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On typology and reference conditions for phytoplankton in rivers and lakes in Germany

Ute Mischke[1)] , Brigitte Nixdorf[2)] and Horst Behrendt[1)]

[1)] *Leibniz-Institute of Freshwater Ecology and Inland Fisheries, Müggelseedamm 310, 12587 Berlin, Germany, email:ute.mischke@gmx.de*
[2)] *Brandenburg University of Technology Cottbus, Water Conservation, Seestrasse 45, 15526 Bad Sarrow, Germany*

Introduction

Phytoplankton characteristics, such as biomass, blooms and composition, reflect the degradation of trophic state in a broad range and the pretictive power is limited (Vollenweider 1968, Reynolds 1997 etc.). The EU-WFD gives the great chance to specify this reaction for different water body types, determined by hydrological and geomorphological processes. The biological descriptions of specific water body types will give us a deeper inside of the response of biological groups to disturbances and the opportunity to define more specific management tools to achieve a higher ecological status.

The water body types must represent typical habitats, which are inhabited by specific assemblages of organisms. Therefore, the types would fit the best with biological characteristics,if they are defined as ecotopes (Platteeuw and van der Molen 2001).On the other hand, it is almost unsolvable to define characteristic habitats, which are meaningful for all four biological groups (fish, macrophytes/phytobenthos, phytoplankton, macroinvertebrates), and to reduce the number of types to a realistic and practicable level (10 to 20 types). This is because Germany´s landscape cover three ecoregions (alps; highlands; flatland) and a lot of different geomorphotypes. This impossible task given by the WFD results in a typology of lakes or rivers, which are adequately only to those biological groups, for which the typology was primarily developed. Development of assessment method for macroinvertebrates are the most advanced ones in Germany. Thus, the authorised typology of rivers is dominated by criteria important for macroinvertebrates. The typology of lakes is a result of former national assessment criteria and of criteria suggested by EU-WFD and is derived from a data set of 319 lakes larger than 0.5 km^2 (Mathes et al. 2002). We have to arrange our biotic data within this given typology, since it is unproductive to develop specific typology for each biological group. We have to verify the typologys applicability for phytoplankton and propose additional criteria, when they are absolutely necessary. Concerning the classification of river phytoplankton, only few of all types must be evaluated by phytoplankton.

Our first preliminary results reveal that even within one degradation state and one water type the reaction of phytoplankton on trophic disturbances is still very broad. Therefore, we recommend the description of alternative states within one degradation status. Describing alternative states also for reference conditions, which are likely in shallow lakes and rivers with a alternative dominance of macrophytes or phytoplankton, is useful for considering the interaction of the different biological groups.

Material and methods

Phytoplankton data of more than 110 lakes and 800 taxa, are measured in former lake assessment programs by regional institutions of Germany, is collected in a data bank. Because of different taxon naming, structure and taxonomic differentiation, all data were first corrected, equalized and completed with morphometric and trophic data of the lakes. A comparable data bank contains phytoplankton data of plankton dominated rivers and riverine lakes of the region of Berlin/Brandenburg. The degradation status of the water bodies were pre-assessed by assessment methods used as a German standard to evaluate the trophic state (LAWA 1999; Länderarbeitsgemeinschaft Wasser 2002).

Typology of lakes in Germany

In Germany, the typology of lakes was developed using following discriminating criteria (Mathes *et al.* 2002): 1) ecoregion (alps and prealps (>800m altitude); highlands (300-800 m altitude); flatland), 2) carbonate concentration (Ca >15 mg/L; Ca <15mg/L) , 3) ratio of catchment area to lake volume (VQ >1.5; VQ <1.5), 4) thermal stratification (stratified or not stratified) and 5) retention time (3-30 days for riverine lakes; >30 days for not stratified lakes in the lowlands). 319 lakes and reservoirs with more than 0.5 km^2 were analysed and were attached to following 14 different types (Mathes *et al.* 2002).

1 prealps: calcareous, relative large catchment area, not stratified
2 prealps: calcareous, relative large catchment area, stratified
3 prealps: calcareous, relative small catchment area, stratified
4 alps: calcareous, stratified
in the highlands (300 – 800 m altitude):
5 calcareous, relative large catchment area, stratified (only reservoirs)
6 calcareous, relative large catchment area, not stratified (almost only reservoirs)
7 calcareous, relative small catchment area, stratified (one reservoir, one lake)
8 poor of calcite, relative large catchment area, stratified (only reservoirs)
9 poor of calcite, relative small catchment area, stratified (almost only reservoirs)
in the lowlands:
10 calcareous, relative large catchment area, stratified
11 calcareous, relative large catchment area, not stratified , retention time > 30d
12 calcareous, relative large catchment area, not stratified , retention time 3 - 30d
13 calcareous, relative small catchment area, stratified
14 calcareous, relative small catchment area, not stratified

Which water body types of lakes are covered by the collected database?

Lakes with available phytoplankton data can be attached to 11 of the 14 lake types. Especially phytoplankton data of reservoirs in the highlands (300-800 altitude) are not included (type number 5-9), since data collection was restricted to natural lakes.

To describe and to define characteristics of phytoplankton for one lake type, we require at least 3 lakes for each ecological status. Up to now, the research sites are to low in number for the most lake types and/or have an uneven distribution along the trophic states, which is regarded as the primary degradation factor. On the other hand, there are some very intensive study sides distributed all over Germany (Lake Constance, Müggelsee, Stechlinsee, Wannsee, Schliersee, Ammersee, Steinhuder Meer a.o.) with a great number of years with frequent phytoplankton investigations. These data sets enable us to analyse year-to-year-differences or to observe the changes in phytoplankton composition along a trophic gradient, since the lakes were exposed to man made eutrophication or re-oligotrophication processes. The number of data for assessment development will be enhanced by including lakes with lake area below 0.5 km^2, which were excluded before.

Can phytoplankton metrics reflect different lake types?

The assessment method will be based on the concept of a multimetric index derived from ecological quality ratios. Total biovolume, ratio of algal classes, lists of indicator species, malus species (lack of specific species) and ratio of functional groups (r- to k-strategists; filamentous species to single cell species) are characteristics of phytoplankton and potentially useful as metrics. The application of the characteristic "abundance" is limited by the enormous range of cell size of phytoplankton and by the various counting practice, which distinguish single cells, colonies or filaments very different for the same species. Also common diversity indeces, such as Shannon-index or evenness are not applicable, since the plateau of species number is not achieved by the common analyse practice of phytoplankton, which count only a small sub-sample.

The lakes types differ in the extent of total biomass distributed along the gradient of degradation. To define the first metric, class boundaries were derived from the distribution of vegetation averages of total biovolume and chlorophyll a concentrations observed within the pool of lakes collected in the data bank (Table 1).

The lakes were previously attached to the five degradation classes by means of their trophic state, since eutrophication is regarded as the main degradation factor of phytoplankton in lakes. Since the trophic status evaluation is also defined by biomass characteristics (chlorophyll a), the metric "total biovolume" is not independently from the pre-classification of degradation. Yet, this first approach makes it obvious, that the water body types have different reference conditions and so, the ranges of total biomass are very specific for each degradation status.

In the case of the not stratified lakes there are no data sets of un-degraded lakes available, thus the reference conditions must be reconstructed by paleolimnological and other methods. The broad range of total biomass within one water body type and one degradation status is a effect of the different influence of grazing, light availabilities and dominance of different algal classes, not reflected in the lake typology. Describing alternative status of phytoplankton assemblages, for example "dominated by Dinoflagellates under high grazing pressure" and alternatively "dominated by Diatoms and Cryptophytes with small grazing pressure", it might be possible reduce the range of the total biomass predicted in one degradation status and one lake type. Additionally, the total biomass of phytoplankton is strongly influenced by a dominance of macrophytes, which is especially expected within the lakes with small anthropogenic influence and shallow water bodies (see indication by "MP" in Table 1). Here, alternative status can be described and can explain the broad range of total biomass of phytoplankton, which we have to expect for the very good and good degradation status. In summary, the metric "total biomass" of phytoplankton can reflect the different water body types given by Mathes *et al.* (2002).

Tab. 1: Preliminary draft of the boundary values defined for the metrics "total biovolume" (BV) and "chlorophyll a-concentrations" (Chl a) along the degradation status (very good to bad; left column) and within the five types of lowland standing water bodies (see text; VQ = ratio of catchment area/lake volume; thermal stratification = stratified or not stratified).

Ecoregion: Lowlands

	VQ<1,5						**VQ > 1,5**			
	stratified		not stratified		stratified		shallow/ not stratified		hallow and riverine lakes	
Typ	**13**		**14**		**10**		**11**		**12**	
	BV	Chl a	BV	Chl a	BV	Chl a	BV	Chl a	BV	Chl a
1 very good	≤0,5	≤2,5	≤1 **MP**	≤5	≤1	≤5.0	≤2 **MP**	≤10	3 **MP**	≤15
2 good	0,5-2	2,5-10	>1-4 **MP**	>5-20	1-3	>5-15	>2-6 **MP?**	>10-30	>3-9	>15-45
3 moderat	>2-4	10-20	>4-8	20-40	3-6	15-30	>6-12	>30-60	>9-18	>45-90
4unsufficient	>4-8	20-40	>8-16	40-80	6-12	30-60	>12-24	>60-120	18-36	>90-180
5 bad	>8,0	>40,0	>16,0	>80	>12	>60	>24	>120	>36	>180

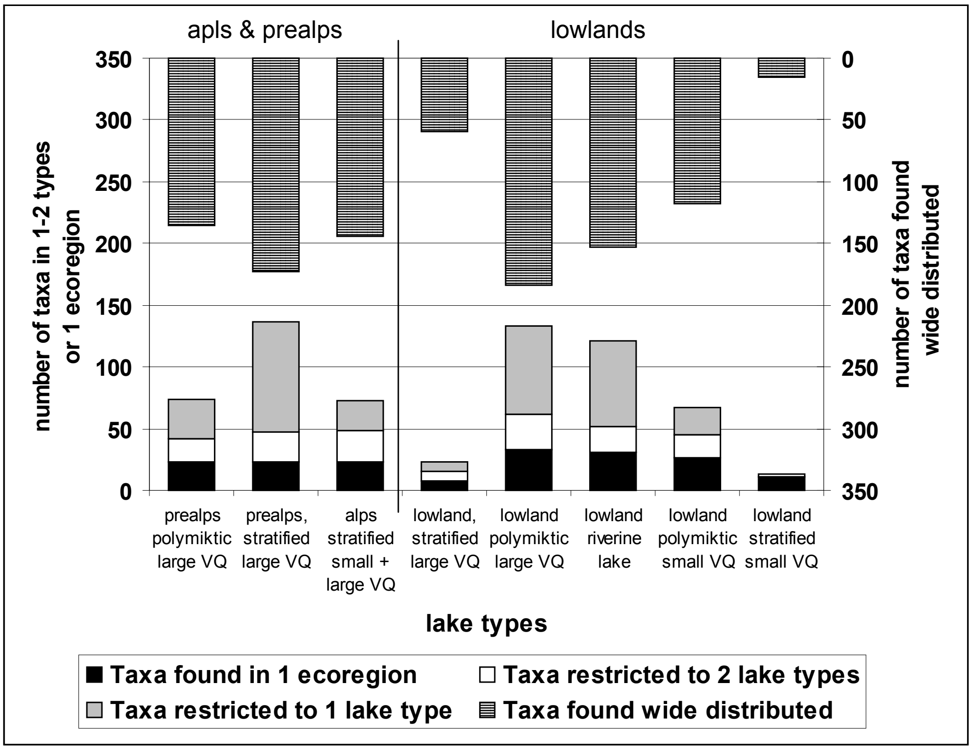

Fig. 1: Distribution of 682 phytoplankton taxa within the lake types of the ecoregions "alps and prealps" and "the lowlands" defined by Mathes et al. (2002), and sorted by their appearance within in the ecoregions. Taxa found wide distributed were found in both ecoregions. The taxa found in 1 or 2 lake types (n = 292) should be tested for indicator function.

Since the data collection is not finished, other metrics on taxonomic level are not tested to discriminate between the water body types. Restricted to a regional random test a first approach is introduced by Mischke *et al.* (2002). Here, we analyse the distribution of taxa within the different water body types to test provisionally, if are there any specific taxa for any water body type. It is obvious from figure 1, that there are groups of taxa, which are mainly found in one ecoregion and even in only one water body type. This unequal distribution of taxa show great promise to extract some phytoplankton species with a indicative characteristic for water body type and degradation status.

Some shortcomings, which resulting from the different taxonomic differentiation, must be excluded first: 1.) The unequal distribution of taxa reflects also the regional practice to determine species (grouping species; go to genus or species level), 2.) Those species with very similar morphotype must be checked for confusing naming in the different regions and 3.) the frequency of appearance within one lake type must be more than one. Still, this analyse helps to restrict the number of taxa, which will be tested for indication function, extracted by the method of Brettum (1989; see also Mischke *et al.* 2002) and Hörnstöm (1981).

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Typology of rivers in Germany

Phytoplankton in rivers is a facultative important biological group. The evaluation of the ecological status can mainly done by criteria of the macrophytes, phytobenthos and macroinvertebrates community. Still, in some river types phytoplankton reduces transparency, causes oxygen deficiency and is the dominant primary producer.

A definition of plankton dominated rivers is suggested by Behrendt & Opitz (2001) and is modified to following criteria:

1) chlorophyll a concentrations more than 30µg/l
2) catchment area more than 1000km^2
3) hydraulic load smaller than 80m/a
4) total phosphorous more than 50µg/l

In Germany, the typology of rivers defines 20 different types, using the criteria "ecoregion", "geomorphological characteristics" and "order by size of catchment area" (creak, small river, large river, stream, Schmedtje *et al.* 2000). Human influences by dams etc. are not included in this system of natural river types. In Germany, the retention time of most large rivers and streams have been drastically changed by human activities. Up to now, the typology of this modified water bodies is not finished, and the criteria is still unclear to attach some of them to the "heavily modified water bodies". Because of all these uncertainties, the assessment development for rivers will start not till next year and will be restricted to 4 rivers types defined.

In which river types phytoplankton is important?

Plankton dominated rivers are mainly found in large rivers and streams in the ecoregion "fladland" (Behrendt and Opitz 2001), which are grouped together in the river types 15 and 20. In large rivers of the prealps and highlands phytoplankton can develop, when the hydraulic load is low and the retention time is increased by dams (type 4 and 10). It is unsatisfactory to group together sections from rivers Rhein, Havel, Elbe and Oder in only one river type (type 20), since they are very different habitats for phytoplankton in respect to hydraulic and light conditions. Thus, comparable nutrient loads result in a broad range of total biovolume of phytoplankton (Behrendt and Opitz 2001). Further criteria such as "depth of river bed", "retention time" and "allochton turbidity" are necessary to add to the typology of rivers in respect to phytoplankton. Especially the river types 10, 14, and 20 must be dividing in further sub-types.

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