Effects of rising CO₂ on the harmful cyanobacterium Microcystis

Sandrini, G.

Publication date
2016

Document Version
Final published version

Citation for published version (APA):
The waters of our planet are full with cyanobacteria that use CO$_2$, water and light for photosynthesis. Cyanobacteria form the base of the food web and have a strong impact on all life on Earth. 

Yet, not all cyanobacteria are beneficial. Harmful cyanobacteria (also known as ‘blue-green algae’) can form dense blooms in lakes and produce toxins, which lead to all sorts of problems. These blooms can threaten drinking water supplies, recreational activities, livestock, birds and human health.

Since the industrial revolution, atmospheric CO$_2$ concentrations are rising strongly. Cyanobacteria are generally assumed to be favored at low CO$_2$ conditions, because of the presence of an effective CO$_2$-concentrating mechanism (CCM) to fix CO$_2$. Yet, how will harmful cyanobacteria, such as the ubiquitous harmful cyanobacterium *Microcystis aeruginosa*, respond to rising CO$_2$? Are they well-adapted to deal with climate change? Will cyanobacterial blooms intensify? Will the genetic composition and toxicity of blooms change? And what can we do to combat these blooms?

These questions and more are discussed in this PhD thesis.
Effects of Rising CO$_2$ on the Harmful Cyanobacterium $Microcystis$
2016
Effects of Rising CO₂ on the Harmful Cyanobacterium *Microcystis*
PhD thesis, Universiteit van Amsterdam

ISBN: 978-94-91407-31-4

Cover and layout: Giovanni Sandrini

Printed: Gildeprint - Enschede, the Netherlands

Publisher: Universiteit van Amsterdam

The research of this thesis was carried out at the Department of Aquatic Microbiology (AMB), of the Institute for Biodiversity and Ecosystem Dynamics (IBED), of the University of Amsterdam. The research was supported by the Netherlands Organization for Scientific Research (NWO).
Effects of Rising CO$_2$ on the Harmful Cyanobacterium *Microcystis*

ACADEMISCH PROEFSCHRIFT
ter verkrijging van de graad van doctor aan de Universiteit van Amsterdam
op gezag van de Rector Magnificus prof. dr. D. C. van den Boom
ten overstaan van een door het College voor Promoties ingestelde commissie,
in het openbaar te verdedigen in de Agnietenkapel
op woensdag 6 april 2016, te 12:00 uur

door

*Giovanni Sandrini*

geboren te Terneuzen
Promotiecommissie

Promotor: Prof. dr. J. Huisman (Universiteit van Amsterdam)
Copromotor: Dr. J. C. P. Matthijs (Universiteit van Amsterdam)

Overige leden: Prof. dr. R. L. Burnap (Oklahoma State University)
               Prof. dr. J. T. M. Elzenga (Rijksuniversiteit Groningen)
               Prof. dr. K. J. Hellingwerf (Universiteit van Amsterdam)
               Prof. dr. B. W. Ibelings (Université de Genève)
               Prof. dr. G. Muyzer (Universiteit van Amsterdam)
               Prof. dr. L. J. Stal (Universiteit van Amsterdam)
               Dr. P. M. Visser (Universiteit van Amsterdam)

Faculteit der Natuurwetenschappen, Wiskunde en Informatica
# Table of contents

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>General introduction</td>
<td>7</td>
</tr>
<tr>
<td>2</td>
<td>Genetic diversity of inorganic carbon uptake systems causes variation in CO₂ response of the cyanobacterium <em>Microcystis</em></td>
<td>27</td>
</tr>
<tr>
<td>3</td>
<td>Changes in gene expression, cell physiology and toxicity of the harmful cyanobacterium <em>Microcystis aeruginosa</em> at elevated CO₂</td>
<td>57</td>
</tr>
<tr>
<td>4</td>
<td>Strains of the harmful cyanobacterium <em>Microcystis aeruginosa</em> differ in gene expression and activity of inorganic carbon uptake systems at elevated CO₂ levels</td>
<td>95</td>
</tr>
<tr>
<td>5</td>
<td>Rapid microevolutionary adaptation of harmful cyanobacteria to changes in CO₂ availability</td>
<td>123</td>
</tr>
<tr>
<td>6</td>
<td>Diel variation in gene expression of the CO₂-concentrating mechanism during a harmful cyanobacterial bloom</td>
<td>149</td>
</tr>
<tr>
<td>7</td>
<td>How rising CO₂ may stimulate harmful cyanobacterial blooms</td>
<td>175</td>
</tr>
<tr>
<td>8</td>
<td>Potassium sensitivity differs among strains of the harmful cyanobacterium <em>Microcystis</em> and correlates with the presence of salt tolerance genes</td>
<td>195</td>
</tr>
<tr>
<td>9</td>
<td>Afterthoughts</td>
<td>209</td>
</tr>
</tbody>
</table>

References 231

List of frequently used abbreviations, symbols and genes 253

Summary 257

Samenvatting 263

Acknowledgements 269

Curriculum Vitae 273