

UKTAG Transitional Water Assessment Method

Fish Fauna

Transitional Fish Classification Index

by

**Water Framework Directive – United Kingdom Technical Advisory Group
(WFD-UKTAG)**



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It is also the responsibility of the user if seeking to practise the method outlined here, to gain appropriate permissions for access to water courses and their biological sampling

UKTAG Guide to the Transitional Fish Classification Index (TFCI) Water Framework Directive: Transitional Waters

Purpose of document: To provide an overview of the Transitional Fish Classification Index (TFCI), to inform Practitioners of how to monitor, assess and classify suitable fish data according to Water Framework Directive (WFD) requirements in transitional waters (TWs).

Note: this document does not fully describe all aspects of the TFCI development and application; for this please refer to the key documents and references provided within this document.

Introduction to WFD Terminology and Assessment: This guide describes a system for classifying in accordance with the requirements of Article 8; Section 1.3 of Annex II and Annex V of the WFD (2000/60/EC). Practitioners should recognise that the terminology used in this document is specific to the WFD and has a meaning defined by the directive.

To carry out a WFD biological assessment, each biological quality element (BQE, defined in the WFD) is required to give a statistically robust definition of the ‘health’ of that element in the sampled water body. The ‘health’ of a BQE is assessed by comparing the measured conditions (observed value) against that described for reference conditions (minimally disturbed). This is reported as an Ecological Quality Ratio (EQR). An EQR with a value of one represents reference conditions and a value of zero represents a severe impact. The EQR is divided into five ecological status classes (High, Good, Moderate, Poor and Bad) that are defined by the changes in the biological community in response to disturbance (Figure 1).

Alongside the EQR score and class status, any assessment must consider the certainty of the assessment (i.e. confidence in the assigned class).

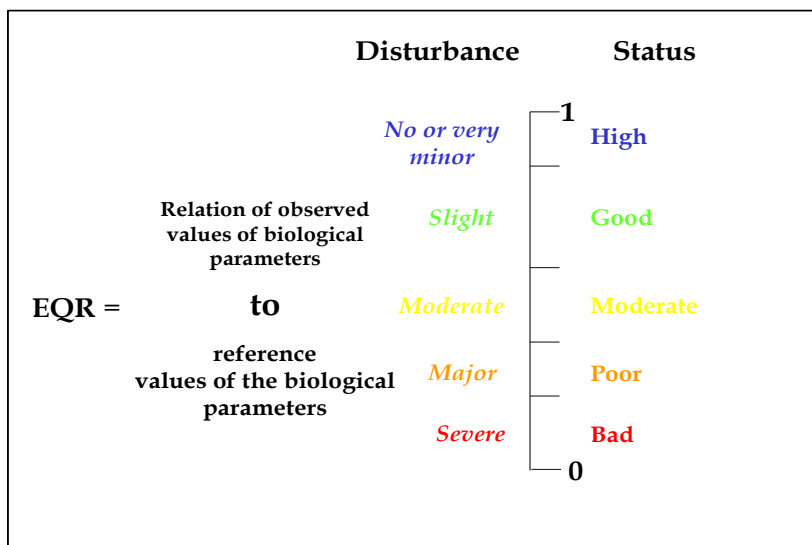


Figure 1: Illustration of the Ecological Quality Ratio and how it relates to the level of disturbance and ecological status during a classification. The class band widths relate to biological changes as a result of disturbance (WFD CIS Guidance Document No. 5, 2003).

1. Key Facts

1.1 Tool Overview: Transitional Fish Classification Index (TFCI)

The TFCI enables an assessment of the ecological health of the biological quality element, "fish fauna" as listed in Table 1.2.3 of Annex V to the WFD (2000/60/EC). The WFD requires that the assessment of the fish fauna quality element considers composition, abundance, and the presence and/or absence of disturbance-sensitive taxa. *Note:* the tool is designed to be applied at the whole water body (estuary) level.

The TFCI is a multimetric index composed of ten individual components known as metrics, these are:

- Species composition
- Presence of indicator species
- Species relative abundance
- Number of taxa that make up 90% of the abundance
- Number of estuarine resident taxa
- Number of estuarine-dependent marine taxa
- Functional guild composition
- Number of benthic invertebrate feeding taxa
- Number of piscivorous taxa
- Feeding guild composition.

The TFCI therefore includes measures of species diversity and composition, species abundance, nursery function, and trophic integrity. Each metric is assessed by comparing the observed metric values with those expected metric values under reference conditions. The TFCI is calculated as the sum of all metric scores and converted into an EQR operating over a range from zero (a severe impact) to one (reference/minimally disturbed). The four class boundaries are:

- High/Good = 0.81
- Good/Moderate = 0.58
- Moderate/Poor = 0.4
- Poor/Bad = 0.2.

This method has been intercalibrated in phase 2 of the NE Atlantic Intercalibration exercise, and is included in Annex 1 of the 2013 European Commission Decision (European Commission, 2013).

To calculate the TFCI a representative sample of the TW fish community, identified to species level is required.

1.2 Applicability

As fishes are relatively long lived and are highly mobile, they provide a good, integrated measure of large-scale habitats. The TFCI is therefore best applied at the whole transitional water (estuary) level rather than specific sites within a particular transitional water. The migratory nature of some of the fish taxa also means that the tool should be applied at a whole transitional water level. *Note:* some transitional waters are sub-divided into separate WFD water bodies but the assessment must be carried out at the whole estuary scale.

Where: The TFCI can be applied to all UK transitional waters with the exception of transitional lagoons (UK TW water type 6). As these lagoons are typically isolated from the

sea, their utilisation by fishes, particularly marine species, is probably very limited and an assessment using the TFCI likely to be inappropriate.

When: The TFCI has been developed using bi-annual (spring and autumn) sampling data, however, the TFCI assessment can also be carried out using annual sampling only. If only annual surveys are conducted, then these should take place during autumn (September to the end of October). Spring sampling should occur from May to the end of June.

Response to pressure: The TFCI has been shown to reflect morphological change, and general physicochemical quality.

1.3. Key Documents

The documents marked * will be hosted on the UK technical advisory group (UKTAG) website www.wfduk.org.

Coates, S. A., Colclough, S. R., Robson, M. A., & Harrison, T. D. (2004) Development of an estuarine classification scheme for the Water Framework Directive. Phases 1 & 2 – transitional fish component. R&D Technical Report E1-131/TR. Environment Agency, Bristol.

Coates, S. A., Waugh, A., Anwar, A., & Robson, M. (2007) Efficacy of a multi-metric fish index as an analysis tool for the transitional fish component of the Water Framework Directive. *Marine Pollution Bulletin*, 55, 225–240.

* UKTAG Biological Status Methods: Transitional Water Assessment Methods – Fish Fauna. – *High level non-technical summary*

2. Background

2.1 Ecological principles

The TFCI was developed as a WFD compliant classification method using fishes as an indicator of overall condition of transitional waters. The WFD requires three biological elements to be included in a fish classification of transitional waters; these include species composition, species abundance, and disturbance-sensitive taxa. The TFCI considers four community characteristics that are represented by ten separate metrics (Table 1).

Table 1: Metrics that comprise the Transitional Fish Classification Index (TFCI).

Community characteristic	No.	Metric
Species diversity and composition	1	Species composition
	2	Presence of indicator species
Species abundance	3	Species relative abundance
	4	Number of taxa that make up 90% of the abundance
Nursery function	5	Number of estuarine resident taxa
	6	Number of estuarine-dependent marine taxa
	7	Functional guild composition
Trophic integrity	8	Number of benthic invertebrate feeding taxa
	9	Number of piscivorous taxa
	10	Feeding guild composition

Using monitoring data, each metric is assessed or scored according to the degree of departure from a reference condition; these scores are then combined into a single, integrated index. All metrics have equal weighting in terms of their contribution to the overall result. To meet the requirements of the WFD, the final index values are re-scaled to an Ecological Quality Ratio (EQR), which ranges between zero (bad) and one (reference).

2.2 Normative definitions

In Annex V (1.2.3) of the WFD, normative definitions describe the aspects of the fish fauna that must be included in the ecological status assessment of transitional waters; these are:

- species composition
- abundance
- disturbance-sensitive species.

The WFD normative definitions of 'high', 'good', and 'moderate' status as described in Annex V of the Directive are presented in Table 2.

Table 2: Description of the characteristics of fish assemblages at 'high', 'good', and 'moderate' WFD status class in accordance with the normative definitions (WFD Annex V).

	High	Good	Moderate
Fish fauna	Species composition and abundance is consistent with undisturbed conditions.	The abundance of the disturbance-sensitive species shows slight signs of distortion from type-specific conditions attributable to anthropogenic impacts on physicochemical or hydromorphological quality elements.	A moderate proportion of the type-specific disturbance-sensitive species are absent as a result of anthropogenic impacts on physicochemical or hydromorphological quality elements.

2.3 Development of the Index

The development of the TFCI followed a multimetric approach, which has been successfully applied to transitional waters (estuaries) both globally and in Europe in the context of the WFD (e.g. Miller *et al.*, 1988; Deegan *et al.*, 1997; USEPA, 2000; Hughes *et al.*, 2002; Borja *et al.*, 2004; Harrison & Whitfield, 2004; 2006; Breine *et al.*, 2007; Coates *et al.*, 2007).

The selection of metrics (Table 1) was devised following a review of existing estuarine multimetric fish indices and further discussion by the UK Fish Task Team (Coates *et al.*, 2004). The candidate metrics are based upon either presence/absence data, relative (%) abundance data or number of taxa present. A description of the metrics and development of the TFCI can be found in Coates *et al.* (2007).

2.4 Reference conditions

The use of appropriate reference conditions is essential for a meaningful WFD assessment of the fish community as they provide the baseline against which fish metrics can be evaluated. Reference conditions must take into account zoogeographic differences, the inherent morphological variation between transitional water types and sampling methodologies.

Annex XI of the WFD identified six ecoregions for European transitional and coastal waters. Transitional waters within the UK fall within two ecoregions: Atlantic Ocean and North Sea. In terms of morphology, the WFD requires that transitional waters are assigned to a typology using factors such as ecoregion, salinity, tidal range, depth, current velocity, wave exposure, residence time, water temperature, mixing characteristics, turbidity, substratum composition, and shape. The purpose of assigning transitional waters to a physical type is to enable the establishment of appropriate reference conditions and to make a valid assessment of the ecological status of each system. The UK Technical Advisory Group (UKTAG) on the WFD identified six types of transitional water within the UK and Republic of Ireland based on mixing characteristics, salinity, mean tidal range, wave exposure, depth and substratum (Table 3).

Table 3: Typology characteristics of transitional water types in the UK and Republic of Ireland (UKTAG, 2004).

Type	Mixing	Salinity	Tidal Range	Exposure	Depth	Substratum
TW1	Partly mixed/ stratified	Mesohaline or polyhaline	Macrotidal	Sheltered	Intertidal/ shallow sub-tidal	Sand and mud
TW2	Partly mixed/ stratified	Mesohaline or polyhaline	Strongly mesotidal	Sheltered	Intertidal/ shallow sub-tidal	Sand and mud
TW3	Fully mixed	Predominantly polyhaline	Macrotidal	Sheltered	Extensive intertidal areas	
TW4	Fully mixed	Polyhaline or euhaline	Mesotidal	Sheltered	Extensive intertidal areas	Sand or mud
TW5 (sea lochs)		Polyhaline	Mesotidal	Sheltered		
TW6 (lagoons)	Partly mixed/ stratified	Oligohaline - polyhaline	N/A	Sheltered	Shallow	Predominately mud

Reference conditions and metric scoring thresholds for the TFCI used a combination of historical records, best available data, and expert judgement. Metric reference conditions for each region /water body type are needed to ensure an effective classification. Sampling strategy also needs to be considered when defining reference conditions to ensure that bias to the metrics resulting from measurement methods is not misinterpreted as an anthropogenic disturbance.

The WFD competent monitoring authorities have established reference conditions for their water bodies, depending on their sampling strategy and water body characteristics. Please refer to the relevant Agency for further details.

Scotland

There are three transitional waters body types (excluding TW6 lagoons) present in Scotland. On the east coast (North Sea Ecoregion) only TW2 occurs. On the west coast (Atlantic Ecoregion) TW2, TW3, and TW5 are present. Reference conditions have been developed for west coast TW2 (Tables 4 & 5) and TW5 (Tables 6 & 7) using a combination of Scottish historical records, and recent data from Scotland and (for TW2) data from Northern Ireland. The Scottish west coast data are dominated by records from the Clyde Estuary, which includes large relatively deep water areas which skews the number of reference species upwards (compared to Northern Ireland) and includes northerly species (e.g. *Zoarces viviparus*) which are scarcer in Ireland (or western England). Augmentation of the Scottish west coast TW2 data with additional records from the adjacent area of Northern Ireland helps diminish the bias towards the Clyde Estuary but maintains the northerly focus of the data.

Reference conditions for east coast TW2 estuaries have been developed using Scottish historical records combined with recent data from east Scotland and an adjacent area of

North East England (Tables 8 & 9). The inclusion of TW2 data from North East England helps reduce a potential bias towards Forth Estuary records. Scottish TW3 transitional waters are restricted to the Solway Estuary and a few nearby smaller estuaries on the coast of Dumfries and Galloway. Development of reference conditions for TW3 is under review and may involve cross-border monitoring data.

Table 4: Reference species lists for Scotland: Atlantic Ecoregion, TW2 transitional waters for metric 1 (species composition), metric 2 (presence of indicator species), and metric 3 (species relative abundance). 'X' indicates presence.

Scientific Name	Metric 1	Metric 2	Metric 3 (% abundance)
<i>Acipenser sturio</i>		X	
<i>Agonus cataphractus</i>	X		1.08
<i>Alosa alosa</i>		X	
<i>Alosa fallax</i>		X	
<i>Anguilla anguilla</i>	X	X	0.51
<i>Chelon labrosus</i>	X		0.52
<i>Ciliata mustela</i>	X		1.83
<i>Clupea harengus</i>	X		6.30
<i>Gadus morhua</i>	X		0.69
<i>Gasterosteus aculeatus</i>	X		3.48
<i>Hippoglossoides platessoides</i>			0.22
<i>Lampetra fluviatilis</i>		X	
<i>Limanda limanda</i>	X		5.69
<i>Liza ramada</i>			0.63
<i>Merlangius merlangus</i>	X		0.35
<i>Myoxocephalus scorpius</i>	X		1.35
<i>Osmerus eperlanus</i>		X	
<i>Petromyzon marinus</i>		X	
<i>Pholis gunnellus</i>	X		0.22
<i>Phoxinus phoxinus</i>	X		0.24
<i>Platichthys flesus</i>	X		33.91
<i>Pleuronectes platessa</i>	X		6.39
<i>Pollachius pollachius</i>	X		4.33
<i>Pollachius virens</i>			1.36
<i>Pomatoschistus microps</i>	X		9.92
<i>Pomatoschistus minutus</i>	X		12.31
<i>Salmo salar</i>	X	X	
<i>Salmo trutta</i>	X	X	0.50
<i>Solea solea</i>	X		0.37
<i>Spinachia spinachia</i>	X		
<i>Sprattus sprattus</i>	X		4.68
<i>Syngnathus rostellatus</i>	X		0.30
<i>Taurulus bubalis</i>	X		0.77
<i>Trisopterus minutus</i>	X		
<i>Zoarces viviparus</i>	X		0.94
Total	26	9	26

Table 5: Reference values for metrics 4 to 10 for Scotland: Atlantic Ecoregion, TW2 transitional waters.

No	Metric	Reference
4	Number of taxa that make up 90% of the abundance	5.9
5	Number of estuarine resident taxa	9.6
6	Number of estuarine-dependent marine taxa	9.3
7	Functional guild composition	6.0
8	Number of benthic invertebrate feeding taxa	14.2
9	Number of piscivorous taxa	6.6
10	Feeding guild composition	4.0

Table 6: Reference species lists for Scotland: Atlantic Ecoregion, TW5 (transitional sea lochs) for metric 1 (species composition), metric 2 (presence of indicator species), and metric 3 (species relative abundance). 'X' indicates presence.

Scientific Name	Metric 1	Metric 2	Metric 3 (% abundance)
<i>Acipenser sturio</i>		X	
<i>Agonus cataphractus</i>	X		
<i>Alosa alosa</i>		X	
<i>Alosa fallax</i>		X	
<i>Anguilla anguilla</i>		X	
<i>Aspitrigla cuculus</i>			0.52
<i>Atherina presbyter</i>			0.50
<i>Callionymus lyra</i>	X		5.91
<i>Callionymus maculatus</i>	X		1.62
<i>Clupea harengus</i>	X		2.40
<i>Eutrigla gurnardus</i>	X		2.47
<i>Gadus morhua</i>	X		2.75
<i>Gasterosteus aculeatus</i>	X		3.14
<i>Gobiusculus flavescens</i>			0.35
<i>Glyptocephalus cynoglossus</i>	X		0.35
<i>Hippoglossoides platessoides</i>	X		7.65
<i>Lampetra fluviatilis</i>		X	
<i>Limanda limanda</i>	X		22.51
<i>Merlangius merlangus</i>	X		27.07
<i>Melanogrammus aeglefinus</i>	X		0.39
<i>Myoxocephalus scorpius</i>	X		0.40
<i>Osmerus eperlanus</i>		X	
<i>Petromyzon marinus</i>		X	
<i>Pholis gunnellus</i>	X		0.53
<i>Platichthys flesus</i>	X		0.60
<i>Pleuronectes platessa</i>	X		4.68
<i>Pollachius virens</i>	X		1.25
<i>Pomatoschistus microps</i>			
<i>Pomatoschistus minutus</i>	X		2.38
<i>Raja clavata</i>	X		0.29
<i>Salmo salar</i>		X	
<i>Salmo trutta</i>		X	0.47
<i>Scyliorhinus canicula</i>	X		
<i>Scomber scombrus</i>	X		
<i>Solea solea</i>	X		0.31
<i>Spinachia spinachia</i>	X		1.74
<i>Sprattus sprattus</i>	X		
<i>Squalus acanthias</i>	X		3.83

Scientific Name	Metric 1	Metric 2	Metric 3 (% abundance)
<i>Taurulus bubalis</i>	X		0.25
<i>Trisopterus esmarkii</i>	X		0.26
<i>Trisopterus minutus</i>	X		2.46
<i>Zoarces viviparus</i>	X		0.41
Total	29	9	29

Table 7: Reference values for metrics 4 to 10 for Scotland: Atlantic Ecoregion, TW5 (transitional sea lochs).

No	Metric	Reference
4	Number of taxa that make up 90% of the abundance	10.3
5	Number of estuarine resident taxa	8.25
6	Number of estuarine-dependent marine taxa	9.8
7	Functional guild composition	6.0
8	Number of benthic invertebrate feeding taxa	20.5
9	Number of piscivorous taxa	7.5
10	Feeding guild composition	4.0

Table 8: Reference species lists for Scotland: North Sea Ecoregion, TW2 transitional waters for metric 1 (species composition), metric 2 (presence of indicator species), and metric 3 (species relative abundance). 'X' indicates presence.

Scientific Name	Metric 1	Metric 2	Metric 3 (% abundance)
<i>Acipenser sturio</i>		X	
<i>Agonus cataphractus</i>	X		1.30
<i>Alosa alosa</i>		X	
<i>Alosa fallax</i>		X	
<i>Ammodytes tobianus</i>	X		6.54
<i>Anguilla anguilla</i>	X	X	1.04
<i>Ciliata mustela</i>	X		2.82
<i>Clupea harengus</i>	X		3.22
<i>Gadus morhua</i>	X		7.95
<i>Gasterosteus aculeatus</i>	X		7.15
<i>Lampetra fluviatilis</i>		X	
<i>Limanda limanda</i>	X		
<i>Merlangius merlangus</i>	X		7.00
<i>Myoxocephalus scorpius</i>	X		2.67
<i>Osmerus eperlanus</i>		X	2.84
<i>Petromyzon marinus</i>		X	
<i>Phoxinus phoxinus</i>			1.14
<i>Platichthys flesus</i>	X		18.31
<i>Pleuronectes platessa</i>	X		7.33
<i>Pollachius pollachius</i>	X		1.22
<i>Pollachius virens</i>	X		2.13
<i>Pomatoschistus microps</i>	X		
<i>Pomatoschistus minutus</i>	X		1.00
<i>Salmo salar</i>	X	X	
<i>Salmo trutta</i>	X	X	1.76
<i>Spinachia spinachia</i>			0.43
<i>Sprattus sprattus</i>	X		18.73
<i>Syngnathus acus</i>	X		
<i>Syngnathus rostellatus</i>	X		1.32
<i>Taurulus bubalis</i>			0.49

Scientific Name	Metric 1	Metric 2	Metric 3 (% abundance)
<i>Zoarcetes viviparus</i>	X		1.45
Total	22	9	22

Table 9: Reference values for metrics 4 to 10 for Scotland: North Sea Ecoregion, TW2 transitional waters.

No	Metric	Reference
4	Number of taxa that make up 90% of the abundance	8.5
5	Number of estuarine resident taxa	8.6
6	Number of estuarine-dependent marine taxa	7.3
7	Functional guild composition	6.0
8	Number of benthic invertebrate feeding taxa	9.1
9	Number of piscivorous taxa	6.6
10	Feeding guild composition	4.0

Northern Ireland

Only one transitional water type (TW2) was identified in Northern Ireland. Reference conditions were established using an all-Ireland approach and included data from both Northern Ireland and the Republic of Ireland. Reference species lists for metric 1 (species composition), metric 2 (presence of indicator species), and metric 3 (species relative abundance) for Northern Ireland type TW2 transitional waters is provided in Table 10 while reference conditions for the remaining metrics (metrics 4 to 10) are given in Table 11.

Table 10: Reference species lists for Northern Ireland TW2 transitional waters for metric 1 (species composition), metric 2 (presence of indicator species), and metric 3 (species relative abundance). 'X' indicates presence.

Scientific Name	Metric 1	Metric 2	Metric 3 (% abundance)
<i>Acipenser sturio</i>		X	
<i>Agonus cataphractus</i>	X		
<i>Alosa alosa</i>		X	
<i>Alosa fallax</i>		X	
<i>Ammodytes tobianus</i>			1.74
<i>Anguilla anguilla</i>	X	X	3.13
<i>Atherina presbyter</i>	X		0.87
<i>Chelon labrosus</i>	X		4.24
<i>Ciliata mustela</i>	X		1.22
<i>Clupea harengus</i>	X		1.49
<i>Gadus morhua</i>	X		0.97
<i>Gasterosteus aculeatus</i>	X		7.80
<i>Lampetra fluviatilis</i>		X	
<i>Limanda limanda</i>	X		0.23
<i>Merlangius merlangus</i>	X		0.50
<i>Osmerus eperlanus</i>	X	X	0.65
<i>Petromyzon marinus</i>		X	
<i>Pholis gunnellus</i>			0.28
<i>Platichthys flesus</i>	X		21.99
<i>Pleuronectes platessa</i>	X		2.25
<i>Pollachius pollachius</i>	X		0.64
<i>Pomatoschistus microps</i>	X		9.70
<i>Pomatoschistus minutus</i>	X		20.65
<i>Salmo salar</i>	X	X	

Scientific Name	Metric 1	Metric 2	Metric 3 (% abundance)
<i>Salmo trutta</i>	X	X	0.38
<i>Solea solea</i>			0.33
<i>Spinachia spinachia</i>	X		0.37
<i>Sprattus sprattus</i>	X		14.38
<i>Syngnathus acus</i>	X		
<i>Taurulus bubalis</i>	X		0.25
Total	22	9	

Table 11: Reference values for metrics 4 to 10 for Northern Ireland TW2 transitional waters.

No	Metric	Reference
4	Number of taxa that make up 90% of the abundance	7.5
5	Number of estuarine resident taxa	8.4
6	Number of estuarine-dependent marine taxa	10.1
7	Functional guild composition	6.0
8	Number of benthic invertebrate feeding taxa	14.2
9	Number of piscivorous taxa	7.0
10	Feeding guild composition	4.0

England and Wales

Four transitional water body types (excluding TW6 lagoons) in two ecoregions are present in England and Wales. However, the wide variety of characteristics, seen across the water bodies, has required an additional step to setting reference conditions.

Monitoring in the range of transitional water bodies cannot be consistently applied, and since the sampling approach (effort and method) strongly influences the data, sampling defined reference conditions are required. Reference conditions for England and Wales are based on existing data captured using existing techniques, which takes account of both the amount and the type of sampling obligated by these geographically and morphologically varied water bodies. Tables 12-19 provide method specific reference conditions. *Important:* Where metrics are sample effort dependent, these reference conditions have to be further adjusted for sample effort (numbers) to ensure any observed/sampled data are compared to relevant reference conditions. Using pooled data from 2006 – 2011 for each method, metric scores are plotted against number of samples to create a 'reference curve' from which the relevant effort-adjusted reference can be established. Please refer to the relevant WFD competent authority for further details.

Table 12: Seine net reference species lists for England and Wales transitional waters for metric 1 (species composition), metric 2 (presence of indicator species), and metric 3 (species relative abundance). 'X' indicates presence.

Latin Name	Metric 1	Metric 2	Metric 3 (% abundance)
<i>Abramis brama</i>			0.29
<i>Acipenser sturio</i>		X	
<i>Agonus cataphractus</i>	X		
<i>Alosa alosa</i>		X	
<i>Alosa fallax</i>		X	
<i>Ammodytes tobianus</i>	X		6.16

Latin Name	Metric 1	Metric 2	Metric 3 (% abundance)
Anguilla anguilla	X	X	0.19
Atherina boyeri			0.03
Atherina presbyter	X		12.47
Callionymus lyra	X		0.02
Chelon labrosus	X		1.34
Clupea harengus	X		9.73
Crenilabrus melops	X		
Dicentrarchus labrax	X		4.97
Echiichthys vipera	X		0.06
Entelurus aequoreus	X		0.05
Gadus morhua	X		0.08
Gasterosteus aculeatus	X		1.37
Gobius niger	X		0.05
Gobiusculus flavescens	X		0.07
Gymnammodytes semisquamatus			0.02
Hyperoplus immaculatus	X		0.31
Hyperoplus lanceolatus	X		0.21
Labrus bergylta	X		0.03
Lampetra fluviatilis		X	
Leuciscus leuciscus	X		1.49
Lipophrys pholis	X		
Liza aurata	X		1.70
Liza ramada	X		3.95
Merlangius merlangus	X		0.12
Myoxocephalus scorpius	X		
Osmerus eperlanus	X	X	0.24
Perca fluviatilis			0.15
Petromyzon marinus		X	
Pholis gunnellus	X		
Phoxinus phoxinus	X		1.02
Platichthys flesus	X		6.22
Pleuronectes platessa	X		2.19
Pollachius pollachius	X		0.14
Pollachius virens			0.03
Pomatoschistus microps	X		2.66
Pomatoschistus minutus	X		18.49
Pomatoschistus pictus	X		0.04
Psetta maxima			0.04
Rutilus rutilus	X		1.37
Salmo salar	X	X	0.58
Salmo trutta	X	X	0.39
Sardina pilchardus			1.68
Scophthalmus rhombus	X		
Solea solea	X		0.33
Spinachia spinachia	X		0.03
Sprattus sprattus	X		19.40
Syngnathus acus	X		0.04
Syngnathus rostellatus	X		0.03
Taurulus bubalis	X		

Table 13: Seine net reference values for metrics 4 to 10 for England and Wales transitional waters.

Number	Metric	Reference
4	Number of taxa that make up 90% of the abundance	7.17
5	Number of estuarine resident taxa	12.20
6	Number of estuarine-dependent marine taxa	14.20
7	Functional guild composition	6.00
8	Number of benthic invertebrate feeding taxa	21.40
9	Number of piscivorous taxa	9.00
10	Feeding guild composition	4.00

Table 14: 1.5m Beam trawl reference species lists for England and Wales transitional waters for metric 1 (species composition), metric 2 (presence of indicator species), and metric 3 (species relative abundance). 'X' indicates presence.

Latin Name	Metric 1	Metric 2	Metric 3 (% abundance)
<i>Acipenser sturio</i>		X	
<i>Agonus cataphractus</i>	X		0.94
<i>Alosa alosa</i>		X	
<i>Alosa fallax</i>		X	
<i>Ammodytes tobianus</i>	X		5.85
<i>Anguilla anguilla</i>	X	X	0.44
<i>Aphia minuta</i>	X		
<i>Atherina presbyter</i>	X		0.32
<i>Chelon labrosus</i>			0.30
<i>Ciliata mustela</i>	X		
<i>Clupea harengus</i>	X		1.99
<i>Dicentrarchus labrax</i>	X		1.43
<i>Gadus morhua</i>	X		1.11
<i>Gasterosteus aculeatus</i>			3.05
<i>Gobius niger</i>	X		0.32
<i>Labrus bergylta</i>	X		2.26
<i>Lampetra fluviatilis</i>		X	
<i>Limanda limanda</i>	X		1.12
<i>Merlangius merlangus</i>	X		2.49
<i>Myoxocephalus scorpius</i>	X		0.30
<i>Osmerus eperlanus</i>	X	X	1.28
<i>Petromyzon marinus</i>		X	
<i>Platichthys flesus</i>	X		15.58
<i>Pleuronectes platessa</i>	X		11.40
<i>Pollachius pollachius</i>			0.71
<i>Pollachius virens</i>			0.77
<i>Pomatoschistus microps</i>	X		6.57
<i>Pomatoschistus minutus</i>	X		28.61
<i>Psetta maxima</i>			1.54
<i>Salmo salar</i>		X	
<i>Salmo trutta</i>		X	
<i>Solea solea</i>	X		5.36
<i>Sprattus sprattus</i>	X		3.21

Latin Name	Metric 1	Metric 2	Metric 3 (% abundance)
<i>Syngnathus acus</i>	X		
<i>Syngnathus rostellatus</i>	X		
<i>Zoarces viviparus</i>	X		

Table 15: 1.5m Beam trawl reference values for metrics 4 to 10 for England and Wales transitional waters.

Number	Metric	Reference
4	Number of taxa that make up 90% of the abundance	5.97
5	Number of estuarine resident taxa	9
6	Number of estuarine-dependent marine taxa	9
7	Functional guild composition	6
8	Number of benthic invertebrate feeding taxa	14.25
9	Number of piscivorous taxa	4.75
10	Feeding guild composition	4

Table 16: Fyke net reference species lists for England and Wales transitional waters for metric 1 (species composition), metric 2 (presence of indicator species), and metric 3 (species relative abundance). 'X' indicates presence.

Latin Name	Metric 1	Metric 2	Metric 3 (% abundance)
<i>Acipenser sturio</i>		X	
<i>Agonus cataphractus</i>	X		0.22
<i>Alosa alosa</i>		X	
<i>Alosa fallax</i>		X	
<i>Anguilla anguilla</i>	X	X	9.07
<i>Atherina presbyter</i>	X		1.21
<i>Chelon labrosus</i>	X		
<i>Ciliata mustela</i>	X		9.78
<i>Clupea harengus</i>	X		5.29
<i>Crenilabrus melops</i>			0.75
<i>Dicentrarchus labrax</i>	X		13.24
<i>Gadus morhua</i>	X		1.54
<i>Gaidropsarus mediterraneus</i>	X		0.30
<i>Gasterosteus aculeatus</i>	X		0.22
<i>Gobius niger</i>	X		0.49
<i>Gobiusculus flavescens</i>			0.10
<i>Labrus bergylta</i>			0.85
<i>Lampetra fluviatilis</i>		X	
<i>Liza aurata</i>			0.68
<i>Liza ramada</i>	X		0.09
<i>Merlangius merlangus</i>	X		4.50
<i>Myoxocephalus scorpius</i>	X		0.36
<i>Nerophis ophidion</i>	X		
<i>Osmerus eperlanus</i>		X	
<i>Perca fluviatilis</i>	X		
<i>Petromyzon marinus</i>		X	
<i>Platichthys flesus</i>	X		16.64

Latin Name	Metric 1	Metric 2	Metric 3 (% abundance)
<i>Pleuronectes platessa</i>	X		3.54
<i>Pollachius pollachius</i>	X		3.79
<i>Pollachius virens</i>	X		6.63
<i>Pomatoschistus minutus</i>	X		7.27
<i>Rutilus rutilus</i>	X		0.09
<i>Salmo salar</i>	X	X	0.09
<i>Salmo trutta</i>	X	X	0.35
<i>Scophthalmus rhombus</i>	X		
<i>Solea solea</i>	X		1.11
<i>Spinachia spinachia</i>	X		4.05
<i>Sprattus sprattus</i>	X		4.55
<i>Syngnathus acus</i>	X		0.17
<i>Taurulus bubalis</i>	X		0.44
<i>Trisopterus luscus</i>	X		0.17
<i>Trisopterus minutus</i>	X		0.99
<i>Zoarces viviparus</i>	X		0.79

Table 17: Fyke net reference species lists for metrics 4 to 10 for England and Wales transitional waters.

Number	Metric	Reference
4	Number of taxa that make up 90% of the abundance	8.48
5	Number of estuarine resident taxa	12
6	Number of estuarine-dependent marine taxa	12
7	Functional guild composition	6
8	Number of benthic invertebrate feeding taxa	16
9	Number of piscivorous taxa	11
10	Feeding guild composition	4

Table 18: Otter trawl reference species lists for England and Wales transitional waters for metric 1 (species composition), metric 2 (presence of indicator species), and metric 3 (species relative abundance). 'X' indicates presence.

Latin Name	Metric 1	Metric 2	Metric 3 (% abundance)
<i>Acipenser sturio</i>		X	
<i>Agonus cataphractus</i>	X		1.98
<i>Alosa alosa</i>		X	
<i>Alosa fallax</i>		X	
<i>Ammodytes marinus</i>	X		
<i>Ammodytes tobianus</i>	X		0.48
<i>Anguilla anguilla</i>	X	X	0.11
<i>Aphia minuta</i>	X		3.40
<i>Arnoglossus laterna</i>	X		0.63
<i>Aspitrigla cuculus</i>	X		0.13
<i>Atherina presbyter</i>	X		0.16
<i>Buglossidium luteum</i>	X		2.36
<i>Callionymus lyra</i>	X		0.14
<i>Callionymus reticulatus</i>	X		0.51

Latin Name	Metric 1	Metric 2	Metric 3 (% abundance)
Chelidonichthys lucernus	X		0.46
Ciliata mustela	X		0.36
Clupea harengus	X		1.87
Dicentrarchus labrax	X		7.75
Echiichthys vipera	X		2.14
Entelurus aequoreus	X		0.27
Eutrigla gurnardus	X		0.59
Gadus morhua	X		0.83
Gobius niger	X		0.21
Lampetra fluviatilis		X	
Limanda limanda	X		6.19
Liparis liparis	X		0.42
Merlangius merlangus	X		7.34
Mullus surmuletus	X		
Mustelus asterias			0.11
Myoxocephalus scorpius	X		
Osmerus eperlanus	X	X	0.37
Petromyzon marinus		X	
Pholis gunnellus	X		
Platichthys flesus	X		7.57
Pleuronectes platessa	X		4.82
Pomatoschistus microps	X		1.01
Pomatoschistus minutus	X		25.76
Raja clavata	X		0.08
Raja microocellata			0.33
Salmo salar		X	
Salmo trutta		X	
Scophthalmus rhombus	X		0.24
Scyliorhinus canicula	X		0.17
Solea solea	X		2.58
Sprattus sprattus	X		14.25
Syngnathus acus	X		0.54
Syngnathus rostellatus			0.25
Taurulus bubalis	X		
Trachurus trachurus			0.13
Trisopterus luscus	X		1.07
Trisopterus minutus	X		1.80
Zoarces viviparus			0.08

Table 19: Otter trawl reference values for metrics 4 to 10 for England and Wales transitional waters.

Number	Metric	Reference
4	Number of taxa that make up 90% of the abundance	10.46
5	Number of estuarine resident taxa	10.67
6	Number of estuarine-dependent marine taxa	15
7	Functional guild composition	6
8	Number of benthic invertebrate feeding taxa	24.67
9	Number of piscivorous taxa	6
10	Feeding guild composition	4

2.5 Class boundaries

Class boundaries were initially defined through a simple mathematical division of the EQR range (0 to 1) and then modified through an intercalibration process for the North East Atlantic Geographical Intercalibration Group (NEAGIG). The ecological status boundaries for the TFCI-EQR values are given in Table 20.

Table 20: Ecological status boundaries for the EQR values.

Status	EQR
High/Good	0.81
Good/Moderate	0.58
Moderate/Poor	0.40
Poor/Bad	0.20

3. Undertaking an assessment

3.1 Summary of the process

The process for undertaking an assessment using the TFCI is summarised below (Figure 2).

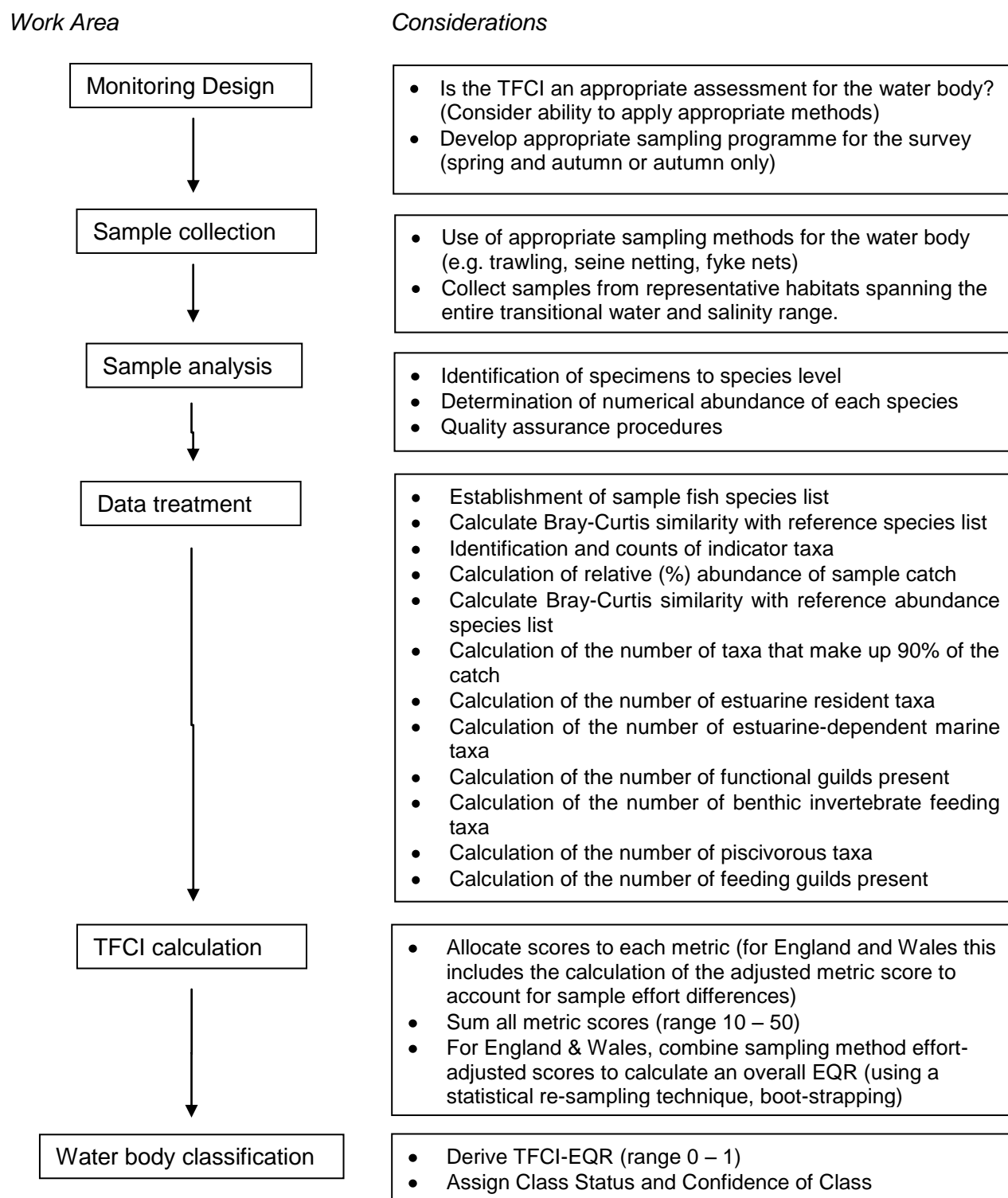


Figure 2: Flow chart summarising the main stages involved in undertaking an assessment using the TFCI.

3.2 Data requirements

Calculation of the TFCI requires a representative sample of the fish community present within the transitional water body. All specimens must be identified to species level and their relative (%) numerical abundance calculated. Knowledge of the appropriate reference conditions for the water body is also required.

3.3 Sampling strategy

A combination of sampling methods should be used to ensure a representative sample of the habitats and fishes present. Sampling can be bi-annual (spring & autumn), or annual; if only annual surveys are conducted, then these should take place during autumn (September – October inclusive). The number of samples required for an assessment is dependent on the size of the transitional water to be surveyed. To ensure a representative sample, sampling should include multiple methods and must cover the entire system. Enough samples must be taken to ensure a representative sample of the fish community is obtained for a realistic assessment. For the sampling strategy for England and Wales a minimum of 30 samples in total must be taken before an assessment. If multiple methods are used, the minimum number of samples for otter trawling is three. For all other methods, the minimum number of samples is six.

3.4 Sampling methodology

The UK monitoring authorities follow a multi-method approach originally developed as a monitoring strategy for the Thames estuary (Colclough *et al.*, 2002). The approach includes a suite of methods that covers a range of conditions and habitats and is designed to provide representative and robust monitoring data. Sampling methods may include, but are not restricted to, seine netting, fyke netting, fish traps, and various forms of trawling. This multi-method survey approach is recognised as an example of European Best Practice in the field (Elliott & Hemingway, 2002).

3.5 Sample Analysis

All fishes captured should be identified to species level and enumerated. Species names should follow the Environment Agency publication 'Key to the Marine and Freshwater Fishes of Britain and Ireland' (Maitland & Herdson, 2009).

3.6 Data treatment

All samples are pooled to provide a composite species list with relative abundance data at the whole transitional water level. Further data processing is required to calculate each metric.

For *metric 1 (species composition)* the list of species captured is compared with the appropriate reference species list using the Bray-Curtis similarity measure:

$$\frac{2c}{S + R} \times 100$$

where:

c is the number of species in common with the reference species list

S is the total number of species captured in the transitional water

R is the total number of species in the reference species list

Metric 2 (presence of indicator species) is calculated by counting the number of indicator species captured.

Metric 3 (species relative abundance) is calculated by comparing the relative (%) numerical abundance of the species captured with the appropriate reference numerical (%) abundance assemblage using the Bray-Curtis similarity measure:

$$\frac{2 \times \sum c_{\min}}{(S_n + R_n)} \times 100$$

where:

$\sum c_{\min}$ is the sum of the minimum values of the species in common with the reference species list

S_n is the total relative abundance of all species captured in a survey

R_n is the total relative abundance of the species in the reference list

Metric 4 (number of taxa that make up 90% of the abundance) is determined by first ranking all the species captured by abundance and then counting the number of top ranking species that make up 90% of the total abundance.

For *metric 5 (number of estuarine resident taxa)*, *metric 6 (number of estuarine-dependent marine taxa)*, and *metric 7 (functional guild composition)*, each species captured is allocated to a functional guild category after Elliott & Hemingway (2002). A list of fish species recorded in UK transitional waters and their allocation to functional guilds is provided in Annex I. For *metric 5*, the number of estuarine resident (ER) taxa captured is counted.

Metric 6 is determined by counting the number of species belonging to the marine juvenile (MJ) and marine seasonal (MS) guilds.

Metric 7 is calculated by counting the number of functional guilds represented in the catch.

For *metric 8 (number of benthic invertebrate feeding taxa)*, *metric 9 (number of piscivorous taxa)*, and *metric 10 (feeding guild composition)*, each species captured is allocated to a feeding guild category (Annex I).

Metrics 8 and 9 are calculated by counting the number of benthic invertebrate feeding taxa (BI) and piscivorous taxa (P) present respectively.

Metric 10 is determined by counting the number of feeding guilds represented in the catch.

Adjusting for sample effort (England and Wales only)

Once the 'observed' metric scores have been calculated for all metrics (as above), the scores have to be adjusted to account for the sample-effort bias. The steps in the process are outlined below:

1. The metric value (observed) is calculated according to the data treatment (above).
2. A 'predicted' metric value is determined as per Equation 1.

Equation 1: Predicted metric value: $MV_{pred} = a\{1 - (1 - b)^s\}$

Where a and b are constants (Table 21) determined from regression analysis using the pooled reference dataset 2006-2011 and s is the number of samples.

- A ratio of the metric value is then created by dividing the observed value by the predicted value, as per equation 2.

Equation 2: Ratio of observed & predicted values: $MV_{ratio} = MV_{obs} / MV_{pred}$

- This ratio is then converted to a score from 1 to 5 as per equation 3.

Equation 3: Adjusted metric score: $MS_{adj} = d + (MV_{ratio} \times c)$

Where *c* and *d* are constants (Table 21) used to create an adjusted metric score from the ratio. Any score of less than one is assigned a score of '1'; any score greater than five is assigned a score of '5'.

- Once the adjusted metric scores are calculated, the TFCI EQRs are calculated per method (following section 3.7).
- The overall EQR per waterbody and accuracy of the EQR assessment is estimated using a bootstrapping algorithm. (Section 3.8)

Table 21: Values for regression constants (a) and (b) that are used to calculate the predicted metric value given the number of samples taken and method used. Constants (c) and (d) that are used to calculate the adjusted metric score from the ratio of observed over predicted values.

Method	Metric	a	b	c	d
Fyke Netting	1	61.26	0.15	3.98	-0.82
Otter trawling	1	1	1	0.09	-2.72
Seine netting	1	74.97	0.05	8.65	-5.56
1.5m beam trawling	1	71.6	0.08	4.51	-1.28
1.5m beam trawling	2	1	1	1	0
Fyke Netting	2	3.275	0.171	3.07	0.078
Otter trawling	2	1	1	1	0
Seine netting	2	3.51	0.056	3.94	-0.79
Seine netting	3	56.4	0.111	3.7	0.62
1.5m beam trawling	3	1	1	0.06	0.39
Fyke Netting	3	57.58	0.135	3.45	-0.29
Otter trawling	3	1	1	0.07	-1.32
1.5m beam trawling	4	1	1	0.58	1.12
Otter trawling	4	1	1	0.28	1.57
Seine netting	4	5.75	0.024	2.52	0.62
Fyke Netting	4	6.214	0.074	1.9	1.252
Otter trawling	5	1	1	0.41	0.6
Fyke Netting	5	4.276	0.13	2.27	0.893
1.5m beam trawling	5	7.92	0.068	1.93	1.18
Seine netting	5	8.04	0.036	2.59	0.56

Method	Metric	a	b	c	d
Fyke Netting	6	5.607	0.095	3.87	-0.73
Otter trawling	6	1	1	0.39	-0.68
Seine netting	6	9.03	0.037	3.07	0.08
1.5m beam trawling	6	1	1	0.55	0.42
Fyke Netting	7	1	1	1	0
Otter trawling	7	1	1	1	0
Seine netting	7	1	1	1	0
1.5m beam trawling	7	3.72	0.096	3.72	-0.64
Otter trawling	8	1	1	0.24	-0.45
1.5m beam trawling	8	9.7	0.091	2.21	0.93
Seine netting	8	12.28	0.025	2.22	0.94
Fyke Netting	8	10.51	0.04	1.77	1.367
1.5m beam trawling	9	2.72	0.067	2.15	0.99
Otter trawling	9	1	1	0.61	1.37
Seine netting	9	5.43	0.022	2.08	1.05
Fyke Netting	9	6.276	0.061	1.75	1.358
1.5m beam trawling	10	1	1	1	0
Seine netting	10	1	1	1	0
Fyke Netting	10	1	1	1	0
Otter trawling	10	1	1	1	0

3.7 EQR calculation

Each metric that comprises the TFCI is allocated a score between 1 and 5 according to the degree of deviation from the appropriate reference conditions (Table 22).

Table 22: Metric scoring criteria for the TFCI.

Score	Reference
5	≥ 80%
4	≥ 60% to < 80%
3	≥ 40% to < 60%
2	≥ 20% to < 40%
1	< 20%

The TFCI is calculated as the sum of all the metric scores and has a theoretical range of between 10 and 50. The TFCI value is then converted into an Ecological Quality Ratio (EQR), which ranges between 0 and 1:

$$EQR = \frac{(TFCI - TFCI_{Min})}{(TFCI_{Max} - TFCI_{Min})}$$

where:

TFCI is the index value for a particular system

TFCI_{Min} is the minimum possible TFCI value (10)

TFCI_{Max} is the maximum possible TFCI value (50)

A value of close to 1 represents high ecological status and values close to 0 represent bad ecological status (Table 20).

For England and Wales a sample method specific EQR is created for each method used in that water body, these are then combined to create a water body EQR (section 3.8).

3.8 Water body level classification

Water body classifications are based on the TFCI-EQR value assessed at the whole transitional water level.

In England and Wales, where EQRs need to be adjusted for sample effort and methods used, after the method specific EQR is calculated, bootstrapping is used to determine an overall EQR per water body and assign a 'confidence of class' to each method EQR. Bootstrapping, a statistical re-sampling technique, offers a means of converting the between-sample variability in fish catch into a measure of precision of the observed EQR. Calculated variance and standard deviation is used to calculate a weighted average for the different method EQRs that are associated with each water body. For example, if there are 2 fishing methods, A and B, in a water body the weights W_A and W_B are $(1/s^2_A)/(1/s^2_A+1/s^2_B)$ and $(1/s^2_B)/(1/s^2_A+1/s^2_B)$. This has the effect of assigning each water body a greater weight to the fishing method with the more certain EQR.

3.9 Understanding the certainty of the assessment

Providing an estimate of the statistical uncertainty of ecological assessments is a statutory requirement of the WFD (Annex V, 1.3). Assessments based on estimates of ecological quality from sample data are subject to elements of variability (spatial, temporal and measurement induced). When assigning discrete ecological status classes, variability means that, depending on the proximity of the assessment result to a class boundary, there is a likelihood that the "true" status (i.e. that status if the EQR for the total population was known with zero error) is different to that assigned. This is termed the 'risk of misclassification' (RoM). Conversely, the statistical confidence that the status assigned from the sample population falls into each of the five ecological status classes is referred to as the 'confidence of class' (CofC). A bias corrected bootstrap method is used in the estimation of RoM and CofC for the TFCI. The interpretation of any classification based on the TFCI should also be used in conjunction with other ecological or water quality assessment methods.

4. Worked Example

A transitional water (X) was sampled using multiple methods in spring (May) and again in autumn (September). Each survey comprised 15 fyke nets, 30 beam trawl tows, and 30 seine net hauls. This yielded a total of 5998 specimens representing 30 fish species (Table 22).

Table 22: Total fish species and relative (%) numerical abundance of fishes captured in transitional water X over two (spring and autumn) surveys.

Scientific Name	% abundance
<i>Agonus cataphractus</i>	0.22
<i>Anguilla anguilla</i>	0.77
<i>Atherina presbyter</i>	0.03
<i>Chelidonichthys lucernus</i>	0.01
<i>Chelon labrosus</i>	0.08
<i>Ciliata mustela</i>	0.08
<i>Clupea harengus</i>	0.83
<i>Gasterosteus aculeatus</i>	1.56
<i>Lampetra fluviatilis</i>	0.04
<i>Limanda limanda</i>	0.03
<i>Merlangius merlangus</i>	0.20
<i>Myoxocephalus scorpius</i>	0.01
<i>Osmerus eperlanus</i>	2.95
<i>Pholis gunnellus</i>	0.03
<i>Phoxinus phoxinus</i>	0.24
<i>Platichthys flesus</i>	70.03
<i>Pleuronectes platessa</i>	2.61
<i>Pollachius pollachius</i>	0.05
<i>Pomatoschistus microps</i>	13.72
<i>Pomatoschistus minutus</i>	4.14
<i>Rutilus rutilus</i>	0.22
<i>Salmo salar</i>	0.20
<i>Salmo trutta</i>	0.21
<i>Solea solea</i>	1.53
<i>Spinachia spinachia</i>	0.01
<i>Sprattus sprattus</i>	0.03
<i>Syngnathus acus</i>	0.01
<i>Syngnathus rostellatus</i>	0.09
<i>Trisopterus luscus</i>	0.01
<i>Trisopterus minutus</i>	0.05

Metric 1 (species composition) was calculated by comparing the list of species captured with the appropriate reference species list (Table 23) using the Bray-Curtis similarity measure:

$$\frac{2c}{S + R} \times 100$$

where:

c is the number of species in common with the reference species list

S is the total number of species captured in the transitional water

R is the total number of species in the reference species list

Table 23: Comparison of fishes captured in transitional water X with a reference species list.

Scientific Name	% abundance	Reference
<i>Agonus cataphractus</i>	0.22	X
<i>Ammodytes tobianus</i>		
<i>Anguilla anguilla</i>	0.77	X
<i>Atherina presbyter</i>	0.03	X
<i>Chelidonichthys lucernus</i>	0.01	
<i>Chelon labrosus</i>	0.08	X
<i>Ciliata mustela</i>	0.08	X
<i>Clupea harengus</i>	0.83	X
<i>Gadus morhua</i>		X
<i>Gasterosteus aculeatus</i>	1.56	X
<i>Lampetra fluviatilis</i>	0.04	
<i>Limanda limanda</i>	0.03	X
<i>Merlangius merlangus</i>	0.20	X
<i>Myoxocephalus scorpius</i>	0.01	
<i>Osmerus eperlanus</i>	2.95	X
<i>Pholis gunnellus</i>	0.03	
<i>Phoxinus phoxinus</i>	0.24	
<i>Platichthys flesus</i>	70.03	X
<i>Pleuronectes platessa</i>	2.61	X
<i>Pollachius pollachius</i>	0.05	X
<i>Pomatoschistus microps</i>	13.72	X
<i>Pomatoschistus minutus</i>	4.14	X
<i>Rutilus rutilus</i>	0.22	
<i>Salmo salar</i>	0.20	X
<i>Salmo trutta</i>	0.21	X
<i>Solea solea</i>	1.53	
<i>Spinachia spinachia</i>	0.01	X
<i>Sprattus sprattus</i>	0.03	X
<i>Syngnathus acus</i>	0.01	X
<i>Syngnathus rostellatus</i>	0.09	
<i>Taurulus bubalis</i>		X
<i>Trisopterus luscus</i>	0.01	
<i>Trisopterus minutus</i>	0.05	
Total taxa	30	22

Twenty species were common to both the sample and the reference list and this yielded a Bray-Curtis similarity of:

$$\begin{aligned} & \frac{2 \times 20}{30 + 22} \times 100 \\ &= \frac{40}{52} \times 100 \\ &= 76.9\% \end{aligned}$$

Indicator species (metric 2) were represented by 5 species (*Anguilla anguilla*, *Lampetra fluviatilis*, *Osmerus eperlanus*, *Salmo salar*, and *Salmo trutta*).

Metric 3 (species abundance) was calculated by comparing the relative abundance of species captured with the appropriate reference species abundance list (Table 24) using the Bray-Curtis similarity measure:

$$\frac{2 \times \sum c_{\min}}{(S_n + R_n)} \times 100$$

where:

$\sum c_{\min}$ is the sum of the minimum values of the species in common with the reference species list

S_n is the total relative abundance of all species captured in a survey

R_n is the total relative abundance of the species in the reference list

Table 24: Comparison of relative abundance of fishes captured in transitional water X with reference species abundance.

Scientific Name	% abundance	Reference % abundance	Minimum value of common taxa
<i>Agonus cataphractus</i>	0.22		
<i>Ammodytes tobianus</i>		1.74	
<i>Anguilla anguilla</i>	0.77	3.13	0.77
<i>Atherina presbyter</i>	0.03	0.87	0.03
<i>Chelidonichthys lucernus</i>	0.01		
<i>Chelon labrosus</i>	0.08	4.24	0.08
<i>Ciliata mustela</i>	0.08	1.22	0.08
<i>Clupea harengus</i>	0.83	1.49	0.83
<i>Gadus morhua</i>		0.97	
<i>Gasterosteus aculeatus</i>	1.56	7.80	1.56
<i>Lampetra fluviatilis</i>	0.04		
<i>Limanda limanda</i>	0.03	0.23	0.03
<i>Merlangius merlangus</i>	0.20	0.50	0.20
<i>Myoxocephalus scorpius</i>	0.01		
<i>Osmerus eperlanus</i>	2.95	0.65	0.65
<i>Pholis gunnellus</i>	0.03	0.28	0.03
<i>Phoxinus phoxinus</i>	0.24		
<i>Platichthys flesus</i>	70.03	21.99	21.99
<i>Pleuronectes platessa</i>	2.61	2.25	2.25
<i>Pollachius pollachius</i>	0.05	0.64	0.05
<i>Pomatoschistus microps</i>	13.72	9.70	9.70
<i>Pomatoschistus minutus</i>	4.14	20.65	4.14
<i>Rutilus rutilus</i>	0.22		
<i>Salmo salar</i>	0.20		
<i>Salmo trutta</i>	0.21	0.38	0.21
<i>Solea solea</i>	1.53	0.33	0.33
<i>Spinachia spinachia</i>	0.01	0.37	0.01
<i>Sprattus sprattus</i>	0.03	14.38	0.03
<i>Syngnathus acus</i>	0.01		
<i>Syngnathus rostellatus</i>	0.09		
<i>Taurulus bubalis</i>		0.25	
<i>Trisopterus luscus</i>	0.01		
<i>Trisopterus minutus</i>	0.05		
Total	100	94.04	42.95

The Bray-Curtis similarity can be calculated as:

$$\begin{aligned} & \frac{2 \times 42.95}{100 + 94.04} \times 100 \\ &= \frac{85.90}{194.04} \times 100 \\ &= 44.3\% \end{aligned}$$

Of the most abundant species captured, four (*Platichthys flesus*, *Pomatoschistus microps*, *Pomatoschistus minutus*, and *Osmerus eperlanus*) comprised 90.9% of the total catch (metric 4).

The allocation of functional guilds and feeding guilds to the fishes captured in the transitional water is presented in Table 25.

Table 25: Allocation of functional guilds and feeding guilds to fishes captured in transitional water X.

Scientific Name	Functional Guild	Feeding Guild	% abundance
<i>Agonus cataphractus</i>	ER	BI	0.22
<i>Anguilla anguilla</i>	CA	P	0.77
<i>Atherina presbyter</i>	MJ	Z	0.03
<i>Chelidonichthys lucernus</i>	MJ	BI	0.01
<i>Chelon labrosus</i>	MS	D	0.08
<i>Ciliata mustela</i>	MS	BI	0.08
<i>Clupea harengus</i>	MJ	Z	0.83
<i>Gasterosteus aculeatus</i>	CA	Z	1.56
<i>Lampetra fluviatilis</i>	CA	P	0.04
<i>Limanda limanda</i>	MJ	BI	0.03
<i>Merlangius merlangus</i>	MJ	P	0.20
<i>Myoxocephalus scorpius</i>	ER	P	0.01
<i>Osmerus eperlanus</i>	CA	Z	2.95
<i>Pholis gunnellus</i>	ER	BI	0.03
<i>Phoxinus phoxinus</i>	FW	Z	0.24
<i>Platichthys flesus</i>	ER	BI	70.03
<i>Pleuronectes platessa</i>	MJ	BI	2.61
<i>Pollachius pollachius</i>	MJ	P	0.05
<i>Pomatoschistus microps</i>	ER	BI	13.72
<i>Pomatoschistus minutus</i>	ER	BI	4.14
<i>Rutilus rutilus</i>	FW	Z	0.22
<i>Salmo salar</i>	CA	P	0.20
<i>Salmo trutta</i>	CA	P	0.21
<i>Solea solea</i>	MJ	BI	1.53
<i>Spinachia spinachia</i>	ER	BI	0.01
<i>Sprattus sprattus</i>	MS	Z	0.03
<i>Syngnathus acus</i>	ER	Z	0.01
<i>Syngnathus rostellatus</i>	ER	Z	0.09
<i>Trisopterus luscus</i>	MJ	BI	0.01
<i>Trisopterus minutus</i>	MA	BI	0.05

Nine estuarine resident (ER) taxa were captured (metric 5), 12 species were estuarine-dependent marine taxa (MJ & MS) (metric 6), and six functional guilds were represented

(metric 7). Thirteen species were benthic invertebrate feeding taxa (BI) (metric 8), seven species were piscivorous taxa (P) (metric 9), and four feeding guilds were represented (metric 10). A summary of all the calculated metrics is given in Table 26.

Table 26: Metric values calculated for transitional water X.

No.	Metric	Value
1	Species composition	76.9%
2	Presence of indicator species	5
3	Species relative abundance	44.3%
4	Number of taxa that make up 90% of the abundance	4
5	Number of estuarine resident taxa	9
6	Number of estuarine-dependent marine taxa	12
7	Functional guild composition	6
8	Number of benthic invertebrate feeding taxa	13
9	Number of piscivorous taxa	7
10	Feeding guild composition	4

Metric values are then scored according to their deviation from the appropriate reference condition. Metric thresholds and scoring for the transitional water in question is provided in Table 27.

Table 27: Metric thresholds and scoring for the Transitional Fish Classification Index (TFCI), appropriate for transitional water X.

No.	Metric	1	2	3	4	5
1	Species composition	<20	≥20 to <40	≥40 to <60	≥60 to <80	≥80
2	Presence of indicator species	<1.8	≥1.8 to <3.6	≥3.6 to <5.4	≥5.4 to <7.2	≥7.2
3	Species relative abundance	<20	≥20 to <40	≥40 to <60	≥60 to <80	≥80
4	Number of taxa that make up 90% of the abundance	<1.5	≥1.5 to <3.0	≥3.0 to <4.5	≥4.5 to <6.0	≥6.0
5	Number of estuarine resident taxa	<1.7	≥1.7 to <3.3	≥3.3 to <5.0	≥5.0 to <6.7	≥6.7
6	Number of estuarine-dependent marine taxa	<2.0	≥2.0 to <4.1	≥4.1 to <6.1	≥6.1 to <8.1	≥8.1
7	Functional guild composition	<1.2	≥1.2 to <2.4	≥2.4 to <3.6	≥3.6 to <4.8	≥4.8
8	Number of benthic invertebrate feeding taxa	<2.8	≥2.8 to <5.7	≥5.7 to <8.5	≥8.5 to <11.4	≥11.4
9	Number of piscivorous taxa	<1.4	≥1.4 to <2.8	≥2.8 to <4.2	≥4.2 to <5.6	≥5.6
10	Feeding guild composition	<0.8	≥0.8 to <1.6	≥1.6 to <2.4	≥2.4 to <3.2	≥3.2

A summary of the calculated metrics and their associated scores and the TFCI is given in Table 28.

Table 28: Metric values and scores calculated for transitional water X.

No.	Metric	Value	Score
1	Species composition	76.9%	4
2	Presence of indicator species	5	3
3	Species relative abundance	44.3%	3
4	Number of taxa that make up 90% of the abundance	4	3
5	Number of estuarine resident taxa	9	5
6	Number of estuarine-dependent marine taxa	12	5
7	Functional guild composition	6	5
8	Number of benthic invertebrate feeding taxa	13	5
9	Number of piscivorous taxa	7	5
10	Feeding guild composition	4	5
	TFCI (sum of metric scores)		43

The TFCI value can be converted into an EQR:

$$EQR = \frac{(TFCI - TFCI_{Min})}{(TFCI_{Max} - TFCI_{Min})}$$

where:

TFCI is the index value for a particular system

TFCI_{Min} is the minimum possible TFCI value (10)

TFCI_{Max} is the maximum possible TFCI value (50)

$$EQR = \frac{(43 - 10)}{(50 - 10)}$$

$$EQR = \frac{(33)}{(40)}$$

$$EQR = 0.83$$

= **High** class

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Annex I. List of fish species reported from UK transitional waters (to 2011) and their allocation to functional and feeding guilds (after Elliott & Hemingway, 2002).

Scientific Name	Func G	Feed G
<i>Abramis bjoerkna</i>	FW	BI
<i>Abramis brama</i>	FW	BI
<i>Acipenser sturio</i>	CA	P
<i>Agonus cataphractus</i>	ER	BI
<i>Alburnus alburnus</i>	FW	Z
<i>Alosa alosa</i>	CA	Z
<i>Alosa fallax</i>	CA	Z
<i>Ammodytes marinus</i>	MA	Z
<i>Ammodytes tobianus</i>	ER	Z
<i>Anarhichas lupus</i>	MA	BI
<i>Anguilla anguilla</i>	CA	P
<i>Aphia minuta</i>	ER	Z
<i>Apletodon dentatus</i>	MS	BI
<i>Apletodon microcephalus</i>	MA	BI
<i>Argentina sphyraena</i>	MA	Z
<i>Argyrosomus regius</i>	MA	P
<i>Arnoglossus laterna</i>	MA	BI
<i>Aspitrigla cuculus</i>	MA	BI
<i>Atherina boyeri</i>	ER	P
<i>Atherina presbyter</i>	MJ	Z
<i>Balistes capriscus</i>	MA	BI
<i>Barbatula barbatula</i>	FW	BI
<i>Barbus barbus</i>	FW	BI
<i>Belone belone</i>	MS	P
<i>Blennius ocellaris</i>	MA	P
<i>Buenia jeffreysii</i>	MS	P
<i>Buglossidium luteum</i>	MA	BI
<i>Callionymus lyra</i>	MA	BI
<i>Callionymus maculatus</i>	MA	BI
<i>Callionymus reticulatus</i>	MA	BI
<i>Carassius auratus</i>	FW	Z
<i>Centrolabrus exoletus</i>	MA	Z
<i>Cepola rubescens</i>	MS	BI
<i>Chelidonichthys lucernus</i>	MJ	BI
<i>Chelon labrosus</i>	MS	D
<i>Chirolophis ascanii</i>	MA	BI
<i>Ciliata mustela</i>	MS	BI
<i>Ciliata septentrionalis</i>	MA	BI
<i>Clupea harengus</i>	MJ	Z
<i>Conger conger</i>	MA	P
<i>Coregonus albula</i>	FW	BI
<i>Coregonus autumnalis</i>	FW	P
<i>Coregonus lavaretus</i>	ER	Z
<i>Coregonus oxyrinchus</i>	ER	Z
<i>Coryphoblennius galerita</i>	MA	Z
<i>Cottus gobio</i>	FW	BI
<i>Crenilabrus melops</i>	ER	BI
<i>Crystallogobius linearis</i>	MA	BI
<i>Ctenolabrus rupestris</i>	MA	BI
<i>Cyclopterus lumpus</i>	MS	BI
<i>Cyprinus carpio</i>	FW	BI
<i>Dasyatis pastinaca</i>	MS	P
<i>Dicentrarchus labrax</i>	MJ	P

<i>Diplecogaster bimaculata</i>	ER	BI
<i>Echiichthys vipera</i>	MA	BI
<i>Enchelyopus cimbrius</i>	MA	BI
<i>Engraulis encrasicolus</i>	MS	Z
<i>Entelurus aequoreus</i>	MA	Z
<i>Esox lucius</i>	FW	P
<i>Eutrigla gurnardus</i>	MS	BI
<i>Gadiculus argenteus</i>	MS	BI
<i>Gadus morhua</i>	MJ	P
<i>Gaidropsarus mediterraneus</i>	MA	BI
<i>Gaidropsarus vulgaris</i>	MA	BI
<i>Galeus melastomus</i>	MS	P
<i>Gasterosteus aculeatus</i>	CA	Z
<i>Glyptocephalus cynoglossus</i>	MA	BI
<i>Gobio gobio</i>	FW	D
<i>Gobius cobitis</i>	MS	BI
<i>Gobius niger</i>	ER	BI
<i>Gobius paganellus</i>	ER	BI
<i>Gobiusculus flavescens</i>	MA	BI
<i>Gymnocephalus cernuus</i>	FW	P
<i>Hippocampus guttulatus</i>	ER	Z
<i>Hippocampus hippocampus</i>	MA	Z
<i>Hippoglossoides platessoides</i>	MA	BI
<i>Hippoglossus hippoglossus</i>	MA	P
<i>Hyperoplus immaculatus</i>	ER	BI
<i>Hyperoplus lanceolatus</i>	ER	BI
<i>Labrus bergylta</i>	MA	BI
<i>Labrus mixtus</i>	MA	BI
<i>Lampetra fluviatilis</i>	CA	P
<i>Lampetra planeri</i>	FW	D
<i>Lepadogaster lepadogaster</i>	MS	P
<i>Lepidorhombus whiffiagonis</i>	MA	P
<i>Lesueurigobius friesii</i>	MS	BI
<i>Leuciscus cephalus</i>	FW	P
<i>Leuciscus leuciscus</i>	FW	Z
<i>Leuciscus leuciscus x Alburnus alburnus</i>	FW	BI
<i>Limanda limanda</i>	MJ	BI
<i>Liparis liparis</i>	ER	BI
<i>Liparis montagui</i>	MA	BI
<i>Lipophrys pholis</i>	MA	BI
<i>Liza aurata</i>	MS	D
<i>Liza ramada</i>	CA	D
<i>Lophius piscatorius</i>	MA	P
<i>Lumpenus lampretaeformis</i>	MA	BI
<i>Maurolicus muelleri</i>	MA	Z
<i>Melanogrammus aeglefinus</i>	MA	BI
<i>Merlangius merlangus</i>	MJ	P
<i>Merluccius merluccius</i>	MA	P
<i>Micrenophrys lilljeborgii</i>	MS	BI
<i>Microchirus variegatus</i>	MA	BI
<i>Micromesistius poutassou</i>	MA	P
<i>Microstomus kitt</i>	MA	BI
<i>Molva molva</i>	MA	P
<i>Mullus surmuletus</i>	MA	BI
<i>Mustelus asterias</i>	MA	BI
<i>Mustelus mustelus</i>	MA	BI
<i>Myoxocephalus scorpius</i>	ER	P
<i>Myxine glutinosa</i>	MA	P

<i>Nerophis lumbriciformis</i>	ER	Z
<i>Nerophis ophidion</i>	ER	Z
<i>Oncorhynchus mykiss</i>	FW	P
<i>Osmerus eperlanus</i>	CA	Z
<i>Pagellus bogaraveo</i>	MJ	BI
<i>Parablennius gattorugine</i>	MA	BI
<i>Pegusa lascaris</i>	MA	BI
<i>Perca fluviatilis</i>	FW	P
<i>Petromyzon marinus</i>	CA	P
<i>Pholis gunnellus</i>	ER	BI
<i>Phoxinus phoxinus</i>	FW	Z
<i>Phrynorhombus norvegicus</i>	MA	BI
<i>Phycis blennoides</i>	MS	P
<i>Platichthys flesus</i>	ER	BI
<i>Pleuronectes platessa</i>	MJ	BI
<i>Pollachius pollachius</i>	MJ	P
<i>Pollachius virens</i>	MA	P
<i>Pomatoschistus lozanoi</i>	MA	BI
<i>Pomatoschistus microps</i>	ER	BI
<i>Pomatoschistus minutus</i>	ER	BI
<i>Pomatoschistus norvegicus</i>	MS	Z
<i>Pomatoschistus pictus</i>	MA	BI
<i>Psetta maxima</i>	MS	P
<i>Pungitius pungitius</i>	ER	Z
<i>Raja batis</i>	MA	P
<i>Raja brachyura</i>	MA	P
<i>Raja clavata</i>	MA	BI
<i>Raja microocellata</i>	MA	P
<i>Raja montagui</i>	MA	BI
<i>Raja naevus</i>	MS	BI
<i>Raniceps raninus</i>	ER	BI
<i>Rutilus rutilus</i>	FW	Z
<i>Rutilus rutilus x Abramis brama</i>	FW	Z
<i>Salmo salar</i>	CA	P
<i>Salmo trutta</i>	CA	P
<i>Salvelinus alpinus</i>	FW	P
<i>Sander lucioperca</i>	FW	Z
<i>Sardina pilchardus</i>	MS	Z
<i>Scardinius erythrophthalmus</i>	FW	Z
<i>Scardinius erythrophthalmus x Abramis brama</i>	FW	P
<i>Scomber scombrus</i>	MA	Z
<i>Scomberesox saurus</i>	MA	P
<i>Scophthalmus rhombus</i>	MA	BI
<i>Scorpaena porcus</i>	MA	P
<i>Scyliorhinus canicula</i>	MA	BI
<i>Scyliorhinus stellaris</i>	MA	BI
<i>Solea solea</i>	MJ	BI
<i>Sparus aurata</i>	MA	P
<i>Spinachia spinachia</i>	ER	BI
<i>Spondyliosoma cantharus</i>	MJ	Z
<i>Sprattus sprattus</i>	MS	Z
<i>Squalus acanthias</i>	MA	P
<i>Squatina squatina</i>	MA	Z
<i>Syngnathus acus</i>	ER	Z
<i>Syngnathus rostellatus</i>	ER	Z
<i>Syngnathus typhle</i>	ER	Z
<i>Taurulus bubalis</i>	MA	BI
<i>Thorogobius ephippiatus</i>	MS	BI

<i>Thymallus thymallus</i>	FW	BI
<i>Tinca tinca</i>	FW	BI
<i>Trachinus draco</i>	MA	P
<i>Trachurus trachurus</i>	MJ	BI
<i>Trigla lyra</i>	MJ	BI
<i>Trigloporus lastoviza</i>	MS	BI
<i>Trisopterus esmarkii</i>	MA	BI
<i>Trisopterus luscus</i>	MJ	BI
<i>Trisopterus minutus</i>	MA	BI
<i>Zeugopterus punctatus</i>	MA	BI
<i>Zeugopterus regius</i>	MS	P
<i>Zeus faber</i>	MA	BI
<i>Zoarces viviparus</i>	ER	BI