Water Framework Directive Intercalibration: Central-Baltic Lake Fish fauna ecological assessment methods. Part A: Descriptions of fish-based lake assessment methods

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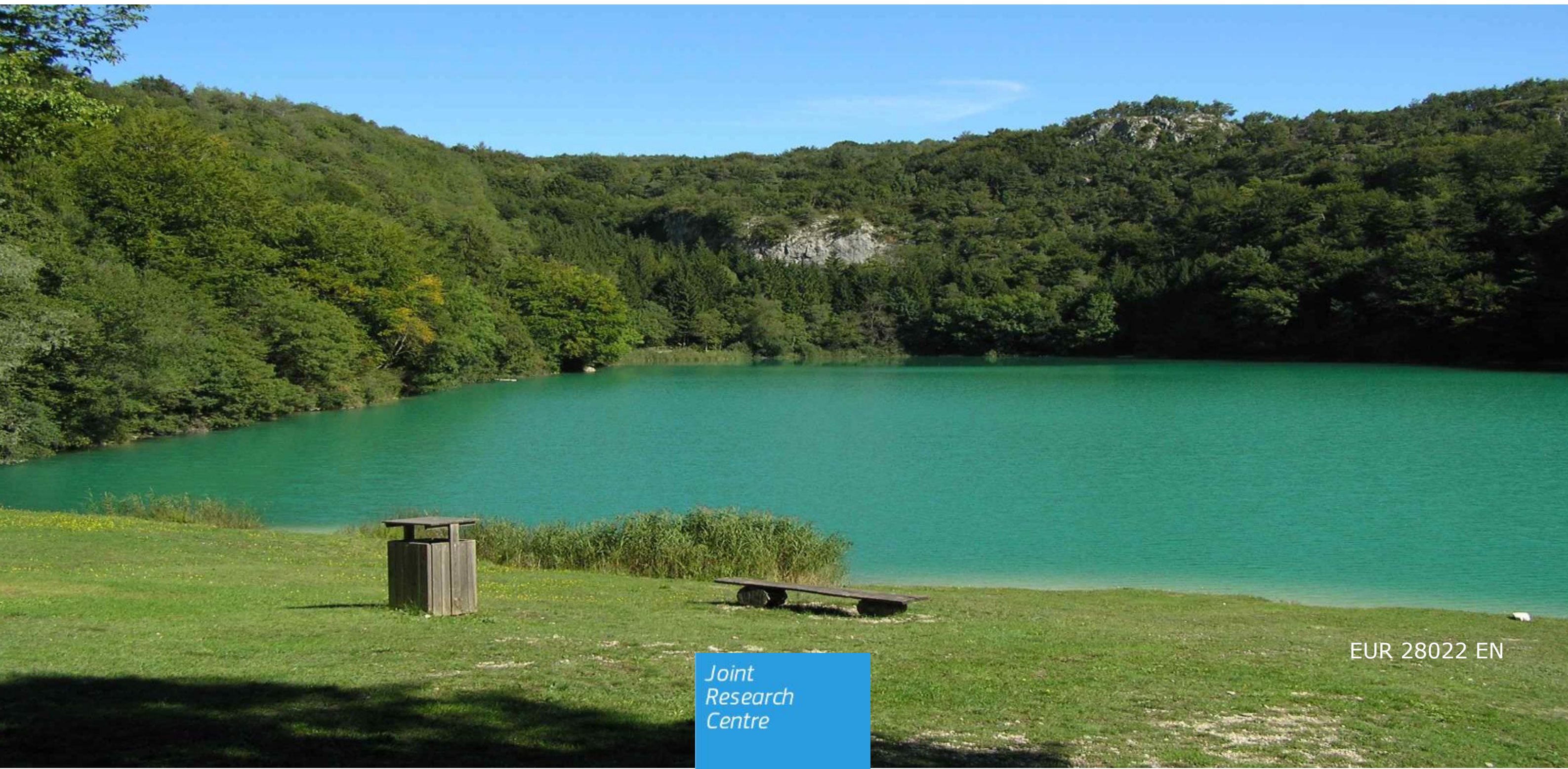

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Water Framework Directive Intercalibration: Central-Baltic Lake Fish fauna ecological assessment methods

Part 1: Descriptions of fish-based lake assessment methods

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Abstract

The European Water Framework Directive (WFD) requires the national classifications of good ecological status to be harmonised through an intercalibration exercise. In this exercise, significant differences in status classification among Member States are harmonized by comparing and, if necessary, adjusting the good status boundaries of the national assessment methods.

Intercalibration is performed for rivers, lakes, coastal and transitional waters, focusing on selected types of water bodies (intercalibration types), anthropogenic pressures and Biological Quality Elements. Intercalibration exercises are carried out in Geographical Intercalibration Groups - larger geographical units including Member States with similar water body types - and followed the procedure described in the WFD Common Implementation Strategy Guidance document on the intercalibration process (European Commission, 2011).

The Technical report on the Water Framework Directive intercalibration describes in detail how the intercalibration exercise has been carried out for the water categories and biological quality elements. The Technical report is organized in volumes according to the water category (rivers, lakes, coastal and transitional waters), Biological Quality Element and Geographical Intercalibration group.

This volume addresses the intercalibration of the Lake Central-Baltic Fish ecological assessment methods.

Part A: This document comprises an overview and detailed descriptions of fish-based lake ecological assessment methods.

Part B describes the construction of multiple pressure index in the Central-Baltic region.

Part C describes the procedure and results of the boundary harmonisation of national fish-based lake assessment systems.

A1 Introduction

In the Central-Baltic Geographical Intercalibration Group nine Member States submitted 10 lake fish-based assessment methods for the intercalibration: Belgium-Flanders, Czech Republic, Denmark, Estonia, France, Germany, Lithuania, the Netherlands, and Poland (two methods).

After evaluation of the WFD compliance and Intercalibration feasibility all methods were included in the intercalibration exercise. Intercalibration "Option 2" was used - indirect comparison of assessment methods using common pressure metrics (TAPI index).

This document provides the overview of the national fish-based lake assessment methods systems, includes the first steps of the intercalibration according to the IC Guidance:

1. Overview of the national fish-based assessment methods: concepts, typologies, metrics, scoring;
2. The WFD compliance check - are all lake fish-based assessment methods in line with the WFD requirements?
3. The intercalibration feasibility check - is there any chance that Intercalibration might be successful?

The detailed national descriptions can be found in Annex I.

A2 Overview

A2.1 Status of national fish-based lake assessment systems

Nearly all Member States (MS) had developed national methods to assess the ecological status of lakes with fish (Table A1). Short descriptions of all systems are available in the annex A1. Comprehensive descriptions exist for Czech Republic (BOROVEC et al. 2014) - in Czech, Denmark (SØNDERGAARD et al. 2013) - in Danish, France (ARGILLIER et al. 2013) and the Netherlands (JAARSMA 2007).

Table A1: Status of Lake fish assessment systems (no method / under development / intercalibratable / official) and year of finalization or expected finalization.

MS	System name	Status	Year	Comment
BE-F		Intercalibratable	2012	
CZ	CZ-FBI	official, national	2013/2014	
DE	DeLFI	Intercalibratable	2011	Finalized but not official
DK	Danish Lake Fish Index	Intercalibratable	2011	
EE	LAFIEE	Intercalibratable	2009	Under revision
FR	2IL	Intercalibratable, national	2013/2014	
LT	LZIE	Intercalibratable	2013	Finalized but not official
NL	VISMAATLAT	Intercalibratable, national	2007	Minor changes made in 2012
PL	LFI+ LFI EN	Intercalibratable Intercalibratable	2011 2013	Two methods: one based on fisheries statistics (LFI+), another developed for EN 14757
UK*		Under development	Unclear	
LV		No method	Unclear	
SK		No method	Not expected	

UK: England and Wales are part of the Central-Baltic (CB) Geographical Intercalibration Group (GIG). The Irish Lake Fish system and the CB methods will be checked for applicability. Gillnet fishing is not an option because of public relation issues.

A2.2 Fish sampling methods

The following Table A2 shows the methods used for fish stock assessment in the CB GIG. The randomized multi-mesh gillnet standard (EN 14757 2005) is widespread, but not used in all MS.

Table A2: Fish sampling methods in the MS. Second column shows the gear used for metric calculation in the national LFI systems.

Nr	MS	Gear for LFI metrics	Database**	Additional gear used ***
1	BE-F	Fyke + electrofishing	No	
2	CZ	ENmod*	Yes (24) in 2014	Electrofishing, hydroacoustics
3	DE	EN / ENmod	Yes (75)	Electrofishing
4	DK	EN	Yes (113)	Electrofishing
5	EE	ENmod	Yes (24)	Fyke nets, electrofishing
6	FR	EN	Yes (40)	
7	LT	ENmod	Yes (46)	
8	LV	Gillnets, trammel nets, statistics		
9	NL	Trawling, seine, electrofishing	No	
10	PL - LFI+	Fisheries statistics (seine, gillnet, fyke)	No	Electrofishing
	PL - EN	En		
11	UK			Plans to use environmental DNA

*EN is EN 14757, ENmod is comparable to EN 14757 but modified (explanations below).

**'Database' shows if data was submitted to the CEMAGREF cross-GIG database with the number of lakes in parentheses. ***Additional gear shows methods used for sampling, but not for metrics in the national LFI.

Comments:

- In CZ the standard 12-mesh sizes gillnets were extended by four larger mesh sizes (70, 90, 110 and 135 mm) for capturing bigger fish (Šmejkal et al. 2015);
- In DE some lakes were fished twice, in spring and autumn with half EN effort each. This is not done any more and a single full EN campaign is used to obtain fish data. Large mesh sizes are included in the netting. Electrofishing data is always present but not included in the system;
- EE uses the EN standard with additional large mesh sizes;
- LT uses the EN standard with reduced and modified mesh sizes: 14, 18, 22, 25, 30, 40, 50, 60 mm, nets are highly modified;
- LV focuses on species of commercial or recreational fishing.

A2.3 Typology

The typologies used in the CB GIG are shown in Table A3. DK and NL apply the common intercalibration types developed in IC phase I (Poikane 2009). The other MS deviate from this typology, although the distinction between shallow polymictic and deeper stratified lakes apparently is the most important criterion. For IC purposes, the MS agreed to adopt the German typology (1st CB IC meeting, 2010, Berlin).

Table A3: National typologies used in the CB Lake Fish intercalibration.

MS	National types	Details and comments
BE-F	Standing waters	Lakes, ponds and canals
CZ	Polymictic Stratified	For HMWB and AWB (no natural lakes with fish > 0.5 km²)
DE	POLY (polymictic) STRAT (stratified) DEEP (stratified, deep)	Functional Functional, < 30 m max. depth > 30 m max. depth
DK	L-CB1 (deep) L-CB2 (shallow) And 7 others (25%)	Stratified, 3-15 m mean depth, alkaline Polymictic, < 3 m mean depth, alkaline and others
EE	Not stratified Stratified Soft and dark Soft and bright And 4 others	Functional, avg. hardness
FR	Not relevant because of site specific approach	
LT	Shallow (LCB-2) Interm. Depth (LCB-1) Deep, stratified (LCB-1)	< 3 m mean depth 3-9 m mean depth > 9 m mean depth
NL	Shallow, buffered Deep, buffered Large, deep, buffered Shallow, calcareous Shallow, peat lake	< 3 m mean depth, 0.5 - 100 km², mineral > 3 m mean depth, 0.5 - 100 km², mineral > 3 m mean depth, > 100 km², mineral < 3 m mean depth, 0.5 - 100 km², calcareous < 3 m mean depth, 0.5 - 100 km², organic
PL	Polymictic Stratified	Functional Functional
LV, SK		No typology

A2.4 Metrics

Table A 4: Metrics of LFI in the CB GIG and their assignment to the normative criteria of the WFD: spn: species' number; %N: percentage of total number; NPUE: number per unit of effort; W: weight; %W: percentage of total weight; WPUE: weight per unit of effort.

MS	Species composition	Abundance	Sensitive species	Age structure
BE	% N specialized spawners % N invertivorous % N omnivorous spn piscivorous %W benthivorous		Tolerance value of species	
CZ	%W Bream %W Perch %N Ruffe %W Rudd %W Salmonidae	WPUE (> 0+) NPUE (> 0+)	See species comp.	Presence 0+ of 6 species
DE	%W or %N Bream %W White Bream %W or %N Ruffe %W Pikeperch	WPUE (total)	Spn obligatory species	Median ind. W of bream, perch, roach

MS	Species composition	Abundance	Sensitive species	Age structure
	%W Perch %W benthic net species %W benthivorous			Reprod. of stocked species (testing)
DK	%W Bream + Roach %W piscivorous	WPUE (per net)	See species comp.	Average individual biomass
EE	%N Perch	logNPUE/ % nonpisciv.*shoredev)	Simpson DW/log area lake	% filled net sections
FR	%N Omnivorous	NPUE WPUE		
LT	%W White Bream %N Perch %W Benthivorous %W perch+stenoterm. %W nonnative + translocated		Spn obligatory species	Avg. ind. W of roach
NL	%W Bream %W Perch+Roach/ eurytopic %W phytophilic species %W low oxygen tolerant	←		%W of pikeperch > 40 cm
PL -	%W Pikeperch %W Pike %W Tench %W Crucian carp %W Perch % W large Roach in total Roach %W large Bream %W small Bream %W large Bream in total Bream %W large Roach % W White Bream	*Total commercial catches* *Average for the last 10 years*	See species comp.	
PL -	%W Pikeperch %W Perch %W Bream %W White Bream %W Roach %W Rudd %W Ruffe %W Tench %W Bleak	BPUE	See species comp.	

A3 WFD compliance

The WFD compliance check was a requirement of the milestone reports in the IC Phase II and is also mentioned in the guidance document (CIS 2011). The compliance criteria should assure that the national systems are in line with the normative definitions of the WFD. The criteria of the milestone reports and the IC guidance are maintained without changes and summarized in Table A 5.

Table A 5: WFD compliance check for the Central Baltic fish systems.

Compliance criteria	Compliance checking conclusions
1. Ecological status is classified by one of **five classes** (high, good, moderate, poor, bad).	Yes for all systems
2. High, good and moderate ecological status are set in line with the WFD's **normative definitions** (**boundary setting procedure**)	Yes for all systems (although definitions like slight changes, moderate differences or signs of disturbance are unclear)
3. **All relevant parameters** indicative of the biological quality element are covered. If parameters are missing, Member States need to demonstrate that the method is sufficiently indicative of the status of the QE as a whole.	**species composition**: Yes for all systems **abundance**: Yes for all systems **sensitive species**: unclear (see Annex AII) **age**: direct - No, indirect - yes for most systems (see Annex AII)
4. A **combination rule** of parameters into assessment BQE is defined.	Yes for all systems
5. Assessment is adapted to **intercalibration common types** that are defined in line with the typological requirements of the WFD Annex AII and approved by WG ECOSTAT	Yes: DK, LT, NL, no for others
6. The water body is assessed against **type-specific near-natural reference conditions**	Yes for most systems, FR uses site specific modelling.
7. Assessment results are expressed as **EQRs**	Yes for all systems.
8. Sampling procedure allows for **representative** information about water body quality/ ecological status **in space and time**	EN and trawl fishing information is representative in space (i.e. the whole lake). Temporal representativeness is under discussion/ investigation. Yes for time and space for Polish LFI+.
9. All data relevant for assessing the biological **parameters** specified in the WFD's normative definitions are covered by the **sampling procedure**	Taxonomic composition: Yes Abundance: Yes Sensitive species: No for EN only, Yes for multiple gear (NL, PL) Age: indirectly,
10. Selected taxonomic level achieves adequate **confidence and precision** in classification	Yes for all systems.

Comments to the WFD compliance check:

Nr 2 normative definitions of the class boundaries: the normative definitions of WFD are pretty vague, of course. The Central Baltic LFI were developed to fulfil the demands of the WFD, and we should suppose that the class boundaries were set with orientation at the normative definitions. It will be a matter of the IC process to control for similar class boundary setting among the CB MS.

Nr 3 normative definitions of indicative BQE parameters: The Annex V, Nr. 1.2.2 of the WFD provides the normative definitions for high, good and moderate ecological status in lakes. For fish, high status is achieved if (unchanged citation):

1. Species composition and abundance correspond totally or nearly totally to undisturbed conditions.
2. All the type-specific sensitive species are present.
3. 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 a particular species.

The normative definition comprises four main aspects of the fish community, i.e. species composition (relative values), species abundance (absolute values), type-specific sensitive species and age structure. As the Central Baltic LFI were developed to fulfil the demands of the WFD, a general compliance should be expected for all of them. However, critical aspects are can be found in the parameters 'sensitive species' and 'age'. The critical aspects are discussed in Annex II. No MS uses a 'real' age metric in the national LFI system. Metrics for age (or size or reproduction) are substituted by length or weight parameters. Scientific justification was provided by the CB GIG lead (see Annex II). On this basis, ECOSTAT decided to include national methods in the current intercalibration exercise even if they do not contain age structure metrics (VAN DE BUND et al. 2011).

Nr 5 intercalibration common types: The national typologies are compliant with type-setting criteria mentioned in Annex II of the WFD. Some MS use the IC typology approved by ECOSTAT. For the intercalibration, the CB Lake Fish GIG decided to use another common typology. We do not accept that practical decisions from Phase I should be a decisive prerequisite for a WFD compliance (or successful intercalibration).

Nr 8 representativeness in space and time: The representativeness of different fish sampling gear in time and space is under heavy discussion. First results show that the national systems are able to account for the data variability and provide stable assessment results. We can affirm this point if we change the request for representative sampling to a request for representative assessment results. However, this point will be investigated in detail.

We conclude that all fish assessment systems are WFD compliant.

A4 Intercalibration feasibility

Similar to the compliance check, the milestone reports and the guidance for IC Phase II asked for an intercalibration feasibility check and provided a list of questions.

A4.1 Typology as a restricting factor

According to the WFD, the assessment systems have to be based on some kind of typology. Type descriptors for lakes are given in the directive itself (Annex II): altitude (< 200, 200-800, > 800 m), mean depth (< 3, 3-15, > 15 m), size (0.5-1, 1-10, 10-100, > 100 km^2), and geology (calcareous, siliceous, organic). Based on these criteria an official common typology was set for the Central-Baltic GIG (2008/915/EC 2008; POIKANE 2009). All types in the CB-GIG are lowland lakes < 200 m altitude. Hydrological water residence time was added to the typology. Three types were defined for the CB GIG:

L-CB1: shallow, calcareous (3-15 m, > 1 meq/l, 1-10 years of residence time)

L-CB2: very shallow, calcareous (< 3 m, > 1 meq/l, 0,1-1 years of residence time)

L-CB3: shallow, small, siliceous (3-15 m, 0,2-1 meq/l, 1-10 years of residence time)

The CB MS have based their national typologies mainly on the descriptors mean depth and alkalinity. However, other descriptors are added in some cases (max depth, stratification yes/no). Some MS have a fish-specific typology, i.e. the typology is chosen in order to maximize statistical differences of corresponding fish community descriptors (DE)

In order to develop a fish specific typology, Germany has done scientific statistical analyses. The analyses have shown that the functional criterion 'stratification' has the hugest impact on the fish community. A typology based on three types was developed (RITTERBUSCH 2010; RITTERBUSCH et al. 2010):

POLY: polymictic lakes

STRAT: stratified lakes

DEEP: stratified lakes deeper than 30 m max depth

Estonia and Lithuania obtained similar results in their investigations. Unfortunately, the 3 m / 15 m mean depth threshold values of the 'official' common intercalibration types do not separate stratified lakes from non-stratified lakes. Therefore, the CB MS decided to use a typology with a stratification criterion. The typology suggested by Germany was adopted as fish-specific common intercalibration typology. Poland has also applied a lake typology with stratification criterion, dividing lakes in polymictic and stratified ones.

A4.2 Pressure criteria as restricting factors

All MS have developed systems that take the effect of eutrophication into account, which is the major human pressure in the CB GIG. In many systems additional pressures are evaluated, e.g. human use, shoreline degradation, water level regulation, connectivity …

Some human impacts do affect the fish community, but their relevance in the context of a WFD compliant assessment is still under discussion in CB the Fish group: alien species, translocated species, climate warming. Acidification is not considered relevant on the GIG level, despite some exceptions (e.g. mining lakes). It has to be taken into account, that pressures are highly intercorrelated and often have comparable effects. Intense use will lead to shoreline degradation and eutrophication which will destroy littoral habitat complexity (e.g. in urban areas). Water level regulation also will destroy habitat complexity. As has been mentioned elsewhere, fish are good indicators for ecological status, but comparably bad proxies for single pressures.

It is concluded that the fish assessment is reflecting total pressure intensity and therefore all fish systems are comparable in respect of their pressure indication.

Table A 6: Pressures addressed by the national fish-based lake assessment systems

MS	Eutrophication	Water level regulation	Shoreline degradation	Combined	Comment
BE-F				X	biotic integrity (habitat quality, water quality)
CZ	X	X	X	X	
DE	X		X	X	
DK	X				
EE	X				overfishing
FR	X				
NL	X	X	X	X	
PL	X			X	
LT	X	X		X	
UK					

A4.3 Sampling comparability

Many MS follow European standard for multimesh-gillnet fishing (EN 14757 2005): CZ, DE, DK, EE, FR, PL follow the EN 14757 more or less exactly, LT excluded small mesh sizes. Although differences might occur due to the deviating application of the EN procedure, the data is generally comparable.

BE-F, NL and PL-LFI use other methods (like trawl, fishery statistics). Data based on different gear is absolutely incomparable to EN data because:

a) Methods sample different habitats,

b) Active (trawl) and passive gears (nets) have different species-specific effectiveness,

c) Selectivity of gears to species or size-classes cannot be converted to other gear,

d) Most systems work with percentages, deviation in one size/species impacts others,

e) The evidence of some species is restricted to certain methods (e.g. littoral species).

The fishing methods are not comparable throughout the GIG. This does not imply that the assessment results are not 'intercalibratable'. We do not want to compare metric values. We want to compare our assessment on a level of the final EQR values and their assignment to status classes. On the other hand, intercalibration methods based on common fish data cannot be applied. Option 1 (common system) and Option 3 (same data acquisition, different systems) have to be ruled out.

A4.4 Metric comparability

Species composition is included in all systems. Abundance is included in all methods, in many cases directly by standardized catches WPUE or NPUE. In some cases, relative abundances of species or functional groups reflect both species composition and abundance traits of the fish communities. Sensitive species are included in most systems, either directly or indirectly. Age is not included or included indirectly. Fish systems generally assess the fish community as a whole, as an integrating BQE for time and place. The total assessment scores are comparable, but the individual metrics are not. Please see comments in Annex AII.

A4.5 Definition of reference conditions and class boundary setting

There are three ways of setting reference conditions and class boundaries (Poikane et al. unpublished):

1. References: The reference is based on near-natural reference sites. No lakes in true abiotic reference conditions exist in the CB GIG. Therefore, some MS applied the concept of least disturbed conditions (LDC), i.e. the best available lakes in terms of pressure intensities. A second possibility to derive reference conditions is the use of historical data. Class boundaries are set in comparison to reference conditions.
2. Alternative: Class boundaries are based on sites at similar impairment level
3. Continuous: References and class boundaries are based on pressure-response gradients

Table A 7: Benchmarking category and concept of reference condition applied in the national lake fish indices (LFI). LDC: least disturbed conditions.

MS	Benchmark, derivation of reference conditions
BE-F	Reference: historical data, lakes of the pike-tench-roach type represent the reference condition
CZ	Alternative: LDC sites, literature review and expert judgment
DE	Continuous/alternative: LDC sites and expert knowledge, pressure-response and site class distribution
DK	Reference: paleolimnological data (for trophic reference), equals LDC combined with expert judgment
EE	Reference: historical data, expert knowledge, LDC sites
FR	Continuous: site specific hindcasting method
LT	Reference: compared to LDC
NL	Reference: LDC sites and expert knowledge
PL	Reference: historical data and expert knowledge (LFI+), LDC and expert knowledge (LFI-EN)

Boundaries were set at national level. The boundary setting procedures are heterogeneous and differ between MS, lakes, or even metrics of individual systems (Table A 8). Some possibilities are:

1. regression lines (NL),
2. definition of H/G boundary and consequent equidistant division (NL, FR)
3. value distributions, discontinuities (DE, CZ)

In most cases, national expert judgment is included in the class boundary setting. There are no common agreements on abiotic parameters and threshold values representing H/G or G/M boundaries.

Table A 8: National method of class boundary setting. Metric: assignment of scores to metrics, EQR: combination rule for metric scores to obtain a total EQR, class: assigning ecological status classes to EQR values.

MS	Value	Setting of class boundaries
BE-F	Metric	complex, see p. 21
	EQR	sum of metric scores is transformed to EQR
	Class	equidistant division of the EQR
CZ	Metric	discontinuities of metric values
	EQR	sum of metric scores is transformed to EQR
	Class	equidistant division of the EQR
DE	Metric	discontinuities of metric values
	EQR	sum of metric scores is transformed to EQR
	Class	least sum of squares between status class and combined pressure index/expert judgment
DK	Metric	Based on predefined impact classes
	EQR	sum of metric scores is transformed to EQR
	Class	Expert judgment
EE	Metric	EQR (reference is hindcasted)
	EQR	mean of metric EQR
	Class	H/G by expert judgment, others equidistant
FR	Metric	EQR (reference is hindcasted)
	EQR	mean of metric EQR
	Class	H/G by expert judgment, others equidistant
LT	Metric	EQR (reference is 75 % percentile in LDC lakes - see WISER)
	EQR	mean of metric EQR
	Class	Discontinuities in pressure-response-relationship, calibrated with expert judgment
NL	Metric	EQR (reference is based on LDC sites and expert judgment)
	EQR	weighted sum of metric EQR
	Class	Expert judgment based on shifts in fish communities G/M: loss of habitat for phytophilic fish - change from dominance of phytophilic to dominance of eurytopic; MP: shift from macrophyte to phytoplankton dominated - shift from dominance of perch/roach to dominance of bream
PL	Metric	EQR (reference is based on historical data for LFI+ or LDC and expert knowledge for LFI-EN)
	EQR	EQR calculated from formulas
	Class	Expert judgment based on WFD definitions and shifts in fish communities

A5 Summary and conclusions

All CB methods demonstrate that the fish community indication of ecological status summarizes spatial and temporal effects. All systems assess the ecology of the lake as a whole system (including littoral, benthic and pelagic fish). Therefore, habitat specific sampling or the selections of different community characteristics do not represent a major problem. All systems deal with the fact that due to size and complexity of the assessed water body, the ecological status will always be affected by multiple human pressures. Main pressures in CB lakes are eutrophication, human use, water level fluctuation… The pressures may be interdependent and self-enhancing; all of them affect the fish community to some extent. All systems are based on the comparison of the current status with a reference condition although benchmarking procedures differ). The intercalibration seems feasible in terms of assessment concepts.

The main challenges are:

1. Application of different fishing methods which interdicts the application of IC Option 1 (common system) and Option 3 (same data acquisition, different systems)
2. Weak correlation between fish metrics and single pressure parameters.

At the 2nd IC meeting for Central Baltic Lake Fish Systems, we agreed that intercalibration should be feasible. However, the options 1 and 3 had to be dropped. The option 2 (different data acquisition, different numerical evaluation) was chosen. This option requires a common metric which clearly reacts to the pressures intercalibrated. Unfortunately, the reaction of fish community metrics to individual pressures usually is low. Furthermore, the development of a common metric/common system in phase II has turned out unsuitable for the huge geographical range of the CB GIG. Therefore we decided to make some major modification in comparison to the description in the phase II guidance: we will not intercalibrate against individual pressures, but against a total index based on all known pressures. Therefore, it was agreed to use this combined pressure index as common metric.

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Annex AI: National descriptions of Lake fish assessment systems

Belgium-Flanders

All lakes used for the index development are artificial or heavily modified and can be considered as polymictic. Only some lakes are connected to a river. The fish protocol used in Flanders in lakes is one overnight fyke/ha for two successive days with a minimum of 4 and a maximum of 20 per lake combined with electric fishing along 250m-long shore transects per ha.

Index development

Fish were attributed to guilds based on literature review. Species were categorized according to their tolerance for oxygen deficiency and habitat structure degradation. Tolerance scores from 1 (tolerant) to 5 (intolerant) were given to each species. For each lake, gear specific metric values were calculated using reference species only.

Statistical analyses

We assessed the number of species and candidate metrics. To retrieve less-skewed distributions percentage metrics were square-root transformed and count metrics were log-transformed (logx+1). Diversity metrics were kept untransformed.

First correlation among pressure scores was assessed (measure of association, p (Fisher)) to avoid colinearity. Pearson correlation was applied to assess correlation between lake depth and lake surface (log x+1) transformed values.

The response of metrics to pressures (log transformed values) was analysed with linear mixed regression models. As some locations were sampled several times we added locality and year as random effects. We started with a full model including all pressures and applied a stepwise backward selection until only significant terms remained. Normality assumptions were assessed with residual plots. Redundancy of responsive metrics was analysed with a Pearson correlation. Model fit and expert judgment, when needed, was used to select one metric among the redundant ones. The statistical package used was R.2.15.2 (R Development Core Team, 2012).

Threshold value determination for the selected metrics followed Breine et al. (Breine et al. 2010). First, the GEP class boundary was defined:

- For metrics assessing number of species 80% of the reference number was taken as the GEP status threshold value.
- For the relative percentage metrics (Mpi metrics) we calculated the ratio of the species occurrence included in a particular metric over the total number of species in the reference list. This value is used as the GEP threshold.

Once the GEP is defined the other integrity classes are defined by applying trisection with GEP values.

- The average value from the highest impacted sites (total pressure >7) was used to define the minimum percentage weight of benthivorous species (BenWei) and the bream and roach associated metric (AbrRut).

The sum of the metric scores obtained with each method gives the index of biotic integrity (IBI) score for a particular lake. To comply with the WFD this score is transformed to an ecological quality ratio (EQR) calculated as a value between 0 and 1: EQR = (IBI -lowest IBI possible)/(maximum IBI possible-lowest IBI possible). The EQR for the MEP status is 1 under which four classes are defined: GEP (lower threshold value 0.75), moderate (0.5), poor (0.25) and bad (<0.25). The transformation to equal interval classes is obtained using following formula for each integrity interval (piecewise transformation):

T EQR = LV T EQR + (O EQR - LV O EQR)/(UV O EQR - LV O EQR)*0.25

O and T stand for original and transformed EQR value, UV and LV (upper and lower value of integrity class). When during one campaign more than one site is assessed within one lake, data obtained with same method is summed and transformed to catch per unit effort (i.e. per m^2 or per fyke day) to calculate the final EQR for the lake. Allowing a class difference of one unit indices were validated by comparing the integrity class obtained per lake with its assessed pressure status. The pressure status appreciation is obtained by applying threshold to the pressure scores: bad (7-9), poor (4-6), moderate (3), GEP (2) and MEP (0-1). We assessed data of lakes used for the index development and an independent set of data consisting of fish data from eight lakes not included in the index development.

Metrics and threshold values

MpiSpa: Percentage of specialized spawners: species composition and richness (electric fish data)

MpiInv: Percentage of invertivorous individuals: trophic composition (electric fish data)

MpiOmn: Percentage of omnivorous individuals: trophic composition (fyke net data)

MnsPis: Number of piscivorous species: trophic composition (fyke net data)

BenWei: Percentage weight of benthivore: species trophic composition (fyke net data)

ManTol: Tolerance value species: composition and richness (fyke net data)

Additional explanations: Mpi values are relative e.g. 100 individuals are caught and 5 of those are omnivorous then MpiOmn=5/100= 5%, this is so for all Mpi metrics. (Please note that the GEP boundary was determined by comparing the % of species to a reference list of species while the metric is calculated as the percentage of individuals in the total catch). ManTol is the sum of the tolerance value (only species on the reference list are taken into account) of all species that are caught within one survey. E.g. 4 species were caught having a tolerance value of 5; 3 and 1; and one species not on the reference list than the ManTol value= 5+3 +1 or 8.

MEP status is obtained when all 21 reference species are present: *Abramis brama* (Linnaeus, 1758), *Anguilla anguilla* (Linnaeus, 1758), *Blicca bjoerkna* (Linnaeus, 1758), *Carassius carassius* (Linnaeus, 1758), *Carassius gibelio* (Bloch, 1782), *Cyprinus carpio carpio* (Linnaeus, 1758), *Esox lucius* (Linnaeus, 1758), *Gasterosteus aculeatus* (Linnaeus, 1758), *Gobio gobio* (Linnaeus, 1758), *Gymnocephalus cernua* (Linnaeus, 1758), *Leucaspius delineatus* (Heckel, 1843), *Leuciscus idus* (Linnaeus, 1758), *Lota lota* (Linnaeus, 1758)**, *Perca fluviatilis* (Linnaeus, 1758), *Pungitius pungitius* (Linnaeus, 1758), *Rhodeus sericeus* (Pallas, 1776), *Rutilus rutilus* (Linnaeus, 1758), *Sander lucioperca* (Linnaeus, 1758), *Scardinius erythrophthalmus* (Linnaeus, 1758), *Silurus glanis* (Linnaeus, 1758)**, *Tinca tinca* (Linnaeus, 1758).

For the GEP status we should have a relative percentage of specialized spawners between 28.5 and 21.4%. In the moderate status percentages range between 21.4 and 14.2% or when it is higher than 28.5%.The species considered are: pike, gudgeon, burbot, ruffe, rudd and tench (Table A 9).

The relative percentage of invertivorous species (perch (<13 cm total length), ruffe and gudgeon) in GEP ranges between 28.9 and 14.2% and in the moderate status between 14.2 and 9.4% or when it is higher than 28.9%.

The omnivorous species include three-spined stickleback, eel, tench, bream, Prussian carp, common carp, ide, ninespine stickleback, roach and rudd. In GEP their relative percentage ranges between 15.9 and 7.9%. The moderate status is achieved when it is less than 7.9% or ranges between 15.9 and 31.7%.

Five species are considered as piscivorous: burbot, wels catfish, pike-perch, perch (≥ 13cm total length) and pike. GEP is obtained if 3 or 4 of these are present. If only 2 are present the lake is in the moderate status for this metric.

The relative weight percentage of benthivore species should range between 14 and 7% to achieve the GEP status. If less than 7% then we have the moderate status which is also obtained when the percentage ranges between 28 and 14. Species considered here are: bream, white bream, common carp, ruffe and tench. Finally the GEP status is obtained when 17 species of the reference list are present (listed above).

Table A 9: Selected metrics for Flemish lakes and their threshold values for the metric and EQR-scores.

	MEP	GEP	Moderate	Poor	Bad
			Electrofishing data		
Metric - score	1	0.8	0.6	0.4	0.2
% Specialised spawners		< 28.5 ≥ 21.4	≥28.5 & < 21.4≥ 14.2	< 14.2 ≥ 7.1	< 7.1
% Invertivorous individuals		< 28.9 ≥ 14.2	≥ 28.9 & < 14.2 ≥ 9.4	< 9.4 ≥ 4.7	< 4.7
			Fyke net data		
Metric - score	1	0.8	0.6	0.4	0.2
% Omnivores		< 15.9 ≥7.9	< 31.7 ≥ 15.9 & <7.9	< 47.6 ≥ 31.7	≥ 47.6
Number of piscivorous species	5	<5 ≥ 3	2	1	0
% Weight of benthivore species		< 14 ≥ 7	< 28.0 ≥ 14.0 & <7	< 42.0 ≥ 28.0	≥ 42.0
Tolerance value	50	<50 ≥40	<40 ≥27	<27 ≥13	<13
EQR	1	< 1 ≥ 0.75	< 0.75 ≥ 0.50	< 0.50 ≥ 0.25	< 0.25
Appreciation	MEP	GEP	Moderate	Poor	Bad

Pressure-response

The response of metrics to pressures (i.e. industry, agriculture activity, shore modification and development constructions log transformed values to meet requirements of linear models) and predictors (depth, surface, trees) was analysed with linear mixed regression models. As some locations were sampled several times we added locality and year as random effects. We started with a full model including all pressures and predictors. We applied a stepwise backward selection until only significant terms remained. Normality assumptions were assessed with residual plots. To define the goodness-of-fit, the marginal and conditional R^2 for each fitted model were calculated as described by NAKAGAWA & SCHIELZETH (2013). Only the metric response to pressures was decisive for the selection (R^2 conditional>35%). Results in Table A 10.

Redundancy of responsive metrics was analysed with a Pearson correlation. To choose among the correlated metrics (c ≥0.7; p ≤0.001), the one with the best fitted model was taken. Secondly, among the less correlated metrics (c <0.7 and ≥0.5; p ≤0.05), the one that least correlates with other metrics was selected. The results are shown in Table A11.

Table A 10: Reaction of metrics with uncorrelated pressures in reservoirs. (Surlake: reservoir surface; Depth: average depth of reservoir; Dev: percentage of construction; Agr: percentage of agriculture activities; Tree: percentage of trees: Nat: percentage of natural banks) described metrics (log (L) or square root (SR) transformed.

	model <-lmer(metric ~ Lake surface + Development + Depth + Natural banks + Agriculture + Trees + (1|reservoir) + (1|year))					
Metrics (E)	**Selected model**	**p value variable 1**	**p value variable 2**	**p value variable 3**	**R^2 Mar**	**R^2 Cond**
LMnsInv	0.460-0.048Tree	0.0154			0.244	0.528
SRMpiSpa	3.177+0.125Nat-0.612Tree	0.0044	0.0244		0.193	0.363
SRManRec	5.786+0.597Agr	0.0485			0.085	0.136
SRMpiOmn	8.384-0.181Depth	0.0008			0.277	0.404
SRMpiPis	4.576+0.193Depth-1.243Tree+0.979Nat	0.0060	0.0234	0.0472	0.264	0.583
SRMpiInv	4.869-1.272Tree+0.144Depth+1.012Nat	0.0101	0.0135	0.0323	0.209	0.523
SRAbrRut	0.3444-0.183Depth	0.0155			0.212	0.360
SRBenWei	1.196-1.775Agr-0.741Dev	0.0002	0.0181		0.254	0.275
SRSanLuc	0.259-0.101Depth+0.426Nat	0.0370	0.0940		0.083	0.168
SRPerFlu	0.346+0.033Surlake+0.124Depth+0.659Dev	0.0038	0.0041	0.0116	0.274	0.282
LManTol	0.622+0.005Depth	0.0717			0.091	0.276
Metrics (F)	**Selected model**					
LMnsTot	0.503+0.18Tree-0.016Depth	0.0007	0.0042		0.358	0.741
LManBio	2.5-0.576Tree-0.031Depth-0.006Surlake	0.0001	0.0040	0.0060	0.165	0.310
LMnsPis	0223+0.056Nat	0.0450			0.139	0.539
SRMpiSpa	1.901+0.187Tree-0.351Surlake-0.401Nat	0.0005	0.0006	0.0020	0.145	0.579
SRMpiOmn	2.021+1.268Agr+1.352Tree	0.0004	0.0024		0.281	0.390
SRMpiPis	3.979-0.316Depth-0.116Surlake	0.0098	0.0341		0.296	0.523
SRMpiInv	6.482-1.591Tree+0.034Surlake	0.0168	0.0495		0.221	0.532
SRAbrRut	-0.196+1.322Tree	0.0090			0.257	0.644
SRBenWei	-0.647+1.219Agr+1.288Tree	0.0036	0.0184		0.296	0.502

Metrics (E)	model <-lmer(metric ~ Lake surface + Development + Depth + Natural banks + Agriculture + Trees + (1|reservoir) + (1|year)) Selected model	p value variable 1	p value variable 2	p value variable 3	R^2 Mar	R^2 Cond
SRSanLuc	-0.453+0.889Tree	0.0310			0.167	0.468
LManTol	0.599-0.044Dev+0.068Tree	0.0150	0.0220		0.268	0.539

Table A 11: Pearson coefficient (c) and significance (**p ≤0.001; * p≤0.05) for correlation analysis of model fitted metrics with electric and fyke data.

Electric	**MnsInv**	**MpiSpa**	**ManRec**	**MpiOmn**	**MpiPis**	**MpiInv**	**AbrRut**	**BenWei**	**PerFlu**	**SanLuc**
MpiSpa	0.0481	1								
ManRec	0.0965	0.2788*	1							
MpiOmn	-0.1699	0.0205*	-0.1964*	1						
MpiPis	0.2766*	0.2166*	0.1864*	-0.7123**	1					
MpiInv	0.3700**	0.1153	0.2349*	-0.7051**	0.9266**	1				
AbrRut	0.0334	-0.2274*	0.2003*	0.2955*	-0.1937*	-0.0756	1			
BenWei	0.1654	0.2111	0.1412	0.0456	-0.1139	-0.0401	0.018	1		
PerFlu	0.1182	-0.0756	0.2642*	-0.5314**	0.6938**	0.6993**	0.0561	-0.2327*	1	
SanLuc	0.1363	-0.0243	-0.1897*	0.0976	-0.0158	-0.0602	-0.0003	-0.0673	-0.2387*	1
Mantol	0.1330	0.4280*	-0.0267	-0.0716	0.1904*	0.0941	-0.2247*	0.0290	0.03782	-0.3105*
Fykes	**MnsTot**	**ManBio**	**MnsPis**	**MpiSpa**	**MpiOmn**	**MpiPis**	**MpiInv**	**AbrRut**	**BenWei**	**SanLuc**
ManBio	0.8138**	1								
MnsPis	0.5750**	0.4796**	1							
MpiSpa	0.2657**	0.1303*	-0.0404	1						
MpiOmn	0.4891**	0.6088**	0.1635	0.2625**	1					
MpiPis	-0.2866**	-0.2991**	0.5132**	-0.3236**	-0.5729**	1				

Fykes	MnsTot	ManBio	MnsPis	MpiSpa	MpiOmn	MpiPis	MpiInv	AbrRut	BenWei	SanLuc
MpiInv	0.0878	0.0391	0.3967**	-0.1591*	-0.2003*	0.5904**	1			
AbrRut	0.5928**	0.3390*	0.2711**	0.0900	0.3486**	-0.1780*	-0.0672	1		
BenWei	0.5391**	0.4457**	0.1795	0.1892*	0.4060**	-0.3292**	-0.1071	0.4883**	1	
SanLuc	0.2201**	0.1935*	0.3908**	-0.1974*	-0.0400	0.2814**	-0.2182*	0.1029	0.0575	1
ManTol	0.3506**	0.4505**	0.3795**	0.2322*	0.4002**	0.1821*	0.5469**	0.0405	0.1603	-0.1484*

Czech Republic

General

Name / abbreviation: Czech fish based index, CZ-FBI

System status: official

System finalized in 2014

Although the Czech Republic does not have any natural lakes with fish, the country is an official member in the Central Baltic Lake Fish Intercalibration Group with assessment methodology for reservoirs. Fish data from 24 reservoirs were included in the IRSTEA database in 2014. The total dataset consisted of 41 reservoir-year campaigns sampled between 2004 and 2012. The subset used for development of the index consisted of four polymictic and 17 stratified reservoirs (the data from the other three reservoirs were available too late). All polymictic lakes were > 50ha, but three stratified reservoirs were < 50ha. The maximum surface area was 4870ha. The sampled reservoirs were spread over the whole country (Figure A 1) and covered large natural (e.g. altitude from mountains to lowland) and anthropogenic gradients (e.g. 100% natural cover up to 73% of agriculture land use in the catchment). The rest of the available data, from seven repeatedly sampled reservoirs, were used in the validation procedure.

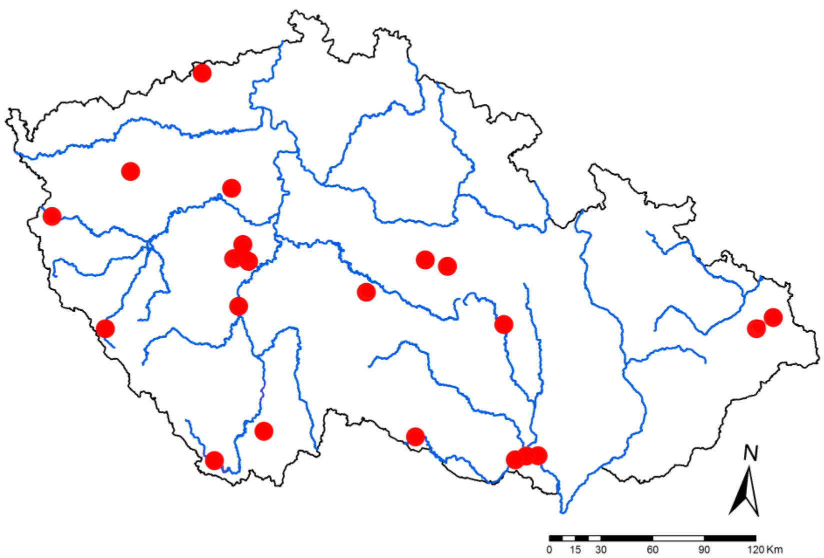


Figure A 1 Map showing the geographic distribution of the reservoirs (red dots) within the Czech Republic.

Literature: CZ-FBI is a part of "Methodology of assessment of the ecological potential heavily modified water bodies and artificial water bodies – lake category", together with assessment of physico-chemical parameters, phytoplankton and macrophytes. This methodology was developed for the Ministry of the Environment of the Czech Republic a year ago (BOROVEC et al. 2014). The methodology was presented to users at first (river authorities) and then slightly modified according to their comments. It is currently undergoing a certification process. The document is available on the official web of the Ministry of the Environment. The methodology is used by river authorities for assessment of reservoirs ecological potential. The methodology is described only in the Czech language but all relevant information were translated and are given below. The Czech version can be downloaded at: http://www.mzp.cz/cz/prehled_akceptovanych_metodik_vod.

Concept

General concept: Because of the limited dataset, simple and robust methods were chosen for metric selection. Assessment was based on simple linear regression, expert judgment and literature review. Eutrophication was considered as the main pressure and total phosphorus (TP) was used as a proxy of the stressor. Because of the fish long lifespan, TP was defined as the three years average (year of sampling plus two previous years) from data collected in the epilimnion layer during vegetative season (April to September) in 2 to 4 localities along the longitudinal gradient of a reservoir. Fish metrics were tested to their relation with the TP concentration. Only metric with good statistical fitting could be chosen for the index calculation, moreover such fit had to be supported by literature and expert assumptions (elimination of randomly positive or negative relationships). Afterwards, logical metrics were chosen based on literature review and expert judgment.

Reference conditions: Reference localities without any anthropogenic impact were not present in the dataset. Therefore, gradient between least and most disturbed localities was used for metrics selection and setting of the scoring criteria.

Class boundary setting: The setting was based on expert judgment and the report written by RITTERBUSCH (2011). Each metric was evaluated to good, moderate and poor quality class. The report describes fish metrics applicable to the whole geographical region and class boundaries settings for good and moderate quality class.

National typology for lakes

Two categories were included to the assessment:

Heavily modified water bodies – HMWB: The category includes reservoirs and ponds. The ponds were excluded from the assessment because their fish community is heavily modified in order to fulfil their primary purpose - fish production.

Artificial water bodies – AWB: The category includes four artificial post coal mining lakes. The post coal mining lakes are in their initial phase of fish community succession (KUBEČKA 1993) and it was not possible to develop a special assessment methodology for these water bodies. Therefore, the same criteria were used for categorization of AWB as those for the HMWB.

The typology was based on System B in Appendix II of the WATER FRAMEWORK DIRECTIVE (2000/60/EC 2000). Water bodies were divided according to the two most important criteria affecting fish community (DIEKMANN et al. 2005; GASSNER et al. 2005; MEHNER et al. 2007; PRCHALOVÁ et al. 2008; RITTERBUSCH et al. 2014):

Altitude:	Average depth:
Lowland < 200 m a.s.l.	Polymictic < 5 m
Middle 200-700 m a.s.l.	Stratified > 5 m
Mountain > 700 m a.s.l.	

<u>Sampling gear</u>

The reservoirs were sampled with benthic (BG) and pelagic gillnets (PG) following EN 14757 (2005) extended by four larger mesh sizes (70, 90, 110 and 135 mm) for capturing bigger fish (ŠMEJKAL et al. 2015). The gillnets were deployed at regular intervals in order to cover the longitudinal gradient (dam to tributary) of a reservoir (2 to 4 sampling localities depending on a reservoir's size) and whole depth profile (nets were deployed in each 3 m layer, separately for benthic and pelagic habitats), for details see PRCHALOVÁ et al. (2008; 2009).

<u>Metrics and scoring</u>

The fish indicators and potential fish metrics were selected based on literature review (KARR 1981; KARR et al. 1986; BELPAIRE et al. 2000; JEPPESEN et al. 2000; GASSNER et al. 2003; DIEKMANN et al. 2005; GASSNER et al. 2005; MEHNER et al. 2005; SØNDERGAARD et al. 2005; CAROL et al. 2006; GARCIA et al. 2006; MEHNER et al. 2007; LAUNOIS et al. 2011a; LAUNOIS et al. 2011b; KELLY et al. 2012; ARGILLIER et al. 2013; BRUCET et al. 2013; BLABOLIL et al. 2015) online information available from the webpage www.fishbase.org and authors experience. Because of high natural fluctuation of young-of-the-year (0+) fish and their underestimation by gillnets (EN 14757), the metrics were counted only for fish older than 0+. The only one exception was metrics evaluating age structure. A total of 59 fish metrics were finally counted, mainly single fish species indicators and occurrence in different habitats (benthic x pelagic) or localities (dam x tributary) due to natural heterogeneity of reservoir´s systems.

For stratified reservoirs new metrics were selected and combined in CZ-FBI. Seven fish metrics out of 53 were selected to have satisfactory statistical fit with TP and covered range allowing establishing quality classes (Table A 12). The first three metrics fulfilled the WFD criteria evaluation of abundance. Both the abundance and biomass of fish increased with nutrient concentration. The correlation between fish biomass and nutrients was stronger in pelagic than in benthic habitats. Moreover, the division to dam and tributary parts reflected the natural decrease of nutrient concentration along the longitudinal gradient of reservoirs. The class boundaries in the tributary part were set to twice as much as in the dam part. Therefore, it was possible to distinguish ecological quality in both parts of a reservoir. On the other hand, in terms of abundance, one number integrated all localities and depth gradient in the benthic habitat. The increase of fish abundance and biomass with nutrient concentration is well described in the scientific literature and metrics connected to this phenomenon were used in many fish assessment methodologies (BELPAIRE et al. 2000; SØNDERGAARD et al. 2005; LAUNOIS et al. 2011a; LAUNOIS et al. 2011b; KELLY et al. 2012; ARGILLIER et al. 2013; BLABOLIL et al. 2015). The increase in populations of eurytopic species such as common bream (*Abramis brama*) and ruffe (*Gymnocephalus cernua*) and the opposite decrease of sensitive species as perch

(*Perca fluviatilis*) or rudd (*Scardinius erythrophthalmus*) with increase in productivity and structural changes in the ecosystem has been well documented (JEPPESEN et al. 2000; MEHNER et al. 2005; GARCIA et al. 2006; KELLY et al. 2012).

The other four metrics were species-specific and therefore dedicated to the evaluation of the species richness WFD criteria. The first two species increased their populations with eutrophication and the structural changes in the ecosystem. These were percentage of biomass common bream (*Abramis brama*) and percentage of abundance of ruffe (*Gymnocephalus cernua*). The relationship for both species was more evident in benthic habitat. The fish biomass is usually a better indicator than abundance to reflect the changes in trophic structure, but ruffe is a small bodied species (adult 50-100 g) and therefore its abundance was used. The opposite indicator is percentage of biomass perch (*Perca fluviatilis*). Populations of this species decreased with nutrient concentration. And a similar trend was observed for percentage of rudd (*Scardinius erythrophthalmus*) biomass. Furthermore, rudd population is sensitive to the presence of macrophytes in the littoral, because it is a strict phytophylous species. The submerged vegetation is a very important part of reservoirs ecosystem and can be reduced not only due to eutrophication, but also by other factors such as water level fluctuations. Submerged vegetation provides preferred spawning substrate for many fish species, but it is also a buffering zone for bank erosion, a sink of nutrients controlling algae and blue algae production, a habitat for many other organisms (e.g. macroinvertebrates), a refuge for 0+ fish or a hunting ground for ambush predators such as northern pike (*Esox lucius*). The advantage of using rudd as an indicator was its wide distribution and the fact that it is not propagated by anglers.

The last species-specific metric was selected based on literature review and expert judgment. Evaluation of fish belonging in family Salmonidae (in the Czech Republic brook trout *Salvelinus frontinalis*, brown trout *Salmo trutta*, grayling *Thymallus thymallus*, rainbow trout *Oncorhynchus mykiss*, maraena whitefish *Coregonus maraena* and peled *Coregonus peled*) was ecologically very important, but it was not possible to establish the relationship between this indicator and stressors with the current dataset. The percentage of biomass Salmonidae is a good indicator of cold, oxygen rich, low nutrients and high quality waters. For deep reservoirs, it is also an indicator of oxygen presence in the hypolimnion during the summer stratification. The conditions naturally differ along the gradient of altitude. Therefore, even in the limited dataset, two different class boundaries reflecting different natural conditions in high altitude (≥ 700 m a.s.l.) and low altitude were established (Table A 12). Species belonging to the family Salmonidae are good indicators of high-quality waters. Their typical preference is cold, nutrients-poor and oxygen-rich water. Therefore, in terms of stratified reservoirs during the summer period, they usually occur in the deep hypolimnion if the concentration of dissolved oxygen allows their survival (GASSNER et al. 2003; GASSNER et al. 2005; CAROL et al. 2006). The different altitudes related to climate should also be taken into account since reservoirs below 700 m a.s.l. usually have suboptimal ecological conditions for Salmonidae. The presence of higher biomass (> 2 %) in lowland and middle altitude reservoirs increase the EQR. On the other hand in mountain reservoirs Salmonidae should be present and biomass < 2 % decreases EQR. The 2% of biomass threshold was chosen arbitrarily but we expect that when a certain salmonid species makes up at least 2 % of in the total biomass then a viable population of the species is present in a reservoir (only absence/presence of Salmonids was not used because these species are sometimes relocated to reservoirs from rivers above during flooding and the detection of single specimens does not indicate good ecological quality). Moreover, salmonids populations are getting endangered by expansion of percids, cyprinids or even pike, cormorants, illegal fishing, acidification, connectivity restriction or other alterations. Their importance is not only for the fishermen in one water body, but also for the fish stock in standing waters since they spawn in tributaries and the offspring can move to other water bodies. Most of the salmonids are in adulthood piscivorous stage and therefore can reduce the abundance of other mostly zooplankivorous fish and improve water quality through trophic cascades (theory of biomanipulation (CARPENTER et al. 1985)).

The last metric assessed natural reproduction of common species (3 Cyprinidae and 3 Percidae). The presence of 0+ fish of 6 common species (bream, roach *Rutilus rutilus*, bleak *Alburnus alburnus*, ruffe, perch, pikeperch *Sander lucioperca*) was a logical metric for reflecting the age structure WFD criterion. Determination of 0+ fish is much easier and precise than the evaluation of the age structure of older fish using scales or otoliths. Although a reservoir is under strong pressure and natural reproduction is still present, it should not be considered as a completely bad ecosystem. On the other hand in many reservoirs with high water quality large populations of piscivorous perch can significantly reduce the cohorts of 0+ fish. This process is fully natural and typical for perch dominated communities (KUBEČKA 1993) and lack of recruitment should not decrease the assessment. In this case, when perch biomass exceeded 20 % this metrics was not used.

Table A 12: Description of the fish metrics, sampled by benthic (BG) or pelagic (PG) gillnets, classification to quality classes together with corresponding score and criteria of Water Framework Directive used for the assessment of ecological potential for stratified lakes

Metric	**Gear**	**Poor (1)**	**Moderate (3)**	**Good (5)**	**WFD criterion**
Total fish (older than 0+) biomass in dam part [kg/1000 m^2]	PG 0-5m	> 35	17-35	< 17	abundance
Total fish (older than 0+) biomass in tributary part [kg/1000 m^2]	PG 0-5m	> 70	35-70	< 35	abundance
Total fish abundance (older than 0+) [ind/1000 m^2]	BG all	> 600	300-600	< 300	abundance
Percentage of biomass common bream *Abramis brama* (older than 0+) [%]	BG all	> 10	5-10	< 5	species composition
Percentage of abundance ruffe *Gymnocephalus cernua* (older than 0+) [%]	BG all	> 20	10-20	< 10	species composition
Percentage of biomass perch *Perca fluviatilis* (older than 0+) [%]	PG all	< 10	10-20	> 20	species composition
Percentage of biomass rudd *Scardinius erythrophthalmus* (older than 0+) [%]	BG and PG all	< 1	1-5	> 5	species composition
Percentage of biomass Salmonidae (older than 0+) [%] < 700 m a.s.l.	BG and PG all	< 1	1-2	> 2	species composition
Percentage of biomass Salmonidae (older than 0+) [%] ≥700m a.s.l.	BG and PG all	< 2	2-5	> 5	species composition
Presence of 0+ fish 6 common species (bream, *roach Rutilus rutilus*, bleak *Alburnus alburnus*, ruffe, perch, pikeperch *Sander lucioperca*) [number of species]*	BG and PG all	< 2	2-3	> 3	age

* Not included if percentage of perch biomass in all gillnets is > 20 %

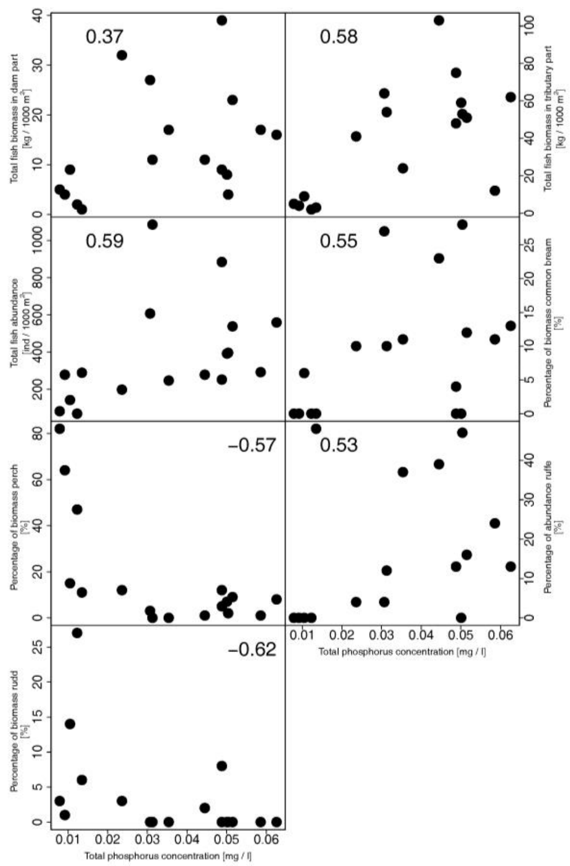


Figure A 2: Plots illustrating the relationships between fish metrics and total phosphorus concentrations in stratified reservoirs. The numbers in the upper part of each plot represent the Spearman rank correlation coefficient between the two variables.

For polymictic reservoirs four data points did not allow the selection of new fish metrics and therefore metrics described by RITTERBUSCH (2011) were chosen and adapted to Czech conditions (Table A 13). The metric description is the same as for stratified reservoirs. All metrics are based on benthic gillnets because pelagic zone is usually very limited in shallow polymictic reservoirs. One exception is the metric “presence of 0+ fish of 6 common species” when both BG and PG were used and also the metric will not be used in condition of high perch population. The abundance (not biomass) is used for the metric “percentage of abundance ruffe”.

Table A 13: Fish metrics, sampled by benthic (BG) or pelagic (PG) gillnets, classification to quality classes together with corresponding score and criteria of Water Framework Directive used for the assessment of ecological potential for polymictic lakes.

Metric	**Gear**	**Poor (1)**	**Moderate (3)**	**Good (5)**	**WFD criterion**
Total fish (older than 0+) biomass [kg/1000 m^2] < 200 m a.s.l.	BG all	>116	60-116	<60	abundance
Total fish (older than 0+) biomass [kg/1000 m^2]] ≥ 200 m a.s.l.	BG all	>60	30-60	<30	abundance
Percentage of biomass common bream (older than 0+) [%]	BG all	>39.5	20-39.5	<20	species composition
Percentage of abundance ruffe (older than 0+) [%]	BG all	>20	10-20	<10	species composition
Percentage of biomass perch (older than 0+) [%]	BG all	<5	5-10.3	>10.3	species composition
Presence of 0+ fish 6 common species (bream, roach, bleak, ruffe, perch, pikeperch) [number of species]*	BG and PG all	<2	2-3	>3	age

* Not included if percentage of perch biomass in all gillnets is > 20 %

Mathematics

The class boundaries were set at discontinuities in the metric value distribution based on expert judgment and the report written by (RITTERBUSCH 2011). Each metric was evaluated to good (the best value), moderate and poor quality class and get 5, 3 or 1 points (Table A 12 and Table A 13).

Scoring: After evaluation of all metrics in each reservoir, the ecological quality ratio (EQR) was calculated as:

EQR = $(\text{score}-\text{score}_{min})/(\text{score}_{max}-\text{score}_{min})$.

Score means the sum of points for all fish metrics assessed in a reservoir. Minimum score is the number of metric (all get point one) and the opposite maximum score is five times number of metrics (all get five points). The range of EQR is between 0 and 1; zero means the most degraded ecosystem and one the best conditions.

The EQR-range of values from 1-0 was divided into 25 % quantiles for classification of ecological potential in four classes. Moreover, the original High and Good class was split in two parts. The High, in this case the theoretical reference status, was set to upper 1/10 of the total range.

HIGH: 1.00-0.91

GOOD: 0.90-0.75

MODERATE: 0.74-0.50

POOR: 0.49-0.25

BAD: 0.24-0.00

Based on the calculation of EQR and classification to ecological potential classes, it was found that the sampled reservoirs covered a large gradient from Good to Bad ecological potential (Figure A 3). Most of the sampled reservoirs was categorized as Poor.

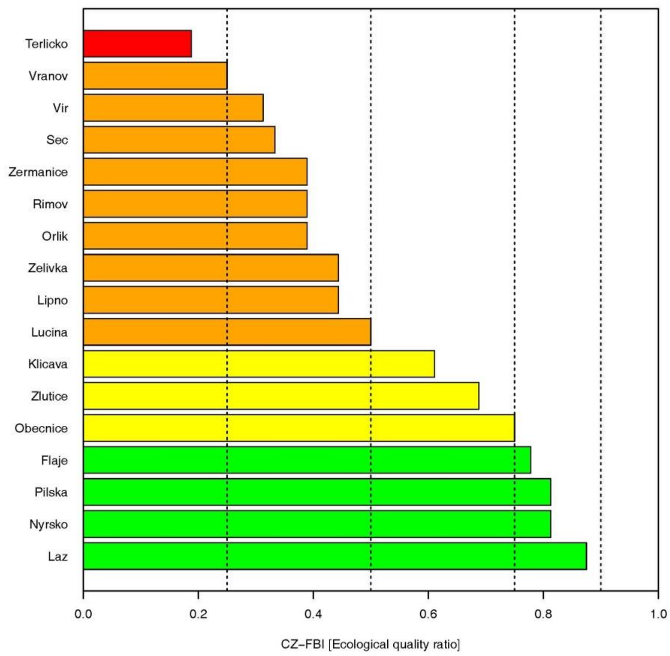


Figure A 3: Results of the assessment of the ecological potential of the sampled reservoirs. The decrease in values indicate a decrease in ecological quality. The colours represent ecological potential categories: green Good, yellow Moderate, orange Poor and red Bad. Vertical lines represent boundaries of ecological potential classes.

Pressure-response

Most pressures are strongly related to eutrophication, the most important stressor in continental Europe (ARGILLIER et al. 2013; BRUCET et al. 2013) (BIRK et al. 2013). Additionally, all fish species belonging to family Salmonidae inhabiting standing water bodies in the Czech Republic are generally sensitive to water quality and changes in the environment. Moreover, rudd is sensitive not only to eutrophication, but also to shoreline degradation. Selected metrics describing the whole fish community react to the general degradation of ecosystem.

Validation with an independent pressure index: An independent pressure index composed of the main stressors affecting the fish community was developed for validation of the assessment methodology. The pressures were eutrophication (scored twice because of the main impact on the community), water level fluctuation, shoreline modification, fisheries management, recreation use and percentage of biomass non-indigenous fish species. For each stressor three class boundaries connected to different level of the impact on ecosystem were set and all reservoirs classified similarly to EQR (Table A 14) and finally scaled to range 0-1. The increase in pressure index indicates higher ecosystem degradation. The data were collected mainly from river authorities managing the reservoirs, but also from direct observation during the field sampling and by using the Google Earth maps for shoreline degradation.

Table A 14: List of anthropogenic pressures and their classification in three classes of impact on fish community together with corresponding score.

Impact and score	**Eutrophication**	**Water level fluctuation (max annual amplitude)**	**Shoreline modification**	**Fisheries management**	**Recreation use**	**% weight of non-indigenous fish in total catch**
No (1)	same as theoretical reference	< 3m	< 10%	All manipulation prohibited	Prohibited	< 1%
Moderate (2)	One class change, e.g. meso. -> eutrophic	3-9 m	10-20%	Special restriction or locality of low interest	Bathing, boating	< 10%
Strong (3)	Two class change, e.g. oligo. -> eutrophic	> 9 m	> 20%	Angling whole year or locality of high interest	Intensive, motorboats	> 10%

The regression with the independent pressure index was relatively tight with a coefficient of determination of 0.67, p<0.001 (Figure A 4). This means good detection ability of the assessment methodology to distinguish between reservoirs under different intensity of pressures.

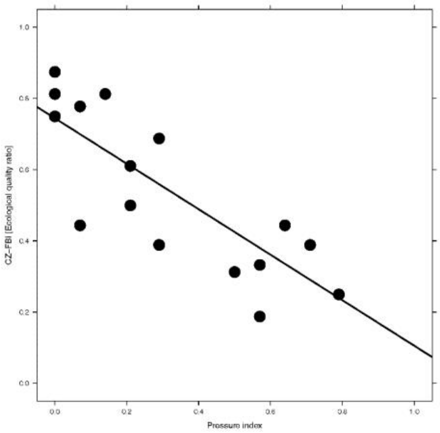


Figure A 4: Relationship between ecological quality ratio of the assessed reservoirs and independent pressure index.

<u>Stability of the assessment</u>: In the second validation procedure long-term stability of the EQR was tested. Data from the seven reservoirs sampled more than once in the period 2004-2012 were used in this procedure. Because of the long lifespan of fish, a high stability of the EQRs was expected.

This test proves the robustness of the assessment methodology. Of the seven reservoirs, only two were classified in different class of ecological potential (Figure A 5). The minimum standard deviation on sample was 0.031 EQR for Zlutice reservoir and the maximum was 0.095 EQR for Vir reservoir, the average standard deviation for the seven examined reservoirs was 0.056 EQR.

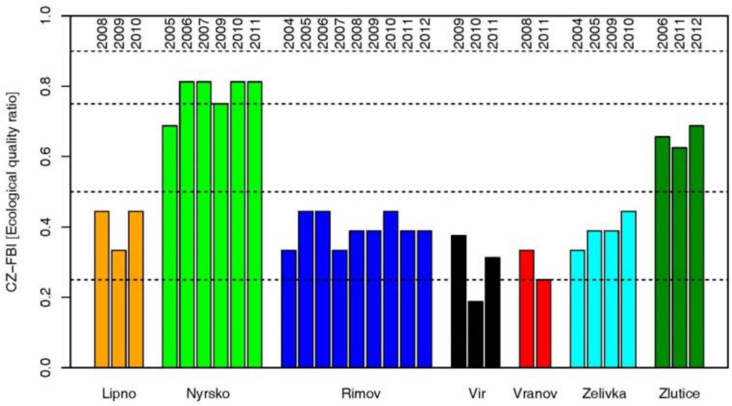


Figure A 5: The long term stability of ecological classification assessment in seven reservoirs sampled repeatedly in 2004-2012. Vertical lines represent boundaries of ecological potential classes and years above each bar the year of sampling.

Sensitivity test: Following the previous results, a one-at-the-time sensitivity test on the complete dataset of 41 reservoir-years was performed. The most sensitive metrics were the total fish abundance and biomasses (Table A 15). The slight deviation ±10% of observed value had on average an impact on 21% of the total EQRs (change 0.06 EQR). The higher change of ±25% increased the percentage of EQRs change to 46%. One particular reason for this result was the complete dataset with no zero values. On the other hand, other metrics always had zero values (the fish species/family was not detect by gillnets in the sampled habitat) or in terms of the metric "presence of 0+ fish" when the metric was not used due to high population density of perch. The highest sensitivity within these species/families specific metrics was observed for relative biomass of common bream and ruffe. The lowest sensitivity was detected for relative biomass of perch, rudd and Salmonidae. Most of the zero values were observed in the metric "relative biomass of Salmonidae". Low abundance of Salmonidae fish is typical even in water bodies with high water quality and therefore even lower abundance in anthropogenically altered waters was not surprising.

Table A 15: Results of one-at-a-time sensitivity test. For each metric two thresholds were examined (±10% and ±25% change). Percentage of EQR change in the total 41 reservoir-years is shown together with the number of zero values and samples when the metric was not used.

	±10% change	**±25% change**	**Zeros**	**Not used**
Total fish biomass in dam part	17	37	0	0
Total fish biomass in tributary part	20	34	0	0
Total fish abundance	27	68	0	0
Percentage of biomass common bream	12	27	29	0
Percentage of abundance ruffe	5	24	24	0
Percentage of biomass perch	2	12	2	0
Percentage of biomass rudd	2	10	27	0
Percentage of biomass Salmonidae	5	10	71	0
Presence of 0+ fish 6 common species	6	9	0	36

Fish communities

Fish are probably the most sensitive indicators to anthropogenic changes in the environment and are used since the first Index of biotic integrity was developed by (KARR 1981). On one hand fish are sensitive to a variety of natural and disturbance factors (KARR 1981; KARR et al. 1986); on the other hand, fish can have their own impact on biological processes in water ecosystems (CARPENTER et al. 1985), each species to a different degree. Fish lifespan is on average rather longer comparable to other biological elements required by WFD. Therefore, they may integrate long-term changes. Concurrently, they are sensitive to acute harmful events in ecosystem. The integration of historical changes can be detected in fish community composition and condition of individual fish. Fish usually belong to several trophic levels and thus show an integrative view of the ecosystem (LINDEMANN 1942). Fish are mobile organisms, providing an integrative view of the ecosystem they live in (KARR 1981). In relative small country such as the Czech Republic, the fish species have the same chance of distribution due to natural spreading or anthropogenic stocking, but the environmental factors and stressors determine the population structure.

The "**High**" class should represent the reference status for Czech water bodies, close to ecosystem without any anthropogenic stressors. The main anthropogenic stressor in the

Czech Republic is eutrophication. In natural conditions the trophic status would be oligo- to mesotrophic due to natural low nutrient load (HEJZLAR et al. 2003). In this condition only limited abundance and biomass of fish would occur (~ 50-150 kg/ha). The species composition would be dominated by species characteristic for low productivity in water such as Salmonidae. The littoral would support submerged and immersed vegetation providing refugee for invertebrates as well as spawning substrate for phytophilous species (e.g. rudd). The natural reproduction would be present every year, but might be poor under condition of natural strong fish predation pressure. Species hybrids as well as fish with morphological anomalies would be absent or extremely rare. The species typical for eutrophic conditions (e.g. common bream and ruffe) would play only a minor role or be completely missing from the community. Therefore, low species richness is typical under such conditions. The pelagic community would be very limited due to low productivity in open water and perch would occur more often than typical zooplanctivorous Cyprinidae fish. Currently, none of the sampled water bodies in the Czech Republic belong to this class. We have historical records of small natural lakes being in that class, but all fish species went extinct from these localities after acidification (VRBA et al. 2000).

Slight changes from the “High” class are required for a reservoir to be classified in the “**Good**” ecological class. The fish community is stable and reflects water productivity. The fish abundance and biomass is only a bit higher due to increased nutrients. Benthic habitats should still have higher biomass than pelagic habitat. Similarly, the species composition is slightly altered. The species typical for nutrients-rich waters still have small populations and sensitive species can stagnate or show minor population decreases. However, sensitive species are still present in the community. Fluctuation in year-class strength is allowed, but the absence of natural reproduction should not extend more seasons since this can result in the collapse of species populations. One example is the Nyrsko reservoir located in the Bohemian Forest. Built mainly for drinking water storage, its long term TP concentration in the dam part of the reservoir is 0.007 - 0.012 mg/l in the inflowing river, angling, bathing and other in lake water use is prohibited, and the percentage of agricultural use in its catchment is 16.2%. Only native species were detected during sampling. Water level fluctuated slightly due to hydropower generation with year amplitude < 2m. Although historical unpublished data records identified high populations of Salmonidae species, none of the species were detected. The reason for their extinction was mainly the increase in water level fluctuations, a new dam in the tributary restricting natural reproduction and stocking of northern pike. The dominant fish species are perch and roach, rudd population is relative high and stable.

The “**Moderate**” class differs moderately from the “High”. Fish abundance and biomass is relative high reflecting higher production in open water. The omnivorous/zooplanctivorous Cyprinidae species play high role in the community. However, specialised species should also be present. The occurrence of sensitive species indicating presence of suitable habitats (e.g. developed littoral and absence of oxygen deficit in hypolimnion of stratified reservoirs) gives information about an ecological status that is not bad. Hybrids, especially of Cyprinids species such as bream and roach are not rare. Non-native species are often found too, however the stocked fish should not play a major role in the system. Species richness is usually relative high. Lucina reservoir is a good example. The long term TP in the dam part is 0.034 mg/l and 0.038 mg/l in the inflowing river, the agriculture use in the catchment area reaches 29.3 %. The water level fluctuation is similar to Nyrsko (year amplitude < 2m). The fish biomass in the benthic and pelagic habitat is nearly equal. The dominant species was roach.

Denmark

General

Name/Abbreviation: Danish Lake Fish Index

System status: Almost finalized, intercalibratable, still unofficial but authorities are testing/using the index on their lake systems.

System is expected to be finished in 2013

Fish data included in the common database at the CEMAGREF: 116 lakes (113 with fish EN data)

Literature (peer review): (SØNDERGAARD et al. 2005)

Literature (reports): (SØNDERGAARD et al. 2013) www.dmu.dk/Pub/SR59.pdf

Concept

General concept: The Danish system focuses on the indication of eutrophication. The status classes of the lakes were pre-classified using thresholds for TP and Chl-a. The class boundaries for the metrics are calculated using the predefined status classes and is being evaluated on an independent dataset in combination with expert judgement.

Reference conditions: High and Good status of lakes were defined using thresholds of TP and Chl-a based on representative paleolimnological records dated back to approx. 1850 and defined as *"least disturbed condition"*. The high/good class boundary for the fish metrics is the average between the median of metric values for the high status of Chl-a and TP. The Danish concept for reference status equals a under current conditions "least disturbed condition" combined with an expert judgement of what is acceptable and what not. Reference is partly a historical status but not a status without human impacts.

Class boundary setting**:** For the description of the fish abundance and fish composition of Danish lakes, seven environmental explaining variables were used: mean depth, area, Secchi depth, total phosphorus (TP), chlorophyll, total nitrogen (TN) and alkalinity. In general data were log transformed, and the final fish CPUE (Catch Per Unit Effort) were based on log-transformed catch data.

To identify the best explainable variables for the fish community, a partial Canonical Correspondence Analysis (pCCA) with the environmental variables was performed. To make this analysis more robust we only included fish species occurring in minimum 5 lakes. Based on an initial cross correlation between the included environmental variables, and due to high co-variance with several variables, Secchi depth was included as a co-variable. After subtracting the effect of Secchi depth, the remaining environmental variables, explained 11 % of the variation in the fish community, with mean depth and TP as significant explaining variables (Table A 16). The inter-correlation between variables was relatively large (largest for chlorophyll a), though weakening the robustness of the analysis.

In the weighted correlation matrix for the analysis, highest correlations were seen between TP and Chlorophyll a, and between mean depth and Chlorophyll a, saying that part of the variation of the fish distribution pattern can be explained by Chlorophyll a. Consequently TP and Chlorophyll a was chosen as the structuring factors for the fish communities. Besides, Chlorophyll a is an integrating variable dependent not only on nutrients such as TP and TN, but also on more general biological and physical conditions such as the fish community, light conditions and macrophyte appearance.

Table A 16: Results of a multivariate analysis (pCCA) of the biomass based fish composition, including 6 environmental variables and Secchi depth as a co-variable. The 6 variables explained 11 % of the fish distribution pattern.

Variable	P	F
Mean depth	0.005	3.36
Total P	0.005	3.05
Area	0.008	2.68
Chlorophyll a	0.060	1.82
Total N	0.345	1.11
Total alkalinity	0.528	0.88

To identify boundaries between quality classes, the 4 metrics (see below) were plotted against TP and Chlorophyll a ranges (TP ranged as: 0-25 µg/liter, >25-50; >5-100; >100-200; >200 µg/liter, and Chlorophyll a ranged as: 0-11 µg/liter, >11-23, >23-56, >56-90, >90 µg/liter). Figure A 6 shows an example for NPUE.

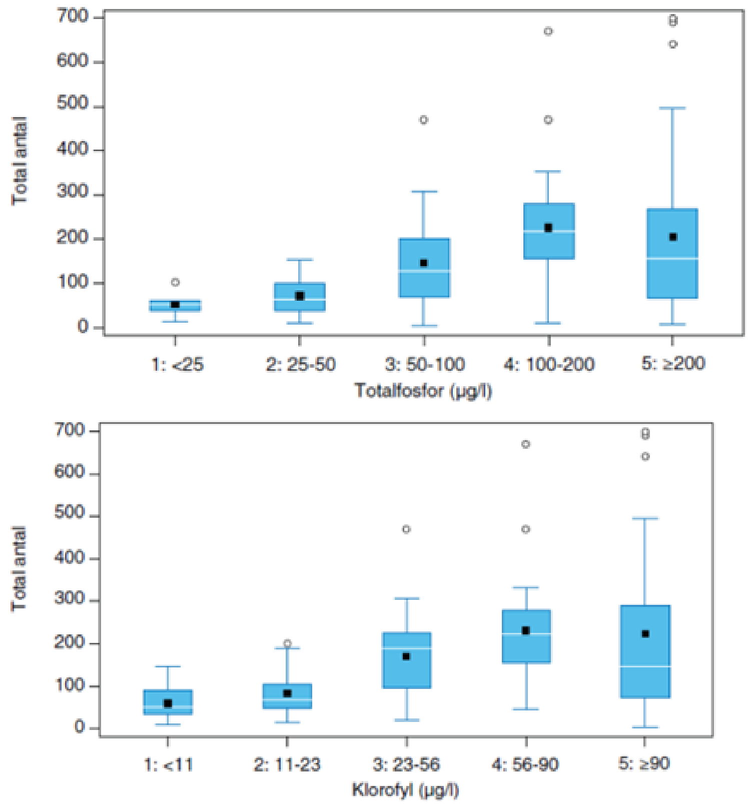


Figure A 6: Correlations between NPUE and the explainable variables TP and Chlorophyll a. The white lines show the median NPUE values for the given category of lakes

The calculation of the boundaries was performed by taking the average values of the two medians for a given TP and Chlorophyll a range. E.g. the boundary between high and good status for shallow lakes is the average of the median for the lowest TP class (0-25 µg/liter) and the median for the lowest chlorophyll class (0-11 µg/liter). The important boundary between good and moderate status is the average of the median for the second TP class (>25-50 µg/liter) and the median for the second chlorophyll class (>11-23 µg/liter). This exercise is performed for all the four metrics and ends up with the table containing all the boundaries used for calculating the EQR values.

Sampling gear

EN 14757 (in some lakes reduced number of nets were used but else the same principles)

Additionally electric gear is used for qualitative information (without using the results for the fish system).

Table A 17: Metrics and scores used in the Danish lake assessment system

Metrics for shallow lakes	**Gear**	**0**	**1**	**2**	**3**	**WFD criteria**
NPUE (per net)	EN	> 158	< 158	< 66	< 52	Abund.
% W piscivores > 10 cm	EN	< 25	> 25	> 29	> 58	spec.comp
% W roach+bream	EN	> 68	< 68	< 64	< 35	spec.comp
Average individual biomass	EN	< 30	> 30	> 52	> 79	Age
Metrics for deep lakes	**Gear**	**0**	**1**	**2**	**3**	**WFD crit**
NPUE (per net)	EN	> 76	< 76	< 66	< 50	Abund.
%W piscivores > 10 cm	EN	< 30	> 30	> 38	> 53	spec.comp
% W roach+bream	EN	> 51	< 51	< 45	< 30	spec.comp
Average individual biomass	EN	-	-	> 42	> 44	Age

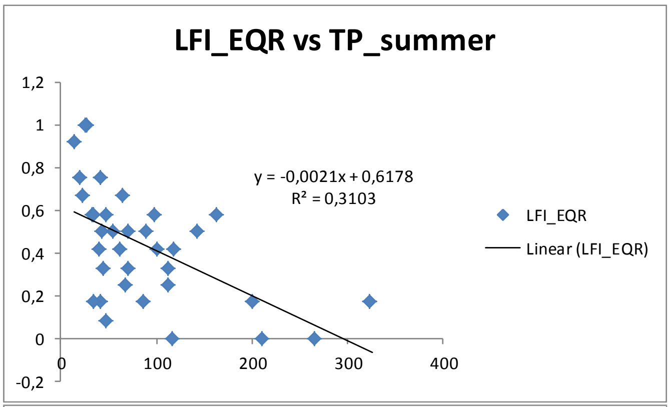
Pressures addressed and pressure impact relationships

The Danish system focuses on eutrophication:

1. NPUE: high numbers shows high productivity as a consequence of eutrophication
2. Piscivores: biomass decreases with increasing eutrophication (well known for perch, pike diminishes if littoral structures decrease, pikeperch percentages are low at high levels of eutrophication)
3. Roach, Bream and roach/bream hybrids: biomass of the two/three species are increasing with eutrophication
4. Individual biomass: size/biomass decreases because of an increase of small fish species and stunted growth

For the intercalibration process on the LCB2 lakes, only lakes >50 ha were used, restricting the number to 37 lakes. For those 37 lakes there was a significant correlation between the overall EQR and TP: EQR = -0.0021 * TP_summer + 0.6178 (R^2 = 0.3103). Loss of habitats was used too in the intercalibration process. Here we also found a significant correlation between the overall EQR and habitat numbers, which can be converted to loss of habitats: EQR = 0.0813 * habitat number (R^2=0.549), thus demonstrating the adequate sensitivity of the fish

EQR. Both correlations are shown in Figure A , please refer to part B of the report for details about the pressures.



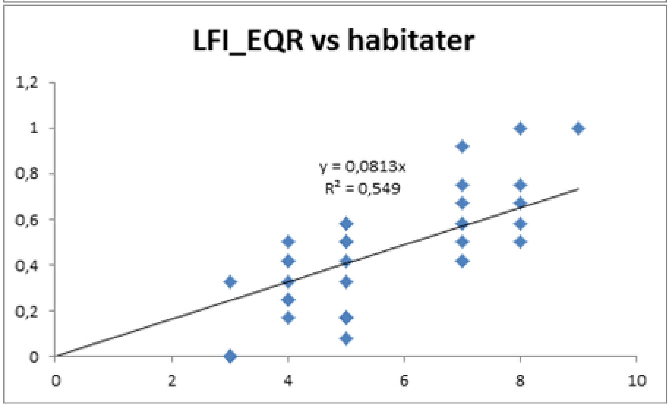


Figure A 7: Regression and coefficients of correlation for the Danish LFI and two anthropogenic pressures; TP_summer and habitatNr.

Mathematics

The class boundaries for the metrics are the mean values between the medians of the metric values for the predefined status classes.

Scoring: The metrics get a 0/1/2/3-points score similar to the IBI concept. The total score is calculated by summing the 4 metrics scores. The total score is then translated into a status class or can be translated into an EQR value from 0 to 1.

Status classes: the total score for the 4 metrics is directly translated into a status class or into an EQR4 value by dividing the total score by the potential maximum score of 12.

Total score	Status class of lake	EQR4
11/12	HIGH	> 0.85
8-10	GOOD	> 0.6
6/7	MODERATE	> 0.45
4/5	POOR	> 0.25
0-3	BAD	

'Performance' of the fish assessment system

The system has been tested on an independent data set, and Danish managers (fish experts) have agreed on the results from the EQR4.

Estonia

General

System status: Finalized, intercalibratable (not official)

System was finalized in 2009, modified in 2013 and 2015

Name/abbreviation: LaFiEstA if first three metrics are used (evaluates the water column), LAFIEE if all four are used (evaluates the whole lake) and rsLAFIEE when the occurrence of the rudd is considered.

Fish data included in the common database at the CEMAGREF: 22 lakes + 2 lakes for WISER

The Estonian system is based on the LaFiesta systems (EQR 3,5, developed in 2009) that contains three required components:

1. taxonomic composition with the metric [Simpson Dw] that reflects land use the best,
2. abundance (with the two metrics [log NPUE/percentage of non-piscivorous fish* shoreline index] with NPUE reflecting the TP concentration
3. age structure (percentage of gillnet panels that caught fish) that reflects the habitat heterogeneity the best

The rsLAFIEE index was developed by shifting the low values of LAFIEE to meet the required 0.6 as a boundary between G/M previously set at 0.17 by the 2011 intercalibration procedure. To make clear difference between G/M additional disturbance sensitive taxa *Scardinius erythrophthalmus* (shown to occur in waters of TP value between 20 and 50 µg/l).

Literature (peer review): (Palm et al. 2012) - can be found in the Dropbox\Literature folder

Literature (reports): Palm, A., Krause, T. (2009): Preliminary indicators of the state of fishes fauna in lakes and the boundaries between quality classes (part of a longer report with a lot of authors, originally in Estonian with an unofficial translation in 2013) - can be found in the Dropbox\Literature folder

Concept

General concept: Our concept was to assess fish assemblages with Nordic gill nets and compare the share of species with pressures. As we had the opportunity to compare the numbers for fish with numbers for pressures only recently, we had to use a proxy for pressure values. For this purpose the already tested indices of Swedish EQR-8 were used. Corrections in the formula were made after we got the pressure data. We had no opportunity to test our system against damming as all main water courses are dammed in Estonia. We had no chance to gather data on the shallowest littoral that is test the occurrence of the loaches as the electrofishing of the littoral of over 50 ha in area lake for the occurrence of loaches takes a whole day and is even then subjective if no loaches are found. It is hard to electrofish in waters with extremely low conductivity usual in lakes that start a river i.e. fed mainly by rain. To be intercalibratable we chose indices also used in Sweden, Danish and Finnish assessment systems, but to get any acceptable result at all we had to modify them adding hydromorphological parameters of the lake into the formula. Littoral part of a lake is usually sampled by mini-fyke nets, these data used in one out of four indices.

Reference conditions: Historical data (about 1950-60, list of species, published) for lakes include too many species per lake (probably all species ever seen around). So we've found reference conditions according to calculations - the highest results.

Class boundary setting: There are no reference lakes i.e. undisturbed lakes in Estonia. Also we did not find any grounds (neither feeding, spawning etc.) to discriminate fish assemblages into six class categories to set boundaries between. Most of Estonian LCB-1 and LCB-2 type lakes (48 in total) are eutrophic, some either with mesotrophic or hypertrophic features. We do not have enough LCB-1 and LCB-2 type lakes to develop a class-boundary system of our own to assess e.g. the only lake in bad state. Despite of that we developed our own equally distanced class boundaries (2009) that were reset with the boundary between G/P as 0.17 for LAFIEE by the previous intercalibration process in 2011. This value (0.17) was elevated to 0.6 by the above described formula. H/G – 0.8, G/M – 0.6, M/P – 0.4, P/B – 0.2.

Sampling gear

Estonia uses a modified EN 14757 procedure

- 1.5*30 m-pelagic nets to cover pelagic zone in shallow lakes (type norden multi-mesh) and 'normal' 6*30 m pelagic nets to cover deeper lakes – data in all metrics;
- additional to EN multimesh norden benthic nets (data used in all metrics) Estonia uses 1.5*30 m nets with one single mesh size (30, 35, 40, 45…70, 75) – data used to calculate % non-piscivorous fish and % perch (percids);
- all depth strata covered, but net numbers are not strictly like the EN guideline (usually less);
- no nets in anoxic hypolimnion (empty benthic nets are eliminated from calculations);
- mini-fyke nets in the littoral area.

According to our database all empty nets are considered, although we usually do not sample the anoxic hypolimnion of stratified lakes. Most of our data are gathered for other projects fitting their goals other than the development of a national system to assess the ecological state of the lake on the basis of fish (ended in 2009).

Table A 17: Metrics used in the Estonian fish assessment system

Metric	Gear	WFD criteria
1. Simpson DW	ENmod	Species composition, diversity index
2. logNPUE/ (% non-pisciv.*shoredev)	ENmod	Abundance
3. % filled sections	ENmod	Age structure
4. % percids	ENmod	Indicator species

Explanations

The metrics of the Estonian system are not type specific as only two species - white bream and bleak have been shown to avoid certain type of waters (see the report). At first we used both NPUE and BPUE, but found later on that biomasses are more indicative in the Simpson index and did not want to overemphasize it by repeated use. Shoredev is shoreline development (lake shoreline length / circumference of a circle of the same area) - probably indicative only for lakes with smaller area than 50 ha (most of lakes in Estonia) % filled net sections: Maximum is 12 (= 100 %). At least one fish in the section over all samples of the lake equals a filled net section. It's a metric for the presence of a year class and a simplification for length-class-measurement. Ageing is extremely time-consuming, although we've done it for several projects.

In scoring the weight of metrics is the highest for those that reflect pressures the best.

Table A 19: Metrics and scoring of Estonian fish assessment system

Metric	Weight with rudd in a sample	Weight without rudd in a sample	High	Good	Moderate	Poor	Bad
1.	0.042	0.083	>0.6	0.45-0.6	0.3-0.45	0.15-0.3	<0.15
2.	0.083	0.167	>1	0.75-1	0.5-0.75	0.25-0.5	<0.25
3.	0.125	0.250	>1.5	1.1-1.5	0.8-1.1	0.5-0.8	<0.5
4.	0.25	0.5	>0.6	0.4-0.6	0.2-0.4	0.01-0.2	<0.01
occurrence of rudd	0.5						

Pressures addressed

Eutrophication: log NPUE/(% non-pisciv.*shoredev)

Anthropogenic pressures including eutrophication and overfishing: Simpson DW/log AreaLake; % perch

Overfishing (also the reproductive success): % filled sections, also indicates conditions for reproduction

Mathematics

The class boundaries are equidistant division of the EQR modified by expert judgement

Scoring: In the Estonian system, metrics get individual scores between 0 to 1.
[illegible]

Class boundaries for total EQR and status classes

HIGH: > 0.8

GOOD: > 0.6

MODERATE: > 0.4

POOR: > 0.2

'Performance' of the fish assessment system

We had an opportunity for relationship-based checking of our systems against pressures when we got pressure data to fulfil the TAPI database. The best of four metrics to indicate eutrophication (Figure A 8) was the percentage of percids that also indicated the land use for LCB-1 (Figure A).

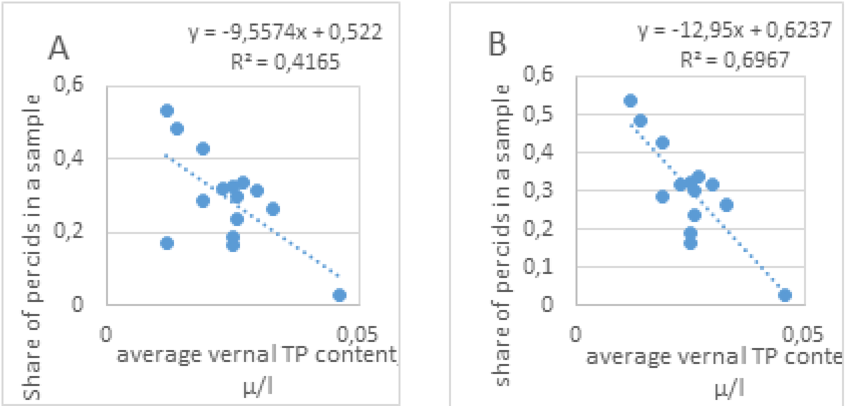


Figure A 8: In LCB-1 lakes the share of percids reflected average vernal TP content (µ/l), when lake Konsu with low retention time and through passing mining waters was elliminated (B) it was even more plaucible as an indicator

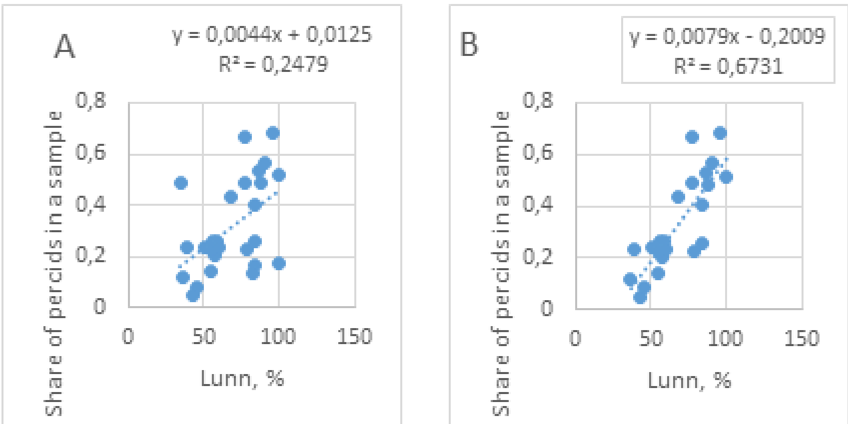


Figure A 9: In LCB-2 lakes the share of percids reflected the land use in a catchment basin (A), it was much better indicator if the lakes without outlet or high share of the pikeperch were eliminated (B)

After being developed on the basis of expert judgement we could test it against eutrophication indicators in 2014 and the values of correlation coefficient are as follows:

Table A 20: Correlation coefficients between trophic indicators and Estonian fish assessment system

	Chl-a avg in epilimnion June-Sept, µg/l	**TP avg vernal May, µg/l**	**TP avg in epilimnion June-Sept, µg/l l**	**%Natural and semi-natural**	**TP µg/l**	**TSI**
LCB-2	-0,49313	-0,36613	-0,26327	0,530368	-0,47155	-0,63507
LCB-1	-0,68172	-0,72964	-0,43539	0,133964	-0,36251	-0,36951

Metrics explanation, ecological background, and indicative value

Metric 1: ‘Simpson DW - taken from Kerstin Holmgren’s EQR8, should show how stable the fish community is. This was the least indicative, but reflected the land use in long term.

Metric 2: ’logNPUE/(% non-piscivorous*shoredev)’ – ‘LogNPUE' is taken from Danish method, but gave for our data better results, (probably because most of our studied lakes are less than 50 ha in area) after deviding by ‘shoredev’. ‘% non-piscivorous’ is taken from Finnish system and added to recalculate the real number of fish i.e. the real load of nutrients incorporated in fish if not consumed by piscivores. Is a good indicator to reflect the chl-a values in summer for both lake types in interest.

[illegible]

Metric 4: ‘% percids' should reflect the state of the bottom of the lake the best if both weight and numbers are averaged. All three percid fish species (the perch, ruffe and pikeperch) inhabiting Estonian lakes are considered. From the ‘nutrient load’ point of view perch alone characterizes mesotrophic waters and with cyprinids eutrophic waters. Is a good indicator for land use in LCB-2 lakes, but reflects the chl-a summer and TP vernal values.

France

Introduction

The Water Framework Directive 2000/60/EC (WFD) (Communauté Européenne 2000) requires the definition of the ecological status of European water bodies. To assess ecological status of lakes, fish communities shall be considered. These fish communities should be described by a single indicator that is a combination of standardized single metrics. According to WFD, the fish index has to combine metrics in relation with composition, abundance and age structure of the fish communities. These metrics must react to measurable stressors such as hydro-morphological pressures and/or eutrophication pressures. The eutrophication status of the CB natural lakes using fish index is extracted from the European method developed in the WISER project (N° 226273).

Dataset

The dataset used to build the index concerns 454 lakes located in 10 European countries. 17 French lakes are in the Central Baltic area. For these lakes, fish data, environmental parameters and anthropogenic descriptors were available and in a similar format. Among these 454 lakes, 96 were considered as in reference conditions or slightly disturbed according to the criteria listed below.

Table A 21: List of criteria used to select the “reference or weakly disturbed” sites.

	Criteria	Thresholds
Eutrophication	% land use « natural »	>80% (Rejection threshold* = 70%)
	Population density	10 hab.km^{-2} (Rejection threshold* at 30hab/km^2)
	Ptot (µg/l)	20 (Rejection threshold* at 50µg/l)
Acidification	pH	> 6 & if <6, expert judgement on the natural origin
Hydromorphology	Impoundment upstream	absence
	Loss of connectivity downstream	absence
	Water level fluctuation	no significant
	Shoreline Bank modification	<10% of shoreline modified
Activity on the lake	Urban/industrial discharge	absence
	Stocking	absence
	Biological or chemical manipulation	absence
	Fishing activities	no significant
	Others activities	no significant

*Rejection thresholds have been fixed in order to not exclude too many lakes in case of missing values. If two of the three parameters reached the reference threshold then it was possible to accept a value up to the rejection threshold for the third parameter.

Fish data

Fish data have been collected in application of the standardised method (CEN 2005). The analyses were only performed on the catches of the benthic nets. All sampling sessions included in the dataset correspond to a single campaign for each lake, in order to be consistent with one-year environmental data. In the frame of the WISER project, metrics tested are related to composition and abundance of fish communities. After the removal of some metrics owing to either their narrow range of variation or their great number of outliers (Hering and al., 2006), 35 metrics were finally considered in the modelling approach.

Environmental data

All the lakes were described using environmental variables that are known to influence fish community structure. Maximum depth and lake area are strong drivers of the species richness (Barbour and Brown 1974, Eadie et al. 1986). Altitude is a factor of isolation that influences community composition (Godinho et al. 1998, Magnuson et al. 1998). Catchment area could be considered as a surrogate for habitat diversity upstream from the lake (Irz et al. 2004). Monthly mean air temperature data obtained in application of the CRU model (New et al. 2002) was used to calculate the mean temperature range between the maximum and the minimum annual temperatures and the annual mean temperature.

Stressors

The stressors used are the percentage of non-natural land cover extracted from Corine Land Cover and the concentration of total phosphorus (µg/L) collected by the different member state and available in the European database. The first one can be considered as a proxy of eutrophication and/or of general degradation, whereas total phosphorus is directly related to eutrophication.

General Statistical Methodology

Extrapolation of reference conditions

Being aware of some difficulties linked to the selection of reference lakes at the European scale, the approach adopted here involved the modelling of the reference conditions (hindcasting modelling; Baker et al. 2005, Kilgour and Stanfield 2006, Launois et al. 2011). It is different from the "reference sites approach" since models include anthropogenic factors as predictor variables in addition to environmental parameters. This method consists of artificially reducing the stressors influence (i.e. stressor values set to 0 or to low level of pressure for all lakes) in order to predict the metric value in reference conditions. This thus assumes that these predictions are representative of what the metric value is likely to be in the absence or for very low level of human disturbances, and could therefore be considered as reference values. It is especially useful when not enough reference sites are available.

Modelling metrics with environmental variables and anthropogenic stressors

Classic monotonic transformations were performed in order to meet the requirements of linear models (normality, linearity): count (abundance, richness) and biomass metrics were log-transformed; proportion metrics were arcsine-square root transformed, whereas diversity indices were kept raw. Maximum depth, lake area and catchment area were log-transformed. The percentage of land use in catchments was arcsine-square-root-transformed.

Each metric was first predicted with a Multiple Linear Regression (MLR) by using environmental variables and stressors as predictors, followed by a stepwise procedure based on the Aikaike Information Criterion (AIC) in order to select the best explaining model for each metric. A cross-validation procedure was applied by dividing the dataset (N = 454) into two distinct subsets:

- The training subset, consisting of a random selection of 2/3 of the lakes of the entire dataset and which corresponds to approximately 300 lakes
- The validation subset, which gathers the remaining lakes.

The MLR and the stepwise procedure were then performed on the training subset and the obtained model was tested using the validation subset. The metrics for which the correlation coefficients between expected and observed values in the validation step were lower than 0.7 have not been retained. The goodness of fit of the designed model was then assessed. This cross-validation procedure was essential to estimate the predictive performance of the selected model.

Then, the quality of the models retained was checked by means of graphical tools (i.e. Quantile-Comparison Plots and Regression Leverage plots) and the value of the adjusted R^2. Only metrics involving a model with (i) an adjusted R2 > 0.3, (ii) normally distributed residuals, and (iii) a weak leverage effect were selected.

Moreover, at least one significant stressor parameter has to be retained by the stepwise procedure to be selected.

To determine the contribution of each predictor to the total explained variance of each model, a hierarchical partitioning was applied using the algorithm developed by Chevan and Sutherland (Chevan and Sutherland 1991).

For each lake, the values of the stressors were then artificially reduce (hindcasting procedure) in the model of each selected metric. This made it possible to predict the values of each metric in the absence of significant pressure.

The difference between the observed metric values (obs_metric) and the predicted metric values (hind_metric) was then computed to obtain a deviation score for each lake and for each metric.

EQR calculation and normalisation

Since a common scale of ecological quality is required by the WFD, this deviation score has to be expressed as an Ecological Quality Ratio (EQR) (i.e. a numerical value between 0 and 1).

For metrics that decrease with increasing stress, EQR was then calculated as:

$$EQR = \frac{(obs\_metric - hind\_metric) - min(obs\_metric - hind\_metric)}{max(obs\_metric - hind\_metric) - min(obs\_metric - hind\_metric)}$$

For metrics that increase with increasing stress, it was calculated as:

$$EQR = 1 - \frac{(obs\_metric - hind\_metric) - min(obs\_metric - hind\_metric)}{max(obs\_metric - hind\_metric) - min(obs\_metric - hind\_metric)}$$

EQR values are then related to the stressors values. For each metric, the Pearson correlation between the EQRs and the stressors must be significant to retain the concerned metric.

Creation of a multimetric index and definition of the ecological class boundaries

After checking that the trend of the targeted metric on the pressure gradient was consistent with the expected one (described in the literature and/or explicable from an ecological point of view), Pearson correlation analysis were performed among the selected metrics (EQR) to only select the ones with a correlation value lower than 0.8 (Hering et al. 2006).

The selected metrics were then averaged to build the final multimetric index.

To evaluate the discriminatory performance of this index, a composite stressor was built on the basis of the two stressors considered in the analyses: the non-natural land cover and the total phosphorus. A Principal Component Analysis was performed on these two variables, and the first axis, accounting for 72% of the variability, was used to construct the composite stressor index. The relationship between the multimetric index and this stressor index was then evaluated.

The class boundaries have been defined by fixing the high/good (H/G) boundary, before dividing the remaining part into four equal parts. According to Hering et al. (2006), it is more suitable to use a percentile of index values from reference sites to define the H/G class boundary than to use the best available conditions as reference values. As a compromise, the 25% percentile of the "reference or weakly disturbed" lakes was thus proposed to define the H/G boundary. In addition, the 25% percentile in our dataset corresponds more or less to the value of the stressor generally used to distinguish reference lakes from non-reference lakes (i.e. 10 % for the percentage of non-natural land cover), and seems consequently in agreement with the Guidance on the intercalibration process. To make this index comparable with the indices used by other member states, we applied a piecewise procedure to mathematically shift the H/G boundary to 0.8 (and consequently the three lower boundaries to 0.6, 0.4 and 0.2), which appears as the most commonly used H/G boundary.

Results

From the 35 available metrics only three passed through the various selection steps and exhibits acceptable correlation with the stressor variables:

- The number of individuals caught per unit effort (CPUE)
- The biomass of individuals caught per unit effort (BPUE)
- The relative number of omnivorous individuals (OMNI)

CPUE and BPUE bring complementary information on fish abundance in the lake.

The abundance of omnivorous individuals is a metric in relation with trophic composition of the fish community. In addition, from a functional point of view, omnivorous species are known to be less sensitive than specialist species.

These three metrics were all significantly correlated to non-natural land cover (Pearson coefficients equal to -0.47, -0.47 and -0.29, respectively) and to the total phosphorus stressor (Pearson coefficients equal to -0.48, -0.50 and -0.35, respectively).

Despite being quite high, the Pearson correlation coefficients did not reach the exclusion threshold of 0.8. Therefore, the three metrics were all proposed as core metrics. For each metric, the details of the final model are presented below.

Table A 22: Pearson rank correlation between the three selected metrics.

BPUE	0.76 ***	-
OMNI	0,72 ***	0,60 ***

****Significant at 0.001 level.*

CPUE

Details of the stepwise multiple linear regression models retained to predict CPUE metric are given in Table 3. Regression coefficients are given for the environmental and stressor variables conserved in the model after stepwise multiple regression. The t-value and the significance of the test tell us whether a variable has statistically significant predictive capability in the presence of the other variables.

Quasi-normality of the residuals were tested and are acceptable (Shapiro-wilk test p>0.05) and model successfully explained around 53% of the variability (Adjusted R-squared). Furthermore, validation procedure shows good results since correlation coefficient between predictions and observed CPUE values is equal to 0.73.

Table A 23: Results of the stepwise multiple linear regression for the CPUE metric: values of the model equation coefficients, their t statistic measure (t-value) and its significance.

	Coefficients	**t-value**	**Significance**
Intercept	0.236	0.454	
(Maximum Depth)2	-0.084	-7.399	***
Lake Area	0.161	3.977	**
Catchment Area	-0.060	-1.922	.
Altitude	-1.85E-03	-2.795	**
(Altitude)2	1.12E-06	1.721	.
Temperature Amplitude	0.303	6.194	***
(Temperature Amplitude)2	-6.18E-03	-4.975	***
% of Non-Natural Land Cover	0.724	5.136	***
Total Phosphorous	0.216	4.329	***

. Significant at 0.1 level * Significant at 0.05 level, ** significant at 0.01 level, *** significant at 0.001 level.

BPUE

Details of the stepwise multiple linear regression model retained to predict BPUE metric are given in the Table 4 (see above CPUE for details). Quasi-normality of the residuals is less verified than for the CPUE model (Shapiro-wilk test $p>0.05$) but is still acceptable and model successfully explained 51% of variability (Adjusted R-squared). Furthermore, validation procedure shows good results since correlation between predictions and observed BPUE values is equal to 0.73.

Table A 24: Results of the stepwise multiple linear regression for the BPUE metric: values of the model equation coefficients, their t statistic measure (t value) and its significance.

	Coefficients	**t value**	**Significance**
Intercept	6.617	14.685	***
(Maximum Depth)^2	-0.072	-7.933	***
Lake Area	0.117	3.261	**
(Lake Area)^2	0.020	1.940	.
Catchment Area	-0.059	-2.328	*
Average Temperature	-0.130	-2.220	*
(Average Temperature)^2	0.009	2.562	*
Temperature Amplitude	0.120	2.383	*
(Temperature Amplitude)^2	-3.75E-03	-2.504	*
% of Non-Natural Land Cover	0.498	4.642	***
Total Phosphorous	0.214	5.457	***

. Significant at 0.1 level * Significant at 0.05 level, ** significant at 0.01 level, *** significant at 0.001 level.

OMNI

Details of the stepwise multiple linear regression model retained to predict OMNI metric are given in the Table 5 (see above CPUE for details). Quasi-normality of the residuals is successfully reached (Shapiro-wilk test $p>0.05$) and model explained 54% of variability (Adjusted R-squared). However, although validation procedure shows good results since correlation between predictions and observed metric values is equal to 0.74, the model seems to meet some difficulties at predicting absence of omnivorous individuals when comparing with the observed ones.

Table A 25: Results of the stepwise multiple linear regression for the Omnivorous Relative Number metric.

	Coefficients	**t value**	**Significance**
Intercept	-8.289	-8.812	***
(Maximum Depth)^2	-0.128	-7.008	***
(Lake Area)^2	0.050	2.274	*
(Catchment Area)^2	0.017	2.588	*
Altitude	-4.25E-03	-3.590	***
(Altitude)^2	3.95E-06	3.484	***
Average Temperature	0.187	3.327	***
Temperature Amplitude	0.780	8.626	***
(Temperature Amplitude)^2	-0.014	-5.587	***
% of Non-Natural Land Cover	0.489	1.876	.
Total Phosphorous	0.329	3.756	***

. Significant at 0.1 level * Significant at 0.05 level, ** significant at 0.01 level, *** significant at 0.001 level.

The Multimetric Index

The multimetric Index resulting from the mean of the three metrics was significantly correlated to the composite stressor index (adjusted R^2=0.42, P value < 0.001; Figure A 10). The ecological class boundaries obtained before and after the application of the piecewise procedure are given in Table A 18.

Table A 18: Class boundaries defined for the European fish index.

Initial thresholds	Modified thresholds	Classes
[1 - 0.56]	[1 - 0.8]	H
[0.56 - 0.42]	[0.8 - 0.6]	G
[0.42 - 0.28]	[0.6 - 0.4]	M
[0.28 - 0.14]	[0.4 - 0.2]	P
[0.14 - 0]	[0.2 - 0]	B

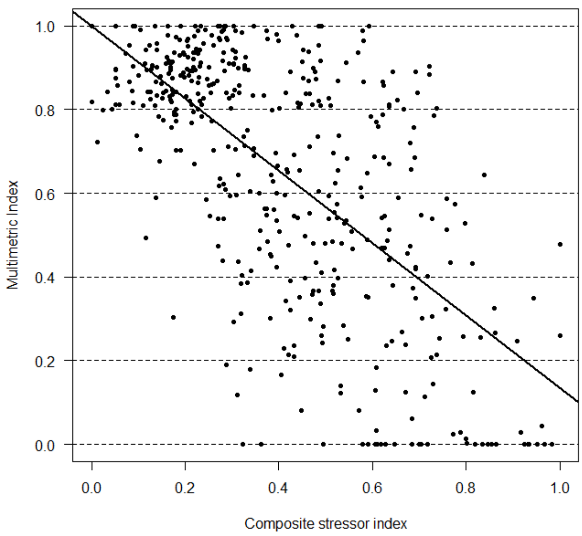


Figure A 10 Relationship between the composite stressor index and the multimetric index resulting from the mean of the three selected metrics. Horizontal dashed lines indicate the ecological class boundaries.

Conclusion

This multimetric index has been developed using a site specific approach. The targeted pressures are eutrophication and also probably “general degradation”. The index includes abundance and composition metrics but does not integrate information regarding the age structure of the fish communities, whose related metrics were not retained during the selection procedure. It has been developed on the WISER European dataset, on which the classification of the CB lakes has been extracted. These results are validated at the national level and the index is now included in the national assessment system.

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Germany

General

Name/Abbreviation: German Lake Fish Index - DeLFI

System status: Finalized, intercalibratable, unofficial

System was finished in 2011

Fish data included in the common database at the CEMAGREF: 75 lakes

Literature (peer review): -

Literature (reports): -

Concept

General concept: The German system works with the catches of benthic nets in EN 14757 fishing campaigns. It identifies the ecological effect of all pressures reflected in the fish community. The metrics used cover all normative criteria of the WFD. The DeLFI assesses frequently occurring species.

Reference conditions: There are no unimpacted lakes in Germany representing true reference conditions. Reference sites were selected using least disturbed conditions for eutrophication parameters, lake use and shoreline degradation, details can be found in RITTERBUSCH et al. (2014).

Class boundary setting: Class boundaries are set at discontinuities in the metric value distribution. The 'best of the best' metric values are the reference values with a fine-tuning by expert judgment. Background is the knowledge of the distribution of ecological status classes along the German lakes: reference is very rare to absent, good is frequent, moderate is frequent, poor is rare, bad is very rare to absent (in lakes > 50 ha).

Sampling gear

EN 14757 (in earlier times, we divided the full standard in two half-standard campaigns, but this is not done any more). Additionally electric gear is used (without using the results for the DeLFI).

National typology for lakes > 50 ha

- POLY polymictic lakes
- STRAT stratified lakes <= 30 m maximum depth
- DEEP stratified lakes > 30 m maximum depth

Table A 27: Metrics and scoring used in the German fish assessment system.

Metric	n.a.	5 points	4 points	3 points	2 points	1 point
LakeType POLY						
obligatory species		all present	-	one missing	-	> one missing
WPUE [kg/m²]	≤ 0.031	≤ 0.05	≤ 0.10	≤ 0.20	≤ 0.30*	> 0.30
benthic net species %W		≤ 60	≤ 85	≤ 95	< 100	= 100
benthivorous species %W		≤ 20	≤ 50	≤ 80	≤ 95*	> 95
Bream %W	= 0	≤ 10	≤ 35	≤ 60	≤ 85*	> 85
Ruffe %W	= 0	≤ 4.5	≤ 6.0	≤ 7.5	≤ 9.0*	> 9.0
White Bream %W	= 0	≤ 10	≤ 20	≤ 40	≤ 50*	> 50
Pikeperch %W		≤ 4	≤ 20	≤ 36	≤ 52*	> 52
Perch %W		≥ 40	≥ 15	≥ 5	≥ 0	= 0
LakeType STRAT						
obligatory species		all present	-	one missing	-	> one missing
BPUE [kg/m²]	≤ 0.011	≤ 0.03	≤ 0.05	≤ 0.08	≤ 0.10*	> 0.10
benthic net species %W		≤ 45	≤ 60	≤ 75	≤ 90*	> 90
benthivor. species %W		≤ 10	≤ 20	≤ 30*	≤ 40	> 40
Bream %N	= 0	≤ 0.6	≤ 3	≤ 5	≤ 7*	> 7
Ruffe %W	= 0	≤ 1.0	≤ 4.0	≤ 7.0*	≤ 9.0*	> 9.0
LakeType DEEP						
obligatory species		all present	-	one missing	-	> one missing
BPUE [kg/m²]	≤ 0.012	≤ 0.02	≤ 0.032	≤ 0.044	≤ 0.066*	> 0.066
benthic net species %W		≤ 45	≤ 60	≤ 75*	≤ 90	> 90
benthivorous species %W		≤ 13	≤ 23	≤ 33*	≤ 43	> 43
Bream %N	= 0	≤ 0.5	≤ 2	≤ 3.5	≤ 5*	> 5
Ruffe %N	= 0	≤ 10	≤ 20	≤ 30	≤ 40	> 40

Metric	n.	5 points	4 points	3 points	2 points	1 point
All Types						
Median weight		Total score is worst individual score of Perch, Bream and Roach				
Perch > 6 g		12-15	< 30	< 45	< 60*	≥ 60
			< 12	< 9	-	-
Bream > 10 g		50-100	< 250	< 400*	?	?
			< 50	< 15	-	-
Roach > 14 g		40-55	< 100	< 145*	< 190	> 190
			< 40	< 18	-	-

Pressures addressed

The main pressures affecting the German lakes are eutrophication and the consequences of intensive use (shoreline degradation, disturbance). The DeLFI does not aim at disentangling the effects of the different pressures, but provides an assessment of the ecological status of the whole lake as a consequence of all pressures taking place. However, some of the metrics are more sensitive to eutrophication, others to other pressures.

Mathematics

Scoring: The metrics get a 1/2/3/4/5-points score similar to the WFD concept. The total score is calculated by summing the metrics scores and then translated into an EQR value between 1 and 0.

Status classes: The class boundaries are

≥ 0.98 high

≥ 0.80 good

≥ 0.60 moderate

≥ 0.40 poor

'Performance' of the fish assessment system

The performance was intensively tested by comparing the assessment results with both expert judgment, single pressure-impact relations and quantitative multiple pressure-indices. The results had been very good. Details will be added later.

Lithuania

General

Name/Abbreviation: **LEZI** (Lietuvos Ežerų Žuvų Indeksas / Lithuanian Lake Fish Index)

System status: Finalized, intercalibrateable, not official

System was finished in 2013

Fish data included in the common database at the CEMAGREF: yes, 46 lakes

Literature (peer review): -

Literature (reports): -

Concept

General concept: The system is type-specific with three types. To assess the ecological status, metrics of the fish community in current condition are compared to reference conditions. Metric values at reference conditions were estimated based on least disturbed (near natural) sites.

Reference conditions: Potentially reference status lakes were selected by common intercalibration criteria (POIKANE 2009). When selecting lakes, an exception was made to the criterion of natural land-cover, i.e. lakes with >50% of their catchment area covered by natural vegetation were also attributed to potentially reference status lakes because in Lithuania there are just a few lakes with > 90% of their catchment covered by natural vegetation, i.e. forests. Reference values for metrics were set as 75th percentile in potentially reference lakes (least disturbed conditions).

Class boundary setting: Expert judgment based on WFD definitions, calibrated against pre-classified sampling sites.

Sampling gear

Metrics are calculated using EN 14757 benthic nets. Nets are modified, no small mesh sizes below 14 mm. Net height is 3 instead of 1.5m and length 40m instead of 30m. Nets have 8 panels with 5m each instead of 12 panels with 2.5 m each. Mesh sizes 14/18/22/25/30/40/50/60 without small mesh sizes of EN (5/6.25/8/10/12.5). Pelagic nets and electrofishing are not used

Typology

The official Lithuanian typology for lakes is based only on average depth.

- Shallow lakes (LCB-2), < 3 m mean depth, 93 lakes;
- Intermediate depth (LCB-1), 3-9 m mean depth, 149 lakes;
- Deep, stratified (LCB-1), > 9 m mean depth, 43 lakes.

For the fish bases assessment of lakes Lithuania adopted the typology proposed for IC at the first CB Lake Fish meeting in Berlin (end of 2011).

Metrics and scoring

Pearson's correlation matrix was calculated between candidate fish metrics and variables describing nutrient conditions (TP, TN, Chl a), Secchi depth and hydromorphological characteristics. Hydromorphological characteristics of lakes were assessed according to water level and exchange, shore and substrate structure, changes in each of which were scored in order to compute the hydromorphological index (thereafter HMI).

For the development of fish index, we selected only those metrics, whose coefficient of correlation with at least one of the above listed variables was ≥0.4 (when P<0.05) - see Table A . A correlation matrix was calculated to select non-redundant metrics. Metrics were assumed to be redundant if the correlation coefficient was >0.8. Reference values of the selected metrics were determined by estimating the 75th percentiles (the 25th percentiles of the metrics increasing under the impact of anthropogenic pressure) in potentially reference status lakes.

Table A 28: Fish metrics selected for status assessment of different type lakes and metrics correlations with environmental variables (correlations significant when P<0.05 are indicated in bold)(POLY – polymictic lakes, L-CB2; S – stratified lakes, L-CB1; DS – deep stratified lakes, L-CB1).

Type	**Variable**	**1 S_bream_Q%**	**2 Benth_Sp_Q%**	**3 Roach_Q_av**	**4 Perch_N%**	**5 Perch_Steno_Q%**	**6 Nb_Oblig_Sp**	**7 Non-nat_Q%**
	(n)	(52)	(65)		(65)		(65)	(17)
	TP	0.21	0.13		-0.23		**-0.33**	0.35
POLY	TN	0.17	**0.28**		-0.12		**-0.34**	**0.48**
	Chl *a*	**0.45**	**0.43**		**-0.40**		**-0.43**	**0.56**
	Secchi depth	**0.31**	**-0.33**		**0.32**		**0.27**	**-0.47**
	HMI [8]	-0.01	-0.04		0.04		**0.27**	-0.09
	(n)		(70)	(70)		(70)	(70)	(7)
	TP		**0.57**	**-0.43**		**-0.29**	**-0.32**	0.68
S	TN		0.20	-0.20		-0.15	**-0.25**	0.63
	Chl *a*		**0.44**	**-0.68**		-0.40	**-0.41**	0.16
	Secchi depth		**-0.63**	**0.66**		**0.45**	**0.36**	0.07
	HMI		**-0.26**	**0.35**		**0.40**	**0.29**	0.09
	(n)		(27)	(27)		(27)	(27)	(3)
	TP		0.29	-0.13		0.02	**-0.48**	0.39
DS	TN		**0.47**	-0.34		**-0.47**	-0.33	0.99
	Chl *a*		**0.59**	**-0.44**		-0.26	**-0.57**	0.99
	Secchi depth		**-0.45**	**0.61**		**0.37**	**0.46**	
	HMI		**-0.48**	-0.11		-0.01	**0.40**	0.63

Details for Table A :

1 - relative biomass of silver bream;

2 - relative biomass of silver bream, bream, and ruff;

3 - mean weight of roach individuals;

4 - relative abundance of perch;

5 - relative biomass of perch, burbot, smelt, vendace and whitefish;

6 - number of obligatory species in CPUE. POLY lakes - bleak, rudd, pike, tench, perch, roach; S lakes - vendace, bleak, rudd, pike, perch, roach; DS lakes - vendace, smelt, burbot, bleak, rudd, pike, perch, roach;

7 - relative biomass of non-native and translocated species (common carp, Prussian carp, silver carp, pikeperch);

8 - lake hydromorphological index

Redundancy of metrics has been checked. A correlation matrix was calculated to select non-redundant metrics. Metrics were assumed to be redundant if the correlation coefficient was >0.8. Primary status class boundaries were set by analyzing discontinuities in the distribution of index values against the pressure gradient. These boundaries were used for pre-classification of lakes into status class. Afterwards, status class boundaries were additionally calibrated by calculating averages between 25th percentile in the lakes at higher status class and 75th percentile in the lakes at lower status class.

Table A 29: The type-specific class boundaries used in the Lithuanian fish system.

Type POLY

Metric	gear	high	good	moderate	poor	WFD crit
Blicca bjoerkna %W	EN mod	< 4	< 11	< 19	< 26	Spec comp
Perca fluviatilis %N	EN mod	> 25	> 17	> 9	> 4	Spec comp
Benthivorous species %W	EN mod	< 20	< 35	< 47	< 61	Spec comp
Obligatory species number	EN mod	6	5	4	< 4	Spec comp
Non native and translocated species %W (only when Nb of ind. >1)	EN mod	0	0	<1	<6	Spec. comp., Abund.

Type STRAT

Metric	gear	high	good	moderate	poor	WFD crit
Blicca bjoerkna %W	EN mod	< 2.5	< 9	< 17	< 26	Spec comp
P.fluviatilis + stenotermic %W	EN mod	> 30	> 17	> 9	> 4	Spec comp
Avg. weight *Rutilus rutilus*	EN mod	> 50	> 34	> 23	> 14	Age
benthivorous species %W	EN mod	< 16	< 29	< 45	< 61	Spec comp
Obligatory species number	EN mod	6	5	4	< 4	Spec comp
Non-native and translocated species %W (only when Nb of ind. >1)	EN mod	0	0	< 1	< 6	Spec. comp., Abund.

Type DEEP

Metric	Gear	High	Good	Moderate	Poor	Wfd crit
Avg. weight *Rutilus rutilus*	EN mod	> 50	> 34	> 23	> 14	Age
benthivorous species %W	EN mod	< 12	< 27	< 41	< 56	Spec comp
P.fluviatilis + stenotermic %W	EN mod	> 35	> 24	> 14	> 4	Spec comp
Obligatory species number	EN mod	≥ 6	> 4	4	< 4	Spec comp
Non native and translocated species %W (only when Nb of ind. >1)	EN mod	0	0	< 1	< 6	Spec. comp., Abund.

Pressures addressed

Relevant pressures are eutrophication and fisheries impact. %W of Blicca bjoerkna and benthivorous species increase with eutrophication. Reaction of metrics *Perca fluviatilis* %N and *P. fluviatilis + stenothermic %W* is of opposite direction. Metrics Avg. weight *Rutilus rutilus* and Obligatory species number decrease together with eutrophication and fishing pressure. %W of non-native/translocated species (*C.gibelio, C. carpio, S. lucioperca*) increases with eutrophication and stocking for fisheries. Metrics derived based on analysis of national dataset and literature analysis.

Mathematics

Scoring: For each metric, the values are transformed to EQR with specific formulas. EQR values are clipped at 1 and 0. Total EQR for the lake is the mean of the metric EQR values.

Status classes: The class boundaries are:

≥ 0.86 high;

≥ 0.61 good;

≥ 0.37 moderate;

≥ 0.18 poor.

'Performance' of the fish assessment system

Regression analysis demonstrated that in all types of lakes the index value varied depending on the variables of nutrient and hydromorphological conditions. In all types of lakes, LZIE values most significantly correlate with the concentration of Chl a and Secchi depth, which in different types of lakes accounted for 43-48% and 27-53% of the total variance respectively (Table A). Changes in TP concentration explained 23-37% of the total variance. Variables of hydromorphological conditions and the concentration of TN explained the least part of the total variance. Regression analysis of all lake types showed that the hydromorphological index alone explains only 19% of the total LZIE variance.

Table A 30: Results of regression analysis of LZIE and environmental variables.

	Polymictic				**Stratified**				**Deep stratified**			
	R	**R^2 adj.**	**F(1, 65)**	**P**	**R**	**R^2 adj.**	**F(1, 68)**	**P**	**R**	**R^2 adj.**	**F(1, 25)**	**P**
TP	-0.48	0.23	18.7	<0.001	-0.58	0.33	33.9	<0.001	-0.61	0.37	14.5	<0.001
TN	-0.37	0.12	10.0	<0.001	-0.40	0.14	12.6	<0.001	-0.63	0.40	16.2	<0.001
Chl a	-0.70	0.48	61.9	<0.001	-0.69	0.46	59.2	<0.001	-0.66	0.43	19.2	<0.001
Secchi depth	0.52	0.27	23.3	<0.001	0.70	0.50	67.0	<0.001	0.74	0.53	30.5	<0.001
HMI	0.26	0.05	4.6	<0.05	0.52	0.26	25.2	<0.001	0.39	0.15	4.6	<0.05

Fish metrics selected for index have approximately equal impact on the index final score (

Table A), except relative biomass of non-native and translocated species. The impact of the latter metric on the final score of the index is lower due to relatively low number of lakes where non-native and translocated species are present.

Table A 31: Correlation of fish metrics with fish index (correlations significant when P < 0.05 are indicated in italics).

Lake type	Fish index	Fish metrics						
		S_bream _Q%	Benth_ Sp_Q%	Roach_ Q_av	Perch_ N%	Perch_ Steno_Q %	Nb_Oblig _Sp	Non-nat_Q%
L-CB1 lakes (S and DS)	LZIE		-0.59	0.65		0.69	0.58	-0.45
L-CB2 lakes (Poly)		-0.60	-0.57		0.63		0.62	-0.42

Netherlands

In 2012 the Dutch assessment system for lakes has been adapted (improved). For the lakes the only changes are the deletion of the metric 'number of species' and the inclusion of the metric '%W pikeperch > limit' for all lakes. The later metric is only neutral of negative, that is if more than 50% of the pikeperch stock is composed of specimens > 40 cm it is neutral, if it is less than 50% it is increasingly negative. In the text I will make clear what the changes are. See page 5.

General

Name/abbreviation: VISMAATLAT

System status: finalized, intercalibratable, official

System was developed in 2007 with improvement in 2012.

No data included in the common database at the IRSTEA because fishing was not done according to EN 14757.

Literature (peer review):

Literature (reports):

JAARSMA, N. (2007): Description of references and metrics for fish in lakes in the Netherlands (unpublished). Witteveen & Bos consulting engineers. (this document is partially outdated, due to the system improvement in 2012)

The improved VISMAATLAT has been described in Dutch and is part of 'Referenties en maatlatten voor natuurlijke watertypen voor de KRW 2015-2021' (391 pages), which is available as pdf-file:

http://krw.stowa.nl/Publicaties/Referenties_en_maatlatten_voor_natuurlijke_watertypen_voor_de_KRW_2015_2021.aspx?eId=5510&pId=1843

Concept

General concept: The fish stock of the lake is modelled using all fish data available. The metrics used are correlated with the different habitats. All habitats are included in the assessment system. The habitats can be impacted by eutrophication, water level fluctuation and shoreline degradation. The Dutch concept is to assess the effects of multiple pressures by evaluating a whole fish community.

Reference conditions: In reference conditions for shallow lakes, zones with clear open water, zones with submerged vegetation and marsh zones are present. Each of these zones has a specific fish community, the fish community of a lake as a whole reflects the (weighted) presence of these habitats. The reference conditions are based on a combination of least disturbed conditions and expert judgment. For eurytopic species (metrics based on relative abundance of bream, roach and perch), reference conditions can be found in clear, vegetated lakes in the Netherlands. For phytophilic/low oxygen tolerant species (other metrics), reference conditions do not exist in the Netherlands anymore but can be found in lakes where flooding still occurs (Danube Delta in Romania). Data of these lakes is used to define the reference fish community.

Class boundary setting: The H/G class boundary is based on expert judgement, the G/M and M/P class boundaries are based on observed shifts in fish communities. The theoretical background is:

G/M: change from dominance of phytophilic to dominance of eurytopic as a result of water level regulation causing disappearance of floodplain areas and marshes and thus loss of habitat for spawning and juveniles of phytophilic fish;

M/P: change from dominance of perch/roach to dominance of bream as a result of eutrophication and the consequential disappearance of submerged vegetation, shift of the lake status from macrophyte to phytoplankton dominated system

Class boundary setting was based on fish data collected in lakes in the Netherlands, Poland and the Danube Delta (Romania). For these lakes eutrophication status and water level fluctuation was used to determine status with regards to reference conditions.

Sampling gear

The calculation of metrics is based on an estimation of standing stock for each species. The sampling methods are:

- trawling in open water of larger lakes;
- electrofishing in the littoral zone of smaller lakes;
- seine netting in smaller lakes.

Each of the habitats present is sampled with prescribed gear and effort. Detailed guidelines for sampling effort, habitats, period and catch efficiency for the Dutch fish sampling can be found in the Netherlands Handbook on fish monitoring and assessment (STOWA 2003, in Dutch).

Attention: The Dutch metrics are not gear specific! Instead, a total standing stock is calculated [kg/ha] based on all the habitats sampled (for each habitat specific gear is used). First, the standing stock per habitat is calculated using the gear specific efficiency for species and length classes. Then the relative area of each of the habitats is calculated. Finally a total standing stock is calculated with a weighted average of the specific habitats.

National typology for lakes > 50 ha

In the Netherlands, 29 lake types are defined, 19 of them are natural. The lake types are based on biologically relevant criteria, meaning distinguishing criteria for one or more biological quality elements. These criteria are not necessarily (always) relevant for fish. For LakeFish assessment only the freshwater lakes are considered here. Soft water lakes are not assessed with Fish. The buffering capacity of the remaining lake types is 1-4 meq/l. The remaining Lake-Types > 50 ha are shown in the next table:

Code	Type	Description	Nr. of lakes
M 14	shallow, buffered	< 3 m mean depth, 0.5 - 100 km², mineral	
M 20	deep, buffered	> 3 m mean depth, 0.5 - 100 km², mineral	
M 21	large, deep, buffered	> 3 m mean depth, > 100 km², mineral	
M 23	shallow, calcareous	< 3 m mean depth, 0.5 - 100 km², calcareous	
M 27	shallow, peat lake	< 3 m mean depth, 0.5 - 100 km², organic	

Metrics

The same set of metrics is used to assess the ecological status of all lake types. Class boundary values for metrics differ between types, except for types M14 and M27 which have identical class boundaries. All metrics can be assigned to the WFD normative criterion species composition and abundance at the same time: % W *Abramis brama* / % W (roach+perch)/eurytopic spec. / % W phytophilic / % W low oxygen tolerant

and 75th percentile in the lakes at lower status class.

Table A 32: The type-specific class boundaries used in the NL fish system.

M14, M27 - Type-specific class boundaries for shallow lakes

Indicator	Weight	Bad	Poor	Moderate	GES	HES (max)
% W *Abramis brama*	0.25	50-100	25-50	8-25	2-8	0,5-2 (0)
% W (roach+perch)/euryt.	0.25	0-10	10-20	20-30	30-35	35-40 (100)
% W phytophilic	0.25	0-8	8-20	20-40	40-65	65-80 (100)
% W low oxygen tolerant	0.25	0-1	1-3	3-10	10-20	20-30 (100)
EQR		***0-0.2***	***0.2-0.4***	***0.4-0.6***	***0.6-0.8***	***0.8-1.0***

M20, M23 - Type-specific class boundaries for deep lakes (M20) and shallow calcareous (M23) lakes.

Indicator	Weight	Bad	Poor	Moderate	GES	HES (max)
% W *Abramis brama*	0.25	60-100	45-60	25-45	15-25	5-15 (0)
% W (roach+perch)/euryt.	0.25	0-15	15-25	25-35	35-45	45-55 (100)
% W phytophilic	0.25	0-2	2-5	5-10	10-15	15-25 (100)
% W low oxygen tolerant	0.25	0-0,5	0,5-1	1-2	2-3	3-5 (100)
EQR		***0-0.2***	***0.2-0.4***	***0.4-0.6***	***0.6-0.8***	***0.8-1.0***

M21 - Type-specific class boundaries for large deep lakes

Indicator	Weight	Bad	Poor	Moderate	GES	HES (max)
% W *Abramis brama*	0.4	60-100	45-60	25-45	15-25	5-15 (0)
% W (roach+perch)/euryt.	0.4	0-15	15-25	25-35	35-45	45-55 (100)
% W phytophilic	0.1	0-1	1-2	2-3	3-5	5-10 (100)
% W low oxygen tolerant	0.1	0-0,1	0,1-0,5	0,5-1	1-1,5	1,5-2 (100)
EQR		***0-0.2***	***0.2-0.4***	***0.4-0.6***	***0.6-0.8***	***0.8-1.0***

Large, deep lakes (and selected lakes with high fishing pressure) have a fifth metric; the %weight share of pikeperch >40cm in the total population:

- share pikeperch > 40 cm < 5 % ➞ -0.2 EKR;
- share pikeperch > 40 cm 5-25 % ➞ -0.1 EKR;
- share pikeperch > 40 cm 25-50 % ➞ -0.05 EKR;
- share pikeperch > 40 cm >50 % ➞ no correction.

Pressures

The concept of the Dutch system is to assess the whole fish community which reacts to all pressures. Therefore the overall pressure intensity is addressed. The single metrics respond to pressure as follows:

% W *Abramis brama*: eutrophication

% W (roach+perch)/eurytopic spec: eutrophication

% W phytophilic: shoreline degradation/water level regulation

% W low oxygen tolerant: shoreline degradation/water level regulation

% pikeperch > legal length limit: fishery intensity

Mathematics

Per (group of) lake type(s) boundary values are defined. Within one quality class the score changes linearly. Values exceeding the upper boundary of the high state are classified as 1. Weight factors show the weight that each metric has on the final judgement. The final (EQR) score is calculated by multiplying each of the metric scores with its weight and then summarise the outcomes. The class boundaries for the total EQR are:

HIGH:	> 0.8
GOOD:	> 0.6
MODERATE:	> 0.4
POOR:	> 0.2

Metrics explanation, ecological background, and indicative value

Most of the Dutch lakes are very shallow, less than 3 metres deep. The Dutch classification system is based mainly on the fish communities in these lakes and their response to human pressures, mainly eutrophication and habitat degradation. Below the relation between metric score and pressure-related parameters is shown for very shallow lakes larger than 50 hectares.

Eutrophication

The metrics % of weight bream and % of weight roach+perch to all eurytopic species (bream, carp, eel etc.) are sensitive to eutrophication. These metrics are especially relevant for the open water area of a lake. When a lake is turbid with high chlorophyll-a concentrations, usually bream is dominant and roach and perch are subdominant. When the lake is clear and large areas are overgrown with submerged vegetation, bream density is low and roach and perch are dominant. This is also the case for lakes (or areas of a lake) that are generally too deep for plant growth. The figures below show the relation of metric scores with total-P, chlorophyll-a and water clarity (secchi-depth). Total-P is not always a good parameter for assessing the eutrophication status. As can be seen, a number of lakes have high total-P but also relatively high EQR values for fish. Some of these have short residence times or lots of filter feeders, which means that the high nutrient concentrations are not translated into algae and turbid conditions. Chlorophyll-a (and secchi-depth) might be better indicators for eutrophication status. There is also a very strong correlation between the abundance of bream and the percentage of submerged plant cover (not shown). The density of plants is strongly related to the degree of eutrophication of a lake.

Habitat degradation

The metrics "% of phytophilic species" (pike, rudd, tench, crucian carp etc.) and "% of low oxygen tolerant species" (tench, crucian carp and weatherfish) are sensitive for the quality of the littoral zone and the presence and relative area of marsh zones and/or floodplains. The low oxygen tolerant species are a subgroup of the phytophilic species. These species use vegetated habitats for spawning and as a habitat for juvenile fish (phytophilic) and as a habitat for adult fish (low oxygen tolerant). Major human pressure for these species in the Netherlands is water level regulation. As a result of this, water levels are more or less fixed and the formerly large inundation areas around lakes (floodplains/marshes) have disappeared. On top of that, in many cases lake shores have been protected against erosion with all kinds of hard materials. This can be shown with the parameter "shore line modification". The overall decrease in habitats as a result of water level regulation and eutrophication is assessed by comparing the current number and quality of habitats by the number of habitats in the reference situation. Below, both metrics are plotted against these parameters.

Sensitivity analysis: As explained before, the Dutch classification system is strongly based on the presence of fish habitats and their quality. Two metrics assess the quality of the open water (%W of bream and %W or perch+roach) and two metrics assess the quality of shallow vegetated areas and marshes (%W phytophilic and %W low oxygen tolerant species). The relation between the single metrics EQR's and the total EQR is shown below:

- The **%W of bream** is highly correlated to the total EQR. If bream abundance is very high, EQR for %W of bream as well as total EQR-values are low. If the %W of bream is low however, and EQR %W bream =1, the total EQR can vary between about 0.4 and 0.8;
- The **%W of perch + roach** is also highly correlated to the total EQR. In this case however, the variation in total EQR is about 0.4 along the whole range of EQR-values for %W perch+ roach;
- The **%W of phytophilic fish** is often so low, that for this metric EQR = 0. This is because in many cases phytophilic fish species have declined very strongly due to habitat loss (emergent+submerged vegetation). The contribution of this metric to total EQR is therefore often negative;
- The **%W of low oxygen tolerant** fish hardly ever scores more than EQR>0. For these fish species habitat loss (marshes) in lakes is almost complete, due to water level regulation. In the current situation the contribution of this metric to total EQR is therefore almost always negative.

Redundancy

Correlation analysis of the single metrics shows that the "%W of bream" and "%W of roach+perch" are quite strongly correlated with total EQR, but not with each other. Correlation between "%W of phytophilic fish" and "%W of low oxygen tolerant fish" with total EQR is low, this is because in many cases these indicators score an EQR of 0.

Table A 33: Correlation between the fish assessment metrics

Metric	EQR total	EQR %W bream	EQR %W Roach+perch	EQR %W phytophilic	EQR %W low O2-tolerant
EQR total	1				
EQR %W bream	0.82	1			
EQR %W Roach+perch	0.50	0.15	1		
%W phytophilic	0.04	-0.19	-0.16	1	
%W low O2-tolerant	0.06	-0.23	-0.21	0.80	1

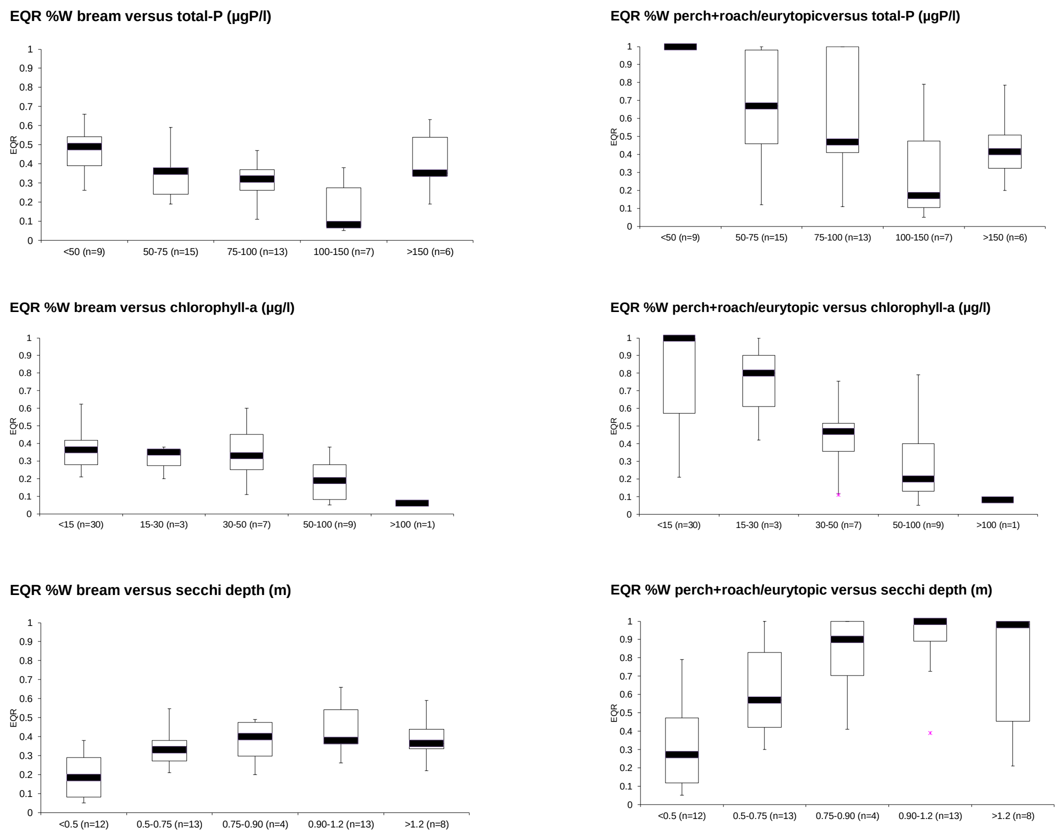


Figure A 11: EQR values for "%W of bream" and "%W of perch + roach / all eurytopic species" as a function of eutrophication (related) parameters.

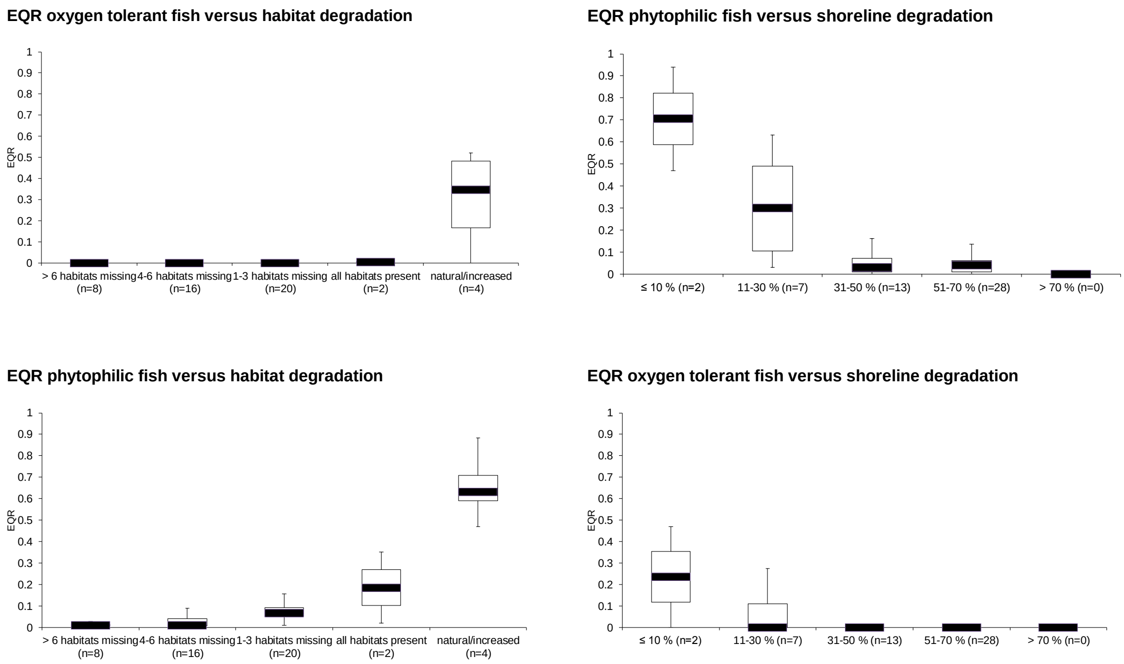


Figure A 12: EQR values for “%W of phytophilic fish” and “%W of low oxygen tolerant fish” as a function of habitat-related parameters “habitat degradation” and “shoreline degradation”.

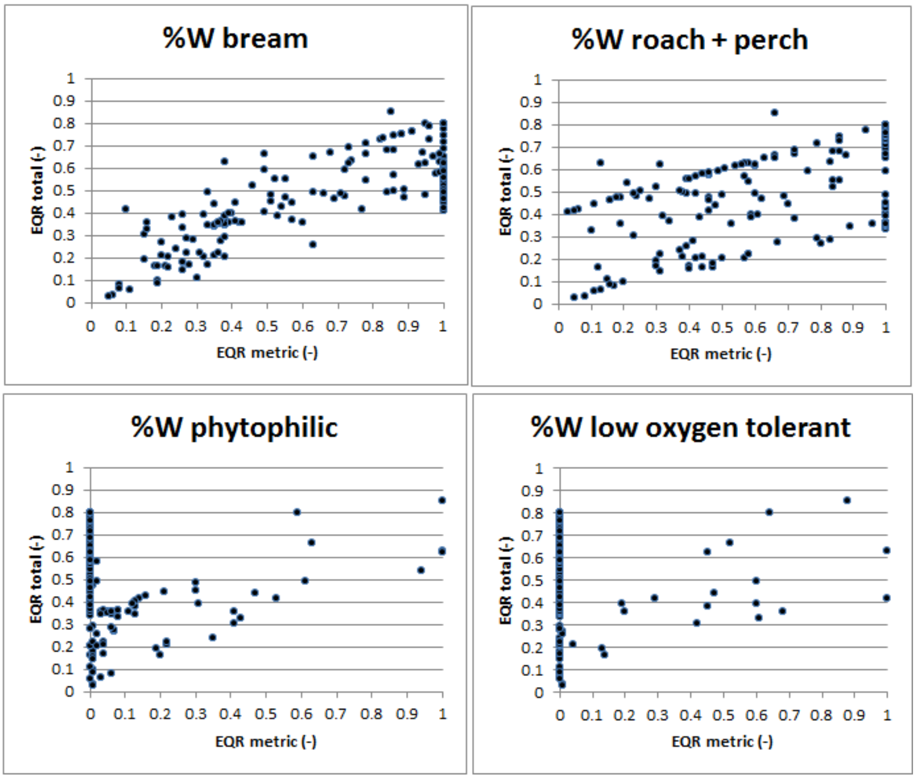


Figure A 13: Total EQR values as a function of EQR values for single metrics (“%W of bream”, “%W of perch + roach over all eurytopic species”, “%W of phytophilic fish and “%W of low oxygen tolerant fish”.

Poland

General

Name/abbreviation: LFI+ and LFI-EN

System status: Poland has two Lake Fish Index systems; the LFI-EN based on EN 14757 multimesh gill net sampling and the LFI+ based on commercial catches and fishery statistics. Both systems rely on the known relationship between lake ichthyofauna structure and the trophic state of the environment (see References). According to the different fish data availability, both LFI systems can be used independently. The LFI systems of the environmental condition evaluation were completed in 2014 and currently are presented for intercalibration exercise.

System finalized in: Both methods finalized in 2014.

No fish data is included in the common database at the CEMAGREF.

Literature peer review: none yet

Literature reports: internal

Concept

General concept: The system is based on the known relationships between the structure of fish fauna and trophic state (the state of the environment, the effects of pressure) (e.g. Colby, Hartmann, Carlson, Persson, Bnińska, Leopold).

The LFI+ is based on a comparison of the fish fauna structure of the top-rated lakes in historic times (from about 200 lakes, since the fifties of the last century) to the present structure of fish fauna in a particular lake. The data are the results of long-term, systematic, commercial fishing.

The LFI-EN is based on a comparison of the ichthyofauna structure of the specific lake to the fish fauna structure of reference values estimated for the top-rated lakes, after rejecting extreme values, below 10 and above 90 percentiles. The data are the results of single fishing event with multi-mesh Nordic gill net, according to the EN standard.

Reference conditions:

LFI+: Calculated as the average percentage of species correlated with indicators of pressure (mainly Carlson TSI) in the best lakes in historic times.

LFI–EN: Calculated as the average percentage of species correlated with indicators of pressure (mainly Carlson TSI) in the best lakes from lakes caught with multi-mesh Nordic gillnets.

Class boundary setting: The class boundaries are set on the basis of the WFD normative definition and compared to the results of estimation other biological and chemical indicators.

Sampling gear

LFI+ is based on long-term results from commercial fisheries (seine, gillnet, fyke) and local history review

LFI-EN is based on multi-mesh gillnet sampling (EN 14757) and local history review.

National typology for lakes > 50 ha

The Lake typology, common for both Lake Fish Indices, is based only on lake stratification and circulation pattern dividing lakes on polymictic and stratified ones.

System	Type	Description	Number of lakes
LFI+	Stratified	Stratified	137
	Nonstratified	Polymictic	62
LFI–EN	Stratified		19
	Polymictic		13

Metrics

In general, together with the deterioration of the lake state, the proportion of small bodied cyprinids with stunted growth rises; the share of perch and littoral species (tench, pike, and rudd) decreases as well as the share of large bream and roach in the total catches of these species. The share of fish species weight in the catches showing the strongest relationship with the pressure eutrophication indices (P, chlorophyll, SD, Carlson TSI) has been selected as the final metrics. Correlation analyses, linear regression and multiple regression (stepwise variable selection) were used in the metrics selection.

LFI+

All metrics are calculated on the basis of the ten years average of total commercial catch.

Multimetric index calculated from multiple regression equations in which the independent variables xi are percentages and the dependent variable Y is calculated LFI index with value between 0 and 1.

Independent variables were selected separately for different types of lakes:

- stratified: pike-perch, perch, tench, crucian carp, large bream, small bream, the share of large bream in total bream catches, large roach and white bream
- polymictic: pike-perch, pike, tench, crucian carp, perch, the share of large roach in total roach catches

LFI–EN

Stratified: perch, ruffe, tench, bream, white bream, roach, rudd, bleak

Polymictic: pike-perch, perch, ruffe, bream, white bream, roach, rudd, and bleak

The class boundaries are set on the basis of the WFD Normative definitions and comparisons with expert judgment and the results of the evaluation of other biological and chemical elements.

Pressures addressed

Eutrophication and degradation - Combined Carlson’s TSI (phosphorus, chlorophyll, visibility) and literature data.

In general, together with the deterioration of the lake (in the type) the share of expansive, small bodied cyprinids with stunted growth rise, the share of perch and littoral species (tench, pike, rudd) decrease, as well as the share of large bream and roach in the total catches of these species.

Mathematics

The class boundaries are set based on expert opinion, comparing the ichthyofauna state of lakes assessed with WFD normative definitions and results of the assessment of other biological and chemical elements.

Each metric is scored as an EQR-value in range 0-1 $(x-x_{min})/(x_{max}-x_{min})$, total score is the mean.

In this manner rated selected metrics modeling phase, rejecting the earlier extreme 10 percentile observations. Then, in order to facilitate the calculation of assessments based on raw data from the catches, the results were mathematicised, yielding a multiple regression equation:

EQR = b0 + b1 metric1 + b2 metric2... + bn metric n

b0-bn - the regression coefficients,

metric1 - metric n - the percentages in the catch of fish considered as metric,

b0-bn may have a sign - or +, depending on the direction of changes in the shares of fish with increasing pressure.

The class boundaries are:

Ecological status	EQR LFI-EN / LFI +
Very good	> 0.70
Good	> 0.45
Moderate (measured)	> 0.25
Poor (low)	> 0.10
Bad (very low)	

'Performance' of the fish assessment system

The performance was checked in many ways:

EQR comparison with expert assessment of fish fauna of lakes assessed the WFD normative definitions, comparing the results of the assessment of other biological and chemical elements and the composite Carlson's TSI. We also compared the results obtained with the German and common metrics. In general, the rate obtained from the formulas corresponds with the expected, but there are the number of cases in which the EQR assessment is incorrect because of faulty data on fish fauna, the fishing results do not reflect the actual composition of the fish fauna of lake:

The LFI + - due to unsystematic or selective fishing activities on the lake;

The LFI-EN - primarily due to defects arising from a set of Nordic single time fishing.

For this reason, we strongly recommend carrying out evaluations only by experts, able to assess the input and output data.

Details for the EN System

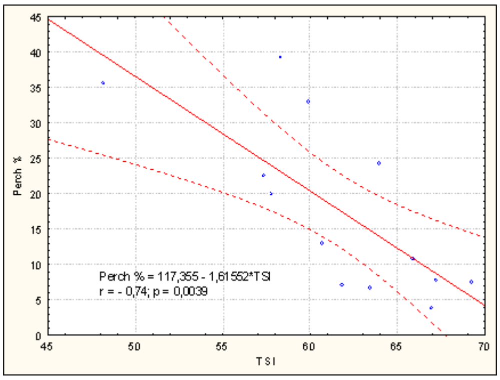
The LFI-EN Index is based on a comparison of the ichthyofauna structure of the specific lake to the reference values estimated for the top-rated lakes, after rejecting extreme values, below 10 and above 90 percentiles. The data are the results of single fishing with multimesh Nordic gill net, according to the EN standard. LFI-EN system is laborious and prone to errors due to the result of single catches influenced by different factors, not only the trophic state of lakes. This system has to be used in the event when better data concerning ichthyofauna are lacking.

For polymictic lakes, the best metrics selected by modelling are: pike-perch, perch, ruffe, bream, white bream, roach, rudd, and bleak. The share of perch and rudd has been decreasing together with the environment deterioration, while the share of the other species has been rising. Correlations table between metrics, pressure indices and LFI-EN is given below.

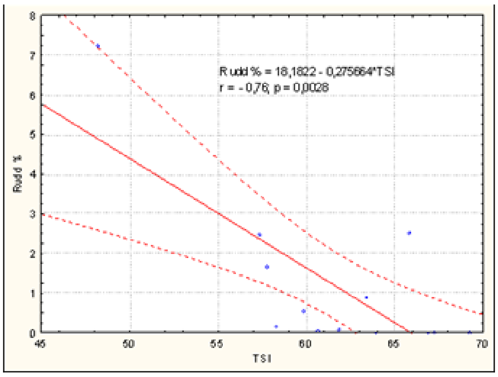
Table A 34: Correlation coefficients between fish assessment metrics, pressure indices and LFI-CEN.

Metric	Secchi depth	TP	Chl-a	TSI	LFI-CEN
Bream %	-0.40	-0.25	0.02	0.12	-0.15
White bream %	-0.11	0.22	0.25	0.27	-0.52
Roach %	-0.03	0.52	0.16	0.25	-0.32
Rudd %	0.84	-0.33	-0.63	-0.75	0.73
Bleak %	-0.20	0.49	0.37	0.40	-0.43
Perch %	0.50	-0.68	-0.67	-0.74	0.83
Ruffe %	-0.40	0.36	0.39	0.49	-0.72
Pike-perch %	-0.40	0.36	0.65	0.51	-0.36

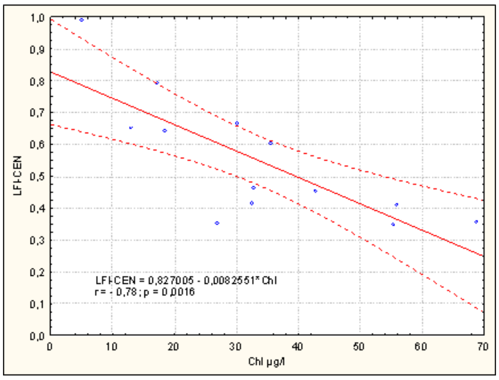
Most of metrics show significant relationship with pressure indices. For some metrics the relationship, due to small sample of lakes, can be weaker but the tendency is similar. Some significant relationship examples are presented below.



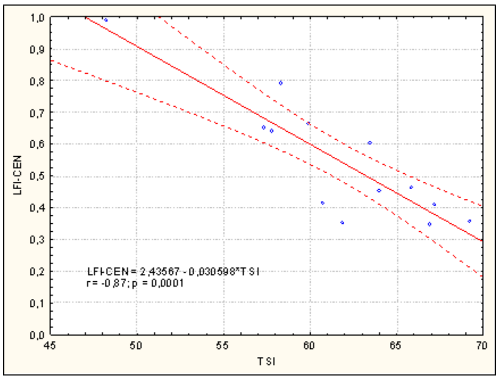
%W Perch vs Carlson's TSI



%W Rudd vs Carlson's TSI



LFI-EN vs Chlorophyll



LFI-EN vs Carlson's TSI

Figure A 14: Relationships between pressure indices and fish metrics (LFI-EN assessment system)

Table A 35: Average metric values with standard deviations for polymictic lakes depending on the lake ecological status.

Metrics	Reference		Very good		Good		Moderate	
	Average	SD	Average	SD	Average	SD	Average	SD
Bream %	12.3	2.0	12.3	2.0	20.0	10.9	19.6	10.6
White bream %	2.4	1.5	2.4	1.5	7.4	6.4	11.5	7.6
Roach %	20.3	4.4	20.3	4.4	27.4	12.7	29.7	11.5
Rudd %	3.7	5.0	3.7	5.0	1.3	1.0	0.0	0.0
Bleak %	2.6	3.7	2.6	3.7	7.2	6.3	11.9	7.7
Perch %	37.5	2.6	37.5	2.6	19.6	9.5	8.0	3.3
Ruffe %	0.2	0.1	0.2	0.1	3.3	2.5	4.3	1.7
Pike-perch %	5.7	8.0	5.7	8.0	3.3	4.3	9.7	11.5

Data indicate that together with deterioration of the ecological status of polymictic lakes the share of rudd and perch decline, whilst an increase in the share of bream, white bream, roach, ruffe and pike-perch is observed.

For stratified lakes the best metrics selected by modelling are: perch, ruffe, tench, bream, white bream, roach, rudd, bleak. The share of perch and rudd have been decreasing together with the environment deterioration, while the share of the other species has been rising.

Table A 36. Correlation coefficients between metrics, pressure indices and LFI-EN.

Metric	SD	P	Chl	TSI	LFI-EN
Tench %	0.24	-0.04	-0.10	-0.08	0.53
Bream %	-0.53	0.49	0.63	0.51	-0.45
White bream %	-0.21	0.05	0.07	0.20	-0.29
Roach %	-0.31	0.50	0.37	0.44	-0.48
Rudd %	0.29	-0.24	-0.33	-0.23	0.69
Bleak %	-0.49	0.53	0.44	0.50	-0.76
Perch %	0.59	-0.57	-0.58	-0.59	0.61
Ruffe %	-0.43	0.38	0.32	0.45	-0.64

Table A 37: Average metric values with standard deviations for stratified lakes depending on the lake ecological status.

Metric	Reference		Very good		Good		Moderate		Poor	
	Avg	**SD**	**Avg**	**SD**	**Avg**	**SD**	**Avg**	**SD**	**Avg**	**SD**
Tench %	4.4	2.8	1.9	2.8	0.6	1.1	0.3	0.6	0.3	
Bream %	2.9	3.8	4.3	4.1	6.8	3.9	11.0	7.7	6.7	
White bream %	5.5	3.3	4.6	2.6	5.1	3.3	8.2	3.6	6.2	
Roach %	19.6	5.3	21.3	4.8	32.0	18.3	28.6	7.9	41.1	
Rudd %	17.0	5.4	9.6	8.6	4.3	4.1	1.4	2.6	0.2	
Bleak %	2.1	2.2	1.6	1.5	3.9	4.2	8.6	3.6	19.4	
Perch %	36.4	5.6	44.8	10.5	36.4	9.5	30.3	13.6	16.2	
Ruffe %	1.4	1.6	1.2	1.0	3.1	1.3	4.8	2.3	5.4	

Data indicate that together with deterioration of the ecological status of stratified lakes, the share of tench, rudd and perch declines, whilst an increase in the share of bream, white bream, roach, bleak and ruffe is observed.

Details for the LFI+ System

The LFI + is based on comparison of the structure of fish fauna in the best lakes in historic times (from about 200 lakes, since the fifties of the last century) to the present structure of fish fauna in a selected lake. The data are the results of long-term, systematic, commercial fishing. In the middle of XX century, industrialization and agriculture intensification in the northern part of Poland, where most of lakes are situated, were minimal and incomparable with the West European countries. Lake fishery was carried on in the traditional way. Rapid changes occurred in the middle of the seventies of the 20th century. That is why it was assumed that the state and structure of fish fauna of the best lakes in that period could be considered as the reference for the present times.

The LFI+ index is much less laborious than LFI-EN index. It can be applied to lakes for which reliable, long term fish statistics exist.

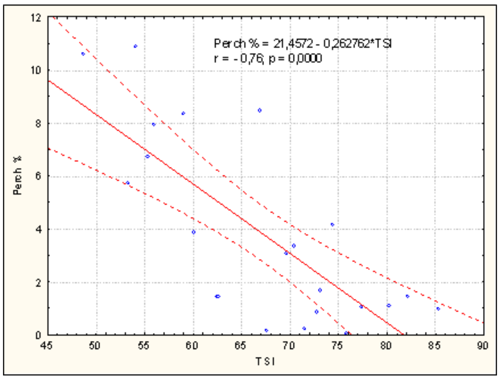
It has to be admitted that on many lakes in Poland fish catches are carried on systematically with a variety of different fishing gears. The results of that catches do not depend so much on random factors. However, the catches of school fish, as bream and roach, can vary substantially in some years. Because of that, ten-years moving average of catches were used in analyses. This allows the systematic evaluation of the ecological status of the lakes. Six years period, as proposed by the Reviewer, in some instances is too short.

For polymictic lakes the best metrics selected by modelling are: pike-perch, pike, tench, crucian carp, perch, the share of large roach in total roach catches. The share of perch, pike and tench has been decreasing together with the environment deterioration, while the share of the other species has been rising.

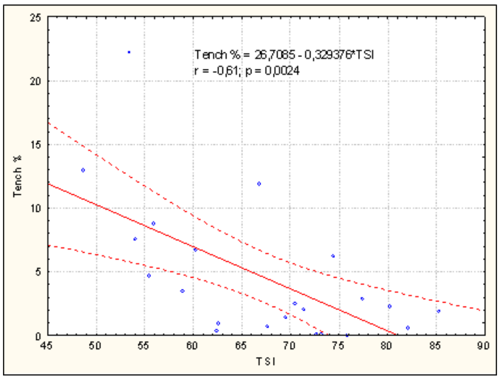
Table A 19: Correlations between metrics, pressure indices and LFI+.

Metric	SD	P	Chl	TSI	LFI+
Pike-perch %	-0,52	-0,03	0,43	0,42	-0,74
Pike %	0,18	-0,44	-0,46	-0,35	0,51
Tench %	0,50	-0,34	-0,61	-0,62	0,67
Crucian carp %	-0,43	0,14	0,22	0,41	-0,58
Perch %	0,71	-0,45	-0,71	-0,76	0,77
Share of large roach in total roach %	0,18	-0,30	-0,34	-0,29	0,44

Most of metrics show significant relationship with pressure indices. Some significant relationships examples are presented below.

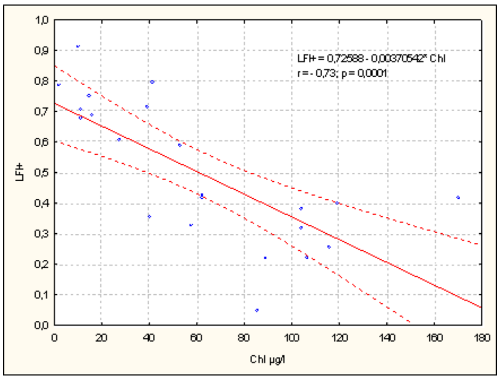


%W Perch vs Carlson's TSI

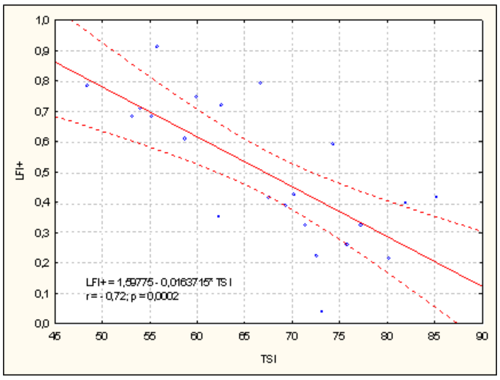


%W Tench vs Carlson's TSI

The estimated LFI+ value significantly correlates with pressure indices (figures below).



LFI+ vs Chlorophyll



LFI+ vs Carlson's TSI

Figure A 15: Relationships between pressure indices and fish metrics (LFI+ assessment system)

Table A 38: Average metric values with standard deviations for polymictic lakes depending on lake ecological status.

Metric	Reference		Very good		Good		Moderate		Poor		Bad
	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg
Pike-perch %	0.0	0.1	2.8	5.8	3.7	6.0	15.2	12.6	25.7	11.7	52.8
Pike %	26.4	3.9	21.3	10.9	14.4	6.6	5.3	5.9	10.2	2.8	18.1
Tench %	35.4	13.1	8.2	4.3	9.2	8.8	1.4	1.0	1.2	1.6	0.1
Crucian carp %	1.6	1.5	0.4	0.7	3.5	3.8	3.3	4.5	10.6	12.1	16.4
Perch %	5.4	1.6	7.2	3.8	6.3	1.7	1.3	1.2	1.0	0.2	1.7
Share of large roach in total roach %	28.6	15.5	54.9	34.4	30.0	30.0	28.5	36.8	2.1	2.9	0.0

Data indicate that together with deterioration of the ecological status of polymictic lakes, the share of pike, tench, perch and large roach decline, whilst an increase in the share of pike-perch and crucian carp is observed.

For stratified lakes the best metrics selected by modelling are: pike-perch, perch, tench, crucian carp, large bream, small bream, the share of large bream in total bream catches, large roach and white bream. The share of perch, tench, large bream and his share in total bream catches, has been decreasing together with the environment deterioration, while the share of the other species has been rising.

Table A 39: Correlations table between metrics, pressure indices and LFI+.

Metric	Secchi depth	TP	Chl-a	Trophic state index	LFI+
Pike-perch %	-0.54	0.32	0.75	0.63	-0.65
Tench %	-0.06	-0.18	0.14	0.03	0.11
Crucian carp %	-0.34	0.15	0.25	0.34	-0.32
Perch %	0.55	-0.39	-0.45	-0.56	0.63
Large bream %	0.01	0.12	-0.21	-0.02	0.30
Small bream %	-0.51	0.27	0.38	0.47	-0.64
Share of large bream in total bream %	0.57	-0.24	-0.41	-0.49	0.69
Big roach %	0.44	-0.23	-0.44	-0.46	0.60
White bream %	-0.38	0.23	0.27	0.37	-0.35

Data indicate that together with deterioration of the ecological status of stratified lakes the share of tench, perch, large bream, the share of large bream and large roach in catches decline, whilst an increase in the share of pike-perch, crucian carp, small bream and white bream is observed.

Class boundary setting: The class boundaries are set basing on expert opinion, comparing the shifts in lake fish communities assessed with WFD normative definitions. The class boundaries are:

Ecological status	EQR LFI-EN / LFI +
Very good	> 0.70
Good	> 0.45
Moderate	> 0.25
Poor	> 0.10
Bad	

Assumed class boundaries are temporary ones. In the ongoing intercalibration process additional pressure indices, such as the extent of shoreline modification, catchment impact, fisheries, stocking etc. are tested and the relations of LFI with newly estimated TAPI pressure indices are examined.

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United Kingdom

The long-term plan in GB is to build a lake fish assessment tool using environmental DNA, and we are currently trying to get this set up. We have taken this approach for the following reasons:

- Lake fish sampling is expensive/resource intensive,
- In terms of cost benefit analysis the additional information that you get back from sampling lake fish over other biological elements is limited, thus we need to find a cost effective means of meeting this WFD obligation.
- We do not have a tradition of lake fish sampling, thus little useful historic data is available. Therefore method development would also have a significant data gathering requirement.
- In England & Wales the Environment Agency faces significant pressures from anglers not to gill net.
- Hydro-acoustics has to be used in tandem with gill netting, thus all of the above also applies to Hydro-acoustics- albeit to a lesser degree

So the plan is as follows:

- Undertake some further assessment of the e-DNA method- e.g. how well does it work in large unproductive lochs.
- Assuming we get a positive outcome from this, take forward a wider sampling campaign, and gather data, our hope is that we would be able to work with the following metrics- Species composition, and relative species abundance, there are other sub-metrics that can be derived from these. I appreciate there are risks with this approach, but the reality is that other sampling methods provide only limited amounts of other data- e.g. age class, and gill net selectivity raises questions about how easy it is to use this data.
- Build an assessment procedure.

Annex AII: comments on the compliance criteria 'age' and 'sensitive species'

This following chapter represents David's opinion concerning the metrics age structure and sensitive species. Both metric categories are part of the normative definitions of the WFD for LakeFish (Annex V, 1.2.2.). Their application has some inherent problems.

The two chapters do not represent a GIG-wide opinion or agreement.

Last update: February 2014

Age structure

The normative definition of the WFD for HIGH status is:

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 a particular species.

The description of this trait is in the WFD is obscure. Strictly speaking, it is impossible to assess the age structure of a fish community. It would be possible to identify the age structure of selected species but some fundamental problems exist with this indicator:

- 'True' age structure can only be assessed for a few very frequent species (e.g. Bream, Roach, and Perch). For other fish species, the number of individuals caught usually is too low to identify structural deficits, even if methods are combined. Frequent species are mostly insensitive. A reaction to pressures by changes in age structure or failure of reproduction is not expected except for very high levels of pressures.
- 'Direct' age data, i.e. aging with scales or otolithes is highly time consuming, expensive and uncertain. The gain of knowledge usually is low.
- The main point in this definition is not age, but the indication of a failure in reproduction or development. This is often misunderstood as aging must not necessarily be the best method to indicate such failures. Other metrics might be used to cover this part of the normative definitions.
- Fish are mobile and can avoid local pressures. They will successfully reproduce as long as any suitable habitat remains within the whole lake. The natural over-production of offspring will hide pressure effects.
- The natural variability of reproductive success is very high. Single depressions of natural reproduction should not lead to a downgrade of ecological status class, as they might well be of natural origin. A reproductive failure caused by human impacts can be distinguished from natural variation by the fact, that it should exceed the natural resilience, i.e. the potential to counterbalance natural oscillations. Such an enduring anthropogenic influence will be shown in species abundance, not age structure.
- The catch data is unreliable and strongly depends on small difference of date and place. Chance or unknown factors might also play a major role (catch a shoal of juveniles or not). Gear specific age/length sampling makes the results incomparable (e.g. EN net catches underestimate YOY and 1+ as well as old/big individuals).
- It is doubtful that size proxies of age are applicable and represent the intention of the WFD.

Summarized, age structure is of minor suitability to assess the ecological status of lakes in the CB GIG. Some MS tested the metric age structure but no clear reaction to human impacts was found (DE, BE, unpublished results). Our experiences show, that all major age classes (YOY, juvenile, adult) of the more common species are always present in lakes. Size metrics can to some degree replace direct age metrics and indicate certain pressures. The absence of large individuals can show intensive fisheries (as done in NL). In EE the absence of large individuals directly reflects the allowed mesh sizes. Additionally large individuals indicate a good quality of deeper waters, which is their main habitat (A. Palm, pers. Comm.). Mean or median individual weight can be used as growth parameter and indicator for eutrophication (DK, DE). Summarized, size parameters can be used as metrics and serve as proxies for 'direct' age measurement. But they seem to be of minor validity and of limited applicability, e.g. type-specific within a smaller geographical range. In the WISER project, reliable relationships between size metrics and pressures were not found (EMMRICH et al. 2011; CAUSSÉ et al. 2012; EMMRICH et al. 2012).

However, the interpretation of the WFD's intention of the 'age' parameter should be that resident fish species ought to reproduce naturally and sufficiently for the maintenance of the standing stock. Such an interpretation is found in the Belgic system, which uses reproductive success of tench and pike (and in the German approach). In lakes, the successful natural reproduction of fish species is usually shown be the mere presence in the catches. This does not apply for stocked species. Therefore, the need to investigate age structure (better success of reproduction) is limited to some species that are or might be stocked. Relevant species are (for Germany): Carp, Pike, Pikeperch, and Whitefish. Eel is not mentioned here because its population is purely dependent on stocking and thus does not indicate the ecological status. If stocking takes place, human influences might impact the species' presence and abundance. This way, effects of lake degradation might be masked. However, many investigations show that stocking rarely increases the abundance of fish species like pike, pikeperch or vendace (no citations at this place).

I conclude that aging is of minor value to indicate failure in reproduction and development. Furthermore, failures in reproduction and development are less suitable to reflect anthropogenic degradation. The consequences of failures in reproduction and development for the fish community are changes in abundance and composition which tend to be more useful for LFI.

The comment on age structure is generally supported by BE, FR, but seen critical by EE

Comments of the following MS were included: BE, FR, EE

Graeme Peirson (UK) commented in June 2015: I see the inclusion of an age- or size-structure population metric as being a supporting, or diagnostic, metric: If the population of a particular species is poor then it may be because of poor recruitment, or poor growth rate of individuals, or poor survival. Age-structure can help identify which of these is the problem.

Result: The previously described point of view towards the suitability of age metrics was submitted as a scientific explanation of the specific challenges of the assessment of lakes with fish. The points were discussed in the ECOSTAT meeting of 30-31 March 2011. The conclusion was: 'It is agreed to include national methods even if they do not contain age structure metrics for the current intercalibration exercise'. The citation refers to VAN DE BUND et al. (2011): Method compliance checking: which methods can be included in the intercalibration exercise? Document discussed at the ECOSTAT meeting of 30-31 March 2011.

Sensitive species

The normative definition of the WFD for HIGH status is:

All the type-specific sensitive species are present.

The terminus 'sensitive species' according to the WFD can have two meanings:

a) any species reacting to a pressure i.e. being sensitive to it or

b) a rare or highly specialized species, mostly of particular conservational interest.

In the first case sensitive species are included in all of the existing systems and approaches. However, all MS of the CB GIG agreed at the Berlin-meeting in December 2010 that the second definition reflects the original intention of the WFD. In this case it is very difficult to include sensitive species in LakeFish assessment systems. Main reasons are:

- Methodology, i.e. the insufficient possibility to reliably catch rare fishes. It is nearly impossible to prove the absence of a rare species. This is especially relevant when relying on single fishing methods, e.g. gillnet catches. Systems based on the combination of multiple fishing gear and systems based on modelled fish communities (e.g. by information provided from fishermen or anglers and expert knowledge) can include information on rare species, but the second concept is absent in the CB GIG.
- There are doubts that 'sensitive fish species' as meant by the WFD do exist. Fish are mobile and species only become extinct from a lake when pressures affect the whole lake in high intensities. Therefore they are not sensitive in the meaning of reacting to minor pressures in restricted areas.
- The normative definition refers to a presence/absence criterion. The expected reaction is a decrease of species numbers with increasing pressures. However, this must not be the case (WHITTIER 1999). Analysis of German data has shown that species do NOT disappear until very intense levels of pressures are reached (meeting moderate status or worse). On the contrary, species numbers <u>in</u>crease with increasing pressures, e.g. because changes of the shoreline can enrich the structural diversity (e.g. artificial beaches, stone packages). A unimodal distribution of species number with increasing trophic status has also been observed (HELMINEN et al. 2000; JEPPESEN et al. 2000).
- In contradiction to the normative definition sensitive fish species are never type specific, but habitat specific. They usually occur in all lake types. As they are rare, they do not occur in all lakes of an individual type (i.e. they are not type specific). When referring to a certain lake type, sensitive species have a type-specific probability of occurrence, but a site specific expert judgment or modelling is necessary to evaluate if a sensitive species is expected or not. This strategy contradicts the concept of type specific approaches used in most MS of the CB GIG.

At all, sensitive species cannot be applied in a type specific German assessment system because these species are rare and not sensitive to the dominant pressures in a way corresponding to the intention of the WFD.

The above mentioned arguments do not imply that sensitive species are generally unsuitable for status indication. If the fish sampling is done with the appropriate gear, intensity and frequency they can show pressures that affect the whole lake, e.g. acidification, water level regulation and migration barriers. However, because of the pressures and the fishing methodology, sensitive species are of minor relevance for most LFI.

Additionally, percentages of sensitive/intolerant/tolerant species are more promising then presence/absence traits, especially if species with higher abundance but lower ‘sensitiveness’ are chosen, e.g. pike or tench (WHITTIER 1999; APPELBERG et al. 2000; BELPAIRE et al. 2000; JAARSMA 2007). Abundances or percentages of the semi-sensitive species pike and tench are used in some CB assessment systems (BE, NL). These species can be caught in sufficient numbers to allow quantitative comparison (but not with multimesh nets) and indicate the structural quality of littoral macrophytes.

The comment on sensitive species is generally supported by BE, but seen critical by EE

Comments are included from: BE, EE

EE: perch, tench and rudd are good indicators for good water quality - as the highest water quality is fishless as well as the worst one.

List of abbreviations and definitions

%N - percentage of total number of fish catch

%W- percentage of total weight

2IL - national fish assessment system of France

AWB – artificial water bodies

BG – benthic gillnets

BQE – Biological Quality Element

CB - Central – Baltic region

CIS – Common Implementation Strategy

CPUE - Catch Per Unit Effort

CZ - Czech Republic

CZ-FBI – national fish assessment system of Czech Republic

DE – Germany

DEEP - stratified, deep lake type

DeLFI - national fish assessment system of Germany

DK – Denmark

EE – Estonia

EQR – Ecological Quality Ratio

FR - France

GEP - good ecological potential

GIG - Geographical Intercalibration region

HMWB - heavily modified water bodies

IBI - index of biotic integrity

IC - Intercalibration of ecological assessment systems

LAFIEE - national fish assessment system of Estonia

L-CB1 – Central-Balti lake type 1: shallow, calcareous lakes (mean depth 3-15 m, alkalinity > 1 meq/l, water residence 1-10 years)

L-CB2 - Central-Balti lake type 2: very shallow, calcareous lakes (mean depth < 3 m, alkalinity > 1 meq/l, water residence 0.1-1 years)

L-CB3 -Central-Balti lake type 3: shallow, small, siliceous lakes (mean depth 3-15 m, alkalinity 0.2 - 1 meq/l, water residence 1-10 years)

LDC - least disturbed conditions

LFI - Lake Fish Index: systems to assess the ecological status of lakes based on fish community data

LFI EN national fish assessment system based on gillnet sampling

LFI+ national fish assessment system of Poland based on fisheries statistics

LT – Lithuania

LV – Latvia

LZIE - national fish assessment system of Lithuania

MEP – moderate ecological potential

MP boundary between moderate and poor ecological status class

MS Member state

NL – the Netherlands

non-fish alien: The metric assesses the impact of non-fish aliens (like mussels, crustaceans, plants). I

NPUE: number per unit of effort,

pCCA - partial Canonical Correspondence Analysis

PG - pelagic gillnets

PL – Poland

POLY - Polymictic lake type

SPEC-flushed - special lake type flushed lake

SPEC-saline - special lake type with high salinity e.g. at shorelines

Stocknat - stocking of native species.

STRAT - stratified lake type

TN - total nitrogen

TP - total phosphorus

TP_class (total phosphorous %; classified): Total phosphorous with type specific class boundaries.

TSI - Trophic State Index

UK – United Kingdom

VISMAATLAT - national fish assessment system of the Netherlands

W - weight

WFD – Water Framework Directive

WPUE - weight per unit of effort.

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