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Improving and Extending the European Fish Index

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1. Summary

Water management in Europe is legally mainly regulated by the European Water Framework **Directive** (WFD). The main goal of the WFD is to achieve “good ecological status” for all water bodies by 2015. The WFD requires standardised assessment of the ecological status of rivers based on fish assemblages. State of the art assessment methods originated in the Index of Biotic Integrity (IBI). IBI’s are multi-metric indices, each of the selected biological metric reflecting important components of the functioning of fish communities, e.g. habitat, migratory, reproductive and trophic guild composition, individual health and abundance. Although assessment methods have been developed recently in a few European countries most national methods are still under construction or are not fully in compliance with the WFD.

A first version of the European Fish Index had been developed in the preceding EC-funded project FAME. In FAME Mediterranean and Central/Eastern countries as well as large floodplain rivers were not so well represented and the ability of the original European Fish Index to reflect hydromorphological pressures was still low.

The overall objective of the EFI+ project was to improve the European Fish Index in terms of existing spatial and river type specific limitations in order to produce more accurate pan-European Fish Index. The specific objectives were:

1. To evaluate the applicability of, and make necessary improvements to the existing EFI in Central-Eastern Europe and Mediterranean ecoregions.
2. To extend the scope of the existing EFI to cover large floodplain rivers.
3. To analyse relationships between hydromorphological pressures (incl. continuity) and fish assemblages to increase the accuracy of the EFI.

The EFI+ consortium consisted of 14 partners from 13 countries with 2 additional countries participating based on national funds. The common database, collated during the project, contained 14 221 sites corresponding to 29 509 sampling occasions distributed across 15 countries. In total, 395 fish species were analysed and species were classified according to 16 guilds. Different sampling methods for large floodplain rivers were tested and appropriate methods were identified. The particulate situation of Mediterranean rivers were analysed and recommendations for the development of indices were derived.

For the development of the new European Fish Index (EFI+) undisturbed calibration sites were used to develop statistical models which allowed prediction of a “theoretical” metric value at a site as a function of natural environmental factors. Metrics with the best model performance and response to different types of pressures were selected for the final index. Two different indices were developed. In the salmonid river zone the most sensitive metrics are based on oxygen intolerant species and habitat intolerant species expressed in “relative” density. For habitat intolerant species fishes < 150 mm showed a stronger response to human pressures than using all length classes. The metrics “relative” richness of species spawning in running waters and “relative” density of gravel spawning species were selected for the cyprinid river zone. The two indices are calculated as the mean metric values. In addition, an estimation of uncertainties of the final index was provided. A web-based software and a manual are available to compute the new European Fish Index (<http://efi-plus.boku.ac.at>). The new European Fish Index works in most countries and ecoregions better than the former FAME assessment method. However, some limitations still exist in terms of particulate environmental conditions and river types. Further research is necessary to improve and widen the applicability of the method across Europe.

2. Introduction

Water management in Europe is legally mainly regulated by the European **Water Framework Directive** (WFD). The main goal of the WFD is to achieve “good ecological status” for all water bodies by 2015. The WFD requires standardised **assessment of the ecological status** of rivers **based on fish assemblages**. State of the art assessment methods originated in the Index of Biotic Integrity (IBI) developed in the 1980’s in the U.S. (Karr 1981)¹. IBI’s are multimetric indices, each of the selected biological metric reflecting important components of the functioning of fish communities, e.g. habitat, migratory, reproductive and trophic guild composition, individual health and abundance. Although assessment methods have been developed recently in a few European countries **most national methods are still under construction or are not fully in compliance with the WFD**. Member states use different concepts, indices and metrics for the development of IBI’s and therefore national assessment results have to be “intercalibrated” according to the WFD in order to guarantee comparability of the ecological status across Europe.

A more efficient **alternative to the national methods** is the development of a **common European method, the European Fish Index**, which is the objective of the EFI+ project. The advantage of a European approach is that the methodological concept is consistent and, hence, the assessment results are comparable across Europe without a need for intercalibration.

2.1. The preceding project FAME

A **first version of the European Fish Index** has been developed in the EC-funded project **FAME**² (<http://fame.boku.ac.at>) finalised in 2004. The original EFI was the first index applicable across a wide range of different ecoregions in Europe. FAME covered mainly Western, Northern and parts of Central Europe, while the number of datasets from Mediterranean as well as Central/Eastern countries was not so well represented. Most bio-assessment methods developed so far in the Mediterranean river basins have had difficulties to uncover responsive biological indicators based on fish assemblage metrics. The ability of the original European Fish Index to reflect hydromorphological pressures (including migration barriers/continuity interruptions) was low in comparison to the capacity of the index to detect water quality pressures. The WFD requires not only an assessment of the fish community but also the population structure of individual species which helps to assess the ecological status in species poor fish assemblages. However, FAME did not cover this issue due to lack of adequate data. Finally, FAME did not deal with very large floodplain rivers as adequate sampling methods were still an open question for this river type.

2.2. Objectives of the EFI+ project

The overall objective of the EFI+ project was to improve the European Fish Index in terms of existing spatial and river type specific limitations in order to produce a more accurate pan-European Fish Index. The specific objectives were:

¹ Karr J.B., 1981. Assessment of biotic integrity using fish communities. *Fisheries* (6) 6, 21-27.

² FAME: “Development, evaluation and implementation of standardised fish-based methods to assess the ecological status of running waters in Europe”; FP5, Energy, Environment and Sustainable Management. Key Action 1: Sustainable Management and Quality of Water, EVK1 -CT-2001-00094.

1. To evaluate the applicability of, and make necessary improvements to the existing EFI in Central-Eastern Europe and Mediterranean ecoregions.
2. To extend the scope of the existing EFI to cover large floodplain rivers.
3. To analyse relationships between hydromorphological pressures (incl. continuity) and fish assemblages to increase the accuracy of the EFI.

Additional objective was to develop user friendly software for the calculation of the new European Fish Index (EFI+). The index and software should be tested in ongoing national and international monitoring programmes, evaluated at end-user workshops and presented at international conferences.

2.3. The EFI+ consortium

The EFI+ consortium consisted of 14 partners from 13 countries. The project was coordinated by the University of Natural Resources and Applied Life Sciences, Vienna (Figure 1).

1. University of Natural Resources and Applied Life Sciences, Austria
2. Joint Research Center, Italy
3. Finnish Game and Fisheries Research Institute, Finland
4. Cemagref – Agricultural and environmental engineering research, France
5. Leibniz-Institute of Freshwater Ecology and Inland Fisheries, Germany
6. Hortobágyi Halgazdaság Rt., Hungary
7. Aquaprogram s.r.l, Italy
8. Inland Fisheries Institute, Poland
9. Instituto Superior de Agronomia, Portugal
10. The Bacău University, Romania
11. Universidad Politécnica de Madrid, Spain
12. Institute of Freshwater Research– Swedish Board of Fisheries, Sweden
13. Swiss Federal Institute of Aquatic Science and Technology, Switzerland
14. University of Hull, United Kingdom

The Netherlands and Lithuania were participating in the EFI+-project via RIZA and the University of Vilnius based on national funds. Besides the indicated partners a number of different organisations contributed to the EFI+ database by providing a lot of valuable data.

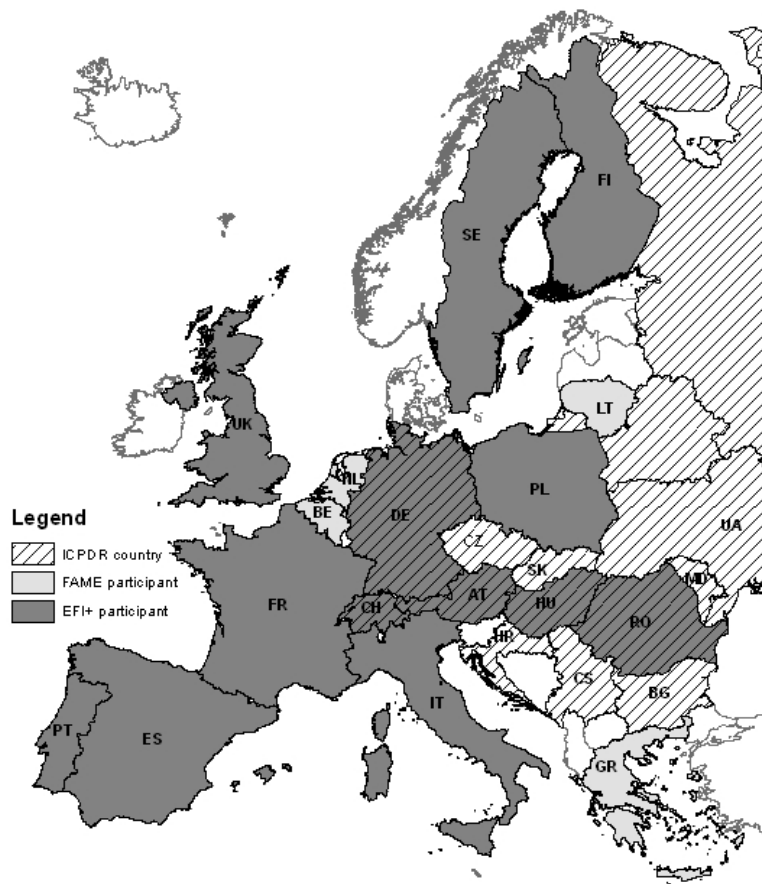


Figure 1: Countries participating and collaborating in EFI+ (ICPDR: International Commission for the Protection of the Danube River)

3. Methods

The project consisted of 7 work packages (WP) (Figure 2). Fish data from field samples (electrofishing) were the fundamental basis for the development of the new European Fish Index (EFI+). The fish data derived from existing field samples were transformed into so-called “metrics” i.e. quantitative criteria describing the main characteristics of the fish fauna (guilds). Reference metrics of unimpacted conditions were predicted by environmental descriptors using multiple regression models. Information on human pressure conditions are collected and analysed. The reaction of the metrics to the pressure was tested and metrics reacting were combined to a fish index. Finally, the fish index was scored into 5 status classes according to the WFD.

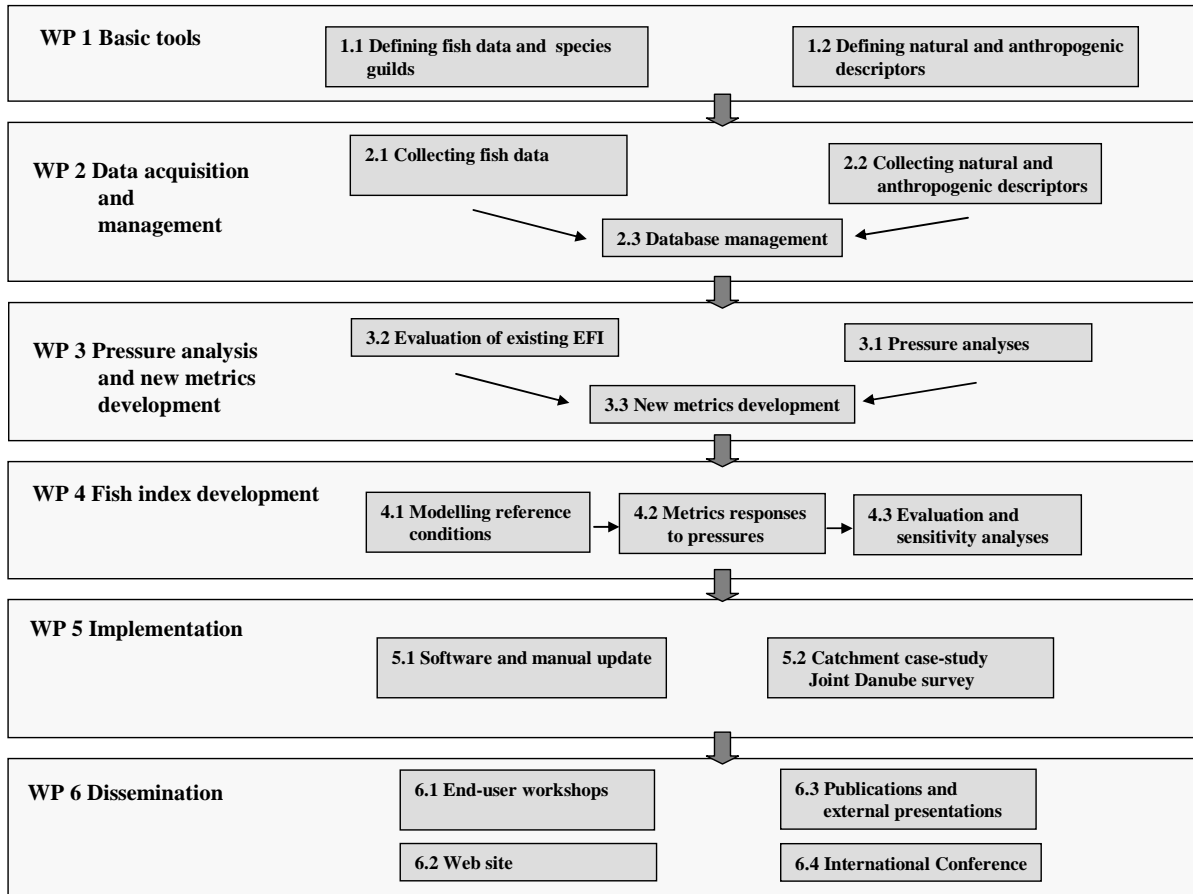


Figure 2: Organisation and work packages (WP) of the EFI+ project

3.1. Data collection and common database

Models and analyses in the EFI+ project are based on a representative dataset of European streams and rivers. Different types of data have been included in the common database: fish data of existing field samples, environmental descriptors and human pressure information.

The definition of the main environmental descriptors explaining natural variability of fish communities in particular river sections and the identification of pressure variables reflecting strong fish-pressure relationships were based on a literature review and the expertise in the EFI+ consortium. For the final selection of variables also data availability had to be considered. While the import of fish data from existing national and institutional databases was a comparable easy job, the collection and harmonisation of pressure data was a very labour intensive task.

For identification of spatial coordinates and for the calculation of 25 environmental variables (e.g. catchment size, precipitation, distance to source, air temperature) we used a European-wide river network (CCM River Network). Altogether 15 environmental variables were collected on the national level. Some are especially related to “natural” or minimally disturbed historical conditions, e.g. natural flow regime, naturally dominant sediment, geomorphological river type. Particular variables have been chosen to account for the conditions in Mediterranean rivers (Natural flow regime) and large rivers (presence of floodplains).

At the national level information on five groups of pressures were collected: Connectivity (7 variables), hydrology (9), morphology (7), water quality (7); navigation as well as artificial collinear connected reservoirs were considered as additional pressure types (2). Altogether, there were 32 pressure variables considered. Finally, a pressure index for characterisation of the overall pressure situation was developed. For this purpose qualitative pressure information was coded along a 5 level classification (“no” = 1, “slight” = 2, “weak” or “intermediate” = 3 and “high” or “strong disturbance” = 5), i.e. from nearly undisturbed to strongly impacted sites. The index was computed by calculating the mean of pressure groups indicating degradation (class > 2) and by multiplying this value with the number of pressure groups affected - in order to reflect the situation of multi-impacted sites.

The taxa and guilds classification of the preceding FAME project was completely revised by an expert group of the EFI+ consortium. Several new guilds were added and physiological characteristics were compiled based on a literature review. All species classifications from the FAME project were checked, discussed among the experts and reclassified if necessary.

The common database contained 14 221 sites corresponding to 29 509 sampling occasions distributed in 15 countries: Austria, Switzerland, Germany, Spain, Finland, France, Hungary, Italy, Lithuania, Netherlands, Poland, Portugal, Romania and Sweden and the United Kingdom.

For the development of the new EFI only one sampling occasion per site and high quality data were retained resulting in 9948 sites available for the analyses. The dataset was split into 3 parts (Figure 3):

- The first corresponds to the slightly disturbed sites (SID, N=2526) which present no or slight degree of perturbation and was used to explore and to test the response of metrics among ecoregions in the « quasi » absence of pressure.
- The second called calibration dataset is a subset of SID with a more strict selection of unimpacted sites of high quality and representative for the area covered by the project (CD, N=533)
- The third also contained disturbed sites (N=7244) and was used to test the response of metrics to human pressures.

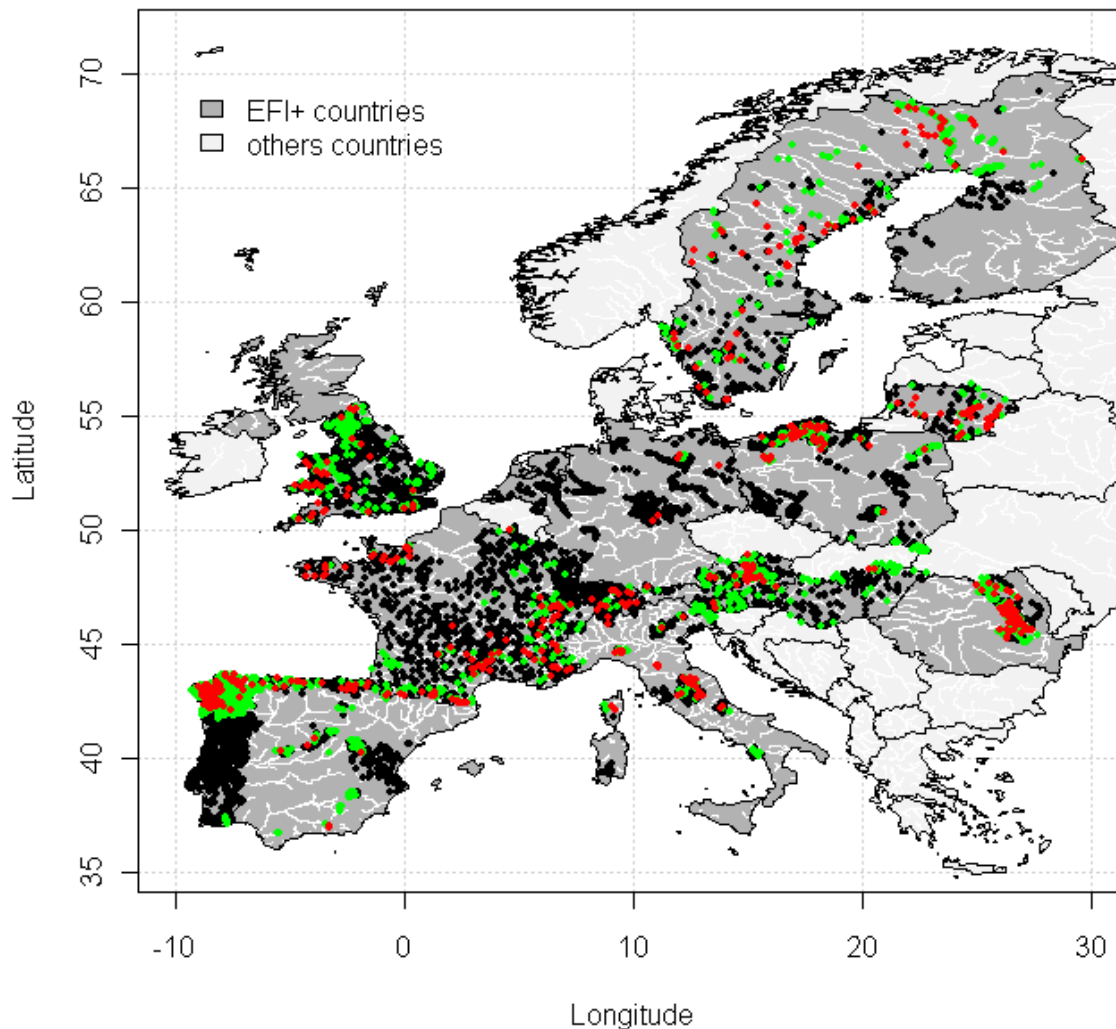


Figure 3: Localisation of the sites contained in the three datasets (N=9948): The green (N=533), red (N=2526) and black (N=7244) points correspond to the calibration, slightly disturbed and disturbed datasets, respectively. The light and dark grey polygons identify the countries included in the EFI+ project (see for more details, <http://efi-plus.boku.ac.at/>).

3.2. Fish index development

The first task was to develop models to predict unimpacted conditions: Calibration sites were used to develop statistical models which allow prediction of a “theoretical” metric value at a site as a function of natural environmental factors. Afterwards, metrics with the best model performance were selected for testing their response to different types of pressures. The metrics showing the best responses were selected for the final index. The index was calculated as mean of selected metrics. For the final assessment score the thresholds between different assessment classes were defined (Figure 4).

The metrics were modelled by generalised linear model using environmental variables integrating morphological and climatic characteristics of running waters, i.e. river slope, July air temperature, temperature amplitude, natural sediment and geomorphological type. Candidate metrics were defined according to the updated guild classification. Different size and age classes of fishes were tested in order to incorporate potential effects of human pressures on the population structure.

The performance of the models was tested in terms of validity, stability and predictive power. Redundant metrics were excluded and representativeness of metrics for all ecoregions was used as additional selection criteria. Metrics were standardised at the level of ecoregions and fish zones (salmonid zone, cyprinid zone) to balance regional differences and rescaled between 0 and 1. A low metric value indicates very bad, a high value very good ecological status.

Finally, only metrics sensitive to human pressures were retained for the final index. To quantify sensitivity slightly disturbed sites were compared with disturbed sites classified in the classes 4 and 5 (strongly impacted). The remaining metrics were used for the index by calculating the mean of the metrics. In addition to a mean value an error estimate was calculated using different statistical techniques (for more details see project report on index development,

<http://efi-plus.boku.ac.at/download.htm>).

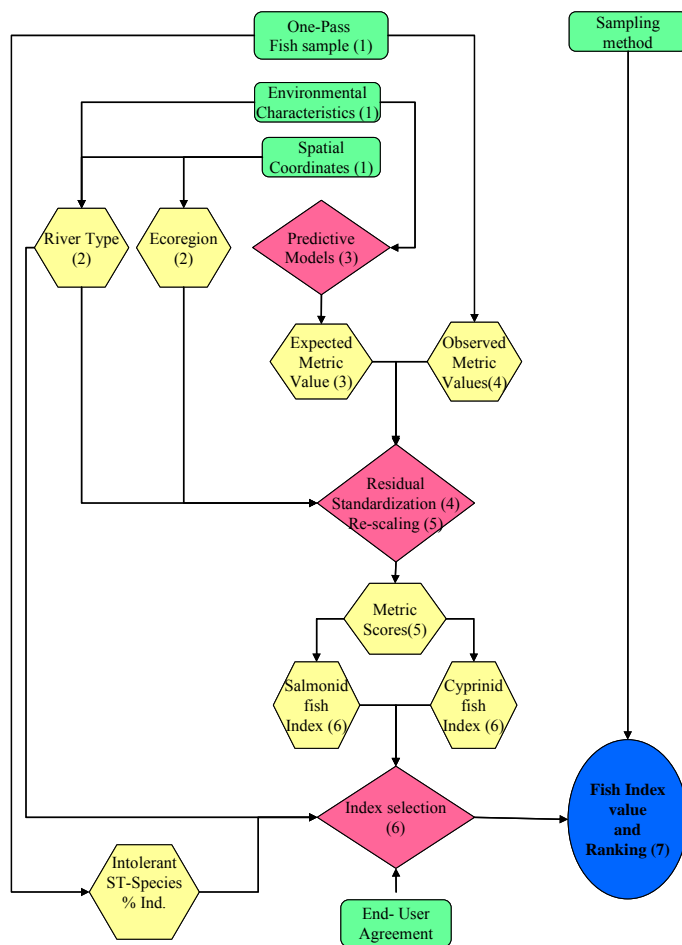


Figure 4: Methodological principle of the development of the new European Fish Index (EFI+)

3.3. Continuity – long distance migrating fish species

The principle of the approach was to calculate a metric for the historical and present distribution of long migratory fish species and to test the sensitivity of the metric to migration barriers. Since historical information on the distribution of fish species is very often incomplete also a potential distribution was modelled based on historical information and environmental data of river sections.

3.4. Large floodplain rivers

Due to the specific requirements of large floodplain rivers (size, sampling techniques, lack of undisturbed sites) a separate data base was compiled. In total, the database contained 3226 fishing occasions covering 415 sites in 18 river systems. The main objective of the work for LFR was to test the efficiency of different sampling techniques and to propose LFR-specific metrics.

3.5. Mediterranean rivers assessment

The main objective of Mediterranean River Assessment was the testing of new ecotaxa guilds for different types of pressures and for combined effects and response types, taking into account the environmental background. Another aim was the improvement of metrics based on tolerance indicator values. Based on these tests final recommendations to be considered in the development of the EFI assessment method were made. The Mediterranean rivers database is a subset of the common database and contains 2105 sites.

4. Results

4.1. Guild classification

The guild classification of the FAME project, characterising the main ecological requirements of European fish species, was completely revised. In total, 395 fish species were analysed and species were classified into 57 modalities of 16 groups (tolerance for water quality in general, O₂, toxic substances, acidification, temperature, habitat degradation, classification of habitat guild, feeding habitat guild, adult trophic guild, migration guild, salinity, reproductive guild, spawning preferences, reproductive behaviour, parental care and trophic index). Physiological parameters were compiled for length, length-weight relationships, shape factor, swimming factor, longevity, fecundity, egg diameter, age of maturity and incubation time.

4.2. Pressure characterisation

Pressure analysis showed that 24 % of sites are affected by single, 22 % by double 19 % by triple and 12 % by four pressure groups. Only 23 % of sites are not affected, i.e. class ≤ 2 . In terms of pressure types, 55 % of analysed sites showed alterations for water quality pressures, 40 % for hydrology, 37 % for morphology and 34 % for connectivity. In 45 % of the cases water quality problems are also associated with other pressures. The results clearly show that European rivers are multi-impacted (Figure 5).

A clear limitation for the accuracy of data and the level of detail was the availability of basic information at the national level. Especially for some pressure variables only presence or absence could be considered (e.g. reservoir flushing, acidification, barriers). The most critical pressure type was water quality. Although there is long tradition in water quality monitoring member states evaluate water quality quite differently. Most countries use chemical parameters while

some countries use a saprobic index besides chemical parameters (Austria, Italy, Romania and Germany). This makes it difficult to compare water quality across Europe. Another problem was the lack of pressure information considerably reducing the number of available sites (see database description).

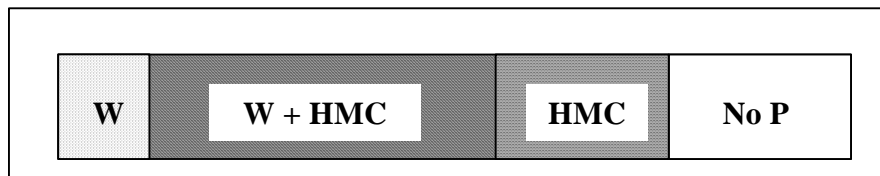


Figure 5: Proportion of sites affected by (a) water quality pressures only (W, 11 %), (b) by water quality and hydromorphological pressures (W + HMC, about 45 %), (c) by hydromorphological pressures only (HMC, 21 %) and (d) nearly undisturbed sites (No P, about 23 %).

4.3. The new European Fish Index – EFI+

In EFI+ two different indices were developed depending on fish assemblages, i.e. salmonid dominated fish assemblages and cyprinid dominated fish assemblages. Both indices are composed of two metrics. The reason for developing 2 indices was that fish communities are completely different and react differently to human pressures in the two zones.

The distinction between the two river types is based on the proportion (relative abundance of individuals) of typical species belonging to salmonid dominated fish assemblage. These 19 species are shown in Table 1. Typically, an undisturbed salmonid river type is dominated by salmonid type species which represent more than 80 – 90 % of the number of individuals caught. Conversely, the relative abundance of these species is less than 10 - 20 % for a typical undisturbed cyprinid river type.

Table 1: List of species typically belonging to salmonid dominated fish communities.

<i>Alburnoides bipunctatus</i>	<i>Cobitis calderoni</i>	<i>Coregonus lavaretus</i>
<i>Cottus gobio</i>	<i>Cottus poecilopus</i>	<i>Eudontomyzon mariae</i>
<i>Hucho hucho</i>	<i>Lampetra planeri</i>	<i>Phoxinus phoxinus</i>
<i>Salmo salar</i>	<i>Salmo trutta fario</i>	<i>Salmo trutta lacustris</i>
<i>Salmo trutta macrostigma</i>	<i>Salmo trutta trutta</i>	<i>Salmo trutta marmoratus</i>
<i>Salvelinus fontinalis</i>	<i>Salvelinus namaycush</i>	<i>Salvelinus umbla</i>
<i>Thymallus thymallus</i>		

In the salmonid river zone the most sensitive metrics are based on oxygen intolerant species and habitat intolerant species expressed in “relative” density. For habitat intolerant species fishes < 150 mm showed a stronger response to human pressures than using all length classes. In the cyprinid zone, the metrics based on oxygen depletion and habitat intolerance cannot be used due to low representativeness in several ecoregions. Finally, the metrics “relative” richness of species spawning in running waters (Ric.RH.PAR) and “relative” density of gravel spawning species

preferring running waters (Ni.LITHO) were selected for the cyprinid type. One metric is expressed in terms of richness, two in density and one in density per size class. Two metrics are based on tolerance responses, and two are based on reproduction habitat requirements. Metrics were modelled using an offset function relating the guild-specific density and species richness to the total density and species richness of each individual sample in order to balance differences in sampling effort. This method resulted in metrics expressed as “quasi” relative density and relative richness. The four metrics showed a negative response to increasing human pressures. The correlations between the two metrics are relatively low (Pearson’s coefficients less than 0.65) in order to guarantee independent metrics.

Table 2: Metrics used to calculate the Salmonid and Cyprinid Fish Index

Index	Metric name	Detailed name - guild
Salmonid	Ni.O2.Intol	Density of species intolerant to oxygen depletion , always more than 6 mg/l O ₂ in water.
	Ni.Hab.Intol.150	Density \leq 150 mm (total length) of species intolerant to habitat degradation .
Cyprinid	Ric.RH.Par	Richness of rheopar species; requiring a rheophilic reproduction habitat , i.e. preference to spawn in running waters.
	Ni.LITHO	Density of species requiring lithophilic reproduction habitat, species which spawn exclusively on gravel, rocks, stones, cobble or pebbles. Their hatchlings are photophobic.

Under the hypothesis that the pressure estimation is an acceptable measure of human alteration, the indices, particularly in cyprinids zone, are typical “rule-in” tests. In spite of low sensitivities, we note that the measures of specificity (spec) and positive predictive value (ppv) are relatively high in the cyprinid zone (spec=0.89 and ppv=0.78). The less significant results in the salmonid river zone (spec=0.93 and ppv=0.54) can be explained by the low prevalence of pressure (prev=0.16). The both indices are optimised to recognize un-degraded sites. Consequently, the detection of an altered situation efficiently confirms the high degraded level of this site. From an economical/management point of view, this objective corresponds to the idea that the risk for managers to invest in restoration measures for unimpacted sites is low.

The main progress of the EFI+ project in comparison to the FAME project was that the pressure information was much more detailed and enabled a better analysis of metric responses. The finally selected metrics respond much better to hydromorphological pressures than in the previous version of the FAME project. Another advantage was the better model performance and higher level of accuracy of the statistical methods applied for model development. Also, a statically based estimation of uncertainties of the final index was provided. All in all the newly developed European Fish Index works in most countries and ecoregions better than the former FAME assessment method. However, some limitations still exist (see below).

For the Cyprinid Fish Index, the size of the 80 % tolerance interval is close to 0.30 units (+/- 0.06 units). This corresponds more or less to one class. The error estimation is presently in an experimental phase and it requires some additional tests before implementing in the software.

Ecological class boundaries were defined only based on the distributions of index values for undisturbed sites in the two river types. As the sampling method (sampling by boat or by wading) showed to influence the score value, especially in the cyprinid zone, class boundaries were computed separately in the cyprinid river zone.

- The limits between class 1 and 2 correspond to the value of the 95% quantile of the index distribution for undisturbed sites.
- The limits between class 2 and 3 correspond to the value of the 25% quantile of the index distribution for undisturbed sites.
- The limits between classes 3-4 and 4-5 are defined in a way that the ranges between classes 3, 4 and 5 are similar.

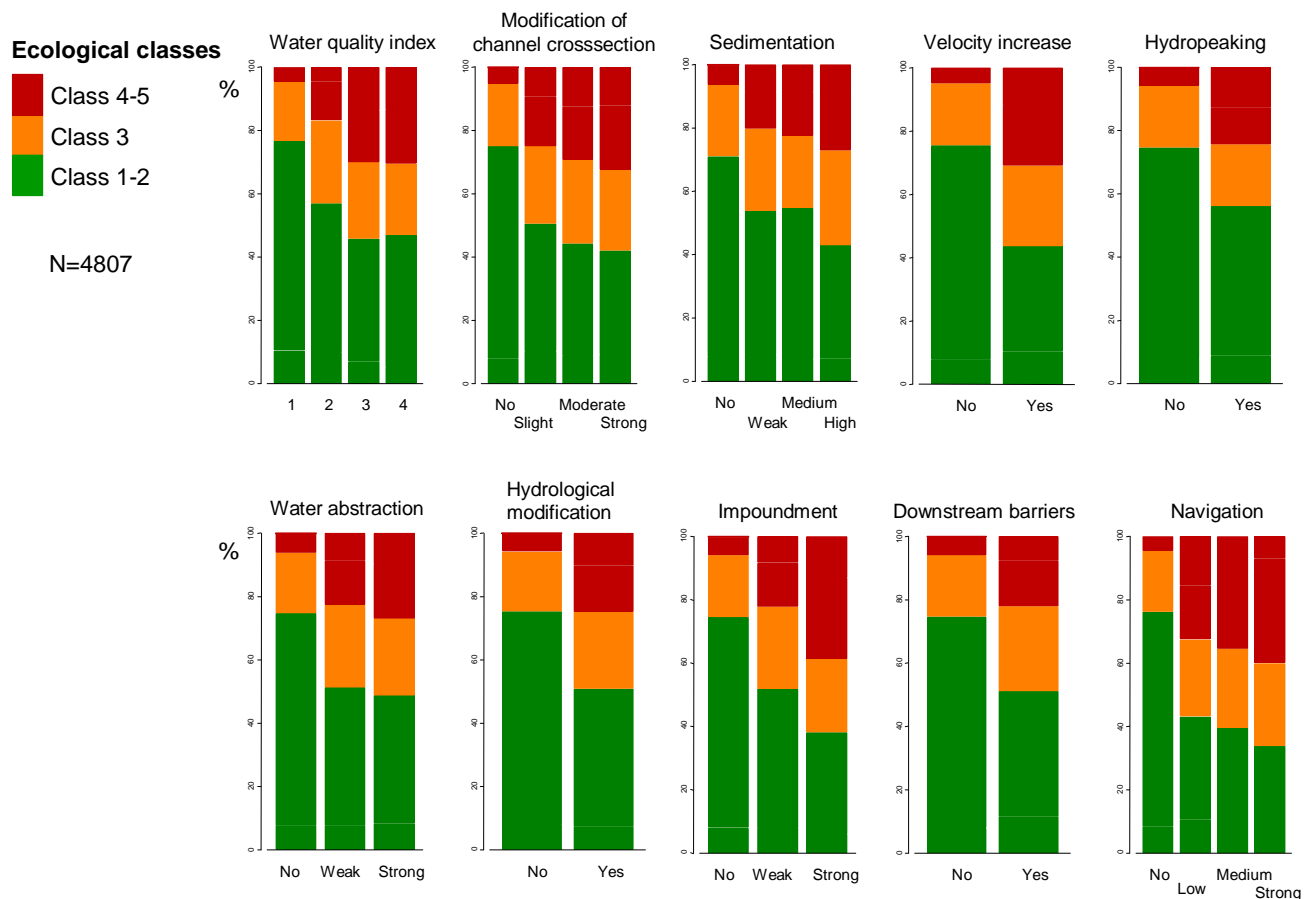


Figure 5: Response of the new European Fish Index (EFI+) to different types of human pressures.

Limitations of the new European Fish Index (EFI+)

Although the new version of the European Fish Index represents a major step forward in comparison to the old version of the FAME project, there are still some limitations: The statistical models that are used for the EFI+ reflect the average response of fish communities to environmental conditions. The application of the EFI for particular environmental situations might cause problems. This index has been developed for sites located in ecoregions and environmental conditions represented by the EFI+ central database. Therefore, the index should not be applied in areas with a fish fauna deviating from those of the tested ecoregions. E.g. the index should be handled with care at the presence of a natural lake upstream of the site, in rivers with winter dry periods and in case of “organic” rivers. Although no clear effects have been observed, the indices must be used with caution for intermittent/summer dry rivers due to the low number of undisturbed sites of this river type used to test the index. The index should be used with caution in the lowland reaches and floodplains of large rivers as no reference sites from these reaches have been used for the calibration of the index. Two additional cases could be problematic: fairly undisturbed rivers with naturally low fish density and heavily disturbed sites where fish are nearly extinct. In the first case, fish are close to the natural limits of occurrence and therefore might not be good indicators for human impacts. If the very low density is caused by severe human impacts more simple methods or even expert judgement are sufficient to assess the ecological status of the river.

4.4. Continuity – long distance migrating fish species

Altogether 18 fish species were considered for the data collection. Especially for the most common and widespread commercial fish species such as eel, salmon, sea trout, Atlantic sturgeon or Allis shad the number of historical records was quite high.

Tests of the specific diadromous species metric (proportion of present diadromous species richness compared with historical species richness) showed a clear response to continuity disruptions. Thus, this metric was also included in the final software. However, due to the different structure of this metric (the presence of species can be derived not only from field samples but also from different sources, i.e. written documents for historical distribution and other fish samples for present occurrence) it was not integrated in the final index. At this step it provides additional information about the tendency of the index when considering continuity impacts particularly.

4.5. Mediterranean Rivers assessment

Some of the metrics tested for Mediterranean rivers showed a fairly good response to human pressures. The selected candidate metrics were generally more responsive to a larger proportion of combined pressure variables in comparison to single pressures, which may suggest an additional effect of interacting pressures. All the selected candidate metrics were based on species richness, while predictive models for metrics based on abundances were generally poor. Four metrics were selected as potentially candidate for their use in biotic integrity indices, all showing an overall negative response to pressures: 1) richness of adult insectivorous species, 2) richness of potamodromous species, 3) richness of rheophilic spawning species (habitat) and 4) richness of lithophilic spawners (substrate). These metrics were selected mainly according to their responsiveness to a maximum number of combined pressures. Nevertheless, among 30 potential candidates as responsive metrics, only five yielded acceptable predictive models.

A consistent result across different tested metrics was the low responsiveness to connectivity related pressures. However, it has to be emphasized that connectivity pressure may be underestimated due to the lack of a thorough field inventory on the number of small and/or old barriers and especially their capacity to be passed by migrating fish.

4.6. Large Floodplain Rivers assessment (LFR)

The contribution of additional sampling gears to the species inventory remained surprisingly low compared to standard electric fishing during the day.

Alternative sampling gears performed better in

- i) recording long-distance migratory fish species,
- ii) recording rare and very rare species,
- iii) obtaining large sized specimens of most of the species and
- iv) yielding large amounts of eurytopic, tolerant fish.

However, the contribution of habitat intolerant indicator fish species by additional sampling gears was negligibly low. In contrast, the most sensitive life stages of nearly all fish species depend on well structured littoral habitats and habitat bottlenecks have been found in the littoral as well. Therefore, it has been suggested to assess the impacts of habitat alterations on river fish assemblages by using data obtained by electric fishing along the banks only. The abundance and proportion of species preferring standing waters proved to adequately reflect the lateral succession of the fish assemblage in floodplain water bodies.

There is still need for further research on large floodplain rivers as the samples used for EFI+ were still too small and inhomogeneous for drawing general conclusions on sampling techniques and metrics. Improved standards for electric fishing in large rivers have to be developed and applied and further metrics tested to improve fish-based assessments of LFR.

5. Implementation and dissemination of project results

For the implementation of the newly developed European Fish Index, a software and a manual were developed. The software works as online tool and offers the possibility for manual data input as well as for input of large datasets by using predefined input data spreadsheets (<http://efiplus.boku.ac.at/software>). The software was successfully tested in two end-user meetings at the end of the project.

Outputs of the software are all metric values (i.e. theoretical metrics, observed metrics, final metric), the river zone and the two indices. Further additional comments are provided for the correct interpretation of the results or possibly necessary corrections of the river zone classification. The diadromous species metric was also integrated in the final output.

The newly developed European Fish Index was tested for the sites sampled during the 2nd Joint Danube Survey. The first application of the EFI+ at the Danube showed that the results were confounded by the large quantities of invasive species. After eliminating this effect the index was able to reflect degraded conditions of the Upper Danube mainly caused by large dams versus the better conditions in the free flowing sections of the Lower Danube. However, the index was not able to detect small scale (local) differences in pressures. As mentioned above, further research is necessary for large rivers to improve the assessment methods.

The international conference organised by the EFI+ project was held in Hull, UK, and attended by about 100 participants. Altogether, 36 presentations were given during 9 sessions. The first end-user meeting was held at the end of the conference at the University of Hull. It was attended by some 30 participants of the conference. The second end-users meeting was focusing in particular on water managers and potential end users in Central/Eastern European countries. It was held at the University of Cluj (Romania) and 50 participants attended the workshop.

Apart from the new European Fish Index the EFI+ central database represents an important output of the project. Parts of the database are published online on the project webpage (metrics, index, scores, environmental and pressure variables).

6. Further perspectives and research needs

Work on the New European Fish Index continue in two recently started projects. One is WISER, an EC-funded research project focusing on the development of methods for assessing and restoring all aquatic ecosystems addressed by the WFD. The second one is FORECASTER, an applied project aiming at the application of output from scientific projects for the implementation of the WFD with special emphasis on ecological response to hydromorphological pressures and rehabilitation.

Due to the influence of FP projects FAME and EFI+ fish sampling is becoming more and more standardised in Europe. However, as realised in EFI+, available pressure data are still not very consistent in member states. Further projects and initiatives are necessary to achieve a better **harmonisation of pressure information across Europe**.

It is an obligation of the WFD to incorporate **metrics referring to the population structure** of indicative species. However, there have been still some countries that did not record length information for their fish samples in the past. Complete analyses of the potential of length-related metrics in fish-based assessment methods will be possible only after the first ecological monitoring in the member states where the new sampling standards will have been fully implemented.

Although compared to the FAME project the EFI+ project has now covered a wider range of European environments there are still some geographical gaps that have to be filled. Countries like Greece and Italy have not been able to deliver sufficient amount of data so far. Furthermore, accession countries like Croatia and other potential candidates inhabit regions with special fish communities (e.g. endemic species) that have to be incorporated in future activities to fully **integrate these additional regions into future European index developments**.

The EFI+ project considerably contributed to a better understanding of the effect of sampling methods in **large floodplain rivers**. However, **further work is necessary** to test specific metrics and develop floodplain specific indices or additional modules to be incorporated in overall assessment tools. As all large floodplain rivers in Europe are degraded, reference conditions should be studied in climatically comparable regions with less human pressures.