On the ecophysiology of Baltic cyanobacteria, focusing on bottom-up factors

Malin Mohlin

Doctoral Thesis

UNIVERSITY OF GOTHENBURG

Faculty of Science

Department of Marine Ecology

Akademisk avhandling för filosofie doktorsexamen i Marin Botanik vid Göteborgs Universitet, som enligt beslut kommer att försvaras offentligt fredagen den 26 november 2010, kl 10.00 i föreläsningssalen på Institutionen för marin ekologi, Carl Skottsbergs gata 22B, Göteborg

Examinator: Professor Kristina Sundbäck, Institutionen för Marin Ekologi, Göteborgs Universitet.

Fakultetsopponent: Professor Catherine Legrand, Institutionen för naturvetenskap, Linnéuniversitet, 391 82 Kalmar

ISBN 91-89677-46-3

ABSTRACT

Cyanobacterial blooms in the Baltic Sea are dominated by diazotrophic cyanobacteria, i.e. *Aphanizomenon* sp. and *Nodularia spumigena*. The blooms coincide with a stable stratification and the organisms are concentrated to the surface water, exposed to high levels of both photosynthetically active radiation (PAR, 400–700 nm) and ultraviolet radiation (UVR, 280–400 nm), in combination with low ratios of dissolved inorganic nitrogen and inorganic phosphorus (DIN:DIP). The ability of nitrogen fixation, a high tolerance to phosphorus starvation and photo-protective strategies (production of mycosporine-like amino acids, MAAs) may explain their competitive advantage in the Baltic Sea. However, intraspecific variation in the response to environmental factors has been commonly overlooked.

The seasonal succession with peaks of *Aphanizomenon* sp. in early summer followed by peaks of *N. spumigena*, has been related to their interspecific preferences and response to abiotic conditions. *N. spumigena* dominates in late summer forming extensive toxic blooms, and its toxin nodularin, a hepatotoxin lethal to wild and domestic animals, may act as a tumour promotor. It has been suggested that the accumulation of nodularin within the *N. spumigena* cells and its release from the cells are affected by environmental factors. Hence, the seasonal succession may be explained by an allelopathic effect of nodularin on *Aphanizomenon* sp.

The aim of this thesis is to elucidate the factors controlling the cyanobacterial blooms, prevailing seasonal succession, intraspecific differences, toxin production and release. Moreover, to analyze the potential of future toxic blooms in a predicted climate change, e.g. increased UVR and stronger stratification due to increased precipitation and temperature. With a multi-factorial approach in the laboratory and in outdoor experiments, interactive effects of radiation (photosynthetic active radiation PAR and PAR + UV-A + UV-B), nutrients (nutrient replete, nitrogen limited, phosphorus limited) and species composition (monocultures of *N. spumigena* and *Aphanizomenon* sp. and mixed cultures with the respective species) were tested on these two species.

Although strain-specific differences in UV-B radiation tolerance were observed, *N. spumigena* is a species that is not generally negatively affected by UV-B radiation corresponding to ambient sea surface intensities/doses. *N. spumigena* tolerates high ambient UVR also under nutrient-limiting conditions and maintains positive growth rates even under severe phosphorus limitation. Interestingly, the specific growth rate of *N. spumigena* was stimulated by the presence of *Aphanizomenon* sp. and in contrast to our hypothesis, *Aphanizomenon* sp. was not negatively affected by the presence of *N. spumigena*. Nodularin accumulation and release were dependent on environmental conditions; it did not affect the co-existing species *Aphanizomenon* sp. The highest intra- and extracellular nodularin concentrations were observed under nitrogen limitation when shielded from UVR. In conclusion, I suggest that the seasonal succession, with peaks of *Aphanizomenon* sp. followed by peaks of *N. spumigena* is a result from species-specific preferences of environmental conditions and/or stimulation by *Aphanizomenon* sp., rather than an allelopathic effect of *N. spumigena*. Moreover, a possible increased toxicity of the *N. spumigena* should be considered when planning sewage treatment, since nitrogen removal may cause problems on a recreational level and increased accumulation of nodularin higher up in the food web. The results from this thesis, together with a predicted stronger stratification and increased UVR due to effects of climate change in the Baltic Sea, reflect a scenario with a continuing future dominance of the toxic *N. spumigena*.

Keywords: Allelopathy; *Aphanizomenon* sp.; Baltic Sea; Cyanobacteria; Diazotrophic; Multi-factorial; Nitrogen; Nodularin; *N. spumigena*; photosynthetic active radiation; Phosphorus; ultraviolet radiation; UV-A; UV-B.