data gaps caused by this single strand survey approach, a multi-method-monitoring programme was established (Colclough *et al* (2000); Colclough *et al* (2002) & Colclough pers.com).The Thames multi-method monitoring strategy has now been recognised as an example of 'European Best Practise' in establishing an estuarine fishery-monitoring programme (European Commission 2000).

The WFD defines Transitional Waters as 'bodies of surface water in the vicinity of river mouths which are partly saline in character as a result of their proximity to coastal waters but which are substantially influenced by freshwater flows' (European Council Directive, 2000). These water bodies have subsequently been defined within the United Kingdom by the UK and Irish Typology projects (UKTAG, 2003).

Within Transitional Waters five biological quality elements are to be assessed. These are phytoplankton, macro-algae, angiosperms, benthic invertebrates & fish. The fish quality element within 'transitional waters' is to be assessed by taking account of the composition and abundance of the fish fauna.

This report describes the development of a metric scoring system in order to develop an Estuarine Fish Community Index (EFCI). It is based in part on a classification scheme developed for use within South African estuaries (Harrison *et al.,* 2000) and forms part of a study to develop a fish-based estuarine classification scheme in support of the WFD.

# 2. METHODS

Following an appraisal of available classification schemes during Phase 1, along with input from a series of technical workshops (Appendix 1 & 2), it was recommended that the most suitable approach was to develop a multi-metric classification scheme (Karr, 1981), that included a variety of biological measures including 'functional guilds' (Elliott &Hemingway, 2002).

The EFCI described here is based on data that was collected within South Africa as part of a national study (Harrison *et al*., 2000) and tested against UK datasets (Appendix 5) as part of EA R&D E1-131/TR. The use of the South African datasets was key to analysing the sensitivity of the metric-scoring system as the project was unable to find any UK data of a long-term basis that utilised a multi-method-monitoring programme. It would also have been advantageous to have obtained data from an estuary that was chronically polluted and involved in a rehabilitation programme. Even the Thames estuary, UK (In: Attrill, 1998) which has recovered from severe pollution did not have the datasets necessary for such analysis (Colclough, Pers.Comm).

The approach and rationale behind the EFCI is described and where possible, related to expanding the 'normative definitions' of the WFD.

## 2.1 Fish Community Measures or Metrics

A metric is a measurable factor that represents some aspect of biological assemblage structure, function, or other community component (USEPA, 2000). The EFCI described here makes use of 14 metrics or measures that include fish community attributes such as species diversity and composition, species abundance, nursery function, and trophic integrity.

The metrics were chosen based partially on a review of measures included in other estuarine fish community indices (e.g. Miller *et al*., 1988; Deegan *et al*., 1997; Harrison *et al*., 2000; USEPA, 2000; Whitfield & Elliott, 2002) as well as their ecological relevance and ease of measurement. Where possible, both qualitative and quantitative measures were included. The 14 metrics and their expected response to environmental stress are summarised in Table 2.1.

The performance of each metric was assessed using data that was collected on the Sezela estuary in South Africa by Harrison *et al* 2000, and then tested against long term datasets from the Clyde and Forth estuaries in Scotland UK.

**Table 2.1. Ecological measures used within the Estuarine Fish Community Index and their response to environmental stress.**

| FISH COMMUNITY INDEX MEASURES | RESPONSE TO STRESS |
|---|---|
| **Species diversity and composition** | |
| 1) Total number of taxa | Reduced |
| 2) Rare/threatened species | Absent |
| 3) Exotic/introduced species | Present |
| 4) Species composition (relative to reference assemblage) | Reduced |
| **Species abundance** | |
| 5) Species relative abundance (relative to reference abundance's) | Reduced |
| 6) Number of species that make up 90% of the abundance. | Reduced |
| **Nursery function** | |
| 7) Number of estuarine resident taxa | Reduced |
| 8) Number of estuarine-dependent marine taxa | Reduced |
| 9) Relative abundance of estuarine resident taxa | Very low or very high |
| 10) Relative abundance of estuarine-dependent marine taxa | Very low or very high |
| **Trophic integrity** | |
| 11) Number of benthic invertebrate feeding taxa | Reduced |
| 12) Number of piscivorous taxa | Reduced |
| 13) Relative abundance of benthic invertebrate feeding taxa | Reduced |
| 14) Relative abundance of piscivorous taxa | Reduced |

## 2.2 Case Study 1 - Sezela Estuary

The Sezela estuary (30°25'S; 30°41'E) is a predominantly closed, medium-sized system situated on the subtropical East Coast of South Africa (Harrison *et al* 2000).

In the past, the system was subject to chronic industrial pollution and was described as the most severely polluted estuary in KwaZulu-Natal (Begg, 1978). Early biological surveys of the system revealed that the estuary was essentially devoid of fish life (Begg, 1984a). However, as a result of rehabilitation efforts, improvements in both the overall water quality and in the biota of the estuary were reported (Ramm *et al*., 1987).

Over the period 1984 to 2002, a series of five surveys of the fish fauna of the Sezela estuary were undertaken. Although each survey had different aims and objectives, the sampling methodologies, as well as the sampling team from the Council for Scientific and Industrial Research (CSIR), were relatively consistent. Furthermore, temporal (seasonal) variation was also accounted for in that each survey was generally conducted over spring/summer.

## 2.3 Case Study 2 – Clyde and Forth Estuaries

The Clyde Estuary, on the West Coast of Scotland (55°60'N; 04°34'W), is a relatively large, partially mixed, mesotidal system comprising of intertidal sands and muds [Type TW 1 (UKTAG 2003)]. It serves the Port of Glasgow and the surrounding conurbation of the Strathclyde Region with the estuary providing a focus in the 19th Century for the industrialisation and shipbuilding of Western Scotland.

The effects of such anthropogenic pressures eventually resulted in poor water quality and led to the end of the salmon run within the catchment. The decline of industry during the late 20th Century along with improvements to Sewage Treatment works has led to an overall improvement to Water Quality (Myles O'Reilly, Pers.Comm). This has been monitored by the Scottish Environmental Protection Agency (SEPA), who along with it's predecessors has been involved in a 25 year survey programme monitoring the recovery of the estuary culminating in the return of the salmon run to the catchment (Myles O'Reilly, Pers.Comm).

The Forth Estuary is to be found on the East Coast of Scotland (56°00'N; 03°00'W) and like the Clyde is a relatively large, partially mixed, mesotidal system comprising of intertidal sands and muds [Type TW 1 (UKTAG 2003)]. Unlike the Clyde, the Forth has never suffered from the same level of anthropogenic pressures (Myles O'Reilly, Pers.Comm) and as such never lost it's salmon run. It has again been subject to a long term monitoring programme studying the fish population.

The individual metrics were developed using the South African datasets and were the result of a multi-method monitoring programme. Survey design issues are highlighted within Elliott *et al* (2002c) with gear limitations discussed. In order to effectively sample a variety of habitats within a given area, then multi-method techniques may be employed such as that by Environment Agency, Thames Region (European Commission, 2000).

The SEPA datasets from the Clyde & Forth are based upon a single-strand-monitoring programme and therefore may not represent a true representation of the icthyofaunal assemblage. They have been included as a UK example for the metric system, but are likely to be underscored in relation to their ecological status. As such no direct comparisons have been made to the metrics, which are discussed as follows.

## 2. 4 Species Diversity and Composition

### 2.4.1 Metric 1, Total number of taxa

Species diversity tends to be reduced in stressed biotic communities (Odum, 1983) and as an attribute of faunal communities it is commonly used in biological assessments of environmental health. Species diversity was not identified as a key biotic measure within the WFD but in developing the EFCI it is a simple measure i.e. total number of taxa.

The number of taxa recorded in the Sezela estuary (excluding exotic and introduced species) generally supported the hypothesis that species richness declines with environmental impact.

It should be noted, however, that species diversity measures are heavily dependent on sampling effort and are often not a true measure of phylogenetic breadth. 'Taxonomic Distinctness' is a new method of monitoring environmental change that is based on the degree of relatedness of a species, or their taxonomic relationships to a 'reference assemblage' (Warwick & Clarke, 1995; 1998; 2001).

Recently developed measures which are not based on the abundance of organisms, but which take into account their taxonomic relationships, have been shown to be useful for detecting spatial and temporal changes related to variations in environmental conditions. These measures have several important potential advantages over measures currently being used to assess environmental change. Furthermore, this measure is relatively insensitive to sampling effort (Paul Somerfield, Pers.comm). Work in developing 'Taxonomic Distinctness' as a metric is still in the development stage, though it is hoped that it will be included within the final EFCI.

### 2.4.2 Metric 2, Rare/threatened species

The presence of rare or threatened taxa was selected on the basis that their occurrence imparts additional conservation value to the ecosystem. Because rare species are fragile, they may become endangered or even locally extinct with increasing anthropogenic stress (Costello *et al*., 2002). Although the WFD does not specifically mention rare or threatened species, it does make reference to disturbance-sensitive species. It also refers to designated areas for the protection of habitats or species under the Habitats & Species Directive (European Council Directive 92/43/EEC). The aim of the Habitats & Species Directive is to ensure biodiversity through the conservation of natural habitats and of wild fauna and flora. Such habitats include estuaries, as well as fish species that are considered endangered, vulnerable, rare, or endemic.

A summary of the status of European fish species, based on available published data (e.g. Berne Convention, Habitats & Species Directive, Red Data Books) revealed that, apart from freshwater taxa, 84 species that are associated with estuaries require some conservation protection (Costello *et al*., 2002). However, it should be noted, that the status of some fish species might vary geographically. For instance, a particular species may be abundant in one region, but threatened in another; this is because some fishes are at the limits of their geographic distribution (Seegert, 2000; Costello *et al*., 2002).

### 2.4.3 Metric 3, Exotic/introduced species

The presence of exotic or introduced species represents a potential threat to naturally occurring taxa through competitive exclusion and predation; they also represent a direct measure of human interference. While the WFD does not mention exotic or introduced species, it does make reference to anthropegenic impacts.

The Habitats & Species Directive also requires that introductions of non-native species should not prejudice natural habitats or species and if necessary, such introductions should be prohibited. Further legislative controls within England & Wales were introduced in 1998 by the Order (1998) under the Import of Live Fish (England & Wales) Act (1980) which includes a list of non-native fish species.

Their presence was considered to be a measure of anthropegenic impact and as such these species were considered.

### 2.4.4 Metric 4, Species composition

A comparison of the amount of overlap (or similarity) in the fish species composition of an estuary and some 'reference/natural assemblage' is a useful measure of ecosystem condition

(Fausch *et al*., 1990). Fish species composition is also a key biotic component identified by the WFD.

The species assemblages recorded in the Sezela estuary were compared with a derived reference assemblage using the Bray-Curtis similarity measure; the results appeared to support the argument that ichthyofaunal assemblages in impacted estuaries deviate from an expected reference assemblage.

## 2.5 Species Abundance

### 2.5.1 Metric 5, Species relative abundance

The proportions or 'relative abundance' of the species within an estuary in relation to a 'reference fish community' provides a quantitative assessment that compliments the species composition metric (Metric 4). The WFD also requires that fish species abundance be included in the assessment of transitional waters.

However, estimates of fish abundance are dependent on the sampling methodologies employed, as well as sampling effort (Elliott *et al*., 2002a). In order to account for variation in sampling effort, measures based on abundance data were standardised by calculating the 'relative abundance' as a percentage of each species rather than using absolute numbers.

A comparison of the relative abundance of the species in the Sezela estuary with a derived reference community, using the Bray-Curtis similarity measure, generally appeared to support the assumption that the relative abundance of fishes in impacted estuaries deviates from that of a derived reference community.

### 2.5.2 Metric 6, Number of species that make up 90% of the abundance

Environmental stress generally results in a change in relative abundance from 'diverse' communities consisting of many species in relatively low proportions to 'simple' assemblages dominated by a few species (Odum, 1983; Fausch *et al.*, 1990). Linked to this is the concept of dominance; the number of taxa required to make up 90% of the total abundance represents a simple measure of dominance.

While dominance is not a key measure identified by the WFD, it is linked to species abundance (Metric 5). The results from the Sezela estuary also appeared to verify the assumption that disturbed systems are dominated by a few taxa with more species dominating as conditions improved.

## 2.6 Nursery Function

A key function of estuaries, in terms of their utilisation by fishes, is the provision of nursery areas for certain marine species as well as serving important habitat for resident taxa (Wallace *et al*., 1984; Whitfield, 1998).

Whitfield (1998) has developed an estuary-association classification system where the fishes occurring in southern African estuaries could be grouped into five broad categories, according to their dependence on these ecosystems (Table 2.2).

The basic life cycle of estuarine-dependent marine species (category II) involves adults spawning at sea, often close inshore and in the vicinity of estuary mouths. Egg and larval development also takes place at sea, but juveniles migrate into estuaries where they use this environment as a nursery area (Wallace *et al*., 1984). Facultative catadromous species (category Vb) have a similar life cycle, with adults spawning at sea and juveniles migrating into estuaries. The only major difference between this group and those belonging to category II is that these species are able to enter and live in the fresh waters (Bruton *et al*., 1987). In assessing estuarine nursery function, facultative catadromous species (category Vb) were combined with estuarine-dependent marine species (category II).

**Table 2.2. Estuary-association categories of southern African fish fauna (after Whitfield, 1998).**

| Category | Description |
|---|---|
| I | Estuarine species which breed in southern African estuaries. Further subdivided into:<br>Ia. Resident species which have not been recorded spawning in marine or freshwater environments.<br>Ib. Resident species which also have marine or freshwater breeding populations. |
| II | Euryhaline marine species which usually breed at sea with the juveniles showing varying degrees of dependence on southern African estuaries. Further subdivided into:<br>IIa. Juveniles dependant on estuaries as nursery areas.<br>Iib. Juveniles occur mainly in estuaries, but are also found at sea.<br>IIc. Juveniles occur in estuaries but are usually more abundant at sea. |
| III | Marine species which occur in estuaries in small numbers but are not dependent on these systems. |
| IV | Freshwater species, whose penetration into estuaries is determined primarily by salinity tolerance. This category includes some species which may breed in both freshwater and estuarine systems. |
| V | Catadromous species which use estuaries as transit routes between the marine and freshwater environments but may also occupy estuaries in certain regions. Further subdivided into:<br>Va. Obligate catadromous species which require a freshwater phase in their development.<br>Vb. Facultative catadromous species which do not require a freshwater phase in their development. |

Although the WFD does not require a functional assessment of the fishes in transitional waters, ecological guilds by incorporating biological attributes rather than taxonomic identities, provide a measure of the availability of ecological niches and the overall physico-chemical functioning of estuaries (Elliott & Dewailly, 1995).

Goethals *et al*. (2002) also included ecological guilds in the development of a multi-metric fish index for the Scheldt estuary, Belgium; these included estuarine resident species, diadromous species, and marine juvenile migrating species (WFD CIS 2.4, 2003). Elliott & Dewailly (1995) have produced an estuary-association classification scheme (Table 2.3), which groups estuarine fishes occurring in European waters into six ecological guilds.

**Table 2.3. Ecological guilds applied to European estuarine fishes (after Elliott & Dewailly, 1995)**

| Ecological guild | Description |
|---|---|
| FW | Freshwater species |
| CA | Diadromous species |
| ER | Estuarine resident species |
| MJ | Marine juvenile migrant species |
| MS | Marine seasonal migrant species |
| MA | Marine adventitious species |

In the assessment of estuarine nursery function for the EFCI, only estuarine resident taxa (category I) and estuarine-dependent marine taxa (category II) were considered.

### 2.6.1 Metric 7, Number of estuarine resident taxa

The number of estuarine/resident taxa measures the group of fish species that are probably most susceptible to estuarine degradation. This is by virtue of their strong dependence or association with these environments. (Elliott *et al*., 2002a). However, the highly variable nature of these ecosystems, results in relatively few fish species being able to live and breed within southern African estuaries (Whitfield, 1998).

The number of estuarine resident taxa recorded in the Sezela estuary was relatively low and somewhat variable, although they did appear to confirm the assumption that environmental stress results in a reduction in the number of these species.

### 2.6.2 Metric 8, Number of estuarine-dependent marine taxa

The number of estuarine-dependent marine taxa is a measure of how well an estuary is fulfilling its role as a nursery habitat.

The number of estuarine-dependent marine species in the Sezela estuary supports the hypothesis that fewer species of this group occur in impacted systems. This metric also mirrored the total number of taxa recorded (Metric 1). This is not surprising since estuarine-dependent marine species generally makeup the dominant group of fishes in estuarine ecosystems (Whitfield, 1998).

Seegert (2000) has cautioned against using metrics that are highly correlated (a practice known as double dipping); however, some redundancy among metrics within the broad categories (e.g. species richness and composition, trophic composition), was considered acceptable.

### 2.6.3 Metric 9, Relative abundance of estuarine resident taxa

The percentage abundance of estuarine resident species (Metric 9) is a complimentary measure to quantitatively assess estuarine habitat quality.

The relative abundance of estuarine resident species in the Sezela estuary appeared somewhat variable; this suggests that this may not be a reliable metric. However, an assumption of many multi-metric approaches, is that changes in communities are linearly related to degradation (Harris & Silveira, 1999). An undisturbed estuary is expected to contain a relatively balanced fish community comprising representatives of both estuarine resident and estuarine-dependent marine groups. An excessively low numerical abundance or unexpected high dominance by one particular group often indicates an imbalance or disturbance within a system (Begg, 1984b).

### 2.6.4 Metric 10, Relative abundance of estuarine-dependent marine taxa

The percentage abundance of estuarine-dependent marine species (metric 10) is a quantitative measure to assess estuarine habitat quality and nursery function.

The relative abundance (percentage) of estuarine-dependent marine species in the Sezela estuary also appeared somewhat variable. As with the previous metric, the relative abundance of estuarine-dependent marine species may not be linearly related to degradation.

## 2.7 Trophic Integrity

Estuaries are among the most productive ecosystems on earth (Odum, 1983; McHugh, 1985). By acting as detritus traps, they provide abundant food resources for filter and deposit-feeding invertebrate prey as well as a variety of fish species. Because estuarine fish communities include species from a variety of trophic groups (e.g. detritivores, herbivores, zooplankivores, benthic invertebrate feeders, and piscivores), they also integrate effects of lower trophic levels and thus provide a good measure of integrated environmental health (USEPA, 2000; Elliott *et al*., 2002b).

Using data contained in Whitfield (1998), the fishes occurring in southern African estuaries could be grouped into a number of broad feeding guilds based on the dominant food item in their diet (Table 2.4).

**Table 2.4. Feeding guilds for southern African estuarine fishes (using data from Whitfield, 1998)**

| Feeding guild | Description |
|---|---|
| P | Species that are primarily piscivorous |
| BI | Fishes that feed mainly on benthic invertebrates |
| Z | Fishes that are predominantly zooplankton feeders |
| M/I | Fish species that consume aquatic macrophytes, filamentous algae, and the associated invertebrate fauna |
| D | Fishes that feed mainly on detritus, benthic microalgae, and meiofauna |

An assessment of the feeding or trophic guilds of transitional fishes is not a requirement of the WFD. However, as with the ecological guild approach, an analysis of feeding guilds provides a measure of the structure and functioning of estuarine fish communities (Elliott & Dewailly, 1995; Elliott *et al*., 2002b). Goethals *et al*. (2002) also included feeding guilds in the development of a multi-metric fish index for the Scheldt estuary, Belgium; these included omnivores and piscivores. Elliott & Deiwally (1995) have also developed a number of feeding guilds for European estuarine fishes based on a combination of food types (Table 2.5)

**Table 2.5. Feeding guilds of European estuarine fishes (Elliott & Dewailly, 1995)**

| Feeding guild | Description |
|---|---|
| FS | Fishes feeding strictly on other fishes |
| IF | Fishes feeding on invertebrates and fishes |
| IS | Fishes feeding strictly on invertebrates |
| PS | Fishes feeding strictly on plankton |
| CS | Carnivorous fishes other than FS, IF, IS or PS |
| HC | Fishes partly herbivorous, partly carnivorous, but not omnivorous |
| OV | Omnivorous fishes |

For the assessment of trophic integrity of South African estuaries, two groups of fishes were considered: benthic invertebrate feeding taxa (BI) and piscivorous taxa (P).

### 2.7.1 Metric 11, Number of benthic invertebrate feeding taxa

The number of benthic invertebrate feeding fish species was selected on the basis that it provides an indirect measure of the condition of the benthic invertebrate fauna.

The number of fish species that feed on benthic invertebrates showed an increase in the Sezela estuary, confirming the assumption that environmental stress results in a reduction in the number of these species.

### 2.7.2 Metric 12, Number of piscivorous taxa

The number of piscivorous taxa was selected on the basis that the presence of top carnivores, is typically representative of a broad and stable trophic network within an estuary (USEPA, 2000). Piscivorous taxa are also the trophic level most sensitive to environmental disturbance.

The number of piscivorous fish species in the Sezela estuary also showed an improvement over time; this supports the hypothesis that stressed environments contain low numbers of these taxa.

### 2.7.3 Metric 13, Relative abundance of benthic invertebrate feeding taxa

The percent abundance of benthic invertebrate feeding fishes provides a quantitative, complimentary analysis of trophic integrity (Elliott *et al*. 2002b).

The relative abundance of benthic invertebrate feeding fishes in the Sezela estuary showed an increasing trend suggesting an improvement in conditions. This appears to support the idea that low numbers of this group of fishes occur in disturbed systems.

### 2.7.4 Metric 14, Relative abundance of piscivorous taxa

The percent abundance of piscivorous fishes also provides a quantitative, complimentary analysis of trophic integrity.

The relative abundance of piscivores in the Sezela estuary also showed a steady increase indicating an improvement in the higher ichthyofaunal trophic levels of the system. These results appear to confirm the assumption that impacted systems contain relatively low numbers of piscivorous fishes.

# 3. RESULTS

## 3.1 Metric Evaluation

### 3.1.1 Species diversity and composition

Reference species richness (Metric 1) was determined by first removing all exotic and introduced taxa from the data set and then calculating the number of taxa captured within each estuary. The data were then ranked and those values that fell within the upper quartile of the data selected. The reference species richness value was calculated as the mean number of taxa of this upper quartile.

Rare and threatened taxa (Metric 2) was tested by Harrison *et al* (2000) and identified by reference to Skelton (1987; 1990; 1993), Groombridge (1993). UK datasets were tested against protected species as scheduled under Wildlife & Countryside Act (1980); Habitats and species Directive (European Council Directive, 1992) and UK Biodiversity Action Plans.

Exotic or introduced taxa (Metric 3) were identified by reference to de Moor & Bruton (1988) and ILFA Order (1998).

A reference species assemblage (Metric 4) was established by first removing all exotic and introduced taxa from the data set and then calculating the frequency of occurrence of each species. The most frequently occurring taxa that corresponded to the reference richness value was then selected as the reference species assemblage.

### 3.1.2 Species abundance

Reference species relative abundance (Metric 5) were determined by first removing all exotic and introduced taxa from the data; the mean relative (%) abundance of each species was then calculated for the group of estuaries. The most abundant taxa, corresponding to the reference richness value were then selected as the reference community.

In determining reference species dominance conditions (metric 6), the number of taxa required to make up 90% of the total fish abundance for each estuary was first calculated. The data were then ranked and the values within the upper quartile selected. Reference conditions were established as the mean of the data that fell within the upper quartile.

### 3.1.3 Nursery function

For the number of estuarine resident taxa (metric 7) and the number of estuarine dependent marine taxa (metric 8), the number of species belonging to each group of fishes within each estuary were first calculated. Reference conditions were then established as the mean of those values that fell within the upper quartile of the data set for each group of fishes.

The relationship between the relative abundance of estuarine resident taxa (metric 9), the relative abundance of estuarine-dependent marine taxa (metric10) and estuarine disturbance was assumed to be non-linear; both very low and very high relative abundance values were considered indicative of impacted conditions. The relative (%) abundance of each group of fishes was calculated for each estuary; reference conditions were based on a combination of the spread of the data and expert input.

### 3.1.4 Trophic integrity

For the number of benthic invertebrate feeding taxa (metric 11) and the number of piscivorous taxa (metric 12), the number of species belonging to each trophic group was calculated for each estuary. Reference conditions were then established as the mean of those values that fell within the upper quartile of each data set.

For metrics 13 (relative abundance of benthic invertebrate feeding taxa) and 14 (Relative abundance of piscivorous taxa), the relative (%) abundance of each trophic group was calculated for each estuary; reference conditions were based on a combination of the spread of the data and expert input.

### 3.1.5 Reference conditions

Each metric was tested against a calculated reference, which was derived from the calculated average of the upper quartile of each dataset in relation to that metric.

### 3.1.6 Metric thresholds

Having established reference conditions, each metric can then be assessed according the extent of its deviation from the reference condition. The WFD has recommended that the values of the biological parameters be expressed as a ratio of the appropriate reference value. The ecological quality ratio (EQR) will range between zero and one, with high ecological status represented by values close to one and bad ecological status by values close to zero.

Metrics, however, vary in their measurement; they can be numbers, percentages, or descriptive terms (e.g. presence/absence). Metric scores for the EFCI developed for South African estuaries were therefore established such that a score of 5 (similar to reference), 3 (different from reference) or 1 (substantially different from reference) could be allocated to each metric, depending on the extent of deviation from the reference condition. This approach was then tested against UK datasets from the Clyde and Forth estuaries.

In order to effectively rate the metrics, however, thresholds are required that adequately describe the degree of deviation from the reference. The WFD has suggested that metric thresholds be established through an intercalibration exercise. Such an exercise requires that a number of sites corresponding to the boundary between high and good status and between good and moderate status be monitored in order to delineate the boundary values. The sites are to be selected based on expert judgement as well as available information.

Seegert (2000) has recommended that metric thresholds should not be based on what `experts' think are the right values but rather on the evaluation of regional site-specific data. Harris & Silveira (1999) and Kurtz *et al*. (2001) adopted a similar procedure where metric thresholds were derived empirically from sampling data. Thresholds for the metrics used in the EFCI were derived either from reference values or from the distribution of metric values obtained from the extensive regional study.

### 3.1.7 Species diversity and composition

For the total number of taxa (metric 1), a species richness of ≥90% of the reference value was assigned a score of 5. A species richness of <90% and ≥50% of the reference value was given a score of 3 and a species richness of <50% of the reference value was assigned a score of 1.

For rare/threatened species (metric 2), a score of 5 was assigned to those cases where rare or threatened taxa were present. Since the absence of rare or threatened species does not necessarily indicate degradation, a score of 3 was allocated where these taxa were not recorded.

In the case of exotic/introduced species (metric 3), a score of 1 was assigned to those instances where exotic/introduced species were recorded. It should be noted that a minimum score is allocated based only on the presence of exotic/introduced species, irrespective of the relative abundance of this group of fishes. Where no exotic/introduced taxa were reported, a score of 3 was given.

For species composition (metric 4), the species assemblage of each estuary was compared with the appropriate reference assemblage using the Bray-Curtis similarity measure based on presence/absence. In this analysis, exotic and introduced species were included since these fishes contribute toward the dissimilarity between the reference assemblage and the estuary in question. Similarity values of ≥80% were given a score of 5, similarities of <80% and ≥50% were assigned a score of 3 and values of <50% were given a score of 1.

### 3.1.8 Species abundance

For species relative abundance (metric 5), the percent numerical abundance of the species within each estuary was compared with the relevant reference community using the Bray-Curtis similarity measure. Again, exotic and introduced species were included in the analysis since they contribute toward the dissimilarity between the reference community and the estuary in question. Similarity values of ≥60% were given a score of 5, similarities of <60% and ≥40% were assigned a score of 3 and similarity values of <40% were given a score of 1.

In terms of the number of species that make up 90% of the abundance (metric 6), a score of 5 was given where the number of taxa was ≥90% of the reference value. A score of 3 was assigned to those cases where the number of taxa was <90% but ≥50% of the reference. Where the number of species was <50% of the reference value, a score of 1 was allocated.

### 3.1.9 Nursery function

For both the number of estuarine resident taxa (metric 7) and the number of estuarine-dependent marine taxa (metric 8), a score of 5 was allocated where the number of taxa was ≥90% of the reference value. Where the number of species was <90% and ≥50% of the reference, a score of 3 was given and where the number of taxa was <50% of the reference value, a score of 1 was assigned.

Thresholds and scoring criteria for the relative abundance of estuarine resident species (metric 9) and the relative abundance of estuarine-dependent marine species (metric 10) were based on a combination of the spread of the data and expert input.

### 3.1.10 Trophic integrity

For both the number of benthic invertebrate feeding taxa (metric 11) and the number of piscivorous taxa (metric 12), a score of 5 was assigned to those cases where the number of species was ≥90% of the reference value. Where the number of species was <90% and ≥50% of the reference, a score of 3 was given and a score of 1 was assigned to those cases where the number of taxa was <50% of the reference value.

For the relative abundance of benthic invertebrate feeding taxa (metric 13) and the relative abundance of piscivorous taxa (metric 14), thresholds and scoring criteria were based on a combination of the spread of the data and expertise. A summary of the metric scoring criteria used is presented in Table 3.1 below.

**Table 3.1. Metric scoring thresholds**

| Fish Community Index metric | Score | | |
|---|---|---|---|
| | 5 | 3 | 1 |
| ***Species diversity and composition*** | | | |
| 1) Total number of taxa | ≥20 | <20 and ≥12 | <12 |
| 2) Rare/threatened species | present | absent | |
| 3) Exotic/introduced species | | absent | present |
| 4) Species composition | ≥80% similarity | <80% and ≥50% similarity | <50% similarity |
| ***Species abundance*** | | | |
| 5) Number of species that make up 90% of the abundance. | ≥9 | <9 and ≥5 | <5 |
| 6) Species relative abundance | ≥60% similarity | <60% and ≥40% similarity | <40% similarity |
| **Nursery function** | | | |
| 7) Number of estuarine resident taxa | ≥5 | <5 and ≥3 | <3 |
| 8) Number of estuarine-dependent marine taxa | ≥14 | <14 and ≥8 | <8 |
| 9) Relative abundance of estuarine resident taxa | 25-60% | ≥5% and <25% or >60% and ≤90% | <5% or >90% |
| 10) Relative abundance of estuarine-dependent marine taxa | 25-70% | ≥10% and <25% or >70% and ≤90% | <10% or >90% |
| **Trophic integrity** | | | |
| 11) Number of benthic invertebrate feeding taxa | ≥6 | <6 and ≥3 | <3 |
| 12) Number of piscivorous taxa | ≥3 | <3 and ≥1 | <1 |
| 13) Relative abundance of benthic invertebrate feeding taxa | ≥10% | <10% and ≥5% | <5% |
| 14) Relative abundance of piscivorous taxa | ≥5% | <5% and ≥1% | <1% |

## 3.2 Index Calculation

Once metric thresholds and scoring criteria have been developed the ecological status of an estuary can then be assessed. The WFD has recommended that the minimum value of the fish community metrics represent the ecological status of the system in question. The EFCI adopts a more integrated approach where the ecological status is determined by summing the various scores of all the metrics. It should be noted, however, that a major assumption is that all metrics have equal weighting in terms of their contribution to the overall index. Based on all 14 metrics, the index values range between 16 and 68.

A major purpose of developing biological assessment methods is to establish biological criteria for surface waters. Biological criteria are guidelines or benchmarks to evaluate the relative biological condition of surface waters. These criteria can be descriptive expressions or numerical values that describe the biological condition of aquatic communities (USEPA, 1990; 2000).

Biological criteria are a practical approach to provide information to support management decisions. These include establishing goals to protect or restore biological integrity, determining whether designated uses have or have not been attained, and also deciding whether the designated uses are appropriate or attainable (Seegert, 2000; Simon, 2000; USEPA, 2000; Kurtz *et al*., 2001).

A key objective of the WFD is to protect, enhance, and restore all bodies of surface water, including transitional waters, with the aim of achieving good surface water status by 2015. Five ecological status classes have been established: high, good, moderate, poor and bad.

To assist in the interpretation of the index results and to facilitate the establishment of biological targets, the final EFCI values were designated a qualitative rating ranging from ‘very poor’ to ‘very good’ (Table 3.2). Since a score of 3 for all metrics yields a total index score of 42, values within the range 40 to 44 were rated as ‘moderate’. Index scores below 40 were rated as ‘poor’ to ‘very poor’ and values between 44 and 68 were arbitrarily divided into ‘moderately good’, ‘good’ and ‘very good’.

**Table 3.2. Rating of total Estuarine Fish Community Index scores.**

| Rating | EFCI Score |
|---|---|
| Very poor | 16-18 |
| Poor | 20-38 |
| Moderate | 40-44 |
| Moderate to good | 46-54 |
| Good | 56-64 |
| Very good | 66-68 |

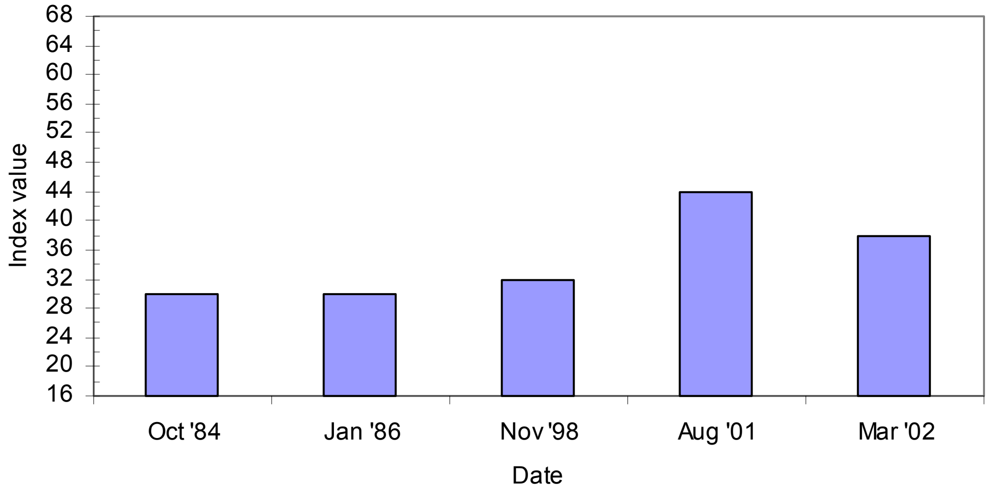
Further evaluation and testing of these qualitative ratings would lead to defining the biological status required within WFD and developing boundary between status e.g. High/Good, Good/Moderate etc.

To be effective, a biological index must respond to environmental stress and thus be able to show the condition of ecosystems (Harris & Silveira, 1999; USEPA, 2000). To test if the

EFCI effectively reflects estuarine fish community and ecosystem health, the final index was applied to the data for the Sezela estuary. The results showed an increase from an index score of 30 in October 1984 and January 1986 to a maximum of 44 in August 2001; the index score decreased again to a value of 38 in March 2002 (Figure 3.1). This decline is probably a result of a fish kill that took place in January 2002 (Trevor Harrison, Pers.Comm).

In terms of its overall rating, the Sezela estuary improved from a rating of 'poor' in October 1984, January 1986 and November 1998 to 'moderate' in August 2001 before decreasing again to a rating of 'poor' in March 2002.

**Figure 3.1. The Estuarine Fish Community Index for the Sezela estuary, October 1984 - March 2002.**




Although limited, the data from the Sezela estuary suggests that the EFCI described here is an effective method that does reflect the status of estuarine fish communities and thus the overall ecosystem condition (Trevor Harrison, Pers.Comm).

In order to test the South African developed EFCI against UK data in the development of an UK index, two long-term SEPA beam trawling datasets from the Clyde & Forth estuaries were analysed (Fig 3.2 & 3.3).

**Figure 3.2. The estuarine Fish community index for the Forth Estuary, 1977 – 2002.**

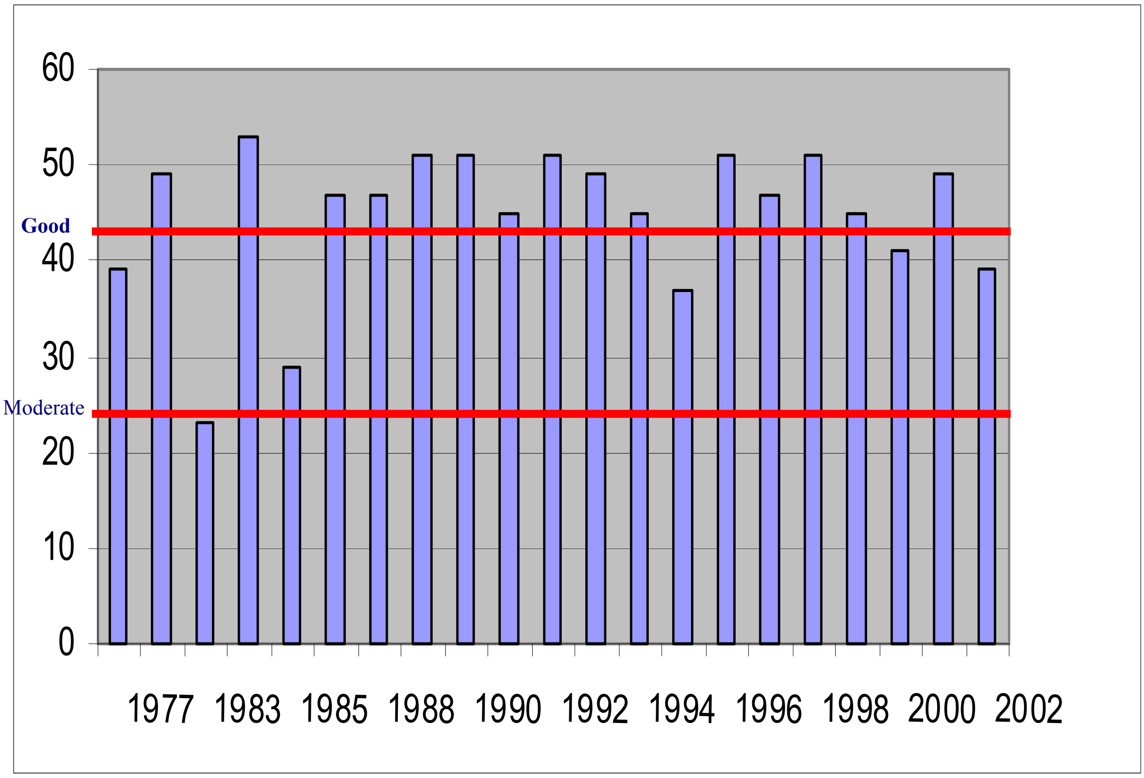
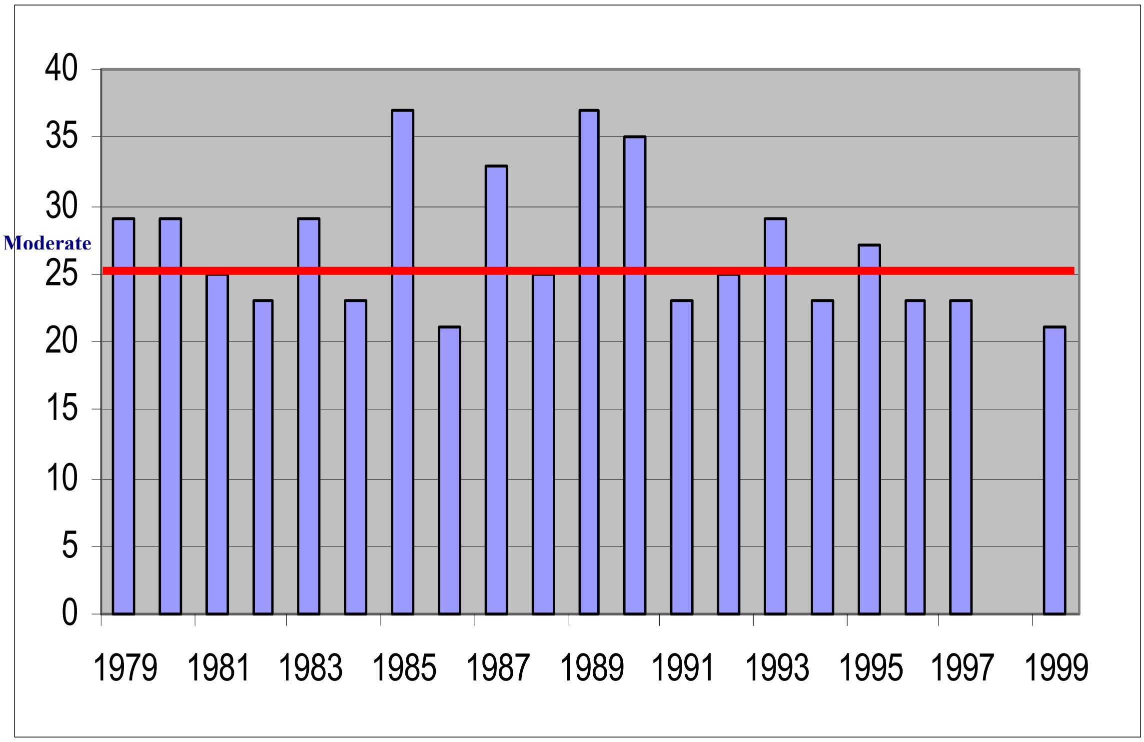



**Figure 3.3. The estuarine Fish community index for the Clyde Estuary 1979 to 1999**



# 4. DISCUSSION

Metrics are biological attributes that allow a meaningful assessment of assemblages and communities in response to perturbation. For a metric to be useful, it must (a) have ecological relevance to the biological assemblage or community under study and (b) be sensitive to environmental stress (USEPA, 2000). Although restricted to a single estuary and based on limited sampling, the evaluation of the metrics using the Sezela estuary suggests that the selected metrics adequately measures the condition of separate but related components of estuarine fish communities and that these reflect environmental condition.

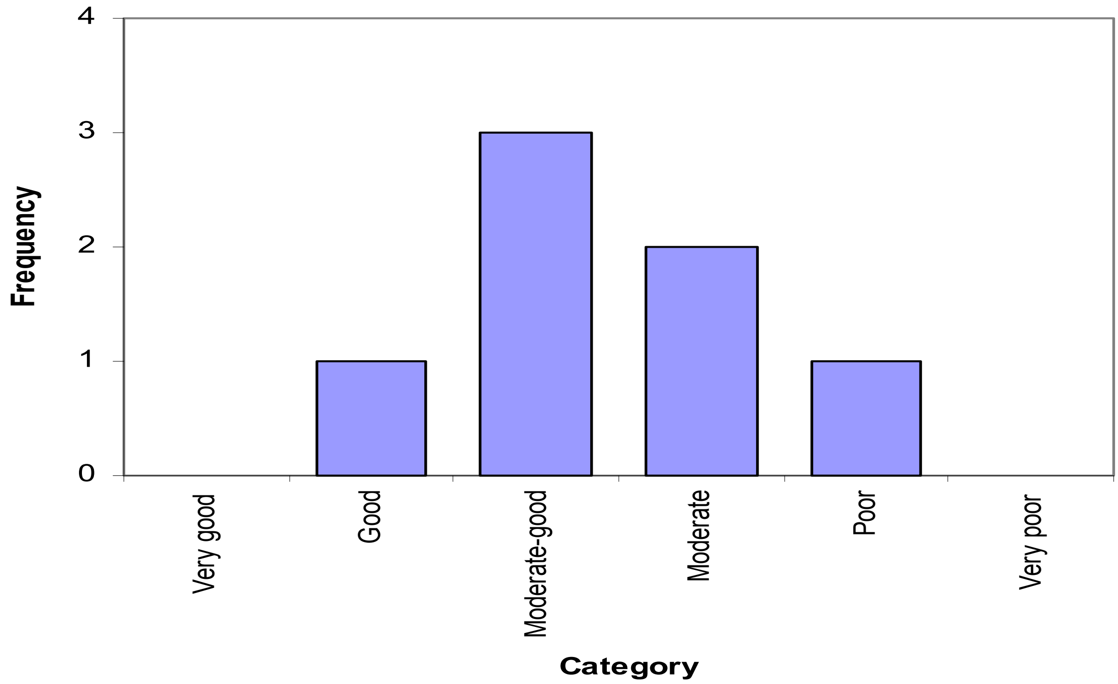
However, studies of fish communities are dependent on surveys and methodologies and as such should provide a representative sample of the community as a whole. Most techniques for sampling fishes are selective, especially with respect to species and size of individuals (Lagler, 1971). Fish communities may vary considerably among the numerous habitat types that may be present in a particular estuary. To effectively sample the variety of habitats within a given system and to capture all components of the fish assemblage, a multi-method approach is often required (Whitfield & Marais, 1999; Hemmingway & Elliott, 2002; European Commission, 2000).

In addition to monitoring change or ecosystem status, an index must also be robust enough to account for natural variability. To test the reproducibility of the index, data collected on the Mhlanga estuary was used (Harrison, Pers.comm). The Mhlanga estuary is also a predominantly closed, moderately sized estuary in the subtropical region and was sampled on a number of occasions from July 1989 to March 2002.

Although the aims and objectives of each survey differed, the sampling methodology and sampling team were relatively standard. Furthermore, in order to remove the effects of seasonal variation, only surveys conducted during the spring/summer were considered. A total of seven surveys were used in this analysis and yielded index scores between 34 ('poor') and 60 ('good').

Three surveys (43%) yielded index scores of between 46 and 50 giving an overall rating of 'moderate-good' while two surveys (29%) yielded index scores of between 42 and 44, yielding an overall rating of 'moderate' (Figure 4.1).

**Figure 4.1. The frequency of Estuarine Fish Community Index categories calculated from spring/summer samples conducted in the Mhlanga estuary, December 1989-March 2002. (Harrison, Unpublished Data).**




Although estuaries are highly variable systems, the EFCI appears to produce results that are reasonably consistent. Overall, the data for the Mhlanga estuary indicates that the system is 'moderate' to 'moderate-good', with over 70% of the surveys falling within these two categories.

This overall categorisation is also fairly realistic as the Mhlanga estuary is not entirely undisturbed; although the system falls within a nature reserve, it lies within the greater metropolitan area of the city of Durban and receives treated sewage effluent.

As part of a routine monitoring programme, the U.K. Environment Agency has evaluated a range of sampling techniques (Appendix 3) and has developed a 'multi-method' sampling approach on a range of sites within the Thames estuary that is cited as an example of European 'best practice' (European Commission, 2000).

## 4.1 Reference Conditions

In order to view fish community data in context, reference or baseline conditions are needed against which this data can be compared (Fausch *et al.*, 1990; USEPA, 1990; Roux *et al.*, 1993). Several approaches to establishing reference conditions have been used and some of these include the use of historical records, expert input, the use of predictive models and selection of those sites that are least impacted (USEPA, 2000).

The WFD also requires the establishment of reference conditions and suggests that these may be spatially based, based on modelling, or may be derived using a combination of these methods. Where it is not possible to use these methods, expert judgement may be used to establish reference conditions.

## 4.2 Historical Data

If available, historical data is useful in providing insight about past and potential fish community composition of estuarine waters (Rogers *et al*., 1998; Pawson *et al*., 2002). Caution, however, should be exercised when using this information. In many cases data were not collected using comparable methods; often the results are insufficiently documented; the objectives of past studies also often differ markedly (Appendix 5).

In many cases sampling programmes concentrated on single species, often those of commercial or recreational importance. For example, in Europe, other than salmonids and eels, estuarine fish populations have not been considered as significant issues in monitoring programs to date. While important for establishing perspective with respect to current data, historical information alone should not be used to establish precise reference conditions (USEPA, 2000). If historical data are to be used, then rigorous criteria must first be established to determine its suitability (Seegert, 2000).

A preliminary collation and review of UK datasets during Phase 1 and available data relating to European estuarine fish communities has revealed much of it to be rather inconsistent and of poor quality; the collation process has also revealed a large number of 'grey literature' data sets (Appendix 5).

## 4.3 Expert Opinion

Expert opinion, using a qualified team of regional specialists, can provide professional judgement for developing reference conditions (USEPA, 2000). The use of expert opinion, however, has also been shown to be problematic. Seegert (2000) described an example where two investigators independently developed metric guidelines for the same river that differed appreciably. In another example, separate groups developed a 12-metric index for the same river system with most of the metrics being identical. The expectations for one group were based on professional judgement while the second group based expectations on field collections. Using a common data set, the differences in index scores were large enough that the classification given to a site (i.e., poor, fair, good) often differed depending on which index was used (Seegert, 2000).

## 4.4 Models

Mathematical models that can be used to establish reference conditions include both descriptive and mechanistic models (USEPA, 2000). Descriptive models (also known as correlative or statistical models) describe observed relationships among measured attributes of a system. However, these models rely on good data, and in many cases, insufficient data exists to construct a useful model. Mechanistic models attempt to explain or describe the system itself as the result of underlying processes. These models, however, have many more constraints and are more time-consuming to construct than descriptive models. Mathematical models that predict biological reference conditions should only be used with great caution, because they are complex and are often based on untested hypotheses (USEPA, 2000).

## 4.5 Least Impacted Sites

The use of least impacted sites assumes that within a population of estuaries, some are minimally disturbed and therefore represent the most natural ambient conditions present (USEPA, 2000). The selection of these reference sites is based on physical or chemical parameters such as those that are substantially free of contaminants, those with little or no industrial point source discharges, systems with little or no urban runoff, and systems with little or no agricultural or diffuse source pollution. The biological attributes of these least impacted sites are then used to generate reference conditions. Reference conditions using this approach are best developed from a relatively large number of sites (USEPA, 2000).

## 4.6 Data Distribution

In cases where prior definition of least disturbed sites is not possible, either because all sites are considered impaired or because too few reference sites exist (e.g., one or two), an alternate method is to establish reference conditions from the biological data set itself (USEPA, 2000). In this approach, reference conditions are derived from the distribution of calculated metrics without an independent (abiotic), pre-selection of any reference sites.

Using the biological data set, the “best” values of candidate metrics are used to establish the biological reference condition (Harris & Silveira, 1999; USEPA, 2000). The data are not specifically selected as being of high quality, but it assumes that some sites that are minimally disturbed are included. The approach also does not assume to know where the best sites are but rather utilises the best values observed to define the expectations for each biotic attribute or metric (Harris & Silveira, 1999).

A similar approach was used in developing the South African EFCI. The state of scientific information on the vast majority of South African estuaries is poor (Whitfield, 2000), and as a result the least disturbed systems could not be adequately identified. Reference conditions were therefore derived from the extensive data set from 257 estuaries collected during an assessment of the state of South Africa’s estuaries (Harrison *et al*., 2000).

Critical to the establishment of reference conditions is an accurate delineation of the zoogeography of the region as well as a clear understanding of the various morphological types of systems present. It would be unrealistic to develop a uniform set of reference conditions that can be applied to all estuarine systems.

## 4.7 Biogeography

A major factor that influences the occurrence and diversity of estuarine fishes is biogeography. It has been observed within the UK datasets (Appendix 5) and was apparent in the South African classification.

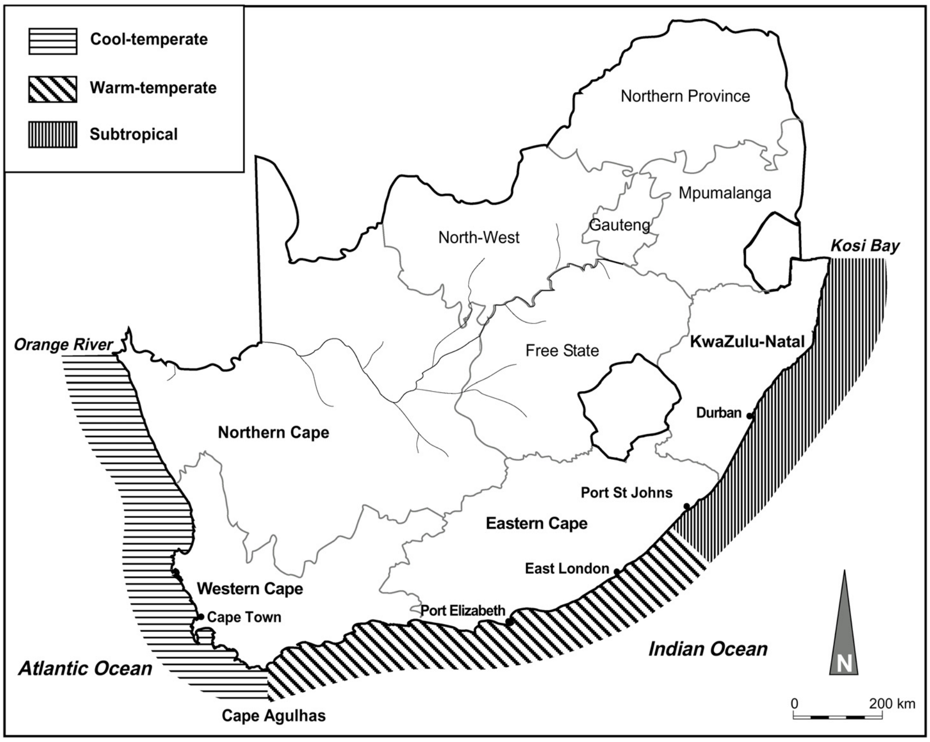
Based on multivariate analyses of their ichthyofauna, Harrison (2002) established three biogeographic provinces for South Africa's estuaries. These included a subtropical East Coast, a warm-temperate south coast, and a cool-temperate west coast (Figure 4.2).

As one moves from the subtropical east coast around to the cool-temperate west coast, estuarine fish diversity declines (Wallace & van der Elst, 1975, Day *et al*., 1981; Whitfield *et al*., 1989). This is linked to the attenuation in the distribution of tropical species where the fauna of East Coast estuaries are dominated by subtropical and tropical Indo-Pacific species (Day *et al*., 1981). Toward the warm-temperate south coast, there is a marked change and the percentage of tropical species decreases while that of endemic species increases. Estuaries on the cool-temperate west coast have a low fish species diversity and comprise mostly cosmopolitan species or cool water endemic taxa (Harrison, 2002).

The WFD has also recognised the importance of biogeography and its affect on estuarine fish community structure; six ecoregions for coastal and transitional waters have been identified. These included the Atlantic Ocean, the Norwegian Sea, the Barents Sea, the North Sea, the Baltic Sea, and the Mediterranean Sea (Figure 4.3).

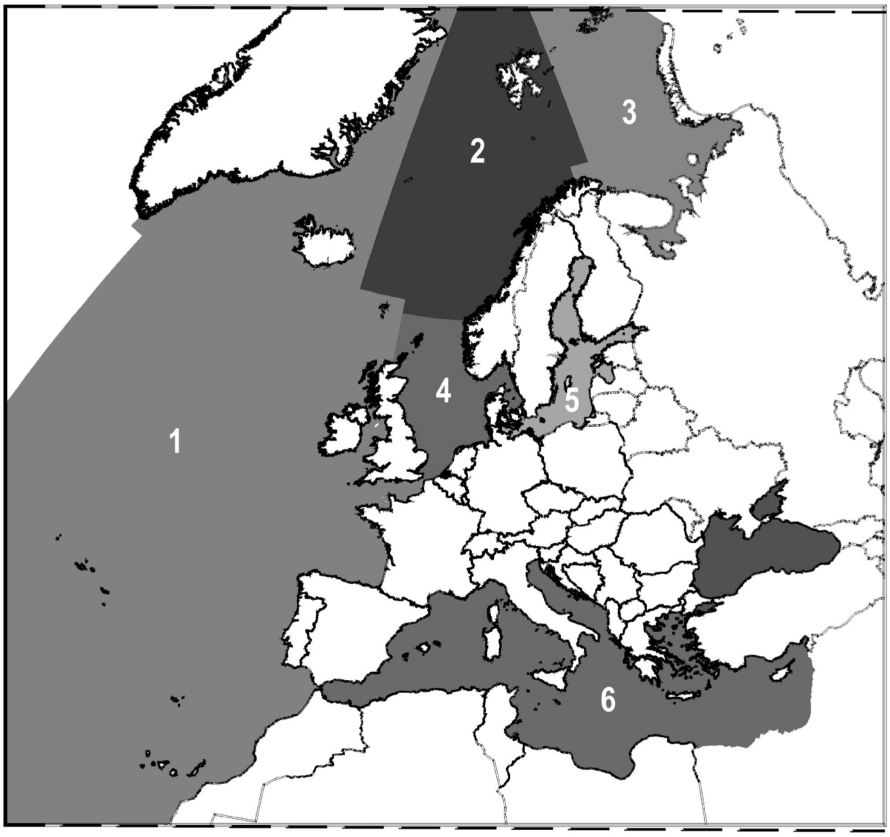
The WFD has also suggested a methodology for determining typology that includes the use of parameters such as latitude, longitude, tidal range, and salinity. Phil *et al*. (2002) divided European coastal waters into three regions, based on a combination of biogeography and factors such as tidal range, salinity, and temperature.

**Figure 4.2. Map of South Africa indicating the three biogeographic provinces, based on estuarine fish communities (after Harrison, 2000).**



Analysis of records of fish species within European estuarine waters is available from information published in Elliott & Hemmingway (2002). The data included records of fish taxa reported in some 23 European estuaries covering nine countries (Table 4.1) as well as commercial species reported in estuarine systems representing 14 countries (Table 4.2).

**Figure 4.3. Estuarine and coastal ecoregions proposed by the Water Framework Directive (European Council Directive 2000/60/EC).**




1) Atlantic Ocean, 2) Norwegian Sea, 3) Barents Sea, 4) North Sea, 5) Baltic Sea, and 6) Mediterranean Sea.

Each dataset was subject to multivariate statistical analyses using the Plymouth Routines in Multivariate Ecological Research package, PRIMER (Clarke & Warwick, 1994; 2001). The Bray-Curtis similarity coefficient, based on presence/absence data, was calculated for each estuary and the data subjected to non-metric multidimensional scaling (MDS).

The results indicate that, based on their fish communities, European estuaries are broadly arranged according to a latitudinal gradient with systems below 45° N situated toward the bottom half of the ordinations and those at latitudes above 45° N located in the top half of the ordinations (Figures 4.4 & 4.5).

**Table 4.1.** **European estuaries for which fish assemblage data were available (in: Elliott & Hemmingway, 2002).**

| Country | System | Latitude (° N) |
|---|---|---|
| France | Loire estuary | 45-50 |
| Germany | Darss-Zingster Bodden Chain | 50-55 |
| Germany | Oderhaff/Stettin lagoon | 50-55 |
| Germany | Weser and Elbe | 50-55 |
| Greece | Messolonghi lagoon | 35-40 |
| Netherlands | Ems-Dollard estuary | 50-55 |
| Netherlands | Oosterschelde | 50-55 |
| Netherlands | Westerschelde | 50-55 |
| Portugal | Mira estuary | 40-45 |
| Portugal | Óbidos | 35-40 |
| Portugal | Ria de Aveiro | 40-45 |
| Portugal | Tagus estuary | 35-40 |
| Scotland | Forth estuary | 55-60 |
| Scotland | Loch Etive | 55-60 |
| Spain | Bay of Cádiz | 35-40 |
| Spain | Ebro estuary | 40-45 |
| Spain | Guadalquivir estuary | 35-40 |
| Sweden | Göta river | 55-60 |
| Sweden | Gullmarsfjord | 55-60 |
| Sweden | NW Åland | 55-60 |
| United Kingdom | Humber estuary | 50-55 |
| United Kingdom | Mersey estuary | 50-55 |
| United Kingdom | Thames estuary | 50-55 |

**Figure 4.4.** **MDS ordination of fish taxa reported in European estuaries; systems are labelled according to latitude.**

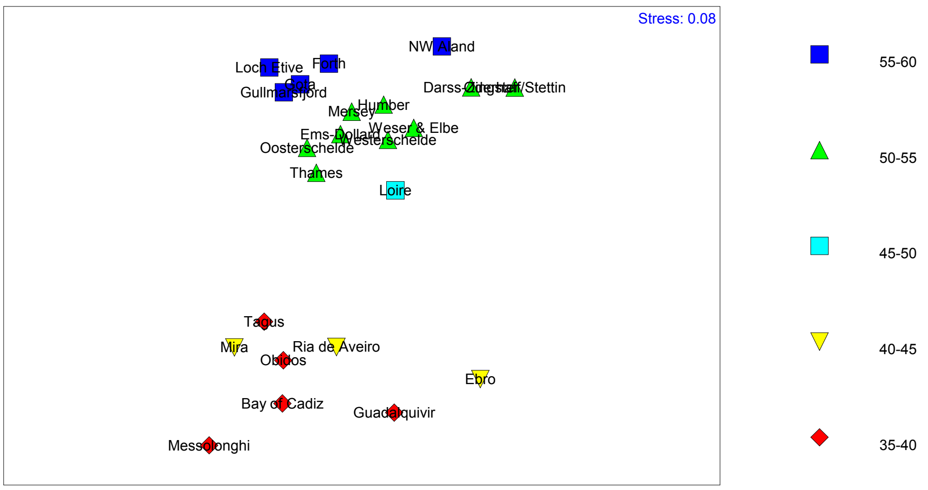
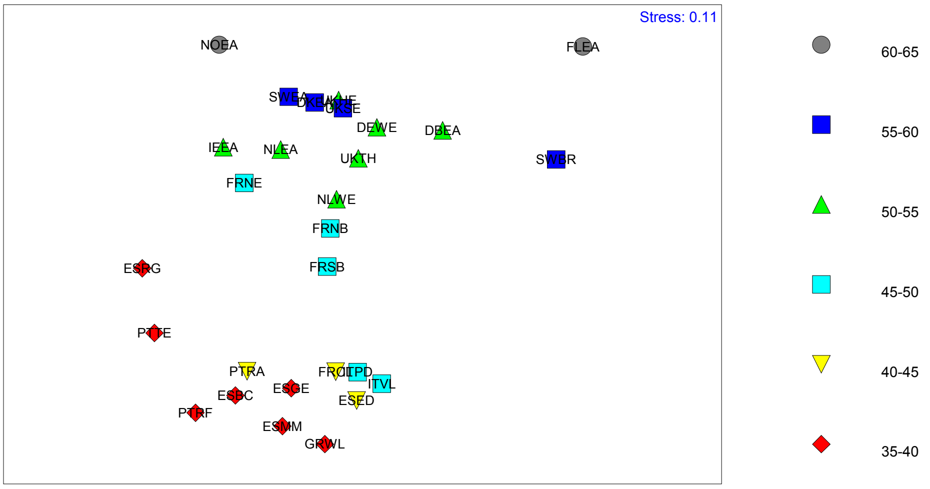


**Table 4.2. European estuaries for which commercial fish data were available (after Costa *et al*., 2002).**

| Country | *System* | Code | Latitude (° N) |
|---|---|---|---|
| Denmark | Denmark estuarine areas | DKEA | 55-60 |
| Finland | Finland estuarine areas (Helsinki & others) | FLEA | 60-65 |
| France | France coastal lagoon (Languedoc-Roussillon) | FRCL | 40-45 |
| France | Normandie estuaries (Bay of Somme and Seine estuary) | FRNE | 45-50 |
| France | Northern Bay of Biscay (Vilaine and Loire estuaries) | FRNB | 45-50 |
| France | Southern Bay of Biscay (Gironde estuary & Arcachon lagoon) | FRSB | 45-50 |
| Germany | German Baltic estuarine areas | DBEA | 50-55 |
| Germany | German Western estuaries (Weser & Elbe) | DEWE | 50-55 |
| Greece | Greece western lagoons (Mesolongi & Etolikon) | GRWL | 35-40 |
| Ireland | Ireland estuarine areas | IEEA | 50-55 |
| Italy | Po Delta | ITPD | 45-50 |
| Italy | Venice lagoon | ITVL | 45-50 |
| Netherlands | Netherlands estuarine areas | NLEA | 50-55 |
| Netherlands | Netherlands Western estuaries (Westerschelde, Oosterschelde & Voordelta) | NLWE | 50-55 |
| Norway | Norway estuarine areas | NOEA | 60-65 |
| Portugal | Ria Averio | PTRA | 40-45 |
| Portugal | Ria Formosa | PTRF | 35-40 |
| Portugal | Tagus estuary | PTTE | 35-40 |
| Scotland | Firth of Forth | UKSE | 55-60 |
| Spain | Bay of Cádiz | ESBC | 35-40 |
| Spain | Ebro Delta | ESED | 40-45 |
| Spain | Guadalquivir estuary | ESGE | 35-40 |
| Spain | Rias Gallegas | ESRG | 35-40 |
| Spain | Spain coastal lagoon (Mar Menor) | ESMM | 35-40 |
| Sweden | Sweden estuarine areas (Baltic region) | SWBR | 55-60 |
| Sweden | Sweden estuarine areas (Skagerrak-Kattegat area) | SWEA | 55-60 |
| United Kingdom | Humber estuary | UKHE | 50-55 |
| United Kingdom | Thames estuary | UKTH | 50-55 |

**Figure 4.5. MDS ordination of commercial fishes reported in European estuaries; systems are labelled according to latitude.**




Superimposing the ecoregions suggested in the WFD on the ordination plots showed a grouping toward the bottom of the plots comprising Mediterranean and Atlantic estuaries. North Sea and Atlantic estuaries were situated toward the centre and top of the ordinations and estuaries in the Baltic Sea region were situated toward the top right of the ordinations (Figures 4.6 & 4.7). Estuaries in the Norwegian Sea were situated at the top left of the ordination for commercial fish catches (Figure 4.7).

**Figure 4.6. MDS ordination of fish communities reported in European estuaries; systems are labelled according to WFD ecoregions.**

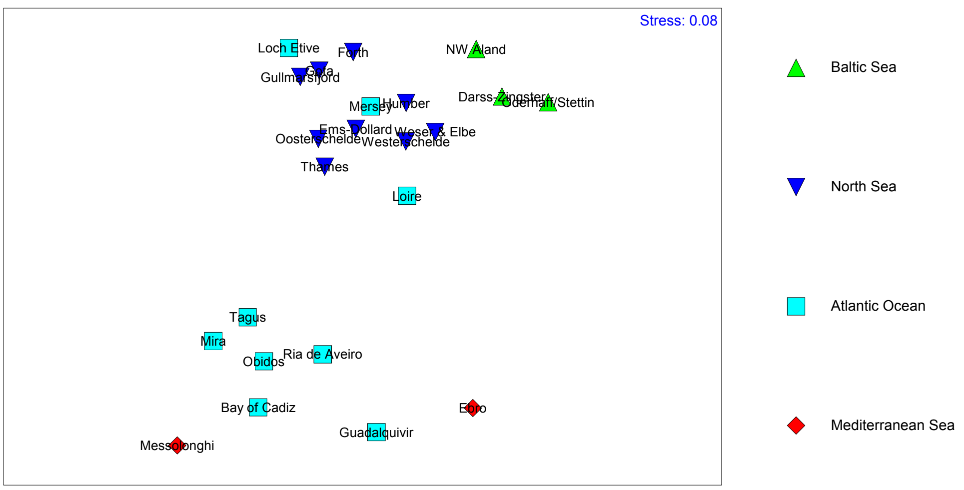
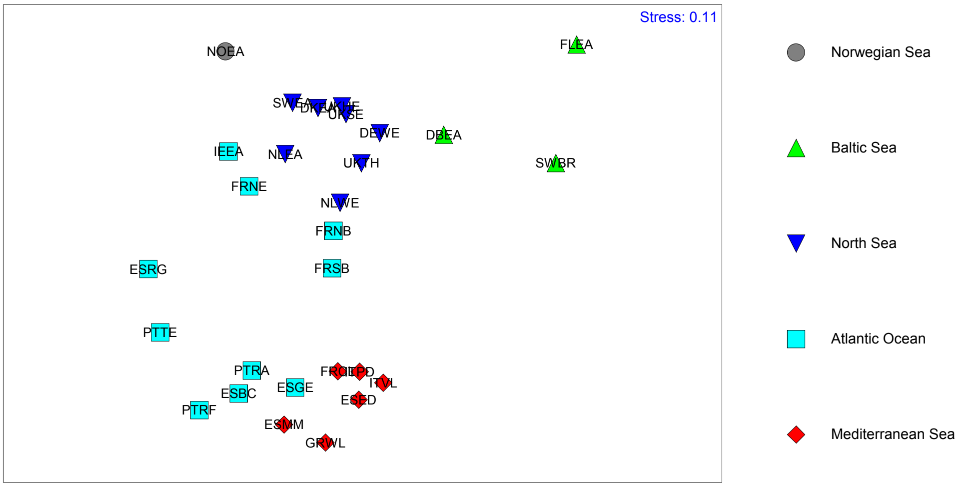


**Figure 4.7. MDS ordination of commercial fishes reported in European estuaries; systems are labelled according to WFD ecoregions.**




Phil *et al*. (2002) divided European coastal waters into three regions on the basis of a combination of biogeography and factors such as tidal range, salinity, and temperature. The Boreal/Atlantic region includes the Atlantic and North Sea coasts from Denmark to Gilbraltar, including the British Isles; estuaries in this region are all influenced by predictable and pronounced semi-diurnal tides.

The Baltic/Skagerrak region includes the region east from the interface with the North Sea between Norway and Denmark and all of the Baltic Sea; estuaries in this region are not influenced by significant tidal movement but both salinity and temperature may be significantly reduced. The Mediterranean region covers the area east from the Strait of Gilbraltar and includes all of the Mediterranean Sea; estuaries in this region are also not influenced by significant tides; salinities are not significantly reduced and average temperatures are higher (Phil *et al*., 2002).

Based on the zoogeographic regions identified by Phil *et al*. (2002), the ordinations revealed that Mediterranean and Boreal/Atlantic systems were situated toward the bottom half of the plots while the top half of the ordinations comprised a mix of Boreal/Atlanic and Baltic/Skagerrak systems (Figures 4.8 & 4.9).

**Figure 4.8. MDS ordination of fish communities reported in European estuaries; systems are labelled according to zoogeographic regions identified by Phil *et al*. (2002).**

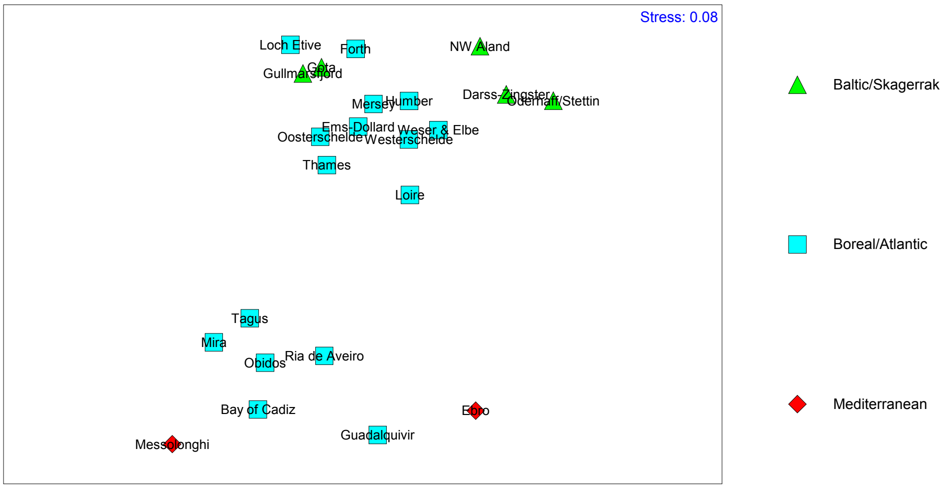
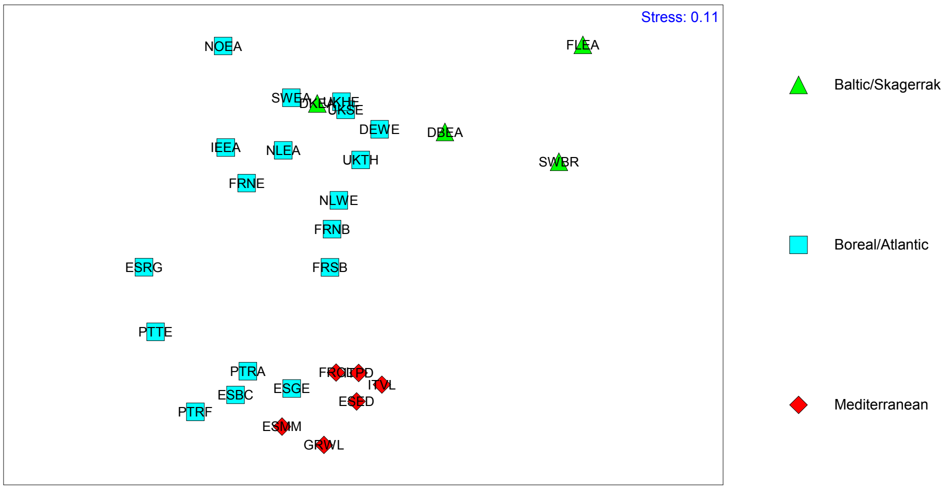



**Figure 4.9. MDS ordination of commercial fishes reported in European estuaries; systems are labelled according to zoogeographic regions identified by Phil *et al*. (2002).**




To test if the estuaries within the various zoogeographic regions suggested by the WFD and Phil *et al*. (2002) were distinct, an analysis of similarities (ANOSIM) was performed on the data. ANOSIM utilises the (rank) similarity matrix underlying the ordination procedure and tests for differences between and within *a priori* groupings (Clarke & Warwick, 1994; 2001; Somerfield *et al.,* 2002). A test statistic (*R*) is computed, which reflects the observed differences between groupings, contrasted with differences within groupings. The *R* statistic usually falls between 0 and 1; if $R = 1$ then all sites within a group are more similar to each other than any sites from different groups and if $R = 0$ then the similarities between and within groups are the same on average. The global $R$ statistic reflects the similarities between all groupings (Clarke & Warwick, 1994; 2001).

The results of an ANOSIM test using the ecoregions suggested by the WFD revealed that the fish communities within each zoogeographic region were somewhat distinct (global $R>0.50$; $p = 0.001$). Baltic and Norwegian Sea estuaries appeared to form the most distinct groups; estuaries in the Atlantic Ocean and Mediterranean Sea regions, as well as estuaries in the Atlantic Ocean and North Sea were less distinct (Tables 4.3 & 4.4). These results support the pattern produced by the MDS ordinations.

**Table 4.3. Results of the ANOSIM analysis (*R* statistic) applied to European fish communities based on WFD zoogeographic regions (global *R* = 0.554; p = 0.001).**

| | Baltic Sea | North Sea | Atlantic Ocean | Mediterranean Sea |
|---|---|---|---|---|
| **Baltic Sea** | | 0.707 (p = 0.005) | 0.644 (p = 0.005) | 1.000 (p = 0.100) |
| **North Sea** | 0.707 (p = 0.005) | | 0.421 (p = 0.005) | 1.000 (p = 0.018) |
| **Atlantic Ocean** | 0.644 (p = 0.005) | 0.421 (p = 0.005) | | 0.297 (p = 0.127) |
| **Mediterranean Sea** | 1.000 (p = 0.100) | 1.000 (p = 0.018) | 0.297 (p = 0.127) | |

**Table 4.4. Results of the ANOSIM analysis (*R* statistic) applied to European commercial fishes based on WFD zoogeographic regions (global *R* = 0.746; p = 0.001).**

| | Norwegian Sea | Baltic Sea | North Sea | Atlantic Ocean | Mediterranean Sea |
|---|---|---|---|---|---|
| **Norwegian Sea** | | 1.000 (p = 0.250) | 0.906 (p = 0.111) | 0.709 (p = 0.091) | 1.000 (p = 0.143) |
| **Baltic Sea** | 1.000 (p = 0.250) | | 0.903 (p = 0.006) | 0.887 (p = 0.003) | 1.000 (p = 0.012) |
| **North Sea** | 0.906 (p = 0.111) | 0.903 (p = 0.006) | | 0.607 (p = 0.001) | 1.000 (p = 0.001) |
| **Atlantic Ocean** | 0.709 (p = 0.091) | 0.887 (p = 0.003) | 0.607 (p = 0.001) | | 0.426 (p = 0.005) |
| **Mediterranean Sea** | 1.000 (p = 0.143) | 1.000 (p = 0.012) | 1.000 (p = 0.001) | 0.426 (p = 0.005) | |

The ANOSIM analysis applied to the zoogeographic regions suggested by Phil *et al.* (2002) also supported the pattern produced by the MDS ordinations. These groupings were not as distinct as those proposed by the WFD (global $R<0.50$; $p<0.005$).

Estuaries in Baltic/Skagerrak and Mediterranean regions were the most distinct groups while systems in the Boreal/Atlantic and Baltic/Skagerrak regions were the least distinct. Systems in the Mediterranean and Boreal/Atlantic regions also exhibited some overlap, particularly using data for commercial fishes (Tables 4.5 & 4.6).

**Table 4.5. Results of the ANOSIM analysis (*R* statistic) applied to European fish communities based on zoogeographic regions identified by Phil *et al.* (2002) (global *R* = 0.368; p = 0.003).**

| | Baltic/Skagerrak | Boreal/Atlantic | Mediterranean |
|---|---|---|---|
| **Baltic/Skagerrak** | | 0.215 (p = 0.060) | 1.000 (p = 0.048) |
| **Boreal/Atlantic** | 0.215 (p = 0.060) | | 0.571 (p = 0.007) |
| **Mediterranean** | 1.000 (p = 0.048) | 0.571 (p = 0.007) | |

**Table 4.6. Results of the ANOSIM analysis (*R* statistic) applied to European commercial fishes based on zoogeographic regions identified by Phil *et al.* (2002) (global *R* = 0.429; p = 0.001).**

| | Baltic/Skagerrak | Boreal/Atlantic | Mediterranean |
|---|---|---|---|
| **Baltic/Skagerrak** | | 0.395 (p = 0.011) | 0.980 (p = 0.005) |
| **Boreal/Atlantic** | 0.395 (p = 0.011) | | 0.336 (p = 0.001) |
| **Mediterranean** | 0.980 (p = 0.005) | 0.336 (p = 0.001) | |

Although Phil *et al*. (2002) considered the North Sea and Atlantic Ocean under one biogeographic region (Boreal/Atlantic), a cluster analysis of fish assemblages from 17 European estuaries indicated strong latitudinal differences, reflecting the separation of more Boreal (cold-temperate) fauna in the north (Elliott & Dewailly, 1995). Systems in Portugal, Spain and France were found to be distinct from estuaries in the United Kingdom, Belgium, the Netherlands, Germany and Norway.

Using a combination of latitude and the zoogeographic regions described above, four alternate zoogeographic regions could be identified. These included:

- Mediterranean/Atlantic (< 45° N).
- North Sea/Atlantic (> 45° N) including those systems in the Skatterag/Kattegat region of the Baltic.
- Baltic Sea
- Norwegian Sea (> 60° N)

These revised regions produced somewhat distinct groupings. Mediterranean/Atlantic (<45° N) estuaries were situated toward the bottom of the ordinations; North Sea/Atlantic (>45° N) estuaries were situated toward the middle and top of the plots, and estuaries in the Baltic Sea were situated toward the top left of the plots (Figures 4.10 & 4.11). In the MDS of commercial fishes, Norwegian estuaries (Norwegian Sea (> 60° N)) were situated in the top right of the ordination (Figure 4.11).

**Figure 4.10. MDS ordination of fish communities reported in European estuaries. Systems are labelled according to modified ecoregions.**

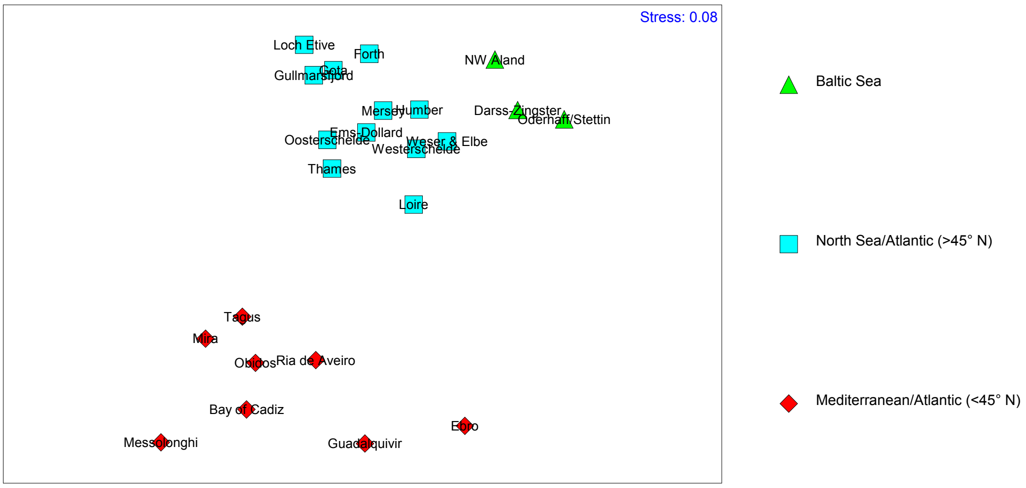
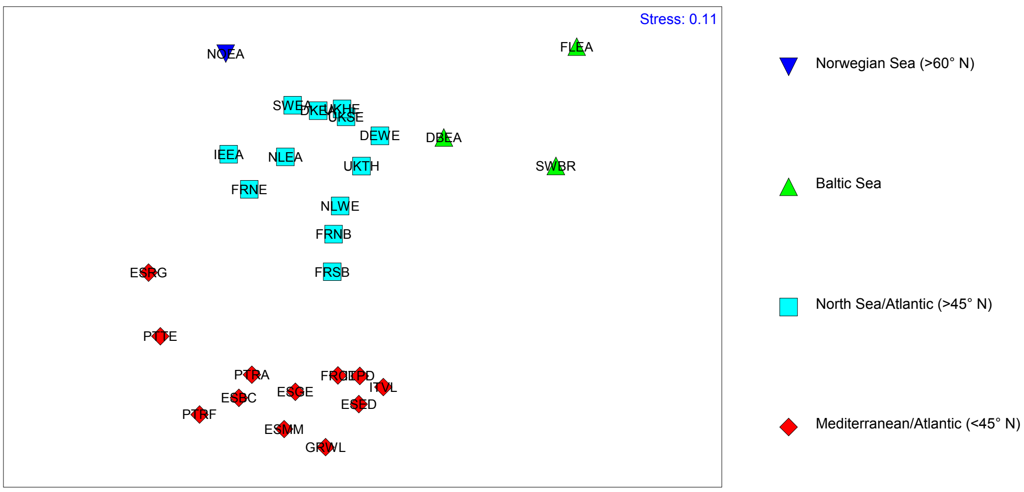



**Figure 4.11 MDS ordination of commercial fishes reported in European estuaries. Systems are labelled according to modified ecoregions.**




An ANOSIM analysis also indicated that these revised zoogeographic regions were more distinct than those suggested either by the WFD or by Phil *et al*. (2002) (global $R$ >0.80; p = 0.001) (Tables 4.7 & 4.8).

**Table 4.7. Results of the ANOSIM analysis (*R* statistic) applied to European fish communities based on revised zoogeographic regions (global *R* = 0.876; p = 0.001).**

| | Baltic Sea | North Sea / Atlantic (> 45° N) | Mediterranean / Atlantic (< 45° N) |
|---|---|---|---|
| **Baltic Sea** | | 0.708 (p = 0.002) | 1.000 (p = 0.006) |
| **North Sea / Atlantic (> 45° N)** | 0.708 (p = 0.002) | | 0.965 (p = 0.001) |
| **Mediterranean / Atlantic (< 45° N)** | 1.000 (p = 0.006) | 0.965 (p = 0.001) | |

**Table 4.8. Results of the ANOSIM analysis (*R* statistic) applied to European fish communities based on WFD zoogeographic regions (global *R* = 0.868; p = 0.001).**

| | Norwegian Sea (> 60° N) | Baltic Sea | North Sea / Atlantic (> 45° N) | Mediterranean / Atlantic (< 45° N) |
|---|---|---|---|---|
| **Norwegian Sea (> 60° N)** | | 1.000 (p = 0.250) | 0.630 (p = 0.077) | 0.989 (p = 0.077) |
| **Baltic Sea** | 1.000 (p = 0.250) | | 0.827 (p = 0.002) | 1.000 (p = 0.002) |
| **North Sea / Atlantic (> 45° N)** | 0.630 (p = 0.077) | 0.827 (p = 0.002) | | 0.881 (p = 0.001) |
| **Mediterranean / Atlantic (< 45° N)** | 0.989 (p = 0.077) | 1.000 (p = 0.002) | 0.881 (p = 0.001) | |

This analysis has shown that fishes in European estuaries contain distinctive fish assemblages and that these are related to zoogeography. It has also shown that, although preliminary, European estuaries can also be grouped into at least four distinct biogeographic regions.

## 4.8 Typology

Another key factor that plays an important role in structuring the fish communities in estuaries is the individual characteristics of each estuary or estuary type (Blaber, 1985). Estuaries are systems where marine and fresh waters meet and, as such, experience great environmental variation in salinity, temperature, dissolved oxygen and turbidity, for example. Because no two estuaries are identical in terms of either biotic or abiotic characteristics, it could be argued that the ichthyofaunas of each estuary would also differ.

Whitfield (1999), however, postulated if the fishes in estuaries respond to the environment in a consistent manner, then the communities occupying similar types of estuaries in a particular region would be expected to reflect this similarity.

Harrison *et al.* (2000) classified South Africa's estuaries into six categories, based on the main forms of morphological variability among these systems along the coast. These were:

- open non-barred estuaries
- predominantly open small estuaries (mean annual runoff (MAR) $<15x10^6$ $m^3$)
- predominantly open moderate to large estuaries (MAR $>15x10^6$ $m^3$)
- predominantly closed small estuaries (surface area <2 Ha)
- predominantly closed moderately sized estuaries (surface area 2-150 Ha)
- predominantly closed large estuaries (surface area >150 Ha)

The WFD also recognises that the ecological character of transitional waters will vary according to their different physical regimes. Two estuarine typology classification schemes have been proposed. One system is based on both mean annual salinity and tidal range while the other is based on a variety of parameters including latitude, longitude, tidal range, salinity, depth, current velocity, wave exposure, residence time, mean water temperature, mixing characteristics, turbidity, mean substratum composition, shape, and water temperature range.

In order to be realistic, reference conditions must take into account both the inherent morphological differences between estuaries as well as zoogeographic differences. In the development of the EFCI, reference conditions were established for each morphological group of estuaries within each biogeographic region separately. By taking these two factors into account, biological comparisons can then be made within each morphological group and will prevent inappropriate comparisons between different types of estuary and between different regions. Furthermore, by comparing the fish characteristics of an estuary with the appropriate reference condition, the state of estuaries from different physical/morphological groups and from different zoogeographic regions can be directly compared.

# 5. CONCLUSIONS

Estuary classification is a key requirement of the Water Framework Directive and once developed, will also help meet some of the requirements of the Habitats & Species Directive.

Fish community measures are derived from a number of individual and/or functional attributes. It is a combination of these that will allow an assessment of the composition and abundance of the fish fauna in order to meet the requirements of the WFD

Analysis of European fish faunal assemblages has shown variation between WFD ecoregions. A key issue is highlighted within ecoregion 1 (Atlantic) and as such any classification scheme must take into account these biogeographic differences. This analysis will also aid future comparisons of datasets within ecoregions and estuary type.

Development of the Estuarine Fish Classification Index (EFCI) has highlighted the inconsistency in monitoring within the EU and the need to standardise techniques and approaches. Current estuarine monitoring strategies tend to be based upon impacted sites, for example the National Marine Monitoring Programme (NMMP), where bioaccumulation studies within flatfish are the key survey drivers.

The EFCI described here is an ecologically based method that combines both structural and functional attributes of estuarine fish communities and integrates these to provide both a robust and sensitive method for assessing the ecological condition of estuarine systems. It is also conceptually simple, the metrics are easily measured and the overall index is straightforward and rapid to calculate.

Initial indications show that this metric EFCI is suitable for UK use, but there are current limitations in testing against single-strand monitoring techniques. The benefits of a multi-method approach are discussed within European Commission (2000) and Elliott & Hemingway (2002). The net effect of a single strand approach is likely to be an under-estimation of the metric score (Steve Colclough, Pers.comm).

The use of 'models' that predict biological reference conditions should only be used with great caution. They are dependent upon the quality of the reference data, are complex and are often based on untested hypotheses (USEPA, 2000).

There is a general lack of data within the less impacted, more pristine estuarine reference sites. As such, the EFCI has been developed by having to calculate 'reference conditions'. This needs to be addressed by testing the classification scheme against a range of reference site where little or no data exists

The next planned phase of this work is to incorporate multi-method survey datasets in order to assess the composition, abundance and community structure of UK fish faunal assemblages.

The EFCI is also an effective communication tool for converting ecological information into an easily understood format for managers, policy makers, and the general public as a whole.

# 6. RECOMENDATIONS

A bi-annual, multi-method monitoring approach should be developed over a range of sites within the UK & Ireland in order to test this classification scheme against the temporal and spatial variability present within fish faunal assemblages.

Standardisation of monitoring techniques and methodologies would lead towards greater comparability of datasets and aid future analysis.

Reference conditions have been calculated from only 32 UK and Irish estuaries. Further monitoring is required in order to provide greater confidence within the overall classification.

A more holistic survey approach should be adopted, not only to meet the requirements of the EU Water Framework Directive but also to focus upon local area needs and management requirements.

Measures based upon abundance data should be standardised by calculating relative abundance as a percentage of each species and avoid the use of absolute numbers.

Phase 3 of the R&D project should target the analysis of all datasets using this methodology in order to test the classification index.

The lack of reference sites of the same type and ecoregion should target future resources and monitoring strategies. It is hoped that this will become a partnership exercise within the UK and Ireland in order to benefit all Government Agency's, resulting in a full operational test of the EFCI.

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# APPENDIX 1

**List of Environment Agency Transitional Waters Technical Fisheries Group**

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3. Adrian Fewings - Technical Specialist – EA Southern Region

4. Alan Starkie - WFD Fisheries Advisor

5. Sarah Peaty - Team Leader EA, North East Region

6. Matthew Robson - Project Data Officer, Thames Region

7. Lindsey Richardson - Water Management – Ecology Advisor Marine

8. Miran Aprahamian - Technical Specialist, NSTFC

9. Andrew Robinson - Environmental Assessment, Wales

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# APPENDIX 3

## Fish populations monitoring method fact sheet, transitional waters - seine netting

| | |
|---|---|
| Water Category | Transitional |
| Water Framework Directive Quality Element | Composition and abundance of fish fauna |
| Name of the method → | Seine Netting |
| *Method proposed by* → | **UK** |
| **Method commonly used in** → | UK |

**Short description of the method**

The seine net is loaded onto a boat with one end of the net held on the shore. During deployment (usually at low water slack), the boat sets the net out in a semi-circle, returning the other end of the net back to the shore. The two ends of the net are then hauled in towards the shore. The target organisms for this method are pelagic fish species. The technique is applied alongside beam trawling and kick sampling at the same sampling location to obtain information on the fish community present at the site.

The fish captured in the seine net are identified to species level in the field, counted and measured (total length). The fish captured are returned to the transitional water alive where possible. A standard method is used to derive measures of total number of species and total abundance.

**Reference basis of method and comparison**

*The measures of fish community structure are not compared to reference conditions at present. Research is ongoing on how measures derived using this method can be used for the purposes of the WFD.*

| | |
|---|---|
| **Reference conditions compliant with WFD** *(yes/no)* | No |

**Status of method**

| | |
|---|---|
| International Standard (yes/no) – *if yes provide reference number* | No |
| National Standard (yes/no) – *if yes provide reference number* | No |
| National method (yes/no) – *if yes provide reference number and details* | Yes – Environment Agency National Marine Procedures Manual (Ref: D103). |
| Published in literature (yes/no) – *if yes provide reference details* | Yes |

***Reference material***

Environment Agency – Tidal Thames Fisheries Survey, EA Thames Region.
European Commission Report – FAIR CT961634: Commercial Fish & European Estuaries – Priorities for Management and Research.
Elliott, M. & Hemingway, K. (ed) (2002). Fishes in Estuaries, Blackwell Science Ltd, London.

***Applicability of the method to WFD***

The method provides the means for estimating the composition and abundance of the pelagic component of fish communities in transitional waters. The method forms part of output of EA R&D Project E1-116 which is looking at developing a fish based classification scheme and monitoring strategy for Transitional Waters.

## Fish populations monitoring method fact sheet, transitional waters – beam trawling

| | |
|---|---|
| Water Category | Transitional |
| Water Framework Directive Quality Element | Composition and abundance of fish fauna |
| Name of the method → | Beam Trawling |
| *Method proposed by →* | **UK** |
| **Method commonly used in →** | UK |

**Short description of the method**

The Beam Trawl is designed to exploit demersal fish and shellfish in transitional waters. The trawl comprises of a net attached to a beam (or frame) which keeps the mouth of the net open. It is deployed from a boat and is designed to be towed along the seabed. This technique is applied alongside seine netting and kick sampling at the same sampling location to obtain information on the fish community present at the site.

The fish captured in the beam trawl sample are identified to species level in the field, counted and measured (total length). The fish captured are returned to the transitional water alive. A standard method is used to derive measures of total number of species and total abundance.

**Reference basis of method and comparison**

*The measures of fish community structure are not compared to reference conditions at present. Research is ongoing on how measures derived using this method can be used for the purposes of the WFD.*

| | |
|---|---|
| **Reference conditions compliant with WFD** *(yes/no)* | No |

**Status of method**

| | |
|---|---|
| International Standard (yes/no) – *if yes provide reference number* | No |
| National Standard (yes/no) – *if yes provide reference number* | No |
| National method (yes/no) – *if yes provide reference number and details* | Yes – Environment Agency National Marine Procedures Manual (Refs: B105 and D103) |
| Published in literature (yes/no) – *if yes provide reference details* | Yes |

***Reference material***

Environment Agency – Tidal Thames Fisheries Survey, EA Thames Region.
European Commission Report – FAIR CT961634: Commercial Fish & European Estuaries – Priorities for Management and Research.
Thomas, M. in: Attrill, M.J. (ed) (1998). A rehabilitated estuarine ecosystem. The environment and ecology of the Thames Estuary, Kluwer Academic Publishers.
UK National Marine Monitoring Programme Green Book
Elliott, M. & Hemingway, K. (ed) (2002). Fishes in Estuaries, Blackwell Science Ltd, London.

***Applicability of the method to WFD***

The method provides the means for estimating the composition and abundance of the demersal component of fish communities in transitional waters. The method forms part of output of EA R&D Project E1-116 which is looking at developing a fish based classification scheme and monitoring strategy for Transitional Waters.

**Fish populations monitoring method fact sheet, transitional waters – Otter trawling**

| | |
|---|---|
| Water Category | Transitional |
| Water Framework Directive Quality Element | Composition and abundance of fish fauna |
| Name of the method → | Otter Trawling |
| *Method proposed by →* | **UK** |
| **Method commonly used in →** | UK |

**Short description of the method** *:*

Otter trawls are usually towed by a single boat and can be dragged along the seabed (for demersal species) or through the water column to catch pelagic species.
The mouth of the net is held open by a weighted ground rope, floats on the headline and the effect of the otter boards. The bridles, warps and otter boards help drive the fish towards the net. The target organisms for this technique are pelagic fish species.

The fish captured in the beam trawl sample are identified to species level in the field, counted and measured (total length). The fish captured are returned to the transitional water alive. A standard method is used to derive measures of total number of species and total abundance.

**Reference basis of method and comparison***:*

*The measures of fish community structure are not compared to reference conditions at present. Research is ongoing on how measures derived using this method can be used for the purposes of the WFD.*

| | |
|---|---|
| **Reference conditions compliant with WFD** *(yes/no)* | No |

**Status of method**

| | |
|---|---|
| International Standard (yes/no) – *if yes provide reference number* | No |
| National Standard (yes/no) – *if yes provide reference number* | No |
| National method (yes/no) – *if yes provide reference number and details* | No |
| Published in literature (yes/no) – *if yes provide reference details* | Yes |

***Reference material***

Environment Agency – Tidal Thames Fisheries Survey, EA Thames Region.
European Commission Report – FAIR CT961634: Commercial Fish & European Estuaries – Priorities for Management and Research.
Thomas, M. in : Attrill, M.J. (ed) (1998). A rehabilitated estuarine ecosystem. The environment and ecology of the Thames Estuary, Kluwer Academic Publishers.
Elliott, M. & Hemingway, K. (ed) (2002). Fishes in Estuaries, Blackwell Science Ltd, London.

***Applicability of the method to WFD***

The method provides the means for estimating the composition and abundance of the pelagic component of fish communities in transitional waters. The method forms part of output of EA R&D Project E1-116 which is looking at developing a fish based classification scheme and monitoring strategy for Transitional Waters.

## Fish populations monitoring method fact sheet, transitional waters – Kick Sampling

| | |
|---|---|
| Water Category | Transitional |
| Water Framework Directive Quality Element | Composition and abundance of fish fauna |
| Name of the method → | Kick Sampling |
| *Method proposed by →* | **UK** |
| **Method commonly used in →** | UK |

**Short description of the method** *:*

The 'biologists' kick sample net is widely used for collecting invertebrates and juvenile fish fry. It involves a D-shaped net attached to a wooden shaft that is held by the operative. The technique used involves the operative walking backwards into the flow of the river, displacing the substrate that they are walking upon for one minute. The net is held a short distance away from the feet and any material disturbed is caught within the net. The target organisms for this technique are fish fry and larvae. This technique is applied alongside beam trawling and seine netting at the same sampling location to obtain information on the fish community present at the site. The fish captured in the kick net sample are identified to species level in the field, counted and measured (total length). The fish captured are returned to the transitional water alive where possible. A standard method is used to derive measures of total number of species and total abundance.

**Reference basis of method and comparison***:*

*The measures of fish community structure are not compared to reference conditions at present. Research is ongoing on how measures derived using this method can be used for the purposes of the WFD.*

| | |
|---|---|
| **Reference conditions compliant with WFD** *(yes/no)* | No |

**Status of method**

| | |
|---|---|
| International Standard (yes/no) – *if yes provide reference number* | Yes - EN 27828:1994; ISO 7828:1985 |
| National Standard (yes/no) – *if yes provide reference number* | Yes |
| National method (yes/no) – *if yes provide reference number and details* | Yes – based on BT001 Procedures for Collecting and Analysing Macro-invertebrate Samples and D103 for estimating total number of species and total abundance in the Environment Agency National Marine Procedures Manual. |
| Published in literature (yes/no) – *if yes provide reference details* | Yes |

***Reference material***

Environment Agency – Tidal Thames Fisheries Survey, EA Thames Region.
European Commission Report – FAIR CT961634: Commercial Fish & European Estuaries – Priorities for Management and Research.
Thomas, M. in : Attrill, M.J. (ed) (1998). A rehabilitated estuarine ecosystem. The environment and ecology of the Thames Estuary, Kluwer Academic Publishers.
Davies, A. (2001). The use & limits of various methods of sampling and interpretation of benthic macro-invertebrates. J. Limnol., 60 (Suppl. 1) : 1-6, 2001.
Elliott, M. & Hemingway, K. (ed) (2002). Fishes in Estuaries, Blackwell Science Ltd, London.

***Applicability of the method to WFD*** (Expert's assessment of method)

The method provides the means for estimating the composition and abundance of the fry and larval component of fish communities in transitional waters. The method forms part of output of EA R&D Project E1-116 which is looking at developing a fish based classification scheme and monitoring strategy for Transitional Waters.

## Fish populations monitoring method fact sheet, transitional waters – Power Station Sampling

| | |
|---|---|
| Water Category | Transitional |
| Water Framework Directive Quality Element | Composition and abundance of fish fauna |
| Name of the method → | Power Station Intake Screens |
| *Method proposed by →* | **UK** |
| **Method commonly used in →** | UK |

**Short description of the method** *(approx. 10 lines):*

Some power stations require large volumes of cooling water (e.g. West Thurrock on the Thames Estuary extracts up to 136 million litres per hour) and for this reason they are located on the coasts of transitional and coastal waters. Cooling water intakes of power stations located in transitional waters have been exploited to sample local fish communities. Screens are used to prevent fish and debris entering the cooling system and the fish entrained on these screens are used to obtain samples of fish populations.

The technique has been used successfully to monitor the recovery of the fish populations in the Thames estuary. It produces estimates of fish species present and of relative abundance.

**Reference basis of method and comparison** *(approx. 10 lines):*

*The measures of fish community structure are not compared to reference conditions at present.*

| | |
|---|---|
| **Reference conditions compliant with WFD** *(yes/no)* | No |

**Status of method**

| | |
|---|---|
| International Standard (yes/no) – *if yes provide reference number* | No |
| National Standard (yes/no) – *if yes provide reference number* | No |
| National method (yes/no) – *if yes provide reference number and details* | Yes |
| Published in literature (yes/no) – *if yes provide reference details* | Yes |

***Reference material***

Environment Agency – Tidal Thames Fisheries Survey, EA Thames Region.
European Commission Report – FAIR CT961634: Commercial Fish & European Estuaries – Priorities for Management and Research.
Thomas, M. in: Attrill, M.J. (ed) (1998). A rehabilitated estuarine ecosystem. The environment and ecology of the Thames Estuary, Kluwer Academic Publishers.
Elliott, M. & Hemingway, K. (ed) (2002). Fishes in Estuaries, Blackwell Science Ltd, London.

***Applicability of the method to WFD*** (Expert's assessment of method)

The method provides the means for estimating the composition and abundance of the pelagic component of fish communities in transitional waters. The method forms part of output of EA R&D Project E1-116 which is looking at developing a fish based classification scheme and monitoring strategy for Transitional Waters.

**Appendix 4    Otter Trawl NMMP Procedure.**

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## 1. GENERAL DESCRIPTION

The otter trawl (Fig. 1) is a very efficient method of capturing pelagic fish and in certain conditions can be effective for sampling flatfish and other epibenthos. Samples collected are suitable for community assessment and bioaccumulation studies. The otter trawl is also an appropriate sampling method where live specimens are required as long as the hauls do not exceed fifteen minutes. Due to the weight and size of the trawl a boat equipped with a winch is required for deployment and retrieval. A minimum of three workers are also required, two to handle the trawl, and one to operate the winch.

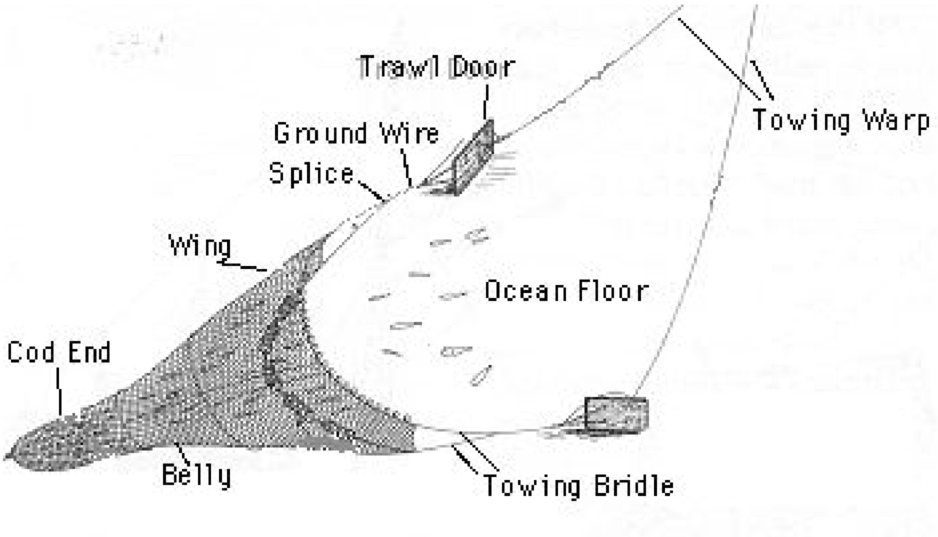


**Figure 1:** Otter trawl

The trawl is kept open vertically by the headrope to which lots of floats and sometimes kites are attached, and horizontally by otter boards. The otter boards or doors are set at a particular angle, so that drag is minimised and spread of the net is maximised. The geometry of the boards therefore has to be perfect as this has a direct bearing on net performance and fuel economy.

A length of rope known as a 'Lazy deckey' can be attached to the cod end and secured to one of the otter boards so that the entire net does not have to be brought on board to be emptied after each trawl. The cod end alone can be winched on to the deck using the 'lazy deckey' saving both time and effort. A 'lazy deckey can also be attached to the ground line so that when the cod end is very heavy, the mouth of the net can also be brought on board so that the whole net can be emptied.

For the trawl to fish effectively for demersal and benthic species it is essential that the ground rope makes good contact with the seabed. Different ground ropes can be used for smooth ground (where wires are used) but on rougher ground bobbins are used to prevent damage to the net, though this can lead to fish escaping under the ground rope. Tickler chains can be attached to the footrope on sandy seabed's if required, although the configuration of the trawl should not be changed during or between routine fish population assessment surveys. The footrope is twice the length of the headrope in order that during trawling it curves back behind the top of the net, therefore forming a roof that will trap any fish escaping upwards when disturbed by the foot rope and if added, tickler chains.

In strong current conditions, towing should be carried out against the direction of the current. This is primarily for safety reasons, as the forward momentum of the vessel will fall much faster when the engines are turned off should the trawl become snagged, hence minimising any damage to the gear and any hazards associated with vessel instability caused by snagged gear. A second reason is to maximise catch as dermersal fish will tend to swim in front of the net and tire more quickly swimming against the tide and hence drop back into the net.

The amount of warp used is dependent upon fishing depth and the speed of the boat. Towing speeds of between 1.5 and 2.5 knots are usually acceptable for benthic and pelagic species, with warp lengths usually ranging between 3-5 times the water depth. If in doubt it is better to have too much warp out than too little.

Boat speed is a critical factor as the faster the boat travels the more the trawl will tend to lift off the seabed. This is particularly important when monitoring pelagic fish stocks such as cod or sea bass where boat speed has to be increased to 5 knots or more.

A run over the site to be trawled with an echo sounder may be a good idea before undertaking trawling, this would identify any objects that may snag the trawl and damage it. The area could also be trawled with a more robust beam trawl if it is known to be full of rubbish, prior to shooting the otter trawl. Damage to a net can mean that an entire day trawling is forfeited, it is therefore practical to carry two nets on board and to protect them as much as possible. In the past a heavy duty piece of net has been attached to the underside of the cod end to protect it as it fills up and is dragged along the bottom.

## 2 OPERATING PROCEDURE

**Equipment used:**

2 x 70 fathom warps
2 x 9ft combination bridles
1 x 6 fathom otter trawl
2 x 3ft otter boards

**Shooting**

2.1 Three workers are required to shoot and retrieve the trawl; one controlling the winch, and two guiding the trawl.

2.2 The warps must be run through the transom, this provides a lower towing point therefore reducing the destabilising effect of towing and any hazards associated with snagged gear. Also if the cable shears, it will recoil against the transom rather than across the deck where it could cause severe injury.

2.3 Prior to shooting the net the cod end should be tied securely.

2.4 The trawl should be shot while the vessel is steaming slowly forward at approximately 1-2 knots. The net should be introduced into the water manually cod end first, and be allowed to stream out behind the vessel until the otter boards are at the stern.

2.5 The otter boards should then be deployed with the end of 'lazy deckey' tied off to one of the otter boards.

2.6 The rest of the trawl and bridle should then be streamed out over the stern.

2.7 Ease off on the warps until they are at least three times the depth of the water and length of the vessel.

2.8 Once the trawl doors are over the stern, the speed of the vessel should be increased to 1-3 knots and the warps payed out to the required length. When the required length is achieved the speed can be reduced to 1.5 knots.

**Hauling**

2.9 Hauling should commence at the end of the station as the vessel is steaming away from the site.

2.10 Winch up on the warps until the otter boards are tight against the transom.

2.11 Untie 'lazy deckey' from the otter board and connect it to a heaving line.

2.12 The vessel should now move ahead at approximately 0.75 knots to push any fish that are caught in the 'belly' of the net in to the cod end.

2.13 The vessel should then be stopped and at the same time the 'lazy deckey' hauled on board.

2.14 The heaving line should be winched up until the cod end is on board. The full trawl should not be brought on board unless there is damage to the net or trawling at the site is complete.

2.15 The cod end line can now be released and the catch dropped on to the deck or a suitable container.

2.16 To re-shoot, re-tie the cod end, ease of on the 'lazy deckey' and ease off on the warps making sure that the 'lazy deckey' is re-attached to the otter board before shooting.

**Recovering Trawl**

2.17 Secure the cod end to the vessel by tying 'lazy deckey' to bollards.

2.18 Ease off gently on the warps one fathom.

2.19 Lift the otter boards onto the deck.

2.20 Pull in the rest of the net.

## 3. SAFETY

3.1 Suitable personal protection equipment should be worn:

- All staff working on the afterdeck of the survey vessel must wear twin-chambered lifejackets, alternatively a safety harness should be worn.
- Steel toe-cap boots to be worn by all workers involved in handling the trawl.
- The wearing of protective gloves is recommended.

- Hard hats should also be worn.

3.2 All personnel operating sampling equipment should have received training/instruction from a suitably experienced person in how to operate the gear correctly.

3.3 While the winch is in operation all workers on the afterdeck are responsible for being aware of where the cables are. Stepping over moving cables should be avoided wherever possible.

3.4 All workers on the afterdeck are responsible for being aware of the hydraulic gantry, and must keep away from moving parts when in use.

3.5 Only suitably qualified individuals should operate the winch. All other workers must be aware of which drum is being used, and keep clear of the winch and cables when in operation.

3.6 When the trawl is being deployed and retrieved the line of sight of the winch operator must not be obstructed.

3.7 The warp should be run through the transom. This gives a lower towing point, reducing the destabilising effects of towing and any hazards associated with snagged gear. Also, if the warp shears it will recoil against the transom rather than across the afterdeck where severe injuries could be inflicted.

3.8 In strong current conditions towing should be done against the direction of flow so that if the gear becomes snagged the forward momentum of the vessel will rapidly reduce once the engines are stopped. This will keep any damage to gear at a minimum, and reduce any hazard associated with vessel instability caused by the snagged gear. Towing may be done in either direction in low current conditions.

3.9 The use of trawling gear in rough weather can be extremely dangerous. Since the responsibility for the safety of all on board the vessel lies with the Master, the decision to proceed with sampling lies solely with the Master.

3.10 Only suitably fit and able-bodied individuals should handle heavy sampling gear or lift or move samples. All workers must be suitably trained in lifting techniques and should refer to the Health and Safety Manual.

3.10 Prior to undertaking work on any Agency vessel all workers should refer to the National Boatwork Code of Practice (Health and Safety Manual, Section 3.6.1), and should be aware of all safety procedures and equipment applicable to the vessel.

**Appendix 5 – Fish survey datasets**

| Estuary | Surveys Undertaken | Source | Data Period | No. of Stations |
|---|---|---|---|---|
| **Blyth** | Blyth beam trawl programme | EA NE | 1990,1992-1995 | 6 |
| **Clyde** | Clyde beam trawl programme | SEPA | 1979-2003 | 6 |
| **Dee** | National Marine Monitoring Programme | EA WA | 2002 | 1 |
| | WFD Intercalibration survey | WFD | 2003 | 1 |
| **Forth** | Forth Beam trawl programme | SEPA | 1977-2003 | 11 |
| **Fal** | WFD Workshop | WFD | 2002 | 9 |
| | Fal tideway survey | WFD | 2003 | 6 |
| **Great Ouse** | Great Ouse beam trawl programme | EA AN | 1989-1994 | 34 |
| **Humber** | Young Fish Survey | CEFAS | 2003 | 6 |
| | National Marine Monitoring Programme | EA AN | 2002-2003 | 3 |
| | WFD Intercalibration survey | WFD | 2003 | 2 |
| | Humber tideway survey | WFD | 2003 | 6 |
| | Stallingborough Power Station survey | ICES | 1999-2000 | 1 |
| **Mawddach** | Mawddach tideway survey | WFD | 2003 | 4 |
| **Medway** | Medway tideway survey | EA SO | 1997-2001 | 5 |
| | National Marine Monitoring Programme | EA SO | 2002 | 1 |
| **Mersey** | Mersey beam trawl programme | EA NW | 1981-1997 | 6 |
| | National Marine Monitoring Programme | EA NW | 2002 | 2 |
| | WFD Intercalibration survey | WFD | 2003 | 2 |
| | WFD Net trials | WFD | 2002 | 2 |
| | DMECS survey | CEFAS | 2002 | 3 |
| **Morecambe Bay** | National Marine Monitoring Programme | EA NW | 2002 | 1 |
| **Ribble** | National Marine Monitoring Programme | EA NW | 2002 | 1 |
| | WFD Intercalibration survey | WFD | 2003 | 1 |
| **Severn** | National Marine Monitoring Programme | EA WA | 2002 | 1 |

| Estuary | Surveys Undertaken | Source | Data Period | No. of Stations |
|---|---|---|---|---|
| | WFD Intercalibration survey | WFD | 2003 | 2 |
| | Hinckley Point Power Station survey | PISCES | 1981-1996 | 1 |
| **Tamar** | National Marine Monitoring Programme | EA SW | 2002 | 2 |
| | WFD Intercalibration survey | WFD | 2003 | 1 |
| **Tay** | Tay Beam Trawl Programme | SEPA | 1997-2001 | 6 |
| **Tees** | Tees beam trawl programme | EA NE | 19893-2000 | 6 |
| | National Marine Monitoring Programme | EA NE | 2002 | 3 |
| | Hartlepool Power Station survey | EA NE | 1991-1993,1996-2002 | 1 |
| **Test (Southampton Water)** | National Marine Monitoring Programme | EA SO | 2002 | 2 |
| | DMECS survey | CEFAS | 2002 | 1 |
| **Thames** | Thames tideway survey | EA TH | 1999-2002 | 6 |
| | National Marine Monitoring Programme | EA TH | 2002 | 2 |
| | DMECS survey | CEFAS | 2002 | 2 |
| | Bass survey | CEFAS | 1997-2002 | 37 |
| | West Thurrock Power Station survey | EA TH | 1974-1993 | 1 |
| **Tweed** | National Marine Monitoring Programme | EA NE | 2002 | 1 |
| **Tyne** | Tyne beam trawl programme | EA NE | 1983-2000 | 6 |
| | National Marine Monitoring Programme | EA NE | 2002 | 2 |
| **Wash** | National Marine Monitoring Programme | EA AN | 2002-2003 | 4 |
| | Ecomaris EIA | Ecomaris | 1998-2000 | 9 |
| **Wear** | Wear beam trawl programme | EA NE | 1982-2001 | 5 |
| | National Marine Monitoring Programme | EA NE | 2002 | 2 |