Functional classification of phytoplankton: materials and methods for developing non-taxonomic quality indices

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THE PARADOX OF THE PLANKTON*

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The problem that I wish to discuss in the present contribution is raised by the very paradoxical situation of the plankton, particularly the phytoplankton, of relatively large bodies of water.

We know from laboratory experiments conducted by many workers over a long period of time (summary in Provasoli and Pintner, 1960) that most members of the phytoplankton are phototrophs, able to reproduce and build up populations in inorganic media containing a source of CO_2, inorganic nitrogen, sulphur, and phosphorus compounds and a considerable number of other elements (Na, K, Mg, Ca, Si, Fe, Mn, B, Cl, Cu, Zn, Mo, Co and V) most of which are required in small concentrations and not all of which are known to be required by all groups. In addition, a number of species are known which require one or more vitamins, namely thiamin, the cobalamines (B_{12} or related compounds), or biotin.

The problem that is presented by the phytoplankton is essentially how it is possible for a number of species to coexist in a relatively isotropic or unstructured environment all competing for the same sorts of materials. The problem is particularly acute because there is adequate evidence from enrichment experiments that natural waters, at least in the summer, present an environment of striking nutrient deficiency, so that competition is likely to be extremely severe.

According to the principle of *competitive exclusion* (Hardin, 1960) known by many names and developed over a long period of time by many investigators (see Rand, 1952; Udvardy, 1959; and Hardin, 1960, for historic reviews), we should expect that one species alone would outcompete all the others so that in a final equilibrium situation the assemblage would reduce to a population of a single species.

The principle of competitive exclusion has recently been under attack from a number of quarters. Since the principle can be deduced mathematically from a relatively simple series of postulates, which with the ordinary postulates of mathematics can be regarded as forming an axiom system, it follows that if the objections to the principle in any cases are valid, some or all the biological axioms introduced are in these cases incorrect. Most objections to the principle appear to imply the belief that equilibrium under a given set of environmental conditions is never in practice obtained. Since the deduction of the principle implies an equilibrium system, if such sys-

*Contribution to a symposium on Modern Aspects of Population Biology. Presented at the meeting of the American Society of Naturalists, cosponsored by the American Society of Zoologists, Ecological Society of America and the Society for the Study of Evolution. American Association for the Advancement of Science, New York, N. Y., December 27, 1960.

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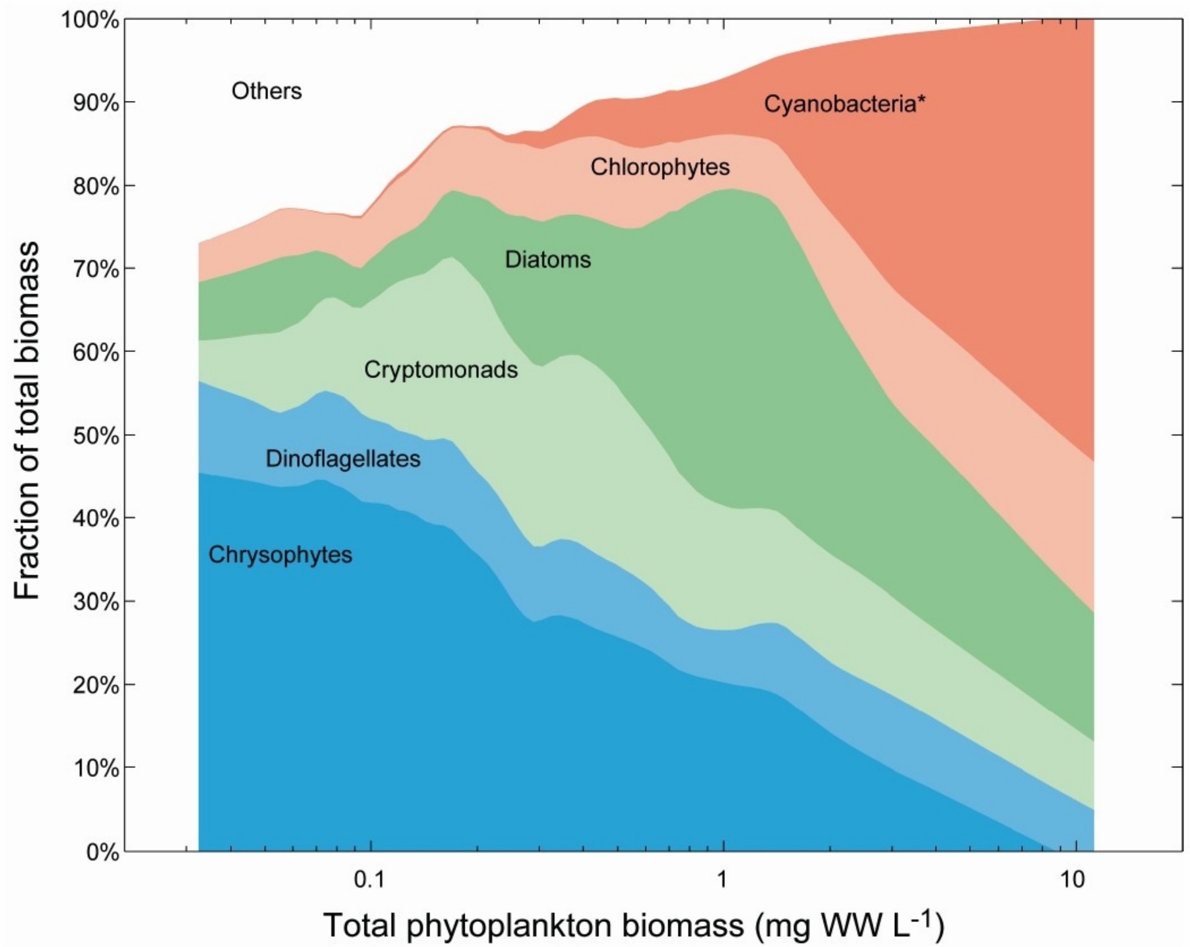

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Dominance ratio between phytoplankton taxonomic groups

Indices based on ratios among numbers of species of different algal groups

- **Thunmark (1945)**
  chlorococcales/desmids ratio
  <1 = oligotrophy
  >1 = eutrophy
- **Nygaard (1949)**
  Many indices based on ratios between families and/or orders
- **Stockner (1971)**
  Algal quotient
  Araphidineae/Centrales
  0.0 -1.0 = oligotrophy
  1.0 - 2.0 = mesotrophy
  > 2.0 = eutrophy
- **Catalan (2003)**
  Biovolume ratio between groups variously dominant across a trophic gradient

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Morpho-functional classification

Reynolds (1984-2002)

Codon	Habitat	Typical representatives	Tolerances	Sensitivities
C	Mixed, eutrophic small-medium lakes	*Asterionella formosa* *Aulacoseira ambigua* *Stephanodiscus rotula*	Light, C deficiencies	Si exhaustion, stratification
P	Eutrophic epilimnia	*Fragilaria crotonensis* *Aulacoseira granulata* *Closterium aciculare*	Mild light and C deficiencies	Stratification Si depletion
T	Deep, well mixed epilimnia	*Geminella, Mougeotia, Tribonema*	Light deficiency	Nutrient deficiency
S1	Turbid mixed layers	*Planktothrix agardhii, Limnothrix redekei, Pseudanabaena*	Highly light deficient conditions	flushing
R	Metalimnia of mesotrophic stratified lakes	*Planktothrix rubescens, P. mougeotii*	Low light, strong segregation	Instability

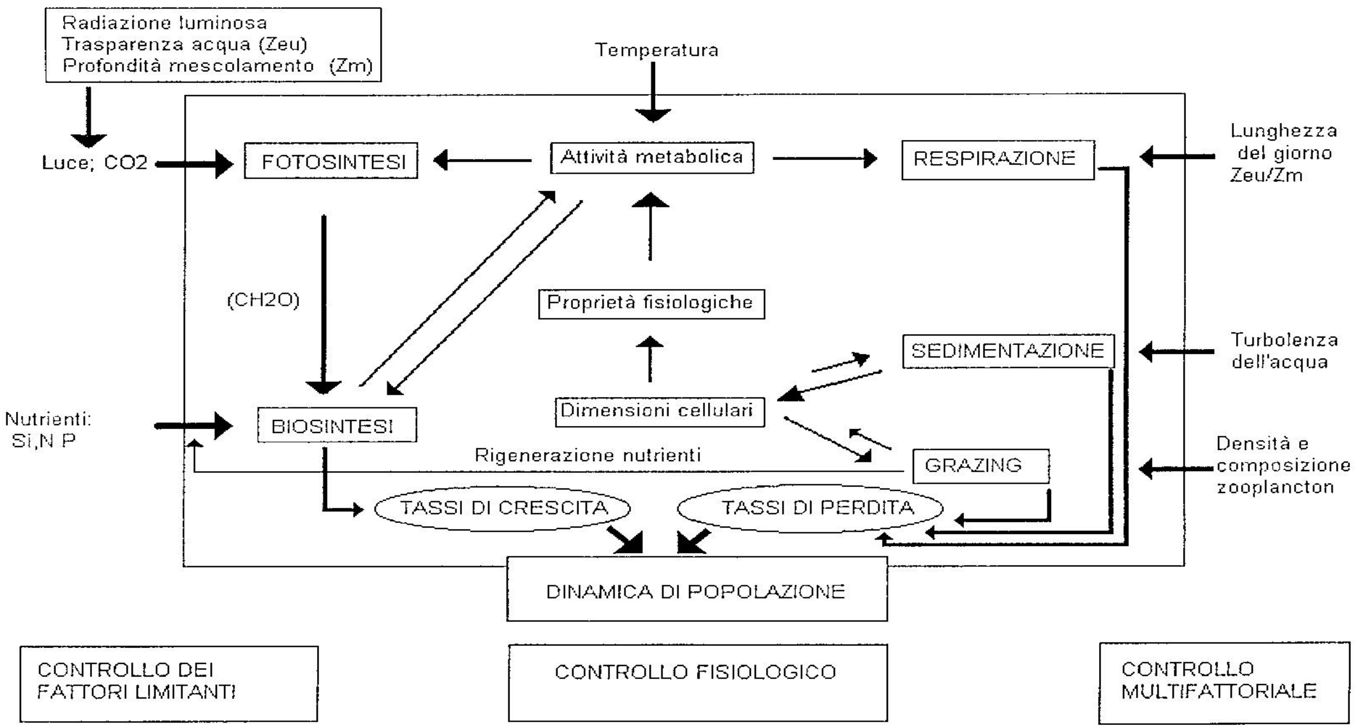

Fig. 1. Fattori di controllo della dinamica della comunità fitoplanctonica e loro interazioni.

EU-FP7 2009-2012

Water bodies in Europe:

Integrative Systems to assess Ecological status and Recovery

Deliverable D3.1-1: Report on phytoplankton composition metrics, including a common metric approach for use in intercalibration by all GIGs

Functional traits metric

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Rationale background for functional traits metric

- Morphology and functions of a phytoplankton cell are strictly related in determining the role of the organisms in the environment and in shaping the structure of a phytoplankton assemblage.
- Phytoplankton cell size is a key feature in the ecological relationships, being related to the efficiency of many eco-physiological processes.
- Following the dimensional approach, a phytoplankton assemblage can be described in terms of size spectra: the use of size spectra in describing the response of a phytoplankton assemblage to environmental gradients has been proven to be a valid instrument.
- The use of simple morphological traits has been proven to be successful in describing a phytoplankton succession in environments with different characteristics (Salmaso & Padisak, 2007).

Approach - Selection of size classes

The classification is done by dividing the cells in a certain number of size classes, created by doubling the cell volume, i.e., by standard increments of the cell size logarithm. In the example, the size classes are ≤0.5 μm3, followed by 0.5-1, 1-2, 2-4 μm3, etc. Each of them is indicated by the notation VX, where V means Volume and X is the upper limit of the size class expressed as logV. A total number of 19 size classes were obtained, from V-0.3 to V5.1.

See Kamenir & Morabito, 2009, J.Limnol.

Taxonomic group	Operational Taxonomic Unit (OTU)	Cell Volume (V, μm^3)	LogV	Size Class: The volume range and the upper border log
CYA	*Aphanothece clathrata (01-02)*	0.4	-0.40	**<=0.5 (-0.3)**
CYA	*Aphanothece smithii (03-05)*	0.4	-0.40	
CYA	*Aphanothece sp.1*	0.4	-0.40	
CYA	*Cfr. Cyanobium sp.*	0.5	-0.30	
CYA	*Aphanocapsa incerta*	0.6	-0.22	**>0.5-1 (0.0)**
CYA	*Aphanothece bachmannii*	0.6	-0.22	
CYA	*Aphanothece cf. floccosa (01-02)*	0.6	-0.22	
CYA	*Aphanothece smithii (02)*	0.6	-0.22	
CYA	*Aphanothece sp.2*	0.6	-0.22	
CYA	*Cfr. Aphanocapsa delicatissima (99-05)*	0.7	-0.15	
CYA	*Aphanothece cf. floccosa (03-05)*	0.8	-0.10	
CYA	*Aphanothece smithii (01)*	0.8	-0.10	
CYA	*Cfr. Aphanocapsa delicatissima (98)*	0.8	-0.10	
CYA	*Microcystis incerta*	1.0	0.00	
CYA	*Aphanothece clathrata (98-00)*	1.1	0.04	**>1-2 (0.3)**
CYA	*Aphanothece smithii (99-00)*	1.1	0.04	
CHLO	*Hyaloraphidium contortum*	1.2	0.08	
CYA	*Aphanothece clathrata (86-90)*	1.3	0.11	
CHLO	*Lyngbya limnetica*	2.7	0.43	**>2-4 (0.6)**
CYA	*Aphanothece clathrata (92-97)*	3.3	0.52	
CYA	*Aphanothece smithii (95-97)*	3.3	0.52	
CHLO	*Choricystis coccoides*	3.3	0.52	
CYA	*Cyanodictyon planctonicum*	3.3	0.52	

Approach – Selection of MF Groups

Table 2. Morpho-Functional Groups. From Salmaso & Padisak (2007).

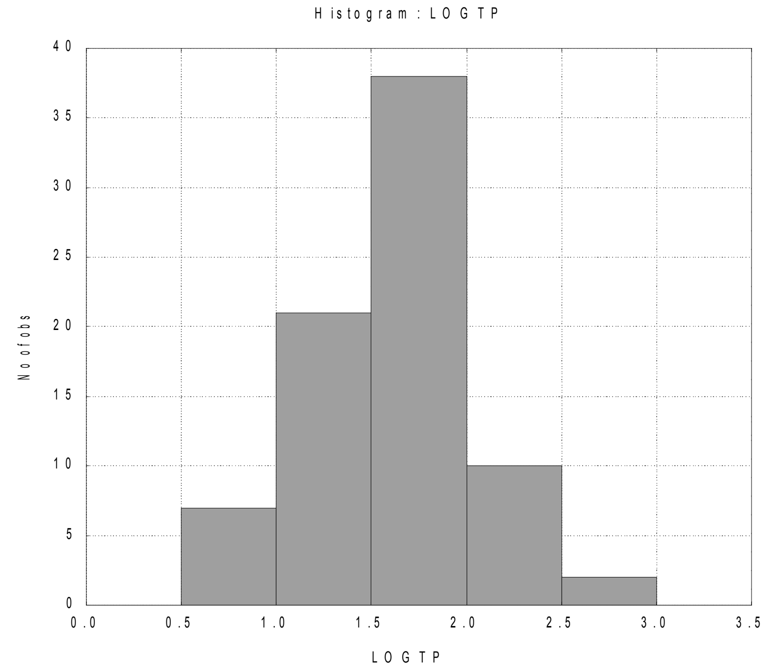
Flagellates	Potential mixotrophs	1 Large (colonial or unicellular)	1a Large Chrysophytes/Haptophytes
			1b Large Dinophytes
			1c Large Euglenophytes
		2 Small (unicellular)	2a Small Chrysophytes/Haptophytes
			2b Small Dinophytes
			2c Small Euglenophytes
			2d Cryptophytes
	Mostly autotrophs	3 Phytomonadina	3a Unicellular Phytomonadina
			3b Colonial Phytomonadina
Without flagella	Cyanobacteria	4 Unicellular	4 Unicellular cyanobacteria
		5 Colonies	5a Thin filaments (Oscillatoriales)
			5b Large vacuolated Chroococcales
			5c Other large colonies, mostly non-vacuolated Chroococcales
			5d Small colonies, Chroococcales
			5e Nostocales
	Diatoms	6 Large	6a Large Centrics
			6b Large Pennates
		7 Small	7a Small Centrics
			7b Small Pennates

Approach - Calculation of the trophic index

1. Calculation of total BV per size class or MFG as sum of species BV.
2. Transformation in percentage and in double square root of percentage BV.
3. Calculation of trophic scores for each size class/MFG using TP values as weights.
4. Calculation of indicator values for each size classes/MFG.
5. Calculation of trophic index (weighted average of trophic scores and indicator values of each size class/MFG).

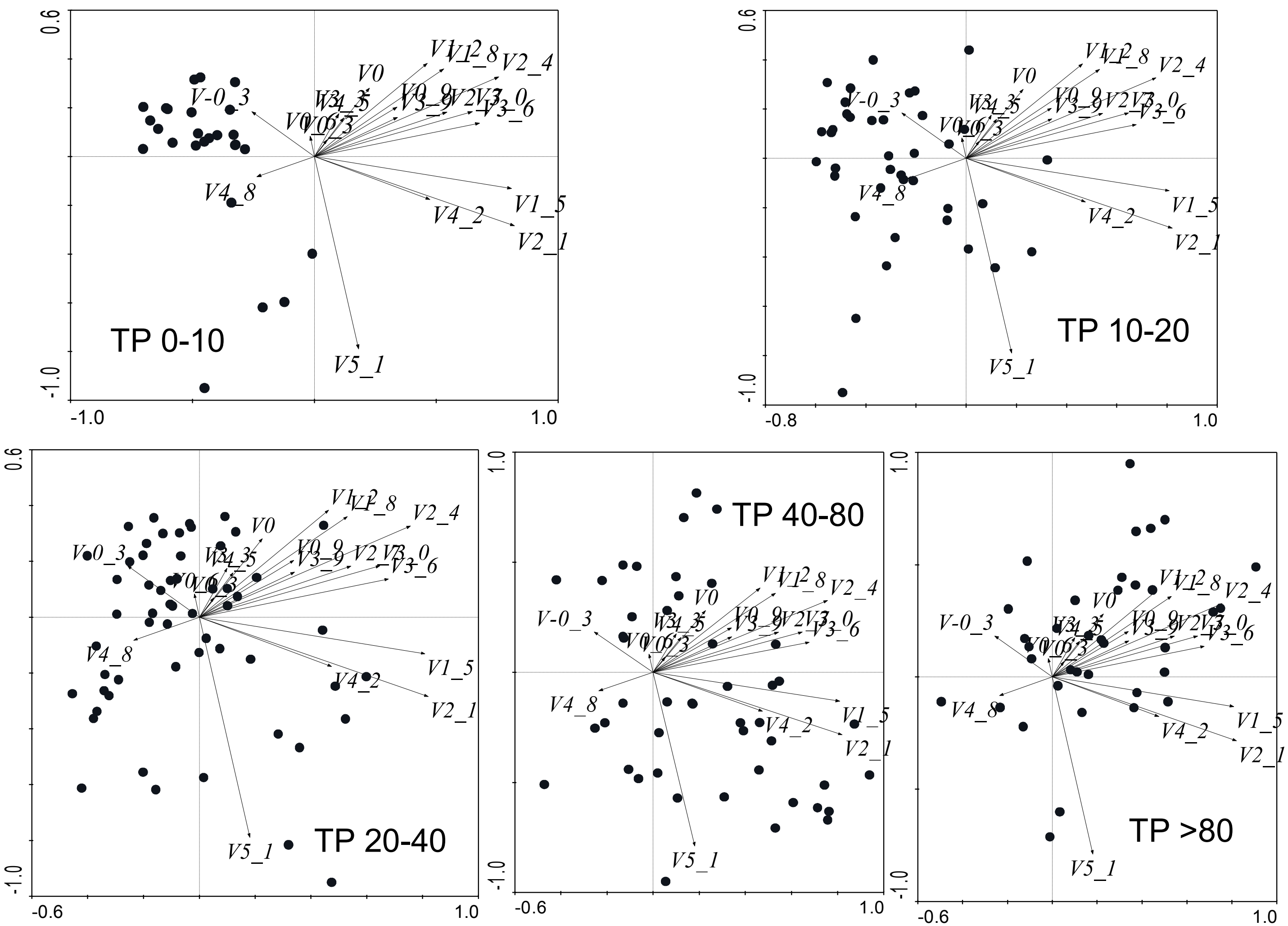
Data set

- WISER Database: >5600 lakes
- Focus on lowland and shallow or very shallow lakes. Lakes with only one sample in the period Jun-Sep were discarded.
- After applying the above criteria, 229 lakes were selected: CBGIG – 119, NGIG – 80, MGIG – 30.



•A calibration dataset was used for calculating the trophic scores. This was composed of 78 lakes, belonging to CB and N GIGs: the lakes selected provide a good covering of the trophic spectrum.

Response to TP gradient – Size classes



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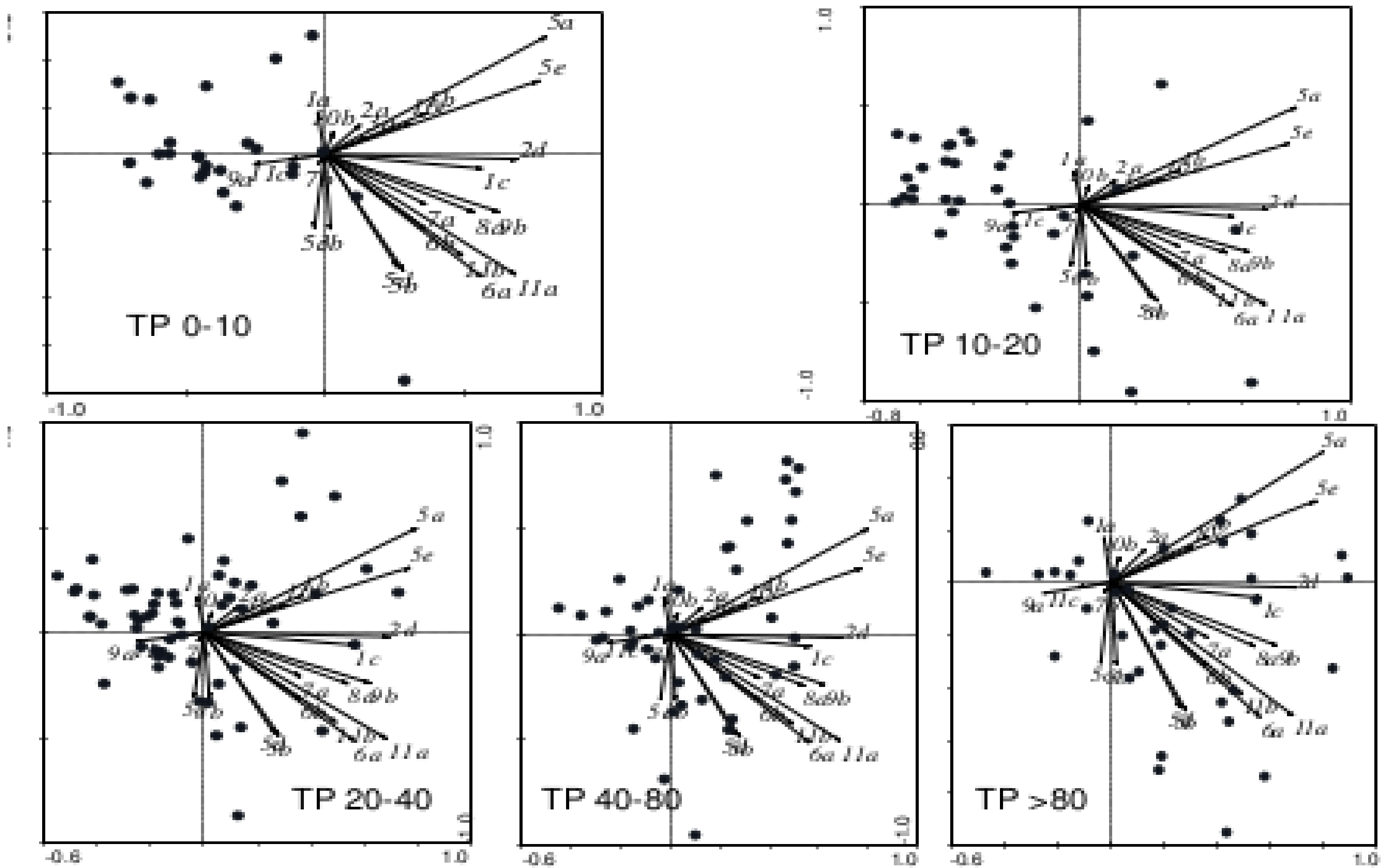
Response to TP gradient – MFG



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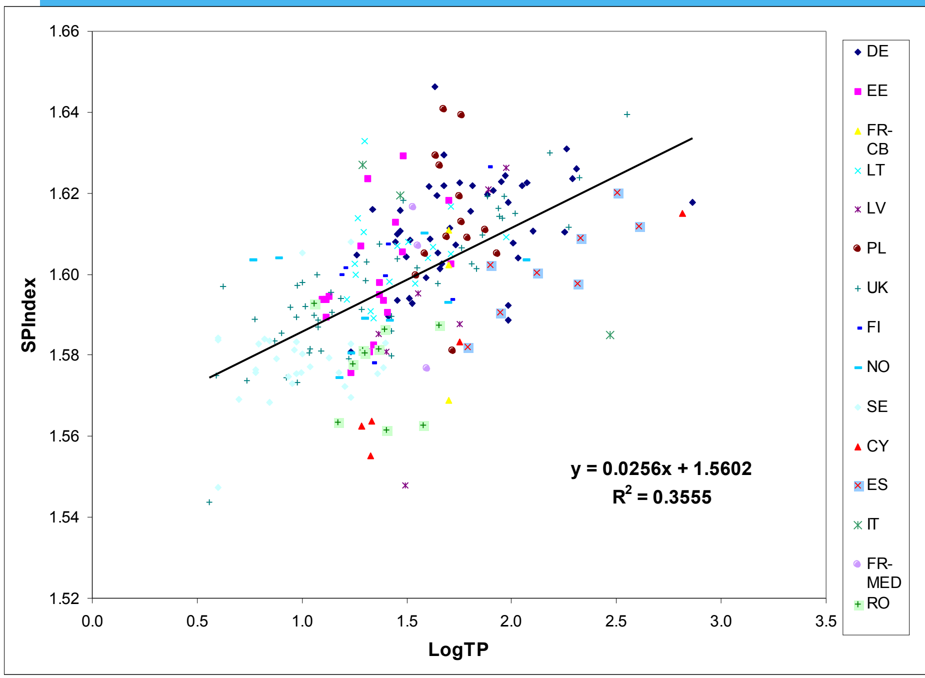
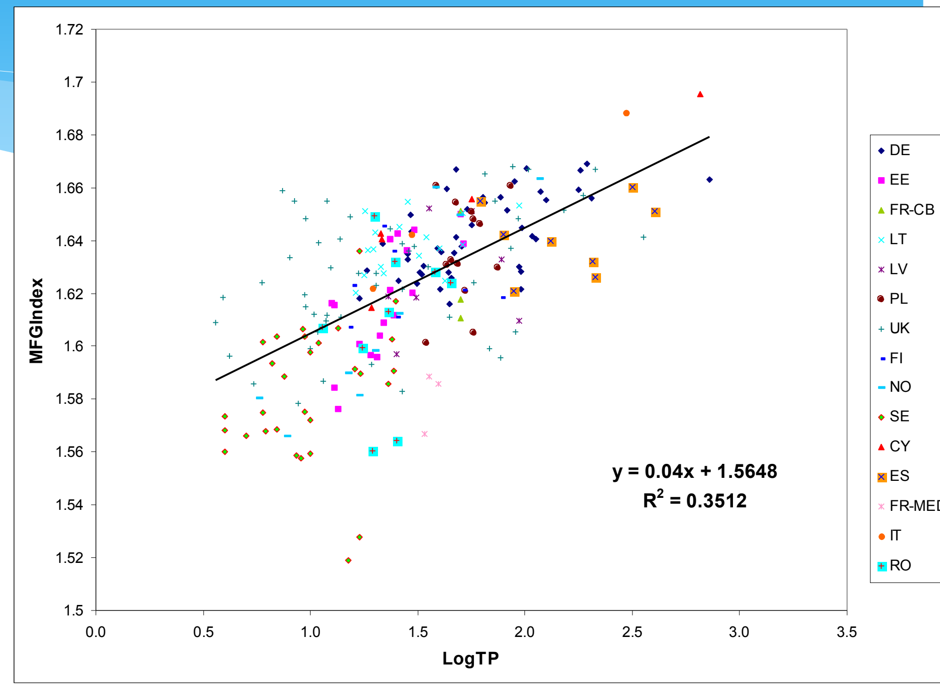
Response to TP gradient – Size and MFG Index

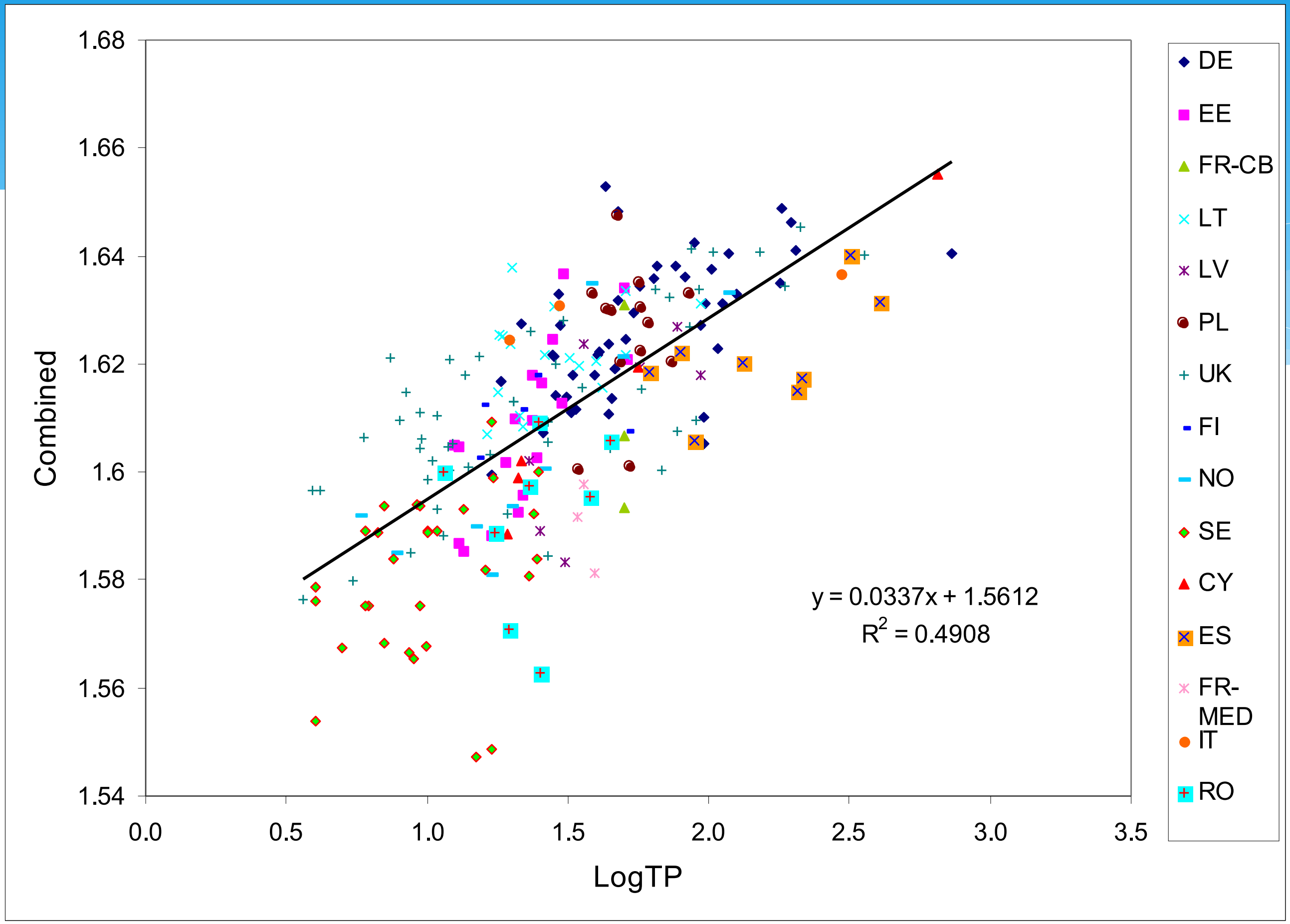




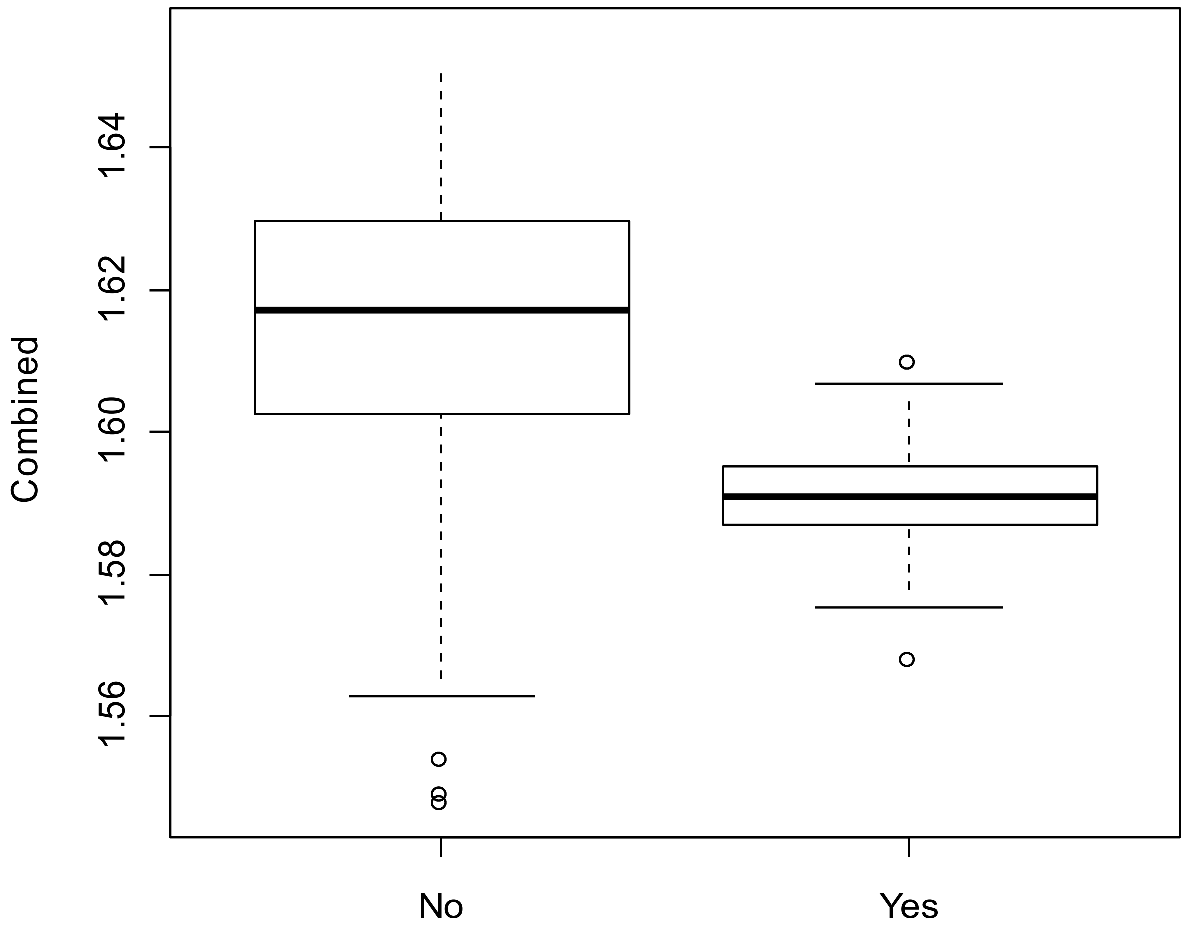
SPI-CB = 0.023LogTP + 1.569; $R^2 = 0.229$; $p<0.0001$; n=122
SPI-N = 0.0239LogTP + 1.559; $R^2 = 0.342$; $p<0.0001$; n=77
SPI-M = 0.019LogTP + 1.559; $R^2 = 0.185$; $p<0.02$; n = 29

MFGI-CB = 0.0333LogTP + 1.581; $R^2 = 0.3345$; $p<0.0001$; n=122
MFGI-N = 0.0221LogTP + 1.579; $R^2 = 0.0496$; $p<0.05$; n=77
MFGI-M = 0.0443LogTP + 1.548; $R^2 = 0.384$; $p<0.001$; n = 29

Response to TP gradient – Combined Index



MFGI-CB = 0.028LogTP + 1.575; R^2 = 0.389; p<0.0001; n=122
MFGI-N = 0.025LogTP + 1.566; R^2 = 0.225; p<0.0001; n=77
MFGI-M = 0.031LogTP + 1.554; R^2 = 0.496; p<0.0001; n = 29



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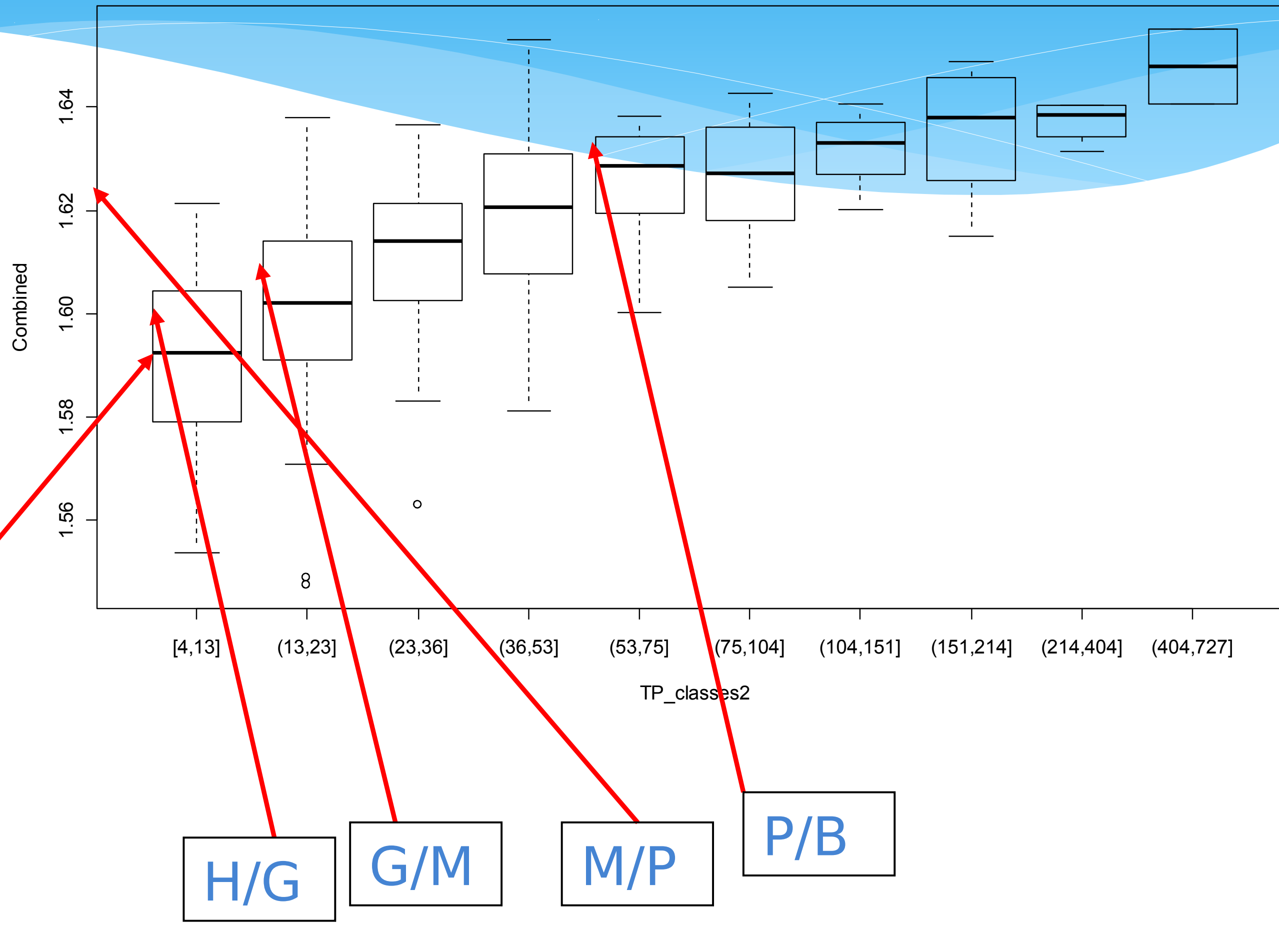
Ref

Calculation of thresholds and EQR

1. Median of reference lakes = reference value
2. 90% quantile = H/G threshold
3. 90% quantile of TP class 13-23 µg l-1 = G/M threshold
4. 90% quantile of TP class 53-75 µg l-1 = P/B threshold
5. M/P threshold obtained from regression between threshold values and norm EQR



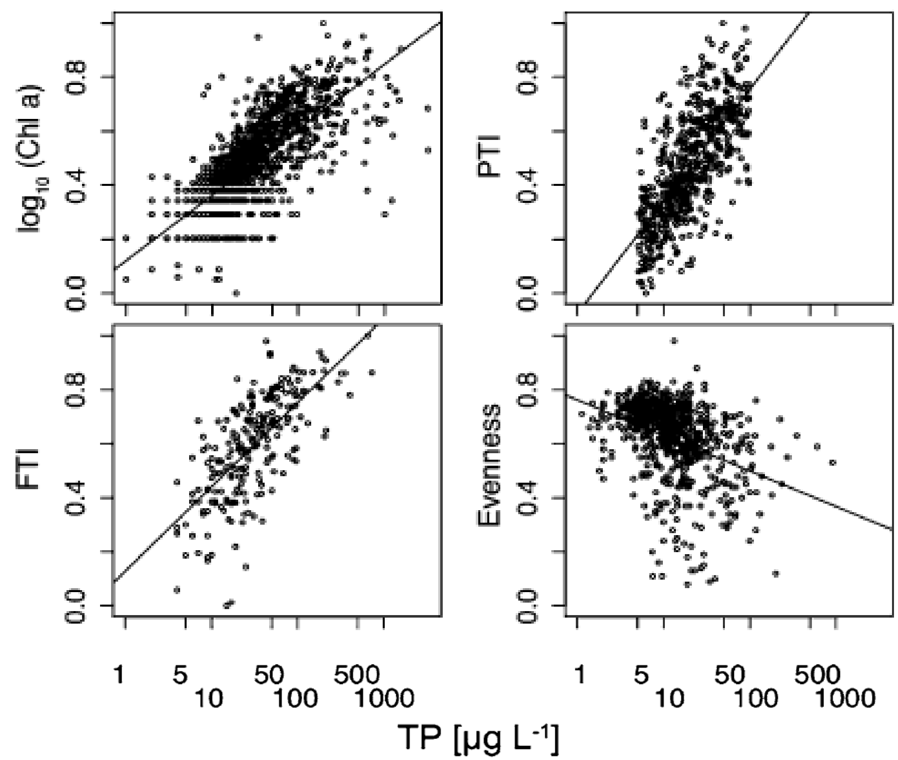
Hydrobiologia (2013) 704:57–74
DOI 10.1007/s10750-012-1436-y

WATER BODIES IN EUROPE

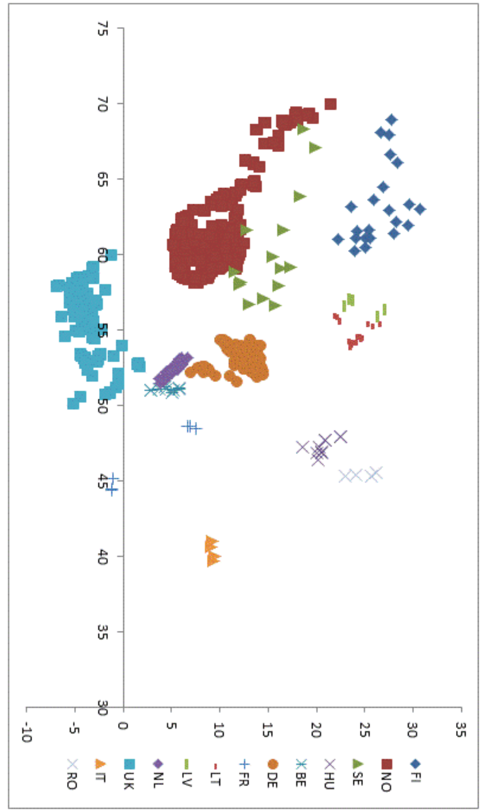
Review Paper

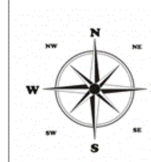
Ecological status assessment of European lakes: a comparison of metrics for phytoplankton, macrophytes, benthic invertebrates and fish

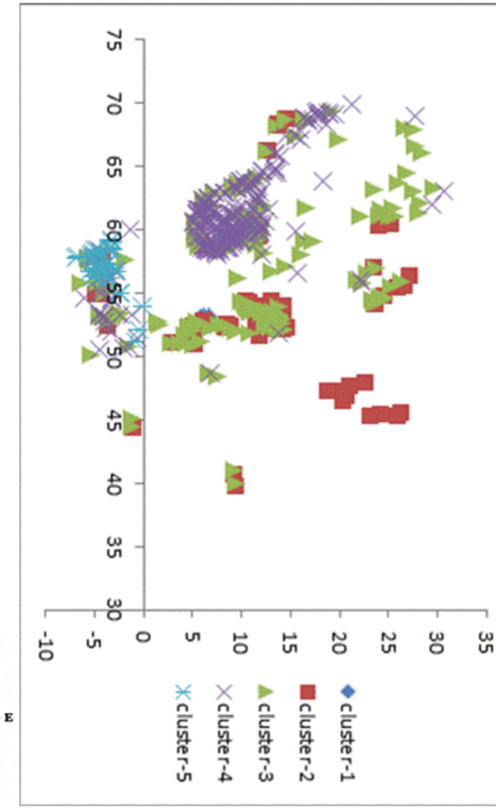
Anne Lyche-Solheim · Christian K. Feld · Sebastian Birk · Geoff Phillips · Laurence Carvalho · Giuseppe Morabito · Ute Mischke · Nigel Willby · Martin Søndergaard · Seppo Hellsten · Agnieszka Kolada · Marit Mjelde · Jürgen Böhmer · Oliver Miler · Martin T. Pusch · Christine Argillier · Erik Jeppesen · Torben L. Lauridsen · Sandra Poikane



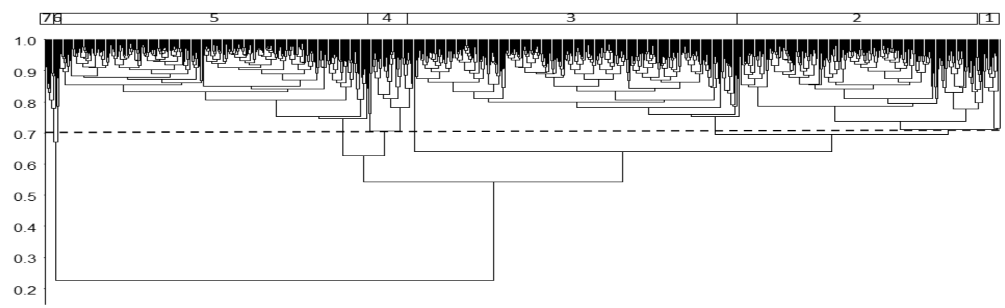
1) single celled,
2) non-filamentous colonial taxa,
3) filamentous colonial taxa,
4) presence of flagella,
5) mixotrophy,
6) size larger than 40 µm,
7) nitrogen fixers,
8) silicified taxa,
9) vacuolated taxa







Data set=831 lakes



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Open questions

1. Which traits are selected under certain environmental conditions?
2. Is the response the result of the environmental heterogeneity?
3. Is there any relationship with geographic distribution of the lakes?
4. Do lakes/lake types with higher environmental patchiness offer more ecological niches and host an higher number of functional traits?
5. Which traits give the better response to eutrophication pressure (considering the needs of the WFD)?

Taxonomy is not a good indicator of ecological diversity, because the functional role of the species is not explicitely established.

Graham P. Harris, 1984

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