FISH-BASED ASSESSMENT OF EUROPEAN RIVERS: PRINCIPLES, METHODS AND APPLICATIONS

Stefan Schmutz
Institute of Hydrobiology and Aquatic Ecosystem Management, BOKU Vienna, Austria,

Objectives

- to assess the ecological status of rivers with standardised methods
- to integrate adequately natural variability of fish communities in methods
- to distinguish between different levels of degradation
- to distinguish between different types of pressures
- to achieve end-users acceptance

The FAME project

Development, Evaluation and Implementation of a standardised Fish-based Assessment Method for the Ecological Status of European Rivers (FAME)

A Contribution to the Water Framework Directive

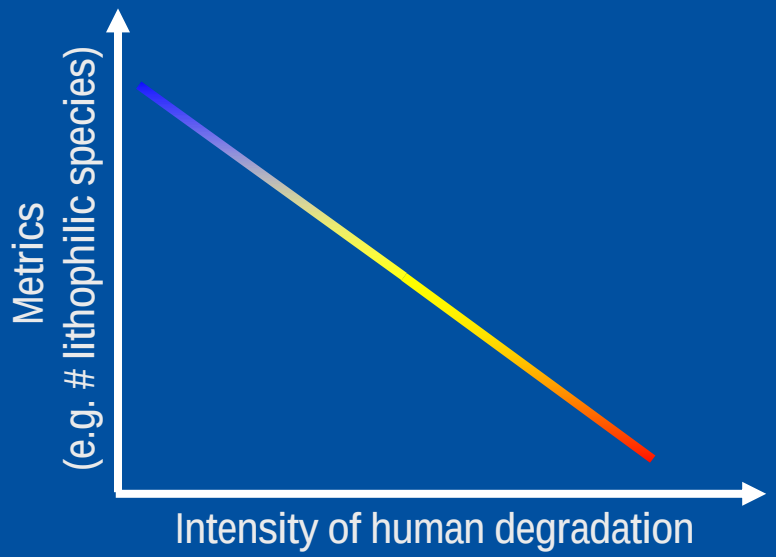
A research project supported by the European Commission under FP 5

2002-2004

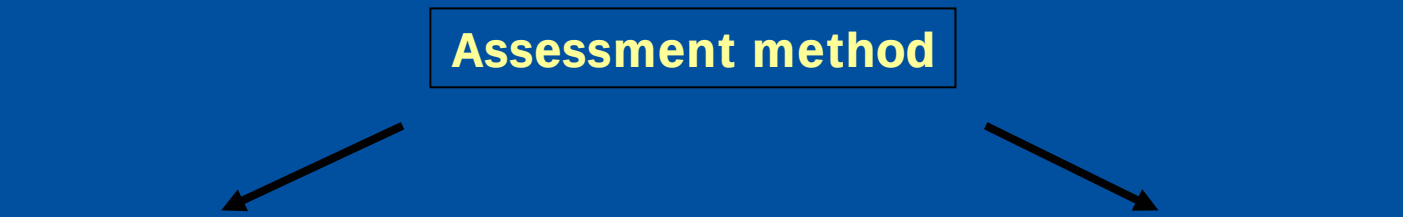
Basic concept

Basis = Index of Biotic Integrity (IBI, Karr 1981):

- description of fish assemblage by metrics
- metrics respond to human pressures
- expert system



Principal types of assessment methods



Expert system

- Expert driven
- Hardly validated
- Flexible, wide applicability
- Simple

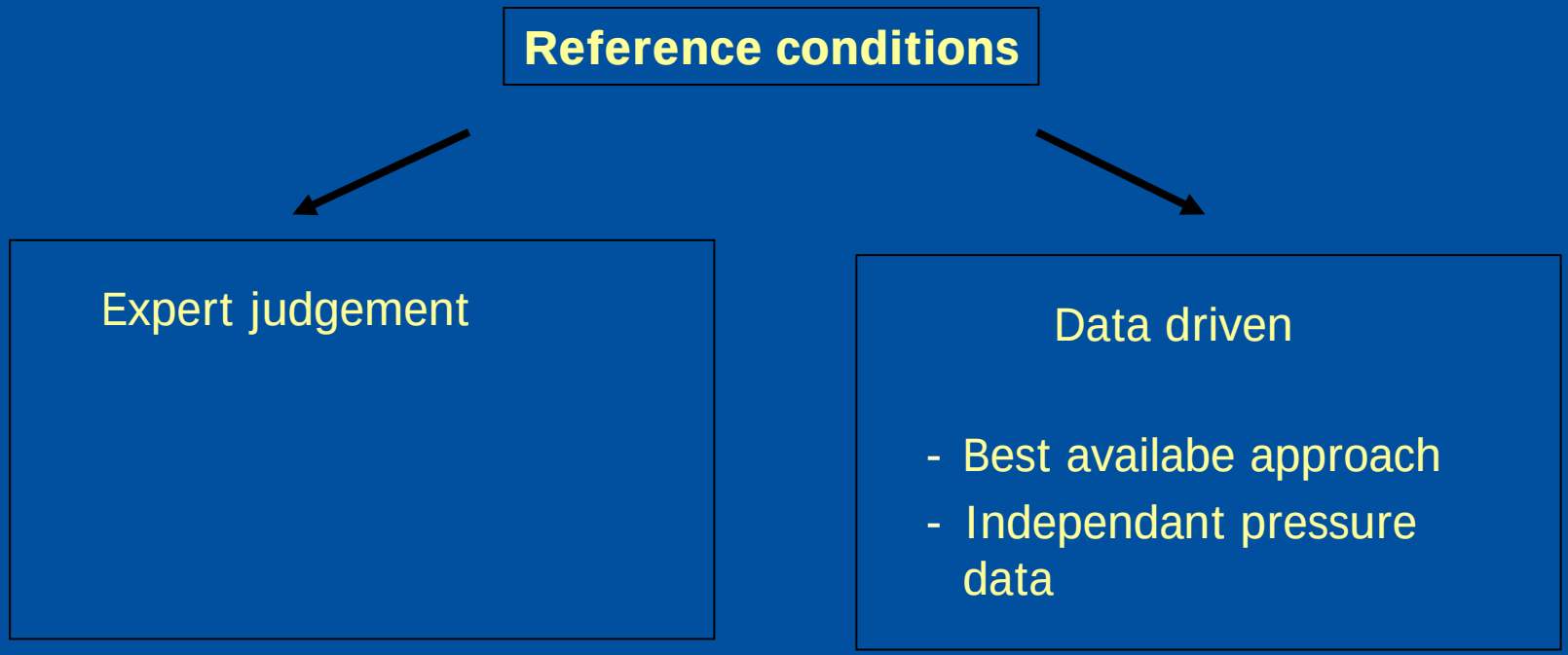
Model-based methods

- Data driven
- Statistically validated
- Appliability depending on data
- Complex

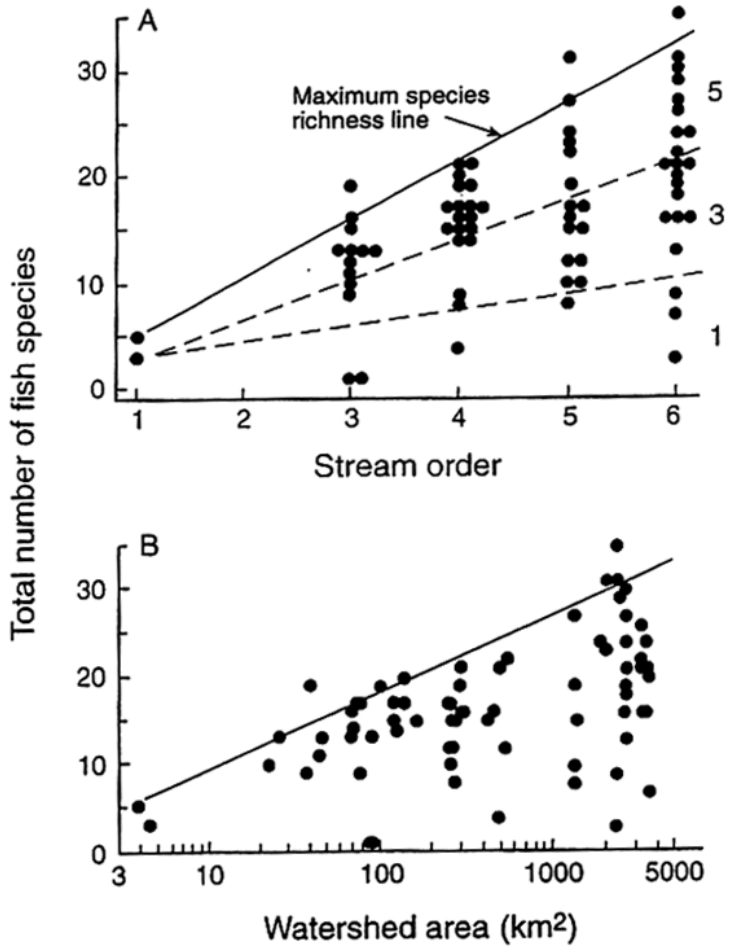
Basic tools for method development

- Reference conditions and pre-classification of human pressure
- Species classification
- Selection and calculation of metrics
- Sampling standard

Defining reference conditions



Best available approach



Fausch et al. 1984

Identification of reference conditions & pre-classification of sites / FAME

Selection of **pressure variables** indicating **impacts** (Basis = CIS paper "Impact & Pressure Classification") to

1. identify sites corresponding to reference conditions and to
2. pre-classify sites based on human pressure status for the calibration of fish-based indices

Identification of reference conditions & pre-classification of sites / FAME

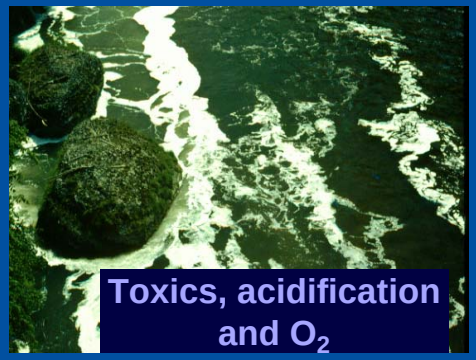
FAME variables	
river basin (3)	land use, urbanisation, connectivity
river segment (6)	land use, urbanisation, connectivity, riparian zone, floodplain lateral movement, sediment load
river site (14)	hydrology (3), morphology, upstream dams, salinity, nutrients, toxicity, fisheries (3), impacts fauna & flora, weed cutting

- **classification on 5 impairment levels** - ranging from no/minor alterations to severe impact on fish fauna

Identification of reference conditions & pre-classification of sites / FAME

Final pre-classification:

mean of up to 5 main pressure variables as:



Species classification

- 236 fish species recorded in FAME countries
- 186 species classified as native / alien in 41 ‘river regions’ (Rhine, Danube, ….)
- 46 sentinel species identified (for density, biomass, age/length structure analyses)

Species classification

123 species classified according to 42 criteria of 13 functional ecological guilds, e.g.:

Habitat	rheophilous, limnophilous, eurytopic (Schiemer & Waidbacher 1992)
Reproduction	lithophilous, phytophilous, …. (Balon ´75, ´81)
Feeding	insectivorous, piscivorous, omnivorous,….
Feeding habitat	water column, benthic
Migration	diadromous, potamodromous
Longevity	short-living, long-living
Tolerance	tolerant, intolerant

Metrics selection

WFD classification (example for “high status”)

Species composition and abundance correspond totally or nearly totally to undisturbed conditions.

All the type specific disturbance sensitive species are present.

The age structures of the fish communities show little sign of anthropogenic disturbance and are not indicative of a failure in the reproduction or development of any particular species.

FAME

- Species diversity
- Species composition
- Population abundance and age structure

Metrics calculation

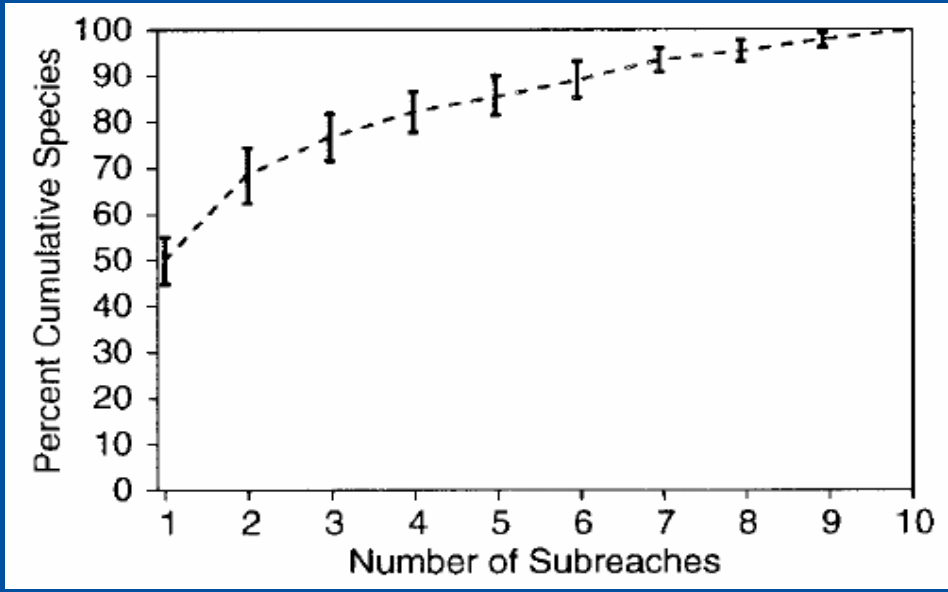
- 12 overall composition and abundance metrics (all, native and alien species)
- 196 guild metrics (98 native, 98 all species)
- 19 historical metrics
- 5 metrics for each of the 46 sentinel species

FIA – Fish Index Austria

Metrics

1. Number of dominating species compared with historical reference
2. Number of accompanying species compared with historical reference
3. Number of rare species compared with historical reference
4. Number of reproductive guilds compared with historical reference
5. Number of habitat guilds compared with historical reference
6. Fish Zone Index
7. Population age structure of dominating species
8. Population age structure of accompanying species
9. Total biomass

Sampling effort



Hughes et al. 2002

a length of 40 times the channel width is necessary to collect at least 90% of the fish species occurring in the stream reach Peck et al. 2002

CEN standard EN 14011, 2003: Water quality – Sampling of fish with electricity

10-20 times the channel width

Sampling strategy

- Fishing method
  - electric fishing: boat, wading
- Fishing intensity
  - CEN/FAME: number of samples, stretch length 10-20 times river width, minimum 100 m^2;
  - 1 anode per 5 m river width
  - boat fishing techniques
- Population density estimation method
  - one pass versus multiple passes,
  - calculation methods

The Fish Database of European Streams

FIDES *Fish database of European streams*

Export database

Input from keyboard (form views)

New Sites,Fishing occasions,Catches,Lengths,Length classes

New Reporters

Input from keyboard advanced users (data sheet views)

New Sites

New Reporters

New Fishing occasions and catches

Catch (browse all catches)

Length (browse all lengths)

Length class (browse all classes)

View data (reports)

All sites

All fishing occations

All catches

Sites, Fishing occasions and Catches

All reporters

Validity tests (data in tables)

Site | Reporter | Fishing occasion

Catch | Length | Length class

Historical data

Help tables

Countries, reasonable values

Other reasonable data

Ecoregions

Historical data

Taxa and Guilds

From the Swedish National Board of Fisheries

FIDES contents

Data sets of:

- 12 countries
- 17 eco-regions
- 2651 rivers
- 8228 sites, ca. 15 000 samples

209 variables in 8 tables (reporter, site, fishing occasion, catch, length/length class, taxa & guilds, historical data

Methodological approach – Principles and Results

Method development

Two different approaches

Spatially based, type-specific methods (SBM)

Scale: Ecoregion, Europe

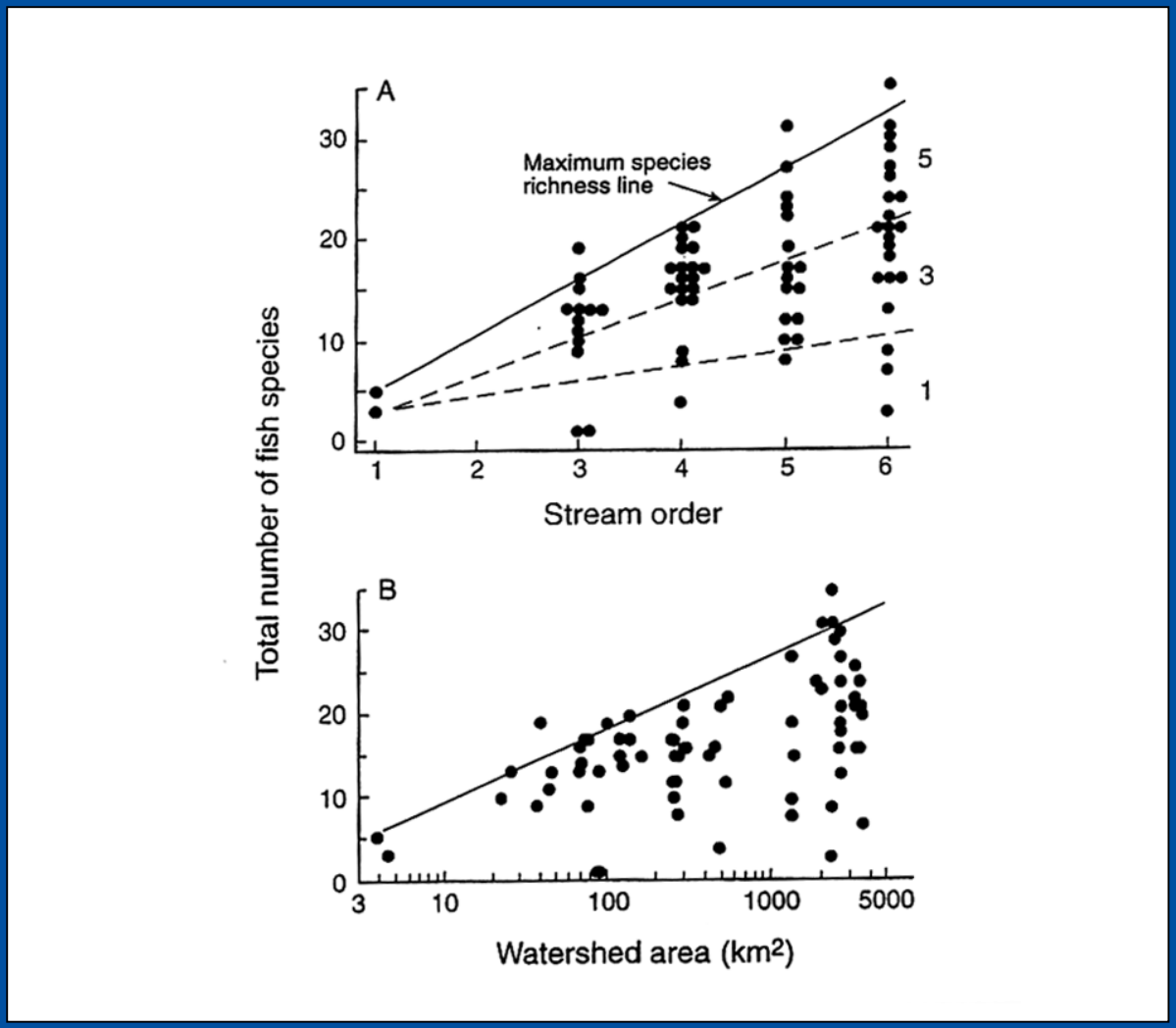
Site specific method (= European Fish Index, EFI)

Scale: Europe

Stratification by regionalisation

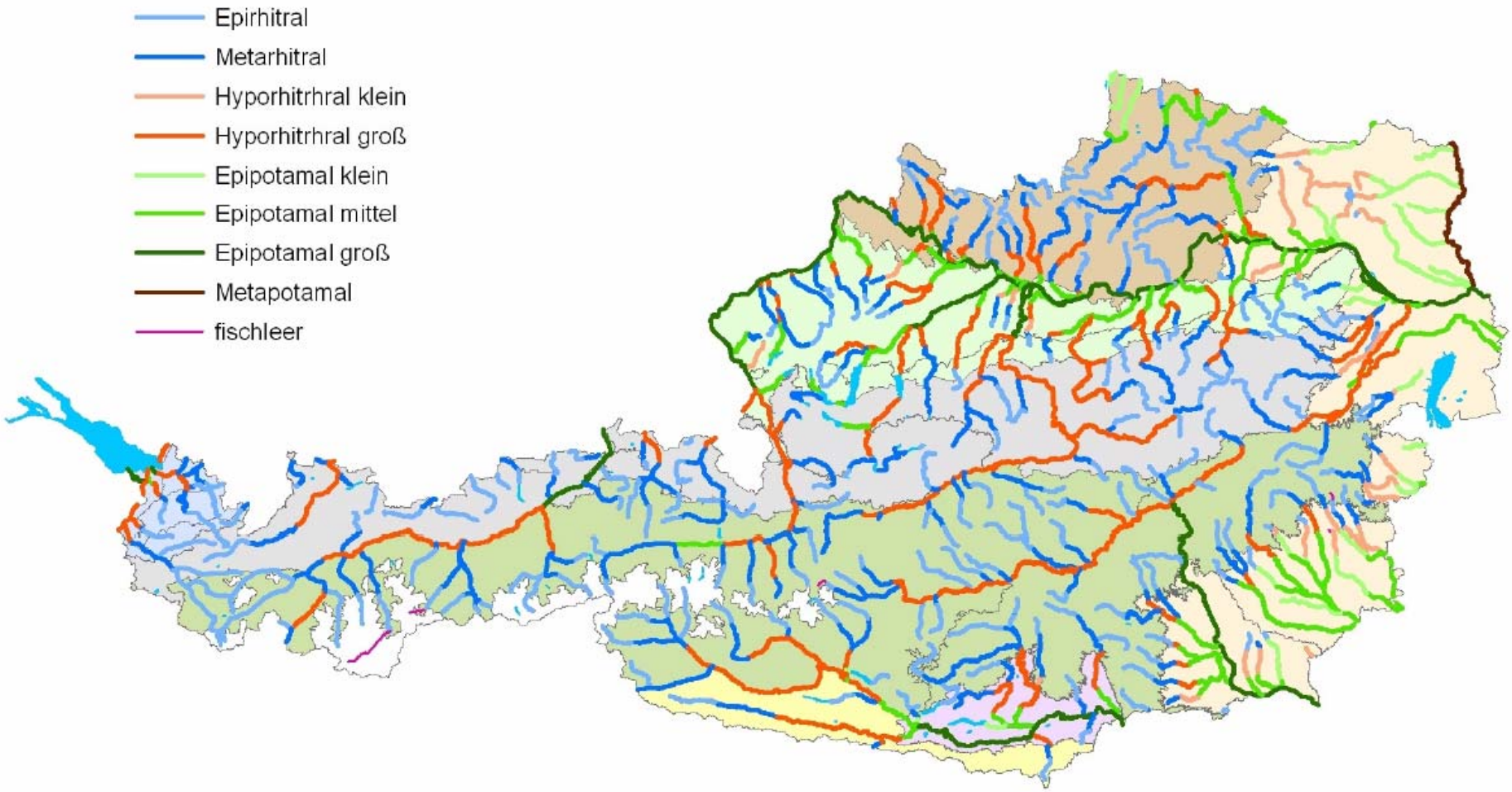
- Bramblett et al. 2005. Development and evaluation of a fish assemblage index of biotic integrity for northwestern Great Plains streams.
- Hughes et al. 2004. A biointegrity index for coldwater streams of western Oregon and Washington.
- McCormick et al. 2001. Development of an index of biotic integrity for the mid-Atlantic highlands region.

Adjusting reference conditions to longitudinal gradients



Fausch et al. 1984

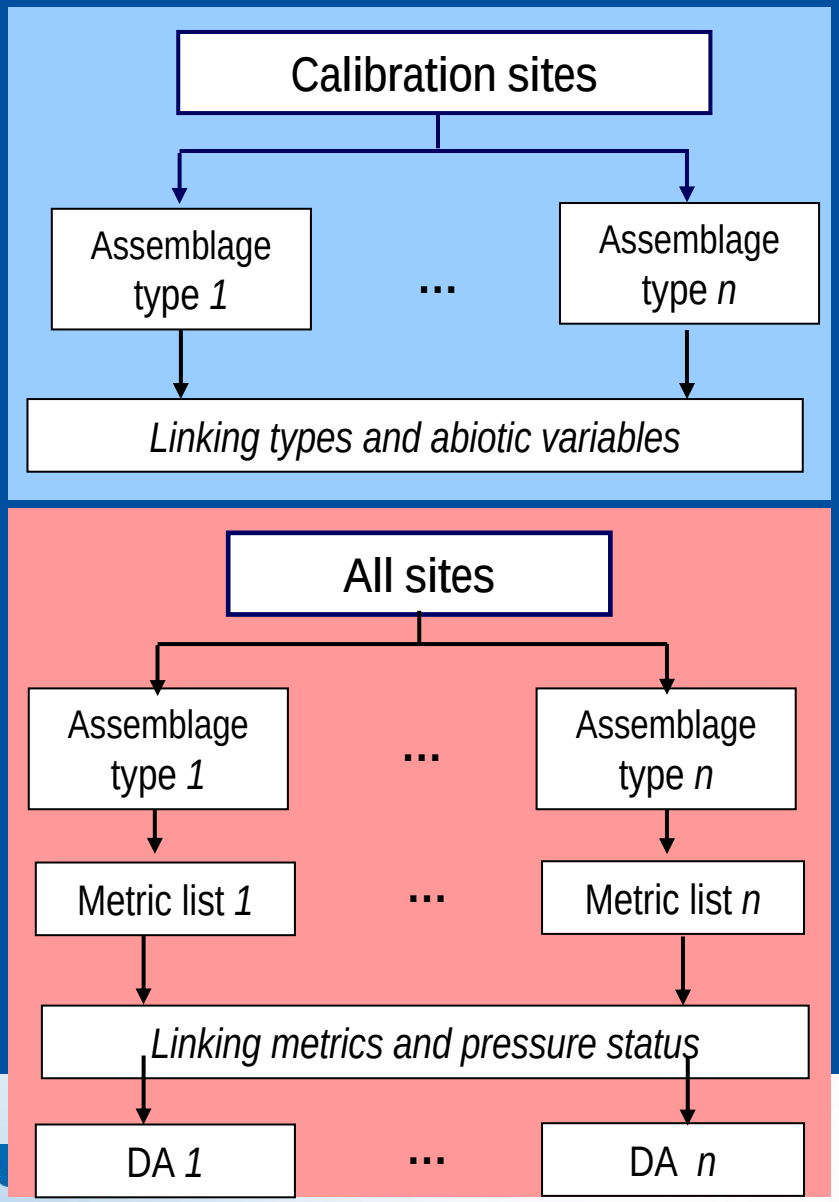
FIA - Fish water types of Austria



Haunschmid et al. 2006

Spatially based methods in FAME

Spatially based methods
results at ecoregional scale



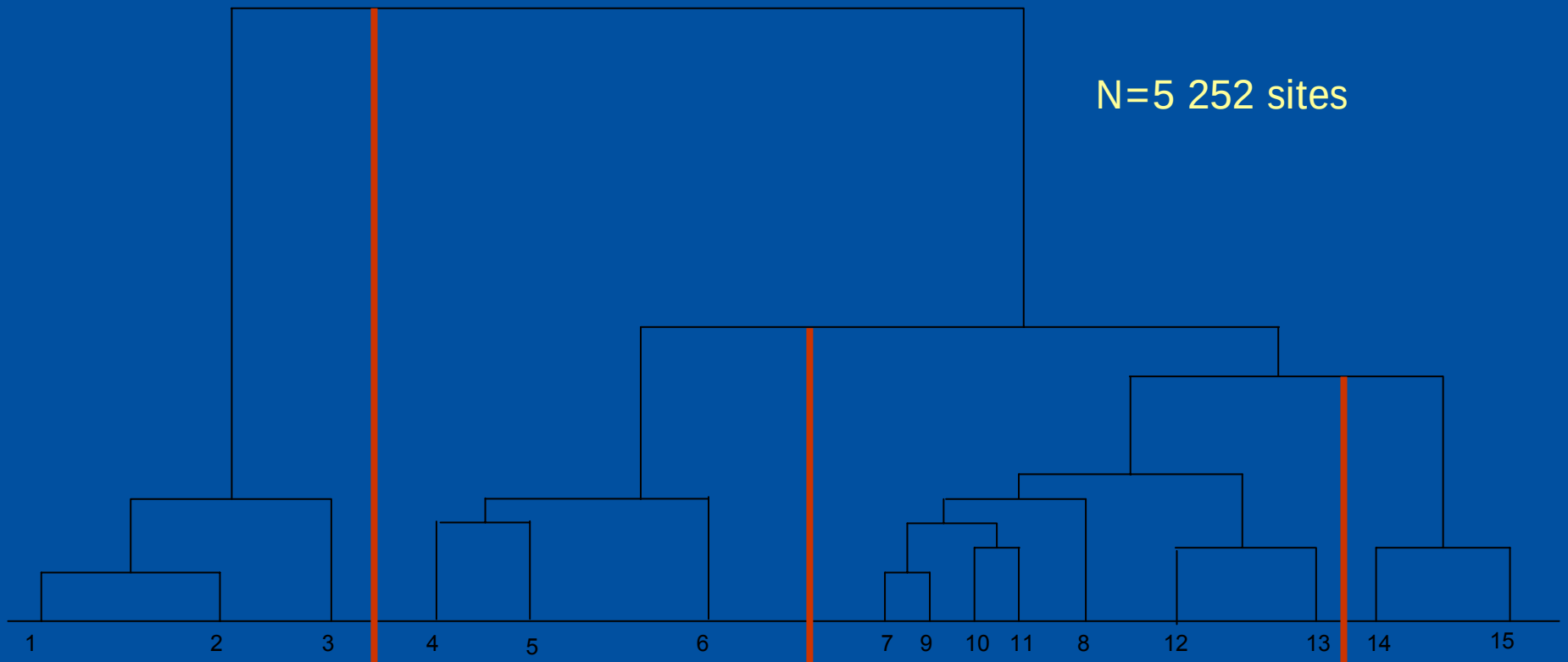
60 fishtypes in 11 ecoregions (2-8 per ecoregion)

altitude, slope, wetted width, air temperature, distance from source

43 methods in 9 ecoregions

in total 130 metrics used
median 9.3 per method

European Fish Types



Melcher et al. in print

Site-specific FAME method in FAME

European Fish Index

FAME-consortium (2005)
Pont et al. (2006)

EFI methodology

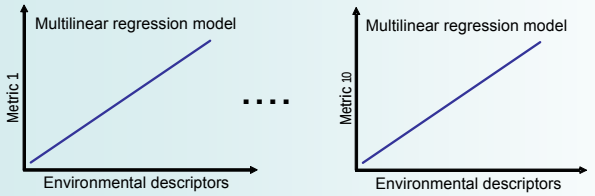
(1) Metric calculation

"observed metrics"

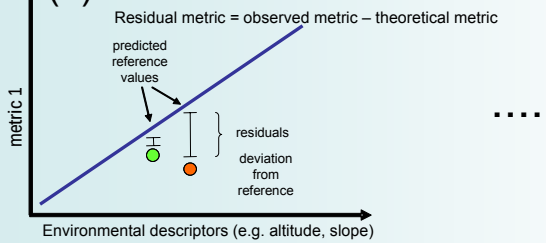
Number of fish caught per species → Value of metric 1 . . . Value of metric 10

(2) Metric prediction

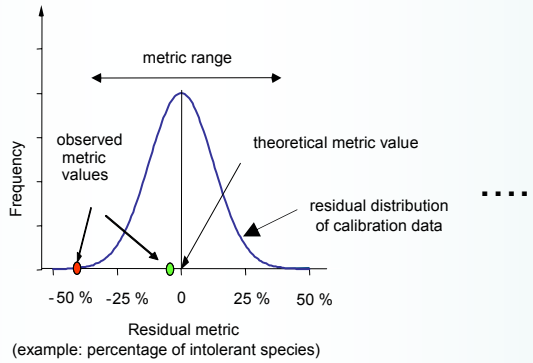
calibration data set for development of reference models



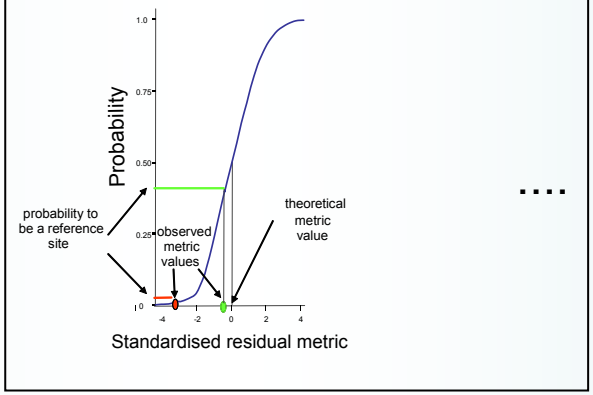
(3) Residual calculation



(4) Residual distribution



(5) Transformation to probabilities



(6) Index calculation

$$\text{Index} = \sum_{x=1}^{10} \text{metrics}_x$$

Index rescaling from 0 to 1

(7) Assignment to ecological status class

EFI

Status class	Score
High:	[0.669 – 1.000]
Good:	[0.449 – 0.669[
Moderate:	[0.279 – 0.449[
Poor:	[0.187 – 0.279[
Bad:	[0.000 – 0.187[

European Fish Index – input variables

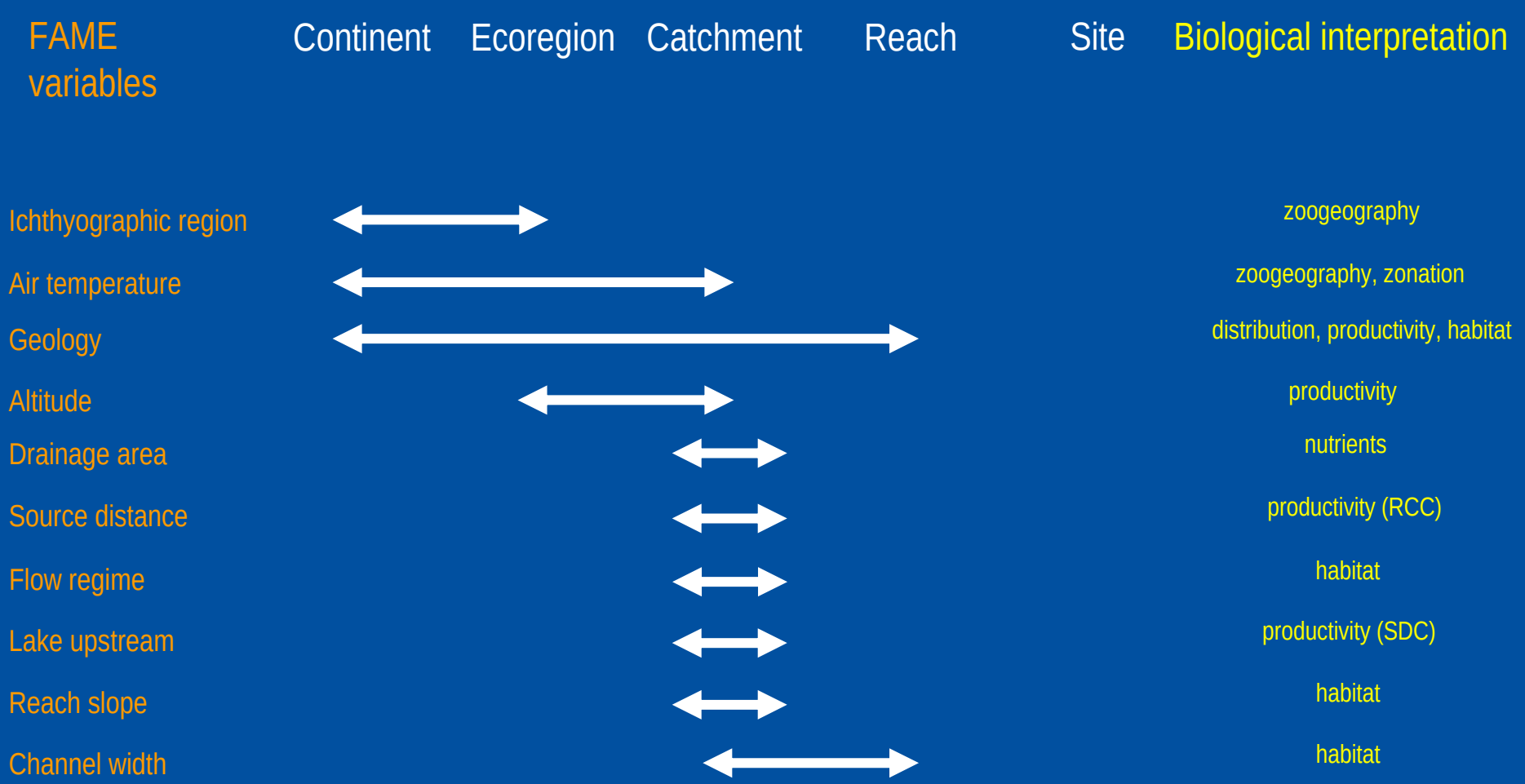
Abiotic variables for metric prediction

1. Geological typology
2. Size of catchment class
3. Altitude
4. Flow regime
5. Lakes upstream
6. Mean air temperature
7. Gradient slope
8. Distance from source
9. Wetted width
10. Sampling strategy
11. Sampling method
12. Fished area
13. Main river catchment/river group

Fish assemblage

Number of individuals per fish species based on semi-quantitative electric fishing data

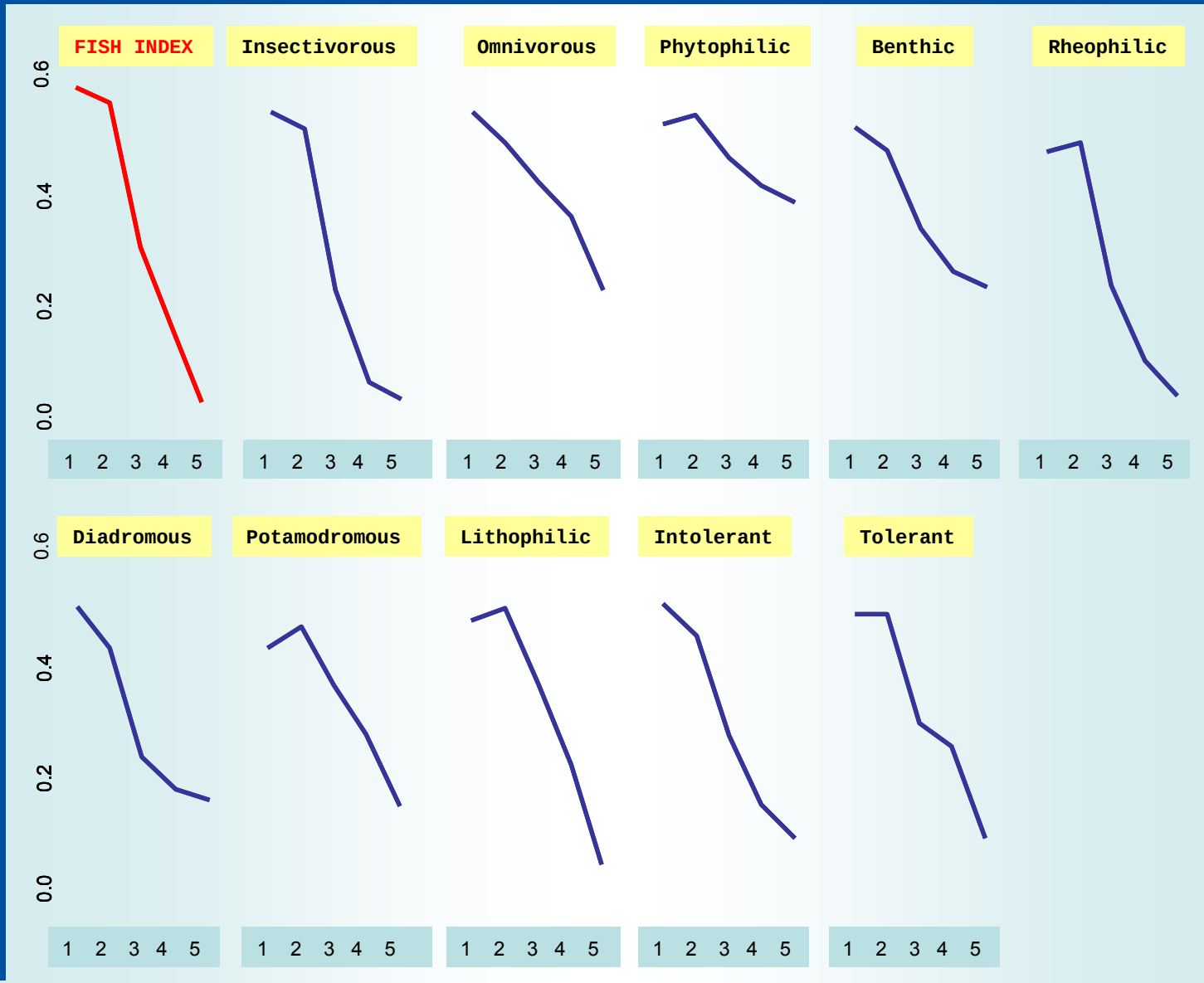
Environmental factors and spatial scales structuring European fish assemblages



European Fish Index – metrics list

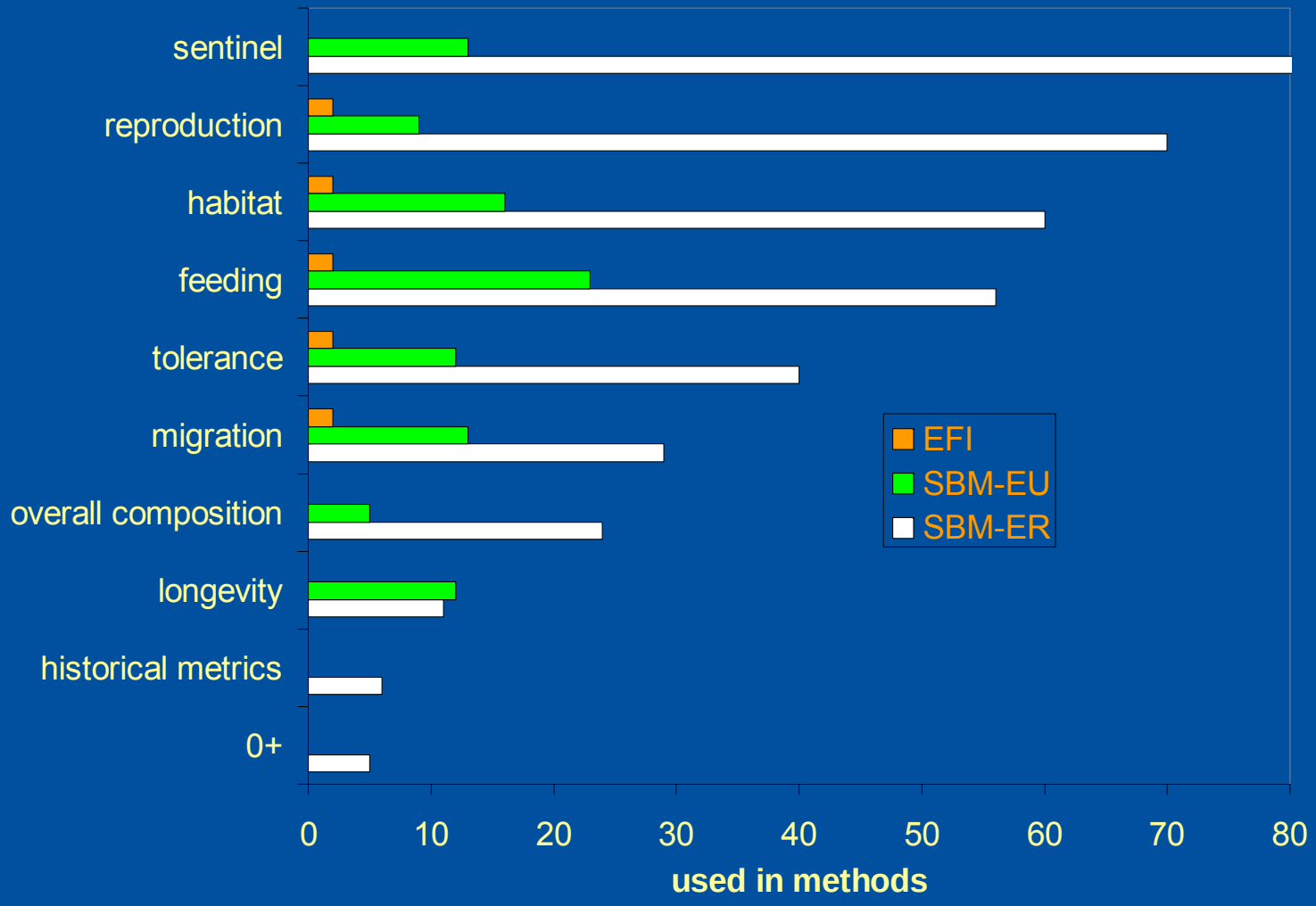
	Trend of reaction to pressures
Trophic structure	
1. Density of insectivorous species	↓
2. Density of omnivorous species	↑
Reproduction guilds	
3. Density of phytophilic species	↑
4. Relative Abundance of lithophilic species	↓
Physical habitat	
5. Number of benthic species	↓
6. Number of rheophilic species	↓
Tolerance to disturbance in general	
7. Relative number of intolerant species	↓
8. Relative number of tolerant species	↑
Migratory species richness	
9. Number of species migrating over long distances	↓
10. Number of potamodromous species	↓

Metrics responses to human pressure



Pressure classification

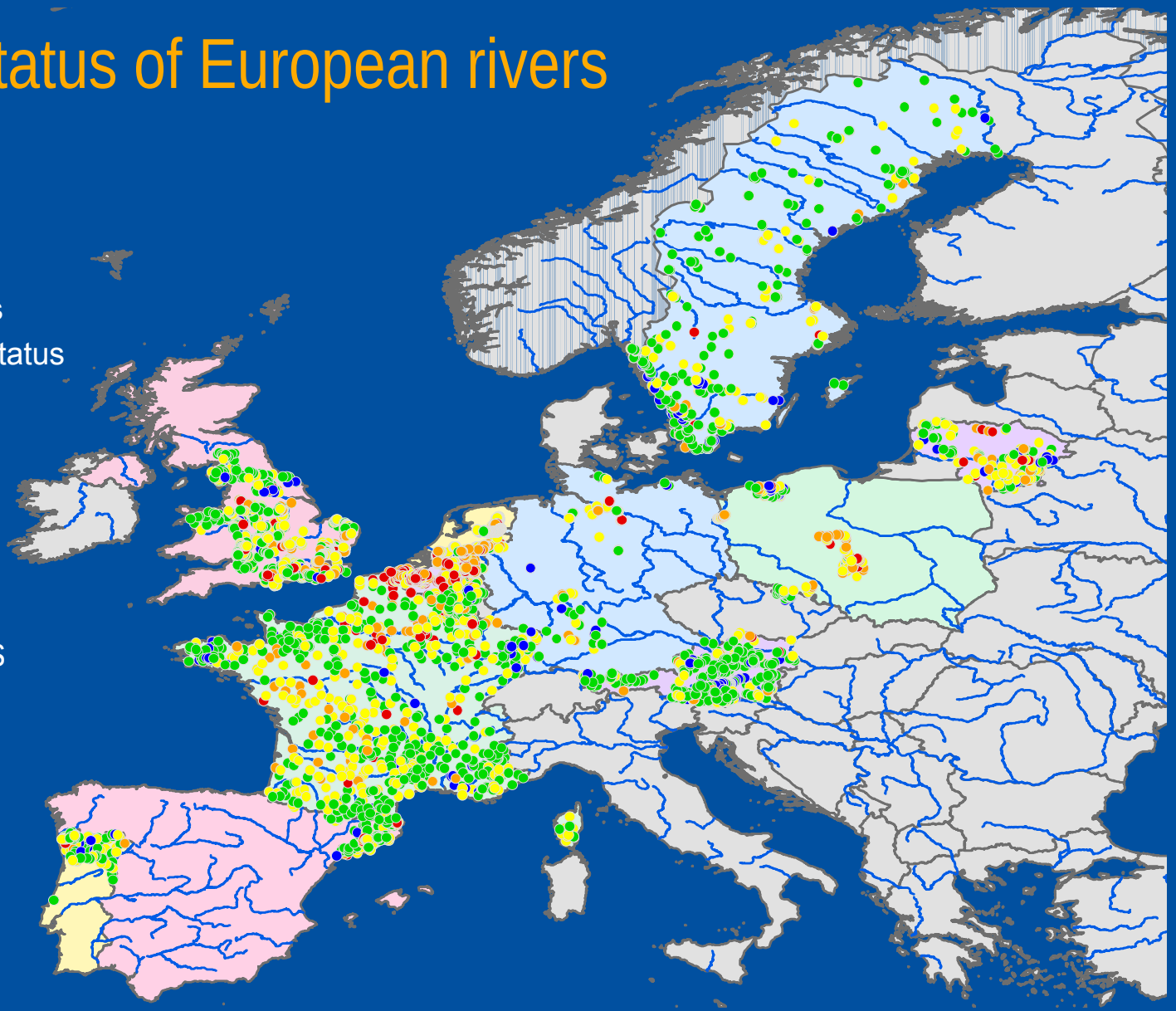
Comparison FAME methods – metric types



Ecological status of European rivers

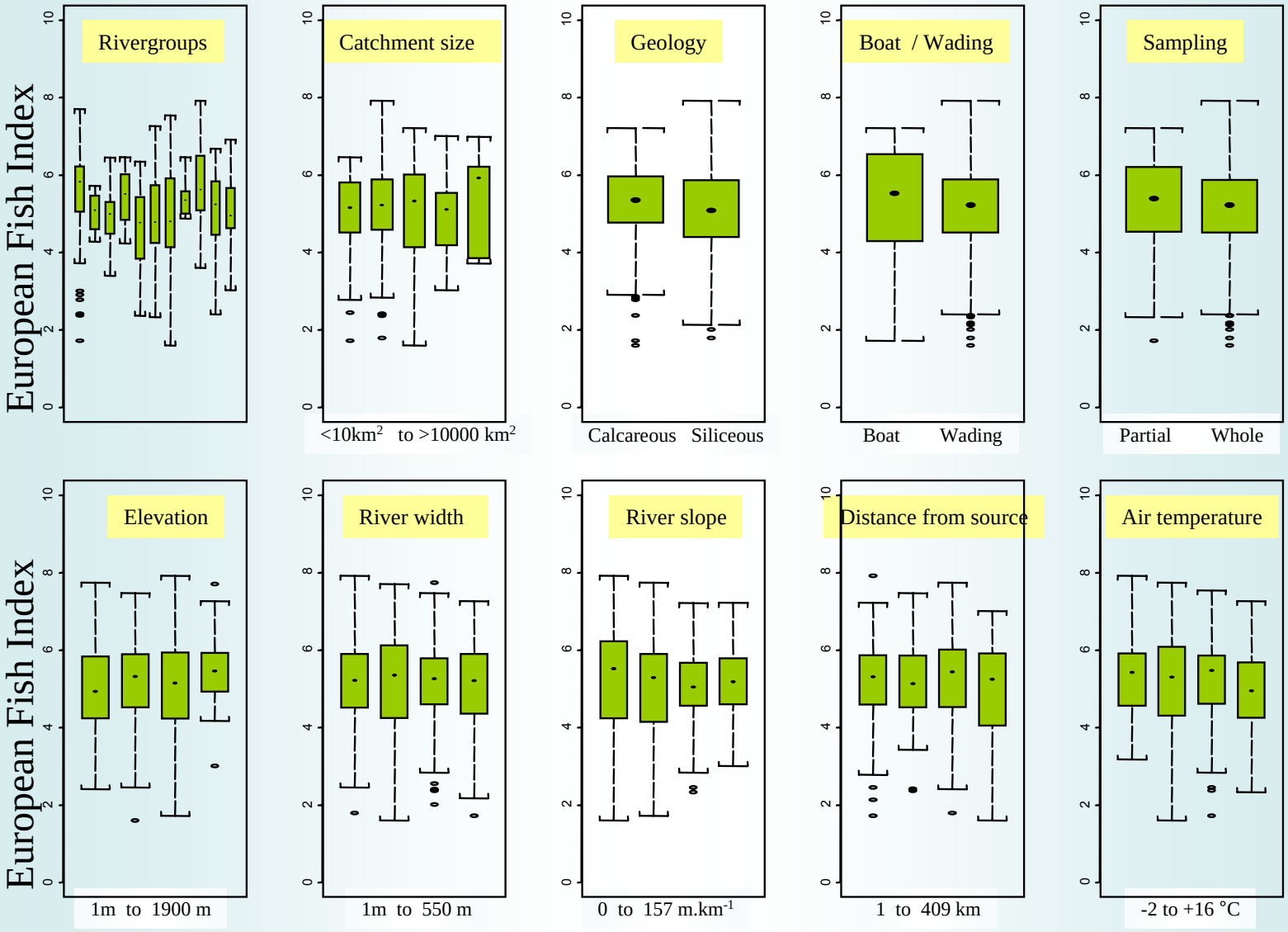
Index classes

- 1 – high status
- 2 – good status
- 3 – moderate status
- 4 – poor status
- 5 – bad status

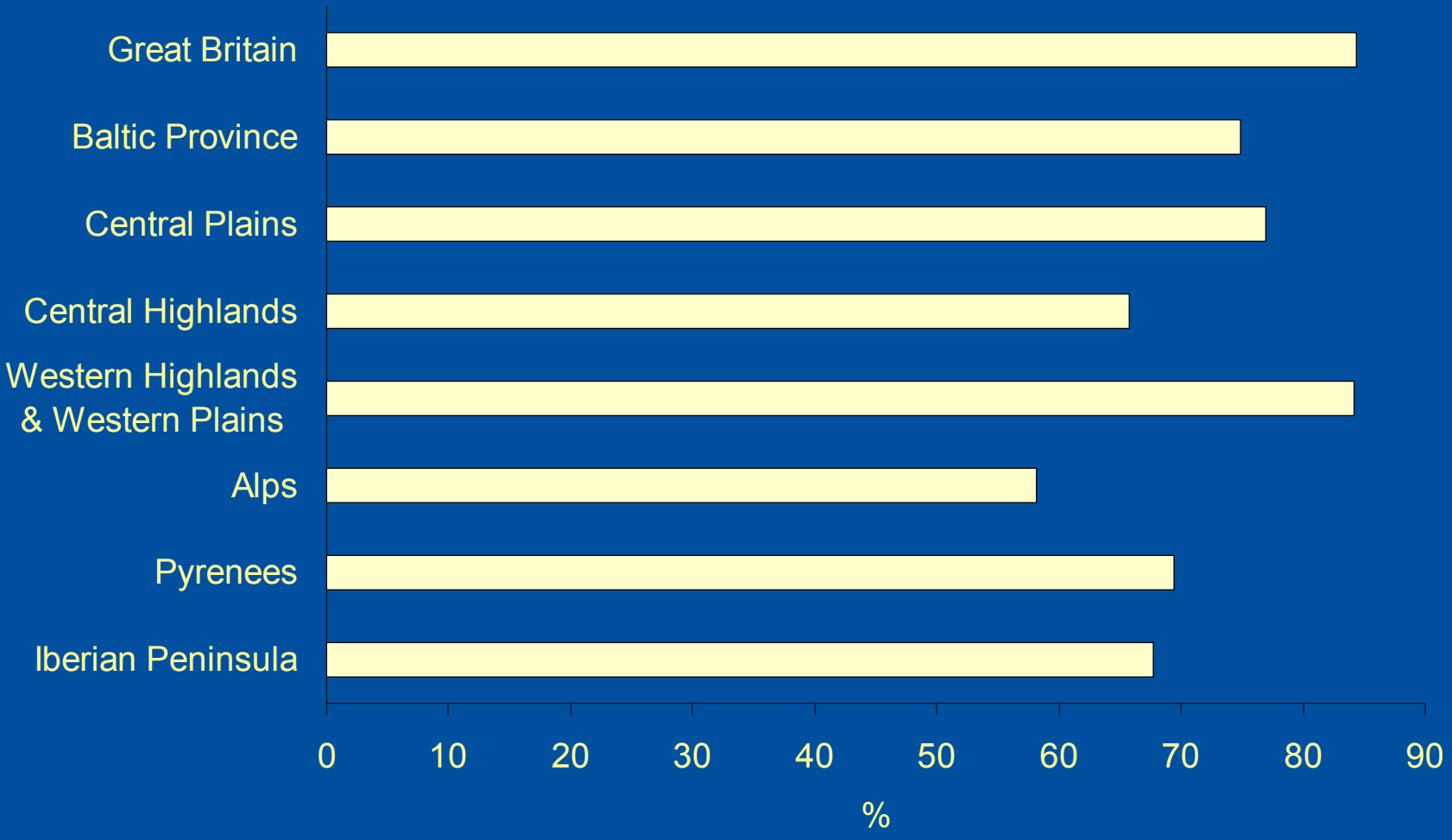


81 % of reference and impacted sites correctly classified when comparing with human pressures

Index validation



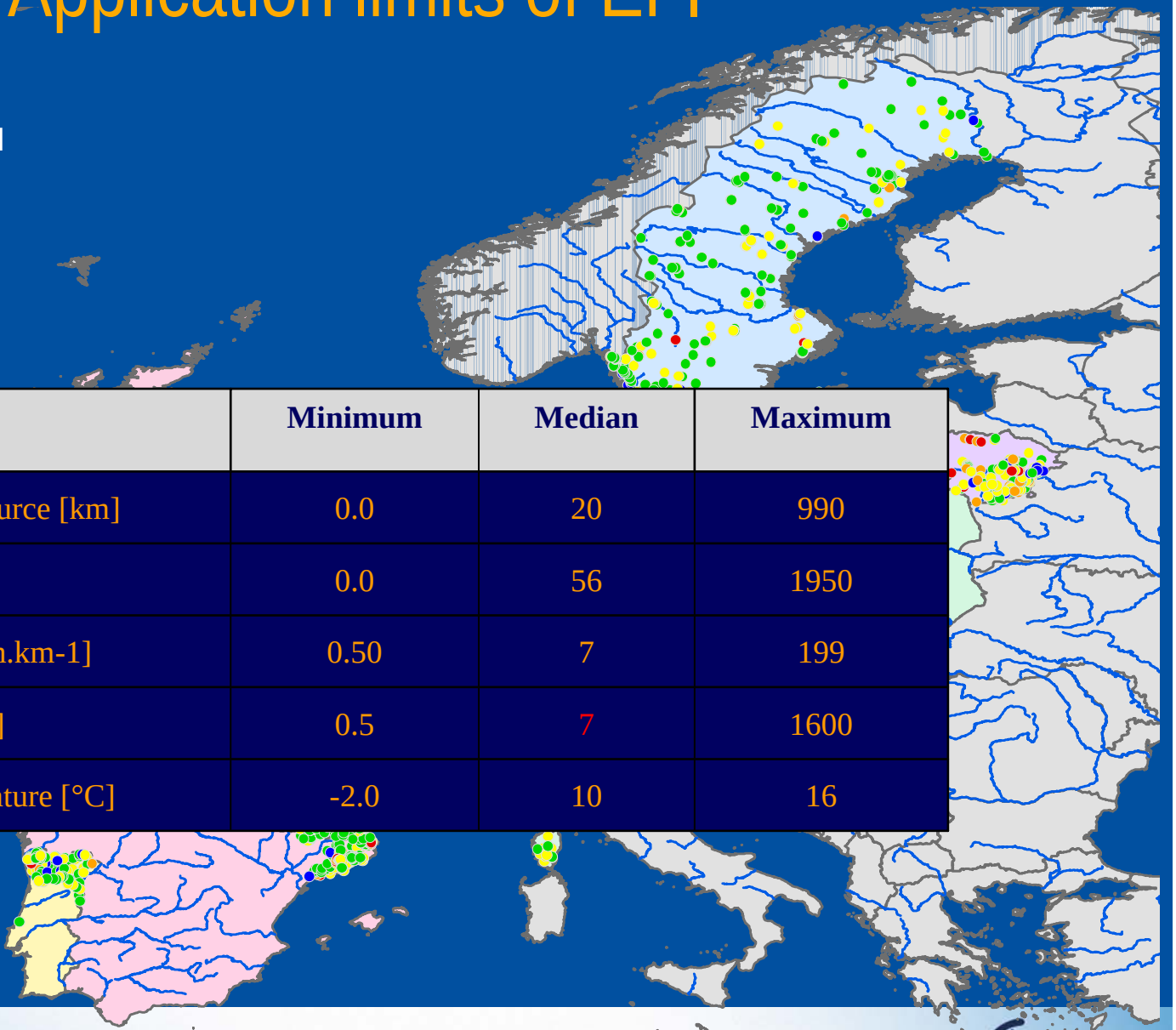
Cross-validation – impacted versus unimpacted



Application limits of EFI

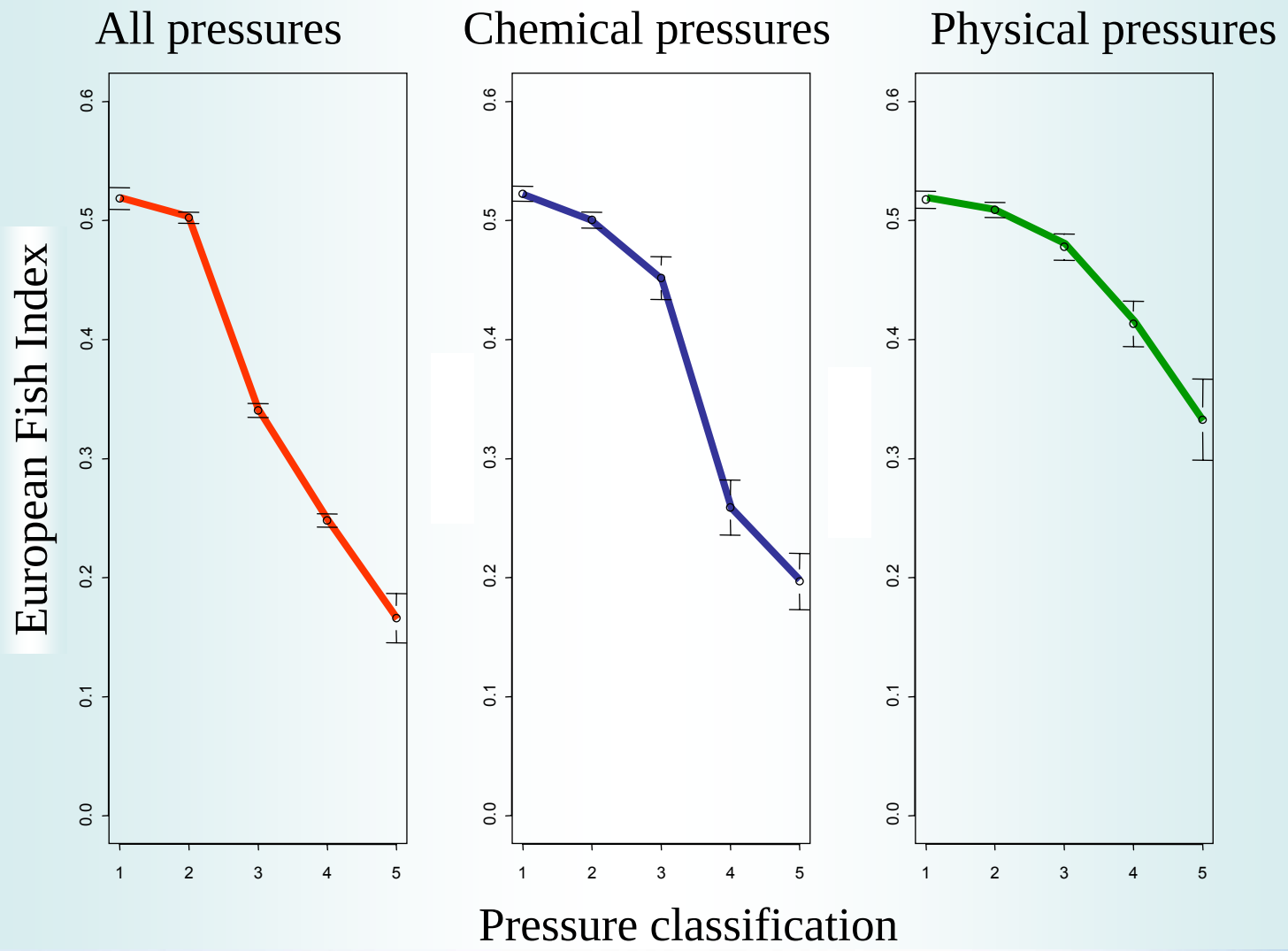
Index classes

- 1 – excellent status
- 2 – good status
- 3 – moderately perturbed
- 4 – perturbed
- 5 – heavily perturbed

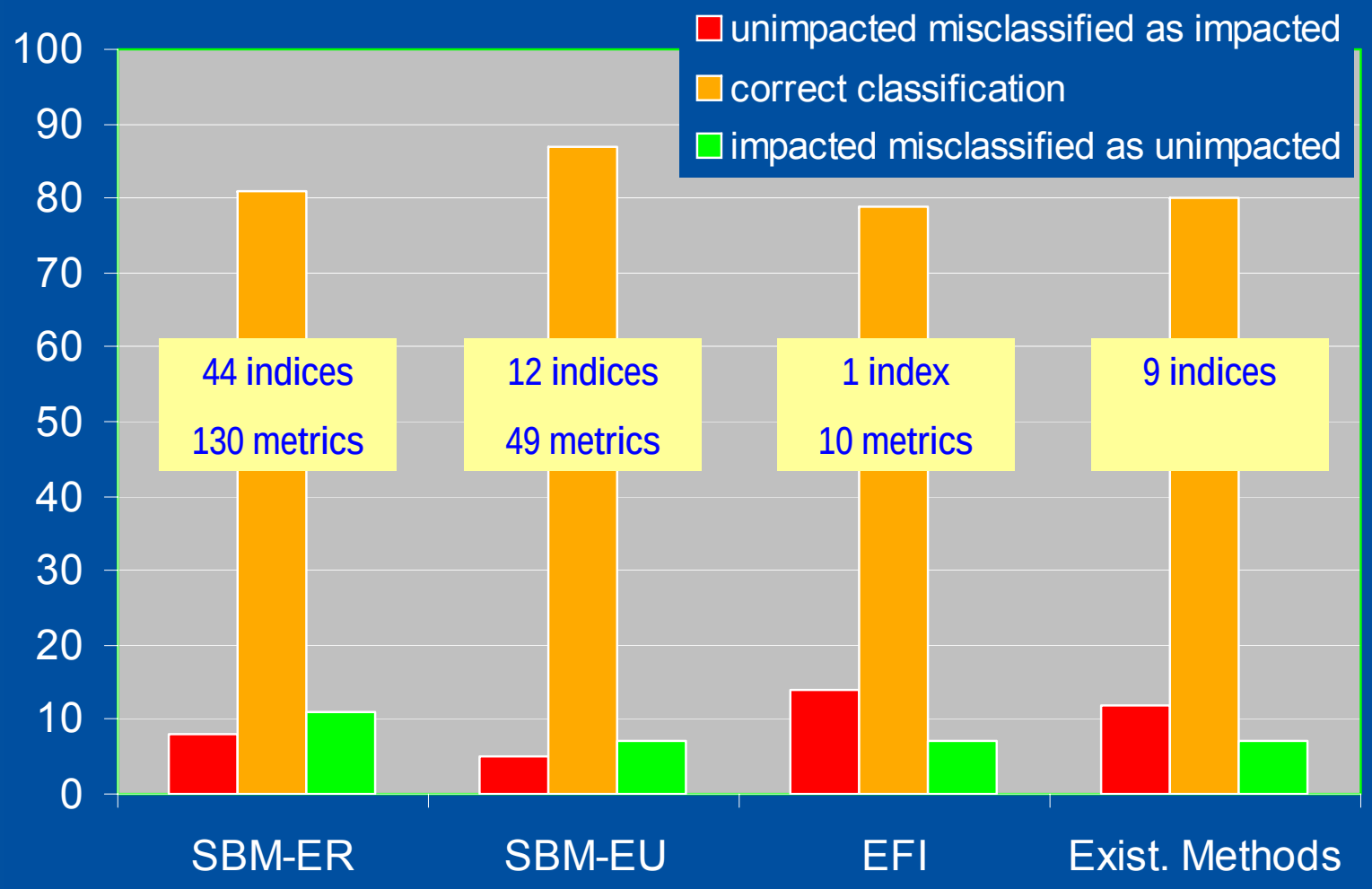


Characteristics	Minimum	Median	Maximum
Distance from source [km]	0.0	20	990
Altitude [m.a.s]	0.0	56	1950
Slope gradient [m.km-1]	0.50	7	199
Wetted width [m]	0.5	7	1600
Mean air temperature [°C]	-2.0	10	16

Index response to different types of human pressures



Comparison FAME and existing methods with pre-classification



Conclusions

- With EFI it is possible to incorporate natural variability of fish in Europe in a single index (except Mediterranean rivers)
- Regional differences can be overcome by using functional metrics
- New metrics such as migratory behaviour improve the quality of assessment methods
- The EFI is as precise as regional methods
- EFI is calibrated against pressures and degradation is assessed as statistically proven deviation from reference conditions
- The EFI methodology is supposed to become a European standard (CEN)
- EFI software and manual can be downloaded from the internet

Further research needs

- Spatial extension to all Europe
  - Mediterranean rivers
  - East of Europe
- Improvement of index accuracy
  - Environmental characteristics (e.g. precipitation)
  - Pressure characteristics (e.g. hydromorphology, continuum, land use)
  - Fish fauna characteristics (e.g. population structure, long distance migrants)

The FAME group

Austria

Stefan Schmutz (Co-ordinator), Gertrud Haidvogl, Andreas Melcher, Christian Frangez, Adeline Mühlberg, Institute of Hydrobiology and Aquatic Ecosystem Management, University of Natural Resources & Applied Life Sciences, Vienna

Albert Jagsch, Reinhard Haunschmid, Institute for Water Ecology, Fisheries Biology and Lake Research, Federal Agency for Water Management, Scharfling/Mondsee

Belgium

Patrick Kestemont, Delphine Goffaux, Gael Grenouillet, Unité de Recherche en Biologie des Organismes, Faculté Universitaires N.D. de la Paix, Namur

Thierry Demol, Pierre-Dominique Gerard, Laboratoire d`Hydrobiologie, Centre de Recherche de la Nature, des Forêts et du Bois, Gembloux

Jan Breine, Ilse Simoens, Paul Quataert, Claude Belpaire, Institute for Forestry and Game Management, Groenendaal-Hoeilaart

Gaby Verhaegen, Monitoring and Research Department, Flemish Environment Agency, Aalst

France

Didier Pont, Bernard Hugueny, Houria Ouici, Yorick Reyols, Crane Rogers, Laboratoire d´Ecologie des Hydrosystèmes Fluviaux, UMR CNRS 5023, Université de Lyon, Villeurbanne.

Romuald Berrebi, Thierry Oberdorff, Nicolas Roset, Conseil Supérieur de la Pêche, Paris.

Germany

Jürgen Böhmer, Institute for Zoology, University of Hohenheim, Hohenheim

Ralf Haberbosch, Uwe Dussling, Rainer Berg, Fisheries Research Station of Baden-Württemberg, Langenargen

Christian Wolter, Dep. Fish Biology and Ecology, Leibniz-Institute of Freshwater Ecology and Inland Fisheries, Berlin

Greece

Alkibiades Economou, Stamatis Zogaris, Sofia Giakoumi, Roberta Barbieri, Maria Stoumboudi, Institute for Inland Waters, Hellenic Centre for Marine Research, Anavyssos

Kostis Karras, Centre for Renewable Energy Sources, Pikermi

The FAME group

Lithuania

Tomas Virbickas, Vitautas Kesminas, Institute of Ecology, Vilnius University, Vilnius

Juozas Molis, Automatic Measurement Systems Dept., Environment Protection Agency, Vilnius

Poland

Malgorzata Lapinska, Jan Bocian, Maciej Zalewski, International Centre of Ecology, Polish Academy of Sciences, Warsaw

Wlodzimierz Andrzejczak, Voivodeship Inspectorate for Environmental Protection, Lodz

Portugal

Teresa Ferreira, Joao Oliveira, Forest & Natural Resources Dept., Inst. Agronomia, Technical University, Lisbon

Jorge Bochechas, Inland Waters Fisheries Div., National Forest & Wildlife Service, Lisbon

Sweden

Ulrika Beier, Erik Degerman, Susanna Pakkasmaa, Herbert Wirlöf, Jonas Pettersson, Institute of Freshwater Research, National Board of Fisheries, Drottningholm

Spain

Nuno Caiola, Adolfo de Sostoa, Animal Biology Department, Faculty of Biology, University of Barcelona

Frederic Casals Marti, Dep. Animal Husbandry, Higher Technical School of Agrarian Engeneering of Lleida, University of Lleida

The Netherlands

Joost Backx, Tom Buijse, Institute for Inland Water Management and Waste Water Treatment (RIZA), Lelystad

Joep de Leeuw, Erwin Winter, Netherlands Institute for Fisheries Research (RIVO), Ijmuiden

United Kingdom

Ian G. Cowx, Richard Noble, International Fisheries Institute, University of Hull

Alan Starkie, Robin Burrough, National Fisheries Technical Team, Environment Agency, Kidderminster