UKTAG RIVERS ASSESSMENT METHODS
FISH FAUNA

(FISHERIES CLASSIFICATION SCHEME 2 (FCS2))

by
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(WFD-UKTAG)

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HEALTH AND SAFETY STATEMENT

WARNING— working in or around water is inherently dangerous; persons using this standard should be familiar with normal laboratory and field practice. This published monitoring system does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user to establish appropriate health and safety practices and to ensure compliance with any national regulatory guidelines.

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

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FISHERIES CLASSIFICATION SCHEME 2 (FCS2)

1. Introduction

This method statement describes a monitoring system for monitoring, assessing and classifying rivers in accordance with the requirements of Article 8; Section 1.3 of Annex II; and Annex V of the Water Framework Directive (2000/60/EC).

1.1 Geographic application of the method

The method can be applied to rivers in England and Wales.

1.2 Quality element assessed by the method

The method enables the assessment of the condition of the quality element, "fish fauna", listed in Table 1.2.1 of Annex V to the Water Framework Directive.

1.3 Pressures to which the method is known to be sensitive

The method has been designed to detect the impact on the quality element of all pressures.

1.4 Parameters used to assess the quality element

The indicators comprise the 23 most prevalent fish species in England and Wales (Annex 1). For modelling purposes, these species are classified as being of low, moderate and high tolerance to environmental disturbance.

2. Sampling and analysis

To apply the method, fish may be sampled by electro-fishing or seine netting.

Counts of fish species present should be obtained from a single removal, using data either from the first pass of depletion sampling, or the catch from “semi-quantitative” catch-per-area sampling. Counts from catch-per-time sampling methods should not be used.

Data on fish abundance classified on a log-abundance scale, or presence-absence data for species that have not been enumerated in historical surveys, may be used in place of counts of fish species.

Where electro-fishing sampling methods are used, they should conform to the following CEN standard:

- BS EN 14011:2003 Water Quality – Guidance standard on sampling fish with electricity.

3. Procedure for deriving the ecological quality ratio for the parameter

3.1 Calculation of the observed value for the parameter

The observed value for the parameter is the count of each fish species listed in Annex 1 caught during sampling.

3.2 Calculation of the reference values for each parameter

Reference conditions were derived using modelling and expert judgement.

The reference value for the parameter should be predicted using a non-parametric (smooth) geostatistical model (e.g Wyatt 2007 and Wyatt et al 2007) relating the prevalence and density of each of the 23 species of fish to environmental variables, and geographic location. The model is used to predict what fish community would be expected for a given river type (defined by the environmental variables and geographic location) under reference conditions (i.e. with the pressure variables set to zero). In order to operate the classification[1], the data for the following environmental and geographical variables must be provided:

Grid reference (from which the parent waterbody and catchment are determined). The grid reference should be recorded to a minimum of eight figures, preferably ten, and corrected so that the site falls on the GIS river network.
Grid reference is obtained from either a field-based GPS, a computer-based GIS or an Ordnance Survey map.

Site altitude (m), preferably extracted for site location using GIS or measured from Ordnance Survey 1:50,000 scale maps in metres above sea level to the nearest five metres.

Distance to tidal limit (km), preferably measured using a GIS.

Mean wetted width (m). The mean width of the water surface (not the stream channel) is measured at right angles to the channel.

Survey area (m^2). The area of water surveyed calculated as the product of the mean wetted width and the site length.

FCS2 reference conditions are defined in terms of the expected catch (c_E) of each species of fish at the survey site, within a particular river type. For each species, reference conditions are not specified in terms of a single value, but as a probability distribution of all possible values. This distribution of possible catches is described by four parameters: the size of the site (a), the prevalence (ρ), the mean (log) density (μ) and the variance (σ^2). The expected catch of fish under reference conditions is related to the four parameters as follows.

The expected density (d) of fish at a site where the species is expected to be present under reference conditions is modelled with a log-Normal distribution.

$$\Pr(\ln(d) \mid \mu, \sigma) = \frac{1}{\sigma(2\pi)^{1/2}} \exp\left[\frac{-(d-\mu)^2}{2\sigma^2}\right]$$

The expected catch of fish at a site is modelled with a Poisson distribution

[1] The current classification scheme (FCS2) is a draft methodology not yet intercalibrated and the following parameters may be subject to change.

$$\Pr(c_E \mid d, \rho, a) = \frac{\lambda^{c_E} e^{-\lambda}}{c_E!}$$

where the expected number (λ) of fish at a site is given by

$$\lambda = \begin{cases} 0, & if\ \ absent \\ d * a, & if\ \ present \end{cases}$$

and the probability that fish will be present at a reference site is given by the prevalence (ρ)

$$\Pr(present) = \rho$$
$$\Pr(absent) = 1 - \rho$$

Finally, the uncertainty in estimating the three unknown parameters is taken into account, to give the probability distribution ($\Pr(c_E|a)$ for the expected catch (c_E) of fish at a site of area (a) under reference conditions

$$\Pr(c_E \mid a) = \int\int\int \Pr(c_E \mid d, \rho, a) \Pr(d \mid \mu, \sigma) \Pr(\mu) \Pr(\sigma) \Pr(\rho)\, d\mu\, d\sigma\, d\rho$$

where the probability distributions for the three parameters ($\Pr(\mu)$, $\Pr(\sigma)$, $\Pr(\rho)$) are provided by the FCS2 statistical model.

3.3 Calculation of the EQR value

The Ecological Quality Ratio (EQR) is calculated from the observed catch (c_O) and the probability distribution of expected catches (c_E). For each species, the probability (p) of catching an equal or lower number of fish at a reference site is calculated.

$$p = \sum_{C_E=0}^{C_O} \Pr(c_E \mid a)$$

The 23 species-specific probabilities (p_j) are then multiplied together

$$\omega = \prod_{j=1}^{23} p_j$$

Probability theory provides the equation for the overall EQR for all species

$$EQR = \sum_{k=1}^{n} \frac{\omega(-\ln(\omega))^{k-1}}{(k-1)!}$$

where n is the expected number of species

$$n = \sum_{j=1}^{23} 1 - \Pr(c_E = 0 \mid a)$$

Annex 1. List of species (indicators) used for the Fisheries Classification Scheme.

Low tolerance

Salmon (*Salmo salar*)
Brown and sea trout (*Salmo trutta*)
Grayling (*Thymallus thymallus*)
Lamprey (*Lampetra planeri, Lampetra fluviatilis, Petromyzon marinus*)
Bullhead (*Cottus gobio*)

Medium tolerance

Stone loach (*Barbatula barbatula*)
Barbel (*Barbus barbus*)
Spined loach (*Cobitis taenia*)
Pike (*Esox lucius*)
Gudgeon (*Gobio gobio*)
Ruffe (*Gymnocephalus cernuus*)
Chub (*Leuciscus cephalus*)
Dace (*Leuciscus leuciscus*)
Minnow (*Phoxinus phoxinus*)
Rudd (*Scardinius erythrophthalmus*)

High tolerance

Bream (*Abramis brama*)
Bleak (*Alburnus alburnus*)
Eel (*Anguilla anguilla*)
Common carp (*Cyprinus carpio*)
3-spined stickleback (*Gasterosteus aculeatus*)
Perch (*Perca fluviatilis*)
Roach (*Rutilus rutilus*)
Tench (*Tinca tinca*)

Annex 2. Worked example.

The following is a fictitious example for illustrative purposes only.

A small, upland stream is surveyed, and only three stone loach are caught. The FCS2 statistical model generates the expected catches for all 23 species for this river type, defined in terms of Pr(μ), Pr(σ) and Pr(ρ). Using the equations in Section 3.2, the probability distributions for the expected catch, given the area of the site (Pr(c_E|a) are calculated. These are shown below.

Number of fish in the catch	Probability of catching trout	Probability of catching salmon	Probability of catching stone loach	Probability of catching all other species
0	0.091	**0.509**	**0.399**	**1.000**
1	0.218	0.037	0.367	0.000
2	**0.261**	0.073	0.169	0.000
3	0.209	0.098	0.052	0.000
4	0.125	0.098	0.012	0.000
5	0.060	0.078	0.002	0.000
6	0.024	0.052	0.000	0.000
7	0.008	0.030	0.000	0.000
8	0.002	0.015	0.000	0.000
9	0.001	0.007	0.000	0.000
10	0.000	0.003	0.000	0.000

According to the FCS2 statistical model, three species may therefore be present under reference conditions: trout (90.9% chance), salmon (49.1% chance) and stone loach (60.1% chance). All other species are expected to be absent. Under reference conditions, the most likely catch (bold in table above) of trout is two, for salmon and stone loach it is zero.

For each species, the probability (p) of catching an equal or lower number of fish at a reference site (grey cells in table above) is calculated.

$$p = \sum_{C_E=0}^{C_O} \Pr(c_E \mid a)$$

For trout, p = 0.091
For salmon, p = 0.509
For stone loach, p = 0.399 + 0.367 + 0.169 + 0.052 = 0.986
For all other species, p = 1.000

The 23 species-specific probabilities (p_j) are then multiplied together

$$\omega = \prod_{j=1}^{23} p_j$$

ω = 0.091 * 0.509 * 0.986 * 1.000 * ... * 1.000 = 0.046

The expected number of species (n) at this site is

$$n = \sum_{j=1}^{23} 1 - \Pr(c_E = 0 \mid a)$$

n = (1-0.091) + (1-0.509) + (1-0.399) + (1-1.000) + ... + (1-1.000) = 2

The equation for the overall EQR for all species is

$$EQR = \sum_{k=1}^{n} \frac{\omega(-\ln(\omega))^{k-1}}{(k-1)!}$$

For an expected number of species (*n*) of 2, this equation simplifies to

$$EQR = \omega(1 - \ln(\omega))$$

EQR = 0.046 * (1 - ln(0.046)) = 0.186

This site is therefore classified as “poor”. The poor status is primarily caused by the absence of trout (*p*=0.091). Salmon are absent at 50.9% of reference sites of the same river type, and therefore their absence at this site does not necessarily indicate an environmental impact (*p*=0.509).

Annex 3. Further Reading

The original Fisheries Classification Scheme (FCS) was a paper-based system for classifying the status of riverine fish populations, developed by the National Rivers Authority in 1994 (Mainstone *et al* 1994a&b, Bailey *et al* 1996). Since then, the overall approach has remained the same, but the underlying methodologies have been updated. The habitat models that are used to estimate the expected fish populations in different river types have been updated in a series of projects to develop a river fish habitat inventory: phase 1 (Wyatt and Barnard 1997), phase 2 (Wyatt 2005) and phase 3 (Wyatt *et al* 2007). The current version of the Fisheries Classification Scheme (FCS2) is based on a hierarchical statistical model (Wyatt 2002), linked to a GIS (Wyatt 2003). A scientific paper is currently being prepared for publication, which will describe the full statistical details of FCS2, as used for the Water Framework Directive.

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BS EN 14011: 2003 Water Quality Sampling of Fish with Electricity

BS EN 14962 : 2006 Water Quality Guidance on the scope and selection of fish sampling methods

Environment Agency Environmental Monitoring Manual Operating Instructions
Routine environmental monitoring in rivers – supporting information for fisheries Document 036- 08
Seine netting for monitoring fish – Document 145 - 03

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