Development, Evaluation & Implementation of a Standardised Fish-based Assessment Method for the Ecological Status of European Rivers - A Contribution to the Water Framework Directive (FAME)

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Metric Selection and Sampling Procedures for FAME (D 4 - 6)

FINAL REPORT

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Summary

Different fish-based methods are used throughout Europe and the world to assess the ecological status of rivers. The objectives of work package 3 were to review these methods, summarise the common components, and identify and classify distinct metrics and sampling procedures. The main outputs of the work package were to propose a selection of metrics to be tested on the large fish database as well as to define standardised river-type-specific procedures which for the field evaluation in work package 9.

1. Reviewing and selecting metrics

An overview of the different metrics used for IBI development world wide indicates that, despite a huge diversity in metric chosen in different countries, most IBI have preserved the original classification of metrics among 4 major categories : species composition and diversity, trophic composition, fish abundance, and reproduction and condition. By comparing the metrics used in North-America (where IBI has been originally developed) and in Europe, it appears that less than 50 % of the metrics are present in both continents, but many functional similarities can be found within the different categories. Metrics used in Europe are generally more diversified, probably due to the lower fish diversity of European ichthyofauna (compared to the North-American one), referring also to reproductive guild and age class distribution. An extensive list of metrics has been used for selection, considering not only metrics of common interest, but also specific metrics dealing with some regional aspects of European ichthyofauna or hydrological conditions (endemic species and water abstraction in Portugal and Greece, large lowland rivers in The Netherlands, low species diversity in small headwaters, etc.). The selected metrics for testing have been classified in 3 major categories : the species composition (including species tolerance), the fish abundance and the age-length structure. The 1^{st} category includes all functional aspects of fish community and refers to the classification of species according to the different ecological guilds defined in work package 1. For each metric, the number of species present, the number of individuals belonging to these species, the percentage of species, the percentage of individuals belonging to these species, the biomass of these species or the percentage of total biomass will be tested and final selection of the most suitable expression of each metric will be made later on, depending on how these different modes of calculation fit well with the presence of a degradation. The fish abundance category contains metrics considering the density and biomass of fish in total, native, non native or sentinel species. For the category age-length structure, the metric 'sentinel species' has been considered as the most appropriate for drawing a length frequency distribution or for calculating a reliable ratio between juveniles (0+) and adults.

2. Reviewing sampling procedure and defining standardised methods

In Europe, sampling methods differ largely between countries, and even between regions or states belonging to the same country. As a corollary, national sampling methods rarely exist. However, in some European countries, fish monitoring programmes have been designed in order to assess the ecological quality of rivers based on fish assemblages. This section reviews the different procedures of fish sampling used in the countries of the FAME consortium, both in wadable and non wadable rivers. The fish sampling procedure commonly used by all partners for river quality assessment is the electric fishing method. Several partners (Belgium, Lithuania, The Netherlands, United Kingdom) use alternatives methods such as gillnet, seine net, trawling, drift net or drag net, hydro-acoustics, angling catch survey, etc., alone or in combination with electric fishing, but these techniques are usually applied in specific conditions and can not be applied on a regular basis by all partners. The low number (or total

absence) of sampling data available with these alternative techniques in most countries of the FAME consortium strongly limits the possibility of comparison of newly obtained data (in work package 9) with those previously existing in each country, and thus prevent definitely the development of alternative standardised sampling procedure within this project. The sampling procedure proposed for application during WP9 takes into account the expertise of the partners in their own country, the number of available sampling data obtained with the different sampling procedures and the possibility of implementation of a common procedure in all countries belonging to the FAME consortium, with limited modifications of the methods currently used by each partner. Standardised electric fishing procedures have been precisely described for wadable and non wadable rivers, in agreement with the CEN directive for water analysis – sampling of fish with electricity (Work Item 230116).

3. *Reviewing existing regional fish-based methods*

This section reviews the methods developed in different European regions or countries in order to assess the ecological quality of rivers by using fish-based methods. Despite the index have been developed quite independently, all these methods have retained the original ecological framework, including a series of metrics that describe the major biological attributes of a fish community. Some IBI methods have been developed for regional applications, or for some specific river types (such as small headwaters with poor species diversity) while some others aim to be applied to wider area, as an entire ecoregion, or even to several ecoregions with different ichthyofauna. The review contains a summary of the following methods : the fish-based, river-type-specific assessment of ecological integrity in Austria (MuLFA), the fish-based index developed for lotic ecosystem assessment in Wallonia, Belgium (IBIP), the IBI methods in Flanders (Belgium), the development and validation of a fish-based index for river health assessment in France (FBI), the use of fish to assess environmental disturbance of lakes and streams in Sweden, the IBI developed to assess ecological integrity in English lowland rivers, the alternative assessment method for species poor streams in Germany, and the EC-Life IBIP-Meuse programme.

Contents

WP 3a – Reviewing and classifying metrics

3a.1 Historical background

3a.1.1 Introduction

Since the first version of the Index of Biotic Integrity (IBI) in North America by Karr (1981), scientists in different countries have tested and/or adapted IBI concepts all over the world (for review, see Miller *et al*., 1988; Simons & Lyons, 1995; Hughes & Oberdorff, 1999). In each new version, the list of metrics changes more or less with the region, country or river type where the index was applied. A relatively exhaustive list of existing metrics contains about 100 different metrics. Few of them were always used in all versions (as number of species, proportion of omnivores, presence of damages, diseases, etc.) but most of them were specifically adapted to the features of ichthyofauna in the different countries, regions or river types. According to the authors, the selection of metrics was based on different criteria such as biological importance (metrics selected because considered as primary describers of the ichthyofauna status), statistical importance (metrics were selected according to their respective loading in multivariate analyses), literature references (metrics currently selected by other authors), expert judgement (metrics describing some regional disturbances of rivers or features of specific ichthyofauna) or specific applications (metrics used because particularly sensitive to specific anthropogenic degradations).

3a.1.2 Overview of metrics used for IBI development world-wide

Despite a huge diversity in metrics chosen in the different countries, most IBI developed world-wide have preserved the original classification of metrics among 4 major categories: species composition and diversity, trophic composition, fish abundance, and reproduction and condition. This classification has been used in the following tables, listing the metrics used by North American (Table 3a.1) and European (Table 3a.2) authors.

By comparing the metrics listed in table 3a.1 and 3a.2, it appears that less than 50 % of the metrics are present in both lists. However, many similarities can be found even if the metrics are named differently. Modifications, metric by metric, of the original IBI have been reviewed recently by Hughes & Oberdorff (1999) and thus, are not presented and discussed here in detail. For example, within the species composition category, the North-American metrics referring to darters, sunfish and green fish have been replaced in Europe by benthic species, water column species and tolerant species respectively (or by some species such as roach or eel). Similarities can also be found in trophic composition and fish abundance and condition categories, but the metrics used in Europe are generally more diversified (probably due to the lower fish diversity of European ichthyofauna compared to the North-American one), referring also to reproductive guild. European IBIs often distinguish between proportion of species, and number or proportion of individuals for a given species group. Moreover, attention has been paid to metrics dealing with age or size class distribution (year classes in species dominant and intolerant, brown trout or pike year classes, etc.).

Additional metrics have been used in IBIs developed for tropical countries (Gutierrez, 1994) in Venezuela, Hoccut *et al*. (1994) in Namibia, Lyons *et al*. (1995) in Mexico, Hay *et al*. (1996) in Guinea, Ganasan & Hughes (1998) in India, and Toham & Teugels (1999) in Cameroon). However, these metrics refer quite exclusively to the presence or abundance of some specific (sometimes endemic) species or families, such as characidae or mormyridae, or to species belonging to some specific trophic class (microphagic or macrophagic carnivores, herbivores, detritivores, etc.).

Table 3a.1. Metrics used in studies aiming to develop a fish-based index adapted to different river systems of USA.

CATEGORY	METRICS	1	2	3	4	5	6	7	8	9	10	11
SPECIES COMPOSITION												
	Number of species	■	■	■	■		■	■		■		■
	Number of native species					■			■			
	% expected number of total species										■	
	Number of darter and sculpin species					■						■
	Species richness and composition of Darters	■	■	■	■			■		■		
	Species richness and composition of Sunfish	■	■		■			■		■	■	■
	Number of water-column species								■			
	Species richness and composition of Suckers	■	■		■			■		■		
	Number of Sucker or catfish species					■						
	Number of shiner species											■
	Number of centrachid species						■		■			
	Number of cyprinid species						■					
	% expected number of native minnow species										■	
	% expected number of madtom and darter species										■	
	% native minnows										■	
	% samples as *Rhinichtihys* spp.					■						
	Presence / Absence of brook trout					■						
	Number of Sunfish or trout species					■						
Tolerance/Intoler.	Presence of intolerant species	■	■	■	■				■	■		■
	% tolerant species individuals						■		■	■		■
	% individuals as green sunfish		■	■	■							
TROPHIC COMPOSITION												
	Proportion of omnivores	■	■	■	■	■	■	■		■		■
	Proportion of individuals as pioneering species											■
	Proportion of insectivorous Cyprinids	■	■	■	■			■		■		
	Proportion of insectivores						■				■	■
	% piscivore biomass					■		■	■	■		
	% generalist biomass								■			
	% specialist biomass								■			
	Proportion of top carnivores	■	■		■							
	% expected number of piscivorous species										■	
ABUNDANCE												
productivity	Biomass of natives (kg.)								■			
	Number of native individuals								■			
	Number of individuals in sample	■	■	■	■			■			■	
	Catch per Unit Effort											
CONDITION and REPRODUCTION												
Health	Proportion with disease, tumors, anomalies, etc.	■	■	■	■	■	■			■	■	■
	Proportion of hybrid individuals	■	■		■					■		
	Exotic species individuals (%)									■		
Ecological niche	% individuals as simple lithophilic species (%)											■
Migrating	Migrating species value						■					

1: Karr, 1981, 2: Faush *et al.*, 1984, 3: Leonard & Orth, 1986, 4. Karr *et al.*, 1987, 5. Steedman, 1988, 6: Bramblett & Faush, 1991, 7: Osborne *et al.*, 1992, 8. Minns *et al.*, 1994, 9: Schields *et al.*, 1995, 10: Paller *et al.*, 1996, 11: Hall *et al.*, 1996.

Table 3a.2. Metrics used in studies aiming to develop a fish-based index adapted to European rivers and ichthyofauna.

CATEGORY	**METRICS**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
SPECIFIC SPECIES										
	Number of species	X	X	X		X		X	X	X
	Number of native species				X		X			
	% benthic species individuals	X	X		X					
	Number of benthic (specialist) species					X		X		
	Number of water-column species	X								
	Sentinel species ratio				X					
	% roach	X								
	% individuals as eel and roach (tolerant species)		X							
	Indicator species			X						
	% rheophilic species									X
	Rheophilic species richness (minus highly tolerant)								X	
	Number of lithophilous species					X			X	
	% lithophilic species (minus exotic and tolerant)									X
	Type species					X				
	Mean typical species value					X		X		
Tolerance/Intoler.	Presence of intolerant species	X			X					
	% tolerant species individuals								X	X
	% intolerant species									X
	% tolerant species									X
	% individuals as sculpin (intolerant species)		X							
	% intolerant individuals				X	X				X
	Occurrence of acid sensitive fish and stages						X			
TROPHIC COMPOSITION										
	Predator			X						
	Proportion of predatory fish (%)			X						
	Euryphagous species			X						
	Proportion of euryphagous fish (%)			X						
	Proportion of ind of bentophagous fish species (%)			X						
	Proportion of omnivores	X	X		X				X	
	% piscivore biomass	X								
	% individuals invertivores							X	X	X
	% individuals as omnivores		X			X				X
	Proportion of top carnivores	X								
	% omnivorous species					X				
	% individuals as piscivore and piscivore-invertivore				X					
	% invertivorous species					X				
	% piscivorous species					X				
	Weight ratio piscivores / non-piscivores					X				
ABUNDANCE										
Productivity	Fish abundance (ind/ha)			X					X	
	Fish biomass (kg/ha)			X	X	X		X		
	Biomass of natives (kg)		X				X			
	Catch per Unit Effort	X	X				X			
	Total number of fish caught per 100m²									X
	Total biomass of fish caught per 100m²									X
Age structure	Year classes in species dominant & intolerant				X					

	Brown trout year classes		■							
	Trout or pike year classes	■								
	value for length classes					■		■		
CONDITION and REPRODUCTION										
Health	Proportion with diseases, tumors, anomalies, etc.	■	■	■						
	Proportion of hybrid individuals			■						
	% of alien / invasive species				■					
	Shannon-Weaver index (species out of place)				■	■		■		
Reproductive guild	% individuals as gravel spawners	■								
	% specialized spawners				■			■		
	% non-specialised spawners				■	■				
	Reproduction of salmonid species native to habitat						■			
	Natural recruitment (%)					■				
Migration	Migrating species value					■		■		

1, 2, 8: France (Oberdorff & Hughes, 1992; Oberdorff & Porcher, 1994; Oberdorff *et al*., 2001), 3: Lithuania (Kesmina & Virbickas, 2000), 4, 5, 7: Belgium (Kestemont *et al*., 2000; Belpaire *et al*., 2000; Breine *et al*., submitted), 6: Sweden (Appelberg *et al*., 2000), 9: International river Meuse (Life-IBIP, 2001).

3a.2 Selection of metrics by FAME partners and comments

3a.2.1 Selected metrics

An extensive list of metrics, though not exhaustive, was presented as a part of the draft of WP3a during the kick-off meeting of FAME in Maastricht (16-18/01/02). This list was used by most partners for selection of metrics, which should be tested on the FAME database during subsequent work packages. Additional metrics were also proposed by some partners in order to consider the specificity of regional ichthyofauna (for example the presence of endemic species in Portugal and Greece) or water systems (numerous large lowland rivers in The Netherlands, water abstraction in Greece, etc.). All metrics selected by FAME partners are listed in table 3a.3. The metrics are not distributed among the four categories of the original IBI, but classified within the 3 major categories of the Water Framework Directive, *i.e.* species composition (including metrics related to trophic composition, reproduction and condition), fish abundance and age-length structure. It is obvious that most of the metrics belong to the 1st category (76 metrics), as this category concerns many ecological describers of fish assemblages, while the two other categories (abundance, age-length structure) contain 13 and 6 metrics, respectively. Fourteen new metrics have been suggested. The number of metrics selected varies according to partners, ranging from 14 in Portugal to 39 in Belgium (Wallonia).

Table 3a.3. List of metrics as selected by the different partners of FAME.

CATEGORY	METRICS	Au	BF	Bw	Fr	Ge	Gr	Pd	Pg	Li	Nl	Sw	UK
Species composition and diversity													
	Number of species	■	■	■	■			■		■	■	■	
	Number of native species	■		■			■	■	■	■	■	■	■
	% expected number of total species	■				■		■			■	■	
	% benthic species individuals			■	■					■			
	Benthic (specialist) species richness									■			
	Number of water-column species												■
	% water column species ind. (minus aliens & tolerant)								■				
	Camargo index					■							
	Indicator species ratio			■									
	Dominant / intolerant age classes									■		■	
	Number of benthic species		■		■								■
	% dominant												
	Indicator species					■		■	■			■	
	Indicator species (biomass)					■		■					
	% native individuals	■		■	■		■	■	■		■	■	
	% rheophilic species individuals			■	■		■	■		■	■	■	■
	% rheophilic species			■	■		■	■		■	■	■	
	Rheophilic species richness (minus highly tolerant)						■			■			
	Number of lithophilous species			■	■					■			
	% lithophilic species (minus exotic and tolerant)									■			
	Number of river type specific species	■	■										
	Mean typical species value		■										
	Lithophil individuals				■					■			
	% simple lithophil individuals (nb)				■								
	% simple lithophil individuals (biomass)				■								
	% salmonids that are brook trout												
	% individuals preferring vegetated areas												■
	Number of limnophilic species		■										
	Presence of intolerant species								■	■		■	
	% intolerant species			■	■	■		■		■			
	% tolerant species			■	■			■		■			
	% ind. as sculpin (intolerant species)									■			

	% tolerant species individuals			■	■	■		■	■	■			■
	% intolerant species individuals			■	■			■		■			
	Mean tolerance		■										
	Occurrence of acid sensitive fish species and stages											■	
	Sensitive species richness											■	
	% sensitive species											■	
	% tolerant individuals (biomass)			■				■				■	
	Predator					■							
	Proportion of predatory fish (%)					■		■		■			
	Euryphagous species					■							
	Proportion of omnivores ind.			■	■	■		■	■				■
	% piscivore biomass		■	■		■		■			■		
	% of individuals invertivores			■	■	■			■	■			■
	% generalist biomass			■									
	% specialist biomass			■			■	■					
	Proportion of top carnivores						■						
	% omnivorous species		■	■	■	■					■		
	% insectivore species					■	■						
	% piscivores species		■			■				■	■		
	% ind. as piscivore and piscivore-invertivore			■		■							■
	% invertivorous species		■		■	■				■			
	% piscivorous species					■					■		
	Weight ratio piscivores / non-piscivores			■						■			
	% omnivorous individuals		■	■		■							
	% of warmwater individuals								■				
	Proportion with disease, tumors and other anomalies			■					■		■		
	Proportion of hybrid individuals										■		
	% alien / invasive individuals			■			■					■	■
	% alien individuals			■									
	% alien / invasive species			■			■					■	
	Diversity index		■	■	■	■		■		■	■		
	% individuals as gravel spawners					■							■
	% specialized spawners		■	■		■							
	% non-specialised spawners			■		■							
	Natural recruitement (%)		■										
	Reproduction of salmonid species native to the habitat											■	

	Presence of population(s) migrating for reproduction			■			■					■	
	Exotic species individuals (%)			■			■				■		
	Non-indigenous individuals			■									
	Fish region criteria					■							
	Migrating species value		■	■			■	■		■		■	
	Diadromous species						■		■				
	% salmonids or brook trout								■				
Abundance													
	Fish abundance (n/ha)	■		■				■		■		■	
	Fish biomass (kg/ha)		■	■				■		■	■	■	
	Biomass of natives (kg)				■		■	■				■	
	Number of native individuals	■			■		■	■				■	
	Number of individuals in sample			■				■				■	
	Catch per Unit Effort			■	■			■		■		■	
	Catch per Unit Effort (biomass)				■			■		■		■	■
	Total number of fish caught per 100m²				■			■	■			■	■
	Total biomass of fish caught per 100m²				■			■				■	
	Weight % of non native species		■									■	
	CPUE in weight of native fish species							■				■	
	CPUE in number of native fish species							■				■	
	% biomass of salmonids in relation to total biomass											■	
Age - length structure													
	Brown trout year classes											■	
	Year classes in species dominant & intolerant			■	■		■	■					
	Trout or pike year classes				■								
	Value for length classes		■										
	Age structure of abundant river type specific species					■		■					
	Presence of several trout length classes								■				
Added metrics													
	Number of eurytopic species	■									■		
	% eurytopic individuals	■									■		
	Number of limnophylic species	■									■		
	% limnophylic individuals	■									■		
	Number of rheophylic species	■									■		
	% rheophylic individuals	■									■		
	% phytophils	■											

	% pelagophils	■											
	Number of red-list (endangered) species										■		
	Number and % long distance migratory species	■											
	Number and % medium distance migratory species	■											
	Number and % short distance migratory species	■											
	Lateral connectivity (river-floodplain interaction)					■					■		
	Longitudinal connectivity (short/long migration)					■	■				■		
	Ratio juvenils /adult individuals							■			■		
	Discontinuities in length distribution										■		
	Even distribution of age groups										■		
	% of 0+, juveniles and adults of indicator species	■											
	Growth										■		
	Proportion of long lived species					■		■					■

3a.2.2 Comments on selected metrics

Criteria for metric selection

As stressed by several partners, the list used for metric selection contains many metrics that ultimately assess the same aspect of a functional community but measures them in different ways. Two levels of criteria must be used during the selection process: ecological suitability and function and statistical criteria. As reported by Noble, Cowx & Starkie (comments to metric selection), the metric 'benthic species' can be used to assess one functional aspect of the community and its changing status with degradation, but there are many ways of measuring it: number of benthic species present, proportion of benthic species present, number of individuals, proportion of individuals, biomass or proportion of biomass of benthic species. The analytical technique used to measure the metric must be suitable to the requirements of the fish-based index, the structure of the community being studied, the ability to define a reference condition and the ease of classification and scoring of the metric within the observed range of values. This is a matter of ecological and statistical sensitivity of the metric chosen. The measure used must be sensitive enough to detect changes in the feature or function of the community being assessed. Overlaid on these criteria are criteria developed from an understanding of sampling and data limitations. Selection of metrics must therefore be justified at three levels and satisfy a range of criteria at each level. Any metric chosen must therefore ultimately be backed up by:

- ecological reasons for choice;
- statistical reason for the measurement used (ability to categorise and score the range of values observed against a valid reference condition);
- understanding of the limitations of the sampling procedure used to assess the metric.

In this respect, the French partners (Roset & Pont, comments on metric selection) have suggested a list of different metrics for which several modes of calculations (e.g. nb of species, nb of individuals, % species, % individual…) and alternatives (minus exotic and/or tolerant, etc.) are possible and should be tested rather than chosen. A candidate metric should be proposed in relation to the expected variation with degradation, and this would constitute one of the main criteria for selecting the most relevant metrics. How the different metrics suggested by Roset & Pont are expected to vary with degradation are presented in table 3a.4.

Problems related to Mediterranean regions (endemic fauna and water abstraction)

Both partners from southern Europe (Greece and Portugal) have pointed out the difficulties of developing a fish-based index in Mediterranean regions, for several reasons: low species richness, high local endemism, and tolerance of endemic species to degraded conditions. Economou (comments to metric selection) mentioned that, due to climatic reasons (a long dry season lasting from four to six months), the rivers and streams of southern Greece, and to a lesser extent of western Greece, are highly variable environments, with conditions such as water quantity and velocity, temperature and dissolved oxygen fluctuating markedly on a spatial, seasonal and annual basis. Such ecological conditions generate survival uncertainty and favour communities dominated by tolerant species, either through genetic adaptation and speciation events, or through the elimination of intolerant species. At the same time, most riverine species exhibit substantial plasticity, as a response to the variable nature of the hydrological and physico-chemical conditions. During the last 30 years the amplitude of environmental perturbations has been increasing due to man's influences. The perturbations induced by man impose to fish a stress additive to the environmental stress and have generated ecological conditions to which many species are evolutionarily inexperienced.

However, the separate effects and relative importance of the environmental and man-made perturbations are often difficult to distinguish, because they often occur concomitantly and thereby confound interpretations about the causing agent.

Table 3a.4. List of metrics proposed by Roset & Pont to be tested on FAME database, and expected trend with degradation.

METRICS	**CALCULATION**	**ALTERNATIVES**	**TREND**
DIVERSITY			
Species richness	Total number of species	minus exotic	↗ (↘)
Diversity index	Shannon, Simpson…	minus exotic	↗ (↘)
NATIVE/EXOT	Number of species		
	Number of individual or biomass (CPUE)		
	% of Total number of species		
	relative abundance (% total number of individuals, biomass)		
HABITAT PREFERENCE			
Benthic	Number of species	minus exotic AND OR Tolerant	↘
	Number of individual or biomass (CPUE)	minus exotic AND OR Tolerant	↘
	% of Total number of species	minus exotic AND OR Tolerant	↘
	relative abundance (% total number of individuals)	minus exotic AND OR Tolerant	↘
Rheophilic	Number of species	minus exotic AND OR Tolerant	↘
	Number of individual or biomass (CPUE)	minus exotic AND OR Tolerant	↘
	% of Total number of species	minus exotic AND OR Tolerant	↘
	relative abundance (% total number of individuals)	minus exotic AND OR Tolerant	↘
SPAWN HABITAT			
Lithophilic	Number of species	minus exotic AND OR Tolerant	↘
	Number of individual or biomass (CPUE)		↘
	% of Total number of species	minus exotic AND OR Tolerant	↘
	relative abundance (% total number of individuals)	minus exotic AND OR Tolerant	↘
TROPHIC GUILD			
Omnivorous	Number of species	minus exotic AND OR Tolerant	↗
	Number of individual or biomass (CPUE)	minus exotic AND OR Tolerant	↗
	% of Total number of species	minus exotic AND OR Tolerant	↗
	relative abundance (% total number of individuals, **biomass**)	minus exotic AND OR Tolerant	↗
Invertivorous	Number of species	minus exotic AND OR Tolerant	↘
	Number of individual or biomass (CPUE)	minus exotic AND OR Tolerant	↘
	% of Total number of species	minus exotic AND OR Tolerant	↘
	relative abundance (% total number of individuals, **biomass**)	minus exotic AND OR Tolerant	↘
TOLERANCE			
Tolerant	Number of species	minus exotic	↗
	Number of individual or biomass (CPUE)	minus exotic	↗
	% of Total number of species	minus exotic	↗
	relative abundance (% total number of individuals, biomass)	minus exotic	↗
Intolerant	Number of species	minus exotic	↘
	Number of individual or biomass (CPUE)	minus exotic	↘
	relative species richness (% of total species richness)	minus exotic	↘
	relative abundance (% total number of individuals, biomass)	minus exotic	↘
Abundance			
CPUE	Number or biomass per 100 m2		↘
	Number or biomass per sampling duration		↘
Age - length structure	PRESENCE of several Trout OR Pike lenght classes (2 or 3 categories)		Absence
	PRESENCE of several Intolerant AND Dominant species lengh	minus exotic	Absence
	PRESENCE of several Dominant species lenght classes (2 or 3)	minus exotic AND Tolerant	Absence
MIGRATION			
Long-distance species	presence	site, reach, basin scale??	Absence
	number of species	site, reach, basin scale??	↘
	% of species	site, reach, basin scale??	↘

Considering these statements, metrics used in IBIs developed for Mediterranean area should take into account the following variables:

- water abstraction: water is a limited resource in many Mediterranean areas and the exploitation of rivers is advanced, mainly for irrigation purposes. The presence and abundance of rheophilic species are suggested as potential metrics. These metrics can be combined with metrics based on life-history data, such as age structure, longevity and maturation age. For example, empirical evidence suggests that the reduction of water quantity below a critical level causes the largest (oldest) fish of some species to disappear from the population. In cases of severe water abstraction, only young-of-the year survive in the dry period. Life-history data may be particularly useful in the case of rivers with low species richness, due to the inability to apply metrics based on community structure.
- existence of dams: species indicating longitudinal connectivity, such as migratory or diadromous species or species performing spawning ascents could be good potential indicator of disruption.
- operation of dams (irregular release of water, altering banks, vegetation and benthic fauna): the presence, abundance or percentage contributions of suitable habitat specialists are suggested as metrics.

Problems related to large lowland rivers

In some countries (the best example is The Netherlands) or regions (Flanders in Belgium, England), the water system is largely composed of large lowland rivers in which quantitative sampling is very difficult or impossible. Moreover, the sampling effort is usually low relative to the high variety of habitats and large water areas. Specific metrics must be thus selected to cope with the low efficiency of fish sampling.

According to the Dutch partners (comments to metric selection), in large lowland rivers, high percentages of either rheophilic or limnophilic species are appreciated, while a strong dominance of eurytopic species is considered an indication of poor habitat diversity or poor water quality. Total biomass due to all sampling difficulties (selectivity and efficiency) is hardly an issue. Time series are considered an important instrument to assess the development in the fish community: increase in species richness (except for exotic species) and evenness, and increase of rheophilic species in running waters and limnophilic species in stagnant waters are thereby considered as a positive development.

Three groups of metrics should be included and newly formulated:

- Metrics regarding migration and connectivity: both in a lateral sense (lowland rivers where connectivity between main channel and floodplain waters is vital) and longitudinal connectivity (migration along the main channel). Metrics of this type are probably the most important in lowland rivers.
- Metrics for ‘age structure’ should be developed. Suggestions are a ratio of juvenile/adult individuals; even distribution of length and/or age groups or growth (length at age, which can be country or water-type specific). UK partners also reported relative growth indices.
- Metrics according to ecological guilds should be more systematic and of 2 types: main groups are eurytopics, rheophylics and limnophylics. Of all three, metrics related to total number of species and % of individuals (or biomass) are needed.

Partners from Germany also suggested the use of semi-quantitative data (CPUE and relative numbers or biomass) when sampling in large rivers.

Problems related to migratory species

The importance of longitudinal and lateral connectivity has been stressed above for the application of IBI to lowland rivers. Metrics referring to migratory species have been also suggested by the German partners (comments to metric selection), not only for long-distance migratory species (diadromous species) but also for potadromous species. Due to several reasons (scarcity, life history), long-distance migratory species can not be detected easily. Therefore, it was agreed in Maastricht that only presence/absence information can be used in many cases, and that references for migratory species for different catchment areas are needed. As suggested by Noble & Cowx (comments on draft WP3 report), migrating species in lowland rivers may not be a problem if juveniles of those species can be sampled upstream in the smaller rivers/reaches of the catchment. The presence of the juveniles upstream can therefore equate to a good migration metric score at downstream sites i.e. indirect (not site specific) measurement.

Problems related to low species richness

It is well known that the fish species diversity is rather low in Europe (except in the Danube basin) compared to the diversity of North American ichthyofauna. In many European countries, headwaters usually contain less than 5 species, or sometimes one or two species only (Sweden). Partners from the Mediterranean areas (Greece, Portugal) have also stressed this problem of low diversity. In such rivers, the efficiency of an index based on fish community structure is obviously low. To cope with this problem, it has been suggested to focus on population structure and dynamics of the few species present in the sampling site. The load of metrics related to age or size structure of specific species should be increased to the detriment of community level metrics. As suggested by the German partner (comments on metric selection), at least age classes 0+, sub-adult and adult (reproductive) should be detected. One possible way to use such a metric is to treat each of the three age classes of a species like different species and to use similarity indices between the observed and expected state, *e.g.* Renkonen's dominance identity. More attention should also be paid to the health status of individuals sampled in such stream with naturally poor diversity.

3a.3 Proposition of metrics to be tested on the FAME database

The selection of metrics presented below takes into consideration the requirements of the Water Framework Directive (particularly the need to consider the three main components of fish assemblages *i.e.* species composition and abundance, the disturbance sensitive species (species tolerance) and the age structure), the selection of metrics by FAME partners, and the limitations of sampling procedure or sample analysis (for example for density or biomass estimation, age structure metrics or health status). When several metrics with similar ecological sensitivity were suggested, the most cited ones were chosen for testing. For a given functional aspect of the fish community, the different ways to measure it are generally proposed for testing.

3a.3.1 Metrics related to species composition (including species tolerance)

This category includes all functional aspects of fish community and refers to the classification of species according to the different ecological guilds (see WP1 – species classification). For each metric, the number of species present, the number of individuals belonging to these species, the percentage of species, the percentage of individuals belonging to these species, the biomass of these species or the percentage of total biomass should be tested and final selection of the most suitable expression of each metric made later on, depending on how these different modes of calculation fit well with the presence of a degradation (Figure 3a.1).

For some guilds, it is proposed that not all classes would be tested but only those assumed to be potentially indicator of degradation. At the national or regional levels, some metrics could be modified to better describe certain forms of degradation. This is for example the case for the metrics related to tolerance, which could focus on intolerance/tolerance to acidification (Sweden), and temperature.

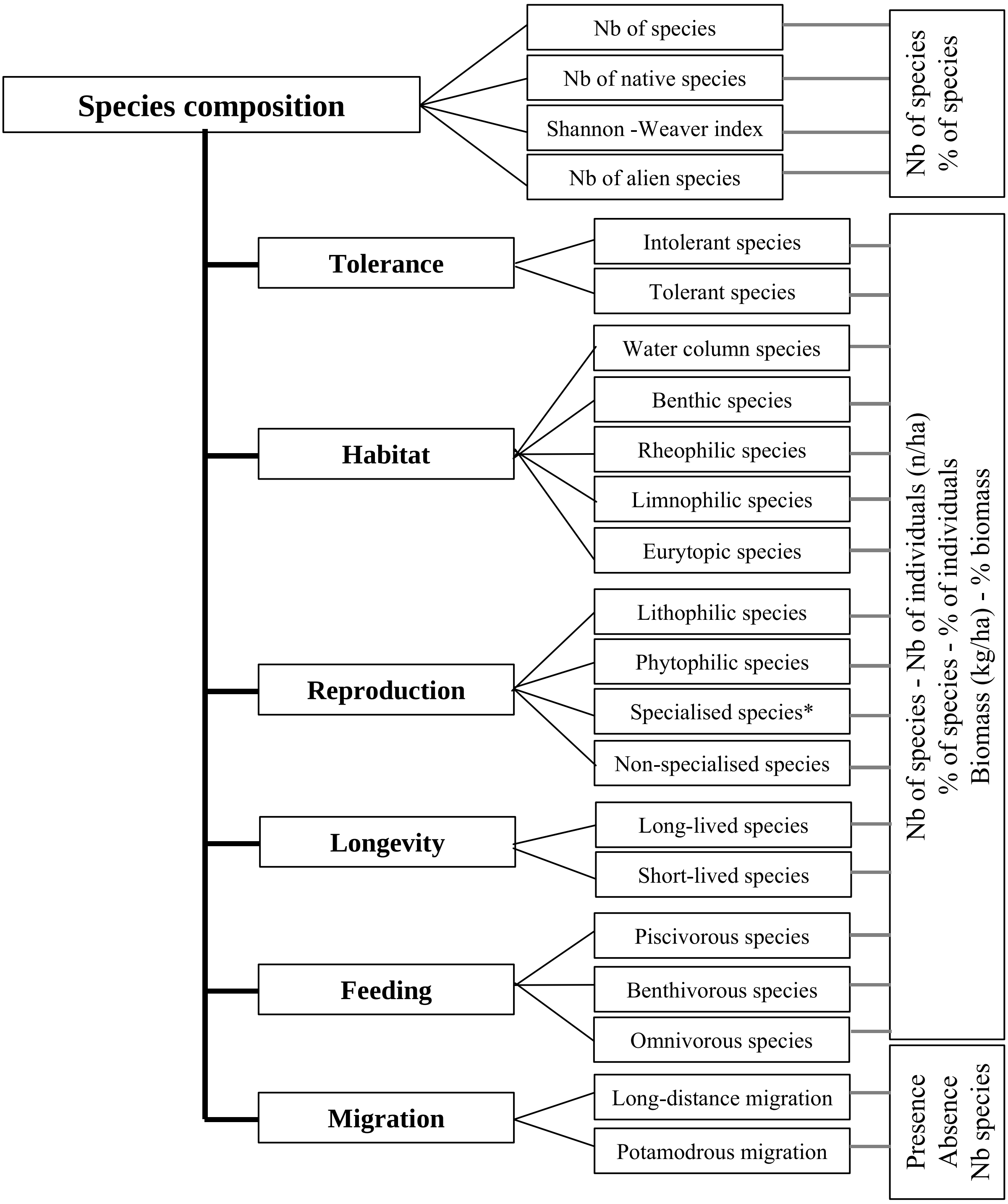

Figure 3a.1. Metrics belonging to the species composition category that should be tested in the common FAME database. *Specialised species except lithophilic and phytophilic species.

Tolerant and intolerant species refer to the sensitivity of species to the physico-chemical degradation of water, rather than to habitat degradation which is already considered in the habitat guild and corresponding metrics. Feeding metrics have been limited to obligatory piscivorous (> 75% of fish in the normal diet), benthivorous and omnivorous species. Additional metrics such as insectivorous/invertivorous species could be tested, depending on time availability

3a.3.2 Metrics related to abundance

The different metrics related to fish abundance are shown in figure 3a.2. As for species composition metrics, different modes of calculations could be used. At least the density (number of individuals) and biomass (kg) of fish should be tested. How density and biomass are expressed is dependent on the type of river sampled (wadable or non-wadable rivers) and the final sampling procedure chosen. Not all partners have at their disposal fish capture data obtained after removal method with several successive passages. It is thus recommended to use the data from the 1st passage, expressed as density or biomass per ha of sampled area. However, the advantage to use estimated density or biomass (based on several successive passages and sampling efficiency by Zippin, Carle & Strub, de Lury or Seber & Le Cren methods) could be tested. If this advantage is low, as demonstrated for the IBI developed for Wallonia, only one passage will be, obviously, more cost-effective. In non-wadable rivers, only data obtained by electric fishing should be used (see 3b.2.1). Semi-quantitative data can be used, since the fish abundance can be calculated per unit of prospected area (ha), regardless of sampling procedure (continuous fishing along the banks, ‘ambience’ method, etc.). The abundance of species of interest could be used, after classification, for each country, of which species is considered as good indicator of degradation.

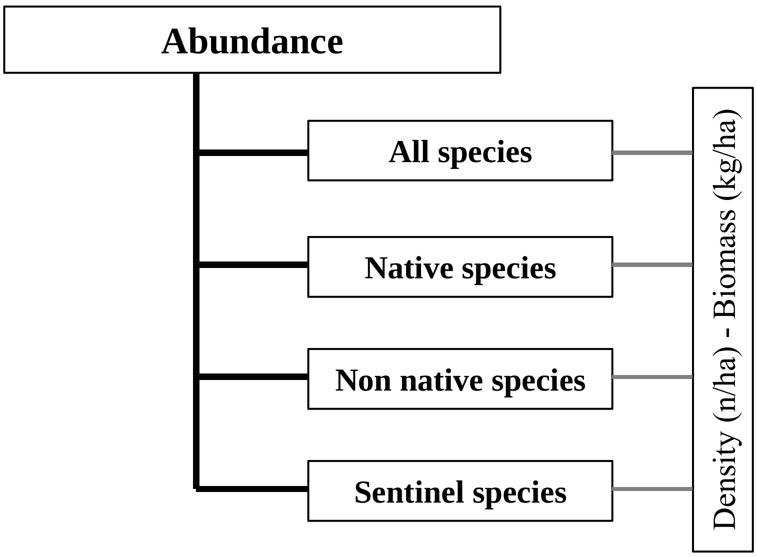

Figure 3a.2. Metrics belonging to the fish abundance category that should be tested in the common FAME database.

3a.3.3 Metrics related to age - length structure

Metrics related to age – length structure are shown in figure 3a.3. It is generally accepted that length frequency distribution is much easier to assess than age frequency distribution, thus the former expression should be used. The metric 'sentinel species' seems the most appropriate for analysis of length frequency distribution or for calculating a reliable ratio between juveniles (0+) and adults. Growth (or relative growth indices) of river-type specific species could provide useful information, but its calculation requires growth modelling for related species and for each ecoregion. This type of data is probably beyond the requirements or scope of FAME, and was not retained in the final list of metrics.

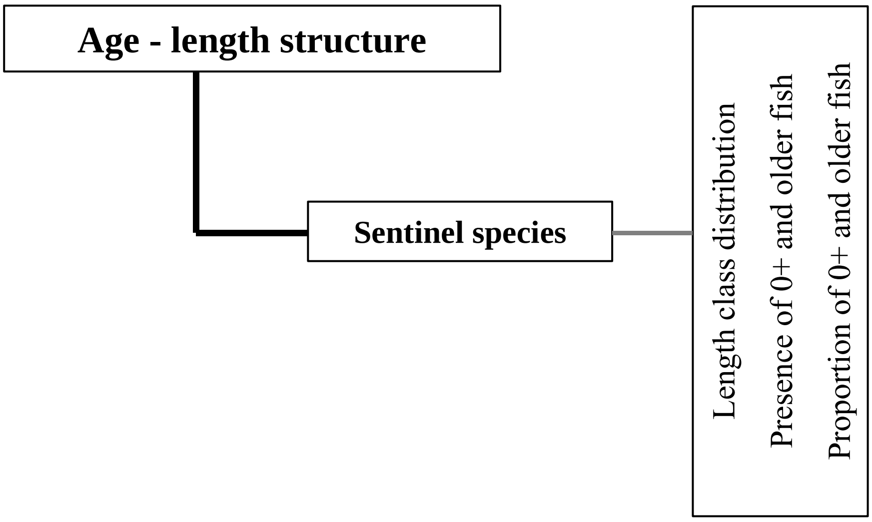

Figure 3a.3. Metric belonging to the age – length structure category that should be tested in the common FAME database.

3a.3.4 Additional metrics

Additional metrics, not included in the different categories described in figures 3a.1-3a.3, were suggested by some partners. The number of Red-List species (species very rare by definition) is not retained in the final list of metrics because they are not in the scope of FAME and WFD. The metrics describing the health and condition status of fish have been also cancelled:

- Proportion of fish with disease, tumours, fin damages and other anomalies
- Proportion of hybrid individuals

The latter one was not considered as important by most partners, and usually considered as difficult to assess (or to get reliable data for F1 or F2 hybrids), the former one is stressed by some partners as relatively well correlated with degradation. However, fish damage may be difficult to assess using currently available data for all regions. Damage classification and causes are not easy to establish. Moreover, diseases may have annual/long term cycles that are not related to hydromorphological or physicochemical conditions in the river. The final list of metrics will not include metrics focusing on individual traits of fish.

WP 3b – Reviewing and classifying sampling methods

3b.1 Identification of existing sampling procedures

3b.1.1 Introduction

In Europe, sampling methods differ greatly between countries, and even between regions or states belonging to the same country. As a corollary, national sampling methods rarely exist. However, in some European countries, fish monitoring programmes have been designed to assess the ecological quality of rivers based on fish assemblages. These monitoring programmes have, to some extent, led to the standardisation of sampling procedures, at least at the regional level. At the national or international levels, the development of fish-based methods of river quality assessment are limited by the diversity of fish sampling procedures, and consequently the fish databases were restricted to sampling sites for which similar fish sampling methods were applied. As an example, the fish database used for the development of a fish-based index in the international basin of the River Meuse (EC-Life project ENV-B-0049) was restricted to data obtained by electric fishing. Data provided by complementary methods such as gillnetting or trawling (of interest for the assessment of large rivers) cannot be introduced in the models because the methods were restricted to specific countries or regions (gillnetting in Wallonia and trawling in The Netherlands). One objective of WP3 was to review and classify the different sampling methods and procedures existing within the different partner countries of the FAME consortium, in order to propose a standardised procedure for sampling fish, which can be used by all partners during WP9.

3b.1.2 Overview of existing sampling procedures used by FAME partners

This section describes the major features of the sampling procedures used by the FAME partners, country by country, on the basis of contributions from all partners. Table 3b.1 summarises the information related to fish sampling by electric fishing, including information pertaining to the availability of sampling site, fishing equipment, physiographic, and main sampling strategy data, in the database of each partner.

Austria

Several fish sampling methods are currently used in Austria. The principal methods are electric fishing in wadable streams or rivers, and electric fishing from a boat, seining, gillnetting and long-lines in large rivers, such as The Danube.

In wadable streams, the removal method is usually applied, with 1-3 passages over a river length of 100-150m, depending on site characteristics and sampling objectives. The number of anodes used is dependent on the river width, ranging from 1 anode for rivers 3 m in width to 4 anodes in rivers wider than 9 m. One hand-net per anode and 1-3 persons for other activities (transporting fish, electric generator control (Direct Current DC – 1.5 + 2.5 KW, etc.). Stop nets are used when applicable. The catch data are separated between passages, in order to estimate catch efficiency per species. Autumn is the preferred sampling season in wadable rivers.

In non-wadable or large rivers, electric fishing is performed from a boat with a Pulsating Direct Current (PDC – 5 + 10 KW) electric generator, principally in autumn, but also in summer in the Danube. A stratified random method is applied on 30-60 habitat-specific "strips" of 50-200 m long.

Belgium – Flanders

In Flanders, fish population surveys are standardised both for wadable and non-wadable rivers. The principal method of fish sampling is electric fishing, but other methods such as gill nets, seine netting or fyke nets are also used in large rivers, and in some specific water systems (e.g. in Polder drainage systems). Electric fishing is carried out using a 5 KW generator with an adjustable output voltage of 300 – 500 V and a pulse frequency of 480 Hz.

In wadable rivers, the number of electric fishing devices and the number of anodes are dependent on river width, from 1 anode for river width smaller than 1.5 m to 4 anodes for rivers of 6-8 m wide. Electric fishing is performed in an upstream direction. At each station (sampled area = 100 m long), a maximum of 200 specimens of each species are individually weighed and measured. Biomass (kg ha^{-1}) and density (individuals ha^{-1}) are calculated based on sampling area and by using the method of Seber & Le Cren (1967).

In non-wadable rivers, electric fishing is performed from a boat with 2 anodes, over a distance of 250 m on both riverbanks. Captures by fyke nets, seine netting and/or gill nets are sometimes used to complement the electric fishing captures, principally in standing waters (channels).

Belgium – Wallonia

Despite the absence of a regular fish monitoring programme defined at the regional level, several institutions (Universities, public administration responsible of natural resource management) perform frequent fish sampling operations in Wallonia. Electric fishing is used by all institutions, with relatively similar, but not standardised, sampling procedure. In addition, fish capture data obtained with gill nets, seine netting, fyke nets or fish pass control are also compiled in the regional fish database.

In wadable rivers, electric fishing is performed over a distance of 150-350 m, regardless of river width, with 1-3 passages depending on sampling objectives and institutions. Stop nets are used as far as possible, but if the water flow is too high or the river too wide, sampling areas are selected in such a way that natural barriers (small weirs or very shallow riffles) delimit the prospected zones. Calculation of IBI developed for the Walloon river basins, (Didier, 1997; Kestemont *et al*., 2000) and based on the fish capture data obtained after 1 or 2 passages, has demonstrated that no or very limited differences were observed by using the data of the 1st passage or of both passages, for about 90 sites belonging to different river categories (trout to bream zones, according to Huet zonation). Regardless of the number of electric fishing passages, 50 % of the sampling sites received exactly the same IBI score and only 8% were concerned by a modification of their integrity class assignment (change of one class maximum). The preferred sampling seasons are summer and autumn.

In non-wadable rivers, electric fishing and horizontal bottom gill net techniques are combined. Electric fishing is performed from a boat, in an upstream or downstream direction along both banks, by a staff of 4 persons including the anode operator. The prospected area ranges between 600 and 1000 m^2 (considering 2-3m wide), as a continuous section of the river or as a combination of several sub-sections representing different habitats. Gill netting is also currently performed in large rivers, by setting a battery of 3 to 8 nets (length = 50 m, height = 2 m) of increasing mesh sizes (from 10 to 80 mm mesh size). The fishing effort is dependent on the area: downstream a dam gillnets are set one by one during 15-30 min, depending on season. Whilst in still waters, gillnets are set concurrently during 2 hours. Both electric fishing and gill netting are usually performed during daylight, but comparisons have been made with sampling performed during the night, indicating that the abundance, frequency and size of species caught varies greatly between day and night.

Table 3b.1. Main characteristics of the electric fishing methods used by the FAME partners and information existing in their database, regarding sampling site, electric fishing equipment and procedure, fishing conditions, and main sampling strategy.

ELECTRIC FISHING INFORMATION	Au	BF	Bw	Fr	Ge	Gr	Pd	Pg	Li	Nl	Sw	UK
Sampling site												
Total number of samples			150	738		>60	120		295		16856	
River (stream) name (%)[1]	100	100	100	100	100	100	100	100	100	100	100	
Location name (%)[1]	100	100	100	100	100		100	100	100	100	92	
Location coordinates (%)[1]	100	100	100	100	100	0**	100	100	100	100	100	
Altitude (%)[1]	100	100	100	100	100	0**	100	100	0	100	100	
Distance to source (%)[1]		100	100	100		0	100	<50	100	100	0	
Watershed area (%)[1]		100	100	100			100			100		
Huet zonation (Y/N)	N	Y	Y	N	N	N	N		N	Y	N	
Date of sampling (%)[1]	100	100	100	100	100	100	100		100	100	100	
Prospected area (100 m^2 or ha) (%)[1]		100	100	100		0	100	0	100	100	100	
Mean river slope (%)[1]	100	100	100	100	100	0**	100	0	>50	100	47	
Mean river width (%)[1]	0	100	100	100	100	0	100	100	100	100	100	
Mean river depth (%)[1]	0	some		100	100	0	100	100	100	100	100	
Maximum river depth (%)[1]	0			0	0	0	25	100	100	100	95	
Electric fishing equipment and procedure												
Type of electric current	DC*	PDC	PDC	PDC	DC	PDC	PDC-DC	DC	PDC	PDC	PDC-DC	PDC
Number of anodes	1-4	1-2	1-4	1-4		1	1-2	1			1-2	1-2
Anode size				0	100	100	100	100	100	100	100	
Number of hand-nets (%)[1]	100		100	100		100	100	100				100
Mesh size of hand-nets												
Number of passages in wadable rivers	1-3	1-2	1-2	1-2	1	1	1-3	1	1-3	1	3	1-3
Data of passages separated (Y/N)	Y	Y	Y	Y	-	-	N	-	N	-	Y	Y
Stop nets in wadable rivers (Y/N)	Y		Y	Y	N	N	Y&N	N	N	N	N	Y
Fishing conditions												
Water temperature (%)[1]	0	100	100	100	100	>80	100	100	100	100	86	
Conductivity (%)[1]	0	75	80		100	>80	100	100	0	0	0	
pH (%)[1]	0	75	80	0		>80	100	100	0	0	0	
Stream velocity (%)[1]	0	few	80	0		0	25	>50	100	100	96	
January air temperature (%)[1]	100	100	100	100	0	0**	100	100	100	100	100	
July air temperature (%)[1]	100	100	100	100	0	0**	100	100	100	100	100	

Main sampling methods												
Wadable rivers	Rl	Rl	Rl	Rl	Rl	Rp	Rl	Rp	Rl	-	Rl	Rl
Non-wadable rivers	Rp	Rp	Rp	Rp	Rp	-	Rp	Rp	Rp	Rp	-	Rp

1. (%): Proportion of samplings for which the data are available. * PDC in electric fishing by boat. ** Data not available but can be estimated. Rl : removal method, Rp : representative method.

Additional techniques of fish sampling in non-wadable rivers include seining (used in straight canals with width less than 30 m), fyke nets (in connection between main channel and backwaters), and control of fish pass and sport angler catches.

France

Electric fishing is the usual method of fish sampling employed nation-wide. Direct Current with adjustable power is provided by an electric generator unit and modified by a "Heron" type electric output-control system. Thus an output ranging between 400 to 600 V and 2 to 4 A is delivered. The preferred season for sampling is autumn, but sampling in small and medium-sized wadable rivers is also performed in late spring and summer.

Wadable streams

Fishing is conducted over the whole river width, moving from downstream to upstream. The sampling area is delimited by two stop nets. During one passage (or more), several anodes (depending on the river width) are moved in the water and followed by hand-nets (4mm-mesh size) for collecting fishes. Each anode is generally followed by 2 hand-newsmen with suitable vessels for transporting fish. This technique usually requires 5 to 8 personnel in the water. One passage is the minimum required, but two or three passages are often carried out in small streams.

Non-wadable rivers

Several sampling protocols have been successively tested:

- The first one was implemented in 1981. The procedure consisted of "continuous banks sampling", i.e. electric fishing of a length of bank including all types of habitat in proportion to their presence on the site. Continuous sampling of a 2 meters-wide stretch along both banks (shores) is carried out over the whole length of the station (about 200 to 1000 meters). A single anode and two hand-netsmen are involved. But this method is effort and time intensive in large rivers where the station (sampling site) is more than 500 meters long, and when the density and the variety of fishes are high. This protocol was used in large rivers until the early 90s.

- The second protocol used is "point abundance sampling" (Persat and Copp 1990). This strategy consists of numerous, small and punctual samples obtained only in the range of influence of an anode quickly immersed and kept motionless. Point abundance sampling can be related to the same spatial scale as microhabitat. Samples must be randomly distributed and numerous enough to be representative of the proportion of habitats on the site. Whereas the "continuous banks sampling" protocol was likely to overestimate (or underestimate) some species (like schooling ones, depending on whether a shoal of fish was met or not), and needed large samples, the multiplication of small samples at random could give a more accurate image of the population, with a smaller variability due to operators. Furthermore, as physical data concerning each point sampled were recorded, this approach seemed appropriate to account for fish-habitat relationship studies. Nevertheless, the implementation of the protocol proved to be more difficult than expected, due in particular to a long practice of field operators in the search of the largest amount of fish present on the site: fish-less sampling points, which are likely to occur frequently were considered as unproductive work, and a permanent drift towards points in which operators were sure to get some fish was observed. Therefore, sampling was not random, and bias due to the fishing team could be all the more important.

- The third protocol was introduced in 1995 and derives from Pouilly (1994) and Capra (1995) and is called "ambience sampling". It consists of a space-stratified sampling protocol with a similar rationale as point abundance sampling, but with larger sampling areas. The "ambience" is defined as an area ranging from about 10 to 100 m^2, taking into account simultaneously morphological characteristics (depth, flow velocity and substrate size), ecological conditions (aquatic vegetation, roots, snags canopy cover, bank morphology, ripisylve structure, undercutting, etc.) and the position in the stream (mid-channel, bank, side-arm…). As the name suggests, the "*ambience*" is supposed to describe realistically the scale between meso- and micro-habitat, at which fishes are influenced by the surrounding conditions, i.e. the scale that really affect their physiological function and behaviour according to their particular life cycle. The aim of this method is to prospect every habitat type in order for samples to reflect the species richness, and the type of assemblage of a given reach. This technique is also useful to account for fish-habitat relationships at the station scale. First, all the "ambiences" representative of the river section are identified and described in terms of water velocity (flow meter), water depth, and heterogeneity of the water depth, dominant and accessory substrate, position within the stream, flow type (riffle, pool,….), bank slope (high, medium, low), canopy cover (%), vegetation type (floating or submerged hydrophytes, helophytes…), snag and undercutting (presence and growth). The width and length of each "ambience" is measured and its position is plotted on a map, ensuring reproducibility from year to year. The surface to sample (effort per "ambience") should be proportional to the extent of the habitat type in the whole section. Every "ambience" represented in the station must be prospected, and the rule is to make several replicates of the dominant types rather than sampling a larger surface, particularly when habitat diversity is low. Then depending on the river and the habitat type, the ambience area should range between 20 to 100 m^2. Each ambience is continuously fished once by boat (or wading if the method is used in wide wadable rivers), and the time spent fishing is recorded to ensure a constant effort from year to year A minimum of 10 "ambiences" must be sampled, but 15 or more ambiences are necessary in large rivers. This method requires one person for driving the boat, two men fishing (one anode and one hand-net) and one other for describing and mapping the habitats. Then the prospection of a station of large river requires about half a day, which is similar to the time spent for a more exhaustive inventory in small streams.

Germany

A standardised German river monitoring system has never been established due to the special situation in Germany where inland fisheries is under the responsibility of Federal States. Each Federal State has its own river monitoring programmes and maintains their own database. Only for some large rivers as Rhine or Elbe there are fish monitoring systems co-ordinated by the affected Federal States or countries. In this respect, the sampling procedure described below is usual only in the Federal State of Baden-Wuerttemberg. Other Federal States may use other sampling procedures.

In wadable rivers, electric fishing is performed using a DC 1,5-7 KW electric generator. The number of anodes and personnel is dependent on river type, but usually 3 people are required. For a given site, the sampling area is at least 100 m in small headwater streams and increases with increasing size and habitat complexity of the sampled river in order to obtain a representative result. One passage is performed. Stop nets are not usually used, but are used in some specific cases. The preferred season for electric fishing extends from late summer to early autumn.

In non-wadable rivers, electric fishing is performed from a boat, usually by 4 persons, with a 7 KW DC generator. The representative method is used.

Greece

In Greece, there is no nation-wide system of fish data collection, and, therefore, there are no nationally standardised sampling methods. The collection of fish data allowing the evaluation of the type and magnitude of impacts on the aquatic environment has never been a sampling objective. As a consequence, sampling techniques have not been appropriately standardised for purposes of water quality assessments.

Although samples have been collected with a variety of fishing techniques (gill nets, seine netting, fyke nets, fry nets, fish pass control, etc.), electric fishing has always been a basic component of all riverine investigations. Effort was devoted (after 1998) to collect from at least one portion of the sampled localities a sample representing the entire fish community. Data exclusively concern wadable rivers, collected in spring if the investigation is targeted to aspects of reproduction and early life stages and in late summer or autumn if the target is the study of human impacts and threats to endangered species.

DC electric generators (300-600 V) are used. The usual sampling practice is one person operating the anode proceeds upstream (sampling stretches of 40-100 m) and one or two other persons with hand-nets follow behind. One passage is performed, and no stop nets are used.

Lithuania

Several sampling gears are currently used in Lithuania. The most extensively used method is electric fishing, representing 88% of the sampling sites, 54% by wading and 34% from a boat. Other methods include stationary gill netting, and the use of drift and dragnets.

In wadable rivers, electric fishing is performed with a 600 V PDC battery, usually involving 3 persons of whom one operates the anode. The sampling intensity depends on the river size. Usually, one site per 10 km length river segment is investigated, with the sampling site covering 100-200 m. For each site, 1-3 passages are performed (in most cases 2 passages) and no stop nets are used. The preferred seasons for sampling are summer and autumn.

In non-wadable rivers, electric fishing, gill nets, drift nets and dragnets are used. Electric fishing is performed from a boat, and sections of about 3 m wide and 100-200 m long along the banks are sampled. When floating nets are used, about 2 km length segments of the main river channel are fished. Bottom gill nets (35-40 m long for each mesh size, ranging from 14-60 mm) are set overnight, for about 10 h.

Poland

1. Fish monitoring in Polish rivers

There is no systematic monitoring programme for fish fauna in polish rivers. There are some propositions of how to conduct such a monitoring programme and which institution can be mainly involved in it. Up to now the Polish Anglers Association is the main institution that collects fish fauna data from the whole Poland. But not all of them can be easy used as a basis for monitoring according to purposes of WFD framework.

Before 1965, only sporadic data of fish fauna composition and distribution in rivers are available. After 1965, a strong Cupertino between Polish Anglers Society and Polish scientific institutions was established (mainly University of: Łódź, Wrocław, Gdańsk, Kraków, Poznań, Olsztyn) to monitor fish fauna in the main Polish rivers.

2. Fish community assessment in Polish rivers

Electric fishing is the main sampling method used in Poland for assessing fish community composition in rivers. Sampling intensity and sampling area are dependent on river size:

- streams and small rivers (width to 10m), 5 to 10 sites (50 to 250 m long) are sampled along the river continuum, using the removal method and 2-3 passages. The size of area sampled is selected to ensure representative sampling of habitats present in the river channel.
- medium size rivers (width 10 to 40 m), 5 to 25 sites (up to 500 m long) are sampled.
- large rivers (width 40-100 m) up to 40 sites (up to 1000 m) are sampled.

Wadable rivers

Electric fishing is performed using one or two anodes. Up to three electric fishing runs are undertaken on each sampling occasion. Most of the data are cumulative from 2 or 3 samplings, and there is a lack of separate data from each sampling. Sampling is usually performed seasonally, from spring to autumn.

Examples for wadable rivers:

- One electric fishing passage by wading upstream for 100 m, 2 hand-nets, length of site 0.8-1 km. Assessments of fish species composition and relative abundance are estimated from a single electric fishing at each site according to the *Beklemieshevs rule. CPUE to assess relative abundance and biomass of fish* (Backiel & Penczak, 1989) (Watra River – Odra River tributary, Przybylski, 1993; Przybylski, 1996).
- One electric fishing passage by wading a section of 100 m and hand-netting stunned fish, lasting 15 min. *CPUE* is used to assess relative abundance and biomass of fish (Pilica River – Wisła River tributary, Penczak, 1999)
- Two electric fishing passages by wading upstream for 50 m to 500 m (depending on the river width). Multiple passages were performed in an upstream direction. The density and biomass of fish were estimated from a regression of percentage of fish captured on the logarithm of mean weight of individual fish captured in a single pulsed DC electric fishing (Zalewski 1983, 1985; Zalewski *et al.*, 1990; Zalewski, 1991)
- Two electric fishing passages by wading upstream for 50 m to 500 m (depending on the river width). Each site is selected in order to sample a representative sequence of habitats (riffle, run and pool). Multiple passages were performed in upstream direction. Stop nets were set to delimit the sampling area. The density and biomass of fish were estimated from a regression of percentage of fish captured on the logarithm of mean weight of individual fish captured in a single pulsed DC electric fishing (Zalewski 1983, 1985) (Lubrzanka River – Wisła River tributary, Grabia River – Odra River tributary, Nowak & Zalewski, 1991; Lapinska, 1996).

Non-wadable rivers

Electric fishing is conducted from a boat by two operators usually with 1-2 anode(s), hand-nets and 1 cathode. Up to three electric fishing runs are undertaken on each sampling occasion. Most of the data are cumulative from 2 or 3 samples. Two or three successive catches, with a constant unit of effort consisting of a combination of a single catch along the left and right banks, are usually used to estimate fish abundance (Penczak & Romero 1990). Lack of separate data from each sampling. Sampling is usually performed seasonally, from spring to autumn.

Examples for non-wadable rivers:

- One electric fishing passage from a boat along both banks, 6-10 sites of 200 to 2200 m in length (Wisła River, Backiel et al.2000)
- One electric fishing passage from a boat along both banks during a 20 minute period, 2 hand-nets, length of site 0.8-1 km. Assessment of fish species composition and relative abundance from a single electric fishing at each site according to the *Beklemieshevs rule*- means that the length of a site was considered sufficient if the number of species recorded did not increase with further increase in length sampled. Thus, this single catch is performed with constant unit of effort (CPUE) (Watra River – Odra River tributary, Przybylski 1993, Przybylski 1996; Pilica River – Wisła River tributary, Backiel & Penczak 1989, Penczak 1999).
- Two electric fishing passages from a boat over a distance of 100 m to 500 m (depending on the river width). Each site is selected in order to sample a representative sequence of habitats (riffle, run and pool). Multiple passages were performed in a downstream direction. The density and biomass of fish were estimated from a regression of percentage of fish captured on the logarithm of mean weight of individual fish captured in a single pulsed DC electric fishing (Zalewski 1983, 1985) (Lubrzanka River – Wisła River tributary, Grabia River – Odra River tributary, Nowak & Zalewski 1991; Lapinska 1996).
- Three replicate electric fishing passages from a boat, along both banks, over a distance of 100-1000 m. The catch-recapture method or the catch per unit of effort (CPUE – 15 to 30 min sampling duration) are used, preferably in summer and autumn (Pilica River – Wisła River tributary, Penczak et al. 1998).
- Three replicate electric fishing passages from a boat using constant unit effort (CPUE) along both banks. Fish captured along right and left banks were combined and considered as a single catch (C1, C2 and C3). The Zippin (1956, 1958) triple-catch removal method was used to estimate population size and the 95% confidence limits. (example: Watra River – Odra River tributary, Pencak & Romero 1990, Penczak 1995).
- Electric fishing from boat using stop nets to delimit the sampling area (to test and improvement of quantitative estimates)
- Electric fishing from a boat and block-off fyke nets (Pilica River, Penczak & Zalewski 1973)
- Electric fishing from a boat and block-off gill nets (method applied on the Warta River by commercial fishermen from the 1960s to the present day).

3. Examples of electric fishing equipment

- 3 kW AC generator set with a full-wave rectified, pulsed DC of 220V, 3-4 A and 50 Hz output,
- 2.5 kW generator Rhino MK 2500, 220 V, 5-6 A,
- 3 kW AC generator set with a full-wave rectified pulsed DC of 230V, 10.8 A and 50 Hz output.

Portugal

All data are obtained by electric fishing, 90% from wadable rivers and 10% from a boat, in large rivers. The equipment consists of a generator-powered DC electric fishing apparatus and a staff composed of 3 persons, including the hand-held anode operator (one anode).

In wadable rivers, each site is selected in order to sample a representative sequence of habitats (riffle, run and pool). A single passage is performed in upstream direction, without stop nets.

Sweden

Electric fishing is the main sampling method used in Sweden, only by wading. Stationary gill nets are occasionally used in wide river bays.

The sampling strategy is a standardised, representative one, based on the successive removal of fish, with 3 passages per sampling site (length of the sampling stretch = 30-70 m). The preferred season is late summer-early autumn (Aug-Sept).

The Netherlands

Several complimentary techniques of fish sampling are used in The Netherlands, principally in large lowland rivers (100-300 m wide). Electric fishing (PDC generator, 300 V, 5A) is usually performed from a boat, along the banks, by a staff of 3 persons. The prospected area averages 1000 m^2, *e.g.* 500 m long, 2 m wide along the banks, where the mean water depth is 0.8 m). The preferred season for electric fishing is from late autumn to early spring (Oct-Apr).

Other techniques, including trawling, fyke and frame nets, are also used in large lowland rivers. The area prospected by trawling averages 0.3 ha, corresponding to a 10 min fishing effort (over a distance of about 1 km) with a trawl of 3 m wide (1 m high) set at a mean water depth of 4 m (on the bottom of the river). The preferred season for trawling extends from April to October. On the other hand, fyke and frame nets are preferably used from spring (April) to autumn (November). Nets of 5-20 m long are set on the bottom of lowland rivers, at a depth of 3 m for periods ranging from 12 to 154 h.

United Kingdom

The gears and strategies used in England and Wales for fish stock assessments were reviewed by Cowx (1995), and are summarised in Table 3b.1. The specific gears and strategies used are generally region and site dependent. Electric fishing is the most common sampling gear used although the gear specifications, technique of application and man-power used has been variable between Environmental Agency (EA) area teams. The review of the EA Monitoring Programme and recent R&D programmes have attempted to standardise the sampling strategy and methods used for each element of the new monitoring programme whilst retaining some flexibility in approach to allow for evolution. The review is also taking full consideration of CEN requirements.

Wadable rivers

<u>Electric fishing</u>

In England and Wales, a variety of electric fishing gears and approaches have been used for sampling fish populations (Table 3b.2). Recent R&D programmes have attempted to establish best practices and standardised approaches and application of electric fishing gears and techniques. Electric fishing surveys are usually carried out in summer months, post spawning season (June – October). However, some regional and site-specific variation occurs depending upon the purpose of the surveys, the accessibility of the site and the conditions for efficient sampling, e.g. weed growth. The new sampling programme has proposed methods to suit different sampling data requirements (Table 3b.3), different habitat conditions (Table 3b.4) and the manpower required to undertake them (Table 3b.5).

Table 3b.2. Summary of fish sampling methods used in England and Wales to evaluate the status of fish stocks (edited from Cowx 1995).

WATER BODY	Sampling gear[a]	Sampling strategy
Small streams <5 m wide	1 hand-held electrode, DC, 50/100 Hz PDC electric fishing, generator supply (c 2 kVa), or battery power backpack, wading (3)	Depletion sampling between stop-netted sections
Small rivers 5 – 15 m wide, pool – pool/riffle topography	1 or 2 hand-held electrode(s), DC, 50/100 Hz PDC electric fishing, generator supply (c 2 kVa), or battery power backpack, wading (3) or boat based in deeper sections (3 – 6)	Depletion sampling between stop-netted sections, if possible
Small rivers 5 – 15 m wide, pool topography, >1 m deep	Boat-based, 2+ hand-held electrodes, DC, 50/100 Hz PDC electric fishing, generator supply (c 2 kVa) (3 – 6) Multiple anode boom array (4)	As above One-catch relative assessment Calibrated sampling
Large rivers and canals >15 m wide >1 m deep	Boat-based, 2 boats (7 – 8), 2+ hand-held electrodes, DC, 50/100 Hz PDC electric fishing, generator supply (c 2 kVa) Multiple anode boom array (4) 4 – 7.5 kVa generators	Depletion sampling Calibrated sampling Relative assessment
	Seine netting (wrap around technique) (6+)	Depletion or calibrated sampling
	Angler-catch statistics/licence returns	Catch effort and trend analysis
	Creel census	Catch effort and trend analysis
	Hydroacoustics	Calibrated biomass and density estimates

[a] Number in brackets indicates the minimum number of personnel used for survey

- Quantitative sampling

Conventional catch depletion sampling is undertaken, involving the isolation of the site with stop nets (and/or natural barriers). Sites are fished at least three times unless (see HMSO, 1988) "when the 2nd catch is very much smaller that the 1st and the field estimates of population size indicate (a) that the population size exceeds 200, and (b) that the probability of capture of an individual fish is greater than 0.6. Under these circumstances a third fishing need not be carried out."

- Semi-quantitative sampling

Two types of semi-quantitative sampling have been identified as suitable approaches:
- A single electric fishing run based on the methods above. Stop nets not used but advantage taken of natural obstacles, e.g. riffles;
- Timed electric-fishing, probably lasting 5 minutes, targeted at riffle areas in streams of greater width than 10 m. This method focuses on salmonid fry, and is typically used to assess the spatial distribution of main river stem spawning.

Table 3b.3. Size of sampling site recommended for each element of the proposed monitoring programme for the UK.

Survey type	Monitoring programme element	Min site length, m	Max site length, m	Timed
Quantitative e/f by wading	Salmonid: Quantitative sites (at least 10 x stream width)	30	100	_
	Coarse: Temporal & Index sites	75	150	
Semi-quantitative e/f by wading	Salmonid: Semiquant sites	30	100	_
	Coarse: Spatial & Sentinel sites	75	150	
Timed electric fishing by wading	Salmonid: Fry surveys in rivers >10m wide	_	_	≥ 5 minutes
Quantitative e/f by boat	Coarse: Temporal and Index	100	300	_
Semi-quantitative e/f by boat (incl boom boat)	Coarse: Spatial and Sentinel	100	300	
	Large river Temporal & Index	250	unlimited	_

Table 3b.4. Summary of proposed electric fishing gear set-ups for different river types.

Site Details Width, m	Mean Depth, m	Suitable Gear wade	Boat	Single Anode	Two Anodes	Lane Nets	Boom Boat	Multi-boat
<5	<0.8	Y		Y				
5-10	<0.8	Y		Y	Y			
10-15	<0.8	Y			Y**			
>15	<0.8	Y			Y**	Y		
<15	>0.8		Y		Y		Y	
>15	>0.8		Y		Y	Y	Y	Y
Canal			Y		Y		Y	

**In certain circumstances more than two anodes might be used when wading, but, all anodes must be operated from the same control box and be set up so that the "one off = all off" rule applies.

Table 3b.5. Manpower requirements for each approach to electric fishing in the UK.

Electric fishing operation	Minimum	Optimal
Backpack gears	3	4
Wading, 1 anode	3	4
Wading, 2 anodes	4	5
Boat, hand-held anode	4	5
Boom boat	3	4
Boom boat + catcher boat	5	6

In recent years only 3 electric fishing equipment manufacturers have built equipment that complied with the Health and Safety Executive guidelines for electric fishing in the UK. Despite the low number of available sources of gears this has lead a relatively diverse set of electric fishing gears which exhibit large variation in electrical output being used by different EA area teams. Generally the equipment specification for electric fishing gears is 240V 50/100 Hz pulsed DC (PDC) output from a generator power supply (c 2 kVa for hand-held gears). However, some control boxes used enable a greater range of outputs to be used including high frequency out puts. The regional history of the EA has left behind artefacts in variable approaches to electric fishing practices and equipment usage. For example, the outputs used (e.g. AC, DC, PDC, frequency, pulse width etc) and also the equipment specification (e.g. size of anodes used is quite variable between manufacturer and regions). Recent R&D by the Environment Agency has aimed to evaluate the best practice for electric fishing and the output of electric fishing boxes to enable efficient capture of fish with optimum fish welfare conditions. AC is no longer allowed in the UK. It is worth noting that the Health and Safety issues regarding the use of electric fishing in the UK are very tight compared to other countries. In particular, two issues arise with gear specification.

- Backpack gears must be battery powered and can only use one anode and no more than one backpack can be used on a survey.
- All anodes used during a survey with bank-side or boat-mounted generator supply gears must be controlled from a single control box and must be set up so anodes cannot be fired individually and the "one off = all off" maxim applies.

<u>Seine netting in rivers</u>

Seine netting is only applied in wide rivers with slow flow and substrate consists of mud and silt. Seine netting practices used in the UK are generally similar to those reviewed by Coles *et al*. (1985) and generally comprise a variety of quantitative techniques.

- Wrap around seine netting - the use of four nets (2 pairs) to undertake quantitative sampling, including a mark-recapture exercise.
- Seine netting between stop nets.
- Isolated area netting – in rivers too wide to use stop nets an encircling net is used to isolate an area within which a seine net is simultaneously set.
- Micromesh netting within margins for juvenile coarse fish – two seines can be set simultaneously and drawn one after the other in a depletion exercise.

The proposed netting survey areas for each component of the new monitoring programme are summarised in Table 3b.6.

Table 3b.6. Site sizes proposed for netting surveys in the new UK monitoring programme.

Survey type	Monitoring programme element		Min site length, m	Max site length, m	Timed
Quantitative netting	Coarse:	Temporal & Index	100	up to 120m,	_
Semi-quantitative netting	Coarse:	Spatial and Sentinel	100	up to 120m,	_
Micromesh seining	Coarse:	Fry surveys	50m^2	150m^2	-

<u>Hydroacoustic surveys in rivers</u>

The use of boat based sonar surveys of fish populations is being developed for use in wide, deep rivers in the UK, >20 m in width and >2 m depth. Surveys use split-beam transducers with scientific echosounders of constant signal amplitude to estimate fish biomass. Survey reaches of a minimum length of 5 km, though preferably >10 km, are surveyed between 1 hour after sunset and 1 hr before sunrise during the late summer months (June – October). Surveys are timed to avoid full moons and survey periods around the new moon are recommended. Horizontal echosounding is undertaken along both banks with sonification directed from the near bank into the middle of the channel. Where possible surveys are repeated under similar temporal conditions and results are calibrated and complimented using an additional sampling technique e.g. boom boat electric fishing or anglers catch returns.

<u>Angler catch data</u>

Angler catch data are commonly used in the UK to assess the performance of fisheries and the status of major fish stocks.

- Salmonids

The fishing licence system for salmonid fishing has a statutory catch return element. This, together with angling logbooks, has provided possibly the longest useful data set. This provides data about fishery performance and is useful for virtually all salmon and sea trout management processes. Although cheap to collect, catch data requires complimentary data on effort and factors influencing catch-per-unit-effort.

- Coarse fisheries

Partnerships with Angling Federations and clubs for key reaches (e.g. River Trent in Nottingham) have been in place for many years. These tend to collect match catch statistics. Match returns are largely restricted to large river fisheries but this is a cheap source of good data if properly co-ordinated and managed. Where organised match data are not available then a structured survey of angler's catches will provide useful data on fishery performance and underlying stocks.

- Eels

The licence system for commercial elver and adult eel fishing includes statutory catch returns.

Non wadable -large rivers

A multi-method sampling approach has been proposed to be the most appropriate for large rivers, combining a number of the following techniques.

<u>Angling catches - Match returns</u>

Advantages- Cheap to collect, but may need a lot of data to control variance.

Disadvantages - No anglers = no data, selective according to angling methods used, little control over effort and may be difficult to collect data. Data errors. No data on individual fish unless specifically collected from keep nets.

<u>Hydroacoustics - side scan sonar</u>

Advantages - Cheap to collect a lot of data. Rapid picture of variation in population densities.

Disadvantages - Expensive data capture equipment. High temporal variance and causes uncertain. Requires sampling by other methods to determine species and sizes of targets recorded. Most effectively sampled at night when fish are dispersed in open water. Interference by entrained air from weirs or boat propellers. River needs to be deep and wide to sample sufficient volume. Experienced practitioners required for survey and analysis of data. Some species poorly sampled (benthic). Species not identified.

<u>Seine netting</u>

Advantages - Quantitative data in habitats suitable for efficient sampling. Simple and relatively inexpensive equipment. Simple capture technique, effective for most species.

Disadvantages - Poor sampling efficiency in some habitats (fast flow, uneven bed, snags, weed beds), but precision at a site may appear to be high. High manpower or vehicle requirements to pull nets. Obstruction to navigation. May be high mortality of small, scaled fish.

<u>Gill netting</u>

Advantages - Passive technique requiring little manpower.

Disadvantages - Highly selective for active swimming species and having body shape vulnerable to mesh entanglement. Affected by water-borne debris. High mortality rate of captured fish.

Fyke netting – demersal sampling

Trawling

Advantages - Active capture

Disadvantages – Only suitable for large, navigable rivers with relatively even bed.

Electric fishing

Advantages - Active technique giving high efficiency in habitats where seine net efficiency is low. Can be scaled up in power and number and size of electrodes. Most species vulnerable.

Disadvantages - Cannot be scaled up sufficiently to cover the width of large rivers at one pass. Some species have low capture efficiency. Some environments poorly sampled (high conductivity, very low conductivity). Avoidance behaviour in open water. Some increased mortality of larger fish. High manpower requirement of trained operatives. Equipment moderately expensive. Low efficiency in deep, open water.

The combination of methods depends upon the resources available, site conditions, target species and the data requirements. A number of sampling methods can be used in conjunction with angler catch statistics where available.

Shoaling species in deep or open water - targeted seine netting and hydroacoustics, possibly gill netting.
Snaggy or weedy areas - boom boat or multi-anode electric fishing
Benthic species - Electric fishing if clear and shallow, fyke nets if deep and/or turbid.

3b.1.3 Overview of the main sampling procedures used world-wide in fish-based methods

As recently reviewed by Cao *et al.* (2001), a critical aspect of assemblage surveys is sampling sufficiency, on which conclusion are often dependent. Karr (1981), with his first version of the IBI, proposed to use seine for small streams and electric seine or electric fishing from a boat for larger streams. Since this first version, works on improvement and standardisation of sampling techniques have been developed worldwide. From a literature survey, it appears that, although the application of techniques can be sometimes very different, depending on regions or experience of the sampling teams, all authors use electric fishing, except in Guinea (Hugueny *et al.*, 1996) (Table 3b.7). Indeed, as mentioned by several authors in their respective study (Zalewski & Cowx, 1989; Casselman *et al.*, 1990; Persat & Copp, 1990; Growns *et al.*, 1996; Wiley & Tsai, 1983 in Pusey *et al.*, 1998; Simons & Sanders, 1999), electric fishing is the single sampling method that provided the best estimate of numerical abundance, species richness, and proportion of frequently encountered common species. They consider electric fishing as the most adequate method for describing the community structure and constitutes the least harmful method of fish sampling, compared with gillnet or trawling (Simons & Sanders, 1999). Backpack electric fishing apparatus is often used in small or medium rivers. In large or great rivers, there is a lack of detailed information on fish sampling methodologies. A single type of gear cannot be considered suitable for quantitative sampling in all large river habitats. However, less effort has been paid to improving the efficiency of sampling methods in large rivers, compared to those investigated in other freshwater systems (Casselman *et al.* 1990). Multiple sampling gears were not considered to accurately depict a great river fish community. When several complimentary gear types are chosen, the most efficient method consists of a combination of gears, usually involving electric fishing (Casselman *et al*., 1990; Simon & Sanders, 1999).

When a second technique was used, in complement to electric fishing, seine netting is the most common (Angemeier *et al.*, 1986; Bramblett & Fausch, 1991; Osborne *et al.*, 1992; Lyons *et al.*, 1994; MacLeod *et al*., 1995; Hay *et al*., 1996; Angemeier *et al.*, 2000; Gammon & Simon, 2000; McCorminck *et al.*, 2001). Species richness estimates from gillnet surveys were typically less than half that encountered with electric fishing techniques, whilst trawls gave an immediate picture. Species richness and total abundance estimated by seine netting were lower than estimates from electric fishing methods, however, seine netting provided better estimates of species richness than trawling, gillnets or hoopnets (Simon & Sanders, 1999). When other nets were used, gillnets were the most common (Bramblett & Fausch, 1991; Schulz et al. 1999) and especially in Africa (Hay, 1996; Hugueny *et al*., 1996) where rivers can be very large and deep.

Table 3b.7. Sampling techniques used worldwide in the development of fish-based methods to assess ecological quality of freshwater ecosystems.

Authors	Country, State	Techniques used
Zachary, H. *et al.*, 1996	USA, Alabama	electric fishing
MacLeod, W.D. *et al.*, 1995	Canada	electric fishing seines
Paler, M. H. 1996	USA, South Carolina	electric fishing
Hughes, R.M. *et al.*, 1998	Oregon	electric fishing
Bramblett, R.G. & Fausch, K.D., 1991	USA, Arkansas	seines gillnet rotenone
Schulz, E. J. *et al.*, 1999.		electric fishing gillnets
Shields, F.D. *et al.*, 1995.	USA, Mississippi	electric fishing
Lyons, J. *et al.*, 1995	Mexico	seines dip nets direct observation electric fishing cast net
Osborne, L.L. *et al.*, 1992	USA, Illinois	electric seine electric fishing
Faush, K.D. *et al.*, 1984	USA, Midwestern	electric fishing
Minns C.K. *et al.*, 1994	Canada	electric fishing
Hugueny B. *et al.*, 1996	Guinea, West Africa	gillnet
Leonard P. M. & Orth, D., 1986	USA, Virginie	electric fishing
Lammert, M. & Allan J.D., 1999	USA, Michigan	electric fishing
Steedman, R.J., 1988	USA, Ontario	electric fishing
Lyons, J. *et al.*, 1996	USA, Wisconsin	electric fishing
Gammon, J.R. & Simon, T. P., 2000	USA, Indiana	electric fishing seines
McCorminck, F.H. *et al.*, 2001	USA, Mid-Atlantic Highlands	electric fishing seines
Hay, C.J. *et al.*, 1996	Namibia	gillnet mosquito net seines rotenone traps castnet D-net
Karr, J. R. *et al.*, 1987	USA, Illinois	seines
Angemeier, P. L. *et al.*, 2000	USA, Mid-Atlantic Highlands	electric fishing seines
Angemeier, P. L. *et al.*, 1986	USA, Illinois	seines dipnets minnow seine
	USA, Ohio	electric fishing
	USA, West Virginia	electric fishing
Bowen, Z. H., *et al.*, 1996	USA, Alabama	electric fishing
Hughes, *et al.*, 1998	USA, Oregon	electric fishing
Toham, A. K. & Teugels, G.G., 1999	Cameroon	electric fishing
Angemeier, P. L. & Schlosser, I.J. 1989	USA, Minnesota, Illinois, Panama	seines

3b.2 Development of a standardised river-type-specific sampling procedure

3b.2.1 Introduction

The sampling procedure described in detail below will be used for the field evaluation planned in WP9. It is based on the analysis of sampling procedures currently used by the different scientific and applied partners of the FAME consortium, as well as on the latest development of the CEN directive for water analysis – sampling of fish with electricity (Work Item 230116, revision of PrEN 14011, October 25, 2001). The sampling procedure proposed for application during WP9 takes into account the expertise of the partners in their own country, the number of available sampling data obtained with the different sampling procedures and the possibility of implementation of a common procedure in all countries belonging to the FAME consortium, with limited modifications of the methods currently used by each partner.

All partners have filled the different worksheets proposed at the 1st FAME workshop (Maastricht, 16-18 January 2002). **Since the fish sampling procedure commonly used by all partners for river quality assessment is electric fishing**, this technique is suggested as the unique standardised river sampling procedure. Several partners (Belgium, Lithuania, The Netherlands, United Kingdom) use alternatives methods such as gillnet, seine net, trawling, drift net or drag net, hydroacoustics, angler-catch survey, etc., alone or in combination with electric fishing, but these techniques are usually applied in specific conditions and cannot be applied on a regular basis by all partners. The low number (or total absence) of sampling data available with these alternative techniques in most countries of the FAME consortium strongly limits the possibility of comparison of newly obtained data (in WP9) with those previously existing in each country. It thus prevents the development of alternative standardised sampling procedures within this project.

Some partners have complemented the sampling method sheets with some suggestions of amendments to the proposed CEN directive for fish sampling with electricity. These suggestions have been included, as far as possible, in the sampling procedure described below.

3b.2.2 Scope

The standardised fish sampling procedure with electricity aims to assess the river ecological quality, in regards to the requirements of the Water Framework Directive. By no means has it been designed for other assessment purposes or objectives, such as fish catch statistics, biodiversity issues or species rehabilitation programmes.

3b.2.3 Fish sampling

As indicated in the CEN directive, the strategy should be to sample a defined area of river using appropriate fishing equipment, safety precautions and procedures using qualified personnel to provide estimates of:

- fish abundance;
- species composition;
- population structure (age or size);

Abundance can be either a relative or an absolute measure of assessment based on a single electric fishing run of a known area of water. Where practical or appropriate multiple fishing of the known area should be carried out to assess the efficiency of the sampling effort to obtain absolute estimates of population density. All sampling should be done in daylight hours.

3b.2.3.1 Size of sampling sites

Definition: A sampling site (also named sampling station in some countries) is defined as a stretch of river representative of the whole river reach in terms of habitat types and diversity, landscape use and intensity of human influence. It should include at least a riffle-run-pool unit, or two meanders. Within a sampling site (station), one or several sampling (or prospected) areas can be defined. If the river (stream) width is smaller than 15 m, then the sampling area usually corresponds to the sampling site. If the river (stream) width is equal to or greater than 15 m, several separated sampling areas can be selected and prospected within a sampling site.

Depending on river width and depth, two different sampling methods can be used. When it is possible (small rivers) each site is sampled by wading. In large rivers, sampling should be undertaken by boat (usually in near shore areas). In all cases the size of the sample should be sufficient to include the home range of the dominant fish species, and encompassing complete sets of the characteristic river form (e.g. riffles, runs and pools) to ensure are representative of the fish community.

Concerning the minimum length to be sampled, because of the variability among streams and rivers within and among regions, and in order to ensure accurate characterisation of a fish community in small streams at a given site electric fishing must be conducted over stream (or river) lengths of at least 10 times the stream (river) width, with a minimum length of 100 m. However, in large shallow water rivers (width >15 m and water depth <70 cm) where electric fishing by wading can be used, several sampling areas cumulating in total at least 1000 m^2 will be prospected, covering all types of mesohabitats present in a given sampling site. The length of the sampling site (station) is also calculated as 10 times the stream (river) width. Electric fishing for absolute estimates of fish populations in large and deep rivers (depth >0.7m) is difficult. A stratified sampling procedure is necessary. The length of the sampling site is defined as described above (10 times the river width). The efficiency of electric fishing is considered sufficient for a 2.5 m “effective corridor” along the bank (the effective field of the anode and the arc through which the operator can manoeuvre the anode). The sampling (fished) area is thus calculated by multiplying the 2.5 m fishing corridor near the shore by the length of the fished zone. A total area of at least 1000 m^2 should be sampled in a given site (station).

3b.2.3.2 Equipment and safety aspects

Regarding general equipment and materials (clothing, lifejacket, nets, fish containers, communication equipment, first aid) as well as electric fishing apparatus and safety aspects, recommendations of the CEN directive (Work Item 230116) should be applicable in the standardised electric fishing method to be used by FAME partners in WP9. FAME partners use either DC (Direct Current) or PDC (Pulsating Direct Current). AC (Alternating Current) is harmful to fish and can not be used. All equipment should comply with current CENELEC and IEC standards, and relevant legislation.

3b.2.3.3 Fishing procedures

Fishing procedures and equipment differs depending upon the water depth of the sampling site. The selection of waveform DC or PDC depends on the conductivity of the water, the dimensions of the water body and the fish species to be expected. The fishing procedure is described below, separately for wadable and non-wadable rivers. In both cases, fishing equipment must be adapted to sample small individuals (young-of-the year), in order to obtain reliable data on age – length structure of the population for some selected (sentinel) species. Hand nets with mesh size of maximum 6 mm are recommended.

a) Wadable rivers

Small rivers (brooks) should be electric fished from the bank or by wading. DC or PDC may be used. The recommended number of anodes depends on the size of stream:
- Streams <5 m wide: 1 anode
- Streams 5-10 m wide: 2 anodes
- Streams 10-15 m wide: minimum 2 anodes, preferably 3 anodes
- Streams >15 m width: minimum 3 anodes.

As a general guide one anode per 5 m width should be appropriate. The operators should fish upstream so that water discoloured by wading does not affect efficiency. They should move slowly, covering the habitat with a sweeping movement of the anodes and attempt to draw fish out of hiding. To aid effective fish capture in fast flowing water any catching net should be held in the wake of the anode. Each anode is generally followed by 1 or 2 hand-netters (hand net: mesh size of 6 mm maximum) and one suitable vessel for transporting fish. Switching the electrode on and off should be appropriate to the waveform being used e.g. with smooth DC it is necessary to recreate the electric field to initially stimulate the fish whereas with pulsed DC the waveform achieves this automatically. However, anodes should not be switched on and off if there is more than one operator, because in this situation anodes cannot safely be energised independently of each other.

For absolute estimation stop nets should be used to delimit survey zones, followed by a method estimating population densities from repeated sampling using identical fishing effort (e.g. Carle & Strub or Zippin methods). For relative estimation it is adequate to use partial barriers such as shallow riffles or weirs when non-territorial and mobile species are expected to be present. Equipment (power source and control box) is best sited on the bank with access to the stream section achieved by fitting long cables to the anodes. An alternative is to use backpack-mounted machines. If the brook is of uniform depth then it is possible to float the power source in a small boat to be towed behind the fish catching team.

b) Non-wadable rivers

In large rivers, the depth (> 0.7 m) and variety of habitats makes prospecting the entire area impossible. Prospecting from a boat is recommended, as wading beyond this depth can be hazardous. Operators holding electrodes and dip nets need to place themselves in positions to optimise use of the electric field. The waveform should be DC (either smooth or pulsed). The boat should either move downstream in such a manner as to facilitate good coverage of the habitat, especially where weed beds are present or hiding places of any kind are likely to conceal fish, or upstream if the flow is high. In slow moving water it is not necessary to match boat movement to water flow, and the boat can be controlled by ropes from the bankside if required. In more rapid water it may be important to allow the boat to travel at the same speed as the water flow, only using outboard motors or paddles for manoeuvring, such that the boat remains close to (drifting) immobilised fish. The larger the river, the more difficult and hazardous it becomes to set stop nets. Whereas good efficiency of capture can more or less be achieved with any waveform in small streams, for larger rivers the best practice with regard to manipulation of pulse shape and frequency should be adopted to improve capture rates for most species.

Qualitative, and to a lesser extent, abundance information can be obtained by using conventional electric fishing with hand held electrodes in the river margins and delimited areas of habitat. Alternatively, where resources exist capture efficiency can be improved by increasing the size of the effective electric field relative to the area being fished by increasing the number of catching electrodes. Arrays comprising many pendant electrodes can be mounted on booms attached to the bows of the fishing boat. The principal array should be entirely anodic with separate provision being made for cathodes. Dependant upon water conductivity current demands of multiple electrodes can become high, and large generators and powerful control boxes may be needed. National legislation should be consult because maximum figures for effect (kW) may exist. Often, however, it is still only possible to sample the margins with any reasonable degree of efficiency and fish in the deeper water evade capture.

3b.2.3.4 Sampling procedure in rivers with low species diversity

To ensure that conclusions on abundance and age structure are valid for the target population in rivers with low species diversity, a sufficient number of sites (n) should be included. This number depends on the spatial variation among sites and whether assessing temporal trends or comparisons between populations is the main aim. The spatial variation is expressed as the coefficient of variation CV = (standard deviation among sites)/ (population mean) for abundance (fish/site). For comparisons among populations, the minimum number of sites (n) for different CVs required is given in Table 1.

Table 3b.1. Minimum number of sampling sites.

Coefficient of variation (CV)	Minimum number of sites (n)
0.2	3
0.4	4
0.6	9
0.8	16

The CV can be determined from a pilot study or from data from similar populations. The selection of sites should be representative of habitats/biomes within the watershed. Due consideration should also be given to ease of access and safety of operational personnel. The timing of sampling should be linked to an understanding of the life history strategies of the target species. In most circumstances sampling should be carried out towards the end of the growing season when juveniles are of a sufficiently large size to be caught by electric fishing. Subsequent sampling of a particular site should be carried out at the same time of year and under similar flow conditions.

3b.2.4 Identification and measurement of fish, and release of catch

All fish should be identified to species by external morphological characters. In cases of specimens with unclear external characters (hybrids, and closely related species, or juveniles), preserved sub-samples should be retained for further examination in a laboratory.

Measurements of fish length (total length or fork length) should be recorded in mm. In cases of expected significant length overlap between year-classes, structures to identify age could be sampled (scales, operculum). Whenever the number of a certain species at a site exceed 30 specimens, then the use of representative samples for age determination is sufficient. Large and medium size specimens should be weighed individually. However, length-weight relationships can be used, rather than individual weighing. When the catch is large (more than 200 individuals of a particular species) it may be appropriate to weigh the whole catch of that species, take a sub-sample and count the sub-sample, and thereby calculate the actual number of fish.

Fish should be handled in ways that minimise damage due to handling and holding. In most cases aeration of water in the holding tank is essential for keeping caught fish in a good condition. Use of anaesthetics may be appropriate for the handling of some species. Due regard should be given to recommended withdrawal periods and possible recapture of fish for food use. Whenever required the equipment should be suitably disinfected after use, particularly if there is a risk of transferring alien species or pathogenic agents.

Except for the fish needed for further examination, all fish shall be released at the capture site following the conclusion of the survey of each site. They should be released into a calm area near the bank - and not in open, fast flowing water. If fish have been anaesthetised they should be held in fresh water long enough to swim away voluntarily. An assessment of sampling mortality should be made and recorded as a percentage (%) or a fraction (µ). Destructive sampling of adults is a questionable practice unless highly justified.

3b.2.5 Results

The results should be presented as species composition, abundance, age structure, and area of the sampling site.

3b.2.5.1 Species composition, abundance and age – length structure

- Species composition is a list of the species caught.
- Abundance of each species per catch should be reported both as total recorded numbers and as numbers per ha (or per 100 m^2).
- Size and age structure: Age can be determined from length-frequency data, scales or other body parts. Scales should be eventually taken, from the appropriate place, for some species with large overlap of length classes. Age structure is to be reported for each species, if possible, as mean length per age group together with standard deviation and number of fish in the sample. For sentinel species (see classification list of WP1 for each country), the number in each age class (0+, older) based on length-frequency data should be reported in order to document possible recruitment failures. If the determination of age is too expensive or too complicated, size repartition may provide useful information on the population structure.

3b.2.5.2 Additional measurements

- Weighing of individual fish and recording of total catch per species
- External anomalies: All fish can be checked for external anomalies and presence of parasites. This should be reported as anomalies per species.

3b.2.6 Report

Reports of electric fishing operations should contain a series of detailed information on the sampling site, sampling procedure and equipment, physiographic data and conditions of sampling, and results of catches. Information to be recorded during WP9 will be listed in agreement with the requirements of the central database, in order to fulfil the fishing report sheets proposed in WP 4.

WP 3c – Review of existing regional fish-based methods in Europe

This section reviews the methods developed in different European regions or countries in order to assess the ecological quality of rivers, using fish-based methods. Despite the independent development of these indices, all these methods have retained the ecological framework of the original IBI, including a series of metrics that describe the major biological attributes of a fish community. Some IBI methods have been developed for regional applications, or for some specific river types (such as small headwaters with poor species diversity) while some others aim to be applied to wider area, such as an entire ecoregion, or even to several ecoregions with different ichthyofauna. The first applications of an IBI method to some French rivers, as described by Oberdorff & Hughes (1992) or Oberdorff & Porcher (1994) has not been reviewed here, since a new method (Oberdorff *et al.*, 2001) have been developed recently to be applicable to the whole French river network and is described in section 3c.4.

3c.1 MuLFA – a fish-based, river-type-specific assessment of ecological integrity in Austria

Authors : Melcher A. & Schmutz S.

The text below is a summary of the method proposed by Schmutz *et al.* (2000) as a multi-level concept for fish-based, river-type-specific assessment of ecological integrity (EI) in Austria.

Introduction

The purpose of this paper is to develop a new concept for a fish-related EI-assessment method based on existing methods and embedded in a theoretical framework. The new method should enable a large-scale, nation-wide EI-assessment in accordance with the proposed WFD whilst simultaneously considering the uniqueness of different river types. Special emphasis is placed on the selection of assessment criteria as well as on the characterisation of river-type-specific reference conditions.

Assessment concept

Assessment criteria

The selection of adequate criteria takes place in the field of tension between ecological considerations that guarantee a sound assessment approach and practical limitations caused by methodological and financial constraints. The resulting selection procedure always represents a compromise between these contradictory objectives, adjusted to the state-of-the-art ecological knowledge and the socio-economic value of the issue (Moog & Chovanec, 2000).

The concept of the proposed assessment method is based on the hierarchical organisation of the biota (Odum, 1971; Allen & Starr, 1982; O'Neill *et al.*, 1986) and the linkages of the various organisation levels to temporal/spatial scales (Frissell *et al.*, 1986, Bayley & Li, 1996, Habersack 2000) as shown in Figure 3c.1.1a. The underlying theoretical principle implicates that higher levels (e.g. fauna/zoogeographic area), compared to lower levels (individual/microhabitat), are more persistent, more stable, relevant for larger areas, and affect lower levels more than vice versa (top-down effects). Consequently, the more human activities alter an ecosystem, the higher the levels affected. Since no single level of organisation is fundamental, the hierarchical concept suggests that EI should be monitored at multiple levels of organisation covering multiple spatial and temporal scales (Noss, 1990; Hughes & Noss, 1992). Therefore, a set of assessment criteria is selected from different hierarchical levels to guarantee that various intensities of human alterations can be detected (Figure 3c.1.1b).

The faunal composition of a given reach is the result of its zoo- and physiogeographic characteristics; it remains fairly constant within a specific river type of an ecoregion and persists over comparatively long time scales compared to criteria of lower hierarchical levels. Along the river continuum, environmental gradients form a sequence of different fish regions inhabited by distinct communities. These coenoses are composed of characteristic sets of guilds that, in turn, consist of several species. Each population of a species can be characterised by its size (biomass or density). The description of the population age structure requires individual information such as the body length (Figure 3c.1.1).

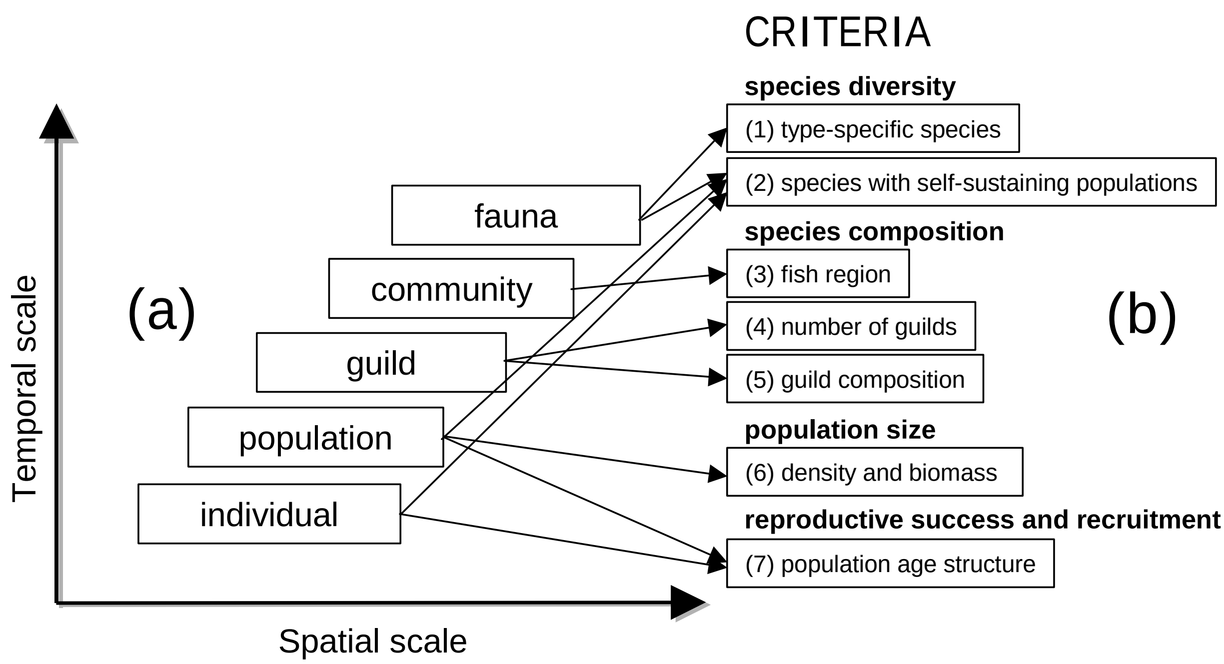

Figure 3c.1.1. Hierarchical organisation of biota, relationships to temporal/spatial scales (a), and derived assessment criteria (b)

Out of the 5 biological organisation levels (fauna, community, guild, population, and individual), 7 criteria were selected: River-type-specific species, species with self-sustaining populations, fish region, number of guilds, guild composition, population size, and population age structure.

Species diversity

<u>Number of river-type-specific species (RTS-species)</u>

This criterion reflects the indigenous fish fauna naturally occurring in the specific type of a river, excluding species not native in a given area (e.g. country), and not autochthonous in the specific river.

Non-RTS-species are not considered in the assessment method. Compared to the total number of species, the RTS-species criterion remains sensitive in situations where diversity is still high, but native species are replaced by non-native species. Numerous examples prove that negative effects on the autochthonous fish fauna by non-RTS-species, in particular by non-native species, are possible (Stauffer, 1984, Welcomme, 1984); they are not, however, obligatory. In addition, the proof and the quantification of negative effects would need a considerable effort not affordable in a routine method. Therefore, the occurrence of alien species is not an adequate assessment criterion. At any rate, potential negative effects of non-autochthonous species are indirectly considered in the assessment method because they are reflected in other criteria if they become decisive.

<u>Number of species with self-sustaining populations (SSP-species)</u>

This criterion reflects the type-specific fauna (RTS-species) composed of species meeting the following minimum criteria: the species are self-reproducing, which is proved by the occurrence of juvenile fishes (that must not be stocked), and maintain at least a minimum population size. According to the 50/500-rule of Franklin (1980) a minimum population size should comprise at least 50, or better 500, individuals capable of reproduction in order to guarantee sufficient genetic variability. This rule merely represents a tentative clue to guarantee the genetic viability of a population and values can vary according to the available information for a given species and situation.

The SSP-criterion excludes RTS-species that fail to fulfil any requirement for successful reproduction and whose population size is below a level guaranteeing mid- or long-term survival. For example, species that have experienced a major stock decline below this threshold, and will probably become extinct in near future, are omitted.

Species composition

<u>Fish region</u>

The riverine fish fauna is characterised by a predictable sequence of distinct communities along the river course. According to the fish zonation concept (Thienemann, 1925) and the biocoenotic region concept (Illies & Botosaneanu, 1963), fish regions are classified and named after the dominating key-species, which are associated with other specific species of that region:

Epirhithral	–	upper trout region
Metarhithral	–	lower trout region
Hyporhithral	–	grayling region
Epipotamal	–	barbel region
Metapotamal	–	bream region
Hypopotamal	–	brackish water region

Human alterations often result in a shift of fish regions to upper or lower regions. For example, channelisation may cause a so-called “rhithralisation effect”, a shift to rhithral species; vice-versa, impoundment may lead to a “potamalisation effect” (Jungwirth *et al.*, 1995).

In contrast to the diversity-criteria the fish region-criteria not only consider the occurrence of single species or groups of species, but also reflect the coenotic composition of the fish fauna. Fish region is a more robust criterion because it is less affected by insufficient reference data such as incomplete historical species lists and it is more indicative for severe human impacts; a shift of fish region only takes place if human activities lead to a complete alteration of the overall character of the river type.

Guild composition

Species of a guild take over the same function within ecosystem, show similar strategies of resource utilisation, and have developed similar life-forms with respect to habitat use, temperature preference, reproductive strategy, feeding habit, migratory behaviour, etc. (Kryzhanovsky, 1948). Therefore, the loss of a guild is much more significant for the EI than the equivalent loss of single species. Guilds have an advantage over species because they can also be used if knowledge on species occurrence is incomplete.

Although a huge amount of information on the autecology of European fish species already exists, appropriate classification schemes that cover all major ecological requirements are still missing. For example, current classifications with respect to reproduction (Balon, 1975; Balon, 1981), feeding habits (Michel & Oberdorff, 1995) only provide information for some European fish species. In the case of the Danube fish fauna, for example, the only available guild scheme is a nearly complete list of species classified according to their main habitat requirements (rheophilous (-A,-B), stagnophilous, eurytopic; Schiemer & Waidbacher, 1992). With respect to the migratory behaviour of fishes, based on available information only very coarse differentiations are possible, such as the distinction into diadromous and potadromous species or short-, mid- and long-distance migrants. Similarly, the classification based on temperature preferences is only feasible on a very general level (e.g. cold, cool and warm water species) due to incomplete knowledge. Since standard guild classifications are widely missing, individual guild schemes must be established for specific river types. Once the guilds are defined, their composition is assessed twofold. First, minor changes in the relative abundance of guilds are used to demonstrate slight human impacts and, second, the absence of certain guilds in connection with a complete alteration of the overall guild composition indicates major impacts.

Population size

Fish population size reflects human-induced alterations before these impacts become limiting for the existence of the species. These low-dose alterations can be detected in both directions, either in an increase (e.g. caused by eutrophication) or, more commonly, in a decrease of the population size. The population size of a species should be characterised by quantitative measures and estimates of the density and biomass per area or river length. Whenever quantitative estimates are prevented by methodological or financial constraints, semi-quantitative sampling methods (e.g. CPUE) are recommended.

Population age structure

Reproduction plays a crucial role within the life history of fish, and the larval and juvenile life stages often are more sensitive than adults are. Human impacts can therefore be detected by analysing the reproductive success and the recruitment before they manifest themselves in criteria at higher organisational levels. As the direct measurement of reproductive success is very labour- and cost-intensive, indirect proof of reproduction is used by analysing length-frequency-plots to assess the population age structure.

Characterisation of reference conditions (WP 2)

The principle of this method is based on assessing the deviation from clearly defined, river-type-specific reference conditions ("Leitbild", Muhar *et al.*, 1995). Reference conditions equate to undisturbed EI defined as the maintenance of all internal and external processes and attributes interacting with the environment in such a way that the biotic community corresponds to the natural state of the relevant aquatic habitat (Adamicka *et al.*, 1992).

Various methods of data acquisition are used to characterise reference conditions (Hughes, 1995; Muhar *et al.*, 1995). The "Leitbild" is compiled with historical abiotic data, historical fish data, data of reference sites, and reference models.
Each method of reference characterisation has its advantages and shortcomings. The application of only one method does not yield a fully satisfactory view of the undisturbed situation. Therefore, compiling all available information into an integrated picture is the best strategy for a sound description of the reference conditions.

Normative classification scheme of EI-levels and Assessment procedure

The spatial assessment unit - the unit of a river, where the method is applied - is predefined by the proposed assessment criteria. As all of the criteria refer to a river type specific fish community, the assessment unit has to reflect all attributes characteristic of a specific river type. Therefore, the smallest possible unit is a subset of a river type comprising all types of water bodies (main channel, floodplain) and habitats (runs, pools, glides, coves, side arms, oxbows, etc.) characteristic of the specific river type. Further, the assessment unit should be large enough to theoretically hold a minimum population size of RTS-species.

Table 3c.1.1 presents a 5-tiered scheme to assess the EI-status based on above-described assessment criteria. The number of EI-levels, their gradation, and the naming of the levels of the classification scheme correspond to the normative definitions of ecological status developed within the WFD.

Table 3c.1.1. Five-tiered normative classification scheme for fish-based assessment of ecological integrity

Criteria	**Ecological integrity levels** 1 high	2 good	3 fair	4 poor	5 bad
(1) Type-specific species	none or nearly none missing	some species missing	several species missing	many species missing	most species missing
(2) Self-sustaining species	none or some missing	several species missing	many species missing	most species missing	nearly all species missing
(3) Fish region	no shift	no shift	shift	shift	shift
(4) Number of guilds	no guild missing	no guild missing	single guilds missing	many guilds missing	most guilds missing
(5) Guild composition	no alteration	slight alteration	substantial alteration	complete alteration	complete alteration
(6) Biomass and density	no or nearly no changes	slight changes	substantial changes	heavy changes	extremely changed
(7) Population age structure	no or nearly no changes	slight changes	substantial changes	heavy changes	extremely changed

The status of the "high" EI-level totally or nearly totally corresponds to the undisturbed reference conditions. "Good" EI-level is characterised by significant but still slight deviations from the undisturbed conditions. At this level some RTS-species and several SSP-species are missing and both guild composition and population size are slightly altered; fish zonation and the number of occurring guilds, however, remain unaltered. At "fair" EI-level all criteria show substantial deviations from the undisturbed conditions. Fish region is shifted and single guilds are missing. "Poor" EI-level is characterised by strong, and "bad" by extreme deviations from the undisturbed conditions.

The assessment method uses 5 levels of EI. A differentiation into more levels would not coincide with the accuracy of the method and is therefore not justifiable. In addition, practical considerations such as compatibility with the WFD scheme factor into this gradation.

The final assessment is a quite simple procedure and is done by comparing the present situation of the assessment reach with the undisturbed reference conditions (table 3c.1.1). The described criteria of the present situation are assigned to that predefined water quality level in table 3c.1.1 showing the highest coincidence. According to the outlined principles of the assessment concept and criteria selection, higher weight is given to the species- than to the population-criteria. The final weighting of the criteria is individually defined for every river type.

Conclusions

The type-specific approach is a compromise between the intention to consider the individuality of running waters, the inability to reconstruct the original characteristic of degraded rivers in detail, and cost-efficiency. Consequently the precision of the method is limited. For the large-scale monitoring programmes specified for the WFD, this degree of exactness is sufficient. A higher precision is probably neither achievable nor politically executable. Nonetheless, other objectives such as environmental impact assessments or evaluations of restoration efforts require a more accurate method.

The advantage of the MuLFA-approach is its potential of consistent sensitivity to low- and high-dose human alterations. Moreover, its general character makes it adaptable to all river types. Successful application relies on the availability of accurate river-type-specific reference characterisations, detailed methodological approaches for specific river types, as well as on the provision of more sophisticated and more complete guild classifications. Above all, more emphasis should be placed on migratory guilds in order to underline the indicative value of fishes for the connectivity conditions.

3c.2 IBIP – a fish-based index developed for assessment of lotic ecosystem in Wallonia (Belgium)

Authors : Kestemont P., Didier J., Depiereux E. & Micha J.C.

This study describes the development of a fish-based index (IBI) for assessing the ecological quality of the Walloon part of the Meuse river basin, in Belgium. The project, funded by regional authorities (General Directorate of Technology, Research and Energy – DGTRE), aimed to analyse data collected during a four-year survey (1993-1996) conducted in several River Meuse tributaries using a standardised electric fishing method, to select the most appropriate assessment metrics for small- to medium-sized wadable streams in North-Western Europe.

Methodology

Study area

The Meuse is an international river that flows from the Langres Plateau in France to the North Sea in the Netherlands where it joins the numerous branches of the Rhine-Meuse-Escaut complex. In its Belgian section (40.7 % of its 36,011 km^2 total area), the Meuse basin is drained by the Meuse River and some major tributaries (Semois, Lesse, Sambre and Ourthe). Geology is a key factor determining the ecological features of running waters in the Belgian part of the Meuse basin. Many rivers belong successively to different types of water, as they rise in the Ardennes, often in peat bogs (alkalinity = 6-20 mg L^{-1} $CaCO_3$), and then flow over Devonian or Carboniferous limestone (alkalinity = 50-110 mg L^{-1} $CaCO_3$); such rivers rarely exceed an alkalinity of 130 mg L^{-1} $CaCO_3$.

Sampling sites and procedure, fish data collection

From 1993 to 1996, 87 sites along the main tributaries of the Walloon part of the Meuse basin were sampled using the same electric fishing methodology. Sampling sites were chosen as close as possible to stations used routinely for the monitoring of physical, chemical and macroinvertebrate indicators by regional authorities. At each sampling site, field data were collected according to the procedure for biological assessment of water quality (NBN T92-402 and AFNOR T90-402 standard). This procedure considers the following items : geographical situation (ORI code, Lambert coordinates), macrohabitat features (stream width and slope, mean depth, type of substrates), and main physical, chemical variables (temperature, dissolved oxygen, pH, hardness and conductivity), measured immediately before or after electric fishing. Additional data for each site, such as contributing drainage area and stream order, distance from spring, altitude) were obtained from PEGASE (Smitz *et al.*, 1997).

Since it has been shown that mesohabitats (riffle, run and pools) can affect the composition of fish communities within a given stream (Didier & Kestemont, 1996), the sampling sectors were selected in such a way that a variety of mesohabitats were sampled. The length of each sector was 150 m. Cumulative IBI scores calculated on three different lengths of sample reach (from 150 to 450 m) in 13 sampling sites located in streams of various sizes (catchment area ranging from 7 to 755 km^2) were very similar: they usually varied by 1 or 2 units only, thus demonstrating that a sampling sector longer than 150 m does not appreciably modify the assessment of ecological integrity of a given site.

Electric fishing was carried out in an upstream direction with one to four generator sets, depending on stream width, each generator set consisting of a 3 KW alternator delivering, after DC transformer, a continuous current (300-400 V, 2-4 Amp.) and a fixed cathode. For each generator set, one operator wading through the water with a hand-held electrode (anode), two persons with landing-nets and one with fish tanks constituted the fishing team. Fishing took place in two consecutive passages and catches from each passage were treated separately. In wadable rivers, this electric fishing method allows the capture of all species present in the fishing sector and provides quantitative and reliable data of their relative abundance. Blocking nets (polyamide-tressnet-h10, 1.2 cm mesh size) were used to isolate the fishing sector and to prevent the escape of rheophilic species.

Before measurement and weighing, all fish were visually assessed, and external deformities or pathologies recorded. For large species, fish were measured (total length, nearest 1 mm) and weighed (nearest 0.1 g) individually. For small species, all individuals were counted and a group weight was taken. Population size and biomass of each species were estimated by the maximum likelihood method of Carle & Strub (1978). Fish density (n ha^{-1}) and biomass (kg ha^{-1}) were calculated when capture probability was > 0.3.

IBI metrics and ecological guilds

The original version of the IBI had 12 metrics that reflected fish species richness and composition, trophic organization, fish abundance, and condition of individual fish. Basically, these metrics were retained in the present study with some modifications required for application in the Meuse basin. Metrics were classified into 4 broad categories : species richness and composition, trophic composition, fish abundance, and reproductive function (Table 3c.3.1). The IBI was calculated for each sampling site according to methods modified from Fausch *et al.* (1984), Karr *et al.* (1986) and Oberdorff & Hughes (1992). For a given

sampling site, each metric received a score ranging from one to five points, according to the level of similarity (low = 1, high = 5) of its value to that expected for a fish assemblage experiencing little human influence. The total IBI score was the sum of the 12 metric scores and ranged from 12 (worst) to 60 (best). Rationale for the selection of the 12 metrics has been described in Didier (1997) and Kestemont *et al.* (2000).
Before computing IBI scores, each species collected was assigned to appropriate ecological guilds using current expertise backed up with references from the scientific literature. Several guilds were used in this study to classify fish species according to their tolerance to water quality degradation, feeding habit, reproductive strategy and habitat preference.

Calculation of IBI metrics

Values for some of the metrics belonging to the 'species richness and composition' (number of native species, number of benthic species, value of intolerant species, % of intolerant individuals) and 'fish abundance' (estimated biomass) categories vary substantially with stream size and were scored from Maximum Value Lines (MVL), using the same approach as that of Fausch *et al.* (1984), in which potential species richness for the sample appears as a function of catchment area (Maximum Species Richness Lines). Species richness or fish abundance values were plotted against Log_{10} catchment area. Because only few undisturbed reaches can be sampled in Belgium, the highest metric values, which were usually obtained at the least disturbed sites, were used as estimates of the reference condition to draw up the least squares linear or 2^{nd} order polynomial regression curve (MVL) between the Log_{10} catchment area (X) and the metric values (Y), depending on how accurately the regression curve fitted to the data (Figure 2). The area under the MVL was divided into five sections and used to rate the corresponding metrics. In other words, a site scored maximum points (5) if the metric value was 0.8 MVL or higher, 4 points for 0.6-0.8 MVL, 3 points for 0.4-0.6 MVL, 2 for 0.2-0.4 MVL and 1 for less than 0.2 MVL.
Since many (mainly anadromous) species disappeared more or less recently from the Belgian section of the River Meuse basin, due to organic and industrial pollutions and/or dam construction, the extinct species were added, if applicable, when drawing up the MVL for the metrics depending on species richness (number of native species, number of benthic species and value of intolerant species).
Metrics that varied less with watershed area and stream size were scored by comparing their scores with those for the same metrics occurring at sites having the maximum number of species and maximum value of intolerant species. Criteria and ratings used for scoring the IBI are summarised in Table 3c.2.1.

Contribution of metrics to IBI and comparison with other indices

Principal Component Analysis, (PCA) was used to determine the contribution of the 12 metrics to the IBI variations and to identify one or several factorial axes integrating the highest percentage of the total variations in the 84 sampling sites containing fish. The distribution of the sampling sites along the two main factorial axes was then interpreted by examining site scores for other physical, chemical and biological indexes.

Results

Establishment of reference system

Amongst the 87 sites sampled between 1993 and 1996, 3 highly disturbed sites did not contain any fish. In the other sites, the total number of species captured ranged from 2 to a maximum of 17 in the same site. A 2^{nd} order polynomial regression ($r^2 = 0.95$) was established between the Log_{10} catchment area (among 14 classes of catchment area) and the maximum number of native species, whereas this relationship was linear (r^2 = 0.96) when extinct species (max. 7 species) were added to the maximum number of species actually captured (Figure 2). Based on this latter relationship, a species richness score of 5 was assigned to about 25 % of the sites sampled while only 5 sites (5.7 %) received a score of 1. Similar relationships between Log_{10} catchment area and other metrics varying with watershed area were drawn with appropriate regression curves. As expected, the MVL of the 'number of benthic species' and 'value of intolerant species', both including extinct species, were positively correlated to catchment area (r^2 = 0.89 and 0.85, respectively) while the MVL of '% individuals as intolerant' (extinct species not included) decreased with increasing catchment area (r^2 = 0.76). With respect to the estimated biomass (based on 2 electric fishing passes), the MVL increased from less than 100 kg ha^{-1} in small catchments to 700 kg ha^{-1} at a catchment area ranging from 56 to 100 km^2 and then decreased markedly. A similar 2nd order polynomial regression could be obtained when captures from the first sampling pass only were plotted against Log_{10} catchment area.

Table 3c.2.1. Scoring criteria for metrics used to calculate the index of biotic integrity for wadable streams and rivers of the Walloon part of the Meuse basin.

Metrics	**Scoring criteria**				
	5	4	3	2	1
Species richness and composition					
1. Number of native species			varies with stream size		
2. Number of benthic species			varies with stream size		
3. Value of intolerant species[1]			varies with stream size		
4. % of intolerant individuals[1]			varies with stream size		
5. Shannon-Weaver diversity index (H')[2]	<0.05	-	0.05-0.1	-	>0.1
6. Presence of fry, juveniles and adults[3]	a	b, c	d	e,f	g
7. Bullhead/bullhead+loach ratio	>0.8	0.6-0.8	0.4-0.6	0.2-0.4	<0.2
Trophic composition					
8. % of individuals as omnivores	<5	-	5-10	-	>10
9. % of individuals as piscivores and piscivores-invertivores	>20	-	10-20	-	<10
Fish health and abundance					
10. Estimated biomass (kg ha^{-1})[4]			varies with stream size		
Reproductive function					
11. % of ind. as specialised spawners	>67	-	33-67	-	<33
12. % of ind. as non specialised spawners	<5	-	5-10	-	>10

1. To water quality degradation, 2. for non-resident species and individuals, 3. for the dominant intolerant species, 4. Captured biomass when based on one passage only.

Ordination of sampling sites on the factorial axes

The PCA based on the matrix scores (12 metrics x 84 sites) produced an arc-like distribution of sites. The first two axes of the PCA accounted for 56.7 % of the total variation of the 12 factors. When site names were replaced by values of the organic pollution index (IPO) and macroinvertebrate based index (IBGN), the sites appeared ordinated along the first axis according to their degree of water quality degradation: sites with high water quality had positive scores and sites with low water quality negative scores. A similar profile was obtained when site names were replaced by total IBI scores. Axis 1 appears highly correlated with IPO, IBGN and total IBI scores whilst correlation between axis 2 and the index scores was lower (except for IBGN). According to the factor loadings shown in Table 3c.2.2, 4 metrics are highly correlated with the first axis: '% intolerant individuals', 'presence of fry, juveniles and adults', 'bullhead/bullhead+loach individuals ratio' and '% individuals as specialised spawners'. The metrics 'number of native species' and 'number of benthic species' were highly correlated with the second factorial axis.

Selection and weight of IBI metrics

To select and balance the importance of the initial IBI metrics, without any significant lack of information, initial metric scores were modified according to the factor-loading matrix. First, the factor loadings on the first axis (Table 3c.2.2) were divided by the square root of the factor variance. The same method was applied to the metric loadings on the second factorial axis. This allowed comparison of metrics loading heavily on 2 different factors. Weight factors were then multiplied by the initial scores of the sampled sites. The sum of the modified scores provided a total score of the weight index (A). The same principle, applied to the factor loadings of the 2nd axis, provided a total score of the weight index (B).
In a second step, several indices were calculated considering the initial scores of the metrics most correlated (factor loadings > 0.7) with the 1st factorial axis. Four successive indices were thus calculated:

sum of the initial scores of metrics 4, 6, 11 and 10 (Table 3c.2.2);

sum of the initial scores of metrics 4, 6, 11, 10 and 8;

sum of the initial scores of metrics 4, 6, 11, 10, 8 and 3;

sum of the initial scores of metrics 4, 6, 11, 10, 8, 3 and 5.

Two other indices were calculated when considering the initial scores of the metrics most correlated with the 2nd factorial axis:

sum of the initial scores of metrics 2 and 1;

sum of the initial scores of metrics 2, 1 and 3.

In a third step, the first 4 indices were compared with weight index (A) and the latter two with weight index (B). Index 1 was highly correlated ($r^2 = 0.942$) with index (A) and contains most of the information provided by the first factorial axis while index 5 was highly correlated ($r^2 = 0.889$) with index (B). Two indices were thus calculated: the first (IBI 1), based on metrics 4,6,10, and 11, ranges from 4 to 20, and can be considered as a descriptor of physical and chemical habitat quality, while the second (IBI 2), based on metrics 1 and 2, ranges from 2 to 10, and can be considered as a descriptor of species richness. By plotting both indices, it becomes feasible to explain the distribution of the different sites along the first two factorial axes.

Among the 12 metrics initially proposed to assess the ecological quality of wadable streams and rivers from the Meuse basin, 6 metrics were selected (Table 3c.2.3). These metrics belong to 3 categories: the first category refers to descriptors of species richness ('number of native species' and 'number of benthic species'), the second category refers to indicators of water quality ('% individuals as intolerant' and 'bullhead/bullhead+loach ratio'), and the third category refers to indicators of physical habitat quality ('% individuals as specialised spawners' and 'presence of fry, juveniles and adults').

Discussion

Sampling methodology

All 87 samples in this study were obtained using a standardised methodology, after examination of the effects of some methodological aspects such as sector length, the number of electric fishing passages or the presence of various mesohabitats, on fish capture and potential IBI score (based on the initial 12 metrics) (Didier, 1997). Angermeier & Karr (1986) also examined the effects of varying length of sample reach on IBI scores and concluded that short sample reaches (less than 280 m) were more variable with respect to IBI scores than long reaches. The authors recommended that sample reaches should always be long enough to include several pool-riffle sequences, thereby ensuring that spatial heterogeneity was incorporated into IBI scores. The need to assess a variety of mesohabitats was recently confirmed by Didier & Kestemont (1996) for River Meuse tributaries. This recommendation was largely applied in the present study.

Table 3c.2.2. IBI metric loadings on the first two PCA axes.

Metrics	Factor loadings	
	Axis 1	Axis 2
1. Number of native species	-0.141	0.870*
2. Number of benthic species	-0.026	0.943*
3. Value of intolerant species	0.525	0.628
4. % of intolerant individuals	0.906*	-0.090
5. Shannon-Weaver diversity index (H')	0.435	0.130
6. Presence of fry, juveniles and adults	0.809*	0.131
7. % of individuals as omnivores	0.166	-0.131
8. % of ind. as piscivores and piscivores-invertivores	0.624	-0.248
9. Estimated biomass (kg ha^{-1})	0.120	0.376
10. Bullhead/bullhead+loach ratio	0.756*	0.053
11. % of ind. as specialised spawners	0.773*	0.061
12. % of ind. as non specialised spawners	0.120	-0.134
Explained variance	3.576	2.328
Proportion	0.298	0.194

* factor loadings > 0.7

Table 3c.2.3. Selected metrics and scoring criteria of IBI to evaluate the ecological quality of wadable streams and rivers of the Walloon part of the Meuse basin.

Categories	Scoring criteria				
Metrics	**5**	**4**	**3**	**2**	**1**
Indicators of species richness					
1. Number of native species			varies with stream size		
2. Number of benthic species			varies with stream size		
Indicators of water quality					
3. % intolerant individuals			varies with stream size		
4. Bullhead/bullhead+loach ratio	> 0.8	0.6-0.8	0.4-0.6	0.2-0.4	< 0.2
Indicators of physical habitat quality					
5. % individuals as specialised spawners	> 67	-	33-67	-	< 33
6. Presence of fry, juveniles and adults	a	b, c	d	e, f	g

Quantitative assessment of fish density and biomass in wadable streams usually requires at least two consecutive passages, with separation of fish captured in each passage. This procedure was routinely applied in this study and all metrics were scored from data obtained after 2 passages. However, Didier (1997) showed that total IBI scores calculated with data of fish captures from the first passage did not vary significantly from those obtained by considering both passages. Regardless of the number of electric fishing passes, 50 % of the 87 sampling sites received the same IBI score and only 8% experienced a modification of their integrity class assignment (change of one class maximum).

Reference system and metric selection

Since its introduction, the IBI has been progressively considered as an efficient tool for assessment of river ecological quality, and widely applied throughout the world, with more or less considerable adaptation owing to regional ichthyofauna and river characteristics. Most modifications were related to the identity of fish attributes or metrics, to the scoring criteria and to the reference system used for scoring criteria. Regardless of the metrics selected, the IBI requires quantitative expectations of the fish community structure under reference or least impacted conditions. As reviewed by Simon & Lyons (1995), two general approaches have been used to generate quantitative expectations for a particular geographic area. The first one requires identification and sampling of a limited number of representative sites in least impacted ecosystems. The second does not involve delineation of high-quality sites but requires more data: a large number of sites are systematically surveyed to provide a representative view of the region, and the best values observed for each metric are then used to define the expectations and to set the scoring criteria. This second approach has been widely used and was retained in this study because of the lack of high-quality sites in a densely populated country such as Belgium. A third approach, based on historical or paleoecological data, has also often been used.

The 87 sites sampled in the Meuse river basin, including a longitudinal gradient from headwaters (catchment area < 3 km^2) to rivers (catchment area > 3,000 km^2) allowed appropriate relationships between watershed area and species richness metrics to be drawn up. A statistical procedure for drawing Maximum Value Lines, based on a distribution of the sampled sites within 14 catchment area classes and using linear or second order polynomial functions when plotting Log_{10} catchment area vs. species richness metrics, appeared more precise and reliable than the by-eye method (including 95 % of the data points) initially proposed by Fausch *et al.* (1984) and used by several authors (Karr *et al.*, 1986; Oberdorff & Hughes, 1992; Lyons *et al.*, 1996).

Since expectations for species richness metrics are usually an increasing function of ecosystem size, the choice of the reference system (stream order, drainage basin area, channel width, etc.) is also important. In the present study the Log_{10} catchment area appeared a more reliable measure of water body size (higher correlation with the other criteria) than stream order.

The number, identity and scoring criteria of metrics have been of primary concern when adapting the IBI to other regions than the one originally chosen by Karr (1981). Reviews are regularly dedicated to the evolution and applications of IBI in different geographic regions and in different types of freshwater ecosystems (see section 3a of this report). The number of metrics ranges from a minimum of 6 for the River Assomption in Canada to a maximum of 14 for lakes and reservoirs in Tennessee. The biological rationale for the use of the 12 original metrics was presented by Karr (1981) and Karr *et al.* (1986) and, when applying the IBI in other regions, authors add or delete some metrics according to their specific environment, mainly from a biological point of view, but rarely consider or discuss the relative

contributions of individual metrics to the final IBI assessment and their ability to detect degradations. In the River Meuse basin, PCA results indicated that some metrics (6 metrics had loadings > 0.7 on the first or second axis) had a predominant contribution to IBI variations, while the 6 remaining ones contributed little information to the final assessment. The metrics belonging to the trophic composition category did not substantially affect the total IBI, even though the loading of '% of individuals as piscivores or piscivores-invertivores on the first principal component was relatively high (0.624).
The low impact of metric 3 ('value of intolerant species') can be explained by the fact that information related to sensitivity of species to water quality degradation is largely provided by metric 4 '% of intolerant individuals' which achieved the highest loading on the first principal component axis. The low loadings of metric 12 ('% of individuals as non specialised spawners') on the first two factorial axes, while metric 11 ('% of individuals as specialised spawners') achieved a high loading on the first axis, support the hypothesis that the absence of sensitive species (due to chemical or physical habitat quality degradation) impacts the final ecological assessment more than the presence or abundance of more tolerant species.
Based on a retrospective analysis of the data set, 6 metrics out of 12 possible ones were selected as indicators of present river ecological quality in the Meuse basin. This index preserves the original ecological framework of IBI, it involves metrics that represent the major classes of biological attributes. However, regional differences in the main causes of river quality degradation (heavy metal or organic pollution, dam construction, spawning area destruction) can orientate the IBI towards the selection of some specific metrics and the omission of some others. Most ichthyofauna alterations in the Belgian Meuse basin are due to organic pollution (sewage effluents) and dams hampering the migration of species rather than to highly toxic pollution inducing severe anomalies and tumours. This explains the major contribution of metrics such as the number of native species (including migratory fish), the number of benthic species, the % of individuals as tolerant or the bullhead/bullhead+loach ratio. For assessing other possible causes of degradation, additional metrics could obviously be added. But the risk of reducing the sensitivity of the present index by the addition of several less sensitive metrics must also be seriously considered.

3c.3 IBI methods used in Flanders (Belgium)

Authors : J. Breine & C. Belpaire

In Flanders, different fish-based methods have been developed recently to evaluate the biotic integrity of upstream brooks (trout and grayling zones, according to Huet classification) or stagnant waters (including barbel and bream zones). The text below summarises these two indices.

Upstream brooks

Using fish assemblage data from electric fishing surveys in Flanders during the period 1994-2000, 154 sites belonging to the grayling and trout zone were used to develop a multimetric indicator system to assess upstream brooks in Flanders. All sites had a slope of at least 3‰ and a maximum width of 4.5 m. The developed IBI consists of 9 variables or metrics scored from 0 to 5. These metrics were selected using univariate and multivariate analyses, and taking into account ecological criteria. Some of the selected metrics correlate significantly with the slope of the river. Threshold values for correlated metrics were defined using the mean trend line through all metric values. If no significant correlation existed scoring criteria were defined using literature. Five integrity classes were defined. The IBI was tested internally by comparing the IBI scores and the attributed habitat quality scores. A similar comparison was done using an independent set of data of known habitat quality. The individual contribution of the selected metrics was assessed. The developed IBI clearly distinguishes good sites from impacted sites and can separate the heavily impacted sites from the fairly impacted. The IBI meets the criteria imposed by the European Water Framework Directive.

Table 3c.1. Selected metrics and their scoring criteria for the calculation of the IBI for upstream waters in Flanders (slope >3‰ and river width < 4.5 m)

Metrics	**Metric score**		
	1	3	5
Species richness and composition			
Total number of species			
Slope class 1 (<4‰)	<4	4-7	>8
Slope class 2 (4-5‰)	<3	3-5	>6
Slope classes 3, 4 & 5 (>5‰)	1	2-4	>5
Typical species value			
Slope class 1	<1.44	1.44-2.88	>2.88
Slope class 2	<1.49	1.49-2.97	>2.97
Slope class 3 (>5-8‰)	<1.57	1.57-3.13	>3.13
Slope class 4 (>8-12.5‰)	<1.69	1.69-3.37	>3.37
Slope class 5 (>12.5‰)	<1.85	1.85-3.69	>3.69
Shannon-Weaver diversity index evenness	<0.53	0.53-0.68	>0.68
Migrating species value	<2	2-4	>4
Fish condition and abundance			
Biomass (kg/ha)			
Slope class 1	<130	130.1-250	>250
Slope class 2	<80	80.1-150	>150
Slope class 3	<46	46.1-100	>100
Slope classes 4 & 5	<30	30.1-60	>60
Length classes value	<2	2-3.99	4-5
Trophic composition and habitat use			
% invertivorous individuals	<26	26-45	>45
Number of benthic species	1	2-3	>3
% specialised spawners			
Slope class 1	<8	8-15.9	>16
Slope class 2	<10	10-20.9	>21
Slope class 3	<12	12-30.9	>31
Slope class 4	<24	24-47.9	>48
Slope class 5	<35	35-69.9	>70

Stagnant water, bream and barbel zones

As fish communities differ substantially between standing waters, running waters of the bream zone and running waters of the barbel zone, 8 candidate metrics for each of these water types or zones were identified, representing three major classes of biological attributes. Huet's typology (1959), based on riverbed slope and cross section, was used to classify fishing localities of running waters. IBI metrics were defined for standing waters (S1: canals, lakes and isolated river arms) and for running waters of bream (C2) and barbel (C3) zone. Trend line regression (polynome $y=-mx^2+nx$ on k percentile of data with k=0.95) was used on C2 and C3 waters to define the scores corresponding to each width class. Metrics that did not correlate with river width were scored using references.

Table 3c.2. Definition of metrics and scores for the calculation of the IBI for Flandrian water bodies of type S1 (lakes, ponds and canals)

Metric			**Type S1**		
Score	5	4	3	2	1
Total number of species	>15	15-12	11-8	7-3	<3
Mean tolerance value	≥2.4	2.39-2	1.99-1.6	1.59-1.2	<1.2
Type species*	≥4.5	4.49-3.5	3.49-2.5	2.49-1.5	<1.5
% *Rutilus rutilus*	*10-25*	*25.1-35* *9.9-7.5*	*35.1-45* *7.4-5*	*45.1-55* *2.5-4.9*	*>55* *<2.5*
% *Scardinius erythrophthalmus*	*≥10*	*9.9-5*	*4.9-2*	*1.9-1*	*<1*
% *Abramis brama*	*0.1-10*	*10.1-20*	*20.1-30*	*30.1-40*	*>40* *0*
Pike recruitment and biomass (kg/ha)**	≥20 (+ recr.)	10-19.9 (+ recr.)	<10 (+ recr.)	≥20 (- recr.)	<20 (- recr.)
Tench recruitment and biomass (kg/ha)**	≥15 (+ recr.)	10-14.9 (+ recr.)	<10 (+ recr.)	≥15 (- recr.)	<15 (- recr.)
Total biomass (kg/ha)	100-349	350-499 75-99	500-649 50-74	650-799 25-49	≥800 <25
Weight % of non-native species	<1	1-3.99	4-6.99	7-9.99	≥10
Weight ratio piscivores/non-piscivores	0.2-0.14	0.139-0.1 0.201-0.25	0.09-0.067 0.251-0.33	0.066-0.05 0.331-0.5	<0.05 >0.5

* score is obtained by taking the mean of the species scores in italics
**: + recr. and - recr. stand for the presence and absence of natural recruitment.

Table 3c.3. Definition of metrics and scores for the calculation of the IBI for Flandrian water bodies of type C2 (river habitat corresponding to the bream zone) and type C3 (river habitat corresponding to the barbel zone).

Metric			Type C2					Type C3		
Score	5	4	3	2	1	5	4	3	2	1
Total number of species										
River width < 3m	*≥7*	*6*	*5-4*	*3-2*	*1*	*≥5*	*4*	*3*	*2*	*1*
River width 3-6.4m	*≥12*	*11-9*	*8-6*	*5-3*	*≤2*	*≥7*	*6*	*5-4*	*3-2*	*1*
River width 6.5-8.9m	*≥13*	*12-10*	*9-7*	*6-4*	*≤3*	*≥10*	*9-8*	*7-6*	*5-4*	*≤3*
River width ≥ 9m	*≥14*	*13-10*	*9-7*	*6-4*	*≤3*	*≥12*	*11-9*	*8-6*	*5-4*	*≤3*
Mean tolerance	≥2.4	2.39-2	1.99-1.6	1.59-1.2	<1.2	≥2.4	2.39-2	1.99-1.6	1.59-1.2	<1.2
Mean typical species value	≥3.3	3.29-3	2.99-2.7	2.69-2.4	<2.4	≥3.1	3.09-2.8	2.79-2.5	2.49-2.2	<2.2
Type species*	≥4.5	4.49-3.5	3.49-2.5	2.49-1.5	<1.5	≥4.5	4.49-3.5	3.49-2.5	2.49-1.5	<1.5
% Gasterosteus aculeatus						*<3*	*3-4.9*	*5-6.9*	*7-8.9*	*≥9*
% Barbatula barbatula						*≥11*	*10.9-9*	*8.9-7*	*6.9-5*	*<5*
*% Leuciscus cephalus***						*>20 (+ recr.)*	*20-5 (+ recr.)*	*<5 (+ recr.)*	*≥25 (- recr.)*	*<25 (- recr.)*
% Rutilus rutilus	*10-25*	*25.1-35 7.5-9.9*	*35.1-45 5-7.4*	*45.1-55 2.5-4.9*	*>55 <2.5*					
% Scardinius erythrophthalmus	*≥10*	*5-9.9*	*2-4.9*	*1-1.9*	*<1*					
*% Tinca tinca***	*≥15 (+ recr.)*	*10-14.9 (+recr.)*	*<10 (+ recr.)*	*≥15 (- recr.)*	*<15 (- recr.)*					
Total biomass (kg/ha)	100-349	350-499 75-99	500-649 50-74	650-799 25-49	≥800 <25	250-349	350-449 100-249	450-549 60-99	550-649 20-59	≥650 <20
Weight % of non-native species	<1	1-3.99	4-6.99	7-9.99	≥10	<1	1-3.99	4-6.99	7-9.99	≥10
Trophic composition*	5-4.3	4.29-3.5	3.49-2.5	2.49-1.7	<1.7	5-4.3	4.29-3.5	3.49-2.5	2.49-1.7	<1.7
% omnivorous species	*<1*		*1-5*		*>5*	*<1*		*1-5*		*>5*
% invertivorous species	*>45*		*45-20*		*<20*	*>45*		*45-20*		*<20*
% piscivorous species	*3-5*		*2.9-1 5.1-7*		*<1 >7*	*3-5*		*2.9-1 5.1-7*		*<1 >7*
Natural recruitment (%)	≥85	84.9-70	69.9-55	54.9-40	<40	≥85	84.9-70	69.9-55	54.9-40	<40

* score is obtained by taking the mean of the species scores in italics

**: + recr. and - recr. stand for the presence and absence of natural recruitment.

3c.4 FBI – Development and validation of a fish-based index for river health assessment in France

Authors : Oberdorff, T., Pont D., Hugueny B. & Porcher J.P.

In Europe, water policy is currently subject to considerable change as emphasised by the recent European Water Framework Directive (WFD), which requires the restoration and maintenance of "healthy" aquatic ecosystems by the assessment of their hydromorphological, chemical and biological characteristics. If the requirements of the WFD are to be met, effective biological tools are needed to measure the "health" of rivers at scales large enough to be useful for management. These tools need to be ecologically based, efficient, rapid and consistently applicable to different ecological regions.

There is currently only one ecological tool based on fish assemblages, using structural and functional components of fish assemblages, available for assessment of river condition: the Index of Biotic Integrity (IBI), first formulated by Karr (1981) for use in Midwestern USA streams. This multimetric index uses the "reference condition approach" (Bailey *et al.*, 1998) which involves testing an ecosystem exposed to a potential stress against a reference condition that is unexposed to such a stress. The IBI employs a series of metrics based on assemblage structure and function (fish or invertebrate assemblages) that give reliable signals of river condition to calculate an index score at a site, which is then compared to the score expected at an unimpaired comparable site.

Properly developed IBI's usually incorporate region-specific metrics and adjust metric criteria (usually only for taxonomic metrics) by river size (e.g. stream order or catchment area) to isolate natural versus anthropogenic influences on local fish assemblage structure. Region-specific criteria are set using broad regional land classification (e.g. ecoregions). Nevertheless, stratifying intra-regional criteria by using only a single factor like river size is not sufficient to accurately set metric criteria for hydrologically complex areas (Smogor & Angermeier, 1999, Oberdorff *et al*., 2001). And most of the time, abundance related metrics (i.e. functional metrics) are not adjusted at all by IBI users, suggesting that these metrics are invariant across river sizes or other environmental factors.

Convinced that the IBI's concept is ecologically sound effective for assessment of the status, trends, and ecological integrity of European water body, an attempt was made to improve the accuracy of such an index (in distinguishing effects of anthropogenic disturbances from natural variation in assemblage structure and richness) while maintaining some of its ecological foundations. To attain this goal, a biological indicator integrating most of the environmental factors acting on fish assemblage structure in natural condition was developed to obtain a response of aquatic biota to human stressors independent of natural variation. The French Water Agencies and the Ministry of the Environment initiated a research programme to develop such a fish-based index that would be applicable nation-wide.

This paper expands on the results of Oberdorff *et al*. (2001), who modelled statistically the occurrence of each of the 34 most common fish species of France in relation to regional and local environmental factors (*i.e.* hydrographic units, climatic variables, position within the upstream downstream gradient and local habitat characteristics), to predict a "theoretical" fish assemblage at a particular site.

Data sources

Two data sets were extracted from the database held by the Conseil Supérieur de la Pêche (Banque Hydrobiologique et Piscicole), covering a period of 13 years (1985 to 1998): 1) a set of 738 reference sites (RS738), fairly evenly distributed across French rivers; 2) a set of 88 exposed (disturbed) sites (DS88) (Oberdorff *et al*., 2001). The selection was done by regional experts (fish biologists) on the basis of water quality map inspection and field reconnaissance. Factors considered in the field inspection included the amount of stream channel modification, channel morphology, substrate character and condition, and the general representativness of the site within the region. Criteria used for selection of reference sites were: 1) sites should belong to the water quality classes "Excellent" or "Good" as defined by the Water Quality Index (WQI) developed by the French Water Agencies (WQI uses 5 qualitative classes i.e. "Excellent", "Good", "Fair", "Bad" and "Very Bad" to integrate the influence of 12 variables i.e. turbidity, chemical oxygen demand, 5-d biological oxygen demand, oxydation, dissolved oxygen, % of oxygen saturation, $NH4^+$, NO_2-, NO_3-, SO_4--, Cl^-, chlorophyll); 2) sites should suffer from minimal habitat perturbations (as measured by the factors used during the field inspection and detailed above). Reference sites were not pristine nor totally undisturbed but were those that have suffered the least impact within a particular biogeographical region (Hughes, 1995). Most of the upstream sites selected were virtually undisturbed but it was impossible to identify completly undisturbed sites for large rivers (at large catchment-level scales). RS738 data set was further randomly divided in two subsets: one set of 650 sites (RS650) that was used to calibrate the models, and one set of 88 sites (RS88) that was used to validate the models. The size of this last data set (RS88) was defined to match the size of the data set of disturbed sites (DS88). Disturbed sites were selected to cover a range of well identified human disturbances including discharge of sewage effluents, urban run-off, channel and bank modifications, presence of weirs. A detailed description of the fish sampling methodology is given in Oberdorff *et al*. (2001).

Local and regional environmental variables

Eight abiotic environmental variables were measured at each site : gradient (‰) (derived from topographic maps) (GRA), elevation (m) (derived from topographic maps) (ELE), July mean daily maximum air temperature (T_{July}), January mean daily maximum air temperature ($T_{January}$), stream width (m) (WID), mean depth (m) (DEP), distance from headwater sources (km) (measured using a digital planimeter on a 1:1000 000-scale map) (DIS), and surface area of the drainage basin (km^2) (measured using a digital planimeter on a 1:1000 000-scale map) (SAD). These variables were combined or transformed to obtain six environmental descriptors.

<u>Velocity Index</u>. A measure of local water velocity was calculated using a Velocity index (V) derived from the Chezy formula.

$$V=\log(WID_m)+\log(DEP_m)+\log(GRA_{‰})-\log(WID_m+2*DEP_m)$$

<u>Elevation</u> was defined as E=log(ELE)

<u>Climatic variables</u> were defined as mean air temperature ($T_1=T_{july}+T_{January}$) and mean range temperature ($T_2= T_{july}-T_{January}$)

<u>Position along the longitudinal gradient</u>. DIS and SAD were used as synthetic variables reflecting the position of each site in the upstream-downstream gradient. The first principal component of a PCA was retained as a synthetic independent variable reflecting the longitudinal gradient (G) for further analyses:

<u>Hydrological units</u>. The 8 hydrological units are discrete physical units that provide well-defined boundaries with a real biological significance for riverine assemblages. The first four hydrological units represent large river basins while the last four hydrological units were

established on the basis of autochtonous fauna lists and a subsequent PCA analysis of faunal similarities.

Candidate metrics

From earlier IBI's applications to European rivers, a list of 14 potential metrics reflecting different aspects of fish assemblage integrity (i.e. taxonomic richness, tolerance guilds, habitat guilds, trophic guilds, individual abundance), were selected for possible inclusion in the final index.

- Total number of species (TNS): This metric is a common measure of species diversity that generally declines with environmental degradation. However, under certain circumstances (e.g. eutrophication) increasing productivity can lead to an increase in species richness.

- Number of lithophilic species (excluding tolerant species) and lithophilic species individuals (excluding tolerant species) (NLS, LSI). Lithophilic spawners are particularly sensitive to siltation since they require clean gravel substrates for reproductive success

- Number of benthic species (excluding tolerant species) and benthic species individuals (excluding tolerant species) (NBS, BSI). These metrics satisfy the objective of assessing the degree to which benthic habitats, and the species requiring them, are perturbed.

- Number of rheophilic species (excluding tolerant species) and rheophilic species individuals (excluding tolerant species) (NRS, RSI). Degradation of lotic areas (e.g. presence of weirs) should be reflected by a decrease in rheophiles.

- Number of intolerant species and intolerant species individuals (NIS, ISI). Intolerant species are those that decline first with environmental degradation. Intolerant species were empirically defined as species having a narrow water quality flexibility and a narrow habitat flexibility, following previous authors.

- Number of tolerant species and tolerant species individuals (NTS, TSI). These metrics represent the degree that tolerant species increase in number and absolute abundance with disturbance. Tolerant species were empirically defined as species having a wde water quality flexibility and a wde habitat flexibility.

- Omnivorous species individuals (OSI). This metric assesses the degree that the food base is altered to favor species that can digest considerable amounts of both plant and animal foods.

- Invertivorous species individuals (INSI). This metric is a surrogate for evaluating the degree that the invertebrate assemblage is degraded by environmental changes.

- Total density of individuals (TDI). Individual abundance is a common surrogate for system productivity, and highly disturbed sites are expected to support fewer individuals than high quality sites. However, as with species richness, increased nutrients and temperature can lead to an increase in individuals.

Modelling metric responses

For metrics based on presence/absence data the predictive models developed by Oberdorff *et al*. (2001) were used, which give the occurrence of each of the 34 most common fish species of France in relation to the 6 regional and local environmental factors presented above (multiple stepwise logistic regression using the Akaïke criterion). For a given site the expected species richness for each metric is given by the sum of the probability of the occurrence of each species considered for these metric.

For metrics based on abundance data, stepwise multiple linear regression analyses were performed (using Akaike Information criterion) for each metric (log ((x + 1)/S) transformed; with S = total surface area prospected (m^2)) on the six explanatory environmental variables.

Using the independent set of reference sites (RS88), the metric models were validated by verifying (using t-tests) that the intercepts of the fourteen regression lines of observed versus predicted metrics values were not statistically different from zero and that the slopes were not statistically different from one. Standardized residuals of each of the 14 metric models were then used as metrics values independent of (natural) environmental factors.

Metrics selection and scoring

Using the RS650 data set, χ^2 tests were used to eliminate metrics for which residuals distribution values statistically differed from a normal distribution (i.e. to be sure that interpretations are not confounded by bias due to unmet assumptions of normality). Verified that the remaining metrics were not too strongly correlated with others (i.e. with Pearson's $r^2 \geq 0.80$) was then sought.

As the remaining residual distribution values are assumed to be a centred standardised normal distribution, then, for metrics expected to decreased with human disturbance, the probability for a residual values to be lower than an observed one could be easily computed and used as a probability for this observed value to be representative of a reference situation. Conversely, for metrics expected to increase with human disturbance, the probability for a residual value to be higher than the observed one is retained. Following the same logic, for metrics assumed to be affected in either direction by disturbances (TDI and TNS), the probability of obtaining a value higher than the absolute value of the observed residual is used. This procedure allows each probability to have the same meaning, whatever the expected response to disturbance of the corresponding metrics (increase, decrease, or both).

Finally, these probabilities are log-transformed ($f(p) = -2\log(p)$): if the sites belong to the reference condition, then the distribution of transformed probabilities is equivalent to a χ^2 distribution with two degrees of freedom.

The sensitivity of metrics to human disturbance were tested using an independent disturbed data set, and all the metrics statistically unresponsive to perturbations were removed. The final list of validated metrics was: Total number of species, Number of lithophilic species, Number of rheophilic species, Number of tolerant species individuals, Number of omnivorous species individuals, Number of invertivorous species individuals, Total density of individuals.

The final value of the index is obtained by summing up the value of each of the 7 remaining metrics. Using the distribution of the percentage of unimpaired sites for RS88 and DS88 as a function of index score values, the index value for the optimal cut-off for impaired site was defined and rated the index in five class (unimpaired: Excellent, Good, impaired: Moderate, Poor and Bad). 74% of the sites for RS88 and 77% of the sites for DS88 was correctly classified respectively as reference and disturbed sites.

In conclusion, the index proposed can be applied in the different regions and river types of France using a consistent set of metrics despite the complex and heterogeneous geology and climate of this country.

Further developments

Further testing and refinement can already be envisaged to test and improve the index. These are:

- to enlarge the scope of the reference sites whilst excluding any sites at which further analysis of the fauna suggests that the site was environmentally stressed or under-sampled;
- to establish its variance and power using long-term data sets
- to test additional metrics, such as the ones describing the health of individual fish, which seem sensitive to many types of toxic pollution.
- to evaluate its general responsiveness to disturbance against other potential stressors (e.g. destruction of riparian vegetation, flow perturbations, obstruction to migration, siltation etc.).

3c.5 Using fish to assess environmental disturbance of Swedish lakes and streams

Authors : M. Appelberg, B. C. Bergquist & E. Degerman

In this study a set of metrics are proposed, based on standardised fish sampling, for assessing changes in fish communities in Swedish lakes and streams caused by environmental disturbances. Reference values for the fish community metrics and scoring criteria in relation to regional and local environments were estimated, using two comprehensive national databases comprising fish community data from lakes and streams. In concordance with Minns *et al*. (1994), the databases were assumed to comprise both degraded and reference habitats.

Methodologies

Two databases at the Institute of Freshwater Research, containing fish community data from all over Sweden, were used to select metrics, estimate reference values, and set scoring criteria for the deviation from reference conditions. In the lake database, a total of 1,048 sampling occasions from 629 lakes were included. The majority of samplings were made with standardised methodology (Appelberg & Bergquist, 1994, Appelberg *et al*., 1995). In addition, data from a national fish survey based on inquiries in 2,296 lakes were also used. For streams, the Swedish electric fishing register was used, which at the time of the study contained data from 6,988 stream sites, sampled on 12,882 occasions.

Because of the large number of sampled locations and wide geographical distribution, it was assumed that all important types of lakes and streams were represented in the data sets. As it was not possible to make a reliable determination of the extent to which fish communities were affected by anthropogenic activities, it was also assumed that all levels of community degradation were included, from habitats empty of fish due, e.g., to severe acidification or intensive farming activities, to unaffected, nearly pristine, habitats.

For metrics where reference values were set in relation to environmental or biological variables, e.g., species richness and species abundance, linear regression was used to establish the relationship between dependent and independent variables. Raw metrics were then calculated as the ratio between measured and reference value. For all other metrics except species and stages sensitive to acidification, measured values were used as raw metrics. For acid sensitive species, an index proposed by Degerman & Lingdell (1993) was adopted. Each raw metric was categorised in accordance with a common scoring criterion containing five classes, ranging from 1 (no, or minor deviation from reference) to 5 (very large deviation from reference). The scoring criterion was based on the distribution of each metric in the two data sets. For single sided metrics, (e.g., species richness, proportion of piscivorous percids) median, 25%, 10% and 5% percentiles were used. Thus, 50% of all fish communities would fall into class 1, 25% into class 2, 15% in class 3, and 5% in class 4 and 5, respectively. For double-sided metrics (e.g., abundance and biomass in lakes), 2%, 5%, 10%, 25% and 75%, 90%, 95% and 98% percentiles were used. The final index value for a given community was calculated as the mean score of all metrics. The final index value was then adjusted to the distribution of final index values for all fish communities in the two data sets, in a similar way as for the single metrics, using median, 25%, 10% and 5% percentiles.

Results

To ensure as broad a coverage of the fish communities as possible, metrics related to species richness and composition, community structure and function, as well as metrics referring to specific guilds, were included (Table 3c.5.1). Only metrics based on data available from standardised fish sampling were used.

Table 3c.5.1. Metrics used for describing fish communities in Swedish lakes (L) and streams (S). All metrics are based on standardised fish sampling. In lakes, biomass and abundance is calculated as weight and number per unit effort (gill net and night). In streams, weight and number per 100 m^2 is used.

Habitat	Category	Metric description
L&S	Structure	Number of fish species native to the habitat
L	Structure	Species evenness (Shannon-Wieners H'/number of native species)
L&S	Structure	Catch per unit effort in weight of fish species native to the habitat
L&S	Structure	Catch per unit effort in numbers of fish species native to the habitat
L	Guild	Proportion biomass of cyprinid species in relation to total biomass
L	Guild	Proportion biomass of piscivorous percid species in relation to total biomass
S	Function	Proportion biomass of salmonid species in relation to total biomass
S	Function	Reproduction of salmonid species native to the habitat
L&S	Env. disturb.	Occurrence of acid sensitive fish species and stages
L	Env. disturb.	Proport. biomass species tolerant to oxygen deficit in relation to total biomass
L&S	Env. disturb.	Proportion biomass of non-native fish species in relation to total biomass

For lake fish communities, estimation of reference values for species richness, abundance and biomass were preceded by multiple regressions that included longitude and latitude, altitude, lake area, and maximum and mean depth as independent variables. Lake area and altitude together explained nearly half of the variation in species richness (r^2=0.47, $p<0.0001$), whereas a quarter of the variation in abundance and biomass were explained by lake altitude and maximum depth (r^2= 0.24, $p<0.01$). Proportions of cyprinid and piscivorous species were found to be positively and negatively related, respectively, to total biomass in the catch. Due to non-linearity, altitude, lake area and maximum depth were classified in three, eight and six classes, respectively. Reference values were then estimated using regression of median values of each metric on single habitat parameters within altitude, area and depth classes.

For stream fish communities, reference values were calculated only for species richness, and expressed as a function of stream width, catchment area, proportion of upstream lakes of the catchment area, and altitude (r^2=0.28, $p<0.001$). Relative abundance and biomass of native fish species declined naturally with increasing altitude, and scoring criteria were based on the distribution within four altitude classes (0-100, 100-300, 300-700 and >700 m a.s.l.). Scoring criteria for the proportion of salmonid species were based on the distribution within four altitude classes and three flow discharge classes (<0.2, 0.2-0.7 and >0.7 m^3/s). In localities inhabited by salmonids, recruitment was estimated as the proportion of salmonid species with age-0 fish. The proportion of non-native fish species was calculated on the basis of biomass. The mean value of all metrics was used to calculate the final index (Table 3c.5.2).

Table 3c.5.2. Final scoring criteria for the index, based on the mean values of the 9 metrics in lakes and the 7 metrics in streams, respectively. Final index adjusted to the distribution of the final index values for all fish communities included in the two databases in such way that 50% will fall into class 1, 25% in class 2, 15% in class 3 and 5 % in classes 4 and 5, respectively.

Final scoring	Criteria description	Mean score of all metrics Lakes	Streams
1	No or minor deviation from reference	<2.0	<2.8
2	Small deviation from reference	2.0-2.7	2.8-3.3
3	Evident deviation from reference	2.7-3.4	3.3-4.5
4	Large deviation from reference	3.4-4.0	4.5-4.9
5	Very large deviation from reference	≥ 4.0	≥ 4.9

In a preliminary test, the index was applied using data from 40 fish communities collected within the national environmental monitoring programmes in acidified, limed or neutral lakes, and on data from 412 electric fished stream sites where habitat degradation was reported. In 20 of the lakes, fish community scores did not deviate from reference values (Fig. 3c.5.1). Among the neutral reference lakes, the majority (12) were classified as class 1 (no, or minor deviation from reference values), and four communities were classified as class 2 (small deviation from reference). One neutral reference lake was possibly misinterpreted as class 3 (evident deviation), probably due to the fact that the fish community in this lake was outside the range of predictable communities. Among the acidified lakes, one fish-less lake was classified as 5 (very large deviation), and one severely acidified lake that still contained fish as 4 (large deviation). Four and two communities were placed in classes 2 and 3, respectively. Fish communities in acidified lakes that also were limed were classified consistent with the degree of recovery of fish after lime treatment (Figure 3c.5.1).

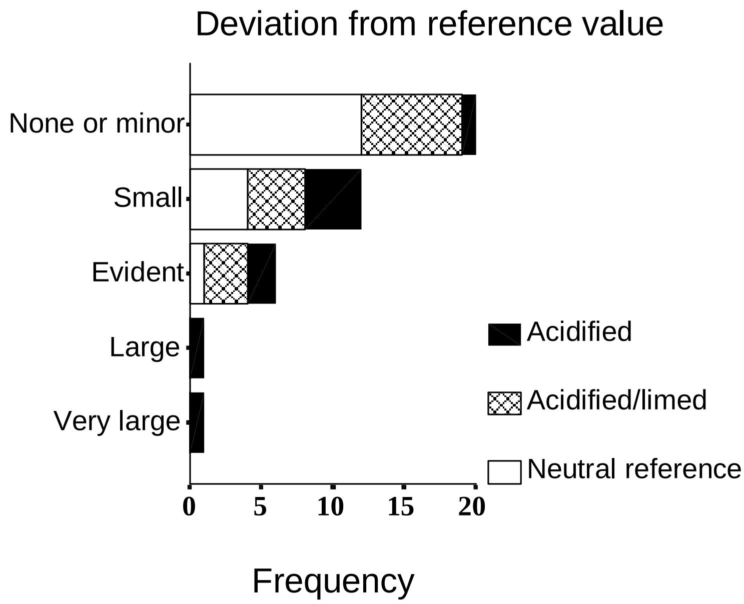

Figure 3c.5.1. Scores for deviation from reference values for fish communities in 40 lakes sampled in the Swedish national monitoring programmes during 1997.

For stream sites, the index classified fish communities that were subjected to five different types of environmental disturbance in higher categories than communities in habitats where some kind of habitat improvement was performed (Figure 3c.5.2). Fish communities in stream sites subjected to habitat improvement did not deviate from reference (class 1), whereas those deviating most from expected were found at sites subjected to water regulation (between class 3 and 4) and digging activities (class 3). Fish communities at sites acting as recipient for waste water, or subjected to canalisation or forestry, were classified between 'small deviation' to 'evident deviation' from expected (classes 2 and 3, respectively).

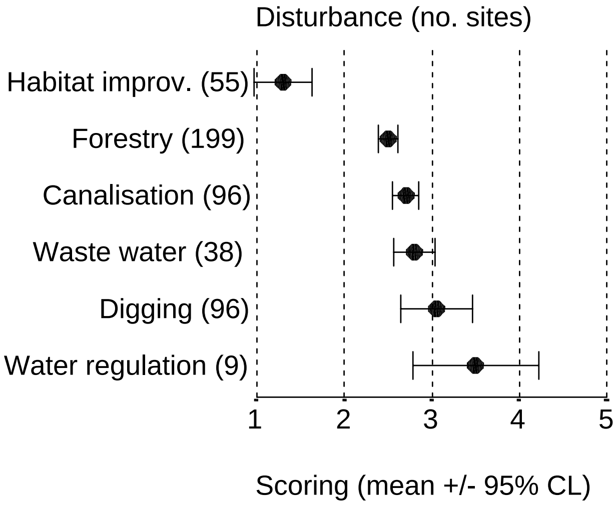

Figure 3c.5.2. Scores for deviation from reference values for fish communities in 412 stream sites that were subjected to different types of environmental disturbance. Mean values and 95% CL.

Discussion

Due to the last ice age, the Scandinavian Peninsula has low species richness with 53 fish species reproducing in Swedish lakes and streams (Ahlén & Tjernberg 1992). Species richness is strongly related to colonisation history and climate, and thereby also correlated to altitude and habitat size. In contrast, latitude and longitude seem to have less influence. The interaction between lakes and streams is evident by the fact that the proportion of upstream lakes within a catchment area is of importance for the composition of stream fish communities (Degerman & Sers 1992).

Environmental disturbances, such as acidification (e.g., Appelberg *et al.* 1989), eutrophication (Svärdson 1976) and habitat degradation (Näslund 1992) also affect species richness and fish community composition. Accordingly, environmental factors such as nutrients, oxygen concentration, discharge, acidity, and temperature affect distribution of fish communities in Swedish lakes and streams (Appelberg *et al*. 1989, Appelberg & Degerman 1991, Degerman & Sers 1992). Generalists, such as cyprinids and cottids, increase in nutrient rich waters, whereas piscivores and salmonids decrease (Svärdson 1976, Leach *et al*. 1977, Persson *et al*. 1991). Increased input of nutrients is usually also reflected in an increase in fish biomass, whereas habitat degradation and toxic compounds are reflected in a decrease in abundance and biomass as well as recruitment failure (Almer 1972, Degerman & Lingdell 1993).

When estimating index of biotic integrity, environmental disturbance has most often been classified in relation to undisturbed reference sites (e.g., Karr 1981, Angermeier & Karr 1986, Karr *et al.*1986, Fausch *et al.* 1990). This approach presumes a thorough knowledge of the fish community in each single habitat. In contrast, the reference values for the fish community and scoring criteria were based on the overall relationship between specific fish community characteristics and habitat parameters from a large number of sites, thereby reducing subjectivity in setting reference values. The major reason not to include only apparently 'unaffected' lakes and streams in the analyses is that even if water bodies seem to be unaffected by anthropogenic influence, it will be difficult, or even impossible, to ensure that the fish community is not affected by man. There is also an obvious risk that the only waters that should be classified as 'pristine' will be small lakes and streams located in remote areas, whereas waters like those in the acidified western part of Sweden, as well as waters in urban, agricultural or heavily forested areas, would be underrepresented or absent in the analyses.

The index presented here will be further developed and applied on independent data sets. Relevant fish community data from high alpine lakes and lowland streams in agricultural areas will be added to extend the validity of the index.It is also planned to extend the number of metrics, using more detailed information from species and communities, such as biomass size spectra, growth rate, and recruitment. By further harmonising the metrics for lake and stream fish communities, classification of whole or parts of water systems would be possible in the future.

3c.6 An IBI developed to assess ecological integrity in English lowland rivers

Authors : K. Rahman, R. A. A. Noble & I. G. Cowx

The text presented below is a summary of a PhD thesis in preparation by Rahman (2002) on the development of a fish-based method adapted to English lowland rivers.

Study sites

Three networks of English rivers from the Thames, the Midlands and the Northeast regions of the Environment Agency were selected for this study, as these regions had the best available fish stock assessment data. Rivers were chosen from three major catchments, the Thames, Trent and Yorkshire Ouse depending on the availability of fishery data. The Thames catchment included five rivers, the Cherwell, Evenlode, Stort, Thame and Windrush. From the Trent catchment 15 rivers, the Anker, Blithe, Blythe, Churnet, Cole, Derwent, Idle, Mease, Penk, Sence, Soar, Sow, Tame, Tean and Trent, were included. The rivers Aire and Nidd were selected from the Yorkshire Ouse catchment. In this study, all the rivers, respective sites and sampling data were selected from the routine monitoring programmes of the Environment Agency (EA) and its predecessors (Regional Water Authorities & National Rivers Authority, NRA). The number of sites and types of sites chosen for a particular river usually reflected the needs of the project and the scientists at the time of selection. A total of 457 sites from 22 rivers in 3 catchments were chosen for this study. The number of sites on a particular river varied from 5 to 182, usually related to the length, width, depth, and habitat features of the river. Sites on the Thames catchment were surveyed between 1990 and 1996, while the Trent catchment was surveyed between 1989 and 1993. The Yorkshire Ouse catchment was surveyed between 1990 and 1996.

Sampling method

Fish populations were sampled by the NRA and EA using different types of electric fishing gear in different catchments. However, the basic method and application were the same in all regions of the UK, but operational differences were found in the Southeast, Midlands and Northeast regions. In all these regions, boom-mounted electric fishing gear was used. Midlands used both straight multiple-anode (usually 10) (Cowx *et al.* 1988) and ring arrays while Northeast used a simplified version (4 anodes) of the straight boom array. Electric fishing equipment in the Thames system was powered from a 7.5 kVA generator and had a square wave pulsed DC output of 100 Hz and a 50% duty cycle. The linear boom-array system used by Northeast region was powered from a 4 kVA generator with a 100 Hz, ¼- sine pulsed DC output. The electric fishing equipment used by the Midland regional team produced several outputs including 50, 100 and 300 Hz square wave at varying duty cycles and was generally powered by 4 kVA or 7.5 kVA generators. In headwaters, where the river is narrow, shallow and steep, fish were sampled by 3 or 4 personnel wading with one or two hand-held electrodes. Output was usually pulsed DC at 50 or 100 Hz from a small generator. In large rivers approximately 50 to 1045 m lengths of each site were sampled. The sections were not isolated by stop nets as natural features at the extremities of the sites were used as obstacles. All major habitats within each site were sampled carefully to obtain a representative sample of the fish assemblage. In most cases, two runs were made at each site but at other sites, single runs were taken due to the small catch. In deeper waters, exceeding 1 m in depth, electric fishing was carried out from a small fibreglass boat, moving in an upstream direction.

Reference conditions

Establishment of a reference condition and IBI was undertaken using a guild approach and therefore information was required on the origin, habitat preference, diversity, density, trophic ecology, reproductive guild, and tolerance to degradation of fishes. Pristine aquatic habitats, having naturally occurring fauna, are rare in English rivers. The hypothesis for the reference condition was that, "least impacted" sites were used to represent pristine conditions as these sites contain the best attainable conditions possible for a watershed within a region. Available monitoring data was corroborated or refined using historical data, paleoecological data and expert judgement to calculate a reference condition based on the maximum expected number of species in each of the guild categories and the maximum expected values for some metrics e.g. abundance.

Establishment of metric expectation criteria

Generally British rivers harbour 45 to 50 fish species (Wheeler 1983, Moss 1988) (Table 3c.6.1). The River Thames (Winfield *et al.* 1994) and the Yorkshire Ouse (Burnett *et al.* 1978) catchments contain 35 fish species each, while about 40 species were reported to inhabit the Trent catchment (Braddock 1977). Using fish distribution data and collection records from 1975 - 1986, the number of species common enough to be collected with a thorough sampling method was estimated. This was done to establish expected values for species richness and composition, and fish abundance and biomass metrics.

Available literature indicates that 41 exotic species have been introduced across the country within the last century. On the basis of total freshwater fish species, the maximum expectation criterion was fixed for this study. Maximum expected values for different ecological categories are presented in Table 3c.6.3). Although situated in different locations, a generalised value for each category was considered for the three catchments (The Thames, Trent and Yorkshire Ouse). Among the 91 species (50 native and 41 exotic), only 30 species are found to be common in many UK rivers.

Analyses of historical monitoring data and available literature were used to assess the "maximum expected number" for each of the guild concept categories used in an IBI assessment to set reference conditions against which suitable metrics were derived and scored. Table 2, the "maximum expected values" and therefore a reference condition based on the most common species, was derived from Table 3c.6.1, which summarises the total fish fauna of rivers in the British Isles.

Table 3c.6.1. Historical and ecological basis of metric expectation values for English rivers.

Criteria	Expected number	Reference / Table / Species
Total native species in UK	50	See Moss (1988)
Total introduced fish in UK	41	
Most common species in UK	30	
Maximum expected number of common native species in lowland rivers	18	
Maximum expected exotic species in lowland rivers	10	Common carp, pikeperch, rainbow trout, bitterling, black bullhead, goldfish, sunbleak, ide, wels and asp
Tolerance		
Intolerant species	9	Rainbow trout, brown trout, Atlantic salmon, grayling, barbel, minnow, chub, dace and bleak
Tolerant species	15	Common carp, crucian carp, tench, roach, common bream, silver bream, 3-spined stickleback, 10-spined stickleback, rudd, gudgeon, pike, perch, pikeperch, ruffe and eel
Habitat guild		
Limnophilic (Vegetation preferring species)	14	Common carp, crucian carp, tench, roach, common bream, silver bream, 3-spined stickleback, 10-spined stickleback, rudd, pike, perch, pikeperch, ruffe and eel
Rheophilic species	10	Rainbow trout, brown trout, Atlantic salmon, grayling, barbel, minnow, chub, dace, bleak and gudgeon
Trophic guild		
Omnivores	10	Common carp, crucian carp, tench, roach, common bream, silver bream, rudd, chub, 3-spined stickleback and 10-spined stickleback
Invertivores	6	Grayling, barbel, minnow, dace, bleak and gudgeon
Piscivores	8	Rainbow trout, brown trout, Atlantic salmon, pike, perch, pikeperch, ruffe and eel
Water-column species	14	Rainbow trout, brown trout, Atlantic salmon, minnow, chub, dace, bleak, 3-spined stickleback, 10-spined stickleback, rudd, pike, perch, pikeperch and ruffe
Benthic species	10	Grayling, barbel, common carp, crucian carp, roach, tench, common bream, silver bream, gudgeon and eel
Reproductive guild		
Phytophilic species	7	Common carp, crucian carp, tench, rudd, perch, pikeperch and ruffe
Phytolithophilic species	5	Roach, common bream, silver bream, pike and bleak
Lithophilic species	8	Rainbow trout, brown trout, Atlantic salmon, grayling, barbel, minnow, chub and dace
Total gravel spawners	13	Rainbow trout, brown trout, Atlantic salmon, grayling, barbel, minnow, chub, dace, roach, common bream, silver bream, pike and bleak
Psammophils	1	Gudgeon
Nest builders	2	3-spined stickleback and 10-spined stickleback
Number of long-lived species in Britain	22	
Number of long-lived species used in this study	2	Chub and common bream

Table 3c.6.2. Summary of the reference condition proposed for English lowland rivers.

Criteria	Reference number	Species
Species composition		
Maximum expected number of common native species in lowland rivers	18	
Maximum expected exotic species in lowland rivers	10	Common carp, pikeperch, bitterling, rainbow trout, black bullhead, goldfish, sunbleak, ide, wels and asp
Tolerance		
Intolerant species	5	Barbel, minnow, chub, dace and bleak
Tolerant species	13	Crucian carp, tench, roach, common bream, silver bream, 3-spined stickleback, 10-spined stickleback, rudd, gudgeon, pike, perch, ruffe and eel
Habitat guild		
Limnophilic (Vegetation preferring species)	12	Crucian carp, tench, roach, common bream, silver bream, 3-spined stickleback, 10-spined stickleback, rudd, pike, perch, ruffe and eel
Rheophilic species	6	Barbel, minnow, chub, dace, bleak and gudgeon
Water-column species	10	Minnow, chub, dace, bleak, 3-spined stickleback, 10-spined stickleback, rudd, pike, perch and ruffe
Benthic species	8	Barbel, crucian carp, roach, tench, common bream, silver bream, gudgeon and eel
Trophic guild		
Omnivores	9	Crucian carp, tench, roach, common bream, silver bream, rudd, chub, 3-spined stickleback and 10-spined stickleback
Invertivores	5	Barbel, minnow, dace, bleak and gudgeon
Piscivores	4	Pike, perch, ruffe and eel
Reproductive guild		
Phytophilic species	5	Crucian carp, tench, rudd, perch, ruffe
Phytolithophilic species	5	Roach, common bream, silver bream, pike and bleak
Lithophilic species	4	Barbel, minnow, chub and dace
Total gravel spawners	9	Barbel, minnow, chub, dace, roach, common bream, silver bream, pike and bleak
Psammophils	1	Gudgeon
Nest builders	2	3-spined stickleback and 10-spined stickleback
Abundance		
Number of individuals of long-lived species used in this study (No. 100 m^{-2})	≥25	Chub and common bream
Number of individuals in sample (No. 100 m^{-2})	≥200	
Biomass for English lowland rivers (g m^{-2})	≥35	

One perceived draw back of setting a reference condition in this way is that recent survey data (<50 years old) may actually represent fish communities under perturbed conditions which have now been rehabilitated. Consequently the communities sampled may represent conditions that are further away from "pristine" than the current communities are and consequently the derived reference condition will not define the best ecological condition or potential. With the on going process of freshwater rehabilitation and the ecological recovery or development of rivers, current monitoring data probably reflects fish communities that are subject to change and often to improvement. They are therefore very unlikely to represent a climax community.

The approach to setting IBI and reference condition criteria used by Rahman (2002, *unpublished research*) represents only one approach based on the limited, available survey data and is yet to be validated by field trials or assessed with new, more recent data.

IBI metric selection

Retaining the basic ideas of existing IBI models, a number of modifications and additions were made to structure a new version of the IBI for English rivers. Initially 19 candidate metrics were tentatively selected to calculate IBIs for English lowland rivers. The metrics "proportion of individuals with deformities, eroded fins, lesions, and tumours", "% of hybrids", "% of standard growth of fishes" and "% of juvenile fishes" were not tested due to lack of existing data. The metrics selected are presented in Table 3c.6.3.

Scoring of metrics

A continuous rating scale was adopted to score the 15 IBI metrics for English lowland rivers. Ratings of 5, 4, 3, 2, 1 and 0 were chosen to assign each metric according to whether its value approximates to (best), deviates somewhat from (good), deviates more from (intermediate), deviates considerably from (bad), deviates strongly (worst) or "No Fish" from the value expected at the minimally disturbed sites. A total of six integrity classes on a continuous scale were chosen to define biotic integrity of the English lowland rivers with following class boundaries: Excellent (56 - 75), Good (42 - 55), Fair (28 - 41), Poor (16 - 27), Very Poor (1 - 15) and "No Fish" (0). The rating system of 7 metrics (metric 1, 3, 5, 6, 13 14 and 15), was based on numerical scale and the remainder (metric 2, 4, 7, 8, 9, 10, 11 and 12, were on percentile scale. Three metrics such as "proportion of individuals as non-natives", "% of individuals as tolerant species" and "% of individuals as omnivores", received the highest score 5, when these species were absent. However, these scores were not considered for "No Fish" categories, as "No Fish" category indicates heavy degradation of a site. The scoring system for each metric is presented in Table 3c.6.4.

Table 3c.6.3. Details of modified IBI metrics adopted for the English rivers (Rahman 2002, *Unpublished data*).

Category	**Metric**	**Expected trend in fish community structure with degradation**
Species richness	1. Total number of native fish species	Declining
	2. Proportion of individuals as non-natives	Increasing*
	3. Number of intolerant species	Declining
	4. % of individuals as tolerant species	Increasing
Habitat composition	5. Number of water-column species	Declining
	6. Number of benthic species	Declining
	7. % of individuals as rheophilic species	Declining
	8. % of individuals preferring vegetated areas	Declining
	9. Proportion of individuals as gravel spawners	Declining
Trophic composition	10. Percentage of individuals as omnivores	Increasing
	11. Percentage of individuals as invertivores	Declining
	12. Percentage of individuals as piscivores	Declining
Fish abundance	13. Number individuals of long-lived species (No 100 m^{-2})	Declining
and biomass	14. Number of individuals in sample (No 100 m^{-2})	Declining
	15. Total biomass (g m^{-2})	Declining

* The expected trend for the proportion of individuals as non-native depends upon the concept behind the IBI and reference condition. The metric will increase with degradation if the IBI is designed to assess "biological pollution", caused by stocking and introduction, as a reduction in ecological integrity.

Redundant metrics

When tested, 5 of the 15 metrics were found to be less sensitive to perceived degradation and had no significant effect on the overall IBI score when left out. Consequently the IBI was based on only 10 metrics. The 5 metrics that were eventually left out were:

- number of water column species;
- % individuals as rheophilic species
- % individuals preferring vegetated areas;
- number of individuals of long-lived species (n m^{-2});
- total biomass (g m^{-2}).

Table 3c.6.4. Scoring criteria of IBI metrics used for the English rivers.

Metric description	**Score**				
	5	**4**	**3**	**2**	**1**
1. Total number of native species (Reference no.18)	14 - 18 (80-100%)	11-13 (60-79)	7 - 10 (40-59)	4 - 6 (20-39)	1 - 3 (1-19)
2. Proportion of individuals as non-natives (Max. expected no.=10)	≤2 (≤11-16)	3 - 4 (17-22)	5 - 6 (28-33)	7 - 9 (39-50)	≥10 (≥56%)
3. Number of intolerant species (5)	5	4	3	2	1
4. % of individuals as tolerant species (13)	≤11-16	17-21	22-38	39-71	≥72%
5. Number of water - column species (10)	10	8-9	6-7	4-5	1-3
6. Number of benthic species (8)	≥8	6 -7	5	3-4	1-2
7. % of individuals as rheophilic species (Rheophilic = 6)	33	28-32	22-27	11-21	≤6-10%
8. % of individuals preferring vegetated areas (Limnophilic = 12)	67	56-66	39-55	28-38	≤11-27%
9. Proportion of individuals as gravel spawner (9)	50	39-49	28-38	22-27	≤11-21%
10. % of individuals as omnivores (O = 9)	≤11-21	22-27	28-38	39-49	≥50%
11. % of individuals as invertivores (I = 5)	28	22-27	17-21	11-16	≤6-10%
12. % of individuals as piscivores (P = 4)	22	17-21	11-16	6-10	≤5%
13. Number of individuals of long-lived species (chub and common bream) (No 100 m^{-2}) (≥ 25)	≥25	20-24	15-19	10-14	1-9
14. Number of individuals in sample (No 100 m^{-2}) (≥ 200 fish)	≥200	100-199	50-99	20-49	1-19
15. Total biomass (B = 35 g m^{-2})	≥35	28-34	17-27	6-16	≤5

3c.7 Alternative assessment method for species poor streams

Authors : J. Böhmer

General remarks

Streams with low species diversity cannot be properly assessed by multimetric indices. From a statistical point of view its senseless to use more metrics than independent input parameters (i.e. species for reference condition and test site together, or additional parameters like % of juveniles), because each additional metric is redundant.

Therefore, it is necessary to increase the amount of input information for those streams. One possibility is to look at different age classes for each species. For the use of metrics, however, this only helps if additional information is available for the age classes, e.g. information on food or habitat preferences. Otherwise the metrics will stay the same as despite the differentiation of age classes.

Since additional ecological information on age classes is not easily available, an assessment system that directly uses the abundance of three age classes of all species was developed. The resulting biocoenotic composition of the test stream is compared with the reference condition. This method fulfils all criteria of the Water Framework Directive, since it takes into account biocoenotic composition, abundance and age structure. It also considers sensitive/robust species directly, since any deviation of their abundance from the reference condition leads to a decrease of the resulting assessment score. It is also possible to stress this criterion by combining the assessment method with a metric for sensitive/robust species. One drawback of the method is that it requires abundance information for age classes in the reference condition, which is not as easily gained as expected metrics.

Short description of the method

The method presented here has only been published in a German report. However, a preceding version was described by Siligato & Böhmer (2001), some aspects of which are outlined below. The way the **reference condition** is derived is not important. A combination of typological/zonational, and historical information with expert judgement were used. For each species the abundance must be given in one of four classes for each age class. Abundance classes are:

0 = not present; 1 = few individuals; 2 = normal stock; 3 = very abundant.

Age classes used were young-of-the-year, sub-adults and adults.

Siligato & Böhmer (2001) used one of the abundance classes for the reference condition. Since some species may have large variations in abundance within a river type, better results were obtained when abundance conditions were used for some species instead of certain abundance values. For example the abundance condition may be ">1" for an age class of a species which may occur in reference streams in few individuals as well as in higher abundance.

For the **assessment procedure** the Renkonen similarity index is calculated between the test stream and the reference condition using the age classes of all species as if they were different species. The Renkonen index may have values between 1 (= 100% similarity) and 0 (= 0% similarity). The resulting ecological status classes are assigned as follows:

High >= 0.8 > good <= 0.6 > fair <= 0.4 > poor <= 0.2 > bad.

3c.8 The EC-Life IBIP-Meuse programme

Authors : N. Roset, D. Goffaux, J. Breine, J. De Leeuw, T. Oberdorff & P. Kestemont

The text below summarises the final report of an EC-Life project (ENV/B/000419) conducted from December 1997 to February 2001 (Goffaux *et al*., 2002).

Objectives of the programme and main steps

The aim of the programme was to develop effective tools based on fish assemblages allowing the development of an effective assessment approach of the ecological status of running waters. The present LIFE project was the first international research initiative in Europe focusing on the standardisation, and the adaptation of a fish-based index for an entire European river basin. To reach this goal a close partnership between three countries (France, Belgium, and The Netherlands), was co-ordinated by the University of Namur (FUNDP, Belgium), and involved three other partners (CSP for France, IBW for Flanders and RIVO for The Netherlands). The programme started in 1997 and was achieved in 2001. Its scientific background came from several national (Oberdorff et al. 2001) or regional experience which aimed to develop a fish-based index. Despite the IBIs developed by Kestemont et al. (2000) and Belpaire et al. (2000) for some portions of the Meuse basin, appropriate regionalisation has not been established, nor have metrics with basin-wide utility been identified. To be useful at this scale (i.e. a whole international river scale), the index must accommodate natural geographic variation of fish assemblages.

The 11 following items summarised the goals addressed through the project:

- to apply IBI principles and the "reference condition approach" (i.e. comparing a fish assemblage exposed to a potential stress against a reference condition that is unexposed to such a stress);
- to define a data set of reference sites evenly distributed across the Meuse Basin;
- to examine the effects of natural environmental factors on the species composition of fish assemblages using this data set of reference sites;
- to examine the potential influence of sampling methods on the estimated species composition of fish assemblages;
- to select a variety of metrics based on occurrence and relative abundance data and reflecting different aspects of the fish assemblage structure and function from available literature, and for their potential to indicate degradation;
- to determine how metrics vary naturally within the basin (i.e. in the absence of anthropogenic perturbation) in order to elaborate the simplest possible response model that adequately explains the observed patterns of each metric for a given site;
- to select the most effective metrics in discriminating between reference and disturbed sites using a second data set of disturbed sites;
- to develop new indices following the two major approaches previously tested within national projects;
- to validate and assess the capacity of the indices to assess anthropogenic perturbations using two independent data sets of reference and disturbed sites;
- to assess the spatial and temporal variability of the two indices;
- to compare their sensitivity against other available fish-based indices (i.e. the FBI developed by Oberdorff *et al*. (2000) for French rivers and the two IBIs previously developed by Kestemont *et al*. (2000) and Belpaire *et al*. (2000) for some regions of the Meuse Basin);
- to discuss the advantages and limitations of each approach, and to suggest the most appropriate method(s) for assessing the ecological status of the Meuse Basin.

Initial concept

The basic goal of the project was to adapt the IBI principle to European rivers. Following the fundamentals of the method and the wide array of application world-wide (Karr & Chu, 1999), and especially previous national experience in Europe (Oberdorff & Hughes, 1992; Oberdorff & Porcher, 1994; Didier, 1997; Belliard *et al*., 1999; Kestemont *et al*., 1998; Belpaire *et al*., 2000; Kestemont *et al*., 2000; Kesminas & Virbickas, 2000), the use of metrics describing fish assemblage structure from individual to assemblage levels, was retain as a basis of the programme. In conformity with the original method, these metrics encompassed species richness, species composition, trophic structure and total fish abundance, as each metric is expected to reflect a different aspect of the fish assemblage that responds in a different manner to aquatic ecosystem stressors (Hughes & Noss, 1992).

Comparison of sampling methods

Several field operations were carried out during the programme on both small and large rivers. The aim was to test the influence of sampling methods (electric fishing, gillnetting and trawling), sampling strategies (continuous versus discrete electric fishing) on fish community picture and assessment methods. Moreover, a large national databases was used to further compare specific differences between methods (electric fishing *Vs* gill-netting; electric fishing *Vs* trawling).

The main results showed that few differences occurred among electric fishing techniques while there were significant deviations between electric fishing, gillnetting and trawling methods (Figure 3c.8.1). Thus, it was decided to work on electric fishing data exclusively for designing and applying the fish index.

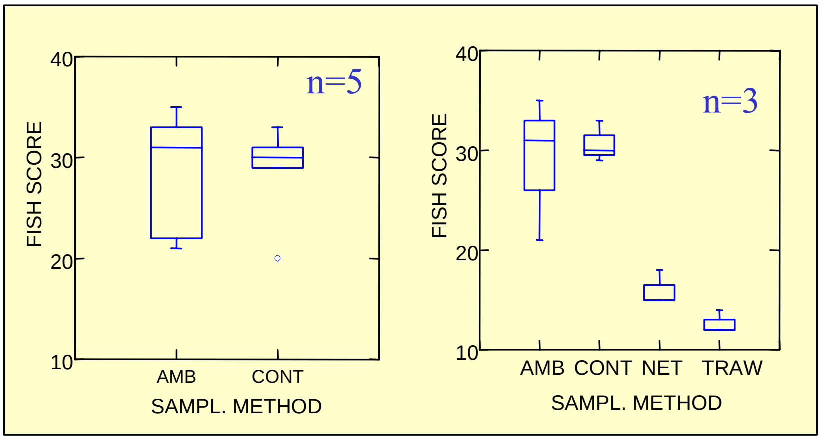

Figure 3c.8.1. Fish score obtained with different sampling techniques (AMB : electric fishing by ambience, CONT: electric fishing in continuous, NET : gillnet, TRAW : trawling).

Global methodology for designing the index

Data set

A large data set on fish species abundance and associated environmental parameters was compiled from national databases produced by both fish resource managers and research institutes involved in the IBIP-Meuse programme. Out of more than 1000 sites where fish have been monitored for years in the frame of national survey programs, 537 locations with homogenous and complete sets of abiotic and biotic parameters were selected, corresponding to 698 fishing operations. Considering the results of the sampling methodology comparison that was carried out at the beginning of the project, which recognised the relative homogeneity between electric fishing techniques, it was decided to work on electric fishing data only for designing the index. Nevertheless, the robustness of the proposed indices to the use of different sampling methods was tested.

The data set contains two kinds of information for all the 698 sites (small and large rivers):

- Environmental describers of climate, river size and river gradient (slope, width, watershed area, distance from source, air temperature in January and July, altitude);

- Fish community characteristics (species, abundance and weight).

Initial abiotic evaluation

Based on previous studies, expert knowledge and field reconnaissance, providing information about water and habitat quality of reaches, a preliminary assessment of sampling stations was carried out. The criteria used for this selection encompassed several aspects of environmental quality, among which were river sinuosity, longitudinal and lateral connectivity, bank structure and vegetation cover, water flow velocity, substrate size, hydrologic regime, nutrient load, organic matter, pH, oxygen rate, temperature. As the information on water and habitat quality was mostly qualitative or semi-quantitative, and because the methodology was not completely standardised between countries, it was translated by national experts into two coded indicators of water and habitat quality. And these two scores were finally combined into a synthetic indicator of abiotic integrity reflecting five levels of degradation from highly impacted (class 1) to the near natural sites (class 5). The last category could be considered has “reference”, representing more the least impacted sites currently available in a given region rather than pristine conditions.

Preliminary data analysis

Development of a system for the assessment of river quality based on fish community requires the separation of natural and degraded conditions. Thus, it requires a good knowledge of the theoretical organisation and key-determinants of fish community structure, and an accurate understanding of the processes that lead to the modification of its structure, when natural events or man-induced degradation occur. That is why a special task of the programme consisted of studying the organisation of fish community in the Meuse basin and identification of the main spatial trends (longitudinal, regional, etc.).

Canonical Correspondence Analysis identified two symmetrical structures in the spatial patterns of fish community organisation in the Meuse basin, both controlled mainly by two distinct combinations of slope (Slop) and altitude (Alt) on one hand, and distance to source (Dist.), width (Wid.) and watershed area (WSA) on the other hand. This structure mainly reflects the upstream-downstream succession of fish species form trout/bullhead and minnow association upstream to bream/bleak/roach downstream. But the singularity of fish community in Flanders was also particularly pointed out, as species composition from Flanders and those from France, Wallonia and even the Netherlands, seemed to respond differently to the same combination of environmental conditions.

Consequently, the development of the fish-based index should encompass the following key-points :

- Slop. and Alt. are the two major factors influencing fish community structure of the least impacted sites of the Meuse basin;
- Dist., WSA and Wid. all reflect the stream size and the position within the upstream-downstream gradient in a similar way. Thus, these three correlated variables could be replaced by a new synthetic variable of the gradient (G as a linear combination of the three initial ones).

- Regional characteristics, which are not encompassed by the previous parameters, should also be accounted.

Two independent subsets

Few index from the literature are rigorously validated on the basis of independent data set. This was attempted by randomly dividing the initial data into two independent subsets:

- the first one called "design" (351 sites) was used for the calibration stage (define thresholds and setting scores)
- the second one called "validation" (347 sites) was used to test the efficiency of the two indices.

Selection of metrics after removal of natural patterns

Several candidate metrics were calculated for their potential inclusion in the final index, based on the review made by Hughes & Oberdorff (1998), and with concern of the specificity of European fish community and the first trials of adaptation of IBI's principles in this regional context (Didier 1997; Kestemont *et al.* 2000; Belpaire *et al.* 2000). But if one of the main interests of IBI is the complementarity between metrics, it is also probable that the greater the number of metrics accounted into the index, the lesser the sensitivity. For this reason it was decided to select the most relevant, least redundant and most complementary metrics for potential inclusion in the final index.

To separate accurately natural variation from anthropogenic ones, and thus to better identify the ability of metric to respond to degradation, it was decided to describe and remove the natural evolution of the metrics with environmental parameters. To reach this goal the residuals of linear models were analysed using each metric as dependent variable and environmental parameters as factors (RQ. the residuals represents the part of the variation, which does not depend on the parameters integrated into the models). Thus, working on the residuals, several ways to test the relevance of the metric were possible, whether the aspect considered was rather the ability of the metric to discriminate different degrees of degradation or the redundancy between metrics. Consequently, two complementary analyses were run. Firstly a one-way analysis of variance (ANOVA) was run for all metrics (as dependent variables) to test the difference of the residuals means between 5 levels of ecological quality (as factor). It was completed by a "Bonferroni's *post hoc* comparison". Secondly, a discriminant analysis (DA) was implemented to discriminate the most redundant metrics from the most sensitive ones.

Following these analyses of the ability of metrics to reflect various levels of degradation and their complementarity, 11 metrics listed below were selected from more than about 30 candidate metrics:

- Species richness
- Total number of fish caught per unit effort (100 m²)
- Total biomass of fish caught per unit effort (100 m²)
- Percentage of lithophilous species minus exotic and tolerant (%SpLito2)
- Percentage of rheophilous species (%SpReo)
- Percentage of intolerant species (%SpIntROT)
- Percentage of tolerant species (%SpTol)
- Percentage of intolerant individuals (%INTROT)

- Percentage of tolerant individuals (%TOL)
- Percentage of invertivorous individual %INV2)
- Percentage of omnivorous individuals (%OMN)

Two approaches tested

Summary of methodological differences

The main differences between the two approaches tested concerned the method used to select reference conditions, and the way reference conditions are employed to define thresholds and attribute scores. Moreover, one of the methods was based on a unique descriptor of natural spatial variations whilst the other was based on a combination of five parameters (Figure 3c.8.2).

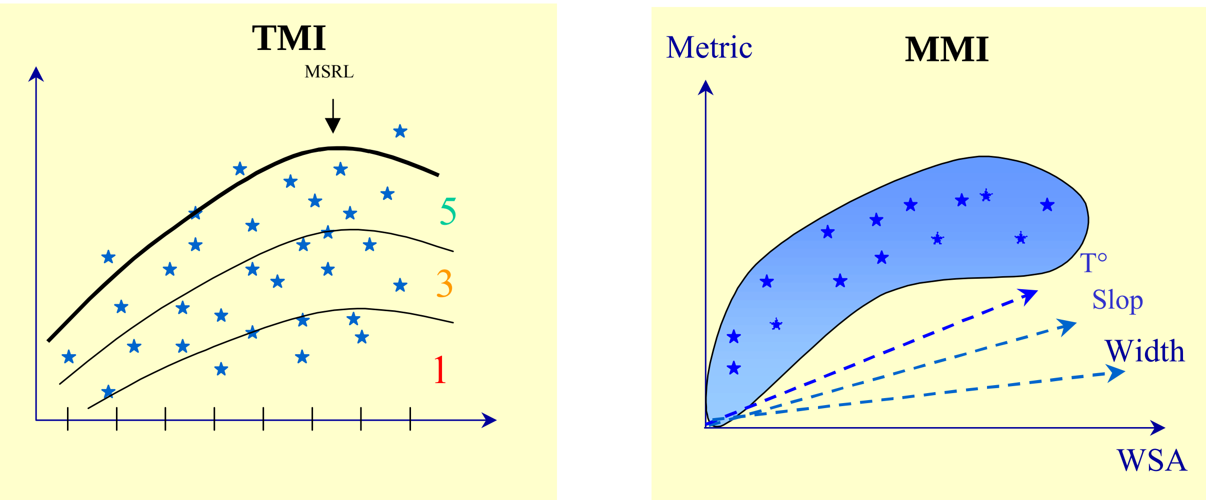

Figure 3c.8.2. Theoretical methods tested on the Meuse data set to design the fish-based index (trisection method TMI and multivariate method MMI).

Trisection method (TMI)

The Belgian strategy for designing a fish based index was developed on the basic concept originally proposed by Karr (1981). Ideally, environmental conditions at the site of concern are compared with the attributes expected in undisturbed streams or rivers of similar size and habitat type located in a similar geographic region. For the 11 metrics selected, the value of each metric was calculated for all samplings in the design set. Based on correlation values, the best describer of metric *Vs* environmental conditions relationships was selected (highest correlation) and its log values transformed into classes. Then values for each metric were plotted against classes of the selected parameters (altitude or watershed area as presented in the list below)

1. Number of species (-exotic species) →Log WSA
2. % Intolerant species→Log WSA
3. % Lithophilic species (- exotic and tolerant species)→Log WSA
4. % Rheophilic species (- exotic species) →Log Alt
5. % Tolerant individuals →Log Alt
6. % Omnivorous individuals →Log Alt

7. % Intolerant individuals (- exotic species) →Log Alt

8. Log biomass / 100m²→Log Alt

9. Log effective / 100 m² →Log Alt

10. % Invertivorous individuals (- exotic and tolerant species) →Log Alt

11. % Tolerant species →Log Alt

Since only few undisturbed reaches can be sampled, 95 % of the highest metric values were retained, and the highest value for each class of WSA or Alt was used as estimates of the reference condition. Based on these maximum values per class a 2nd order polynomial regression curve (MVL) was fitted to describe the “natural” relation between the metric and changes in environment condition.

The area under the MVL was then divided into three sections (i.e.2Y/3 and Y/3 curves) and used as threshold values to rate the corresponding metrics (Figure 3c.8.2). A rating of 5, 3 or 1 was then assigned to each metric, according to whether its value approximates (5), deviates moderately from (3) or strongly deviates from (1) the value expected at the reference sites. The final IBI is the sum of the 11 ratings and varies from 11 to 55 in 5 quality classes: excellent, good, fair, poor and very poor (see below). A "no fish" class was assigned when repeated sampling found no fish.

Score	**Integrity classes**
[50-55]	very good
[44-49]	good
[33-43]	fair
[22-32]	poor
[11-21]	very poor
No fish	

Multi-parameters models on reference sites (MMI)

The French strategy for designing a fish based index was inspired from the method recently developed in France for standardising a Fish Biotic Index usable nation-wide (Oberdorff *et al*., 2001 and Oberdorff *et al*., 2002). The fundamentals of the approach are to describe the link between fish community attributes and several relevant environmental parameters in the absence of degradation (Oberdorff *et al*., 2001). The aim was to predict the characteristics of fish assemblages at a given site as a function of a set of variables reflecting natural conditions at different scales, from local to regional.

Reference selection

The first step consisted of selecting the “reference sites” of the DESIG data set on the basis of the global indicator of ecological quality previously defined. They represented about one third of the samples

Models

The method aims to predict the values of each metric to be expected at a given site depending on a combination of several descriptors of environmental conditions, and in the absence of major environmental stress.

Stepwise multiple linear regression was used to analyse the relationships between each metric and the explanatory variables. These regressions were run on the "DESIG" data set restricted to the 94 locations considered as "reference". Five abiotic variables (Dist, Wid, WSA,, Alt, Slop, Jan and Jul Air T°) easy to measure and previously recognised as major determinants of fish assemblage patterns were introduced in the models as dependant variables, after transformation to remove colinearity (G as linear combination of Dist, WSA and Wid ; Jan+Jul and Jul-Jan air T°), minimise the effect of non-normality (Log and square transformation) and to increase the linearity of the relation.

Measure of the deviation and scoring criteria

Based on the reference situation of the "DESIG" data set, the previous models led to the prediction of the theoretical values of the metrics as a function of environmental conditions. Using the whole DESIG data set (representing a wide range of situations from highly impaired degraded to roughly intact situations), the deviation between observed and expected values of each of the metric model was used as indicator of the degree of degradation. For each metric, the distribution of residual values was divided into 5 equal categories ranging from 1 to 5 (reflecting respectively degraded to unimpaired situations) and five corresponding thresholds values. Depending on the expected variation trend of each metric as a function of degradation, two symmetric scoring systems were used. For the metrics expected to increase with degradation (%OMN, %TOL, and %SpTol), the higher the deviation values, the stronger the degradation. Conversely, for the metrics expected to decrease with degradation, the lower the values, the stronger the degradation. This step allowed identification of the thresholds values that were used for the assessment of sites.

Finally, the sum of the 11 scores produced a continuous scoring index ranging from 11 to 55. This range of values was transformed into five equal classes of fish integrity to rate the sampling sites as follow: Very Degraded [11-20], Degraded [21-28], Modified [29-38],Sub-Conform [39-47] and Conform [48-55].

Validation - Discussion

The study of both indices variations, and especially the tests of sensitivity were conducted on the "VAL" data set, which was independent from "DESIG" one, that has been used for the models adjustment and determination of the scoring calibration. The validation was based on several criteria among which were the global sensitivity to degradation, the study of rating accuracy, and the robustness to regions, river types and sampling variations.

Global sensitivity to degradation

Based on ANOVA using index score as dependent variable and expected abiotic quality as factor, both indices were very efficient in discriminating over a gradient of anthropogenic perturbations. TMI discerned the first four classes of ecological quality but fails in discriminating between class 4 and class 5, while MMI statistically discerns significantly every classes except one (between 3 and 4), but conforms with the expected general linear increase between fish index score and expected abiotic quality of sites (Figure 3c.8.3).There is no way, at this stage, to definitively promote one method instead of the other.

Accuracy of the rating, and robustness to regional and river type variations

We studied the conformity of fish assessment relative to abiotic assessment with a tolerance of one class difference between fish and abiotic index, both expressed through five quality classes. Assessment of biotic integrity was roughly accurate for both indices without significant differences, as they reach respectively 80% and 81% of conformity with abiotic classification. But the accuracy of the rating is quite different depending on the river type and the region. MMI was the most efficient in Wallonia (87%) and for grayling and bream zone (84%) whilst the worst results were recorded in The Netherlands (67%) and the trout zone (76%). Concerning the TMI, the best results were recorded in Wallonia (93%) while success in Flanders was particularly low (57%). Considering river types, the results of TMI were more homogenous, but the best results were recorded for the trout zone while the worst concerned the barbel (77%) and the bream (78%) zones.

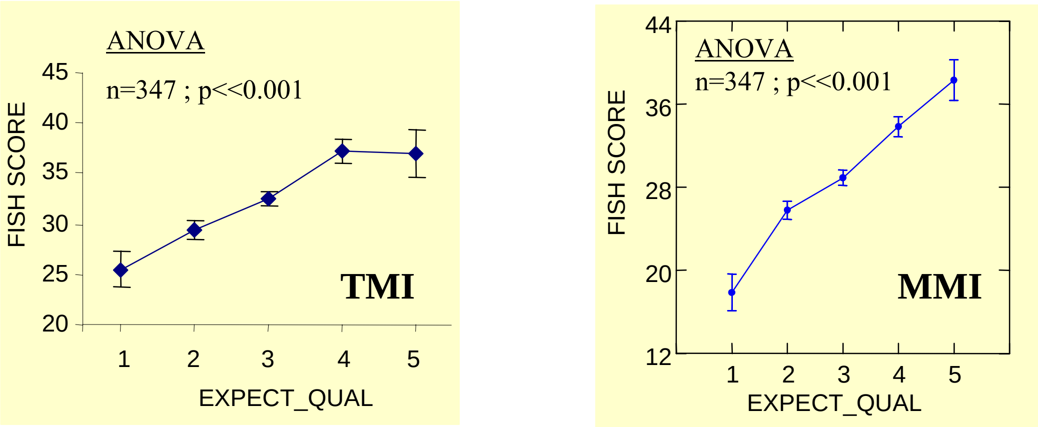

Figure 3c.8.3. Results obtained by the two methodologies applied to the Meuse data set (TMI and MMI).

Conclusion

Both indices gave very satisfying in assessing biotic integrity of streams and rivers of the Meuse basin, but they have their own advantages and drawbacks. TMI is simple to design and apply and does not require many environmental parameters, nor initial selection of reference sites to be built, but it does not implicitly integrate all major environmental factors that cause, or at least explain, the patterns of assemblage composition and distribution within and among water bodies at various spatio-temporal scales under natural conditions. MMI responds better to those criteria, but becomes more complex, and requires more information and particularly it needs a preliminary selection of reference sites that is somewhat difficult and subjective.

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