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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Development of a river-type classification system (D1)

Compilation and harmonisation of fish species classification (D2)

FINAL REPORT

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A project under the 5th Framework Programme Energy, Environment and Sustainable Management. Key Action 1: Sustainable Management and Quality of Water

Contract n°: EVK1 -CT-2001-00094

May 2002

SUMMARY

Work Package 1a: Development of a river typology

Integration of the existing national river classification systems of FAME member countries with the requirements of the Water Framework Directive is an ongoing process, with few countries at a stage where their system wholly complies with either of the two schemes proposed in the WFD. The typology developed within FAME to account for fish distribution in European rivers was derived on two main levels, using common themes from national schemes and the models proposed by the WFD.

- Grouping similar basins/rivers together at a "whole river/basin" level.
- Within river zonation to account for river zone variations.

This "two levels of variability" approach should ultimately produce groups of rivers for which river-type specific reference conditions can be created. These river-type specific reference conditions should then be applicable to a number of similar rivers and then can be modified/modelled to account for within-river zonation. A scheme was proposed for use during the FAME project, using a four-level series of abiotic criteria. The abiotic criteria selected describe the habitat conditions that "should" be present under undisturbed conditions. Ultimately the biotic community present should be a function of the prevalent abiotic habitat (bearing in mind zoogeographic factors). The two levels of the typology (hydro-ecoregion and basin size) grouping "whole-river" types should account for the majority of zoogeographic features of fish distribution. However, the within-river zonation is difficult to assess on a purely prescriptive basis. The development of the FAME typology to account for within-river zonation will include biocoenotic modelling to either establish the typology (set type boundaries) or to validate an *a priori*, prescriptive, zone-typology.

Work Package 1b: Fish species classification

The use of a multi-level, functional-community approach, to the assessment of fish populations and ecological quality requires that all fish species are classified according to their functional position within the community and ecological requirements. The FAME project has developed a standardised scheme, based around the functional guild concept, to address the requirements of a multi-metric assessment index. Published scientific literature, national fisheries reports and unpublished "grey" literature were collated, together with information from existing classification schemes, to produce a standardised classification scheme for fish species which are known to occur in FAME countries.

Fish were classified according to their zoogeographic status (Native, Introduced, Endemic), trophic guild, reproductive guild, habitat guild (degree of rheophily and position in the water column), migratory behaviour, longevity and tolerance capacity. Where possible tolerance to specific stresses was assessed, including habitat degradation, water quality and acidification. Where information was lacking an overall assessment of general tolerance was made. A group of sentinel species, which were known to be common in specific river-zones and which provide good information of ecological quality was identified for each ecoregion. For these species information regarding size or age structure will be required in the multi-metric assessment.

CONTENTS

1. WP 1A: DEVELOPMENT OF A RIVER-TYPE CLASSIFICATION SYSTEM

1.1. Identification and characterisation of significant river types within FAME

Grouping of similar rivers is a prerequisite to following the river-type specific approach of the Water Framework Directive. The objective of this work package is to identify and characterise river types that are covered by the FAME central database and analysed in the subsequent workpackages, but not to establish a thorough river typology for every (sub-) ecoregion of concern. The characterisation of river types is based on the guidelines of the Water Framework Directive (Annex II) and existing national classifications.

Classification of river types to identify relatively homogeneous ecological systems and associated biological communities is generally required for two main purposes:

- Development of river-type specific reference conditions for the assessment of ecological integrity.
- Development and implementation of river monitoring programmes to give suitable coverage to all river- and reach-types.

The key aim for the FAME project is to develop a typology which proposes the major river types of 16 ecoregions at the national scale so that river-type specific approaches to reference conditions and ecological analyses can be undertaken in the later workpackages (WP 6 and 7 modelling of reference and degraded conditions).

1.2. Concepts in river typology and the WFD

There is a long history of organising information and classification of biological and ecological systems so that understanding can be advanced, and management principles and practice can be developed. Most attention remains focused on conceptual and regional approaches to stream classification rather than on general approaches across contrasting ecoregions. It could be argued that such a quest is of academic merit only, and that because of the inherent complex characteristics within each stream type (system structure, bio-geochemistry, resistance and resilience to change and productivity), which are related to local climate, geology, disturbance due to cultural, demographic, economic and political regimes, the conceptual and regional approach is the realistic one by which assessment of fisheries potential can be translated into management prescriptions and application.

It is against this conceptual background that the WFD has dictated the classification of river types based on geographical and abiotic criteria. As the first stage in establishing the ecological status of surface waters, the WFD requires that a water body is placed into one of the regional "types" described by Illies (1996). This classification assumes that the 25 biogeographical regions or ecoregions (Figure 1) proposed are relatively homogeneous ecological systems, and the biological communities, e.g. fishes, are correlated with these ecoregions. For fishes this is implicitly untrue, as many of the ecoregions are large, and there may be variations in the natural biological communities within an ecoregion. The WFD requires that this variation is described by dividing (for example) rivers into water body types or ecotypes. The water body type is determined by physicochemical descriptors. The ones proposed under the WFD for rivers, extracted from Annex II, are listed in Box 1.

All biotic classification schemes assume a predictable relationship between the stream biota and geomorphological and hydrological controlling factors acting on the system. Ultimately, however, zoogeographic factors restrict the geographic scope of classification schemes based on fish assemblages. Many other factors affect community dynamics and limit geographical scope. Environmental regimes vary with climate and geology, regional variations from predictable to highly variable flow patterns, producing persistent, resilient communities, to those which show sharp temporal fluctuations in structure. Consequently, development of a river typology is extremely complex and requires a holistic approach, which may be beyond the scope of this project. Notwithstanding this, there is a need to develop a typology for river systems that forms the basis of the IBI system to be promoted under FAME. This requires the classification of ecologically equivalent units that comprise functionally similar species, life stages and/or communities so that generalisations can be elucidated. For simplicity, classification of the rivers probably needs to be developed on two scales: the ecoregion, the drainage-stream reach level.

Ecoregion: Ecoregional classifications such as that proposed by the EU, WFD, describe the potential distribution of fishes in relation landscape and geomorphic patterns. The Illies' (1978) classification, however suffers from the large size of many of the ecoregions and the variance within, For example, in the Iberian Peninsula (Ecoregion 1), the northern area is characterised by rivers with continuous flows of temperate regions, whilst southern rivers have a typical Mediterranean intermittent flow regimes. Consequently the river typology is highly variable and optional factors under WFD system B (Box 1) need to be applied to the typology. Also, some large rivers cross ecoregions (e.g. the Danube) and consequently exist on a larger spatial scale than Illies' ecoregions.

Drainage-stream reach: The basis of this level is to find large gradients (generic sense) to which the fauna must respond. Zonation schemes have used stream order, hydraulic stress and power, temperature and physicochemical gradients. Huet's (1949, 1954) longitudinal zonation uses a combination of gradient and stream width to relate reaches to fish communities characterised by individual species (Figure 2). This approach is difficult to apply to rich faunal assemblages covering various climatic zones but can be used when empirically derived for a particular area. It also shows inconsistencies with observed data (Cowx 2001), mainly because man has impacted on rivers (Woolland *et al.* 1977). Furthermore, longitudinal zonation does not explain how stream reaches influence assemblages, does not account for potadromy, and does not explain the distribution of fishes in rivers with significant floodplains. Consequently a generic model is required. The concept of Schumm (1977; Figure 3) offers such an approach. In this scheme, channel size is assumed to increase systematically through a river system as the increasing drainage area contributes larger flows to the trunk channel. The morphological scale of the channel changes accordingly (Figure 3). Because of the significant correlation between channel scale and position in a drainage system, classification of river channels of the basis of their position in the drainage system is of relevance, as shown in Figure 3.

From the above dialogue it can be seen that to classify rivers into types is fraught with difficulties. The FAME typology must define the relationship between river typology and reference condition (Workpackage 2). The categorisation is important because the river types that are defined represent the basis for the river-type-specific reference conditions. Note, the more "differentiated" the river types are defined the more precisely human impacts can be detected but the more bifurcated and disjointed the classification becomes. One of the biggest problems faced was that there is an inconsistency in the WFD as the river types/reference conditions are defined by abiotic criteria and the assessment is done by biotic metrics. If the typology does not account for the biological zonation we will have a potential mine field in which natural characteristics override human impacts.

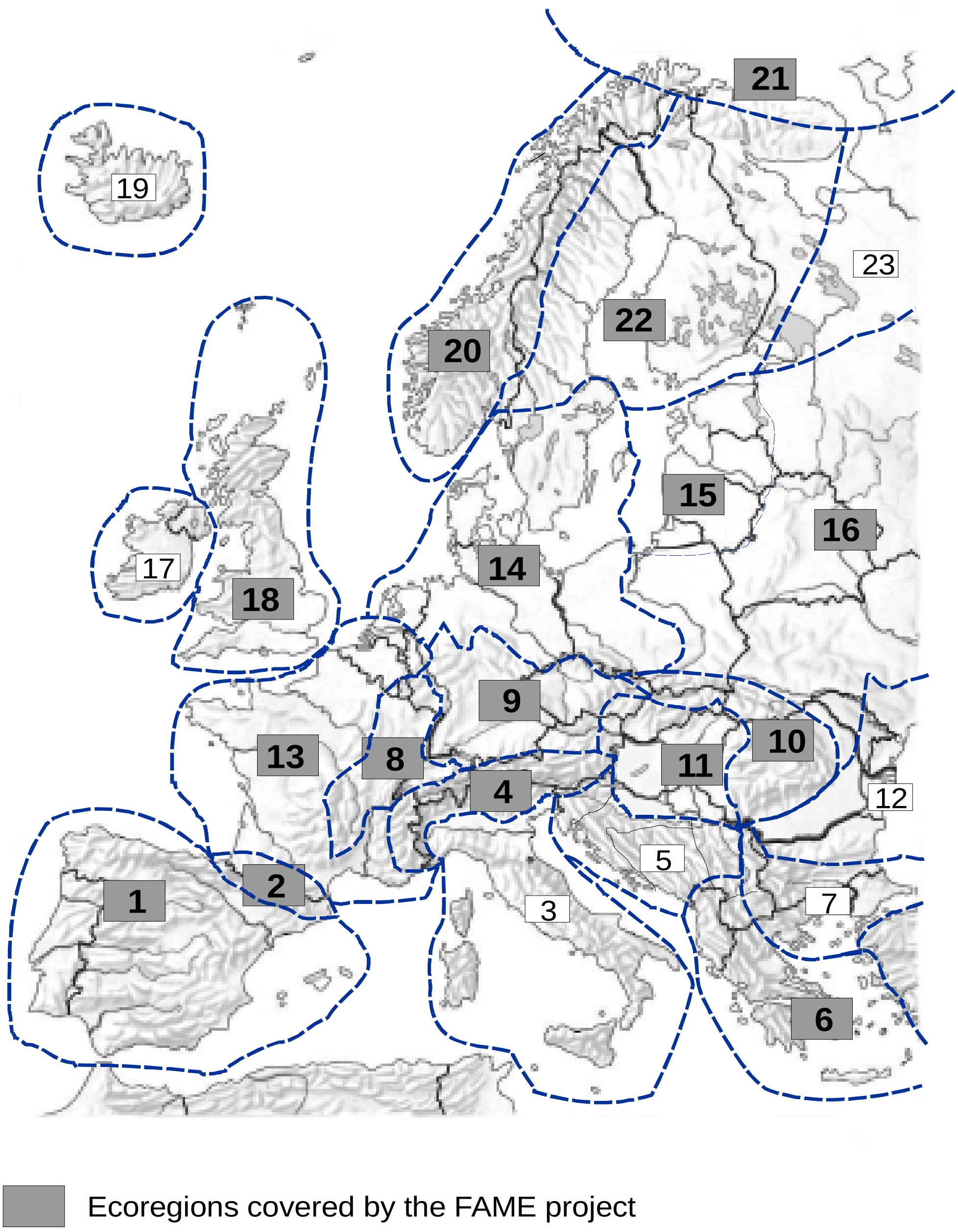
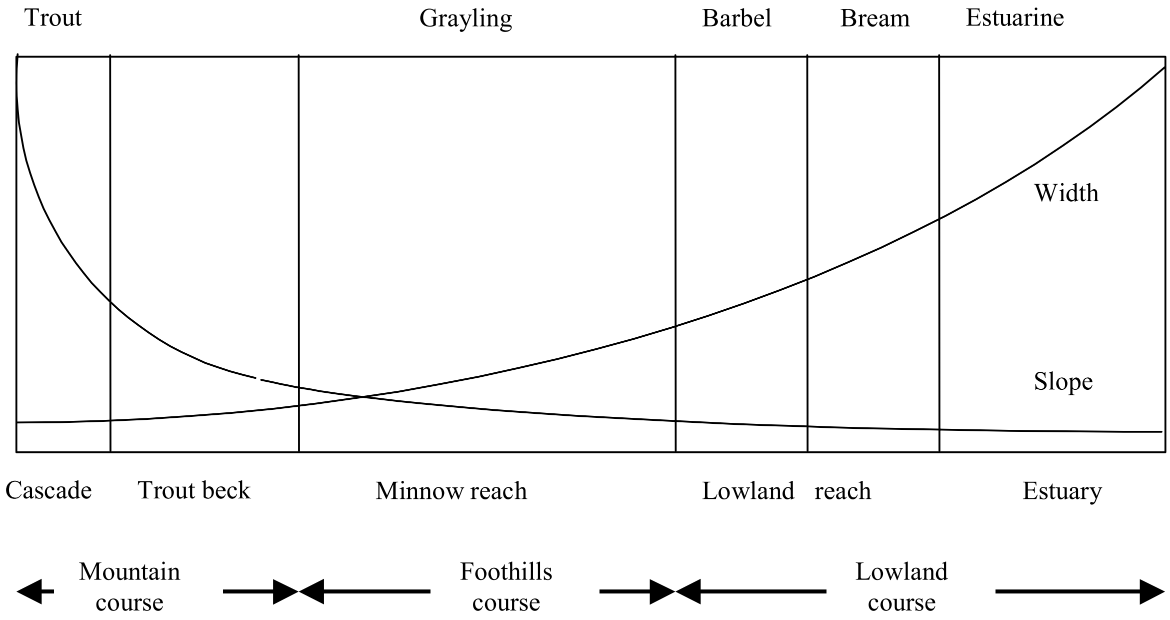


Figure 1 Map of ecoregions in Europe as defined by WFD

Box 1: Definitions of ecoregions and Surface Water Body Types from the Water Framework Directive :Rivers	
System A	
Fixed Typology	Descriptors
Ecoregion	Ecoregions shown on Map A in Annex XI (Figure 1)
Type	Altitude typology high > 800 m mid-altitude 200 to 800 m lowland < 200 m Size typology based on catchment area small 10 - 100 km^2 medium > 100 to 1 000 km^2 large > 1 000 to 10 000 km^2 very large > 10 000 km^2 Geology Calcareous Siliceous Organic
System B	
Alternative Characterisation	Physical and chemical factors that determine the characteristics of the river or part of the river and hence the biological population structure and composition
Obligatory factors	Altitude Latitude Longitude Geology Size
Optional factors	Distance from river source energy of flow (function of flow and slope) mean water width mean water depth mean water slope form and shape of main river bed river discharge (flow) category valley shape transport of solids acid neutralising capacity mean substratum composition chloride air temperature range mean air temperature precipitation



Zone	1	2	3
Mean monthly temperature	Rises to 20°C		Rise to over 20°C
Substrate	Rocks, stones, gravel EROSIONAL		Fine gravel, sand, silt accumulation DEPOSITIONAL
Flow	Fast turbulent		Variable to stable, water turbid
Oxygen	High to saturated		Variable to deficient
Faunal community	Low to increasing species diversity	High diversity	Diversity maintained
Biocenosis	Plecoptera, Trichoptera, Ephemeroptera, Coleoptera, Diptera	Ephemeroptera, Trichoptera, Diptera	Trichoptera, Diptera, Mollusca, Crustacea, Hirudinea, Hemiptera, Odonata, Tubificid worms
Trophic group	Shredders	Collectors, grazers	Grazers, filter feeders
Class	← RHITHRON →	← POTAMON	→
Dominant and common associated fish species	*Salmo trutta* *Salmo salar*	*Thymallus* *Barbatula* *Phoxinus* *Cottus* *Barbus*	*Rutilus* *Leuciscus cephalus* *Leuciscus leuciscus* *Abramis* *Cyprinus* *Esox*

Figure 2 River zones, biotopes and biocoenoses (Huet 1949, 1954).

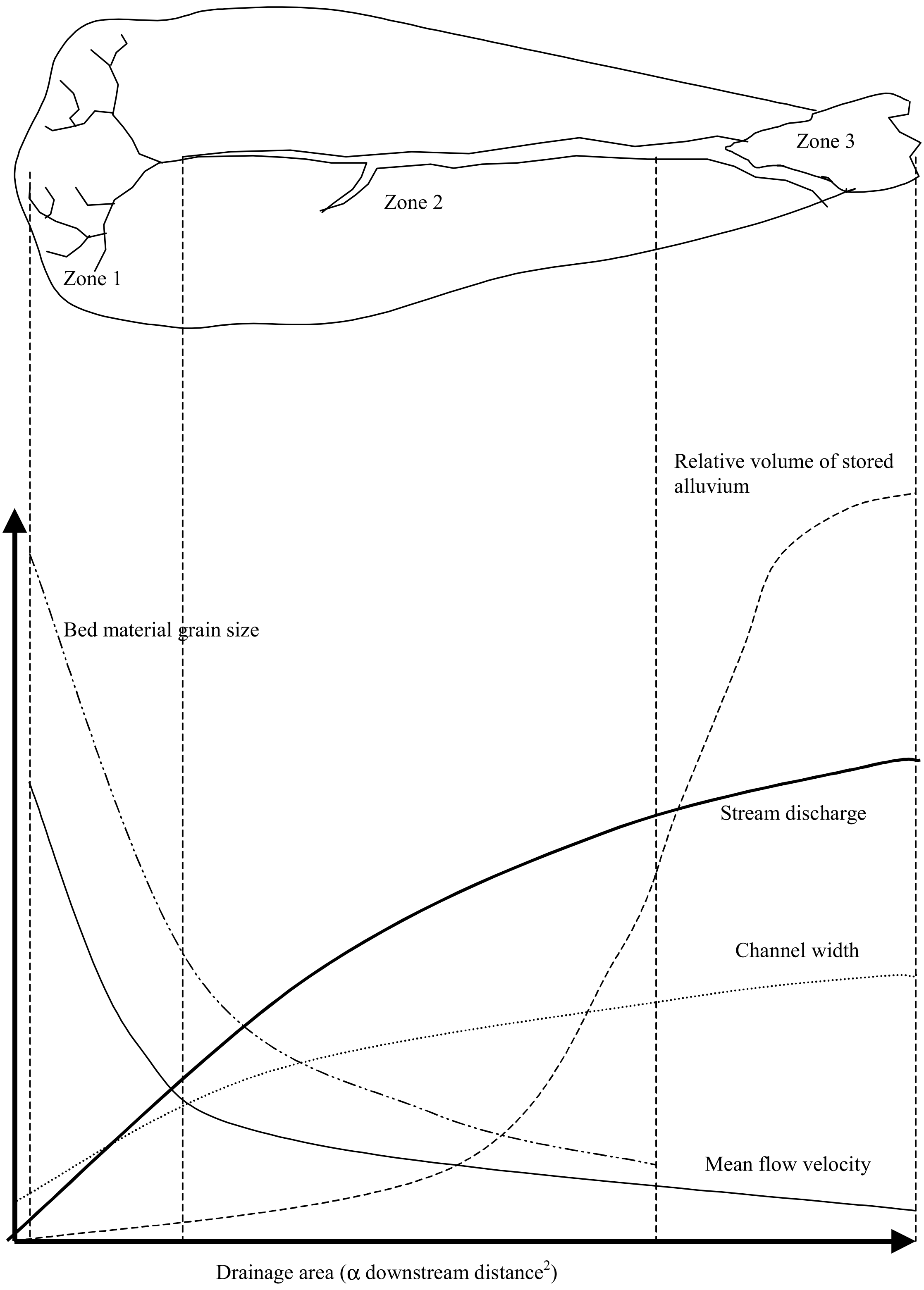


Figure 3 Schematic representation of the variation in channel properties through a drainage based (based on Schumm 1977).

1.3. National river classification schemes and comments from FAME partner countries

1.3.1. *The Netherlands*

There is to date no agreed river typology in the Netherlands nor has a choice been made for either System A or B of the EU-WFD. The partners in the Netherlands reported that river typology and zoogeographic factors together are the basis for defining reference fish assemblages. Consequently river typology needs to be developed on various (two?) scales including ecoregion (zoogeographic) and catchment level criteria. Traditional longitudinal zonation may be too simplistic as similar characteristics may be found at more sites (‘beads on a string’ concept) depending on the geological setting. The Netherlands advocated selecting environmental criteria that are known to structure fish communities (e.g. flow, depth, substrate and vegetation). Also, for floodplain rivers, typology and consequently the sampling of a representative stretch should cover the full width of the active floodplain (e.g. 20-100 yr flood event). The partners in the Netherlands suggested that floodplains are also an essential part of rivers for fish and, therefore, boundaries for the active floodplain width have to be defined e.g. the area covered with water during a 20- or 100-yr flood event. Otherwise, a biased subset of the fish community is selected and typical floodplain species i.e. limnophilic or ‘black fish species’ (e.g. *Misgurnus fossilis, Carassius carassius*) are left out. The Dutch team presented the key aquatic components of lowland floodplain rivers (Table 1).

Table 1 Aquatic components of lowland floodplain rivers (adapted from van der Molen *et al.* 2000)

Ecotope	Hydro- and morphodynamics	Depth	Substrate	Vegetation
Main channel	strong – very strong	> 2, 1-2 or < 1 m	gravel or sand	+ or – aquatic
Secondary channel	normal –strong – very strong	> 2, 1-2 or < 1 m	gravel, sand or silt	+ or – aquatic
One-sided connected floodplain water body	normal	> 5, 2 – 5, 1-2 or < 1 m	sand, clay or silt	+ or – aquatic
Floodplain water body	low (< 20 d.yr-1 connected) or normal (> 20)	> 5, 2 – 5, 1-2 or < 1 m	sand, clay or silt	+ or – aquatic; + or – helophytes

1.3.2. *Germany*

The current typological approach in Germany has been developed by a working group of non-fisheries biologists. Currently this typology still has draft-character although it is seen as obligatory for Germany and for all WFD relevant species groups. Further verification and development by people working on the different species groups key to the WFD has to be undertaken to finalise the typology. For defining fish-reference-conditions for the different river types it was considered that the following adaptations of the typology approach were needed:

- As the current typology makes very detailed distinctions in small rivers (15 types/subtypes), which cannot be confirmed by different coenotic compositions, one reference will cover several "small river types".
- A further splitting of "very large river types" is necessary as only two types currently cover streams with floodplains. Distinction of river basins with different species composition (e.g. Danube and Rhine) is essential. This is not possible within the current German typology approach.

Regional stream typologies have been developed for several parts of Germany since the early 1990s. They generally consider parameters of morphology, water geochemistry, hydrology and biocoenoses (most often based on benthic macroinvertebrates). A digital and analogue map of ‘aquatic landscape units’ including the network of watercourses and the dominant valley forms has been developed. These landscapes are geomorphologically and geochemically more or less homogenous landscape units, in which specific water types have their prevalent occurrence. Consequently the “most important, biologically relevant stream types in Germany” were derived (Schmedtje *et al*. 2001). The typology was designed as a basis for several projects and applications relying on a valid typological description of waterways. A compilation of the 20 most important, biologically relevant stream types was presented last year. River type descriptions were based on both “top-down” (map of ‘aquatic landscape units’ in Germany) and “bottom-up” approaches (regional typologies from the federal states). All geomorphological stream types, biologically relevant stream types and the relevant longitudinal zonation types were considered. Biological differentiation was based mainly on macroinvertebrate assemblages. The rough structure of the German river typology principally follows WFD System A (altitude, geochemistry, catchment area), while the detailed typology itself, is based on parameters listed under System B. It is presently planned to validate and update this basic set of 20 stream types and include some common hydrological variants of some stream types in the year 2002. The large rivers also require a more detailed differentiation based on the fish fauna. Thus a total of 30 stream types is to be expected (Figure 4).

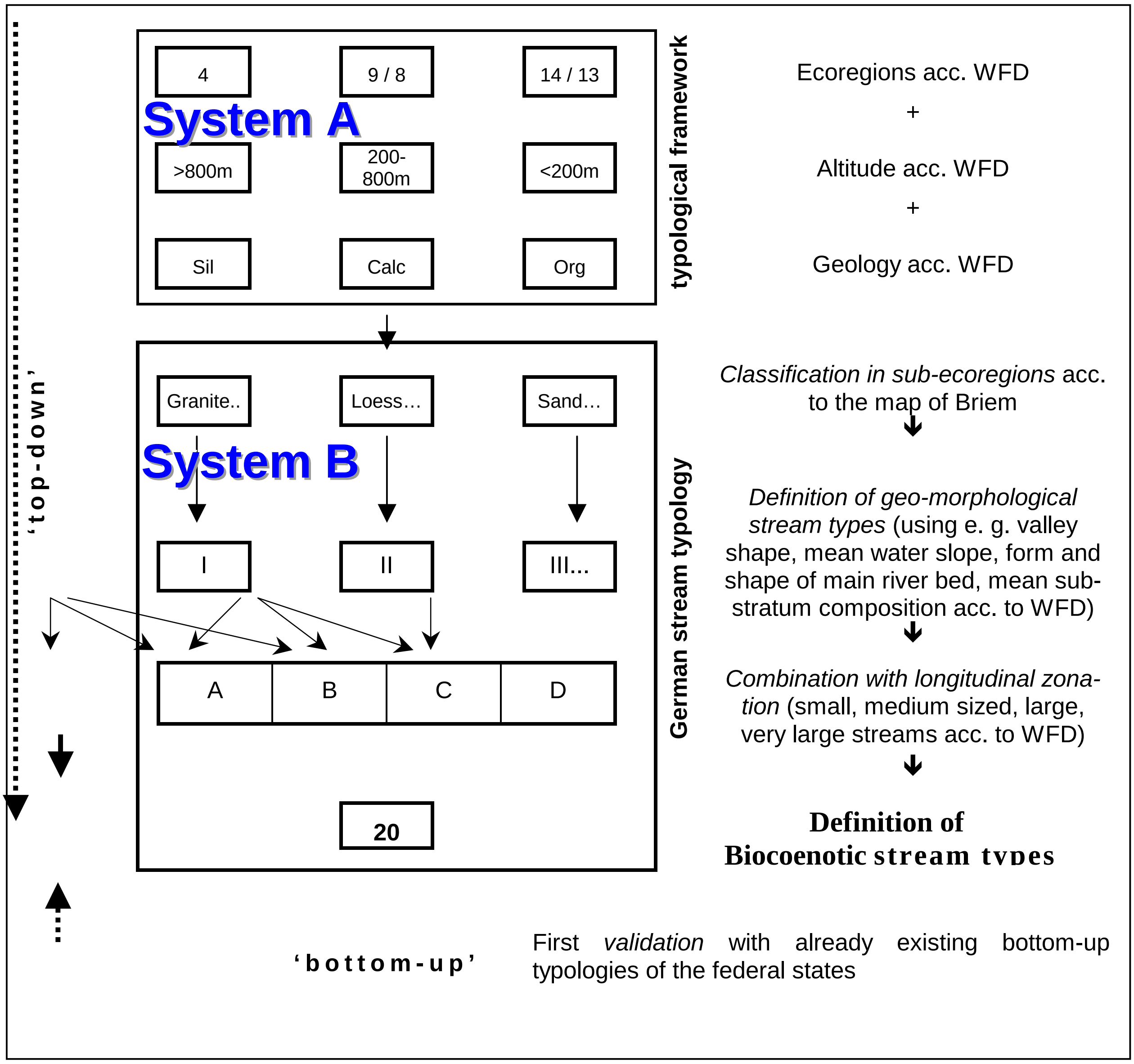


Figure 4 Classification scheme for the German river typology.

1.3.3. *Belgium*

Huet's (1949, 1954) approach to river typology is the scheme currently used in Belgium. River slope and width are used to define the different river zones based on fish community structure. This distinguishes the Trout-zone, Grayling-zone, Barbel-zone and Bream-zone. A fifth zone is the brackish water zone although at present there is no agreement on the delimitation of the brackish water zone. These criteria are used to define the kind of river type specific index and reference condition to apply in Belgium. Further research is being undertaken on another approach to define different typologies in Flanders, which will combine the Huet typology and ecoregional variations (e.g. sandy soil area, loam soil area etc…). The results are due at the end of May 2002.

Table 2 Criteria to define the zonation (based on Huet 1949).

Width (m)	Slope ‰	Zone	Slope ‰	Zone	Slope ‰	Zone	Slope ‰	Zone
≥ 100	<0.25	bream	≥ 0.25	barbel				
≥60	<0.33	bream	<1.25	barbel	<4.5	grayling	≥4.5	trout
≥30	<0.45	bream	<1.5	barbel	<5	grayling	≥5	trout
≥25	<0.5	bream	<1.75	barbel	<5.5	grayling	≥5.5	trout
≥20	<0.5	bream	<2	barbel	<5.7	grayling	≥5.7	trout
≥15	<0.6	bream	<2	barbel	<6	grayling	≥6	trout
≥10	<0.7	bream	<2.3	barbel	<6.5	grayling	≥6.5	trout
>4.5	<1	bream	<2.7	barbel	<7	grayling	≥7	trout
≤4.5	<1	bream	<3	barbel	≥3	upstream *		

* Includes trout and grayling zone

1.3.4. *France*

System B of the WFD was retained as the approach to river typology in France. France initially conducted a "hydro-ecoregion" approach to provide the regional framework necessary to derive a typological classification of freshwaters. The approach used was an adaptation of the terrestrial ecoregion concept for aquatic systems. The "hydro-ecoregions" defined for France (Figure 5) focused on geology, topography and climate as controlling environmental factors. To establish water body types at the national level these "Hydro-Ecoregions" were linked with different classes of stream order (Strahler 1952) for the whole hydrographic network (work in progress). Three classes of stream order were retained:

1) stream orders 1, 2 & 3;
2) stream orders 4 & 5;
3) and stream orders ≥ 6.

This should result in around 80 types of water body for all French rivers (results should be available in July 2002).

Figure 5 French "hydro-ecoregions" based on geology, topography and climate as the controlling environmental factors.

1.3.5. *Greece*

In Greece there is no existing official system for the typological characterisation of rivers. However, Skoulikidis (1993) categorised the Greek mainland into three basic river types, using geological, climatic and hydro-chemical criteria. This classification has been extended, in the framework of AQEM project, and the whole country was separated into three core river types, that were additionally based on System A (according to the specifications of AQEM project) (Figure 6). This classification used catchment size, mean catchment altitude, catchment geology, river hydrochemistry and climatic variations. The three core Greek river types established for the AQEM project were:

- Mid-altitude, mid-sized, siliceous streams in northeastern Greece.
- Mid-altitude, large, siliceous streams in central and north Greece.
- Mid-altitude, mid-sized, calcareous streams in western Greece.

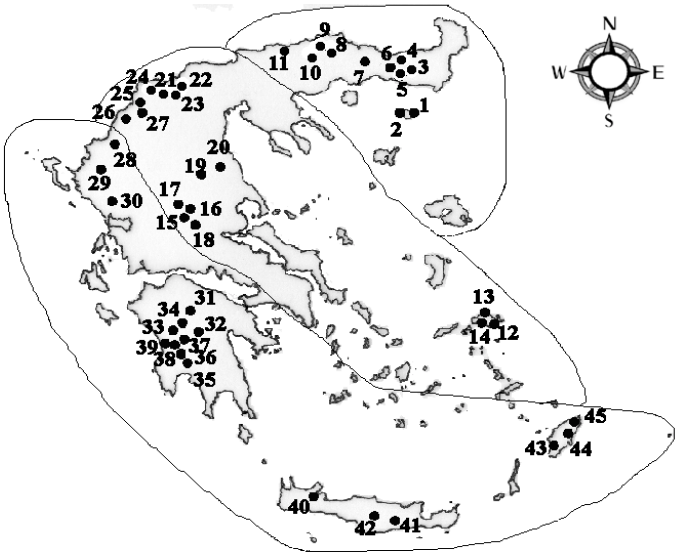


Figure 6 The three Greek core river types and sampling stations used in the AQEM project

1.3.6. *Portugal*

In Portugal, no attempts were made to define a national river typology (or hydro-regions) before the Water Framework Directive. As a first attempt, the existing Portuguese biogeographical regions (based on geology, climate and natural vegetation) were proposed as ecoregions (Figure 7). The classification of water body ecotypes by the Portuguese Water Authorities is currently undertaken using System A from the WFD. Nevertheless, the comparison of these *a priori* ecoregions with the *a posteriori* biological zonation, based on river macrophytes, macroinvertebrates and fish, showed differences between those ecoregions, the biological zonation, and also between communities. Furthermore, multivariate analyses showed that abiotic factors other than those obligatory in the WFD should be considered. Therefore, the partners in Portugal have recommended the WFD System B approach to the Portuguese Water Authorities. For practical purposes, the partners in Portugal use the following river typology:

- Coldwater streams;
- Small and medium-sized, permanent, warmwater streams;
- Small and medium-sized, intermittent streams;
- Large rivers.

The partners in Portugal stressed that the typology developed for FAME will require testing for applicability.

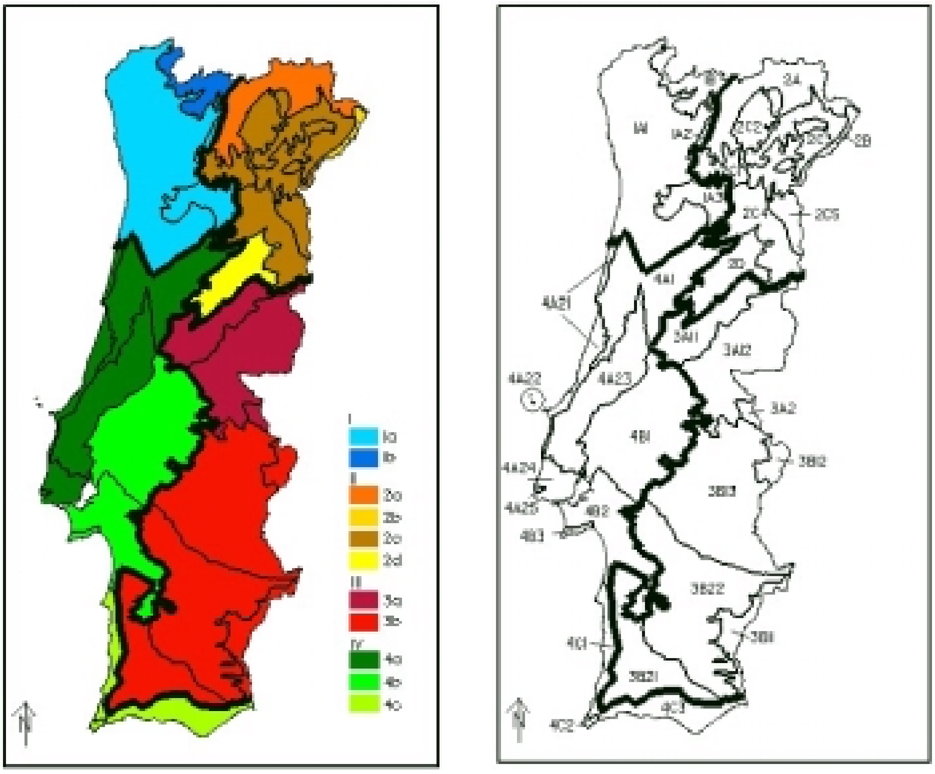


Figure 7 Sub-ecoregions proposed for Portugal.

1.3.7. *Lithuania*

The previous typology used in Lithuania for IBI assessment was based mainly on the similarity of fish communities and the genesis of the main body and facultative part of fish communities with increasing river length (distance from source). The main bodies of 12 types were singled out in four groups of rivers, differing in length (brooks - up to 10 km length, streams – 10-50 km, middle-size rivers – 50-200 km, large rivers - >200 km). This classification almost entirely conformed to a classification by catchment size. Fish communities in each river length group were divided into two main sub-types, differing mainly in one distinctive feature – presence or absence of salmonid community. The main abiotic criteria for river grouping into subtypes was average water temperature in July – above or below 18° C, i.e. rivers supporting populations of salmonids (or salmonid complex fish species) and rivers clearly predominated by cyprinid fish species.

Although other abiotic criteria were not taken into account, this typology of rivers based on fish communities conformed quite well to hydrological regionalism of Lithuanian rivers. Three main regions differing in river hydrology (prevailing water supply and soils) were identified (Table 3).

- Southeastern hydrological region (Baltic highlands). Features: sandy soils, >50% underground water supply, average water temperature in July ~18°C, medium to low mineralisation (200-300 mg/l). Rivers are predominated by salmonids and typical accompanying fish assemblage.
- Western (Samogitian) highland. Features: composite soils and hydrology, mineralisation >500 mg/l, average water temperature in July - ~18-20°C, rivers support salmonid and mixed type fish assemblages.

- Mid-Lithuanian and Baltic seacoast lowland. Features: hard soils, underground water supply < 25%, mineralisation > 500 mg/l. average t° in July >20°C. Rivers clearly predominated by cyprinids. Sometimes salmonids are present in the smallest streams or upper reaches of large rivers.

The partners in Lithuania considered that WFD classification is entirely inappropriate in their region. Differences in type of water supply determine that none of the WFD B optional factors seemed to be relevant. Average water temperature in summer time was identified to be the determining variable. Each hydro-region possesses typical rivers and intermediate forms. Data analysis and detailed classification is an ongoing process. The Lithuanian partners expect to obtain around 15 river types.

Table 3 Preliminary classification of Lithuanian rivers.

I				II			III				Sub-eco(hydro)regions	WFD B criteria
< 200				< 200			< 100				Altitude, m	WFD B criteria
Soft soils				Mixed soils			Hard soils				Geology	WFD B criteria
200-300				> 500			> 500				Mineralisation, mg/l	WFD B criteria
<100	<1000	<10000	>10000	<100	<1000	<10000	<100	<1000	<10000	>10000	Catchments size groups	WFD B criteria
18°C				18-20°C			>20°C				Av. water T°C in July	
S, S-C				S, S-C			S-C, C				Fish assemblages supported	
~15 types											Nos. of river types expected	

1.3.8. *Poland*

The Polish partners consider that there is a need to separate rivers according to catchment scale and river size. Also, there is a need to separate rivers on the basis of underlying geology. The best proposed river typology might be a combination of System A and B and should include physical and chemical factors which are considered as most important in structuring riverine fish communities. There is, as yet, no agreement upon typology in Poland. Currently, most biocoenotic river type classification systems are based on System B – physical and chemical description of altitude, latitude, longitude, geology and size, and the characteristics of the flow regime.

1.3.9. *Austria*

Austrian attempts to typify rivers go back more than a decade (Moog & Wimmer 1990). Nation-wide classifications of Austrian rivers are available in terms of stream order (Wimmer & Moog 1994), flow regime (Mader *et al*. 1996), ecoregions (Moog *et al*. 2001, Schmidt-Kloiber *et al.* 2001) and landscape types (Fink *et al*. 2001). In respect to the implementation of the WFD, the Austrian government decided to use System B of Annex II of the WFD as the basis for the development of the Austrian river typology.

The process of developing an Austrian river typology suitable for the WFD is still ongoing. The classification system is being devised in three steps:

- Abiotic classification.
- Biotic validation.
- Final definition of river types.

For the first step, Wimmer *et al.* (2000) developed a pre-classification of Austrian rivers based on landscape types (Fink *et al.* 2001), altitude (class boundaries: 200, 500, 800, 1500 m), ecoregion (Illies 1978, adapted by Moog *et al.* 2001), as well as on geology and flow regime (Mader *et al.* 1996), yielding 17 "type-regions" and 9 additional special types ("large rivers"), comprising a total of 26 "basic types". Additionally, two fish-based classification approaches are currently being undertaken in Austria, both are based on the fish region concept and are described below.

An expert panel composed of government representatives of Austrian provinces and private consultants ("Austrian governmental WFD sub-working group on fish", chaired by the FAME applied partner) is developing a classification according to the fish region concept within the abiotic "basic types". It distinguishes between small, medium and large rivers, resulting in the following fish region (sub-) types:

- Epirhithral
- Metarhithral
- Hyporhithral small
- Hyporhithral large
- Epipotamal small
- Epipotamal medium
- Epipotamal large
- Metapotamal

The second approach also follows the fish region concept, yet is based on statistical analyses of fish data (research project of the FAME scientific partner). Fish data were available for 274 rivers and 3229 sampling sites/occasions representative of a large proportion of Austrian rivers. Additional information on human impacts exists for 2716 sites on 188 rivers. Data for 1284 near-natural or only slightly impacted sites were also extracted for the analysis. Due to the topography rhithral rivers predominate in Austria. To overcome the spatial differences of samples and to generate larger spatial units, a two-step approach in classifying fish communities was used. Firstly, fish samples were clustered into sample-specific fish communities. 16 sample-specific community types could be identified. For the second step, an existing river section classification system of Austrian rivers was used as spatial units (Muhar *et al.* 2000). These homogeneous river sections were defined based on geology, valley shape and morphological river type (mean section length 6.4 km). Sections with similar compositions of sample-specific communities were combined to homogeneous fish types by means of hierarchical cluster analysis. The cluster analysis on the river segment level, differentiated 9 fish community types (Figure 8 and Table 4).

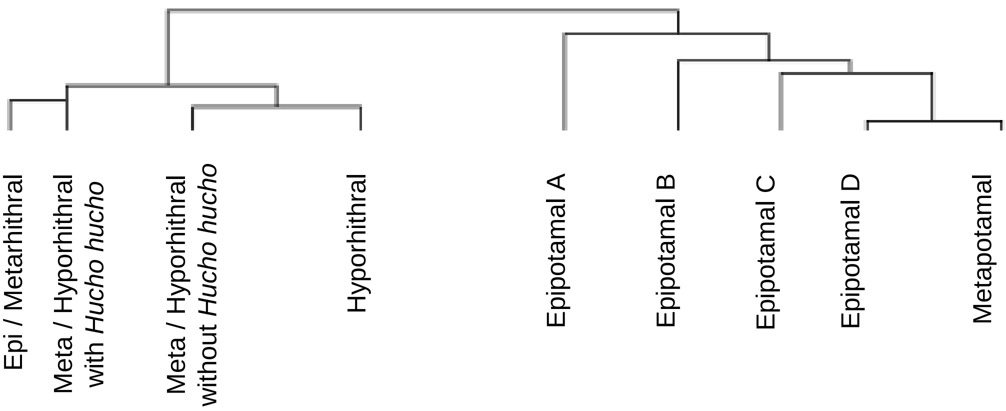


Figure 8 Dendrogram of river-section-specific fish community types in Austria.

Table 4 Summary of river-section-specific fish community types (main types) in Austria.

	Fish species (dominant)	**Total number of species per type > 1 %**	**Type**
Main type 1	*Salmo trutta*	3	Epi- / Metarhithral
Main type 2	*Salmo trutta, Thymallus thymallus*	8	Meta- Hyporhithral without Hucho hucho
Main type 3	*Salmo trutta, Thymallus thymallus*	11	Meta- Hyporhithral with Hucho hucho
Main type 4	*Thymallus thymallus, Salmo trutta*	14	Hyporhithral
Main type 5	*Salmo trutta, Leuciscus cephalus, Phoxinus phoxinus, Barbatula barbatula, Thymallus thymallus, Leuciscus leuciscus*	25	Epipotamal A
Main type 6	*Barbatula barbatula, Leuciscus cephalus, Gobio gobio*	15	Epipotamal B
Main type 7	*Leuciscus cephalus, Chondrostoma nasus, Barbus barbus*	16	Epipotamal C
Main type 8	*Chondrostoma nasus, Barbus barbus, Leuciscus cephalus, Alburnoides bipunctatus*	24	Epipotamal D
Main type 9	*Abramis brama, Abramis bjoerkna*	24	Metapotamal

In addition to current fish data of near-natural reference sites, historical presence/absence data for the larger rivers and more common or economically valuable species were also used in a hierarchical cluster analysis. This analysis identified four main types of river fish community.

The first step – the analysis of current data in near natural sections – distinguished nine main types. The historical approach produced two additional types, the hyporhithral/epipotamal-floodplain and the epi-/metapotamal with a high proportion of Danube endemics. From the latter, the so-called Danube complex was "extracted" and added – together with the floodplain type – to the types identified with current data. Current data indicated a more differentiated picture of the epipotamal than expected from the classical fish region concept. Epipotamal A represents a transition region between hyporhithral and epipotamal, with a high proportion of brown trout. Epipotamal B is dominated by loach, chub and gudgeon. Epipotamal C and D represent the typical barbel region with nase and barbel dominating, whereby the latter is more related to the metapotamal. The metapotamal is clearly separated but plays a subordinate role in Austria. Thus, the total number of fish types increases to 11 (respectively 12) (Figure 9).

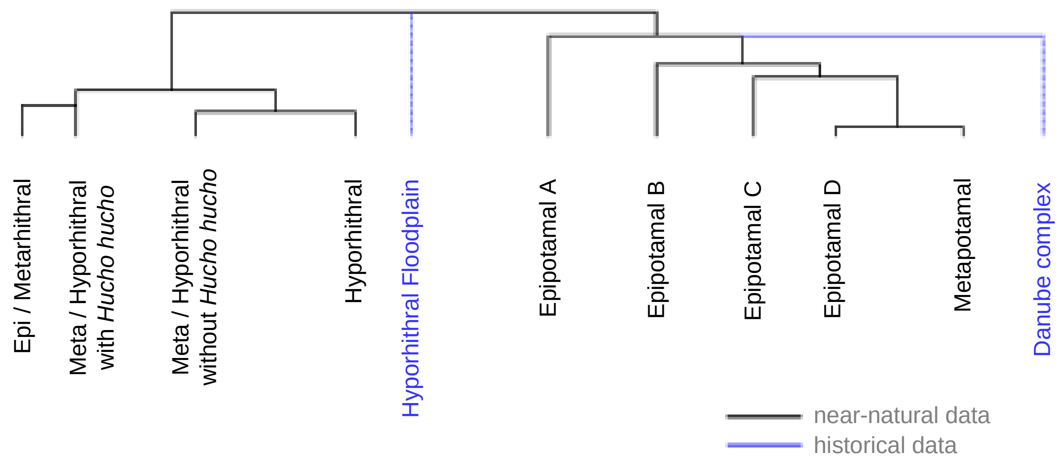


Figure 9 Synthesis of current and historical Austrian data.

The Austrian results show that neither current data nor historical data alone are sufficient to explain the whole range of fish type variability in Austria. Integrating both sources of information, however, reflects a more complete picture of the original fish-based river types.

As shown above many activities are dedicated to the development of river typologies. The next steps are to develop a common river type classification will be the:

- integration of existing fish-based typological concepts into a common Austrian-wide classification;
- linking of biological element classifications (fish, macrozoobenthos, and phytobenthos) by common abiotic characteristics.

1.3.10. *Sweden*

A common typology according to the WFD has not yet been decided for Sweden. The WFD System A results in 84 types of streams and rivers. However, the Swedish partners feel that System A will not give the maximum relevance for the fish fauna. A research project "DElimitation of Swedish Ichthyological Regions" (DESIRE) has been undertaken to describe water body types in Sweden according to fish community type. To approach a typology scheme, the initial phase was a delimitation of regions that would be relevant for fish. DESIRE attempted to combine four ecoregion divisions into one classification scheme. The four criteria that were most important in defining fish specific ecoregions were:

- approximate Illies' ecoregions;
- marine regions;
- water districts with borders from main river catchments (Vattendragsutredningen 1996);
- the highest post-glacial marine coastal line (HC).

These four criteria were assessed to be critical given the history of the Swedish freshwater systems following glaciation and the resulting, variable, re-colonisation by fish. The resulting twelve regions show reasonable separation with respect to fish variables. With regard to fish species occurrence, species richness, density of individuals as well as abiotic factors, the number could be diminished from twelve to eleven or ten clearly distinguishable regions (Figure 10, Table 5).

Table 5 Approximate correspondence with Illies' ecoregions, highest marine coastal line (HC, above=1, below=0) and marine region of the seven areas and twelve regions in Sweden defined in DESIRE (DElimitation of Swedish Ichthyological REgions).

Area	**Region**	**HC**	**Denotation**	**Ecoregion (approximate)**	**Marine region**
1	11	1	Northern mountains	Boreal highlands	Bothnian Bay
2	21	1	Southern mountains	Boreal highlands	North Coast
4	40	0	North Norrland below HC	Fennoscandian shield	Bothnian Bay
	41	1	North Norrland above HC (excluding mountains)	Fennoscandian shield	Bothnian Bay
5	50	0	South Norrland below HC	Fennoscandian shield	North Coast
	51	1	South Norrland above HC (excluding mountains)	Fennoscandian shield	North Coast
6	60	0	South Eastern Swedish lowlands (below HC)	Central plains	South Coast
	61	1	South Eastern Swedish highlands (above HC)	Central plains	South Coast
7	70	0	North Vänern region below HC	Fennoscandian shield	West Coast
	71	1	North Vänern region above HC	Fennoscandian shield	West Coast
8	80	0	South Western Swedish lowlands (below HC)	Central plains	West Coast
	81	1	South Western Swedish highlands (above HC)	Central plains	West Coast

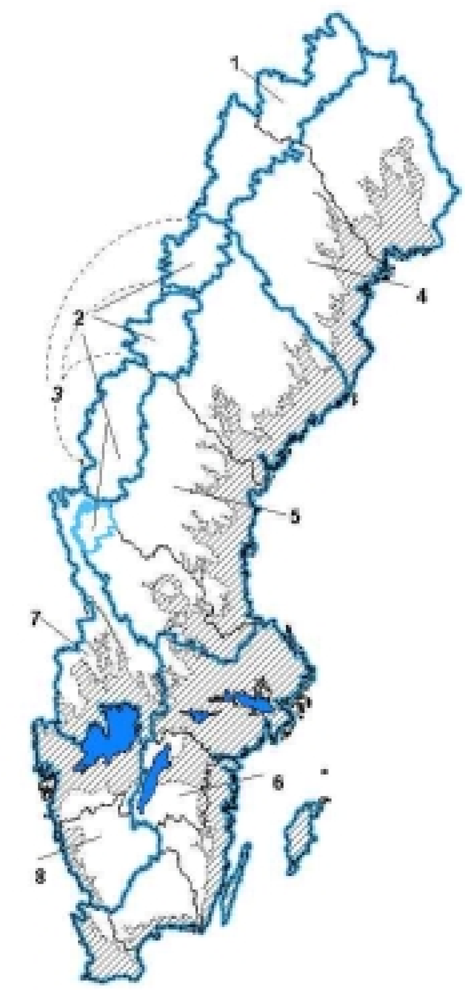


Figure 10 Proposed regions according to DESIRE for typification of lakes and running waters in Sweden for the WFD.

Hatched area is below the highest marine coastal line (HC). Area 1 – Northern mountains, 2 – Southern mountains, 3 – Mountain areas with western discharge (here added together with area 2), 4 –North Norrland, 5 – South Norrland, 6 – South East Sweden, 7 – North Vänern region, 8 – South West Sweden. Areas are divided into above and below HC, giving 12 regions: Region 11 - Northern mountains, 21- Southern mountains (including area 3), 40 - North Norrland below HC, 41 - North Norrland except mountains above HC, 50 - South Norrland below HC, 51 - South Norrland except mountains above HC, 60 – South Eastern Swedish lowlands (below HC), 61 - South Eastern Swedish highlands (above HC), 70 - North Vänern region below HC, 71 - North Vänern region above HC, 80 - South Western Swedish lowlands (below HC), 81 – South Western Swedish highlands (above HC).

1.3.11. *United Kingdom*

Although the UK represents only one ecoregion according to Illies (1978) the natural distribution of fish species, caused by their post-glacial distribution and dispersal, reflects a number of sub-ecoregions. However, these sub-ecoregions are not specifically defined and have rarely been taken into consideration in defining river typologies with regards to fish. The majority of river typology approaches in the UK are based upon predictive modelling of one aspect of river systems (e.g. macroinvertebrates) against a range of environmental criteria. The River InVertebrate Prediction and Classification System (RIVPACS) was developed by the Institute of Freshwater Ecology to predict and characterise macroinvertebrate communities as a function of a series of environmental variables (Wright *et al.* 1993).

The Environment Agency (covering rivers in England and Wales) implemented a survey methodology (River Habitat Survey RHS), based on recording physical structure of the river channel, banks and adjacent land use to develop a classification of river habitat quality as a measure of wildlife value. Data regarding predominant substrate of bed and banks, and flow types were collected from ten river-width transects in each 500-m site as well as a series of back ground variables such as solid and drift geology, valley slope, altitude, distance from source and height of source. Data from these analyses were compared with the national survey of stream order (Smith & Lyle 1979). The approach adopted was to interrogate channel substrate composition and flow related biotopes, chosen as a key component of channel habitats, of semi-natural sites to establish a relationship between these and a set of stable descriptors, features not affected by human management. Data for substrate groups and flow biotopes from semi-natural sites identified a series of 9 river types, each describing a distinct semi-natural character (Fox *et al.* 1996, NRA 1996).

As yet there is no accepted classification scheme for the UK which has been developed that describes river-types based on fish regions. Zones of river are generally described according to the Huet (1949, 1954, 1959) classification scheme and the associated fish communities.

1.4. Common themes and conclusions

It is apparent from the variable status of river classification schemes across Europe and the general comments from each of the FAME partner countries that the standardised, general, scheme developed for FAME must:

- adequately describe the different river habitats present in FAME ecoregions;
- produce a scheme which describes relatively homogenous river-types for the assessment of type-specific reference conditions;
- account for different "fish regions" at both the ecoregion/sub-ecoregion level and within a catchment;
- address the specific issues of FAME and the WFD.

The WFD schemes are primarily concerned with hydromorphological and physicochemical status of rivers. As such, the schemes use purely abiotic criteria to define river types. It is, therefore, critical that the scheme adopted by FAME is purely based on abiotic criteria. Beyond this, it is preferable to use criteria that are not affected by human management to describe river types so that the types and associated reference conditions reflect natural features. The abiotic criteria selected should describe the habitat conditions that "should" be present under undisturbed conditions. Ultimately the biotic community present should be a function of the prevalent abiotic habitat (bearing in mind zoogeographic factors). The use of purely abiotic factors would preclude the use of in-stream variables such as presence of aquatic macrophytes, which are ultimately biotic features of river systems.

The major problem for any general scheme for FAME is the production of homogenous zones for the development of type-specific reference conditions. Production of homogenous zones requires that the boundaries of each type are adequately described. Establishment of these boundaries must also be relevant to not only the features they describe but also the variable they are being used to assess. A basic typology using ecoregion and catchment level abiotic variables could be set up to describe river types for the purpose of habitat descriptions and monitoring purposes and yet this scheme could produce zones that are completely irrelevant to fish community composition and distribution. The common approach to overcome this problem is to use a "bottom up" approach where statistical analyses of fish data are used to describe the different fish communities/regions within a zone of study. Secondary analyses of the prevalent habitat conditions at each of the sampling sites are then used to define the ranges of key abiotic variables that would adequately predict the presence of each community type. It is difficult to see how any classification system based purely using a "top down" approach with abiotic criteria could produce homogenous river-types/zones that will enable establishment of type-specific reference conditions for fish communities. Any scheme developed will need to be tested and modified using the central database created for FAME to produce meaningful river types and associated reference conditions.

The classification scheme for FAME must assess not only the composition and distributions of fish communities within river channels (and associated floodplains) but also the zoogeographic distribution of species. The systems proposed by the WFD can be used to account for both of these sources of variation in fish communities although a combination of Systems A and B may have to be used. The natural zoogeographic distribution of species can be accounted for using a suitable ecoregion/sub-ecoregion level of classification. The ecoregions proposed by the WFD do not adequately differentiate the distribution of fish species so a number of sub-ecoregions must be produced. A number of criteria have been used to develop these sub-ecoregion schemes at the national level, including:

- marine zones;
- altitude;
- geology;
- highest marine coastal line;
- climate.

The ecoregion level of classification essentially needs to group similar river basins. Criteria such as ecoregion, latitude and longitude, marine zone, climate and highest marine coastal line will basically describe the major (historical) factors that were influential in structuring the fish community of river basins. Features such as the geographic location of river mouths (confluence with estuaries, i.e. delimitation of freshwater fauna by saline zone), equivalent to the "marine zone" system used in Sweden, should group rivers in such a way that it adequately describes natural fish communities of the basins. This would overcome the zoogeographic problems encountered for cross-boundary river basins when ecoregion schemes are based purely on terrestrial features such as geology or altitude.

Once an adequate scheme is established to define "whole-river" types the next level of the classification scheme must then distinguish the different zones within river basins. It is at this level of the classification that the most appropriate criteria must be selected; those that are primarily responsible for structuring the distribution of fish species within river basins. Factors such as altitude, geology, channel morphology, flow dynamics, location within the river course (e.g. distance from source/estuary), active floodplain features and water chemistry can be used to describe the reaches. However, many will ultimately represent the same feature so some will become redundant and ultimately the typology will be based on a lower number of key variables. It is here that the question of river and descriptor variable is important i.e. does the variable describe river-type or river zone. This is a question of the relative scale of the river and the descriptor variable. For example, for a "small" river the underlying geology may be of only one type and as such geology can adequately be used to describe the whole river. However, for a "large" river the geological setting may be variable and hence this would be an unsuitable descriptor for a "whole-river-type" level of classification. Consequently, the choice of descriptor variable for "whole-river-types" must be equal to or larger than the scale of the river which they describe.

The use of catchment size/area appears to be a key criterion (System A and an obligatory factor in System B). However, using this criteria in a meaningful way can be problematic (is there a fundamental difference between small and large rivers or are the processes the same just on different scales? How big is a large river?……). It is apparent that a "small" river within a large basin may be different to a "small" river in a small basin and also may differ from another "small" river in the same large basin. The way "river" size is described must therefore be meaningful to the distribution of fish species within basins. Although the abiotic conditions of a reach of a river are generally only influence by processes upstream (i.e. unidirectional flow of rivers) the biota can be influenced both by what is upstream and by what is downstream. Consequently the question of the scale over which "upstream/downstream" processes occur is of importance when considering "river size". Lower-order "tributary" rivers in the upper reaches of a large main river must therefore be considered to be large rivers given the scale over which processes can occur downstream of the "end" of the conventional (or lay-mans) river unit.

It is apparent that all classification/typology schemes reported by FAME partners have been developed for specific purposes and to meet specific objectives. The typology developed for FAME must therefore address the specific objective of FAME.

- Develop a typology that proposes the major river types of 16 ecoregions at the national scale so that river-type specific approaches to reference conditions and ecological analyses can be undertaken in the later workpackages.

Whether the typology will ultimately be transferable for use for the establishment of monitoring programmes, especially those that are not specifically fish based, is a question that can be asked later. Developing a river typology scheme that creates zones that can be used in monitoring where assessment is based on aquatic plants or macroinvertebrates etc is beyond the scope of this stage of FAME. Intercalibration is an issue that may be addressed later.

1.5. Way forward

1.5.1. *Scheme and definitions*

Integration of the existing national classification systems of FAME member countries with the requirements of the WFD is an ongoing process, with few countries at a stage where their system wholly complies with either of the two WFD schemes. It is apparent that the scheme used by FAME must not only produce a classification system that accounts for the different river-types and river-zones in terms of fish species distribution but also incorporate the descriptors and criteria required in the WFD systems. It is clear that for the FAME typology to account for fish distribution that the system should work on two main levels.

- Grouping similar basins/rivers together at a "whole river/basin" level.
- Within river zonation to account for river zone variations.

This "two levels of variability" approach should ultimately produce groups of rivers for which river-type specific reference conditions can be created. These river-type specific reference conditions should then be applicable to a number of similar rivers and then can be modified/modelled to account for within-river zonation. A scheme is proposed for use during the FAME project, using a four-level series of abiotic criteria (Figure 11). However, the main problem with using purely prescriptive abiotic system is making the resulting river types/zones applicable and suitable for the zonation of fish species. The usual approach for this is statistical analysis and modelling of fish communities to identify the different fish regions and then working back to the key abiotic variables to create a predictive model/typology. The scheme presented in Figure 11 outlines the proposed classification tree for FAME and incorporates the feature required by the WFD although it is a mix of Systems A and B. Before describing the system it is essential to set out a few basic definitions which should be applicable throughout FAME.

- RIVER BASIN
  A group of river catchments which form a drainage basin. The basin is delimited by the geographic point at which the main river channel becomes saline (forming discrete units within which freshwater communities are delimited). Therefore, a number of basins may share the same estuary.
- RIVER
  The definition of the basic river unit is more complex that it would first appear given the preconceived river nomenclature (e.g. River Rhine, River Thames, River Danube etc) and the diversity of scales across Europe. The general definition of a river is a distinct drainage channel, between the headwaters and its confluence with another larger river or an estuary, that may comprises a number of zones. This is a very basic description but it is essential to define the basic river unit as FAME utilises a "River-type-specific" approach. It should be noted that this only defines rivers as distinct by their name and not by the size of the basin in which they are located. It is important to consider basin size and the location of the river within that basin when determining river size (i.e. the scale over which river processes occur).
- RIVER CATCHMENT
  The geographic area over which the river is formed by catchment drainage processes.

- RIVER ZONE (or SEGMENT)
  A zone within a river within which abiotic or biotic characteristics are, more or less, homogenous.

These definitions prescribe the typology system required to assess river types and the zonation within them. It is apparent that broadly similar river zones (e.g. functional-community-type zones) may occur yet be found in different river types (e.g. species specific zoogeography). Therefore, the basic structure of a reference condition of a particular zone-type may be similar and yet the specific (species) structure will vary between river-type (zoogeography).

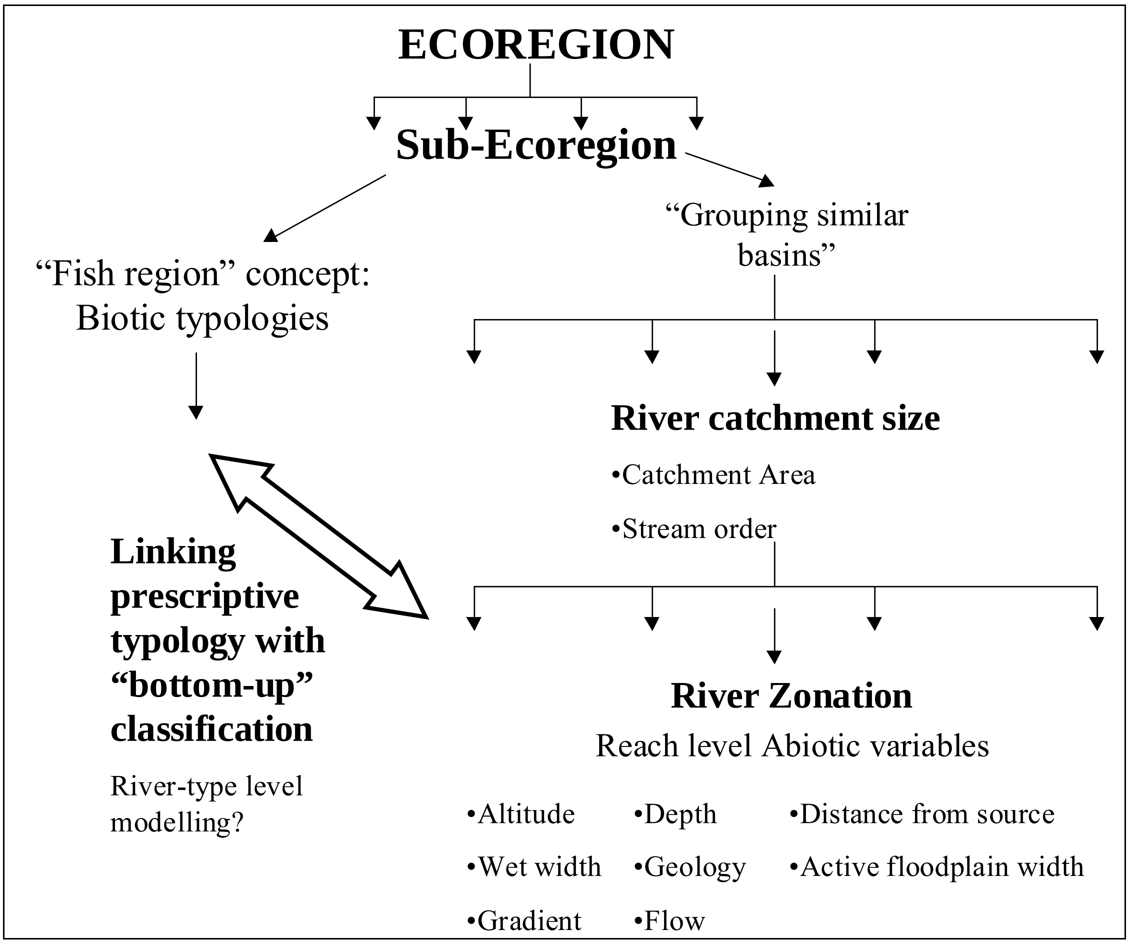


Figure 11 Proposal for a prescriptive abiotic classification scheme and the problem of making it suitable for definition of reference conditions.

The system proposed for the FAME river typology is as follows.

1.5.2. *Ecoregion*

The first level of the river typology is the main variable required by the WFD. The use of the main ecoregions proposed within the WFD will, to a certain extent, characterise the natural zoogeographic features of European fish fauna. However, it is recognised that the use of these ecoregions is too coarse to account for all natural zoogeographic variations between rivers and basins within each ecoregion. This ecoregion classification also causes major problems for the large cross-boundary rivers and basins. Therefore, a system of sub-ecoregions or aquatic landscape units is required as a second level.

1.5.3. *Sub-ecoregion*

The purpose of the sub-ecoregion level is to produce a tier in the system that groups similar river basins and accounts for natural zoogeography between river basins. It is proposed that sub-ecoregions are based upon a key aquatic variable. The most appropriate variable for this would appear to be the geographic location of the end-point of the river basin (the location of delimitation by a saline zone). This is similar to the marine zones used by some FAME member countries to define their aquatic landscape units. Grouping of rivers and basins by their region of marine confluence will add another criteria to refine the zoogeographic variation. This level is specifically designed to group similar basins, independent of their size.

1.5.4. *River catchment size*

This level of the classification system groups similar whole-river basin types by their catchment size within each group of similar river basins. This is a key criterion within both systems A and B of the WFD. The level will group rivers and at the same time account for some of the river zonation issues. Within a drainage basin the “smaller” rivers (traditional sense) will usually be in the upper reaches of the main or larger river, or be similar to upland rivers, so the river types produced should exhibit similar features. It is proposed that catchment area, stream order or combinations of both are the key characteristics used at this level in the typology. It is at this level that the bulk of the river-type specific grouping should occur. The main problem at this level is how to classify the size of a river catchment within a basin. The catchments of the main rivers in a basin are comprised of the catchments of the other tributaries so effectively the catchment of the main river is in fact the basin catchment size. This problem is exacerbated by the large cross-boundary rivers whose ultimate catchment size is massive. In very large basins a low order river in the lower reaches may be very different to a low order river in the upper reaches of the main river given the scale over which river processes can occur. One criterion that may overcome this problem would be to utilise the longitudinal length/catchment size of rivers e.g. from source to the marine confluence. Including in this both the length/catchment size of the specific river and the distance from the river's confluence with the main river to the main rivers marine confluence would characterise the scale over which the river processes occur. This also accounts for the fact that the biocoenoses of the upper reach rivers can be directly influenced by the basin downstream of its confluence with the main river although the level or extent of influence may depend upon the scale over which zonation occurs.

1.5.5. *River zonation level*

The last level in the river typology should account for river zonation and the description of more or less homogenous river zones. It is at this level that criteria such as altitude, wetted width, depth, flow, gradient, distance from source and width of active floodplain are used to characterise river zones. These are the primary features that usually define the distribution and composition of fish communities in rivers on a zone/reach level. Unlike the WFD systems geology can be placed at the river zonation level because for large rivers the spatial scale of the river may be much larger than the spatial scale of the geological regions.

1.5.6. *Grouping types and zones and setting class boundaries: integration with biocoenotic zonation?*

It is apparent from the many typological approaches presented by FAME partners that a purely prescriptive abiotic classification system will always fail to adequately describe the biocoenoses unless the class boundaries of the different criteria are set at biotically relevant intervals. The biocoenotic approach utilised by many countries to develop typologies does not integrate well with the requirements of the WFD. However, it has been suggested that there is potential to use a biocoenotic approach within the sub-ecoregion/basin/river levels and to model the zonation of fish within river lengths as a function of a number of abiotic variables. This works backward toward a typology prescribed by biotic variables but which can ultimately be described by the prevalent abiotic variables associated with each biotic zone. However, it is unclear how this can be fully and successfully integrated into the abiotic approach required by the WFD (and hence FAME) or that required by countries with limited fish data on which to base biocoenotic typologies.

Zone-type boundaries cannot be set up unless there is suitable biotic data upon which to base them or the typology is significantly tested. Justification of the choice of criteria boundaries is essential to a meaningful typology. Qualitative variables such as geology and stream order have well established systems of classification and the geographic, sub-ecoregion, grouping should identify groups relatively easily. However, the values presented in the WFD for some of the quantitative variables e.g. catchment size, altitude etc do not appear to have a solid justification and are just values chosen to break down the range of available values into a number of groups. The key criteria, which need to have their boundaries justified within the FAME project, are:

- catchment size;
- altitude;
- distance from source;
- river length;
- site specific channel characteristics (width, depth, slope);
- active floodplain size.

Of these the catchment size and altitude criteria have boundaries which are prescribed in the WFD systems A or B. These boundaries can be utilised by FAME although their applicability to the requirements of defining biotic reference conditions has yet to be tested. Off all the other variables only width and slope have been broken down into biotic meaningful groups/zones (Huet 1949). However, Huet's system was biotically derived for the rivers of Western Europe and its transferability between ecoregions is unclear.

The classification of floodplain systems has been deemed to be essential to adequately describe the fish communities within floodplain rivers. However, the question remains of how to characterise these zones within the FAME typology. The Dutch partners have identified the key features and processes within floodplains and propose that adequate sampling of a floodplain river must include the entire width of the active floodplain. The question to be resolved for the classification of floodplains is the size of the active floodplain. The active floodplain is described by the frequency of the flooding events e.g. 5 yr^{-1}, 10 yr^{-1}, 50^{-1}. Although the choice of which level of "activeness" is used to delimit the floodplain is probably a question of sampling methodology it will affect any "size/width of active floodplain" criteria in the typology. It is proposed that the level chosen should be set at a level of flooding activity that perpetuates a significant influence over the fish community structure or distribution for the majority of the between flooding period. This is probably linked to the lifecycle and longevity of the key fish species affected by flooding processes. The size of the active flood plain can was, therefore, set as the area flooded during a $15yr^{-1}$ flood event as this links in with the boundary between intermediate and long-lived fish species (Workpackage 1b species classification).

In conclusion, it is apparent that the two levels of the typology grouping river-types at a "whole-river" are relatively feasible and should account for the majority of zoogeographic features. However, it is the within-river zonation that is difficult to assess on a purely prescriptive basis. The development of the FAME typology to account for within-river zonation may have to include biocoenotic modelling to either establish the typology or to validate an *a priori*, prescriptive, zone-typology. In reality the use of a precsriptive, *a priori*, typology of river types at the sub-ecoregion/similar basin/catchment size level fits well with the WFD models so long as it is based on adequate local knowledge to define the boundaries. This *a priori* will need verification using the FAME database once established. The use of *a posteriori* typologies has been discussed by REFCOND (van der Bund 2001) and agreed that typologies according to WFD B could be developed using this approach. Therefore, it is proposed that an *a priori* approach (as detailed above) is used to assess similar river types based upon suitable local knowledge/existing systems. River zonation issue will have to be assessed using an *a posteriori* approach, modelling fish communities using the available data within similar rivers.

2. WP 1B: COMPILATION AND HARMONISATION OF FISH SPECIES CLASSIFICATION

2.1. European freshwater fish

The zoogeography of European freshwater fish species is determined by the post-glacial dispersal characteristics of the individual species, hydrological and physical conditions, and by climatic and human-induced events. Freshwater fishes belong to two zoological groups. The lampreys, very primitive vertebrates from super class Agnatha, and advanced bony fish, belonging to the super order Teleostei. The majority of European freshwater fish species belong to the orders Cypriniformes and Salmoniformes and particularly to the families Cyprinidae and Salmonidae (Wheeler 1992). Fish are also classified as game (e.g. salmon, trout, charr & grayling) and coarse fish. Examples of coarse fish species in European rivers include roach, dace, chub, common bream, silver bream, barbel, rudd, tench, common carp, bleak, gudgeon, pike, perch, ruffe and pikeperch (Cowx 2001). The freshwater fish fauna in northern Europe is poor compared with that of central and southern Europe. The main reason for the limited northern fauna is that the glaciations during the Pleistocene Era virtually eliminated the fauna that was living in this region. The zoogeographic distribution of European fish fauna thus needs characterising in a manner that is both simple but applicable to the wide range of ecoregions and diversity of fish fauna present.

In this context each fish species has characteristic tolerances or preferences for water quality, habitat and other environmental conditions. They have specific requirements for breeding, feeding, growth, recruitment and survival. These characteristics have been used to classify fish species according to the concept of the ecological/functional guild, which was developed to simplify analysis and assist in the prediction of community change (Austen *et al*. 1994). Root (1967) defined guilds in the ecological sense as "a group of species that exploit the same class of environmental resources in a similar way." Guilds were developed based on reproduction, feeding, habitat use and morphology. One strength of the guild approach is that it simplifies analysis of the community by providing an operational unit between the individual species and the community as a whole (Root 1967). Species are grouped based on some degree of overlap in their niches regardless of taxonomic relationships. As such the guild approach is the corner stone of fish-based, multi-metric methods of assessing ecological integrity/quality of aquatic environments.

The initial fish species list for European rivers covered by the FAME project was compiled from a number of sources and aimed to be comprehensive of all species that may occur in assessment of European rivers. Data regarding distribution of species and guild level classification were submitted by each national partner on the basis of published texts, national reports and "grey" literature. The guilds that were assigned included:

- trophic;
- reproductive;
- habitat;
- residency;
- tolerance;
- longevity and maturation.

The original species list was designed to be comprehensive and included all European freshwater fish species recorded in key published lists (e.g. Wheeler 1983, Kottelat 1997). However, the list was edited so that only fish species which are known to occur in rivers (even if only rarely) were retained. Many euryhaline species were retained, as they are typical of the lower freshwater zones of rivers above the transitional zones and estuaries. Although transitional zones are not within the scope of FAME many partners considered that many of these species were present in freshwater zones of rivers and were good indicators of the connectivity of lowland rivers.

The data returned were fairly complete for the major European species, although there are a number of species for which no data were presented. There are number of reasons for this including a general lack of ecological knowledge for the species and a restricted distribution of the species outside the range of FAME countries. Only Fish species known to occur within FAME rivers were retained in the final spreadsheet. For the major species data were obtained from a number of published texts, national reports and grey data. This lead to some disagreements over the classification of the characteristics of certain species. Some disagreement will inevitably remain depending upon the data used, the sources quoted and the status of the particular species within the ecoregion in question (e.g. optimal/sub-optimal conditions based on species range). The final national data spreadsheet has retained all the data submitted by each individual country whilst presenting, where possible, a standardised classification for the FAME project. The accuracy of the classification scheme is important given the nature of IBIs and their requirements for appropriate reference conditions and metrics with predictable responses to degradation. Consequently some regional variation in classification may be required (see later sections).

All data submitted were compiled into a single spreadsheet of standardised classification for FAME with a standardised key (FAMEFISH.XLS). The following report accompanies the spreadsheet and presents the guilds, justifications, annotations and resources used.

2.2. Nomenclature

The FAME species list followed the nomenclature presented by Kottelat (1997). The pan-European nature of FAME precludes the standard use of “common” names, unless they are standard between all FAME partners. As is typical with taxonomy there were a number of species for which there were disagreements or recent changes. Where possible the names used were those that are the most recent and widely accepted. Table 1 identifies the main species concerned, their approved Latin names and the key reference.

Table 1 Queried species names (Authorities are given in bold, additional references are also presented).

Proposed name	Query	FAME name	Authority/Reference
Barbus comizo			**Steindachner 1865**
	Barbus comiza	**Barbus comizo**	KOTTELAT 1997
Rutilus alburnoides	*Leuciscus alburnoides*	*Squalius alburnoides*	**Steindachner 1866**
			Alves *et al*. 2002
Aphanius iberus			**Valenciennes 1846**
	Lebias ibera	**Aphanius iberus**	Kottelat 1997
Stizostedion lucioperca	*Sander Lucioperca*		**(L.)**
		Sander lucioperca	Kottelat 1997
Blicca bjoerkna			**(L.)**
	Abramis bjoerkna	**Blicca bjoerkna**	

2.3. Polymorphism and speciation

During recent years the issues of polymorphism and speciation have become prevalent within the European fish fauna. It was anticipated that, at this stage, these problems were unlikely to have a direct impact on the classification system. However, it was considered that some species may exhibit different ecological traits depending upon their geographic location and local adaptation. Whilst it is recognised that brown trout (*Salmo trutta fario*) and sea trout (*Salmo trutta trutta*) are no longer recognised as distinct species (Jonsson 1985, Hindar, Jonsson, Ryman & Stahl 1991), the two forms are retained in the classification scheme because of the potential for the presence of adult sea-run trout (which are relatively easy to distinguish from resident trout) to be a good indicator of longitudinal connectivity within a river basin.

2.4. Fish species distribution and residency status

Development of an IBI requires clear definition of fish species that actually reflect ambient environmental conditions based on residency. In most cases, European freshwater fish species are classified as follows:

Resident indigenous: naturally occurring native species populating suitable aquatic habitats.
Resident naturalised: well-established non-native species populating suitable aquatic habitats.
Non-resident transient: non-populating fish species found to occur in unsuitable aquatic habitats.
Non-resident stocked: non-populating fish species introduced for a recreational fishery only.

Each FAME partner submitted data for the species list regarding the status of each species in their country. Species were classified as NATIVE, INTRODUCED, INTRODUCED TO EUROPE, ENDEMIC (to country or specific ecoregion). Where known the date of any introduction was recorded. Any significant translocations of species between water bodies within each country were also recorded. This issue of introduction or translocation was resolved in a harmonised way such that if a species was not historically present in the water body (river of reach of a river) concerned it must be considered an alien.

The proposed classification of the status of each species in each partner country as Common (C) / Minor (M) / Rare / Endangered or Extinct was modified by some countries so that it indicated both the range and abundance of the species. A system was proposed by the partners in Portugal to include:

LC - large distribution in the country and commonly captured in its distribution area;
LU - large distribution but uncommon;
RC - restricted distribution but common (i.e. locally/regionally abundant);
RU - RESTRICTED DISTRIBUTION AND UNCOMMON.

Several IBIs use historical status as the reference conditions for defining pristine state. This has potentially a problem when considering species that have now become extinct in an ecoregion. For example, burbot has been extinct from UK waters for at least 100 years and any move to reinstate it will be blocked by the Environment Agency in England and Wales. Consequently, due accord needs to be given to extinct species and the role they may take in establishing reference conditions. All known extinctions have been indicated by each FAME partner.

2.5. Classification guilds

2.5.1. *Trophic guild*

Fish display a wide range of feeding habits. They occupy many trophic roles from detritivores to secondary carnivores. However, it is rare for fish to specialise in one particular food category throughout their entire life cycle. There is often a correlation between morphological traits and trophic role because morphology determines how a fish can feed. Generally body shape, mouth morphology, teeth, gill rakers and the structure of the alimentary canal are important to diet selection. Goldstein & Simon (1999) proposed a classification for North American freshwater fishes (Appendix 1) in which five main feeding guilds and 26 modes of feeding were found.

This classification was considered too complex for the European fish fauna and the available ecological information. Consequently, a simplification was proposed (Table 2). The definition of each of the guilds was generally considered to be too quantitatively prescriptive for the level of ecological understanding of many European fish species. Therefore, the trophic guilds were also assessed using a “high proportion” or “most important” approach.

The problem arises with fish species that have a multiple trophic states over the course of their lives. These are linked to ontogenetic niche shifts, changes in diet based on availability and food partitioning. It was proposed that data regarding ontogenetic shift in diet are too variable and uncertain to be meaningful for inclusion, so classification should be limited to the trophic guild of adults. The final spreadsheet has retained any information submitted regarding ontogenetic shifts in diet. However, for the purpose of FAME and the future analysis each species is assigned to one guild based on the composition of the adult diet. Some FAME partners suggested that the category

BENTHIVORE should be excluded, as this is not a true indicator of dietary preference and overlaps with the habitat guild. The definition above categorises Benthivore as "consisting of >75% (*a high proportion*) of benthic organisms. As such it uses both a habitat-related definition but also to some extent a food type definition as well. It is recognised that some benthivores may also, technically, be placed into one of the other categories e.g. OMNIVORE if only food type is used in the definition. The benthivore category is also covered by the guild describing habitat preference (BENTHIC (B) or WATER COLUMN (WC)). However, given the limited trophic data for some species, the benthivore category was retained.

Table 2 Proposed trophic guild classification for European fishes.

***Planktivores* (PLAN)**: adult diet consists of more than 75% zooplankton and / or phytoplankton (Lyons *et al*. 1995). Fish, having fine gill-rakers and elongated pharyngeal teeth, do inertial sucking of water containing food. They have no stomach but have an elongated, undifferentiated intestine (Goldstein & Simon 1999).
***Herbivores* (HERB)**: adult diet consists of more than 75% plant material (Lyons *et al*. 1995). Fish have terminal or subterminal mouth with bony slashing jaw for clipping and tearing aquatic vegetation / weed. In most cases, the digestive tract is as long or longer than the total length of the individual (Goldstein & Simon 1999).
Detritivores* (DETR)*: Adult diet consists of high proportion of detritus (non-living, organic matter and its associated microflora). The digestive tract is simple and unspecialised.
***Omnivores* (OMNI)**: adult diet consists of more than 25% plant material and more than 25% animal material (Schlosser 1982b). They are also called "generalists" as they take food from a wide range of flora and fauna (Leonard & Orth 1986).
***Insectivores / Invertivores* (INSV)**: adult diet consists of more than 75% insects (Lyons *et al*. 1995). Fish with terminal or supraterminal mouth, take aerial, drifting or swimming insects and invertebrates. Invertivores compose the largest and perhaps the most diverse trophic class. It includes species that feed on the smallest midge, to species that consume large molluscs (Goldstein & Simon 1999).
***Benthivores* (BENT)**: adult diet consists of more than 75% benthic organisms (Goldstein & Simon 1999). Fish have ventro-terminal, sometimes a highly protractile mouth that are used to vacuum-clean. They have file-like teeth that comb and sort small organisms.
***Piscivores* (PISC)**: adult diet consists of more than 75% fish (Goldstein & Simon 1999, Lyons *et al*. 1995). Fish have a wide mouth aperture with needle-like teeth and a strong jaw with marginal and palatal bones. They are capable of capturing active, mobile prey, inclusive of larger invertebrates. They pursue a prey by stalking, chasing, ambushing or lying-in-wait approach (Simon & Emery 1995).
***Parasite* (PARA)**: fish species that exhibit a parasitic feeding mode.

Following this classification a number of species did not fall into discrete categories but also were not true omnivores. This was most prevalent for species which exhibited distinct trophic shifts or a range of potential trophic status. In these circumstances the species were classified into joint groups e.g. INSV/PISC. This was deemed essential given the potential use of the OMNIVORE guild as a specific metric in a multi-metric assessment. Additionally, this was essential to separate the "obligate" piscivores (e.g.. *Esox lucius*) from species whose diet may include a high proportion of fish but, however, do not solely rely on a piscivorous diet (e.g. salmonids and *Perca fluviatilis*).

2.5.2. *Reproductive guild*

Fish have diverse forms of reproduction. Some fishes produce large numbers of small eggs and others produce few eggs of large diameter. They show different spawning behaviour and use diverse spawning grounds. On the basis of ontogeny, spawning behaviour and the place of egg deposition, Balon (1975, 1981a, b) classified fish into 33 groups known as "Reproductive guilds" (Appendix 2).

This classification scheme is considered inappropriate for development of the models in FAME because many of the categories are for marine or tropical species. Also Simon (1999) considered that assigning species to the correct reproductive guild is problematic until further behavioural and early ontogenic data become available. As a result a simplified system of reproductive guilds was developed (Table 3) based on the classification proposed by Balon (1975) and the concept modified by Chadwick (1976), Balon *et al*. (1977), Balon (1981a, b), Mahon (1984), Berkman & Rabeni (1987), Bruton & Merron (1990), Oberdorff & Hughes (1992), Boet *et al.* (1999) and Cowx (2001). The classification was primarily based on the preferred spawning habitat as this fits in well with the requirements and structure of IBIs.

Table 3 Proposed system of classification of reproductive guilds

***Lithophils* (LITH):** Fish spawn exclusively on gravel, rocks, stones, rubble or pebbles. Spawning success depends on the availability of suitable sized and clean gravel. Hatchlings are photophobic.
***Phytophils* (PHYT):** Fish spawn especially on plants, leaf and roots of live or dead vegetation. Larvae of this group are not photophobic.
***Phytolithophils* (PHLI)**: Fish deposit eggs in relatively clear water habitats on submerged plants, if available, or on other submerged items such as logs, gravel and rocks. Larvae exhibit photophobia like lithophils.
Psammophils* (PSAM)*: Fish spawn on roots or grass above sandy bottom or on the sand itself. Larvae are not photophobic.
Ostracophils* (OSTR)*: Fish spawn in shells of bivalve molluscs.
Pelagophils* (PELA)*: Fish spawn into the pelagic zone
Lithopelagophils* (LIPE)*:
***Ariadnophlis* (ARIAD):** Specialised nest building species may include some level of parental care
Speleophils* (SPEL)*: Fish species spawn in interstitial spaces, crevices or caves.
***Viviparous* (VIVI):** Live bearers.
***Polyphils* (POLY):** Non-specialised spawners, no preferred habitat or specialised behaviour.

ARIADNOPHIL, SPELEOPHIL, VIVIPOROUS and POLYPHIL were added to the original "reproductive habitat" guild classification to account for the slightly more specialised (or non-specialised in the case of Polyphils) behaviour of certain species. A range of metrics (WP3) was identified relating to reproductive guilds, which relate both to habitat and specialised behaviours. It was therefore apparent that the classification should include both an indication of reproductive habitat and any specialised behaviour.

2.5.3. *Habitat guild*

Each fish species has preferred habitat requirements, which result in changes in community structure along the upstream-downstream gradient of a river (Wheeler 1969). These habitat requirements have long been recognised and used to classify different zones in a river (Hawkes 1975), where different fish species with similar habitat preferences are grouped. It is widely acknowledged that the size, vitality, and spatial distribution of species are dependent on the quantity and quality of their habitat (Karr 1991). Generally species composition and population structure are changed as a result of habitat degradation due to physical, chemical or biological alterations. Fish have been classified according to habitat utilisation as described by Schlosser (1982b), Bain *et al*. (1988), Leonard & Orth (1988), Lobb & Orth (1991) and Mann (1996). A simple guild structure (Table 4 & 5) was adopted to indicate the preference of the various species and the type of habitat they occupy. Initial discussion in Maastricht proposed a 4-group classification for habitat linked to flow rate preference and position in the water column. Further comments form partners have lead to the proposal of classification based on the degree of rheophily (Schiemer & Spindler 1989) identifying three groups RHEOPHILIC, EURYTOPIC and LIMNOPHILIC.

Table 4 System of classification of habitat guilds based on three levels of "rheophily" (Schiemer & Spindler 1989).

Rheophilic* (RH)*: prefer to live in a habitat with high flow conditions, and clear water using this habitat both for breeding and feeding purposes.
Eurytopic* (EURY)*: fish that exhibit a wide tolerance of flow conditions, although generally not considered to be rheophilic.
Limnophilic* (LI)*: prefer to live, feed and reproduce in a habitat with slow flowing to stagnant conditions. This guild covers the key floodplain species.

The definitions of these categories are purely based upon distributions and preferences in rivers rather than considering the presence of the species in lakes. However, it is considered that floodplain species will be classified as LIMNOPHILIC unless they exhibit tolerance of relatively high flows when they will be EURYTOPIC.

An additional 2-group classification based on feeding habitat e.g. WATER COLUMN or BENTHIC was selected, this also reinforces the BENTHIVORE group from the trophic classification. It was anticipated that this guild may ultimately be proved redundant due to the complimentary nature of the classification (i.e. a species can only be one or the other), the overlaps with trophic guilds and the problem of vertical scale dependant upon river zone. The vertical scale in shallow upland rivers is much less than that of deeper lowland rivers and consequently true benthic or water column species may ultimately only occur in the deeper lowland sections where the vertical spatial scale allows differentiation.

Table 5 Feeding habitat classification guilds.

***Water-column* (WC)**: prefer to live and feed in the water column. These species usually do not go the bottom to search for food
***Benthic* (B)**: prefer to live on or near to the bottom, from where they take food, and usually do not go to the surface for feeding purpose.

2.5.4. *Residency/migration guild*

Migratory behaviour of fish in rivers can be divided into two major types: potadromy and diadromy, the former referring to that occurring entirely within the inland waters of a river system (Northcote 1999), and the latter to that taking place across a transition zone between fresh and marine waters (McDowall 1997). Diadromy can be further divided into three sub-categories:

Anadromy (running up rivers) refers to fishes that live as older juveniles and sub-adults in the sea but at maturity migrate up rivers to spawn, e.g. Atlantic salmon.
Catadromy (running down rivers) refers to fishes that have lived all their early life in fresh water – feeding and growing – but at maturity migrate down rivers to spawn in the sea, e.g. Anguillid eels.
Amphidromy (running between rivers and the ocean) refers to fishes that spend appreciable parts of their life in both fresh and sea waters, feeding and growing in both, and whose migrations seem to have no direct relationship to reproduction (McDowall 1997).

Despite this, categorisation it is not as distinct as first appears and some species, e.g. *Salmo trutta*, exhibit a range of migratory traits having both iteroparous and semelparous life histories. The issue of residency/migratory habits is important because absence of migratory species where they once existed often means environmental degradation at one or all stages of the life cycle, or obstructions to movement.

Four classes were proposed SHORT (SM), INTERMEDIATE (IM), LONG ANADROMOUS/CATADROMOUS (LMA and LMC) and fitted in with a number of classification schemes already used within partner countries. The first two classes were designed to cover potadromy over different spatial scales whilst the long migration categories covered all anadromous and catadromous migration. Short migrations covered species that only moved within a particular river zone whereas Intermediate migration covered species with potadramic migrations between river zones (i.e. within river migration on a larger spatial scale). Some FAME partners indicated that for some Euryhaline species the migrations were really only over an intermediate spatial scale but were anadromous and as such classified them as IMA.

However, it was identified that this scheme links purely with longitudinal migration. It was proposed that the scheme should more accurately reflect the connectivity of a river system and include scope for classification of LATERAL migration requirements of flood plain species. However, for the purposes of an IBI approach, the use of a metric concerning the presence of limnophilic species was considered to be adequate for assessing lateral connectivity.

2.5.5. *Tolerance capacity*

Tolerance capacity to pollution and environmental degradation of a species depends on its genetic and physiological characters. Moreover, it varies with the nature and type of degradation. Tolerance to water quality degradation, habitat degradation and temperature were identified as key parameters. Additional parameters, such as tolerance to acidification, were identified to be important by some partners at a national level. An initial scheme was proposed following that suggested by Breine (2002 *in press*) scoring tolerance to different parameters on a 5-point scale with 1 being the most tolerant and 5 being the most intolerant.

The concept of tolerance classification was perhaps the guild with the most issues raised. A number of schemes were reported including tolerance to habitat and water quality degradation (e.g. the two schemes presented by France). However, concern was raised about classification of tolerance that, despite published schemes and the recent research and impending publication of others, the concept of classification of tolerance with a five-point scheme was too detailed given our lack of understanding of "tolerance" and that "overall tolerance" classification is of very little use without specifying tolerance to one particular variable. It was proposed that "tolerance" to specific degradations could be picked up by the habitat and trophic guild classifications used and consequently "tolerance" guilds would become redundant. The French partners concluded that despite the two schemes they presented (one a 5-point scale derived by multivariate statistics and one based on how "demanding" certain species were for specific habitat conditions (scored 0.03 – 0.55)) eventually they could only classify into three groups TOLERANT, INTERMEDIATE and INTOLERANT. Therefore the tolerance classification scheme used in the FAME project was limited to this three-group classification. The spreadsheet has retained the 5-point scheme reported by each country but the overall FAME classification is given according the three-group classification.

Two additional tolerance schemes were identified to be important on a national level ACIDIFICATION (Sweden) and TEMPERATURE (Portugal indicated whether the species were WARM water tolerant, COLD water tolerant or EURythermal, however, these were equated to TOLE, INTOL and INTE respectively in the final guild table). Where used, tolerance should always be linked to specific forms of degradation as these may be of great importance in determining the biotic communities. This links with WP3 and the choice of metrics so it would appear that where possible the classification scheme should include any nationally important tolerance scheme. This national level variation in tolerance (and variables key to structuring communities) is apparent for some species depending upon their range and the ecoregion concerned. The apparent tolerance of a certain species to a particular variable will depend upon the location of the species within its geographic range. A species in sub-optimal conditions on the edge of its range is likely to be more sensitive to an additional stressor that it would be under optimal conditions. Therefore, the spreadsheet has retained the 5-point scheme reported by each country but the in the final FAME classification tolerance was classified (based on group concensus) according the three-group classification.

The final guild table retained an overall tolerance guild which combined the tolerance to water quality, chemical (Acidification) and habitat degradation. Temperature tolerance was considered to be a specific issue which was not related to river degradation but to geographic variation. The global tolerance guild was assigned on the basis of the guild for the other tolerance variables and was designed to identify the most tolerant or intolerant species. Therefore, for a species to be identified as having an overall tolerance or intolerance it must have been classified in that guild for the majority of the other tolerance groups but not have been classified as exhibiting the other extreme of tolerance for one of the other groups (e.g. a tolerant species must not have been scored as intolerant in one of the tolerance guilds).

2.5.6. *Longevity and maturation guild*

These guilds were designed to address simply the requirements of a number of IBI metrics commonly used to reflect the longevity of different species. Comments from different partners identified a need to formalise the group boundaries used in the classification. Two boundaries were proposed to classify short-lived species, <3yrs or <5yrs. It was also proposed that an additional class should be included to reflect species of intermediate longevity. It was proposed that the longevity scheme should include SHORT-LIVED (SL) (typically <5yrs), INTERMEDIATE (IM) (5 – 15 yrs) and LONG-LIVED (LL) (>15yrs). In addition it was proposed that the early (LLE) / late spawning (LLL) should be formalised for long-lived species as </> 25% of the life span. However, the longevity and age of maturation of each species can also be a reflection of the geographic location of the population within its natural range, the stability of the habitat and the optimal/sub-optimal nature of the habitat. The proposed classification can deal adequately with potential longevity across the scope of FAME.

2.6. Sentinel species

A number of species were identified as "sentinel" species, those species that are deemed to be indicative of a particular river zone but also those which will provide information on ecological status. For these key species information regarding recruitment and population structure (0+ or older/length data) was deemed essential. Consequently, the sentinel species were also those that are relatively common, easily caught and for which electric fishing is not considered to be significantly size selective. In western Europe the key species identified were generally those dominant and associated species in the Huet zonation scheme (Huet 1949, 1954; Workpackage 1a). Key species identified by each partner are presented in a separate table within FAMEFISH.XLS.

2.7. Additional annotations in the national data in FAMEFISH.XLS

The final spreadsheet of national data in FAMEFISH.XLS, is as comprehensive as possible and has retained as much of the information and as many of the comments from each partner as possible. A number of formats and legends were used to indicate certain features or sources of information. The final spreadsheet was cross-checked against FishBase (http://www.fishbase.org/home.htm) in an attempt to standardise some of the classification and also to fill some of the gaps. The majority of the abbreviations are presented in the descriptions of each guild. However, a number of additional annotations were made:

- France identified EURYHALINE species with a TAN colour background. This was retained in the final spreadsheet.
- France used the symbol * to indicate Keith & Allardi (2001), considered as "grey" literature.
- France used the symbol ° to indicate data from FishBase.

- Under habitat guild France identified sources of information as
  - (A) POUILLY, 1994 AND LAMOUROUX *ET AL.* 1999;
  - (b) Schiemer & Waidbacher 1992;
  - (c) Cowx & Welcomme 1998;
  - (d) Mallet *et al.* 2000.
- The proposed classifications for FAME are highlighted with an AQUA background.
- A number of comments have been left in the cells where they were deemed to be important and are identified by a red triangle in the top right-hand corner of the cell.

2.8. Summary

In all 301 species of fish were identified to inhabit European rivers. However, not all of these were identified as occurring in countries within the scope of FAME (227 species). Of the 301 species 44 were identified as species which have been introduced into Europe. The national data spreadsheet in FAMEFISH.XLS includes all 301 species within the species list, however, ecological information was only collated for those species which occurred within FAME partner countries. The final spreadsheet collated data regarding distribution and status (Table 6) as well as the classification into ecological guilds (Table 7). The data concerning ontogenetic diet shifts were retained in the final spreadsheet of national data despite the conclusion that they were too limited and variable to be used for FAME. However, they were excluded from the final FAME guild table. Separate report tables for the occurrence and native/introduced status of each species in each of the FAME countries are also presented within FAMEFISH.XLS.

Table 6 Species distribution and status, sub-section of the national data in the final FAMEFISH.XLS spreadsheet. Possible answers are indicated, abbreviations are underlined.

Country	Common Name	Latin Name	Authority	Introduced into Europe	Native in Country	Endemic to Country /Ecoregion	Common or Minor species	Introduced into Country	Translocated within Country
				Yes	Yes Portugal Spain	Yes Greece Ecoregion 6 European Ponto-Caspic Euro-Siberian Danube Palaearctic Holarctic Nordic	Common Minor Rare **Extinct** Large range Common Large range Uncommon Restricted range Common Restricted range Uncommon	Yes (date may be indicated)	Yes (dates and comments may be indicated)

Table 7 Ecological guild information presented in the final FAMEFISH.XLS spreadsheet. Abbreviations of guilds are indicated (See text for details).

Adult trophic guild	Reproductive guilds			Degree of rheophily	Feeding habitat	Migration guild	Water quality tolerance	Habitat degradation tolerance	Temperature tolerance	Acid tolerance	Overall Tolerance	Life history
	Guild	Timing	Behaviour									
INSV PLAN OMNI PISC HERB DETR PARA BENT	LITH PHYT PHLI PELA LIPE ARIAD OSTR POLY PSAM SPEL VIVI	Season or month range indicated	Single Fractional Protracted Multiple	Rheophilic EURYtopic LImnophilic	Water-Column Benthic	SM IM LMA LMC	TOLE INTOL INTE	TOLE INTOL INTE	TOLE INTOL INTE	TOLE INTOL INTE	TOLE INTOL INTE	SL IM LL LLE LLL

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4. APPENDICES TO WP 1B

4.1. Appendix 1

Trophic classification scheme for North American freshwater fishes (Goldstein & Simon 1999).

Trophic class	Trophic subclass	Trophic mode
I. Herbivores	Particulate feeder	Grazer
		Browser
II. Detritivores	Filter feeder	Suction feeder
		Filterer
	Particulate feeder	Biters
		Scoopers
III. Planktivores	Filter feeders	Mechanical sieve
		Mucus entrapment
		Ram filteration
		Pump filteration
		Gulping
	Particulate feeders	Size-selective pickers
IV. Invertivores	Benthic predators	Grazers
		Crushers
		Hunters of mobile benthos
		Lie-in-wait predators
		Tearers
		Diggers
	Drift predators	Surface feeders
		Water column feeders
V. Carnivores	Whole body	Stalking
		Chasing
		Ambush
		Protective resemblance
	Parasites	Blood suckers

4.2. Appendix 2

Classification of reproductive strategies of fish based on spawning habits (After Balon 1975, 1981a. b)

I. Non guarders A. Open substrate spawners 1. Pelagic spawners 2. Benthic spawners a. Spawners on coarse bottoms i. Spawners on coarse bottoms with pelagic larvae ii. Spawners on coarse bottoms with pelagic larvae b. Spawners on plants i. Obligate spawners on plants ii. Non-obligatory spawners on plants 3. Terrestial spawners B Brood hiders 1. Benthic spawners 2. Crevice spawners 3. Spawners on invertebrates 4. Beach spawners	II. Guarders A. Substratum choosers 1. Rock tenders 2. Plant tenders 3. Terrestial tenders 4. Pelagic tenders B. Nest spawners 1. Rock and gravel nesters 2. Sand nesters 3. Plant material nesters a. Gluemakers b. Non-gluemakers 4. Froth nesters 5. Hole nesters 6. Miscellaneous-materials nesters 7. Anemone nesters III. Bearers A. External bearers 1. Transfer brooders 2. Auxillary brooders 3. Mouth brooders 4. Gill-chamber brooders 5. Pouch brooders B. Internal bearers 1. Facultative internal bearers 2. Obligate internal bearers 3. Live bearers