Harmful Algae 58 (2016) 74–84

Contents lists available at ScienceDirect

Harmful Algae

journal homepage: www.elsevier.com/locate/hal

Assessing in situ dominance pattern of phytoplankton classes by dominance analysis as a proxy for realized niches

Susanne Dunker [a,b,*], Karin Nadrowski [c], Torsten Jakob [d], Peter Kasprzak [e], Annette Becker [f], Uwe Langner [g], Christfried Kunath [d], Stan Harpole [a,b], Christian Wilhelm [b,d]

[a] Helmholtz Centre for Environmental Research GmbH – UFZ, Permoserstraße 15, 04318 Leipzig, Germany
[b] German Centre for Integrative Biodiversity Research (iDiv), Deutscher Platz 5a, 04103 Leipzig, Germany
[c] Institute of Biology, Department of Systematic Botany and Functional Biodiversity, University of Leipzig, Johannisallee 21, 04103 Leipzig, Germany
[d] Institute of Biology, Department of Plant Physiology, University of Leipzig, Johannisallee 23, 04103 Leipzig, Germany
[e] Leibniz-Institute of Freshwater Ecology and Inland Fisheries, Alte Fischerhütte 2, OT Neuglobsow, 16775 Stechlin, Germany
[f] Federal Institute of Hydrology (BfG), Am Mainzer Tor 1, 56068 Koblenz, Germany
[g] Institute of Plant Physiology, Martin Luther University Halle-Wittenberg, Weinbergweg 10, 06120 Halle (Saale), Germany

A R T I C L E   I N F O

Article history:
Received 1 June 2016
Received in revised form 15 August 2016
Accepted 19 August 2016
Available online 1 September 2016

Keywords:
Potential optimal growth conditions
Cyanobacteria
Eutrophic conditions
Phytoplankton dynamics
Dominance

A B S T R A C T

This study looks at two facets of dominant phytoplankton classes during phytoplankton succession. A detailed assessment of this issue is of special interest with regard to realized niches from a theoretical point of view but also for lake management as practical application.

A realized niche mirrors the functional adaptability of an organism in a lake-specific constellation of environmental parameters. Therefore, the characterization of realized niches could be a key factor for management of problematic waters. Different strategies exist to control eutrophication and the risk of blooms by harmful algae. During the last decades, many restoration measures were initiated to manage eutrophicated inland lakes. In the past, it has become evident several times that restoration strategies do not necessarily lead to a reduction of biomass of undesirable cyanobacteria but can even promote their development.

Due to this uncertainty of success and the high costs for remediation strategies, new prediction tools are required – ideally, based on routine monitoring data. Therefore, we developed a new method to extract potential optimal growth conditions (POGC) as indicators of realized niches for different phytoplankton taxa from existing data to improve existing strategies used in lake remediation and restoration.

The analysis presented in this work is based on dominance pattern of different phytoplankton groups relative to environmental variables. Interpretation of these dominance patterns as indicators of POGC showed distinct pattern for several phytoplankton classes for all investigated objects. We identified low nitrogen and phosphate concentrations as favorable condition for cyanobacteria in Lake Auensee and Lake Feldberger Haussee. The reservoir Bleilochtalsperre showed a high N/P-concentration and cyanobacteria dominance was generally very low.

1. Introduction

1.1. Phytoplankton succession and realized niches

Phytoplankton succession is a complex process driven by several interacting abiotic and biotic factors (Sommer, 2012). Research on phytoplankton succession is of special interest with regard to two aspects: on the one hand, from a theoretical point of view with respect to the concept of a realized niche, and, on the other hand, from the practical perspective of lake management.

Phytoplankton succession is influenced inter alia by temperature, light intensity, availability of nutrients and varying grazing pressure by herbivorous zooplankton. Depending on preferred growth conditions and individual traits, different species occur at different periods throughout the year. This specific constellation of environmental factors in a habitat leading to occurrence of a species or a taxonomic group can be

Abbreviations: Chl *a*, chlorophyll *a*; POGC, potential optimal growth conditions.

* Corresponding author at: Helmholtz Centre for Environmental Research GmbH – UFZ, Deutscher Platz 5a, 04103 Leipzig, Germany.
E-mail address: susanne.dunker@ufz.de (S. Dunker).

http://dx.doi.org/10.1016/j.hal.2016.08.004
1568-9883/

interpreted as a niche or habitat optima. According to Litchman et al. (2012), a niche can be defined as an environmental space that a species occupies or the functional role that a species plays. A further definition according to Hutchinson (Litchman et al., 2012; Polechová and Storch, 2008; Hutchinson, 1957) is: A niche is an abstract n-dimensional space, where one species occurs, also called fundamental niche. The fundamental niche is different from a smaller realized niche which results from a unique interaction of abiotic and biotic factors.

In general, it is difficult to get information about realized niches occupied by phytoplankton species in the field due to the multidimensionality and overlap of influencing factors. But habitat optima or niches are of great importance, because they describe preferential conditions for organisms and can, therefore, be used as predictive tools. Today, high relevance of predictors is given by climate change scenarios, worldwide eutrophication effects and nuisance phytoplankton blooms.

1.2. Management of eutrophication

Eutrophication in inland waters is a problem that was mainly scientifically recognized during the last decades (Lewis et al., 2011). Strong nutrient load leads to high biomass production by phytoplankton (Heisler et al., 2008), especially to significant growth of harmful algae (harmful algae blooms – HABs). While high biomass by itself causes severe problems, furthermore toxicity of HABs for aquatic organisms but also for humans by using the water or any affected aquatic organisms (mussels) thereof is a problem with increasing relevance (Dolah, 2000). Toxicity can mainly be found in phytoplankton groups like cyanobacteria, yellow-brown algae (e.g. ichthyotoxicity by *Prymnesium parvum*) and dinophytes (e.g. shellfish poisoning by *Gonyaulax tamarensis*), while toxic cyanobacteria have the highest relevance in freshwater lakes, addressed in this study. Over the last decades, various efforts were made in the United States and the European Union to control eutrophication and water quality (Lewis et al., 2011). However, it was also shown that lake restoration strategies do not necessarily lead to the desired outcome (Steinberg and Tille-Backhaus, 1990; Antenucci et al., 2005; Moss et al., 2005; Conley et al., 2009; Posch et al., 2012; Horn et al., 2014).

As a result of the findings of Vollenweider and Kerekes (1982), phosphate reduction became the most important measure of re-oligotrophication (Reynolds, 1992). Reduction of phosphorus load showed positive results in many cases (Schindler, 2012). By contrast, in Lake Zurichsee or Reservoir Saidenbach a strong P reduction did not help to avoid cyanobacteria but promoted their dominance (Posch et al., 2012; Horn et al., 2014). The same was shown by Schindler et al. (2008) for N reduction. N_2-fixing cyanobacteria dominated the phytoplankton community as a result of N reduction.

As a further measure of re-oligotrophication Heo and Kim (2004), described the positive effect that artificial destratification had on the prevention of cyanobacteria development. Conversely, in Lake Fischkaltersee (Bavaria, Germany) and North Pine Dam (Brisbane, Australia) destratification promoted the development of the cyanobacterium *Limnothrix redeckii* and *Cylindrosspermopsis raciborskii* respectively (Steinberg and Tille-Backhaus, 1990; Antenucci et al., 2005).

These contrasting examples show that there is no ‘‘master strategy’’ for re-oligotrophication with respect to species composition. Depending on geological origins and geographical position, every water body is an individual ecosystem, requiring an adapted re-oligotrophication method. One principal goal of re-oligotrophication is the reduction of nutrients, but to which extent is a question of needs and costs.

Discussing about regulation of phosphorus or/and nitrogen concentrations, Schindler (2012) concludes that the costs for additional N reduction must be justified, because it is much more expensive than P reduction. But nevertheless, every measure to reduce eutrophication involves high costs (Conley et al., 2009; Lewis et al., 2011). Due to the before-mentioned aspects of uncertainty concerning the success of strategies, it is essential to get an overview of the most important factors influencing the phytoplankton composition before starting such an operation. The intention of this study is to help understanding how phytoplankton composition in situ is influenced by abiotic and biotic parameters and how it can be managed accordingly.

One solution to extract habitat preferences from field data is applied in terrestrial science by ‘‘Species Distribution Models’’ (Elith and Leathwick, 2009). These models combine environmental and species abundance data to estimate habitat optima for different species. To get these data for phytoplankton species, Irwin et al. (2012) combined environmental and species abundance data to reconstruct marine phytoplankton niches from field data. In situ environmental conditions are extremely complex and, therefore, difficult to interpret. Nevertheless, the analysis of field data is a promising possibility to get an impression of realized niches. Instead of using a statistical combination of abundance data and environmental factors, it is also possible to sample field water inocula and to treat them with several combinations of factors in the laboratory (Shapiro, 1973). This method bears the risk of artifacts and the significance of these findings is restricted to a limited number of analyzed niche factors.

Our approach aims to detect realized niches with the help of the so-called dominance analysis. It does not only combine prevailing environmental factors and abundance data, but also dominance pattern as well as the strength of dominance. In comparison to abundance data, characterization of dominance includes information about intensity of growth in comparison to other species and, therefore, is a much better reflection of growth optima under specific natural constellation of environmental factors. For many reservoirs or lakes, especially for the ecologically critical ones, large data sets are already available, which could be used for this kind of statistical analysis. We are trying to get insights into realized niches of phytoplankton groups on the basis of exemplary data sets for three eutrophic inland surface waters.

2. Material and methods

2.1. Data analysis

For this study, data from Lake Auensee, Lake Feldberger Haussee and Reservoir Bleilochtalsperre were used (Table 1). Table 1 provides general information on the studied water bodies and on the sampling procedure. Sampling took place on a regular basis for all sites ($\sim$ bimonthly during vegetation period from April until September and for the rest of the year, monthly or rarely). All three studied objects form a gradient of size and restoration intensity/destabilization of lake biology.

Lake Auensee is the smallest analyzed lake and covers an area of 12 ha. The lake is situated in Leipzig, Germany (51.37°, 12.32°), and is the result of gravel mining. It represents a dimictic, shallow, hypertrophic water with a maximum depth of 7 m and a mean depth between 3 and 4 m. The lake is fed by groundwater at a water exchange rate of 1.8 years (Langner et al., 2004). Data for Lake Auensee were measured from 2002 to 2011, a period where no restoration measure was performed.

Lake Feldberger Haussee is a glacial lake, situated in Eastern Mecklenburg, Germany (53.20°, 13.27°). The lake covers an area of about 130 ha (second largest water body in this study), has a maximal depth of 12 m and a retention time of 3–5 years (Krienitz