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Intercalibration of the national classifications of ecological status for Eastern Continental lakes

Biological quality Element: Phytoplankton

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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 were 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 reports are 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 Eastern Continental Lake GIG Phytoplankton ecological assessment methods.

Three countries (Bulgaria, Hungary, Romania) participated in the intercalibration exercise and harmonised their phytoplankton assessment systems. The results were approved by the WG ECOSTAT and included in the EC Decision on intercalibration (European Commission, 2018).

1. Introduction

In the Eastern Continental Lake GIG:

- Three member states participated (Hungary, Romania and Bulgaria);
- Intercalibration "Option 1" was used – all member states use the same method;
- The method ("Hungarian Lake Phytoplankton Index", HLPI) addresses the pressures eutrophication (TP, TN), the impact of fish and fish-related processes as well as the impairment of the balance between primary producers (macrophytes and algae).

The final results include normalized EQRs of HLPI for the common intercalibration type L EC1.

2. Description of the national assessment methods

Bulgaria, Hungary and Romania have agreed to use the Hungarian classification method for lake phytoplankton assessment (Option 1). Development of the method (setting of boundaries) were carried out with the involvement of national experts of the countries.

Table 1. Overview of Eastern Continental GIG lake phytoplankton assessment methods.

MS	Method	Status
BG	Hungarian lake phytoplankton index (HLPI)	Finalized but not formally agreed national method
HU	Hungarian lake phytoplankton index (HLPI)	Finalized but not formally agreed national method
RO	Hungarian lake phytoplankton index (HLPI)	Finalized but not formally agreed national method

2.1. Required BQE parameters

The HLPI includes all parameters (**Table 2**, **Figure**).

Table 2. Overview of the metrics included in the national phytoplankton assessment method

MS	Biomass	Taxonomic composition and abundance	Algal blooms	Combination rule of metrics
all	Chlorophyll-a	Q index = composition metric based on functional groups [1]	Absolute abundance of cyanobacteria	Weighted average of normalized EQR of biomass and composition metric; bloom metric included when cyanobacteria biomass exceeds 10 mgl^{-1}

[1] Padisák et al. (2006)

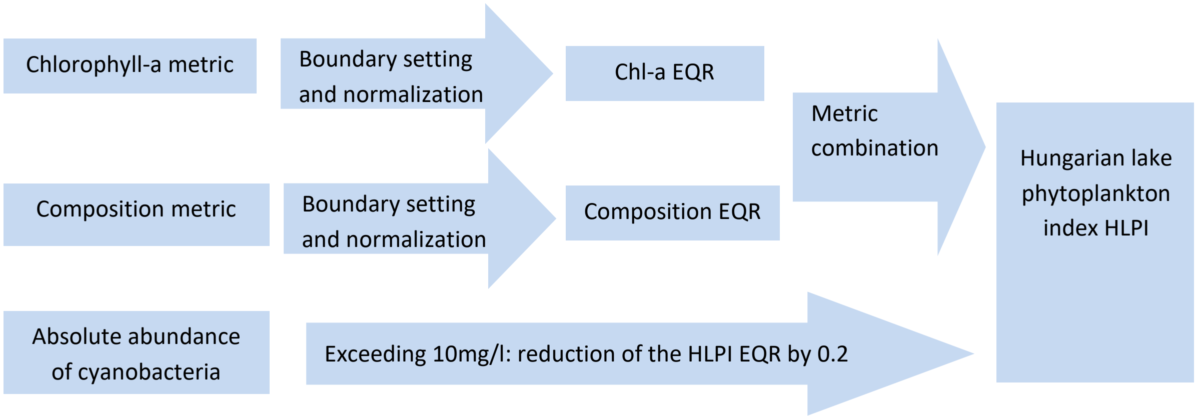


Figure 1. Phytoplankton metrics and their contributions in the Hungarian Lake Phytoplankton Index (HLPI).

Comparing the data distribution and the strength of the relationships between the composition and biomass metrics, the biomass metric seems to be a reliable estimation of nutrient input and can be the better predictor of the ecological state. Therefore, in the combination of the two metrics a weighted average of the composition and biomass metric EQR values was proposed.

$$HLPI = \frac{EQR_Q + 2 \times EQR_{Chl-a}}{3}$$

HLPI: Hungarian lake phytoplankton index
EQRQ: normalized EQR of the composition metric
EQRChl-a: normalized EQR of the biomass (Chlorophyll-a metric)

Bloom metric:

The WFD requires that the frequency and intensity of algal blooms are considered in phytoplankton-based quality assessment. Since the term water bloom is not clearly defined in the hydrobiological literature, several approaches such as evenness and relative or absolute abundance of cyanobacteria have been tested. Neither the evenness nor the relative abundance of cyanobacteria seemed to be applicable in the EC-GIG as bloom metric, while the absolute abundance of cyanobacteria turned out to be a promising predictor of algal blooms. The following threshold was defined:

If cyanobacteria biomass is<10 mgl^{-1}, the value of the HLPI can directly be applied.

If cyanobacteria biomass is >10 mgl^{-1}, then:

National EQR >0.6 → the HLPI is reduced by 0.2

National EQR <0.6 → no change of the HLPI

The calculated EQR values (HLPI) show high variability especially in the higher range of stressors, therefore lake-year data are calculated. Nevertheless lake-year results might also show considerable variability, therefore the mean of EQRs calculated for the three consecutive years is to be considered for the assessment.

2.2. Sampling and data processing

All countries use the same sampling strategy and data processing technique (**Table 3**).

Table 3. Overview of the sampling and data processing of the national phytoplankton assessment methods

MS	Sampling strategy	Data processing
all	Integrated sample over the euphotic zone (2.5 x Secchi depth) at the deepest point of the lake at least 4 times a year (May – September)	Phytoplankton: Utermöhl technique[2]; Chlorophyll-a IS 2060:1992 (phaeophytin correction)

[2] Inverted microscopy of Lugol-preserved samples after Utermöhl (1958); phytoplankton biovolume determination based on the calculation of the volume of each unit from appropriate geometric formulae (Hillebrandt et al. 1999).

2.3. National reference conditions

The following Table 4 summarizes the reference criteria to select reference sites. After screeing the data, not true reference sites were found. Therefore the alternative benchmark approach was followed (see below).

Table 4. Reference condition criteria for selection of lake reference sites in the EC GIG

Pressure type	Criterion
Diffuse source pollution	Reference" threshold <20% of intensive agriculture in the catchment area. "Rejection" threshold >50% of intensive agriculture in the catchment area (estimated from Corine data). Intensive agriculture between 20% and 50%: Validation with physico-chemical parameters at the site scale.
Point source pollution	No known point source discharge, or very localized impact with self-purification.
Water abstraction	Only very minor reductions in flow level changes having no more than very minor effects on the quality elements.
Littoral vegetation modification	Only minor modification of the shoreline. Ratio of the natural littoral vegetation >90%. Complete zonation of the macrophytes in the littoral zone.
Biological pressures	No biomanipulation
Chemical pressures	TP: 76 $\mu g\ l^{-1}$ (defined as 25th percentile of TP values in the benchmark lake population) TN: 400 $\mu g\ l^{-1}$ (defined as 25th percentile of TN values in the benchmark lake population) BOD: 2.5 $mg\ l^{-1}$ If values are higher validation with chemical and biological parameters is necessary
Other pressures	No nearby intensive recreational use at the site scale: No regular bathing activities or motor boating. Occasional recreational uses (such as camping, swimming, boating, etc.) should lead to no or very minor impairment of the ecosystem.

2.4. National boundary setting

Selection of alternative benchmark sites

Since lakes fulfilling all reference criteria were not found in the region, we focused on lakes that meet all those criteria which are important from the point of view of phytoplankton. They represent least disturbed lakes and were considered as alternative benchmark lakes for phytoplankton. During the lake selection the following criteria were used to define these alternative benchmark lakes:

- no major point sources in catchment, complete zonation of the macrophytes in the littoral zone,
- no (or insignificant) artificial modifications of the shore line,
- no mass recreation (camping, swimming, rowing)
- low/moderate fishing (fish standing stock <50 kg ha^{-1})
- Based on TP, TN, COD values and intensity of fishing a combined stressor was developed. The stressor ranges from 0–4. Lakes considered as alternative benchmark sites have a combined stressor value <1.5. This means that:
    - Fishing is low (fish stock <50 kg ha^{-1})
    - Vegetation period mean TP <115 µg l^{-1}
    - Vegetation period mean TN <1550 µg l^{-1}.

Data were provided by the regional HU, RO and BG water authorities. In addition, experts from the regional environment agencies were involved in the final decision making. Thus the criteria used consisted of pressure data, impact data, knowledge of biology and chemistry, land-use data in conjunction with expert judgement.

Since the majority of sites in the EC GIG are oxbow lakes without permanent surface tributary, the definition of a catchment area is difficult. Although occasional floods from the main river may enter the oxbow lakes, the catchment of the rivers are not appropriate to define the potential anthropogenic impact on the water body from the catchment (see poor relationship in Fig. 5a-d).

The key criteria for the benchmark site selection were:

i) the macrophyte zonation;

ii) the modification of the shore line (as a proxy of diffuse nutrient input as well as of naturalness of macrophytes at the riparian zone);

iii) the use of the water body for other purposes such as fisheries (see relationship with lake-use in Figure 2f).

The relevance of macrophytes in the benchmark site selection refers to the well-known phenomenon of alternative stable states between phytoplankton and macrophytes. The impact of fisheries addresses internal loading from sediment resuspension.

The use of total phosphorus has been used as single pressure parameter in lakes, where it is a strong predictor of chlorophyll-a biomass (e.g. deep, stratified lakes Alpine lakes). In EC lakes, the TP – Chl-a relationship is very poor, because other factors such as macrophyte dominance and fisheries have a significantly higher impact on the phytoplankton.

Based on the criteria listed above, 6 sites (2 RO, 4 HU) with a total of 18 lake-years were seletced as alternative benchmark sites (see Table 17 in Annex).

Boundary setting for the biomass metric

Sestonic Chl-a concentration is used as biomass metric. For the boundary setting, the population of least disturbed sites as alternative benchmark sites was used (see Appendix A-5). High/good boundary was considered as the 25th percentile of the Chl-a values in the benchmark lakes population (11.8 $\mu g l^{-1}$).

This value was validated by a multiple regression modell proposed to this lake group by (Borics et al., 2013). The used formula is:

$$\mathrm{LogChl\text{-}a} = -0{,}087 \times \log \mathrm{depth} + 0.0424 \times \log \mathrm{TP} + 0.149 \times \log \mathrm{TN} + 0.62 \times \mathrm{lake\ use} + 0.051$$

When inserting the 25^{th} percentile of the TP (76 $\mu g l^{-1}$) and TN (400 $\mu g l^{-1}$) of the benchmark lakes as well as lake-use 1 category, the regression model gives a Chl-a value of 12.43 $\mu g l^{-1}$. This value is in accordance with the proposed HG boundary value derived from the benchmark lakes population (11.8 $\mu g l^{-1}$).

Good/Moderate boundary was considered as the 90th percentile of the Chl-a values in the benchmark lake population (24.6 $\mu g l^{-1}$).

This value was validated by the Chl-a – Secchi transparency relationship (Figure). Since depth of the photic layer can be approximated by 2.5 × Secchi depth, in those cases when SD 120–150 cm reduction of the oxygen content in the bottom of a ≈3 m deep water column can be expected. Chl-a >25 $\mu g l^{-1}$, SD <150 cm (oxygen depletion occurs at ≈3 m depth). This corresponds to a Chl-a value of 25–30 $\mu g l^{-1}$. The value derived from the benchmark lakes population lies within this range. Because of the ecological significance of the Chl-a – Secchi depth relationship, Chl-a = 24,6 $\mu g l^{-1}$ value was accepted as GM boundary.

Poor/Bad boundary was considered as the median value of the annual mean Chl-a concentrations in the heavily impacted lake population (Chl-a = 105.1 $\mu g l^{-1}$). Heavily impacted lakes were defined as sites with lake use = 3 (see Appendix A-3 and A-9).

Moderate/Poor boundary (Chl-a = 64.8 $\mu g l^{-1}$) was calculated as the average [equal distance] of the boundaries GM (24.6 $\mu g l^{-1}$) and PB (105.1 $\mu g l^{-1}$).

Using the following 3^{rd} order polynomial regeression formula

EQRChl-a = IF(X>200; 0; IF(X<105.1;-0.000002444 X3 + 0.0004479 X2 – 0.0294 X + 1.089; -0.002 X + 0.3949))

X: Chl-a ($\mu g l^{-1}$),

chlorophyll-a values are converted to the normalized scale with equal class widths and standardized class boundaries, where the HG, GM, MP, and PB boundaries are 0.8, 0.6, 0.4, 0.2, respectively (Table 5).

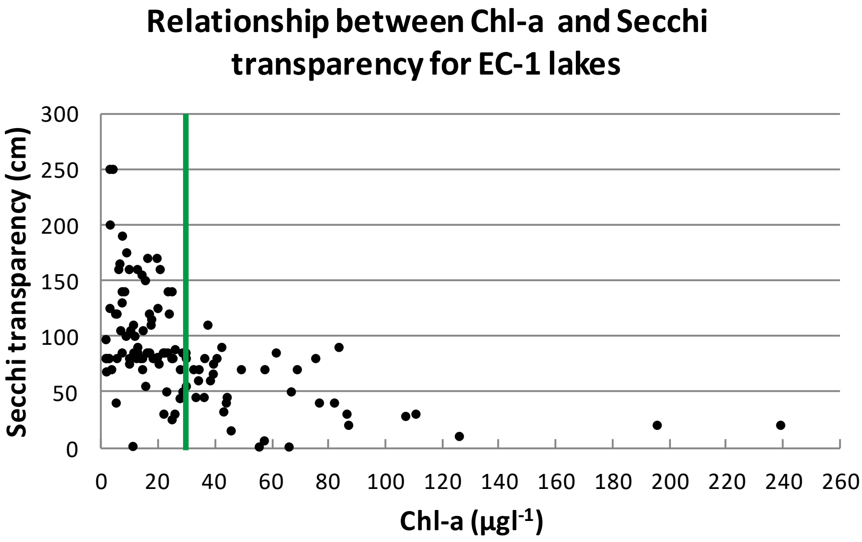


Figure 2. Chlorophyll-a – Secchi depth relationship in EC-1 lakes. The green line indicates the Chl-a concentration, above which SD >150 cm cannot be expected.

Table 5. Chlorophyll-a and EQR boundaries.

Quality classes	Chl-a (µgl−1) boundaries	EQR boundaries
HIGH	≤11.8	0.8
GOOD	≤24.6	0.6
MODERATE	≤64.8	0.4
POOR	≤105.1	0.2
BAD	>105.1	<0.2

Calculation and boundary setting for the composition metric (Qk)

Assessment is based on the quantitative phytoplankton data. The applied composition metric (Qk) is based on the "Assemblage index" (Q) published by Padisák et al. (2006). Qk is given as

$$Q_k = \sum_{i=1}^{s} (p_i F),$$

pi: the relative contribution of the ith assemblage to the total biomass,

F: is a factor number that evaluates the given assemblage in the given lake type.

The factor number (F) is based on the evaluation of functional groups (FG) of algae. The FG scores (F) were given by considering the distribution of the FGs along the combined stressor values.

Factor values

S1	S2	SN	YPh	H1	G	J	M	C	P	T	X1	LM	W1	W2	Q	D	Y	E	K	LO	WS	MP	A	B	N	Z	X3	X2	F	U	V
1	1	1	1	1	3	3	3	5	5	5	5	5	5	5	5	7	7	7	7	7	7	7	9	9	9	9	9	9	9	9	9

The calculated Q index values were standardized by dividing by the maximum (Qk=7.95) of the common database.

For the standardised Q value, High/Good and Good/Moderate boundaries were set in the same way as for Chl a. Since the response is inverse, the 75th percentile of the standardized Q values (Q=0.82) in the benchmark lake population was considered as HG boundary and the 10th percentile (Q=0.52) as GM boundary.

For setting the Moderate/Poor and the Poor/Bad boundary relationship between the abundance of cyanobacteria (%) and Q metric was used. 50% of Cyanobacteria defined the MP boundary (Q = 0.40), while 80% of Cyanobacteria was used a threshold to define the PB boundary (Q = 0.2).

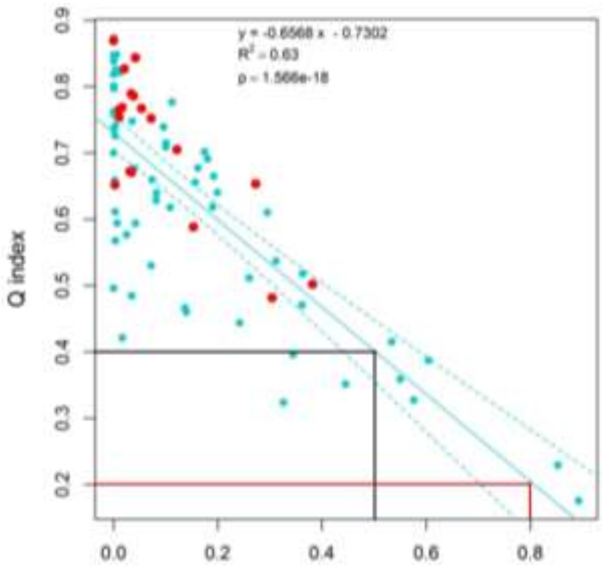


Figure 3. Relationship between the relative abundance of cyanobacteria and Q metric

Each metric EQR is converted to the normalized scale with equal class widths and standardized class boundaries, where the HG, GM, MP, and PB boundaries are 0.8, 0.6, 0.4, 0.2, respectively (Table 6). For the normalization the following 3rd order polynomial regeression formula was used:

EQRQ =IF(Q>0.4; 5.511 × Q3 -11.971 × Q2 + 9.1614 × Q – 1.7019;Q)

Table 6. Q metrics and EQR class boundaries

Quality classes	Composition metric (Q) boundaries	EQR boundaries
HIGH	≥ 0.82	0.8
GOOD	≥ 0.52	0.6
MODERATE	≥ 0.40	0.4
POOR	≥ 0.20	0.2
BAD	<0.20	<0.2

Overview of boundary setting

Table 7 gives an overview of boundary setting methodology and **Table 8** summarizes the statistics and the gives the final class boundaries.

Table 7. Overview of the methodology used to derive ecological class boundaries

MS	Conclusion of compliance	Boundary setting procedure
all	Compliant	HG defined as 25th percentile (Q index 75th percentile) and GM defined as 90th percentile (Q index 10th percentile) of the benchmark sites. PB for chlorophyll-a defined as median of highly disturbed sites (lake use = 3) and MP as the mean of GM and PB boundary. MP and PB for Q index derived from the correlation with % cyanobacteria (MP at 50% cyanobacteria, PB at 80% cyanobacteria)

Table 8 Statistics on benchmark sites and highly disturbed sites (lake use = 3) for chlorophyll-a and the Q index

Statistics	Benchmark sites		Highly disturbed sites	
	Chl-a	**Q index**	**Chl-a**	**Q index**
n	18	18	21	21
min	4.0	0.497	43.4	0.172
10th percentile	8.8	0.52	60.4	0.33
25th percentile	11.82	0.597	79.5	0.427
median	17.64	0.695	105.1	0.532
75th percentile	22.0	0.82	219,1	0.65
90th percentile	24.60	0.85	432,6	0.725
max	48.3	0.891	782.8	0.74

2.5. Pressure – response relationships

Single pressures versus chlorophyll-a

The pressures addressed are eutrophication (total phosphorus TP, total nitrogen TN), the impact of fish and fish-related processes as well as the impairment of the balance between primary producers (macrophytes and algae). **Table 9** summarizes the regression models between various pressures and chlorophyll-a (data from Hungarian lakes only, Borics et al., 2013). Apart from lake depth and pH, significant regressions models were found for TN, COD and NH4-N. Comparable results were gained using the whole GIG dataset (Fig. 4).

Table 9. Regression equations for log10 chlorophyll-a concentration as a function of potential descriptor variables (Borics et al., 2013)

Variables	Equation	R^2	p
log depth	1.5661-0.9694x	-0.4517	0.0007
log TP	0.8306+0.196x	0.1905	0.1718
log TN	0.1125+0.4005x	0.3076	0.0251
log COD	0.9219+0.0084x	0.6836	0.0000
log NO3-N	1.5249-0.0966x	-0.0745	0.5998
log NH4-N	0.2894+0.5198x	0.4938	0.0002
log PO4-P	1.1136+0.1397x	0.1745	0.2256
log pH	-4.4526+0.7204x	0.6466	0.0000
log Electrical conductivity	1.2709+0.00008x	0.0548	0.0697
urban areas	1.3461-0.0052x	-0.1143	0.4152
intensive agriculture	1.4964-0.0031x	-0.2337	0.0921
non-intensive agriculture	1.282+0.0055x	0.1496	0.2851
forests and natural wetlands	1.2358+0.0027x	0.2093	0.1325

No significant relationship was found with land use as pressure (Figure 2 a-d). This can be explained by the fact that many L-EC1 lakes are oxbow lakes without surface in- and outflow. Therefore, point nutrient sources in the catchment area have limited impact on the lake. A significant correlation, however, was found between the lake use and the phytoplankton community (Figure 2f).

Combined stressor development

The nutrient content of EC1 lakes (even in a natural state) is typically found at a concentration range where the Chl-a = f(Nutrients) models show asymptotic behaviour (Phillips et al., 2008) and can be characterised by increased variation (Figure 1 - Fig. 8).

Since the nutrients as single variables are not strong predictors of phytoplankton biomass (Borics et al., 2013), combination of various stressors were proposed in Hungary. The possible stressors (e.g. TP, TN, COD, lake-use) were expressed in normalized values (in 0–1 range) and then summed up. Since recreational fishing/angling is the most important lake use in the region, this stressor was used to create three lake categories:

- Lake group 1: no fishing/angling activity and no artificial stocking of fish, fish abundance <50 kg ha^{-1};
- Lake group 2: moderate fishing/angling activity with occasional artificial fish stocking, fish abundance is between 50 and 200 kg ha^{-1};
- Lake group 3: intensive fishing/angling, regular fish stocking, fish abundance >200 kg ha^{-1}.

Median values of the TP, TN, and COD were calculated for the data in lake group 1 and lake group 3 (Table 10). These values were used as boundaries for transforming the measured concentrations into normalized values.

Table 10. Median values of nutrient and COD concentration for two respective lake groups and maximum values in the dataset.

	TP (µg l^{-1})	TN (µg l^{-1})	COD (mg l^{-1})	Normalized values
Lake group 1	94	1310	31.83	0.33
Lake group 3	250	2370	50	0.66
Maximum values	500	4000	100	1.0

*The values in this table have been calculated by the 2014 year's version of the dataset

Using polynomial and/or piecewise linear transformation, each concentration are converted to normalized scale. Lake-use categories were also described by numerical value (LG1: 0.33; LG2: 0.66; LG3: 1.0).

The combined stressor was defined as the sum of the four metrics. Implicitly, the minimum value of the stressor is approximately 0.5, while the maximum is 4.

Figure 3 and Figure 4 show the correlation between the combined stressor and the single metrics as raw data (Figure 3: chlorophyll-a) and as normalized EQR (Figure 4: chlorophyll-a and Q index). The position of the benchmark sites in these plots is illustrated in Figure 5.

Finally, intercepts and slopes of the global regression of combined stressor against HLPI were tested (Figure 6). No significant country effects were observed. Systematic deviation of country data from the global regression was not observed.

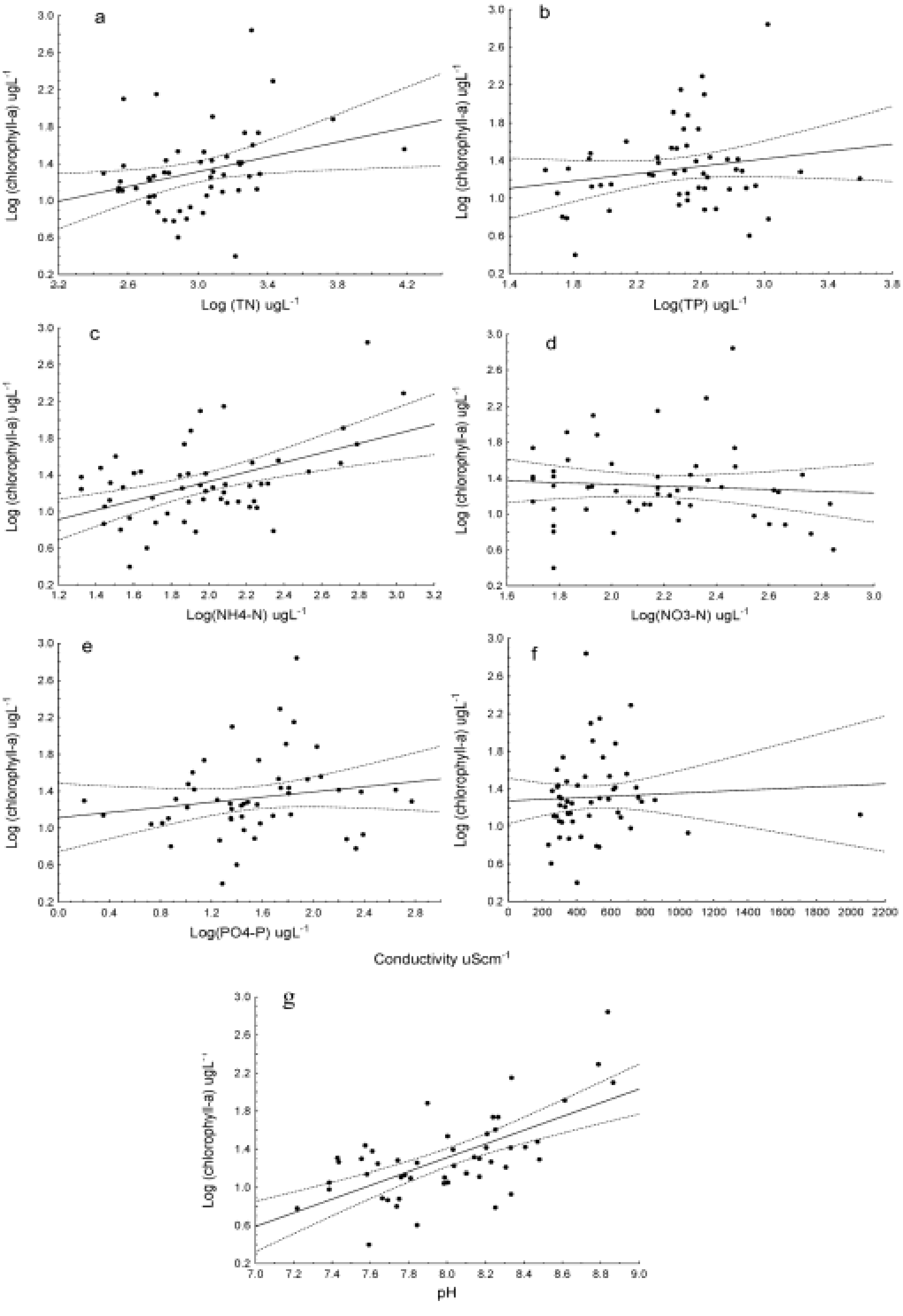


Figure 1. Changes of Chl-a in relation to various stressors (relationship was calculated for the intercalibration database)

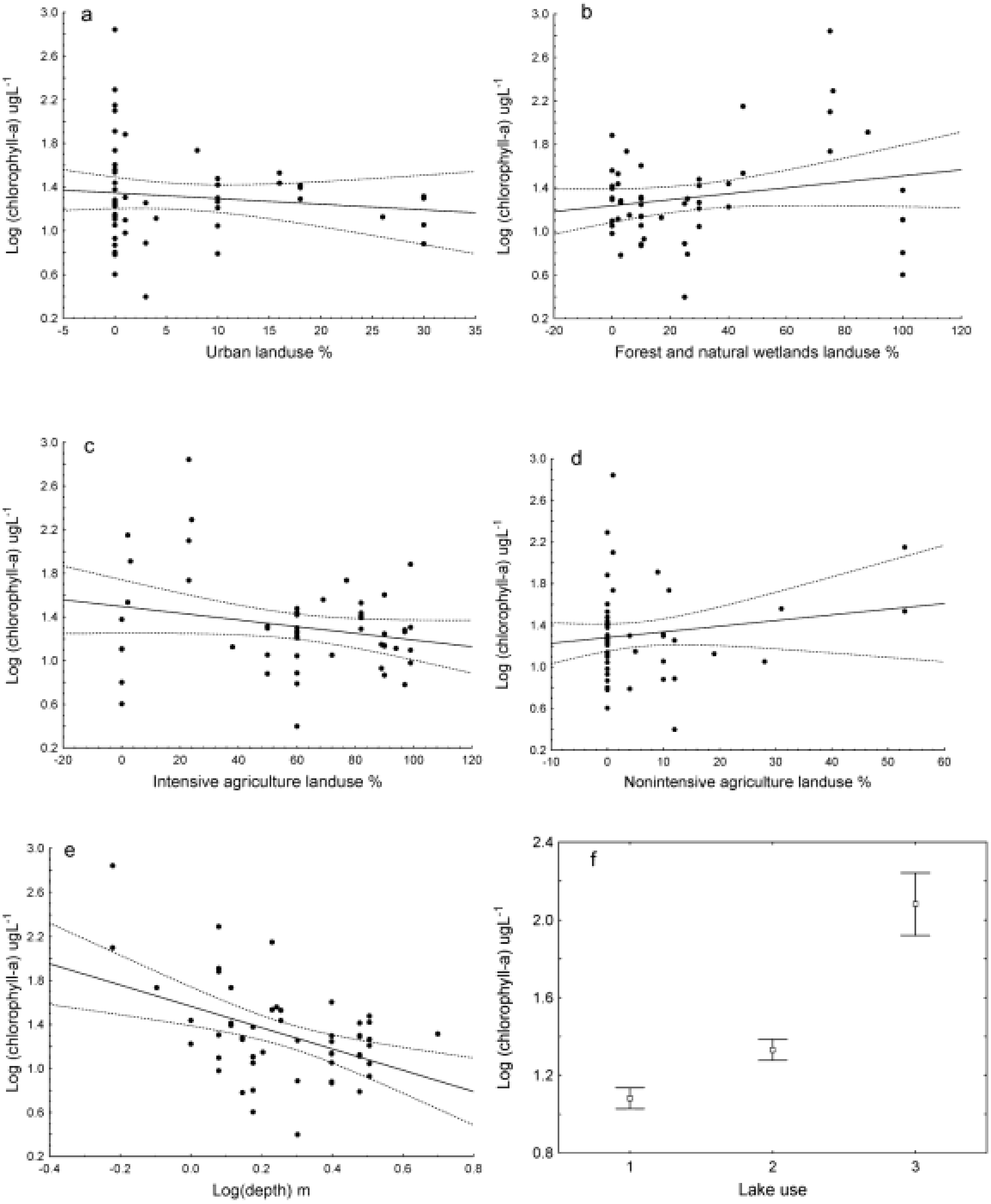


Figure 2. Changes of Chl-a in relation to land use categories (a-d), lake depth (e) and in the reference impacted and heavily impacted lake categories (f). (Source Borics et al., 2013)

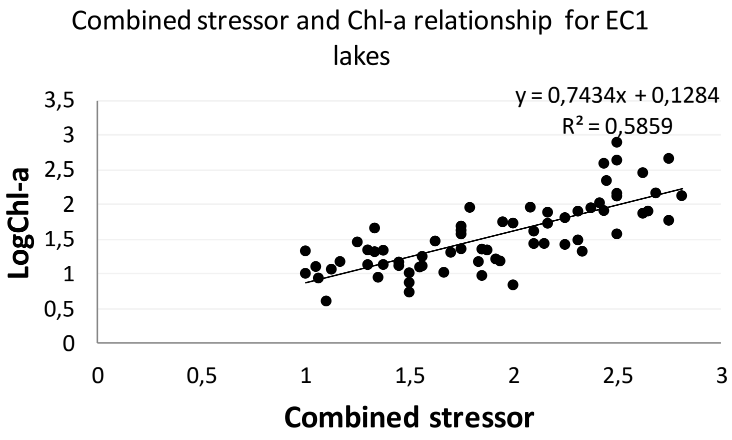


Figure 3. Distribution of growing season average chlorophyll-a concentrations along different values of the combined stressor

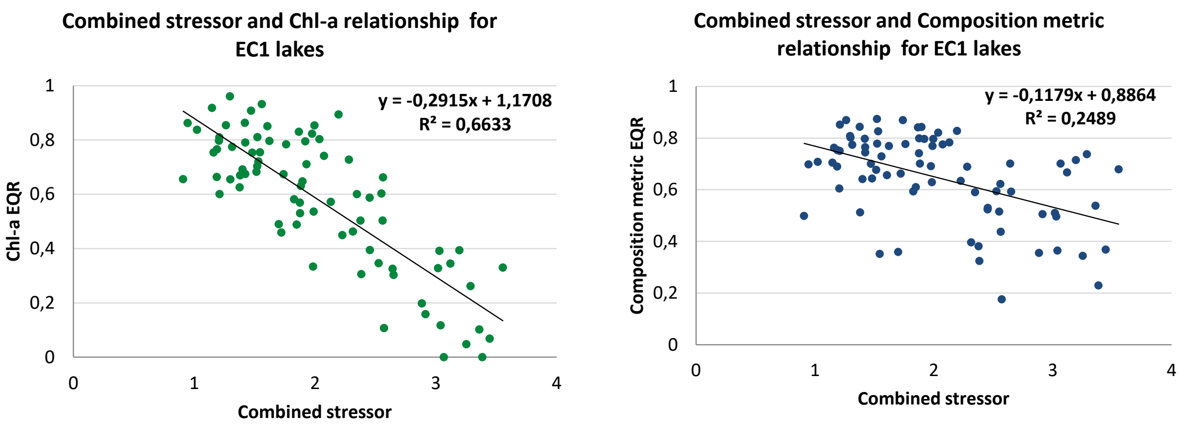


Figure 4. Relationship between the combined stressor and metric EQRs for the chlorophyll-a metric (left) and the composition metric (EQR $_{Qk}$) (right)

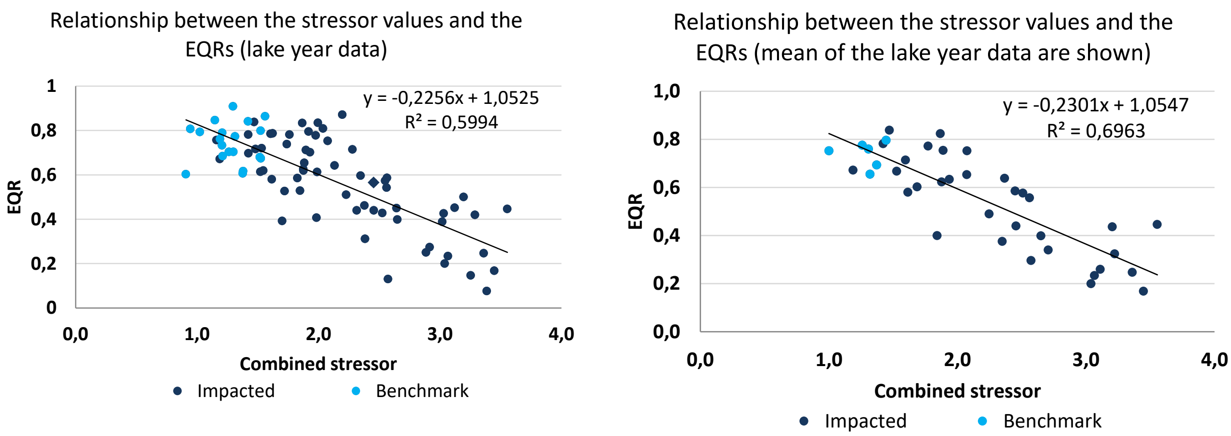
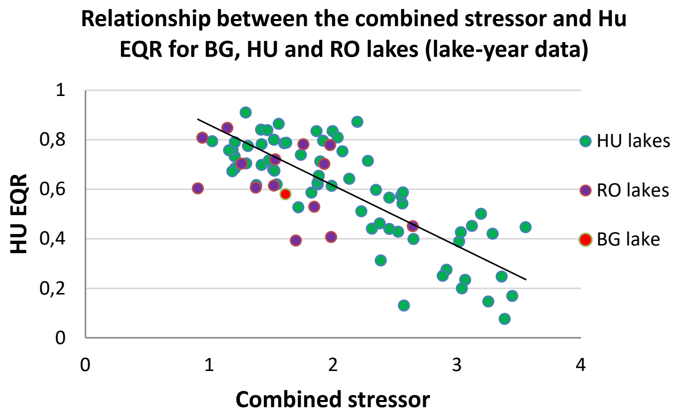
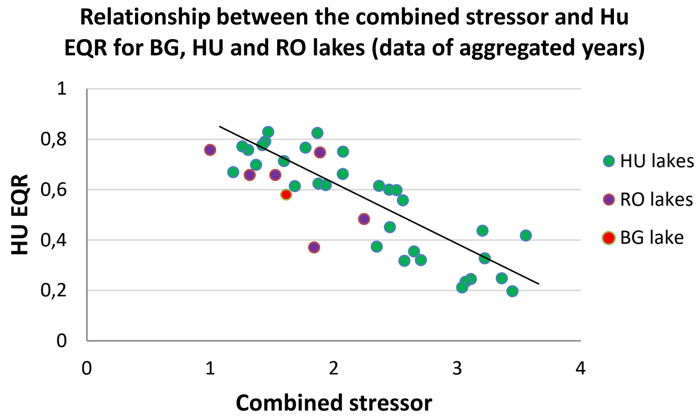


Figure 5. Relationship between the combined stressor and the HLPI for the BG, HU and RO lakes. Pale blue symbols indicate the position of benchmark lakes.



a



b

Figure 6. Relationship between the combined stressor and the HLPI (HU EQR) for BG, HU and RO lakes based on lake-year data (a) and lake mean data (b).

3. Results of WFD compliance checking

The Hungarian assessment method (HLPI) is considered WFD compliant (Table 11).

Table 11. List of the WFD compliance criteria and the WFD compliance checking process and results.

1. Ecological status is classified by one of five classes (high, good, moderate, poor and bad).	Yes
2. High, good and moderate ecological status are set in line with the WFD's normative definitions (Boundary setting procedure)	Yes
3. All relevant parameters indicative of the biological quality element are covered (see Table 1 in the IC Guidance). A combination rule to combine para-meter assessment into BQE assessment has to be defined. If parameters are missing, Member States need to demonstrate that the method is sufficiently indicative of the status of the QE as a whole.	Biomass metric and composition metric has been elaborated. The index is the weighted average of these two metrics. The absolute abundance of cyanobacteria is used as a bloom metric.
4. Assessment is adapted to intercalibration common types that are defined in line with the typological requirements of the WFD Annex II and approved by WG ECOSTAT	Yes
5. The water body is assessed against type-specific near-natural reference conditions	In the lack of true reference sites, least disturbed sites as alternative benchmark sites were considered. Reference values were considered as 25th percentile of the Chl-a values and 75th percentile of the Q index values in the benchmark sites. Reference Chl-a value has been validated by the multiple regression model proposed to this lake group (Borics et al., 2013). The used formula is: LogChl-a = -0,087×log depth+ 0.0424×log TP+ 0.149×logTN+0.62×lake use + 0.051 Model inputs: 25th percentile of the TP (76 μgl^{-1});25th percentile of the TN (400 μgl^{-1}); Lake use 1; Depth 3,0 m. Chl-a value estimated by the model: 12.43 μgl^{-1}. Proposed H/G boundary value derived from the benchmark lakes population (11.8 μgl^{-1}). (This value falls in the range of those considered as reference in LCB GIG countries). Reference values were considered as HG boundaries both for Chl-a and Q index.
6. Assessment results expressed as EQRs	Yes
7. Sampling procedure allows for representative information about water body quality/ ecol. status in space and time	Yes
8. All data relevant for assessing the biological parameters specified in the WFD's normative definitions are covered by the sampling procedure	Yes
9. Selected taxonomic level achieves adequate confidence and precision in classification	Yes

4. IC Feasibility checking

4.1. Typology

Intercalibration types

At the beginning of the IC exercise, five common intercalibration types were defined. The IC exercise was carried out on 1 type only, where all three member states contributed with data (Table 12).

Table 12. EC GIG lake types

Common IC type	Type characteristics	MS sharing IC common type
EC1 Lowland very shallow hard-water	Altitude <200m Depth< 6m Conductivity 300-1000 (µS/cm Alkalinity 1-4 (meq/l HCO3)	HU Yes RO Yes BG Yes
EC2 Lowland very shallow but very high alkalinity	Altitude <200m Depth< 6m Conductivity >1000 (µS/cm) Alkalinity >4 (meq/l HCO3)	HU Yes RO No
EC3	Altitude 200-800m Depth <6m Conductivity 200-1000(µS/cm) Alkalinity 1-4 (meq/l HCO3)	HU No RO Yes
EC4	Altitude 200-800m Depth>6m Conductivity 200-1000(µS/cm) Alkalinity 1-4 (meq/l HCO3)	HU No RO Yes
EC5 Reservoirs	Altitude 200-800 m Depth>6m Conductivity 200-1000(µS/cm) Alkalinity 1-4 (meq/l HCO3)	HU No RO Yes

National typologies

Hungary

For Hungarian lakes in the Pannonian Ecoregion a top-down lake typology was developed (Szilágyi et al. 2008). Besides the obligatory descriptors of System A, water regime (i.e. astatic and perennial lakes) were also considered. This typology contains 17 lake types (Table 13).

Table 13 Hungarian national lake types. Bold rows and grey shade indicates the types that can be pooled in the EC1 lake type (Borics et al., 2014)

Type code	Size (km^2)	Average depth (m)	Lake bed material	Water regime	Altitude
1	> 10 (km^2)	> 3-6 m	calcareous	perennial	lowland
2	> 10 (km^2)	< 3m	soda	perennial	lowland
3	1- 10 (km^2)	< 1m	soda	astatic	lowland
4	1- 10 (km^2)	< 3m	soda	perennial	lowland
5	< 1 (km^2)	< 3m	soda	perennial	lowland
6	< 1 (km^2)	< 1m	soda	astatic	lowland
7	**1- 10 (km^2)**	**< 3m**	**organic**	**perennial**	**lowland**

8	**< 1 (km²)**	**< 3m**	**organic**	**perennial**	**lowland**
9	**1- 10 (km²)**	**< 3m**	**calcareous**	**perennial**	**lowland**
10	1- 10 (km²)	3-6 m	calcareous	perennial	lowland
11	**< 1 (km²)**	**< 3m**	**calcareous**	**perennial**	**lowland**
12	< 1 (km²)	> 3m	calcareous	perennial	lowland
13	**> 10 (km²)**	**< 3m**	**calcareous**	**perennial**	**lowland**
14	**> 10 (km²)**	**< 3m**	**calcareous**	**perennial**	**lowland**
15	**< 10 (km²)**	**< 3m**	**calcareous**	**perennial**	**colline**
16	< 10 (km²)	< 1m	calcareous	astatic	colline
17	< 10 (km²)	< 3m	calcareous	astatic	lowland

Bulgaria

Bulgaria followed a comparable approach in using additional criteria for the national typology. 17 national lake types are distinguished based on the following criteria (

Table **14**):

- Ecoregion
- Altitude
- Mean depth
- Geology
- Size/surface area
- Maximum depth (optional)
- Residence time (optional)
- Mixing character (optional)
- Salinity (optional)

Among these, five lake types include natural lakes >0.5 km^2 (

Table **14**), while the remaining types include artificial lakes (reservoirs) or natural lakes <0.5 km^2 (not listed here).

Table 14. Bulgarian national lake types in the ecoregion 12 (Cheshmedijev et al. 2010, slightly modified during the DICON-UBA project 2014-2016). Only types, which include natural lakes >0.5 km^2, are shown. The bold row highlights the type L5a which corresponds to the EC1 lake type.

Code	Type	Altitude	avg depth	Area	Salinity
L5a	**Riverine marshes in ER12 >0.5 km²**	**<80m**	**usually <3m**	**>0.5km²**	**<0.5‰**
L7	Black Sea freshwater coastal lakes	<12m	usually <3m	usually <3.5km²	<0.5‰ *
L8	Black Sea oligohaline coastal lakes	<10m	<3m	up to >10km²	0.5–5‰
L9	Black Sea meso- or polyhaline coastal lakes	<5m	usually <3m	up to >15km²	5–30‰
L10	Black Sea eu- or hyperhaline coastal lakes	<5m	<1.5m	<20km²	>40‰

* occasional salt intrusion

4.2. Pressures and assessment concept

Intercalibration is feasible in terms of pressures and assessment concepts, since all member states use the same methods.

Collection of IC dataset

The three EC countries established a common database. Prior to data collection data acceptance criteria were defined (Table 15).

Table 15. Data acceptance criteria used for the data quality control and results of data acceptance checking process and results.

Data acceptance criteria	Data acceptance checking
1. Data requirements (obligatory and optional)	all 3 MS: data from the vegetation period
2. The sampling and analytical methodology	all 3 MS: sampling of the euphotic layer, determination of the absolute and relative abundance of taxa by inverted microscope
3. Level of taxonomic precision required and taxalists with codes	all 3 MS: Taxa have to be identified to species level
4. The minimum number of sites / samples per intercalibration type	all 3 MS: 1 common IC type can be intercalibrated. The database contains 80 lake-year data
5. Sufficient covering of all relevant quality classes per type	all 3 MS together: Data cover a wide range of stressors
6. Other aspects where applicable	In order to have data in the heavily impacted lake category, data from some lakes <50 ha were also considered.

The number of lake-years in the common database is summarized in Table 16. The lake-year raw data for pressures, chlorophyll-a, Q index and EQR are summarized in Table 17.

Table 16. Number of lake-years in the three Member States.

	Biological data	Physico-chemical data	Data for other pressures
Hungary	268	268	268
Romania	41	41	41
Bulgaria	1	1	1

4.3. Benchmark standardization

Benchmark standardization was not carried out, because there was no significant country effect in the pressure response relationship (*cf* chapter0). There was neither any difference between the benchmark sites, which would justify a correction for member states.

5. Comparison of methods – IC procedure

Intercalibration “option 1” was used in the EC Lakes exercise. Reference values and class boundaries of the metrics used are fully identical in all three MS and transferred to the corresponding national lake type.

6. Description of biological communities in the five quality classes

Ecol. status	Normative definitions (WFD)	Interpretations
High EQR 0.8–1.0	The values of the biological quality elements for the surface water body reflect those normally associated with that type under undisturbed conditions, and show no, or only very minor, evidence of distortion. "The taxonomic composition corresponds totally or nearly totally to undisturbed conditions. The average phytoplankton biomass is consistent with the type-specific physico-chemical conditions "	Taxa (species) richness is high. The relative frequency of taxa considered as reference (taxa that belong to A, B, C, D, P, Y, Lo, MP functional groups) is higher than 80%. The ratio of the impacted taxa (taxa that belong to H1, S1, S2, Sn, M, functional groups) is smaller than 20%. The biomass expressed in chlorophyll-a can fluctuate during the vegetation period, but the Chl-a maxima does not exceeds 30μgl^{-1}. The mean Chl-a value in the growing season is less than 12 μgl^{-1}. The Secchi transparency usually higher than 1.5 ms. Blooms do not occur. Decrease of the oxygen concentration might occur towards the deeper layers, but oxygen depletion never develops. Normalised HLPI index > 0.8.
Good EQR = 0.6–0.8	The values of the biological quality elements for the surface water body type show low levels of distortion resulting from human activity, but deviate only slightly from those normally associated with the surface water body type under undisturbed conditions. "There are slight changes in the composition and abundance of planktonic taxa compared to the type-specific communities. Such changes do not indicate any accelerated growth of algae resulting in undesirable disturbance to the balance of organisms present in the water body or to the physico-chemical quality of the water or sediment."	As compared with that of the reference state, there is a slight decrease in the ratio of the reference assemblages. >60%. The ratio of the impacted taxa is higher than in the reference state, but < 30%. Value of the composition metric (Q) > 0.6 The biomass expressed in chlorophyll-a can change considerably during the vegetation period (Chl-a: 5 – 60 μgl^{-1}), but the mean value in the growing season is less than 25 μgl^{-1}. Higher algal biomass can occasionally develop, but long lasting blooms do not. The Secchi depth usually higher than 1.5 m. Decrease of the oxygen concentration might occur towards the deeper layers, but oxygen depletion does not develop.

Ecol. status	Normative definitions (WFD)	Interpretations
Moderate EQR = 0.4–0.6	The values of the biological quality elements for the surface water body type deviate moderately from those normally associated with the surface water body type under undisturbed conditions. The values show moderate signs of distortion resulting from human activity and are significantly more disturbed than under conditions of good status. "The composition and abundance of planktonic taxa differ moderately from the type-specific communities. Biomass is moderately disturbed and may be such as to produce a significant undesirable disturbance in the condition of other biological quality elements and the physico-chemical quality of the water or sediment."	At this state the ratio of the impacted taxa may reach the 30%. Dominance of neutral taxa (F=5) can be expected. Relative abundance of the reference assemblages less than 50%. Value of the composition metric (Q) > 0.4 The biomass expressed in chlorophyll-a can change considerably during the vegetation period (Chl-a: 5μgl^{-1} – >80 μgl^{-1}), but the mean value in the growing season is less than 65 μgl^{-1}. Higher algal biomass can frequently develop in late summer. Longer blooms may occur. The Secchi depth is frequently less than 1m. Decrease of the oxygen concentration occurs towards the deeper layers, and oxygen depletion may develop.
Poor 0.2-0.4	Waters showing evidence of major alterations to the values of the biological quality elements for the surface water body type and in which the relevant biological communities deviate substantially from those normally associated with the surface water body type under undisturbed conditions, shall be classified as poor.	The ratio of the impacted taxa > 50 %. Relative abundance of the reference assemblages is less than 30%. Value of the composition metric (Q) > 0.2 Algal blooms frequently develop. The mean value of the Chl-a is higher than 65μgl^{-1}. Daily fluctuation of the oxygen is high. Over-saturation may develop. The bottom layer can be anoxic in late summer period.
Bad < 0.2	Waters showing evidence of severe alterations to the values of the biological quality elements for the surface water body type and in which large portions of the relevant biological communities normally associated with the surface water body type under undisturbed conditions are absent, shall be classified as bad.	Ratio of the reference and neutral taxa is smaller than 20 %. Impacted taxa dominate. (>80%) The value of the composition metric (Q) < 0.2 Continuous blooms may develop in the growing season. The mean value of the Chl-a >105μgl^{-1}. Daily fluctuation of the oxygen is very high. Over-saturation can frequently occur. The bottom layer can be anoxic. Early morning oxygen depletion frequently occurs. Development of noxious compounds might be expected.

7. Conclusion

Three participating in the intercalibration exercise and harmonised their assessment systems. Results are presented in Table 20 and included in the EC Decision on intercalibration (EC 2018).

Table 17. Results: Ecological quality ratios of national classification methods intercalibrated

Country	National classification systems intercalibrated	Ecological Quality Ratios	
		High-good boundary	Good-moderate boundary
Bulgaria	HLPI-Hungarian lake phytoplankton index	0.80	0.60
Hungary	HLPI-Hungarian lake phytoplankton index	0.80	0.60
Romania	HLPI-Hungarian lake phytoplankton index	0.80	0.60

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Annex

Table 17 Raw data for lake years in the EC GIG. TP = total phosphorus [µgl⁻¹], TN = total nitrogen [mgl⁻¹], COD = chemical oxygen demand [mgl⁻¹], LU = lake use, Stressor = combined stressor index, HLPI = Hungarian lake phytoplankton index, Chl-a = chlorophyll-a [µgl⁻¹], Ab_{Cyano} = relative abundance of Cyanobacteria [range 0 – 1], Q = Q index, Q / Qmax (see chapter0), EQRComp.=composition metric EQR. Benchmark sites are indicated by * and written in bold.

MS	Lake name	Year	TP	TN	COD	LU	Stressor	HLPI	Chl-a	EQR_{Chla}	Ab_{cyano}	Q	Q/Qmax	EQR_{Comp}
HU	**Egyek-Kócsi Tározó, Górés ***	2005	498	0,57	36,13	1	1,52	0,80	12,5	0,81	0,01	6,08	0,64	0,79
		2006	190	0,37	47,28	1	1,52	0,68	20,3	0,68	0,00	5,18	0,69	0,68
		2009	65	1,64	29,16	1	1,30	0,92	4,0	0,96	0,02	6,57	0,82	0,85
RO	**Snagov ***	2008	42	0,68	26,41	1	0,91	0,60	21,3	0,66	0,30	3,83	0,41	0,50
		2009	58	0,64	20,07	1	0,95	0,81	8,7	0,86	0,03	5,33	0,73	0,70
		2010	110	0,48	26,99	1	1,15	0,86	24,1	0,92	0,12	5,60	0,82	0,73
HU	**Tiszadobi Holt-Tisza, Malom-Tisza úszóláp ***	2005	422	0,59	29,44	1	1,42	0,85	8,9	0,86	0,04	6,25	0,88	0,81
		2006	316	0,29	30,92	1	1,30	0,71	22,0	0,65	0,03	6,27	0,67	0,81
		2009	50	1,12	32,40	1	1,21	0,73	12,7	0,80	0,15	4,68	0,58	0,61
HU	**Tiszadobi Holt-Tisza, Darab Tisza ***	2005	512	0,57	14,40	1	1,39	0,66	25,5	0,59	0,02	6,11	0,77	0,79
		2006	422	0,35	23,58	1	1,31	0,78	13,5	0,77	0,05	6,10	0,58	0,79
		2007	770	0,37	20,77	1	1,19	0,77	15,0	0,77	0,01	5,99	0,57	0,78
		2009	54	0,86	22,28	1	1,02	0,79	10,1	0,84	0,03	5,34	0,66	0,70
HU	**Tiszadobi Holt-Tisza, Falu-Tisza ***	2005	273	0,56	31,83	1	1,38	0,62	21,8	0,67	0,38	3,99	0,21	0,52
		2006	293	0,53	23,45	1	1,21	0,80	11,6	0,81	0,07	5,98	0,70	0,78
		2007	412	0,36	31,17	1	1,40	0,68	20,7	0,69	0,27	5,19	0,89	0,67
RO	**Dunarea Veche ***	2009	240	1,10	9,36	1	1,26	0,72	24,2	0,64	0,00	6,91	0,86	0,89
		2010	526	1,15	10,50	1	1,38	0,59	48,3	0,45	0,04	6,70	0,80	0,86
HU	Atkai-Holt Tisza alsó vége, Algyő	2009	292	0,90	30,90	1	1,61	0,79	10,3	0,85	0,08	5,08	0,70	0,66
HU	Atkai-Holt Tisza, Szeged (felső vég)	2007	755	0,48	45,15	1	1,90	0,72	22,0	0,65	0,00	6,73	0,86	0,87
HU	Atkai-Holt Tisza, Szeged (gátőrház)	2007	390	0,48	46,94	1	1,74	0,75	22,6	0,67	0,00	6,91	0,85	0,89
		2008	390	0,90	30,50	1	1,62	0,79	13,1	0,80	0,00	6,06	0,59	0,79
		2010	336	1,56	41,70	1	2,00	0,84	9,4	0,85	0,00	6,36	0,85	0,83
HU	Szelidi-tó, Dunapataj	2008	105	1,07	88,78	1	1,83	0,59	29,6	0,58	0,04	4,72	0,65	0,62
		2009	83	2,18	59,25	1	1,54	0,62	17,8	0,75	0,45	2,79	0,18	0,36
HU	Szöglegelői Holt Tisza	2006	330	0,56	23,70	1	1,42	0,79	13,6	0,79	0,00	6,02	0,81	0,78
HU	Tiszadobi Holt-Tisza, Malom-Tisza kanyar	2009	59	1,22	32,35	1	1,19	0,68	28,6	0,66	0,16	5,38	0,72	0,70
HU	Tiszadobi Holt-Tisza, Szűcs-Tisza	2005	200	0,52	35,70	1	1,42	0,70	22,8	0,67	0,10	5,87	0,77	0,76
		2006	94	0,35	34,00	1	1,16	0,76	14,7	0,75	0,00	5,89	0,75	0,77
		2007	883	0,44	38,23	1	1,48	0,71	14,9	0,75	0,00	4,86	0,63	0,63
		2009	136	2,06	46,20	1	1,72	0,53	55,9	0,46	0,20	5,09	0,59	0,66

MS	Lake name	Year	TP	TN	COD	LU	Stressor	HLPI	Chl-a	EQR$_{Chla}$	Ab$_{Cyano}$	Q	Q/Qmax	EQR$_{Comp}$
		2010	107	1,07	34,30	1	2,17	0,88	7,5	0,89	0,07	6,67	0,80	0,86
RO	Garla Mare	2009	180	1,71	14,76	1	1,52	0,63	38,2	0,50	0,00	6,94	0,87	0,89
		2010	210	1,55	15,20	1	1,53	0,68	35,7	0,60	0,00	6,56	0,78	0,85
HU	Egyeki Holt Tisza, Egyek	2005	330	0,52	49,03	2	2,04	0,82	15,3	0,80	0,01	6,53	0,80	0,84
		2006	666	0,64	44,08	2	2,13	0,64	41,0	0,57	0,01	6,04	0,80	0,78
		2007	605	1,38	52,45	2	2,28	0,71	26,4	0,73	0,00	5,24	0,63	0,68
		2009	331	5,96	81,30	2	3,02	0,39	79,8	0,33	0,00	3,94	0,48	0,51
HU	Vadkerti-tó, Soltvadkert	2008	125	1,96	57,80	2	2,31	0,44	53,2	0,46	0,46	3,15	0,47	0,41
		2009	97	2,70	74,10	2	2,38	0,31	90,7	0,31	0,33	2,58	0,14	0,33
HU	Félhalmi-holtág,a vízkivételnél	2009	109	1,19	89,40	2	2,08	0,75	16,3	0,74	0,04	5,94	0,90	0,77
HU	Nagyréti - tározó	2010	326	15,33	52,10	2	2,56	0,53	37,4	0,50	0,00	4,51	0,58	0,59
HU	Szarvas-Békés-szentandrási holtág,	2007	282	1,08	20,23	2	1,88	0,63	37,3	0,53	0,00	6,51	0,82	0,84
		2009	213	1,20	22,70	2	1,88	0,63	48,5	0,57	0,00	5,77	0,80	0,75
HU	Szarvasi-holtág torkolat	2005	377	0,85	27,00	2	1,47	0,85	6,9	0,91	0,00	5,56	0,66	0,73
RO	Galaţui	2008	191	1,91	15,00	2	1,93	0,70	27,7	0,71	0,16	5,21	0,66	0,68
		2009	205	2,01	15,00	2	1,98	0,79	13,4	0,82	0,18	5,49	0,78	0,72
		2010	135	1,09	36,78	2	1,76	0,79	13,4	0,78	0,11	6,17	0,55	0,79
HU	Holt-Szamos, Géberjén	2007	588	1,72	49,68	2	2,55	0,57	30,6	0,60	0,03	3,85	0,44	0,50
		2009	373	1,74	33,28	2	2,35	0,60	27,2	0,60	0,02	4,58	0,52	0,60
HU	Holt-Szamos, Tunyogmatolcs	2007	727	2,27	48,20	2	2,56	0,59	21,0	0,66	0,02	3,35	0,45	0,43
		2009	684	1,78	36,28	2	2,45	0,57	27,2	0,59	0,26	4,06	0,39	0,53
HU	Rétközi-tó, Szabolcsveresmart	2009	312	2,22	39,42	2	2,46	0,45	64,2	0,39	0,07	4,21	0,44	0,55
HU	Tiszadobi Holt-Tisza, Felső Darab Tisza	2005	457	0,65	35,98	2	1,99	0,61	90,2	0,54	0,00	5,86	0,66	0,76
		2006	440	0,53	42,16	2	1,88	0,65	42,2	0,63	0,00	5,20	0,68	0,68
HU	Gyovai-Mámai Holt-Tisza, Csongrád (alsó vég)	2009	188	1,20	73,20	2	2,23	0,51	53,6	0,45	0,19	4,92	0,42	0,64
HU	Gyovai-Mámai Holt-Tisza, Csongrád (felső vég)	2009	80	1,18	42,40	2	1,92	0,80	13,0	0,79	0,00	6,34	0,76	0,82
HU	Nagybaracskai Holt-Duna, Dunafalva	2010	170	1,43	29,60	2	1,87	0,84	10,5	0,83	0,01	6,74	0,86	0,87
BG	Srebarna	2014	84	1,18	34,26	2	1,62	0,58	38,9	0,57	0,33	5,80	0,73	0,61
HU	Fancsika 1-es tározó, Debrecen	1993	408	2,69	134,00	3	3,45	0,19	219,6	0,07	0,53	3,30	0,55	0,43
HU	Fancsika 2-es tározó, Debrecen	1993	269	1,21	55,50	3	2,65	0,39	89,0	0,30	0,31	4,27	0,63	0,56
HU	Kati-tó, Debrecen	1999	262	0,77	41,33	3	2,38	0,49	76,8	0,50	0,24	3,53	0,27	0,46
		2000	300	0,58	60,50	3	2,57	0,13	143,9	0,11	0,89	1,40	0,23	0,17
HU	Mézeshegyi tó, Debrecen	1993	1053	2,03	232,00	3	3,39	0,08	782,8	0,00	0,85	1,82	0,15	0,23
		1994	386	1,85	64,25	3	3,03	0,42	81,1	0,39	0,14	3,66	0,43	0,47
		1995	420	0,38	101,00	3	2,92	0,27	131,4	0,16	0,14	3,70	0,40	0,48
HU	Kakasszéki-tó, Székkutas	2010	410	16,51	109,75	3	3,56	0,45	133,0	0,33	0,15	5,31	0,77	0,69

MS	Lake name	Year	TP	TN	COD	LU	Stressor	HLPI	Chl-a	EQR_{Chla}	Ab_{Cyano}	Q	Q/Qmax	EQR_{Comp}
HU	Madarász-tó, Mórahalom (2-es tó, észak)	2007	2788	1,87	198,18	3	3,25	0,14	457,6	0,05	0,58	2,60	0,28	0,33
		2010	288	2,33	81,48	3	3,20	0,51	58,7	0,39	0,10	5,68	0,72	0,74
HU	Madarász-tó, Mórahalom (4-es tó, dél)	2007	715	1,48	163,40	3	3,36	0,25	285,2	0,10	0,36	4,11	0,83	0,53
HU	Serházzugi Holt-Tisza, Csongrád (sportpálya)	2008	1527	1,67	65,80	3	2,89	0,29	105,1	0,20	0,36	3,74	0,58	0,49
		2010	158	1,93	41,40	3	2,53	0,44	79,6	0,35	0,01	4,72	0,75	0,62
HU	Tiszakécskei Holt-Tisza	2005	570	0,88	113,00	3	3,07	0,23	432,6	0,00	0,07	5,24	0,77	0,68
HU	Tiszaugi Holt-Tisza	2007	288	1,39	112,60	3	3,04	0,21	389,4	0,12	0,60	3,08	0,34	0,40
HU	Vidreéri halastavak, Felgyő (1-as tó)	2008	308	1,95	88,03	3	3,12	0,44	74,2	0,34	0,11	4,91	0,63	0,64
HU	Vidreéri halastavak, Felgyő (4-as tó)	2008	450	2,47	110,03	3	3,29	0,42	145,7	0,26	0,10	5,63	0,57	0,73
RO	Victoria-Geormane	2009	53	1,35	11,45	3	1,70	0,45	60,36	0,49	0,55	2,85	0,26	0,37
		2010	65	2,12	12,07	3	1,98	0,44	92,38	0,33	0,08	5,00	0,57	0,65
RO	Iezer Calarasi	2009	91	1,66	83,34	3	2,64	0,46	82,88	0,33	0,17	5,58	0,52	0,73
		2010	93	0,85	26,63	3	1,85	0,54	43,41	0,49	0,30	4,85	0,34	0,63

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