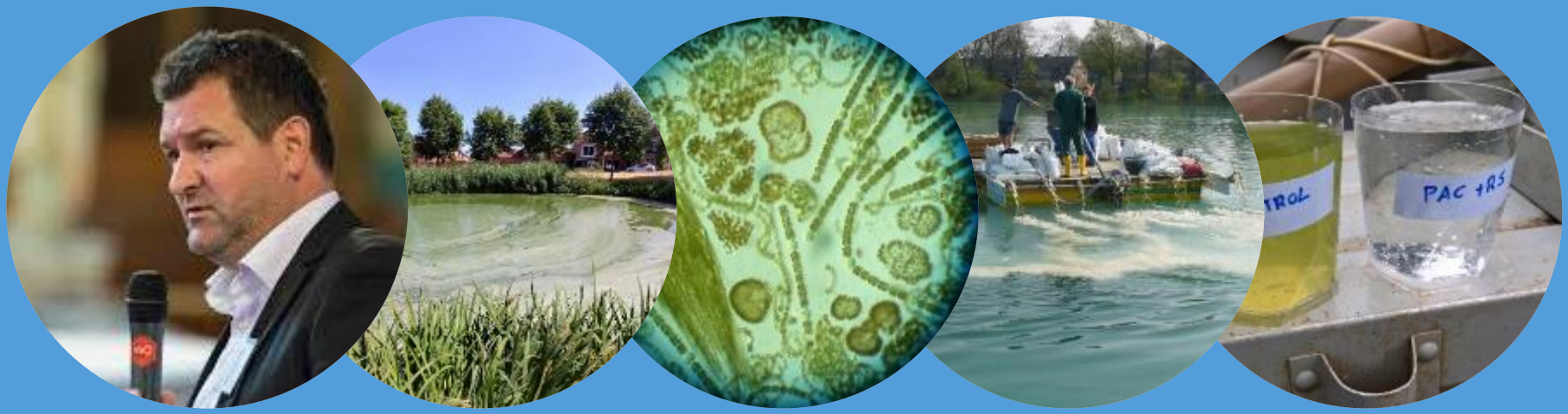
Managing Eutrophication and Controlling Cyanobacterial Blooms in the Netherlands

30-01-2019, Miquel (Mike) Lürling



WAGENINGEN UNIVERSITY & RESEARCH

akwa

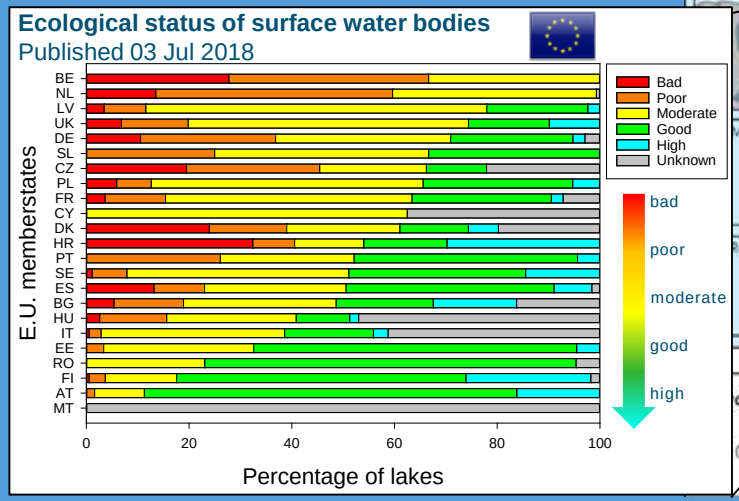
SIWA

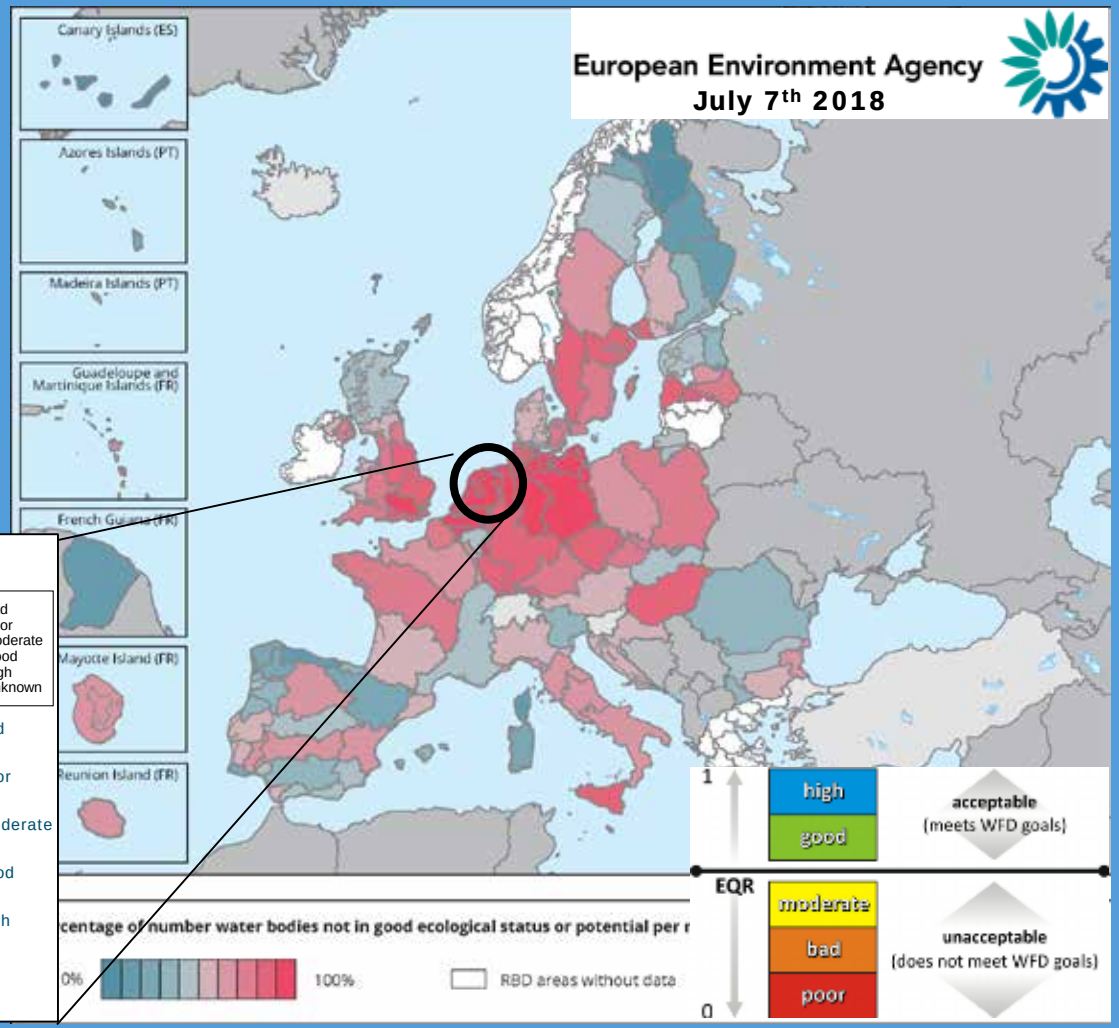
SIL

Working Group on Lake Restoration

Water quality issues in the Netherlands

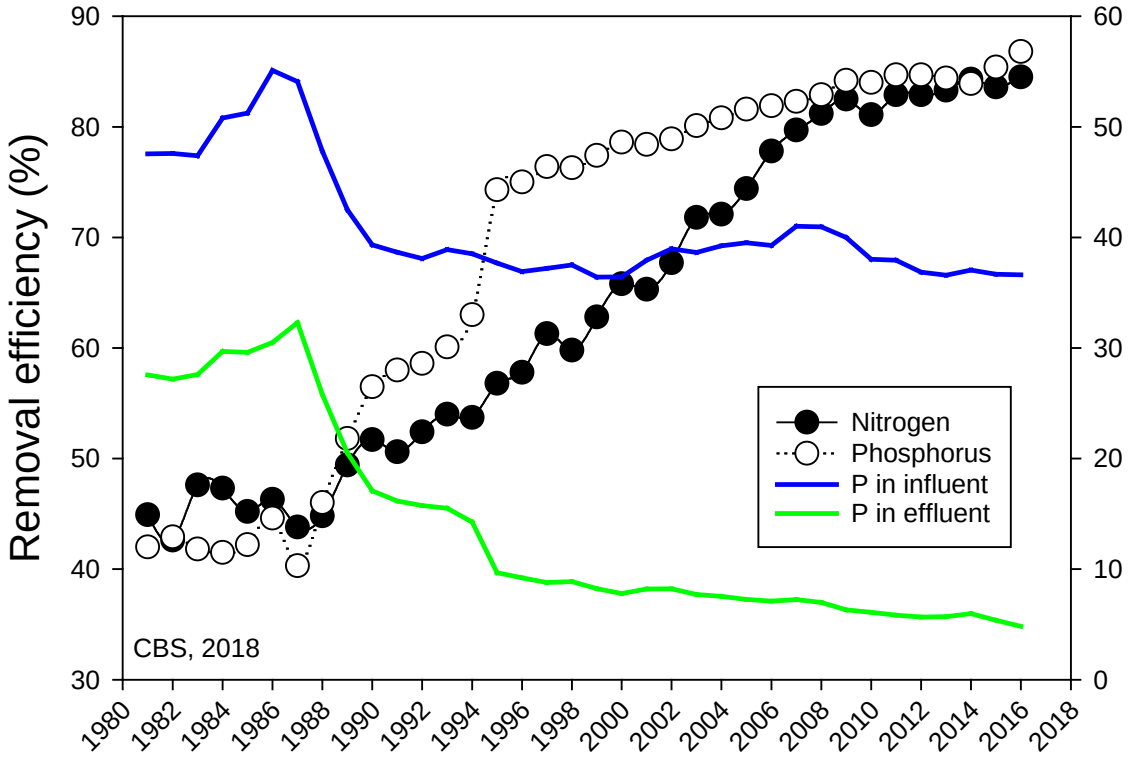
- Country in NW-E.U.
- Almost all surface water not in unacceptable ecological condition

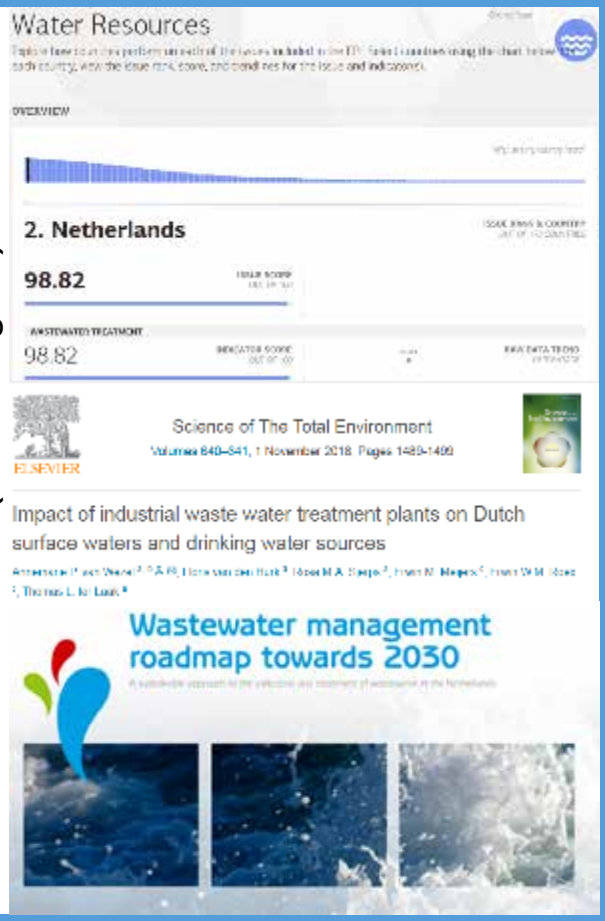




The Netherlands has world leading WWT

§ Point source nutrient pollution has been tackled





Legacies and diffuse loads remain an issue

EUROPEAN COMMISSION

Brussels, 3.2.2017
SWD(2017) 52 final

COMMISSION STAFF WORKING DOCUMENT

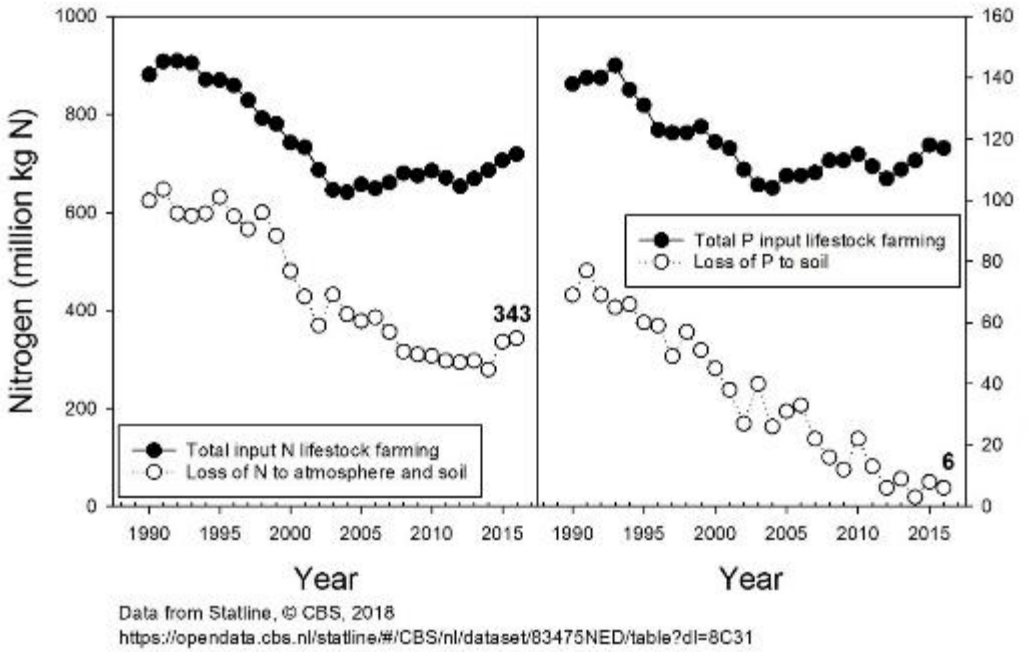
The EU Environmental Implementation Review
Country Report - THE NETHERLANDS

almost all (99%) of the water bodies are still subject to significant pressures. In all the four RBDs the basic measures were not enough to meet the Water Framework Directive objectives of ecological quality of surface waters in rivers and lakes. Roughly half of rivers, drainage ditches and lakes have too high concentrations of nitrogen and phosphates as a result of over-fertilization in agricultural areas[85].

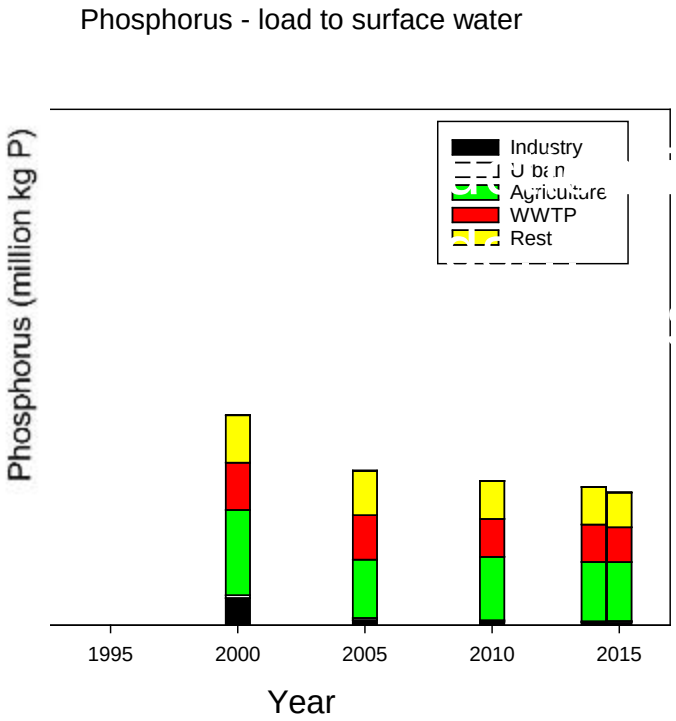
The main pressure on the Dutch surface waters is diffuse pollution[86] that affects 90% of water bodies

Legacies and diffuse loads remain an issue

§ Agriculture is large contributor to loads



Data from Statline, © CBS, 2018
https://opendata.cbs.nl/statline/#/CBS/nl/dataset/83475NED/table?dl=8C31



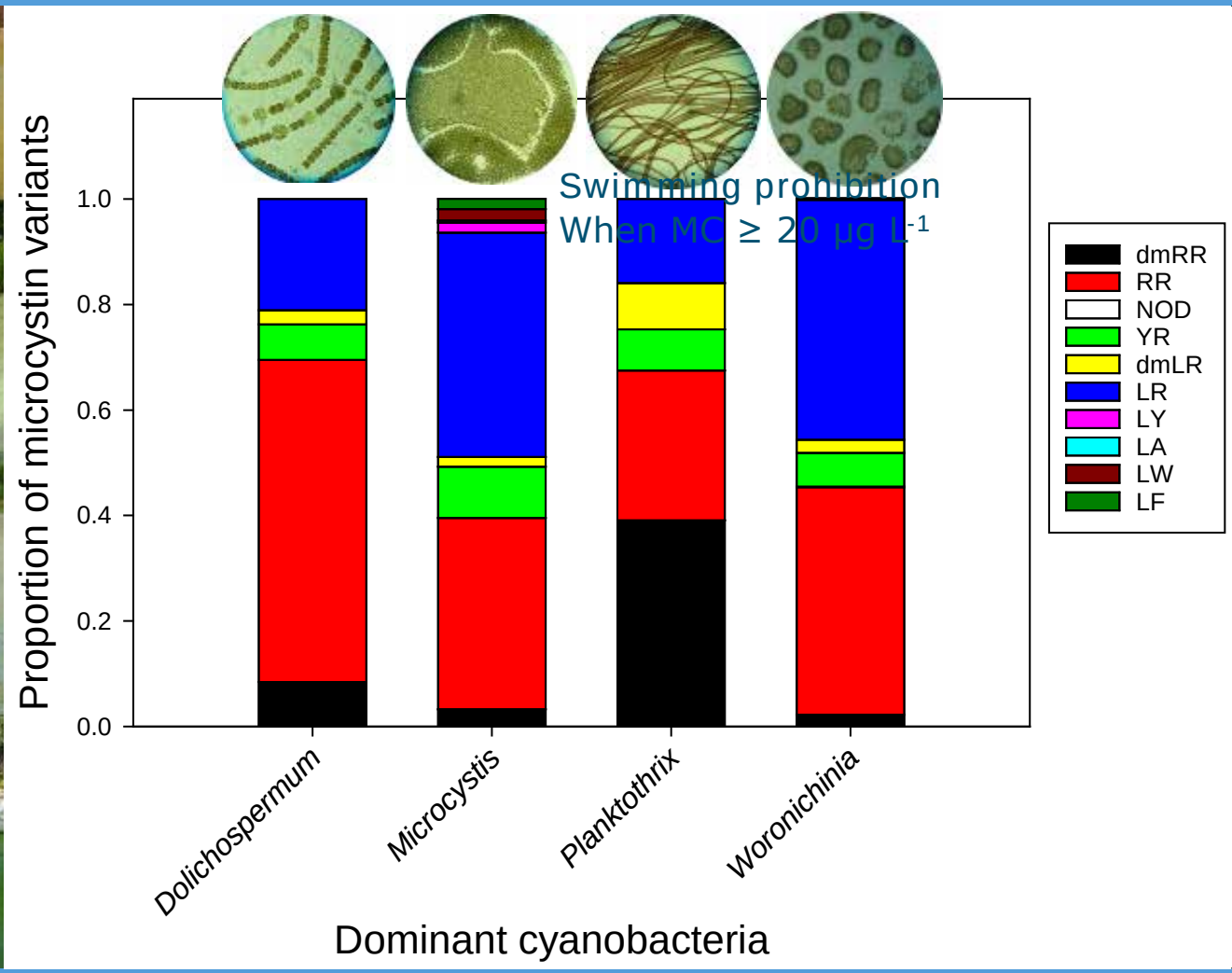
High nutrient loads to surface water = no.1 water quality issue in the Netherlands

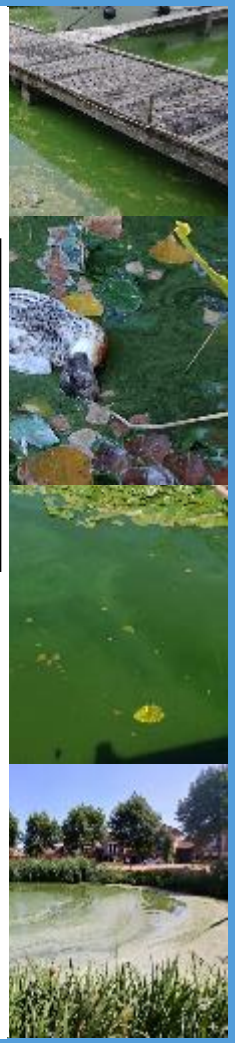
§ Eutrophication: Cyanobacterial bloom in the river Meuse

Pictures made by Rijkswaterstaat Zuid-Nederland – August 2018

§ Cyanobacterial blooms in many surface waters

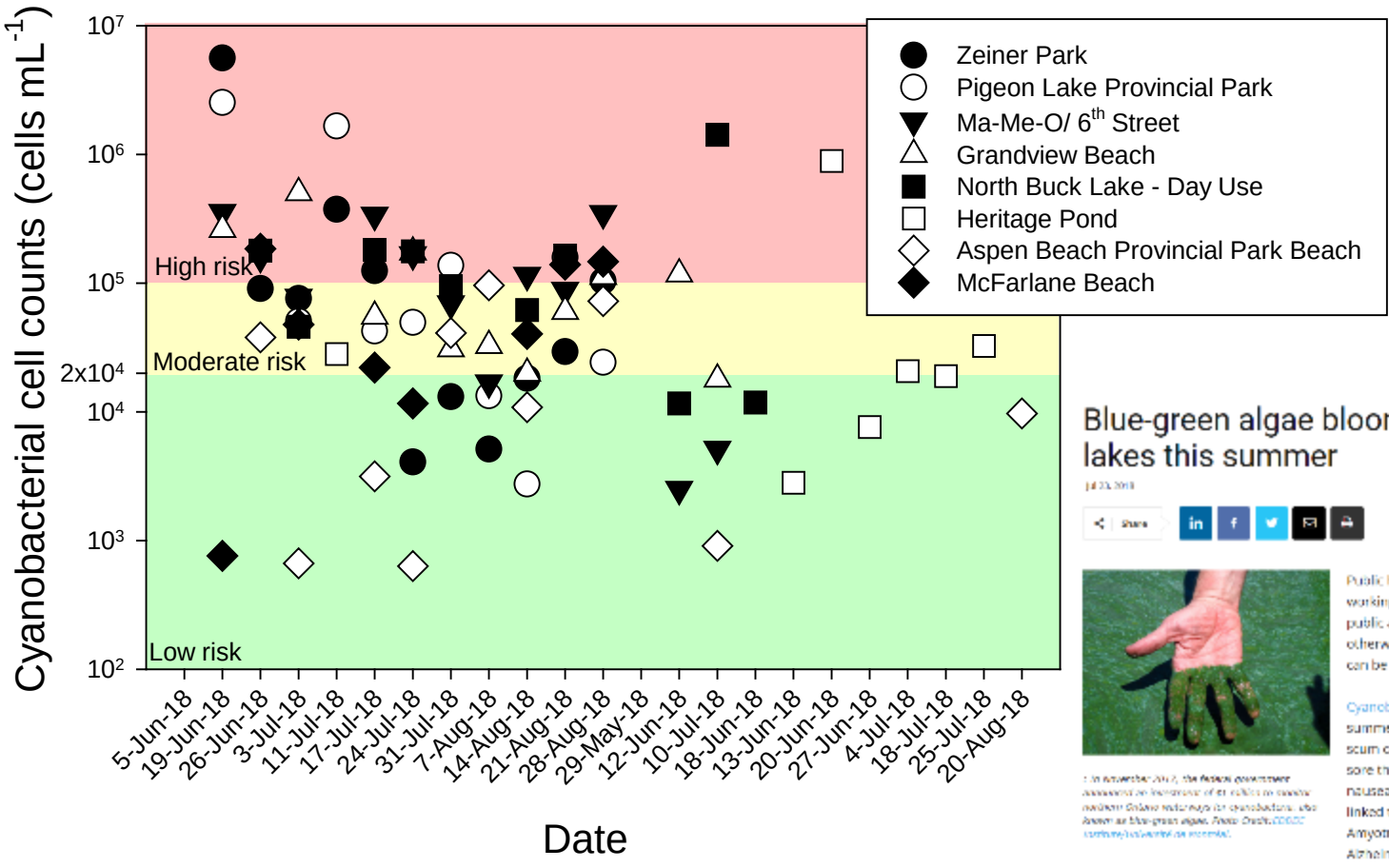
No.1 water quality issue in the Netherlands

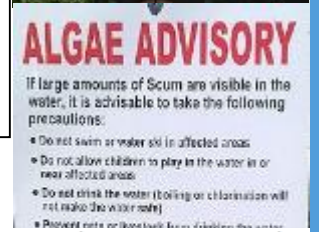




Swimming bans

https://open.alberta.ca/opendata/cyanobacterial-blooms-in-alberta-recreational-waters#summary





EUTROPHICATION

no.203.078 — From Weber until now — - Since 1907

In-lake measures are inevitable

Legacies delay recovery

Nutrients accumulated in lake beds may delay recovery for many decades, scientists say.

Diffuse loads

Are extremely problematic. Overly enriched soils keep on leaching nutrients, and particularly phosphorus, to groundwater and surface water. A recent study by Goyette and co-workers in the journal Nature Geosciences revealed it might take 100 to 2000 years!

Investments

Large upfront investments are needed in third world countries and countries in transition to tackle pint sources. WWTP should be built.

To bridge the time between their effectiveness in-lake actions are the single solution to bring relief to people fully relying on the polluted waters.

System analysis

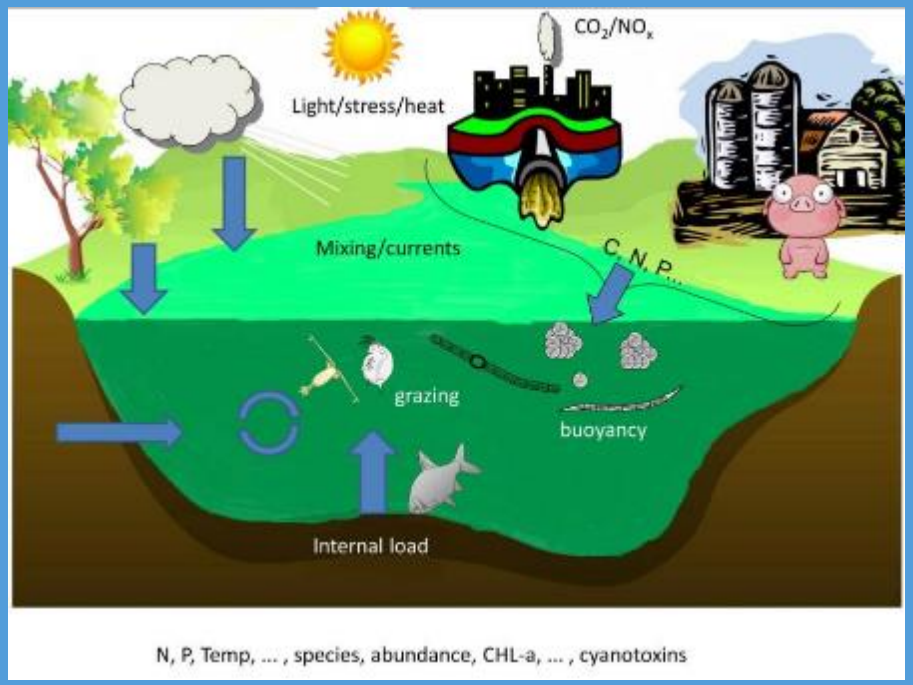
The actions should be based on a thorough understanding of the problem in each individual lake, according to the scientist.

There is NO silver bullet

Mitigation should always start with a system analysis

- Water- and nutrient fluxes
- Biological make-up
- Functions

} = diagnosis ® measures



Public oriented measures

- Information about risks, increase awareness
- Change of habits
- Warnings (e.g. swimming ban)

Public oriented measures

§ Warnings

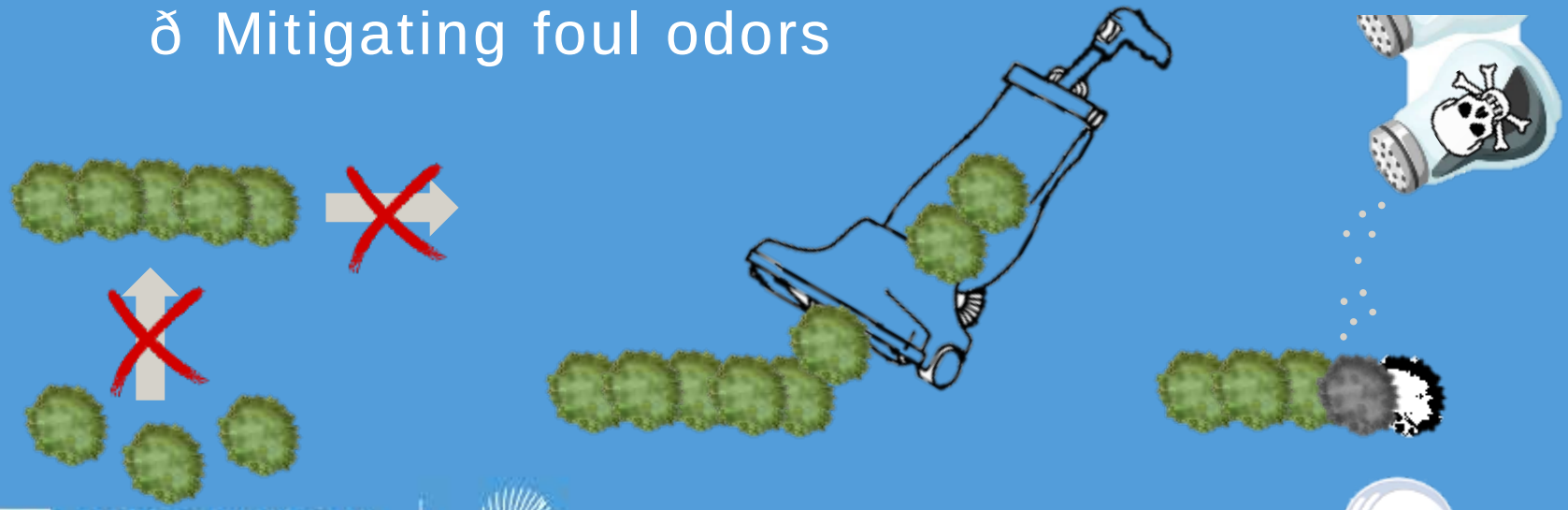
Public oriented measures

§ General information in booklets, newspapers, on website

http://www.wageningenur.nl/nl/Dossiers/dossier/Blauwalg.htm

Effect oriented measures

- Reduce nuisance, fighting the symptoms:
  - ð Preventing scum formation
  - ð Preventing inflow cyanobacteria
  - ð Removing scums/biomass
  - ð Preventing growth/killing cyanobacteria
  - ð Mitigating foul odors



Effect oriented measures

§ Numerous measures proposed and applied:

- **Physical**: Aeration/water movement, ultrasound, jets, bubble screen, dam, floating screen...
- **Chemical**: Algaecides, H_2O_2, coagulant + ballast...
- **Biological**: Barley straw, *Dreissena,* EM, Golden algae, plant extracts...

§ Some are promising, others come with dubious claims and without proper scientific testing




Physical measures

§ Screens: trying to prevent inflow of surface accumulated cyanobacteria (dams maybe more effective…)

Physical measures

§ Scum removal: skimmers, suction devices

Physical measures

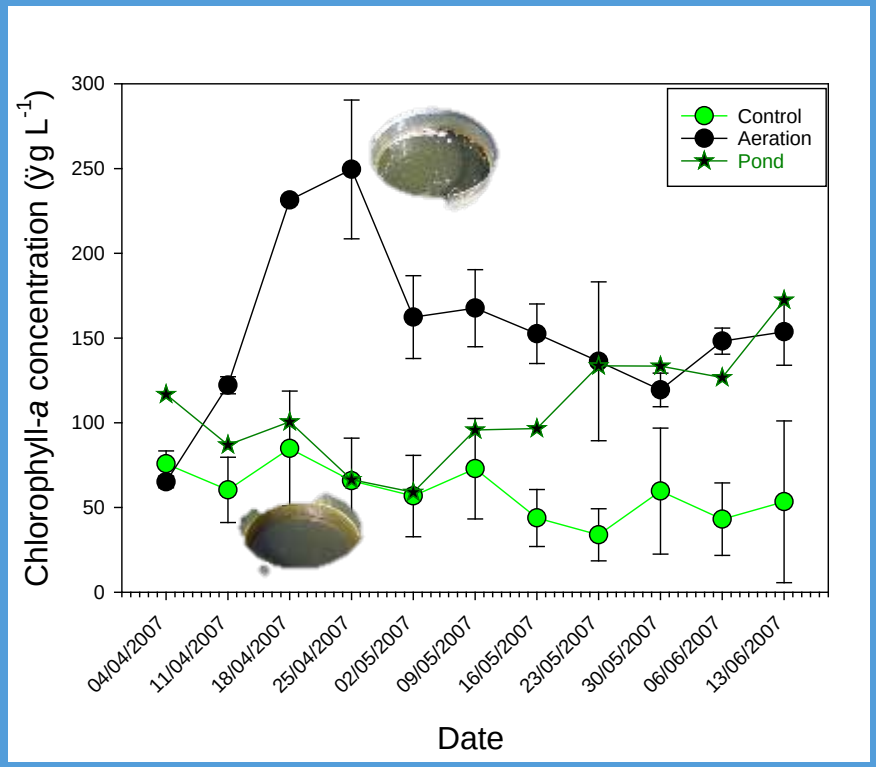
§ Bubble screen: trying to prevent inflow of surface accumulated cyanobacteria (Almere-Haven, NL)

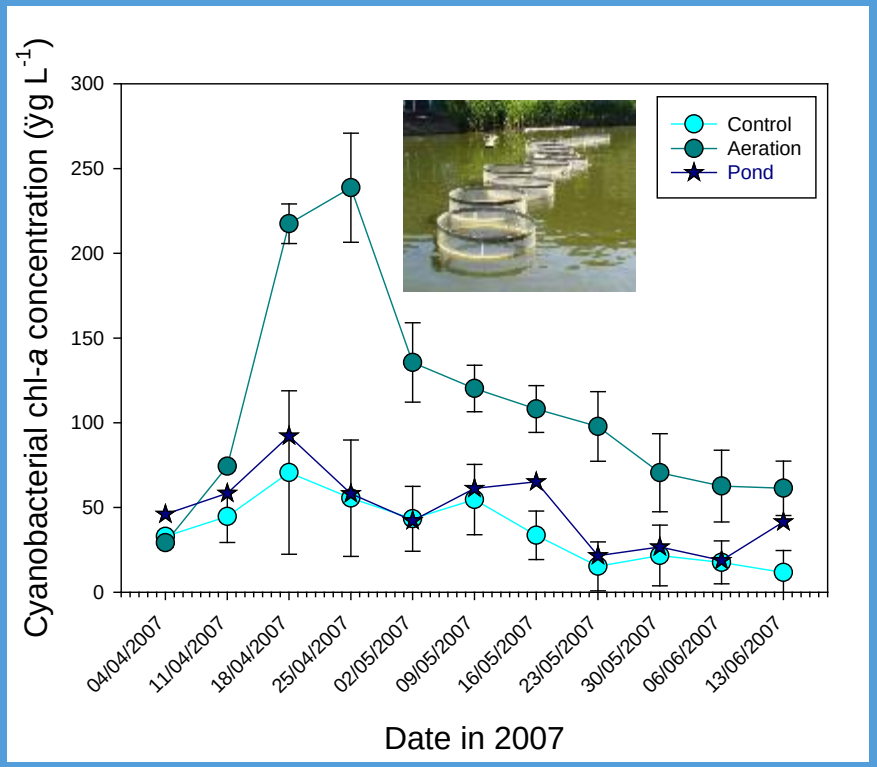
Physical measures

§ **Mixers**: accumulation in “dead zones”

Aeration/mixing

§ In shallow waters stimulation of cyanobacteria





Artificial mixing in deep lake Nieuwe Meer

§ Mixing in deep lakes can reduce blooms

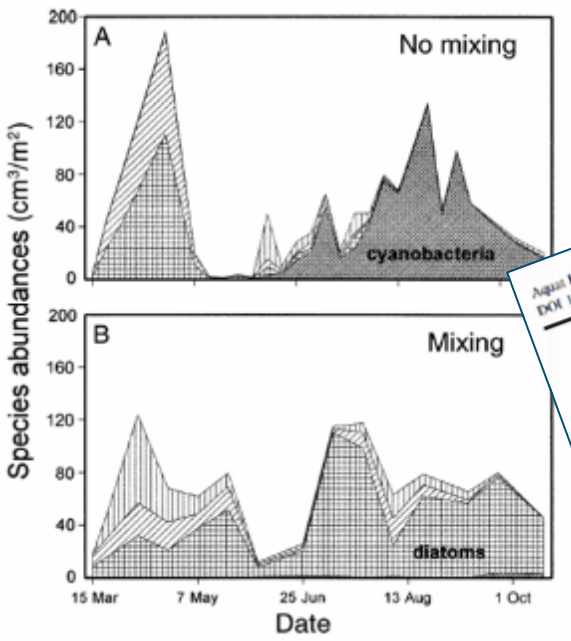
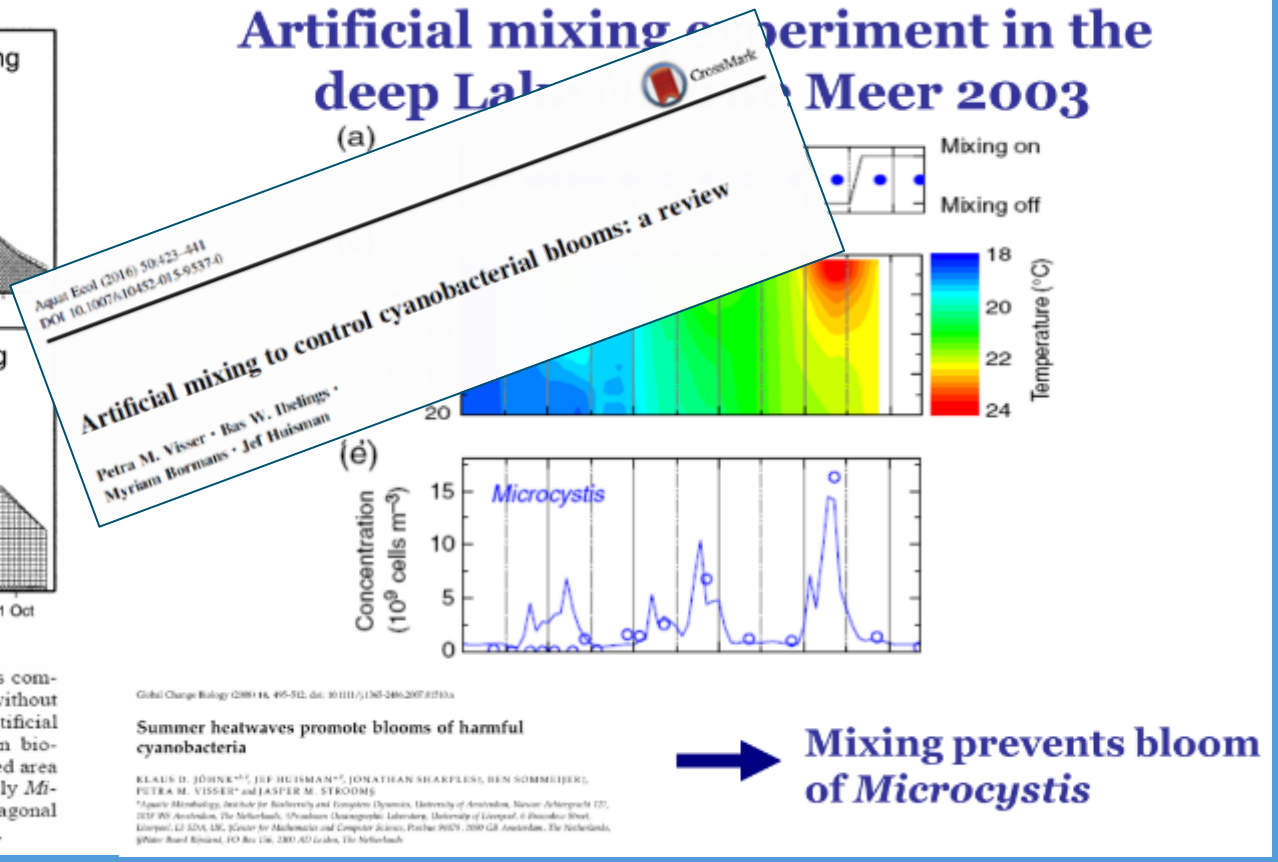


FIG. 6. Seasonal patterns in phytoplankton species composition in Lake Nieuwe Meer. (A) Example of a year without artificial mixing (1990). (B) Example of a year with artificial mixing (1993). Species abundances are expressed in biovolumes per unit surface area of the lake. Dark hatched area (finely spaced cross-hatching) = cyanobacteria (mostly *Microcystis*); boxes (wider cross-hatching) = diatoms; diagonal lines = green algae; vertical lines = small flagellates.



Aquat Ecol (2016) 50:423–441
DOI 10.1007/s10452-015-9537-0

Artificial mixing to control cyanobacterial blooms: a review

Petra M. Visser · Bas W. Ibelings · Myriam Bormans · Jef Huisman

Global Change Biology (2008) 14, 495–512, doi: 10.1111/j.1365-2486.2007.01510.x

Summer heatwaves promote blooms of harmful cyanobacteria

KLAUS D. JÖHNK*,†,‡, JEF HUISMAN*,†, JONATHAN SHARPLES§, BEN SOMMEIJER‖, PETRA M. VISSER* and JASPER M. STROOMS*

Mixing prevents bloom of *Microcystis*

Huisman et al. 2004 *Ecology* 85: 2960-2970

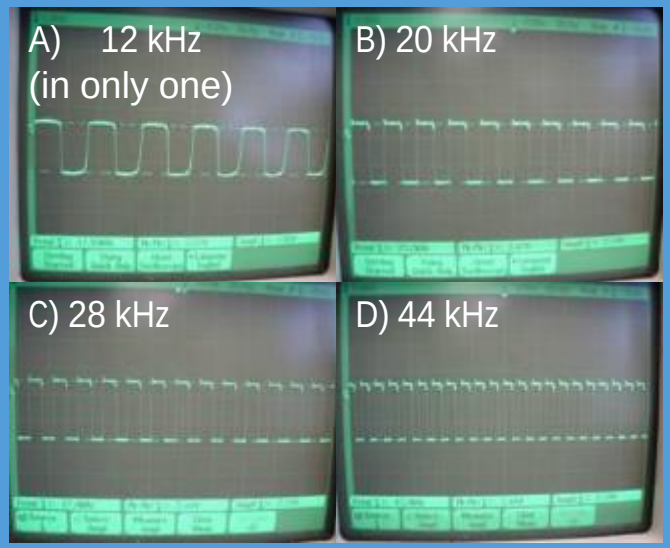
Ultrasound

Ultrasoon geluid kan schadelijke blauwalgen kapotmaken

§ Heavily promoted in the Netherlands

§ Claims: No cavitation, low energy, bringing gasvesicles in resonance, harmless to other aquatic life

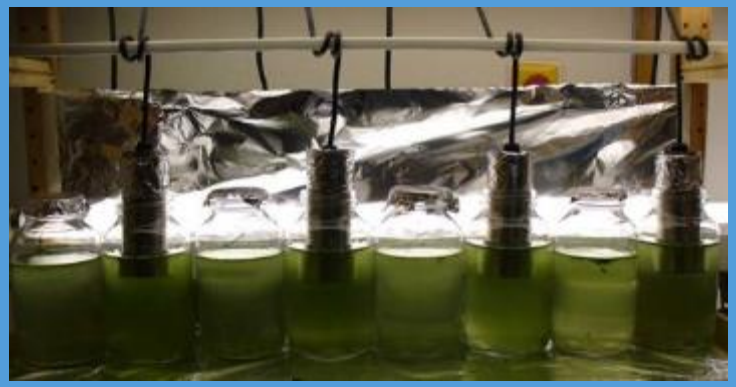
Agilent 54622D Mixed Signal Oscilloscope

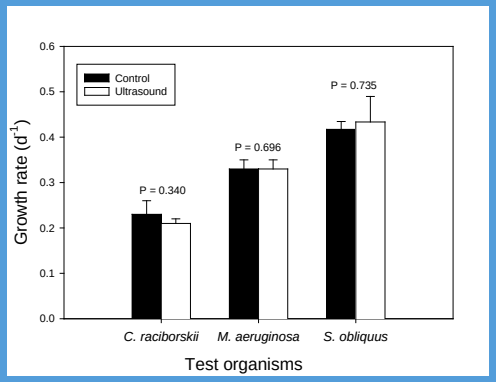


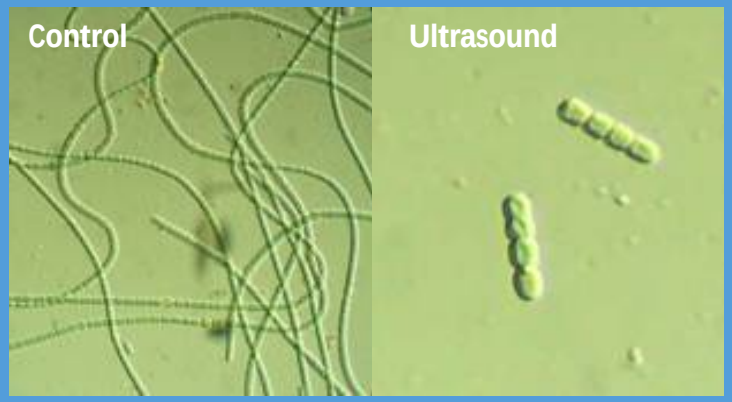
® Low frequency ultrasound (20 - 44 kHz)

Ultrasound: No killing of cyanobacteria

§ Controlled laboratory experiments







No proof for loss of buoyancy, i.e., no collapse of gasvesicles

No effect on
Cylindrospermopsis
Microcystis aeruginosa
Scenedesmus obliquus

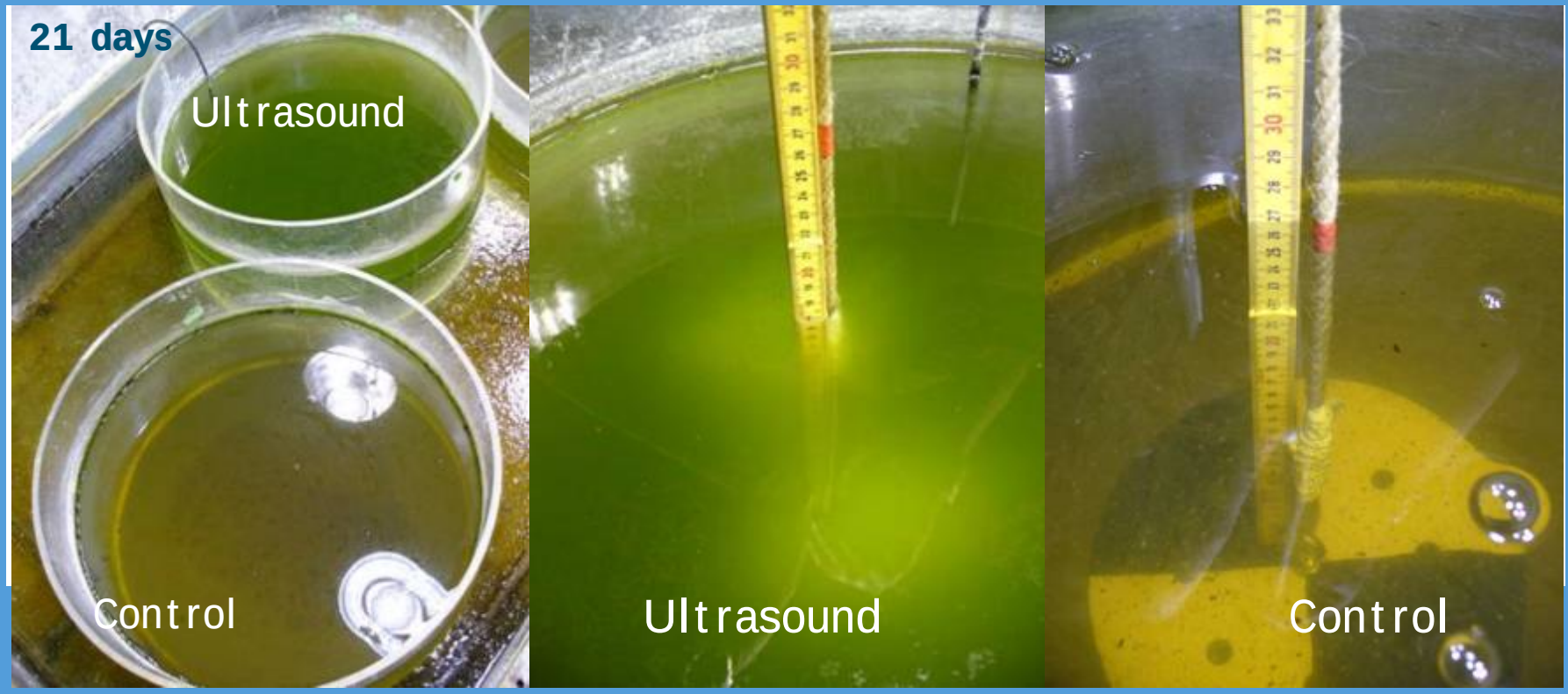
Shortened filaments in *Anabaena* sp. PCC7122
No effect on Photosystem II
No growth inhibition

Ultrasound is lethal for *Daphnia* in lab tests

§ Frequencies from transducers kill *Daphnia* within 2 hours

Ultrasound can make water more green

§ In 85 L tanks ultrasound killed the *Daphnia* releasing the phytoplankton from grazing pressure



Science shows: ultrasound does not control cyanobacteria and is not harmless

§ Read our papers!

WATER RESEARCH 66 (2014) 361–373

Available online at www.sciencedirect.com

ScienceDirect

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

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WATER RESEARCH

CrossMark

Beating the blues: Is there any music in fighting cyanobacteria with ultrasound?

Miquel Lürling [a,b,*], Yora Tolman [a,c]

[a] Aquatic Ecology & Water Quality Management Group, Department of Environmental Sciences, Wageningen University, P.O. Box 47, 6700 AA Wageningen, The Netherlands
[b] Department of Aquatic Ecology, Netherlands Institute of Ecology (NIOO-KNAW), P.O. Box 50, 6700 AB Wageningen, The Netherlands
[c] Regional Water Authority Delfland, P.O. Box 3061, 2061 DB Delft, The Netherlands

Evaluation of several end-of-pipe measures proposed to control cyanobacteria

Miquel Lürling · Guido Waajen · Lisette N. de Senerpont Domis

Water **2014**, *6*, 3247-3263; doi:10.3390/w6113247

OPEN ACCESS

water

ISSN 2073-4441
www.mdpi.com/journal/water

Article

Effects of Commercially Available Ultrasound on the Zooplankton Grazer *Daphnia* and Consequent Water Greening in Laboratory Experiments

Miquel Lürling [1,2,*] and Yora Tolman [1,3]

Toxins **2014**, *6*, 3260-3280; doi:10.3390/toxins6123260

OPEN ACCESS

toxins

ISSN 2072-6651
www.mdpi.com/journal/toxins

Article

Effects of Hydrogen Peroxide and Ultrasound on Biomass Reduction and Toxin Release in the Cyanobacterium, *Microcystis aeruginosa*

Miquel Lürling [1,2,*], Debin Meng [1] and Elisabeth J. Faassen [1]

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100years

SIL

Working Group on Lake Restoration

This was already shown by field experiments more than a decade ago

Nat'l Water Authority: In-situ experiment stopped, cyano's deaf for ultrasound

Algen doof voor geluid

17 apr 2008, 09:02 - THOLEN - Rijkswaterstaat blaast de proef waarin blauwalg in de haven van Tholen met ultrasone geluiden te lijf wordt gegaan, af. De pilot die vorig jaar met veel tamtam werd gelanceerd heeft niets uitgehaald.

Government of South Australia
Adelaide and Mount Lofty Ranges Natural Resources Management Board

Torrens Taskforce

Treatment Processes

Tholen en Gouden Ham

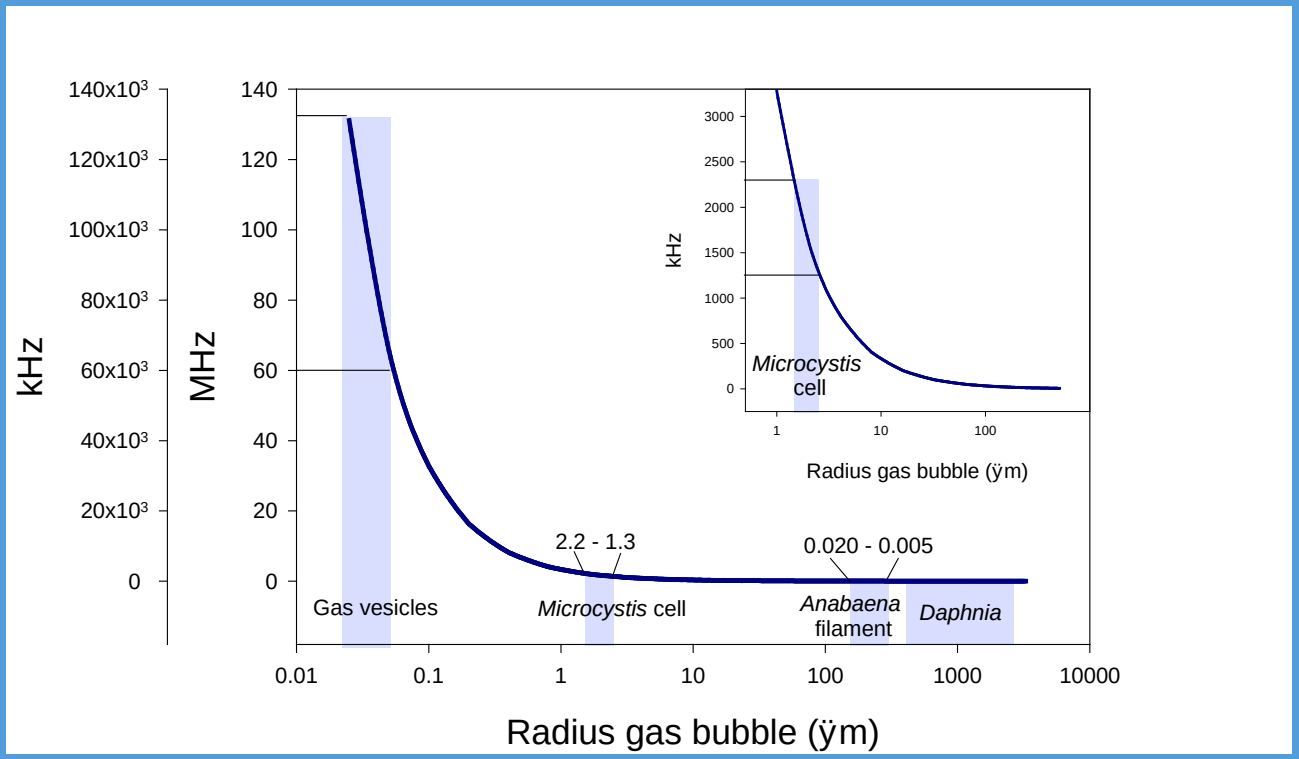
Kardinaal *et al.*, 2008: Ultrasound could **NOT prevent** cyanoblooms and surface scums

The Australian Water Quality Centre (AWQC) has studied commercial ultrasonic systems and concluded that they were not effective at preventing algal growth. The study found that

“Buoys” do not control blooms either

§ Ultrasound ineffective: Water authority will now use H_2O_2

Experiments show it, physics explains it: Low energy, low frequencies ultrasound CANNOT work.



Resonance frequency can be calculated:

$$f_0 = \frac{1}{2\pi}\sqrt{\left(\frac{3\gamma}{R_0^2\rho}\left(p_0 + \frac{2\sigma}{R_0} + \frac{2\chi}{R_0}\right) - \left(\frac{2\sigma + 6\chi}{R_0^3\rho}\right)\right)}$$

There is no music in fighting cyanobacteria with ultrasound

§ “Buoys” are old wine in new packaging

Scepsis

Ondanks dat de MPC-Buoy getest is door diverse universiteiten in Groot-Brittannië, Italië en Oostenrijk is dr.ir. Miquel Lurling, onderzoeker bij de leerstoelgroep aquatische ecologie en waterkwaliteitsbeheer aan de universiteit van Wageningen, sceptisch over de voorgenomen aanpak in Zoetermeer. ‘De gebruikte frequenties zijn simpelweg veel te laag om gasblaasjes in resonantie te brengen. Eerdere proeven in 2007 en 2008, onder andere uitgevoerd door het hoogheemraadschap van Rijnland, brengen naar voren dat er nul komma nul effect is van ultrageluid op het verwijderen van blauwalg.’

Wethouder Paalvast is op de hoogte van de eerder gedane proeven in Nederland, maar heeft daar een andere mening over. ‘De techniek heeft sinds die tijd niet stilgestaan. De MPC-Buoy levert maatwerk, dat maakt een wereld van verschil. Daarnaast gaat het om een innovatieve uitdaging en mocht de pilot niet slagen, hebben we wel interessante informatie over de waterkwaliteit verkregen.’

“*Ultrasonic buoy as new weapon against blue-green algae in Noord-Aa*.”

A system and method for predicting,monitoring, preventing and controlling algae in open water

WO 2013055207 A1

The frequency range (20kHz to 100kHz) can be input to the transducer driven circuit by using PC,

The patent shows that “new” has nothing to do with power or frequencies. Hence, buoys will not bring gasvesicles into resonance and will not sink cyanobacteria.

Be aware of “before-after pictures”

Installations and Results

- Wilding Acres West Virginia waste water lagoon
- 4 weeks

SONICSOLUTIONS

https://conference.ifas.ufl.edu/aw13/Presentations/2-Wednesday/Grand%20Floridian/Session%208b/0300%20Whatley.pdf

SONICSOLUTIONS

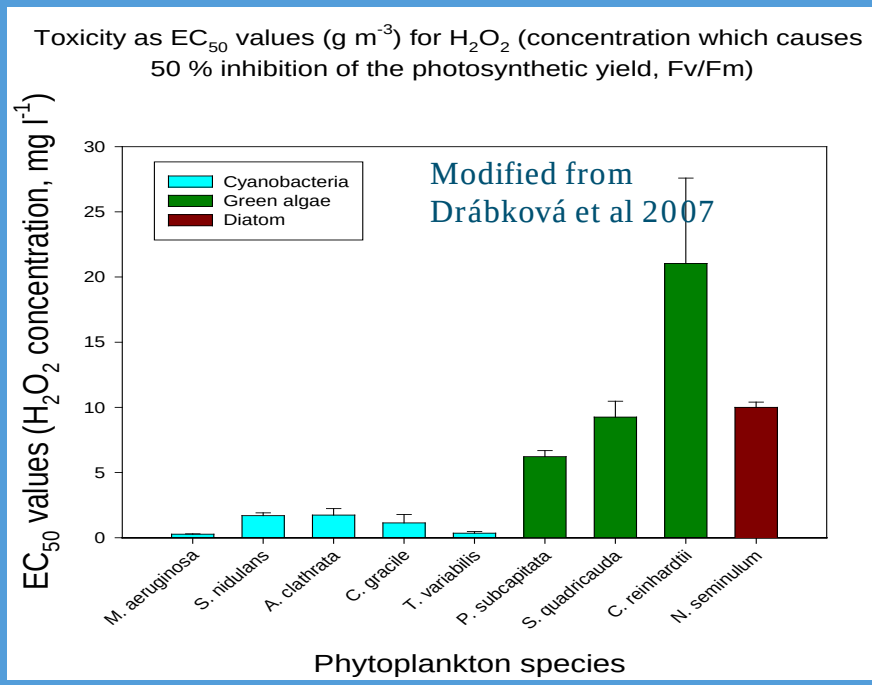
Chemical measures

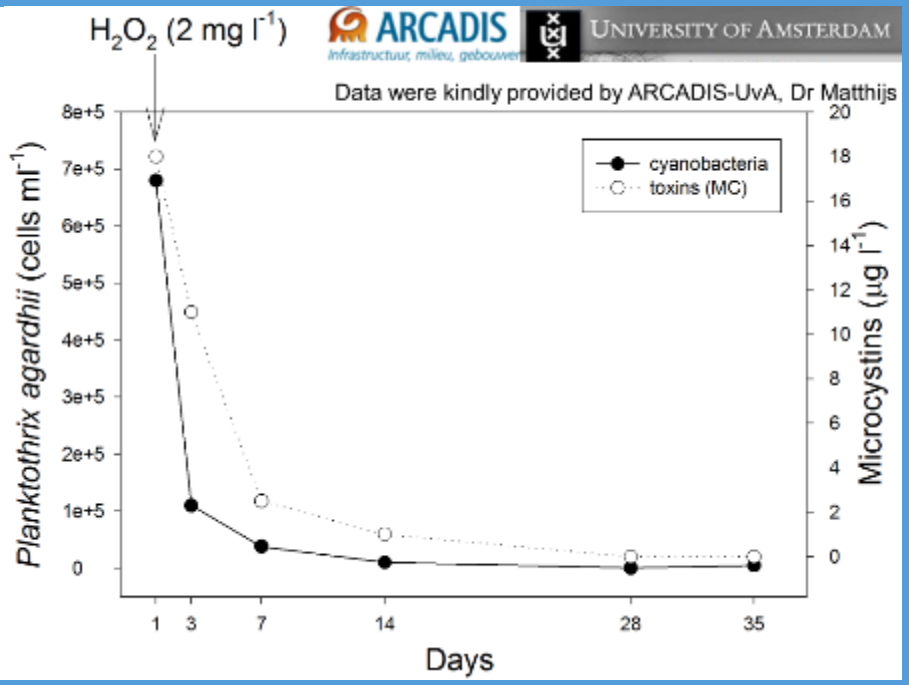
§ Algaecides and coagulants are most common

§ Intended effect: decimating/removing cyano-biomass

Hydrogen peroxide

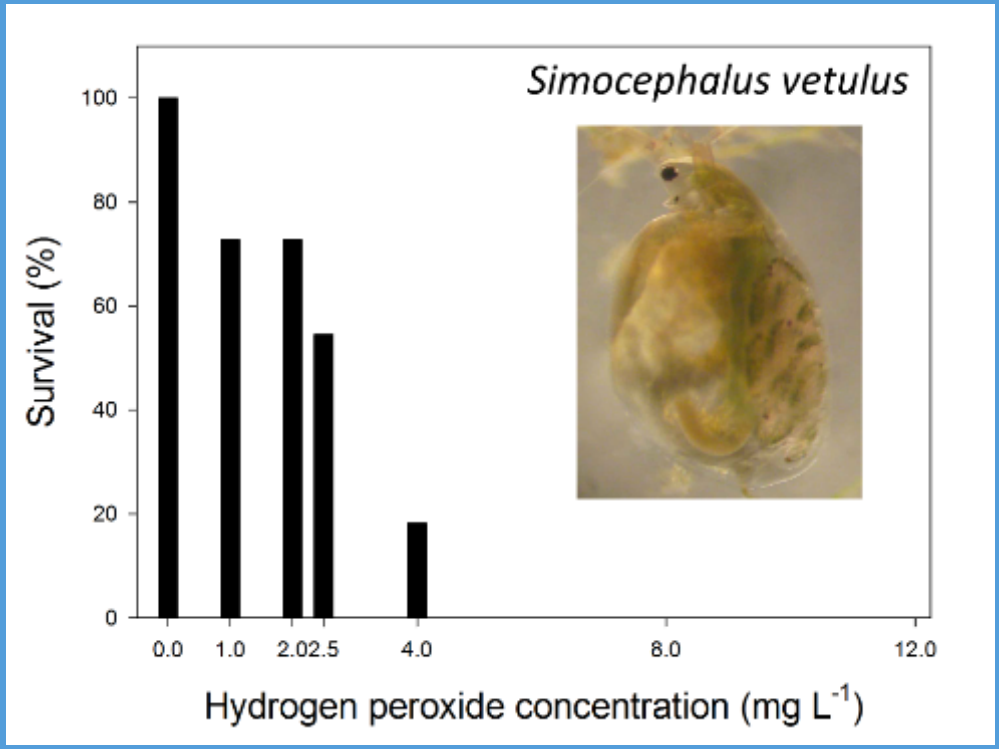
§ Cyanobacteria are more sensitive than eukaryotes to H_2O_2





Hydrogen peroxide

§ Several causes for variability in efficacy



S Presence other algae

S *Microcystis* in colonies and mucus

S DOC and/or sulphides

S Particulate organic matter

F Higher doses?

Coagulants

§ Inorganic – alum, polyaluminium chloride, ferric chloride

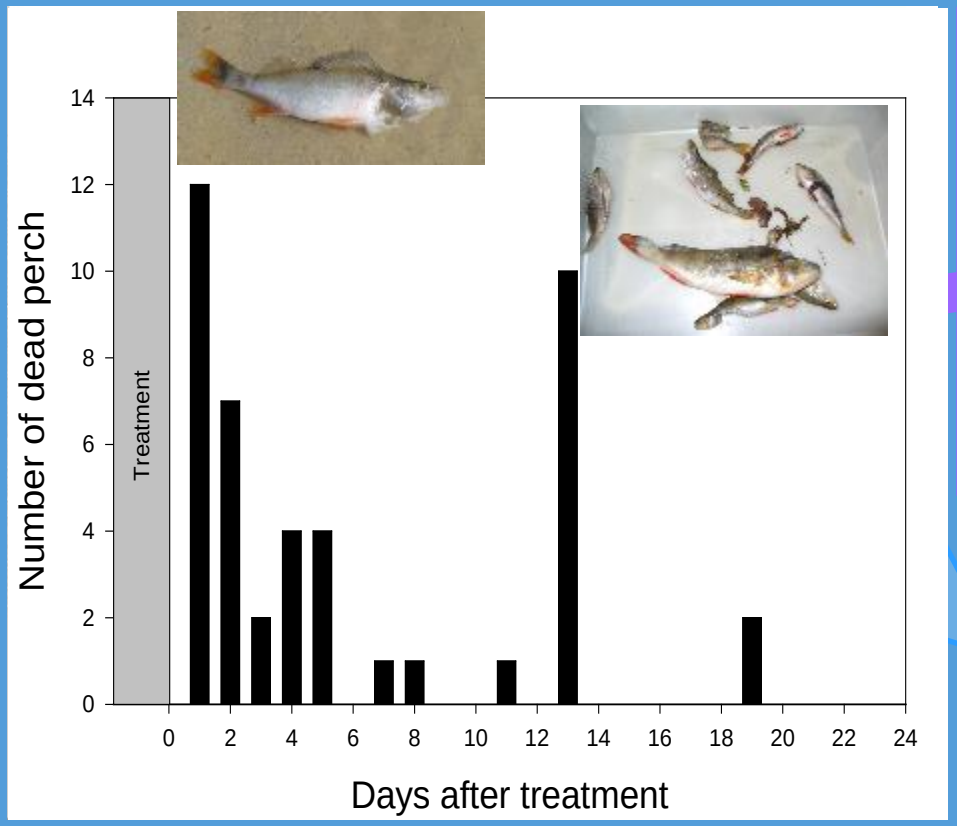
§ Organic – chitosan, polyacrylamides, *Moringa* extract…

Coagulants

§ In general good flocculation, depending on environment

§ There are risks...

Al toxicity in fish also by precipitation of $Al(OH)_3$ on gills and suffocation of the fish (Wauer et al. 2004).



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Aquatic Toxicology 31 (1995) 347–356

AQUATIC TOXICOLOGY

Aluminium polymerization — a mechanism of acute toxicity of aqueous aluminium to fish

Antonio B.S. Poléo

Original Paper

Microchimica Acta
Printed in Austria

Analysis of Toxic Aluminium Species in Natural Waters

Gerlinde Wauer[1,*], Hans-Jürgen Heckemann[2], and Rainer Koschel[1]

ECOTOXICOLOGY AND ENVIRONMENTAL SAFETY 10, 253–267 (1985)

The Influence of pH on the Toxicity of Aluminum, Cadmium, and Iron to Eggs and Larvae of the Zebrafish, *Brachydanio rerio*

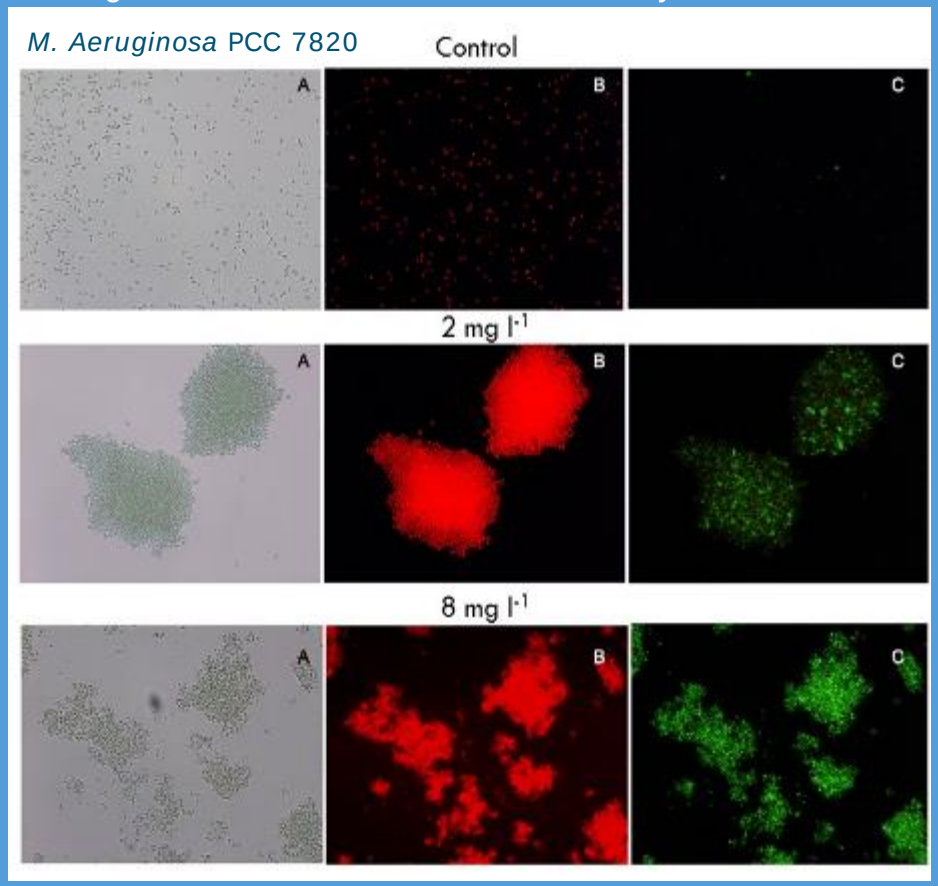
GÖRAN DAVE

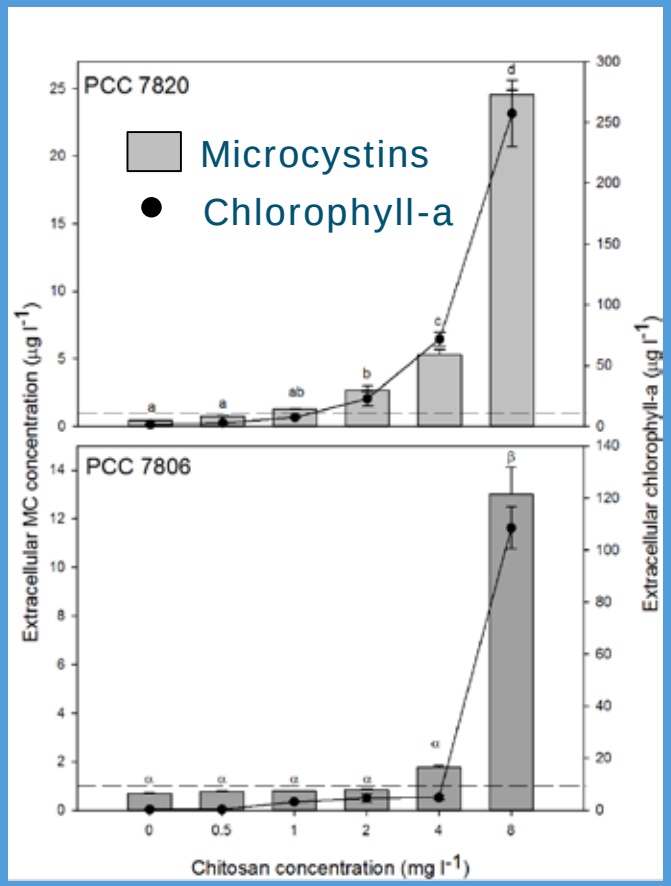
pH, Hardness, and Humic Acid Influence Aluminum Toxicity to Rainbow Trout (*Oncorhynchus mykiss*) in Weakly Alkaline Waters

Deke T. Gundersen, Sjahrul Bustaman, Wayne K. Seim, and Lawrence R. Curtis[1]

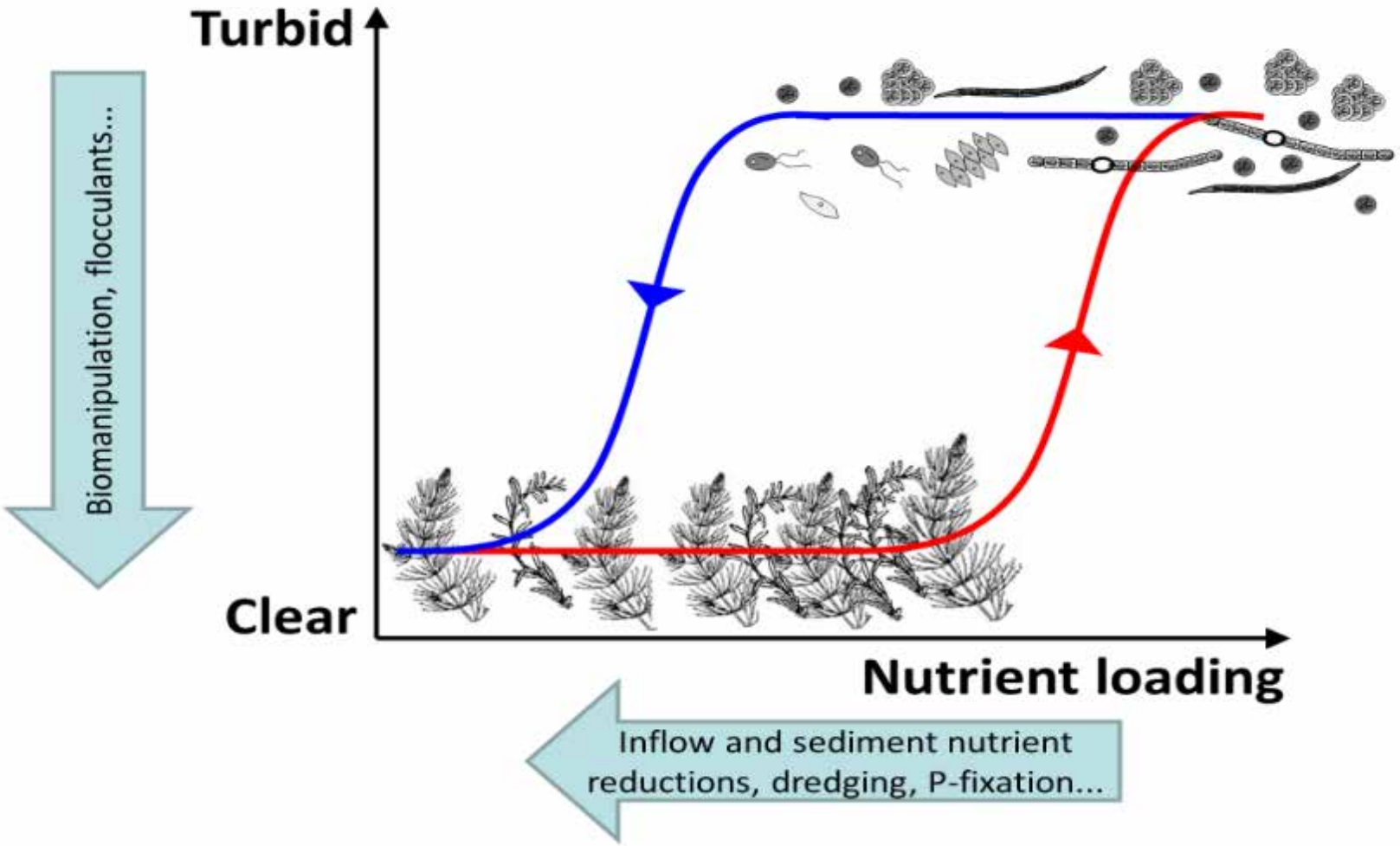
Chitosan damages cell wall

§ Constituents are being released from damaged cells





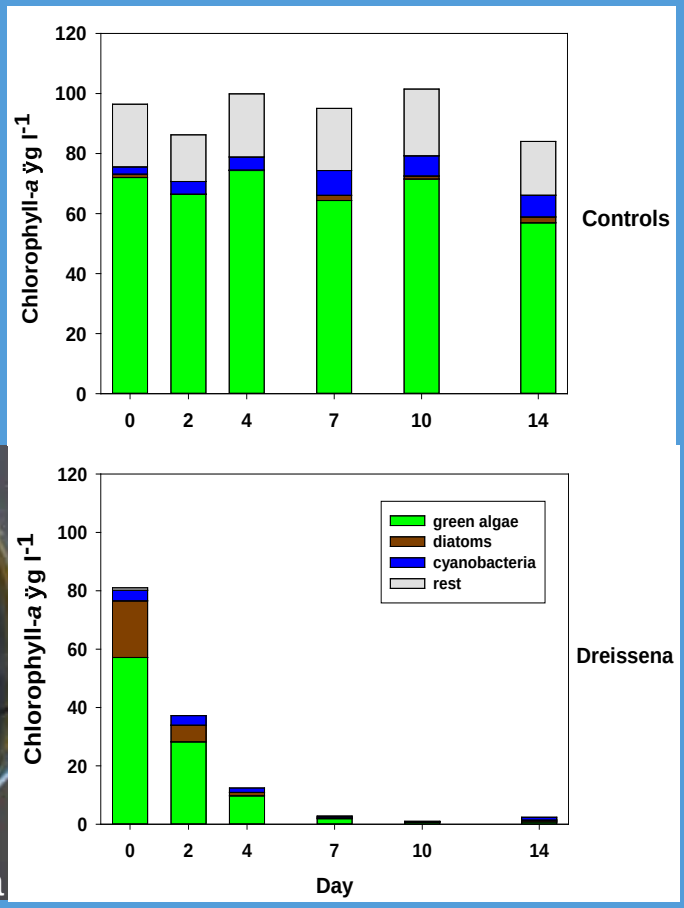
Biological measures



Zebra mussels

§ Filtering could reduce phytoplankton biomass

Experiment with 1600 crates of dreissenids placed in 1.1 ha urban pond (Linievijver Breda) failed, because mussels didn't reproduce and died in three years time.



1000-faces of “Effective Micro-organisms”

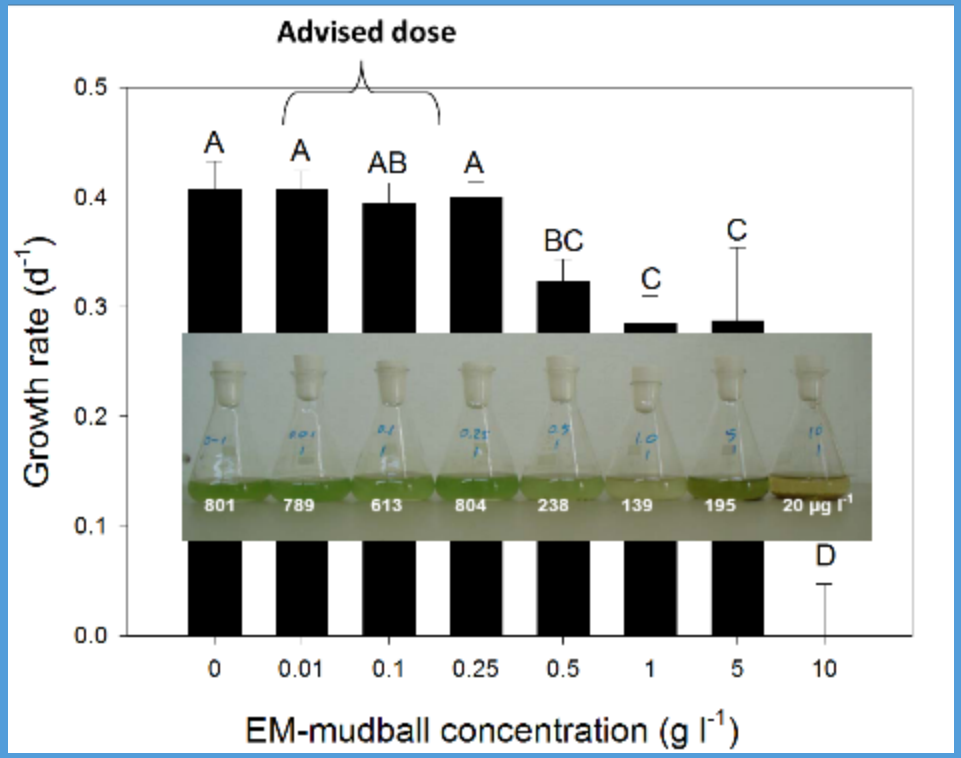
They come in many formulations, but are they as ‘effective’ as claimed?

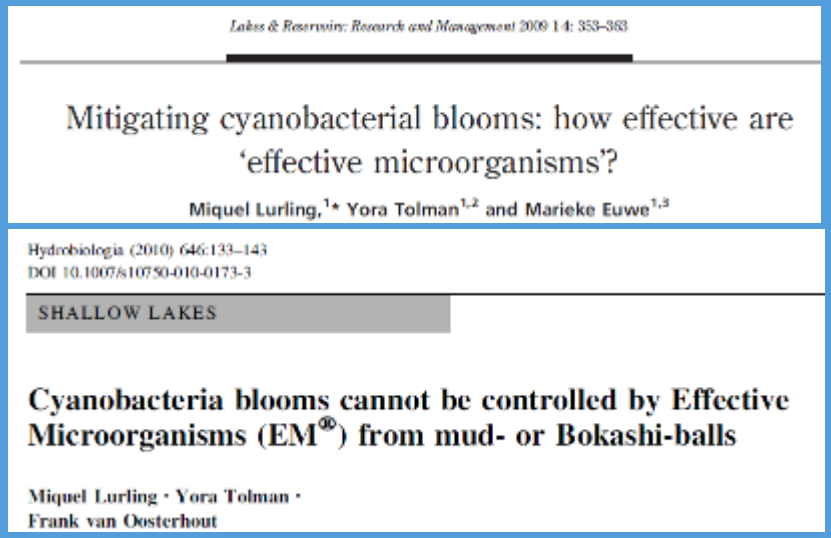
H	H	H	H	H
EM-A suspension	EM-mudballs	ACF32	Poco	CBX

“Effective microbes” are not effective at all

§ Do not remove or permanently fix P

§ Are on menu grazers ® Green soups remain





Lakes & Reservoirs: Research and Management 2009 14: 353–363

Mitigating cyanobacterial blooms: how effective are ‘effective microorganisms’?

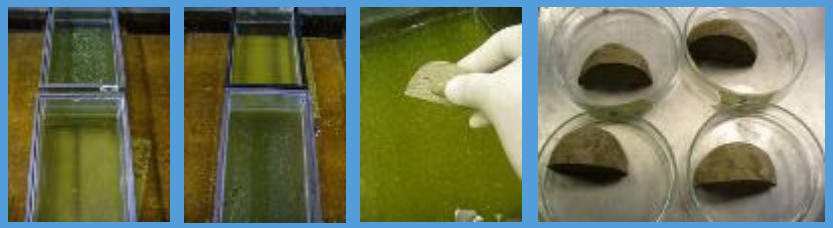
Miquel Lurling,[1]* Yora Tolman[1,2] and Marieke Euwe[1,3]

Hydrobiologia (2010) 646:133–143
DOI 10.1007/s10750-010-0173-3

SHALLOW LAKES

Cyanobacteria blooms cannot be controlled by Effective Microorganisms (EM®) from mud- or Bokashi-balls

Miquel Lurling · Yora Tolman · Frank van Oosterhout



Golden algae

Het goudalgje smult van de blauwalg

HOME

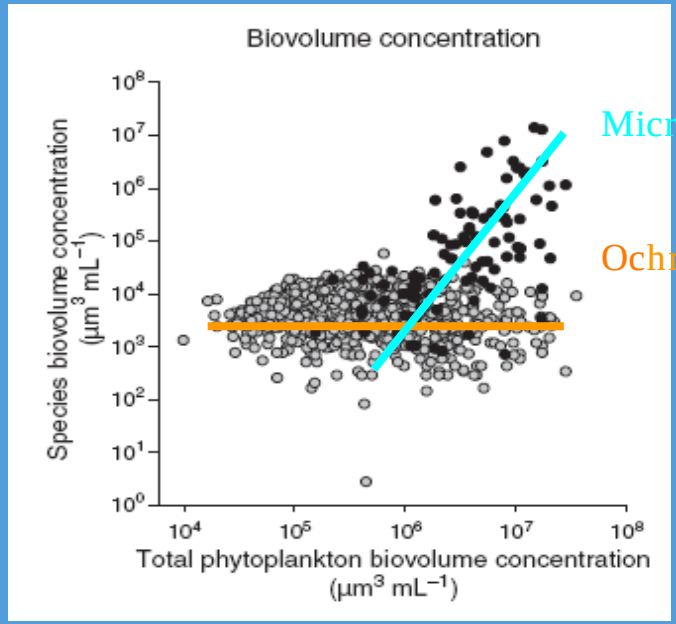
Carla van Lingen – 13 juli 2010

Voor bestrijding van de blauwalg – dé zomerplaag van open zwemwater – zijn verschillende methoden ontwikkeld. Geen een pakt het kwaad bij de wortel aan, zegt aquatisch bioloog Ellen van Donk. Zij zoekt de oplossing in de natuur zelf: organismen die de blauwalg opeten.

Freshwater Biology (2009) 54, 1843–1855 doi:10.1111/j.1365-2427.2009.02227.x

The effect of a mixotrophic chrysophyte on toxic and colony-forming cyanobacteria

ELLEN VAN DONK*, SLAWEK CERBIN*, SUSANNE WILKEN*, NICO R. HELMSING*, ROBERT PTACNIK† AND ANTONIE M. VERSCHOOR*
*Netherlands Institute of Ecology (NIOO-KNAW), Centre for Limnology, Nieuwersluis, The Netherlands
†Norwegian Institute for Water Research, Oslo, Norway



From: Van donk et al 2009

- *(Poterio)Ochromonas* only eats *Microcystis* cells and small colonies
- Golden algae are omnipresent, still cyano's
- Golden algae may produce foul odours and toxins (chlorosulfolipids)
- Golden algae may cause fish kills
- If successful, no cyano-, but golden bloom

Plant-tree and extracts

§ Many claims:

"it will become the most promising method to control algal bloom" (Hu and Hong 2008)

"barley straw can be an effective control method" (Purcell et al. 2013)

"effective and environmentally-sound option for the control of cyanobacterial and microalgal blooms" (Iredale et al. 2012)

"very useful for controlling of M. aeruginosa based blooms" (Shao et al. 2013)

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Barley straw

ELSEVIER

Available online at www.sciencedirect.com

SCIENCE DIRECT®

Bioresource Technology 96 (2005) 1788–1795

BIORESOURCE TECHNOLOGY

The effects of barley straw (*Hordeum vulgare*) on the growth of freshwater algae

M.D. Ferrier [a,*], B.R. Butler Sr. [b], D.E. Terlizzi [c], R.V. Lacouture [d]

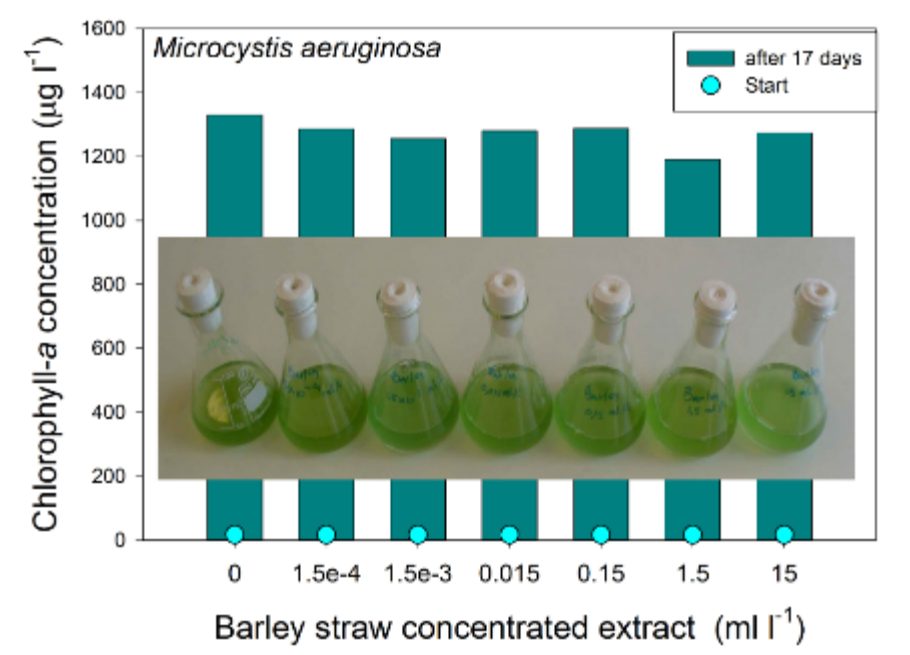
In a related field study, we treated four of six ponds with barley straw and monitored their chlorophyll *a* levels for one growing season. While phytoplankton populations in all ponds decreased in midsummer, the phytoplankton biomass in treated ponds did not differ significantly from that of control ponds, suggesting that the application of barley straw had no effect on algal growth in these systems.

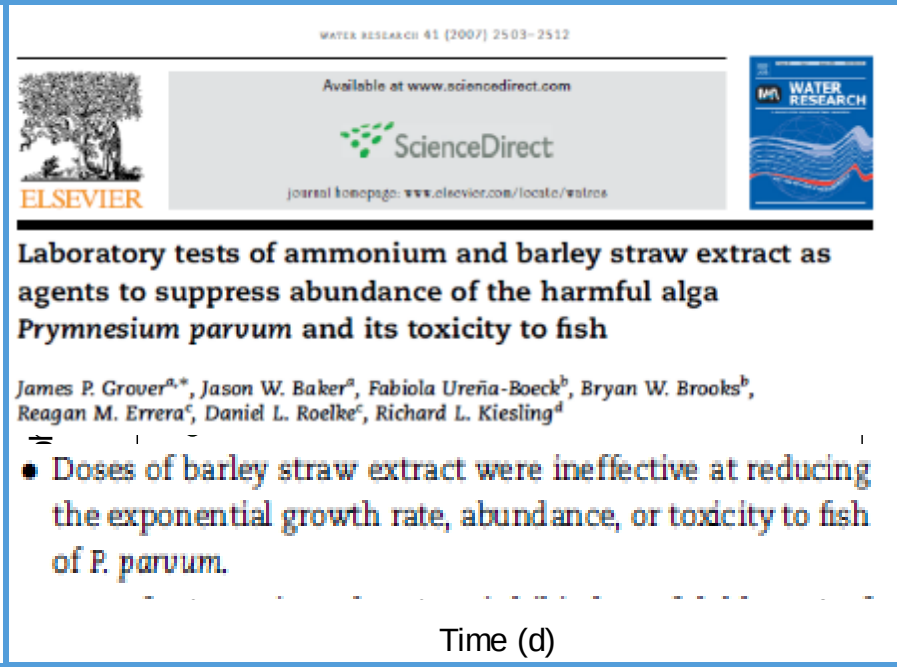
No effect in other pond study too

Barley straw extract

§ No growth reduction in nutrient rich Microcystis strain

growth stimulation of natural phytoplankton





Informing colleagues

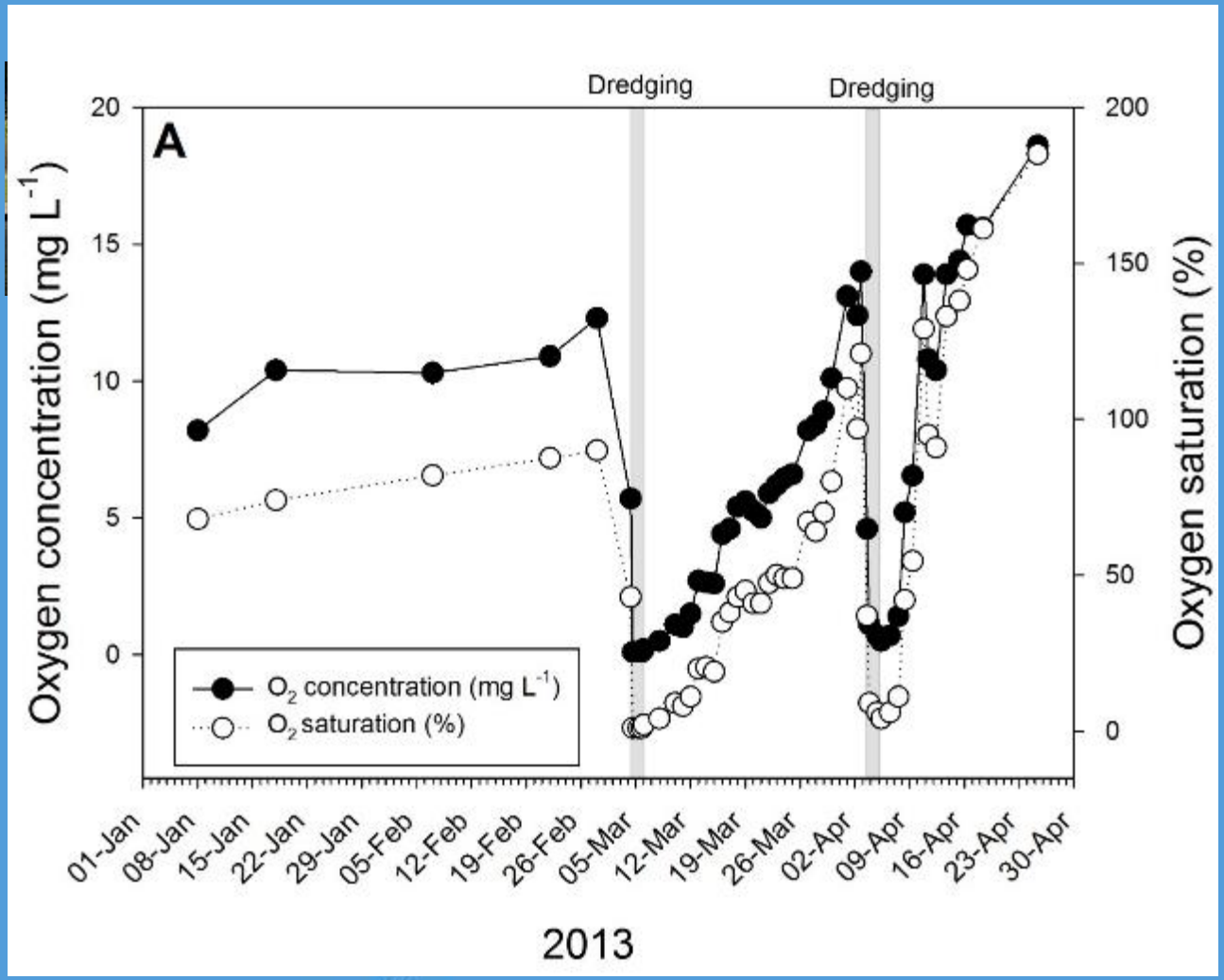
Source oriented measures

- Strong reduction/prevention nutrient input
  - Waste water treatment plants
  - Diverting/dismantling sewer overflow systems
  - Agricultural/urban run-off
  - Animals feeding prohibition…
- Strong reduction of internal loading
  - Chemical fixation of phosphorus, oxygenation
  - Dredging
  - Hypolimnetic withdrawal
- Biomanipulation (= harvesting nutrients)

Sediment removal

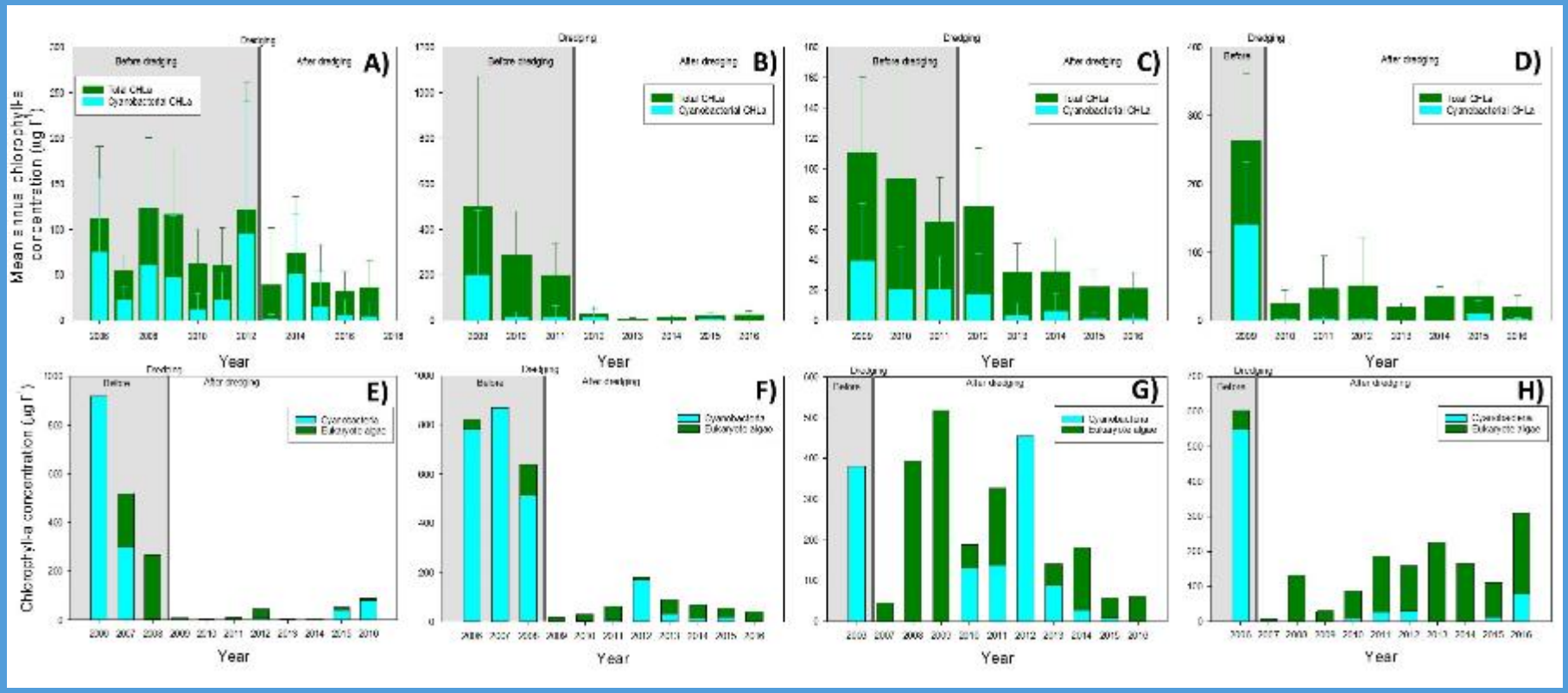
§ Dredging and excavation

Wet dredging is also active fish removal



Dredging is common in urban waters

§ Variable results dredging; costly (€25-60 per m^3 sediment)



All ponds are in The Netherlands: A) pond Molenwiel (Sint-Oedenrode), B) pond Dongen (Dongen), C) pond Stiffelio (Eindhoven), D) pond Heesch (Heesch), E) pond Anton van Duinkerkenpark (Bergen-op-Zoom), F) pond Etten-Leur (Etten-Leur), G) pond Loovevijver (Someren), H) pond Bennekom (Bennekom).

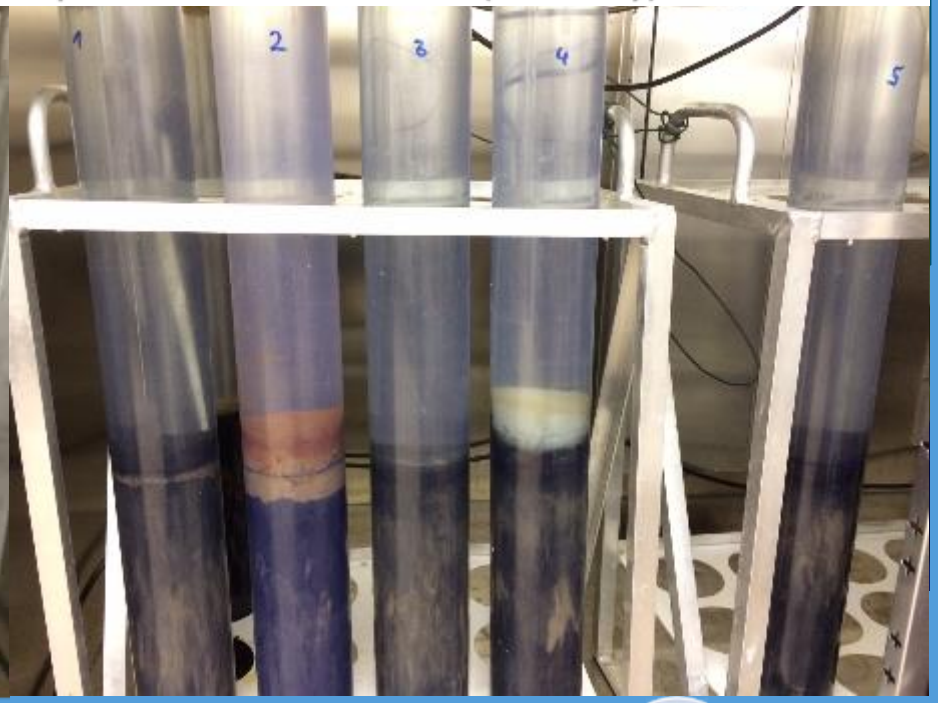
P-fixation – blocking sediment P release

§ Testing numerous compounds

Dr Said Yasseri – Limnological Institute Dr Nowak, Germany

P-incubation tests

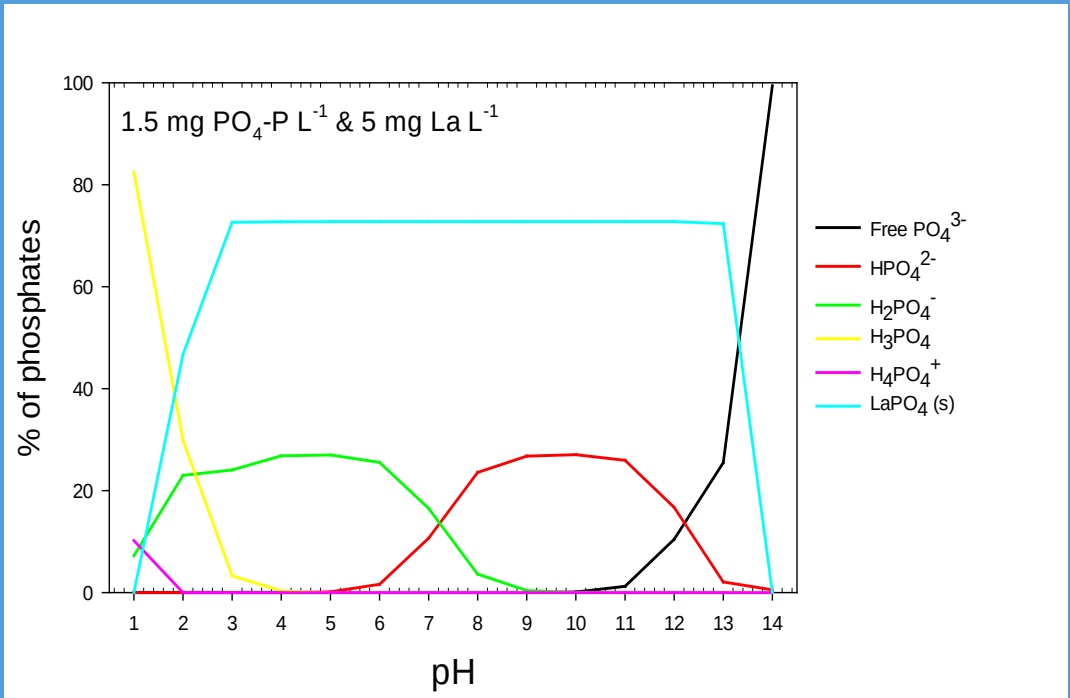
Incubation of sediment cores from Bothkamper See and Werratalsee (Germany)



In cases with high internal load Phoslock® is a powerful tool

§ Active ingredient is rare earth element lanthanum

§ Extremely low solubility lanthanum – orthophosphate:



$La(OH)^{2+} + HPO_4^{2-} \rightarrow LaPO_4 \times H_2O$

$La^{3+} + PO_4^{3-} \rightarrow LaPO_4$

$LaPO_4 \times nH_2O$ = rhabdophane
$LaPO_4$ = monazite

Phoslock yes, but not alum in Netherlands?

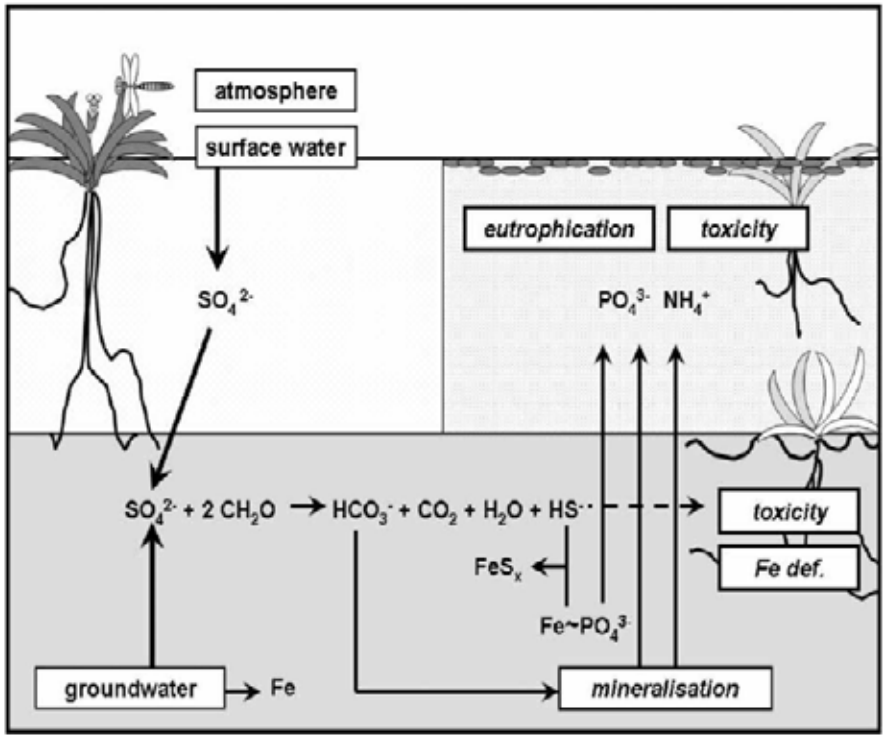


Figure 5. Multiple environmental stress hypothesis explaining the decline of *Stratiotes aloides* in the Netherlands. Sulphate enters via surface water, groundwater, or atmospheric deposition. The reduction of sulphate to sulphide causes eutrophication as the sulphide interacts with P binding, and mineralization is stimulated by alkalinity generation. As a result, the water layer becomes eutrophied, leading to the dominance of floating species and algae. Simultaneously, sulphide and ammonium toxicity and iron deficiency may occur.

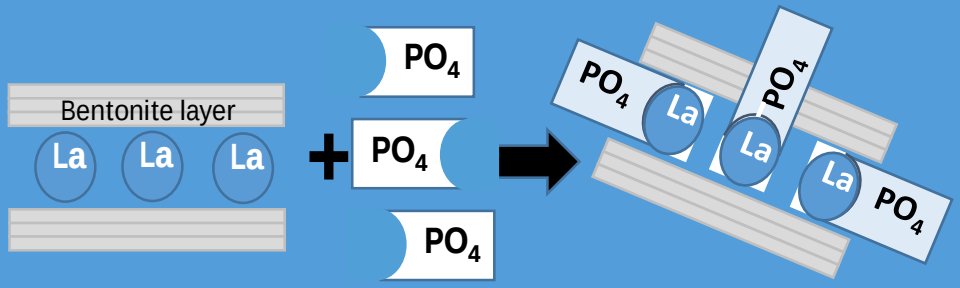
Chemistry and Ecology
Vol. 22, No. 2, April 2006, 93–111
Taylor & Francis

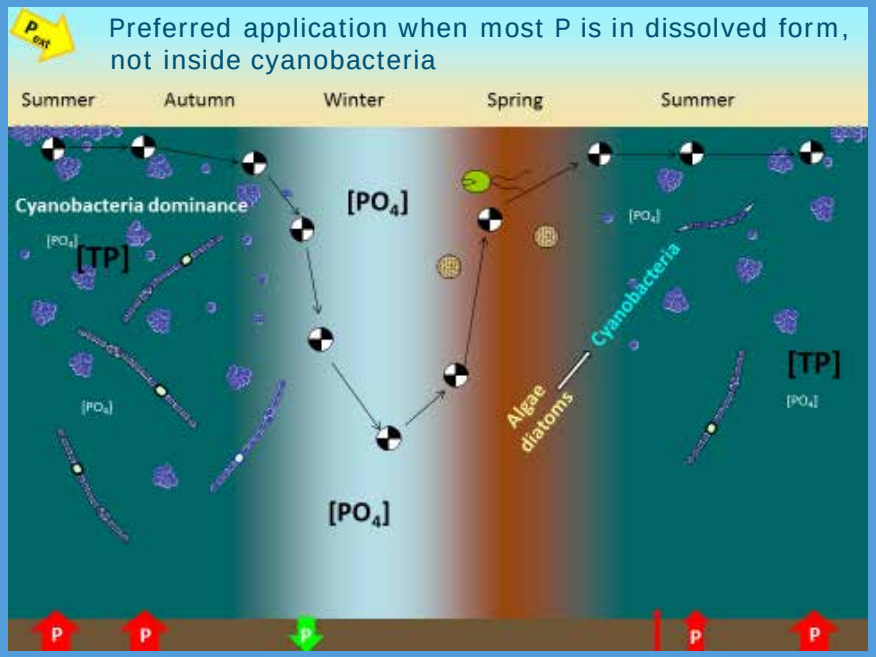
storation by in-lake precipitation of PO_4^{3-} with
is commonly used but there is currently no good
ies for calculating doses (amounts and application)
n ensure long lasting effects. We studied the effect of
f $Al(OH)_3$ on PO_4^{3-} adsorption and desorption properties
d without PO_4^{3-} in solution and found that $Al(OH)_3$
ithout PO_4^{3-} lost 75% of the maximum adsorption capacity
ays after which no further changes occurred. $Al(OH)_3$
presence of PO_4^{3-} maintained the adsorption capacity
6 months and even increased it for PO_4^{3-} concentrations
M. On this basis, we suggest that repeated dosing of
Al-aliquots may be more efficient than adding a
ig dose. Also, Al should be added at the time when
vailability in the lake is highest. At laboratory conditions
ained molar P:Al binding ratios of 0.12–0.19 at PO_4^{3-}
trations similar to those in eutrophic lake sediments, but
xamining $Al(OH)_3$ aged in situ in two lake sediments
atios (~0.1) were found. We suggest that total Al-dosage
be calculated relative to the pool of potential mobile
lake with a molar ratio not less than 10 Al: 1 P.

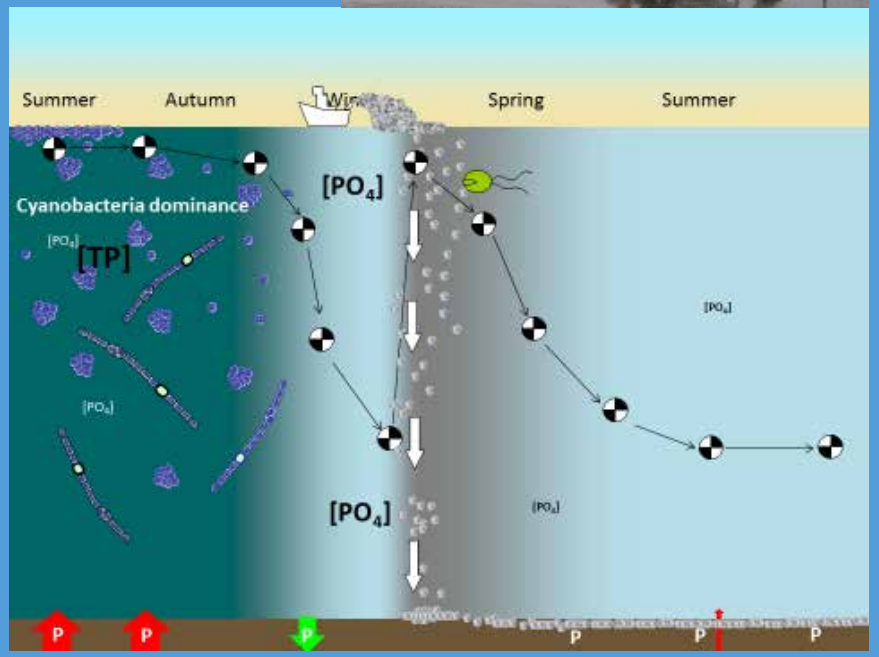
Phoslock – lanthanum modified bentonite

Lanthanum is primarily in interlayer between bentonite sheets (exchangeable cations)

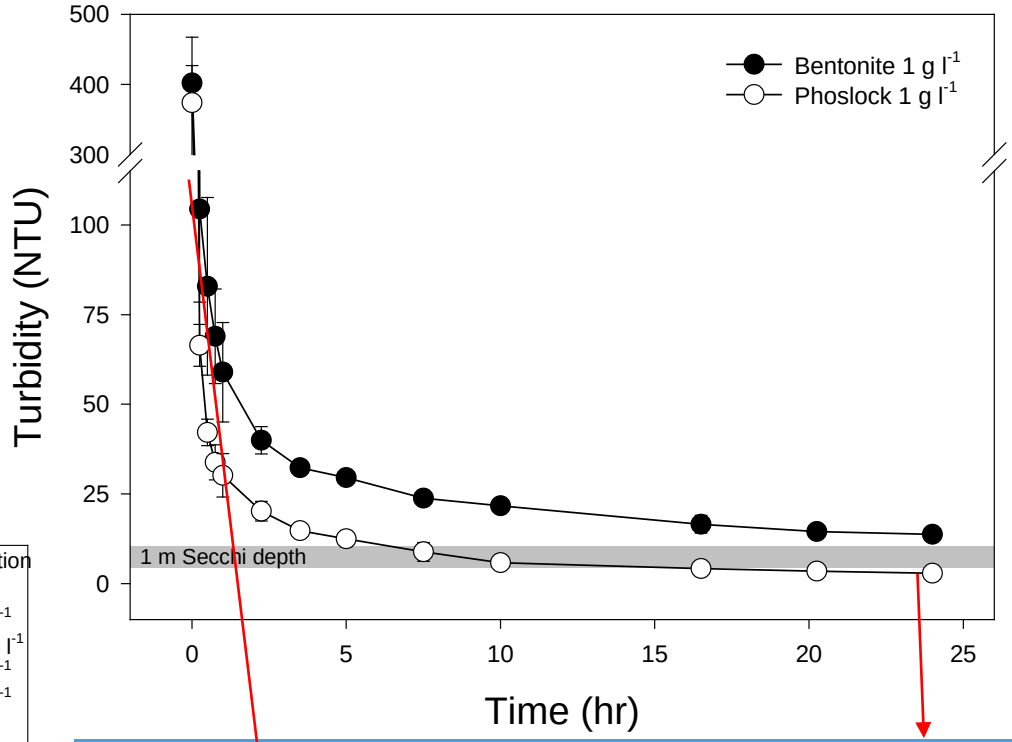
Bentonite = carrier, facilitates transport La to sediment

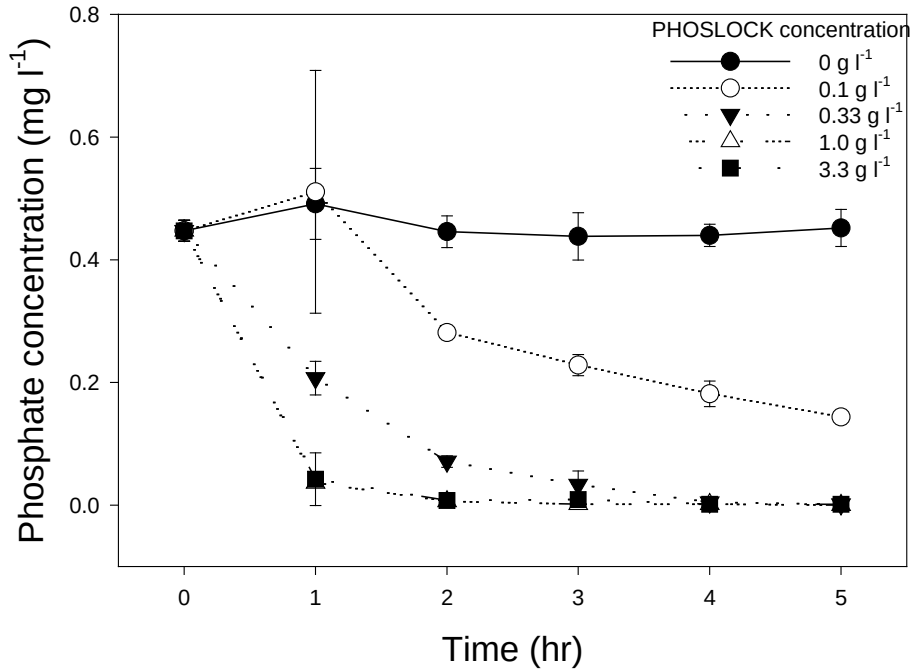






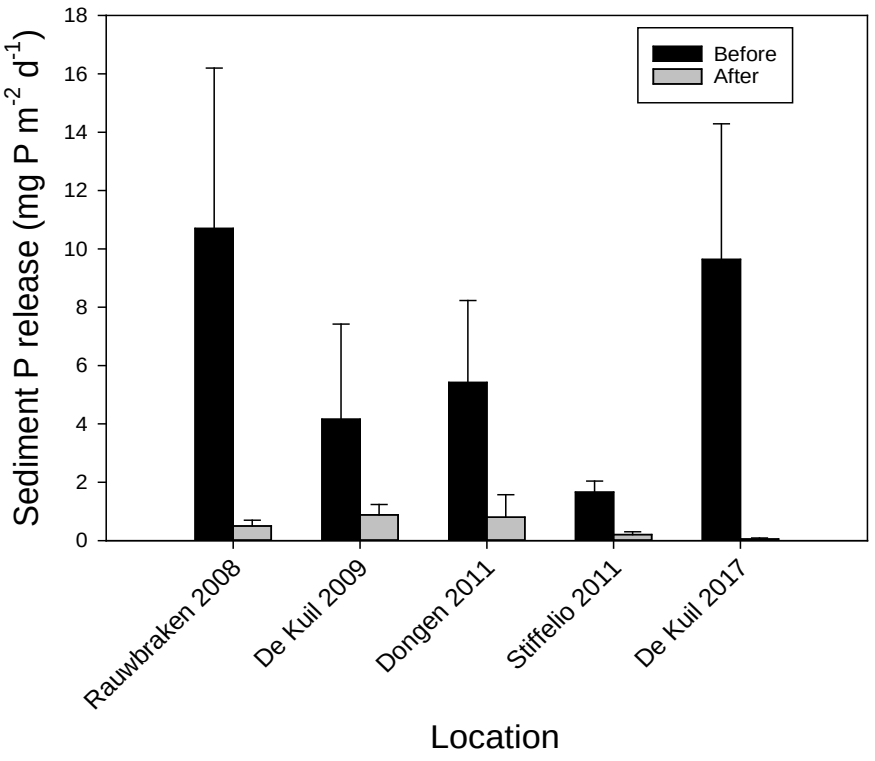
Added to the water as slurry:
Increased turbidity
Rapid phosphate sorption



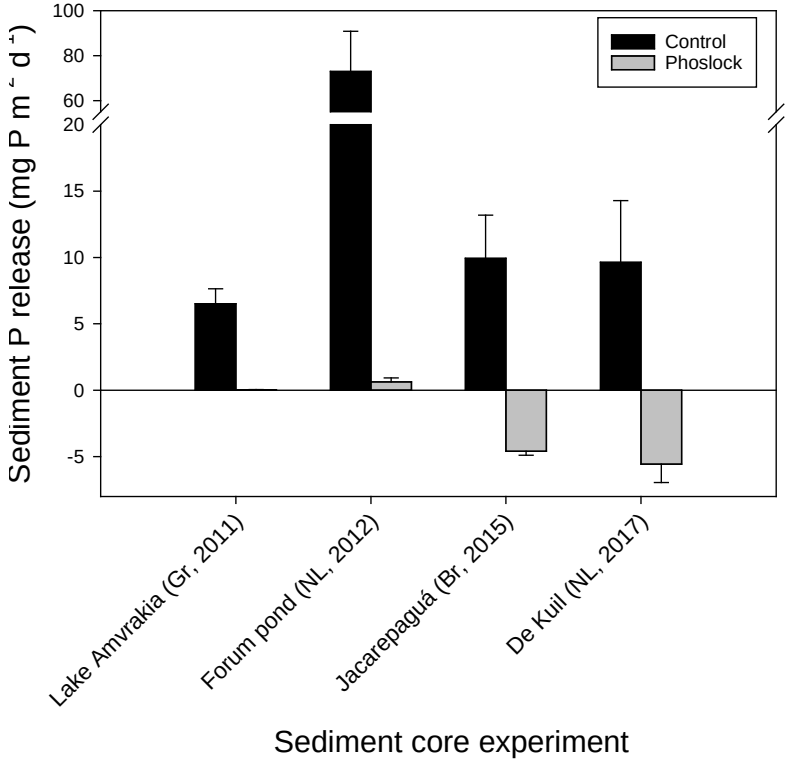


Phoslock strongly reduced sediment P release – also effective under anoxia

Sediment P release in cores from different lakes before and after Phoslock treatment



Effect of Phoslock on sediment P release in cores from different lakes



Phoslock treatment: predominantly $LaPO_4$ is formed in sediment

Water Research 97 (2016) 101–110

Contents lists available at ScienceDirect

Water Research

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

Responses in sediment phosphorus and lanthanum concentrations and composition across 10 lakes following applications of lanthanum modified bentonite

Line Dithmer [a, b], Ulla Gro Nielsen [a], Miquel Lürling [c], Bryan M. Spears [d], Said Yasseri [e], Daniel Lundberg [f], Alanna Moore [d], Nicholai D. Jensen [a], Kasper Reitzel [b, *]

La was distributed across the upper 10 cm of bed sediments in most of the ten LMB-treated lakes. The majority of La was recovered in the HCl-fraction following sequential chemical extraction procedures, and rhabdophane was identified as the dominant La phosphate mineral by solid state ^{31}P NMR and EXAFS spectroscopy.

Field experiments in the Netherlands

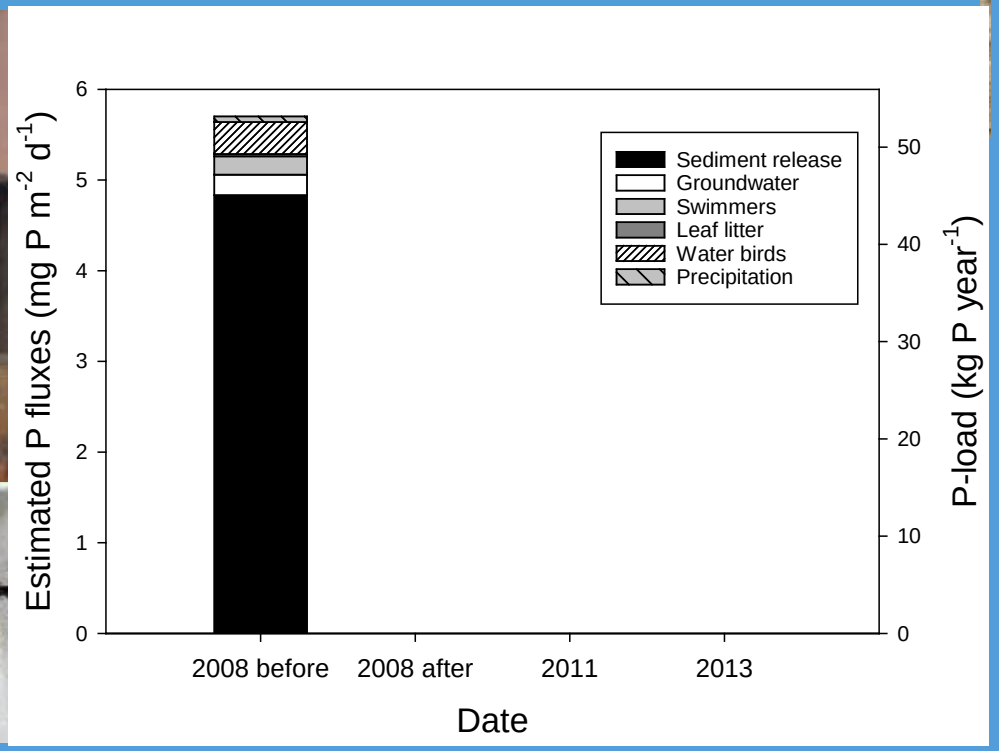
Pond Eindhoven	0.7	Compartments	9/2009 – 9/2011	1.13 kg/m2
Pond Eindhoven	0.7	Enclosures	Aug – Sep 2010	1.3 kg/m2
Pond Heesch	0.16	Enclosures	Jul – Sep 2009	0.3 kg/m2
Kleine Melanen	4	Enclosures	Mar – Jun 2010	0.3 kg/m2
Kleine Melanen	4	Field	Aug – Oct 2010	16.6 ton Phoslock®
Grootte Melanen	4.8	Field	19/20 Apr 2016 20 Apr 2016	13.7 ton Phoslock® 4 ton PAC

Lake Rauwbraken – official bathing site

Lake Rauwbraken

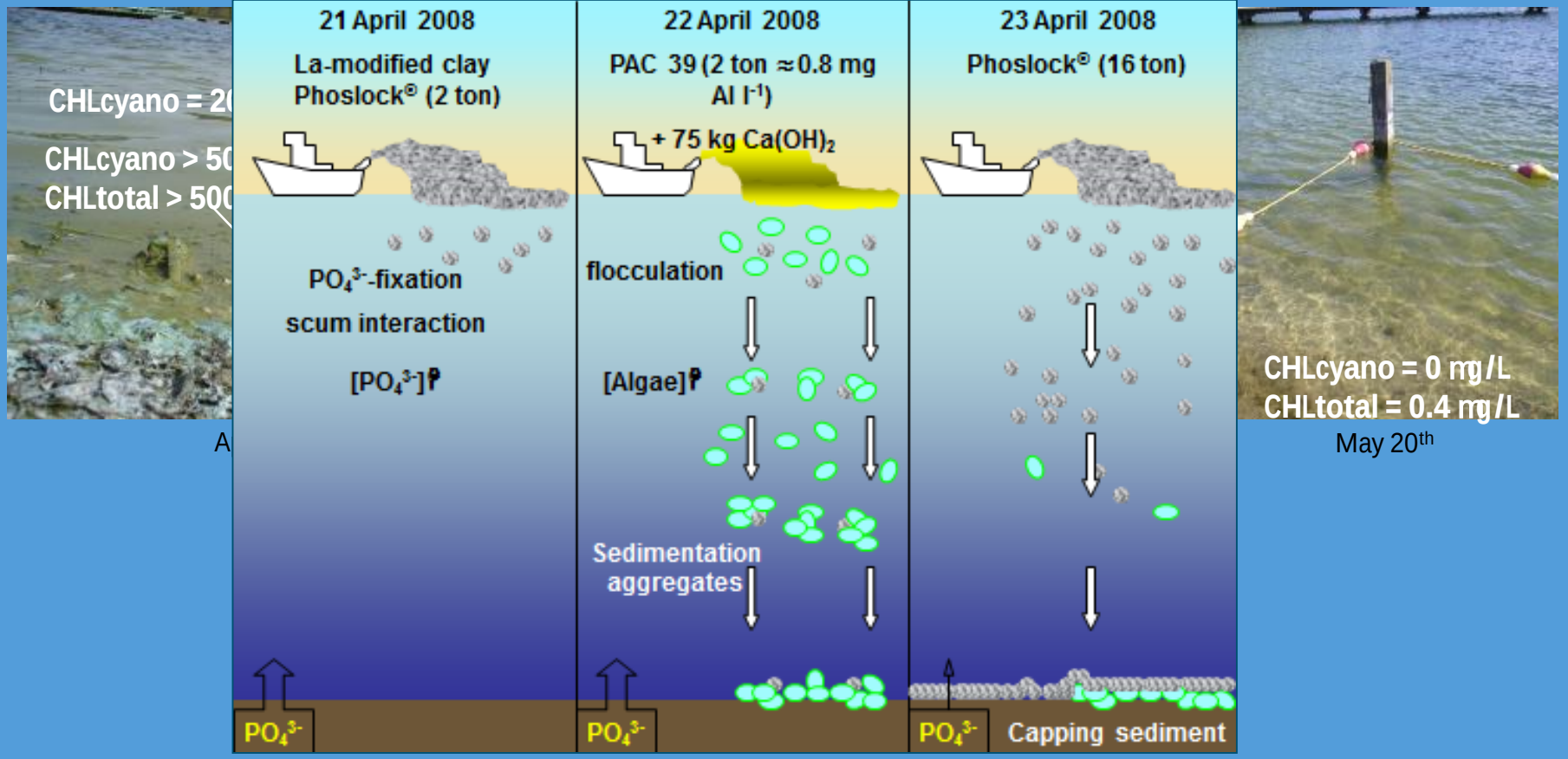
Water: No inflow, no outflow, precipitation, evaporation, groundwater

P: P in precipitation, P in groundwater, P from leaf litter, P from birds, P from bathers, P from sediment…



Combined coagulant + P-fixative addition

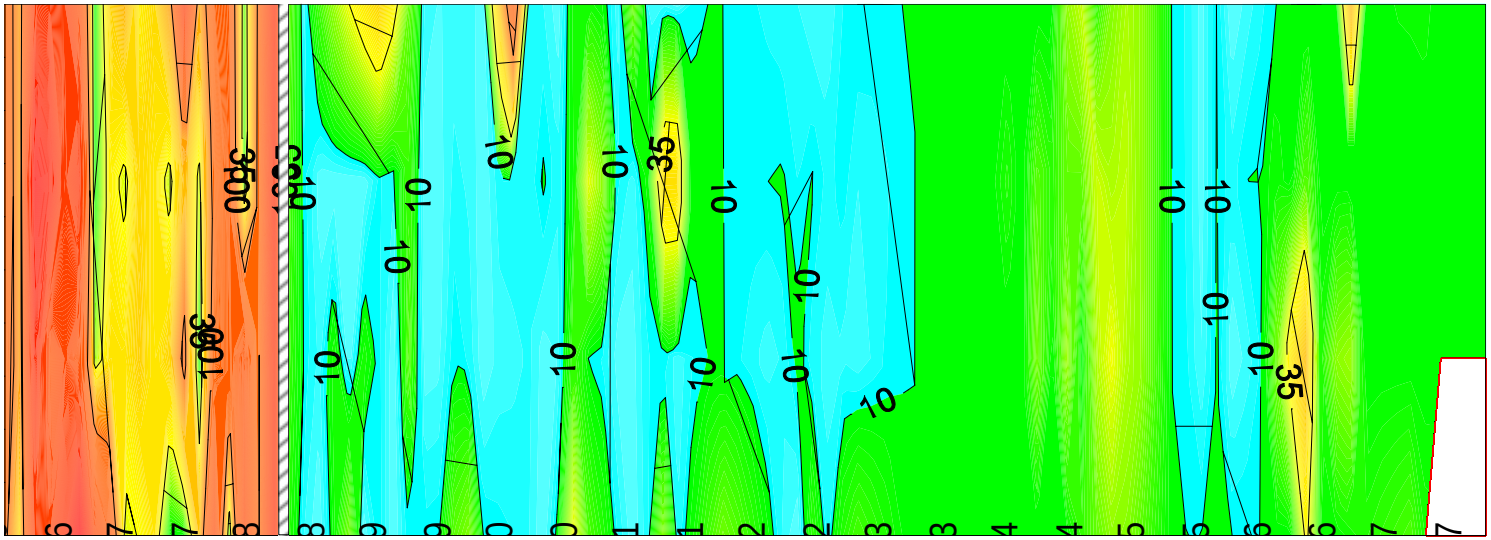
§ Immediate removal of cyanobacteria and reduction internal P release



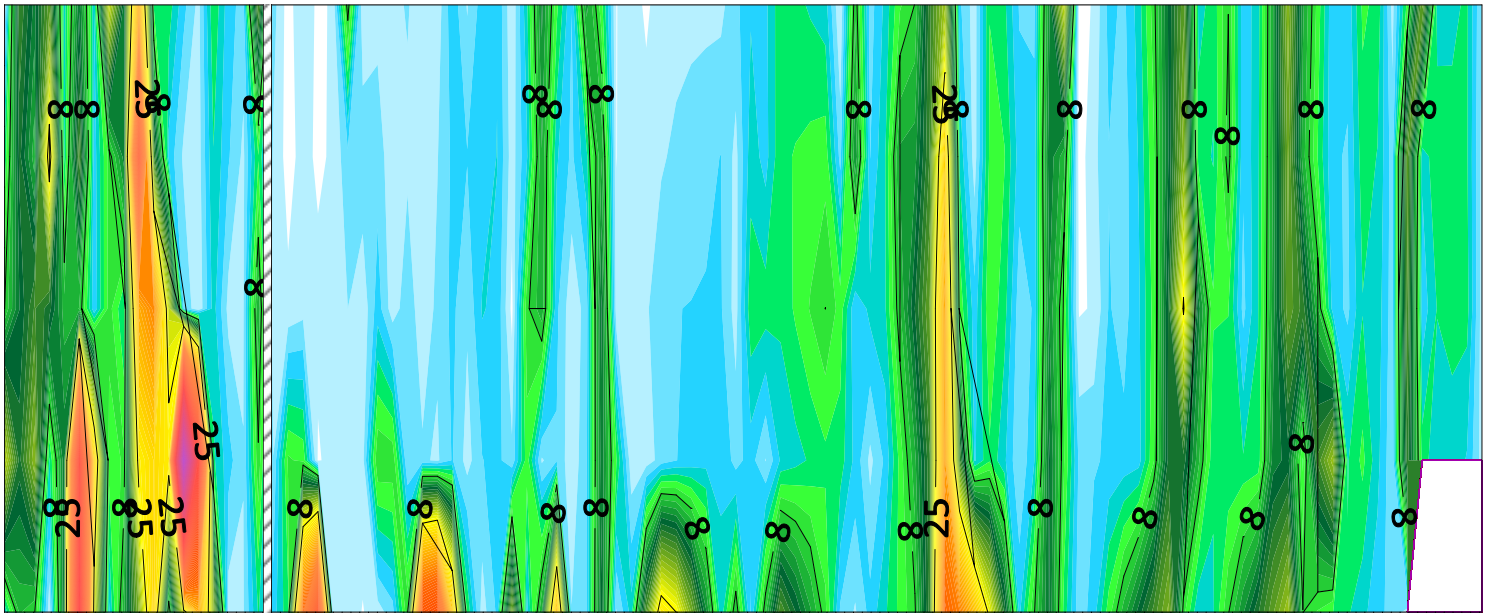
Lake Rauwbraken – Total Phosphorus

134 µg L^{-1}

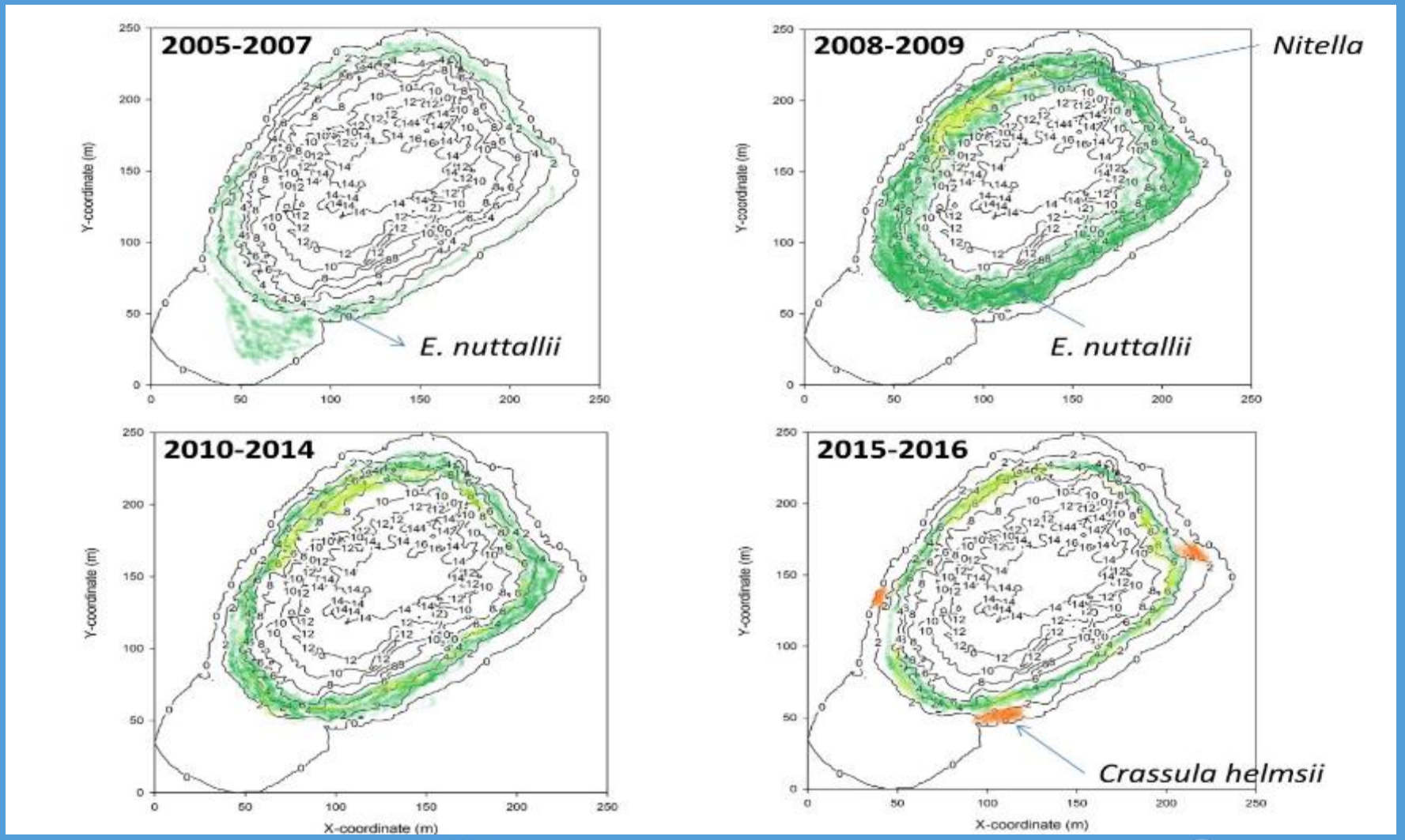
16 µg L^{-1}



Lake Rauwbraken

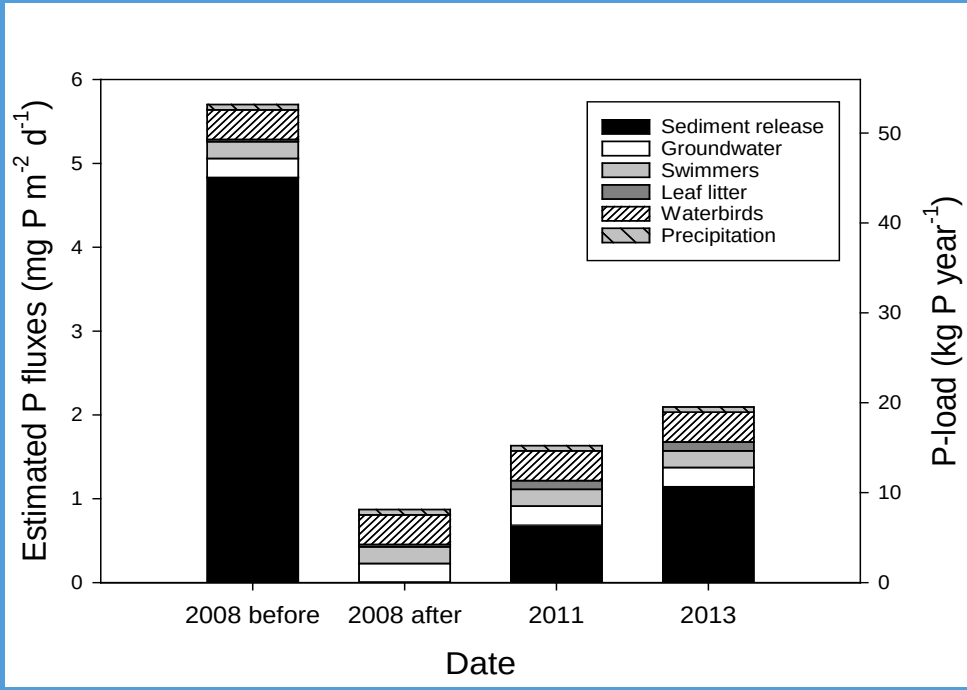


Lake Rauwbraken



Lake Rauwbraken

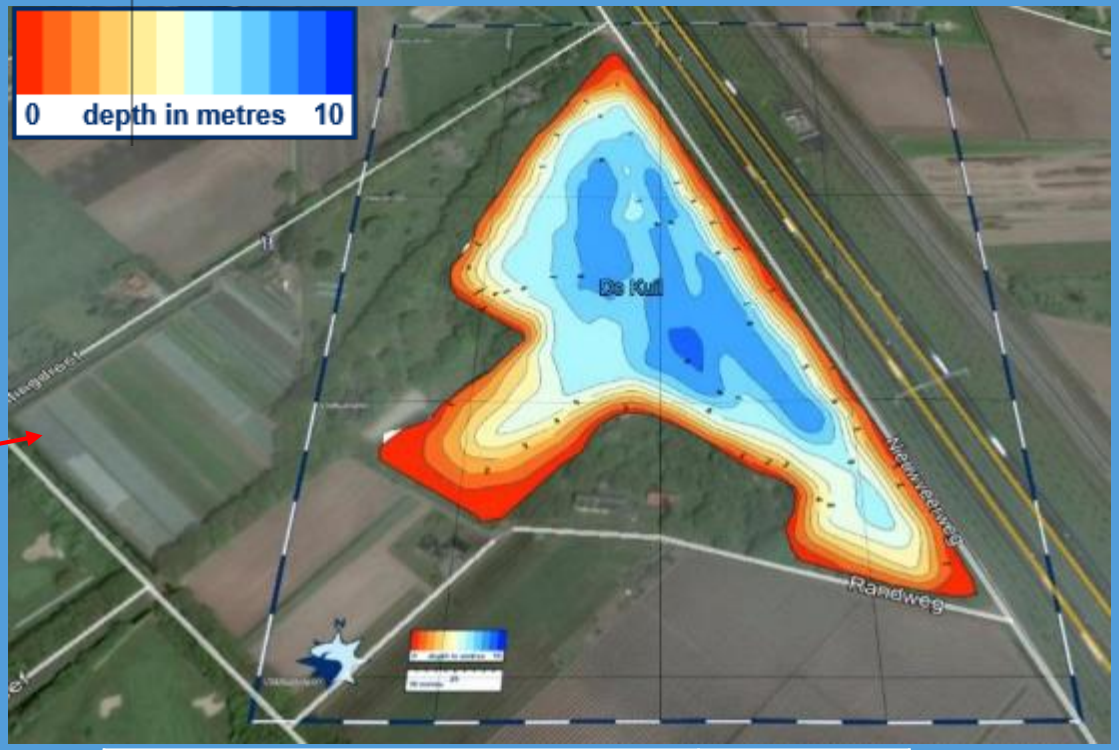
§ Repeated interventions are inevitable = maintenance

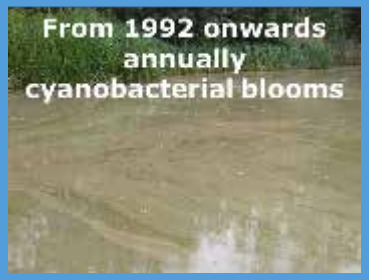


Application costed € 50.000,-
~ € 4.500,- per season

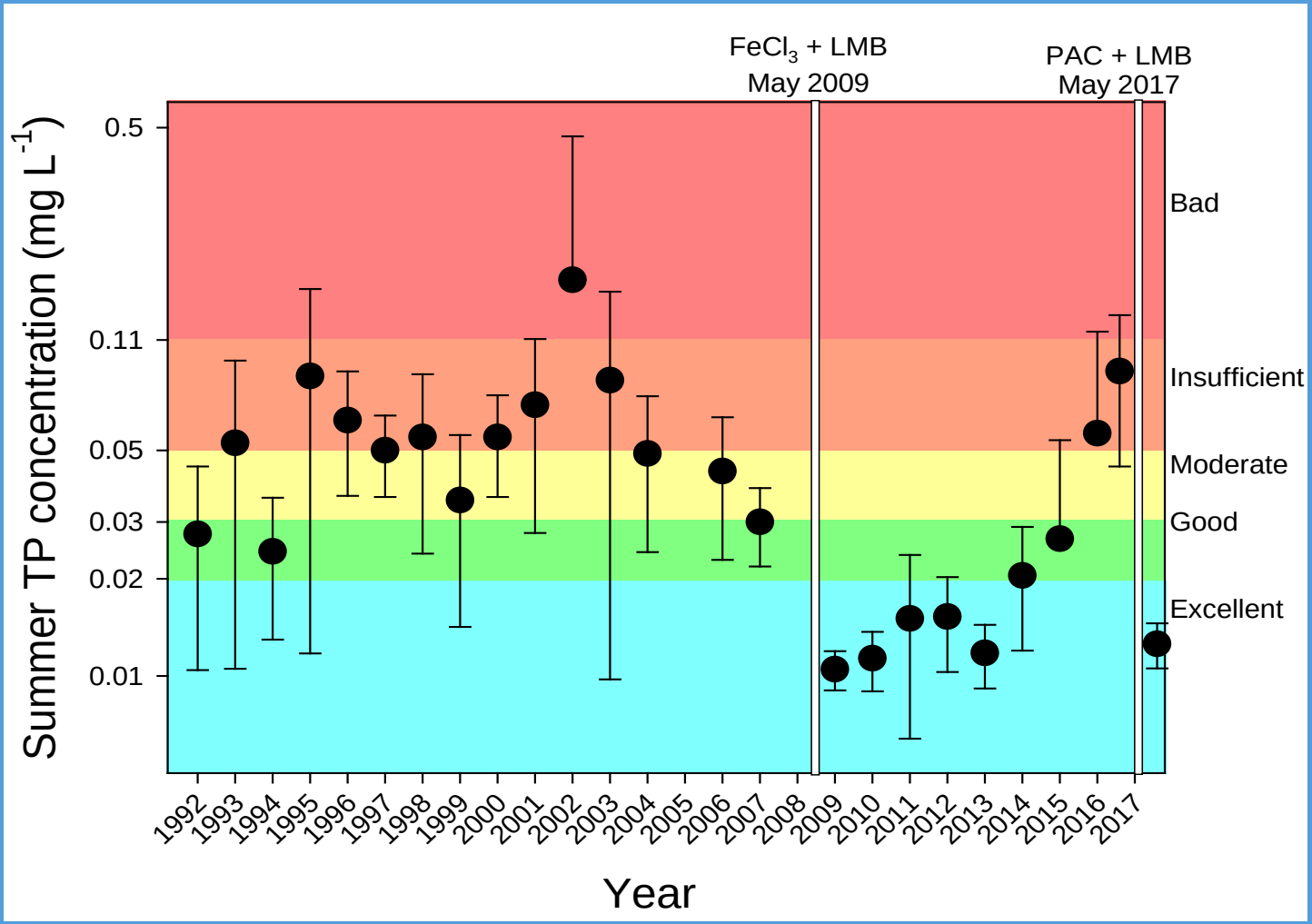
§ Lake Rauwbraken is not unique for NL, diffuse pollution is everywhere

Lake De Kuil – The Netherlands





Area (ha)	6.7
Mean water depth (m)	4
Maximum water depth (m)	9
Volume (m^3)	268000



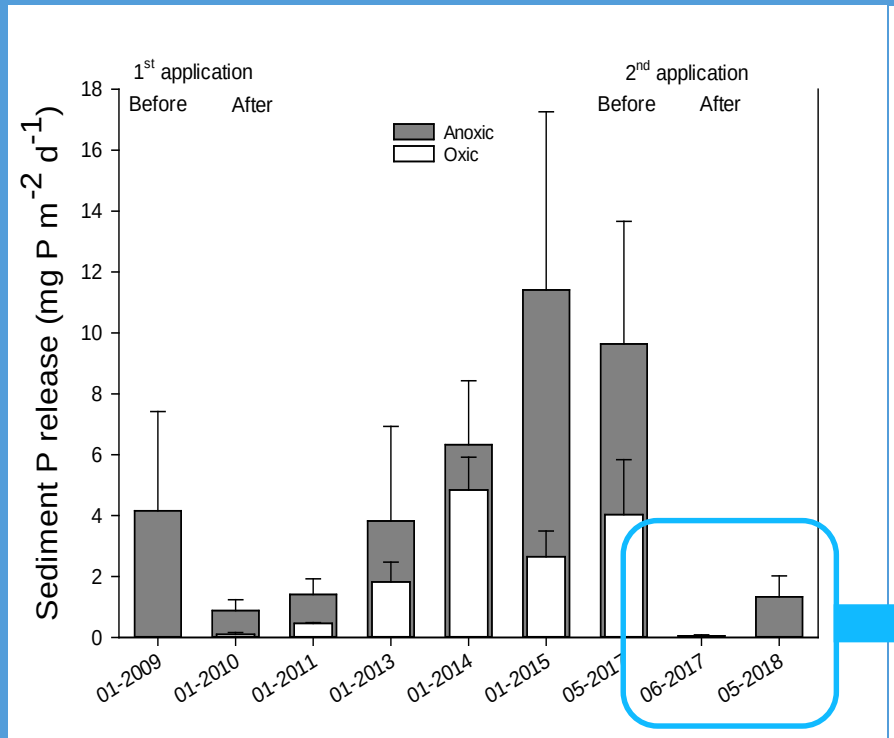
§ Lake De Kuil - € 140 000,- for 8 years

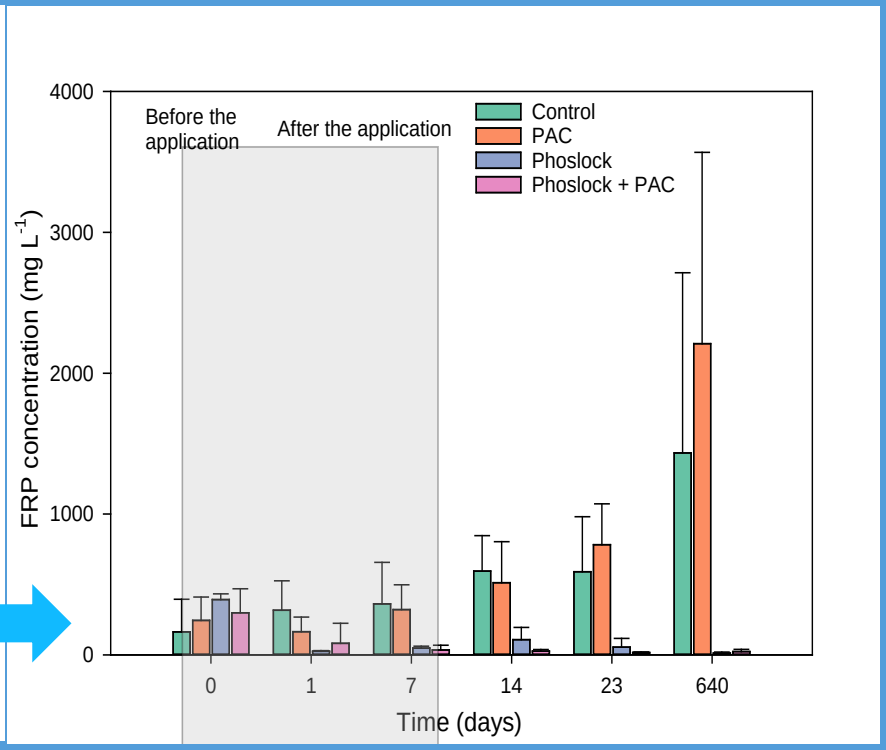
§ Reapplication - € 100 000,- has been done in 2017

Internal P load

Intervention caused strong reduction internal load

Increase observed in field is not seen in cores kept in lab

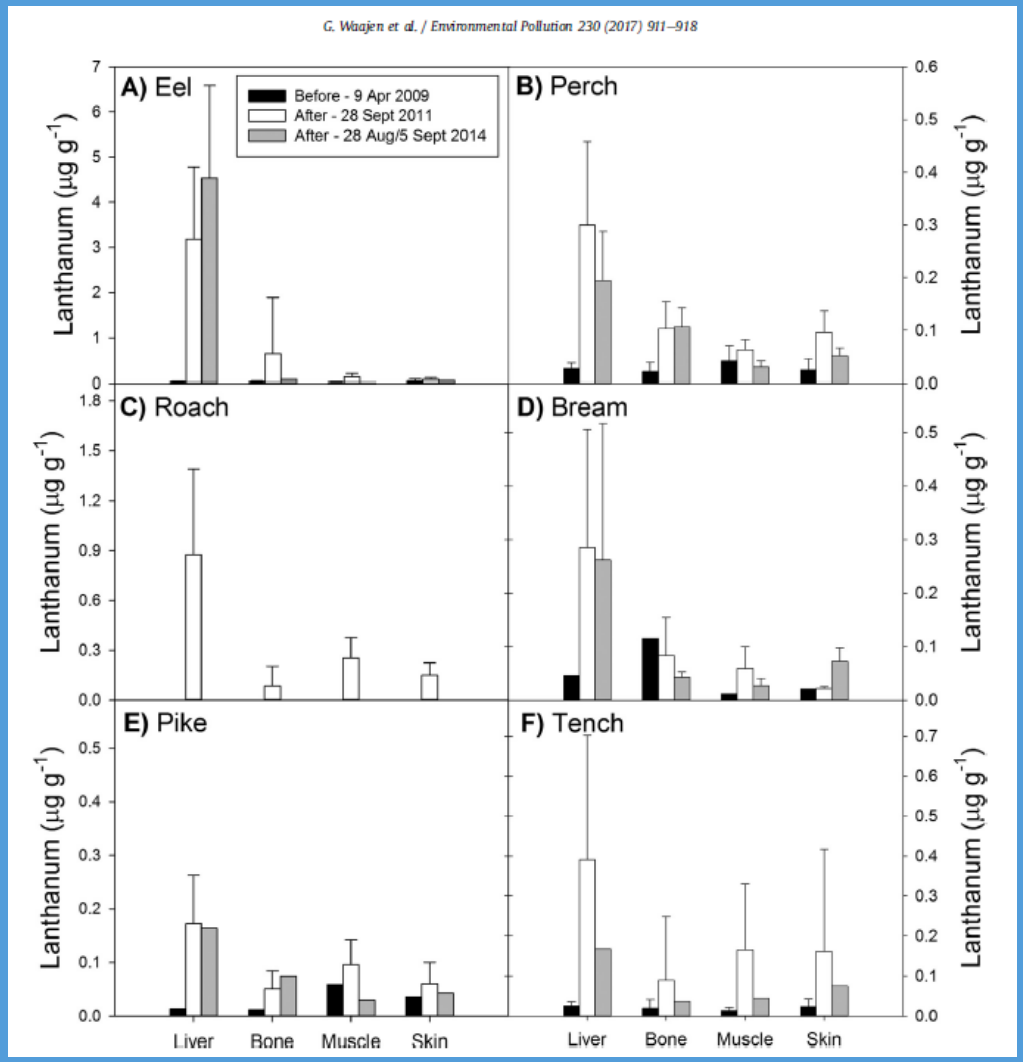




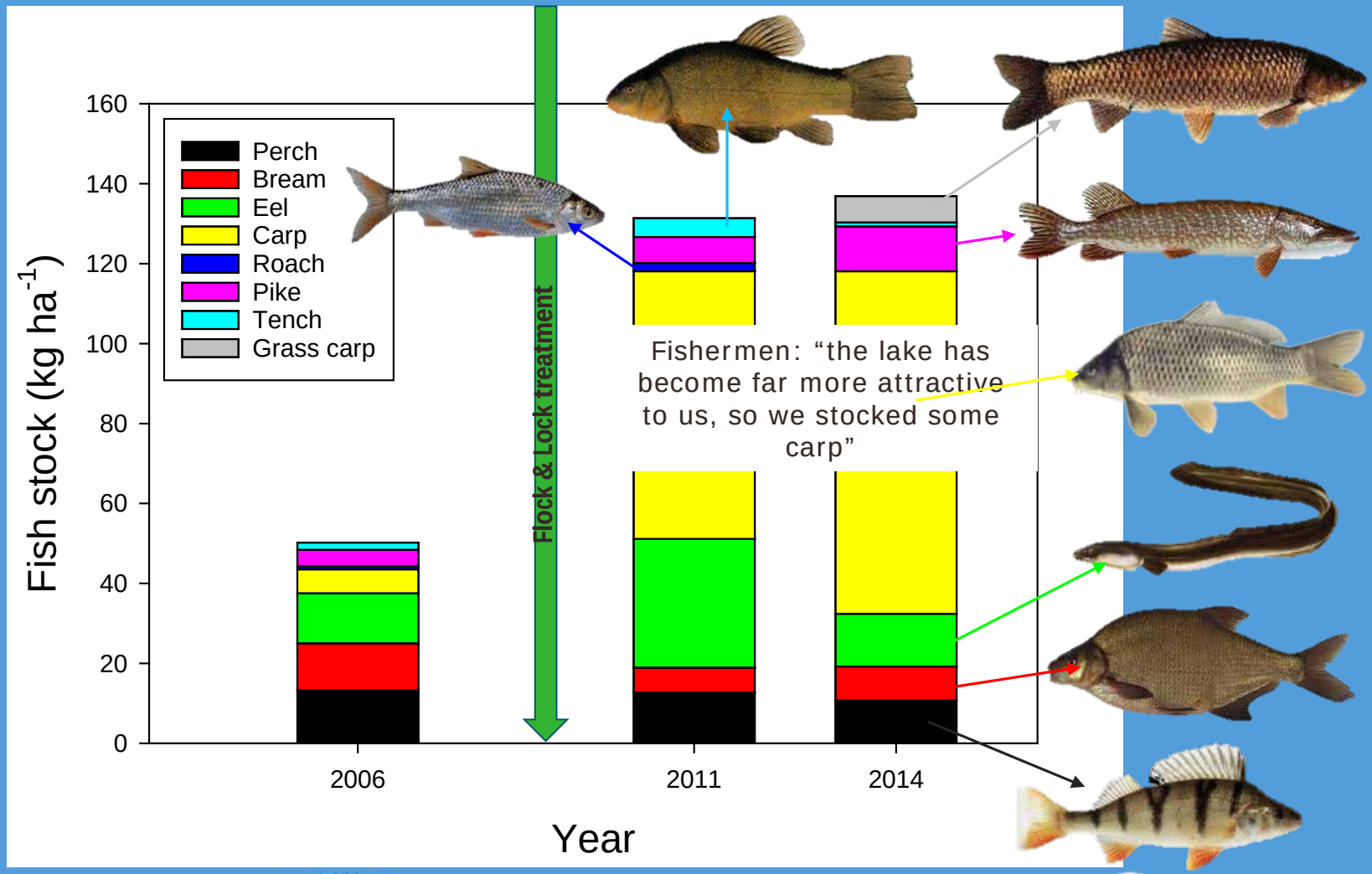
Whole lake experiments – De Kuil

Lanthanum is found in fish tissues

No signs of toxicity



Whole lake experiments – De Kuil

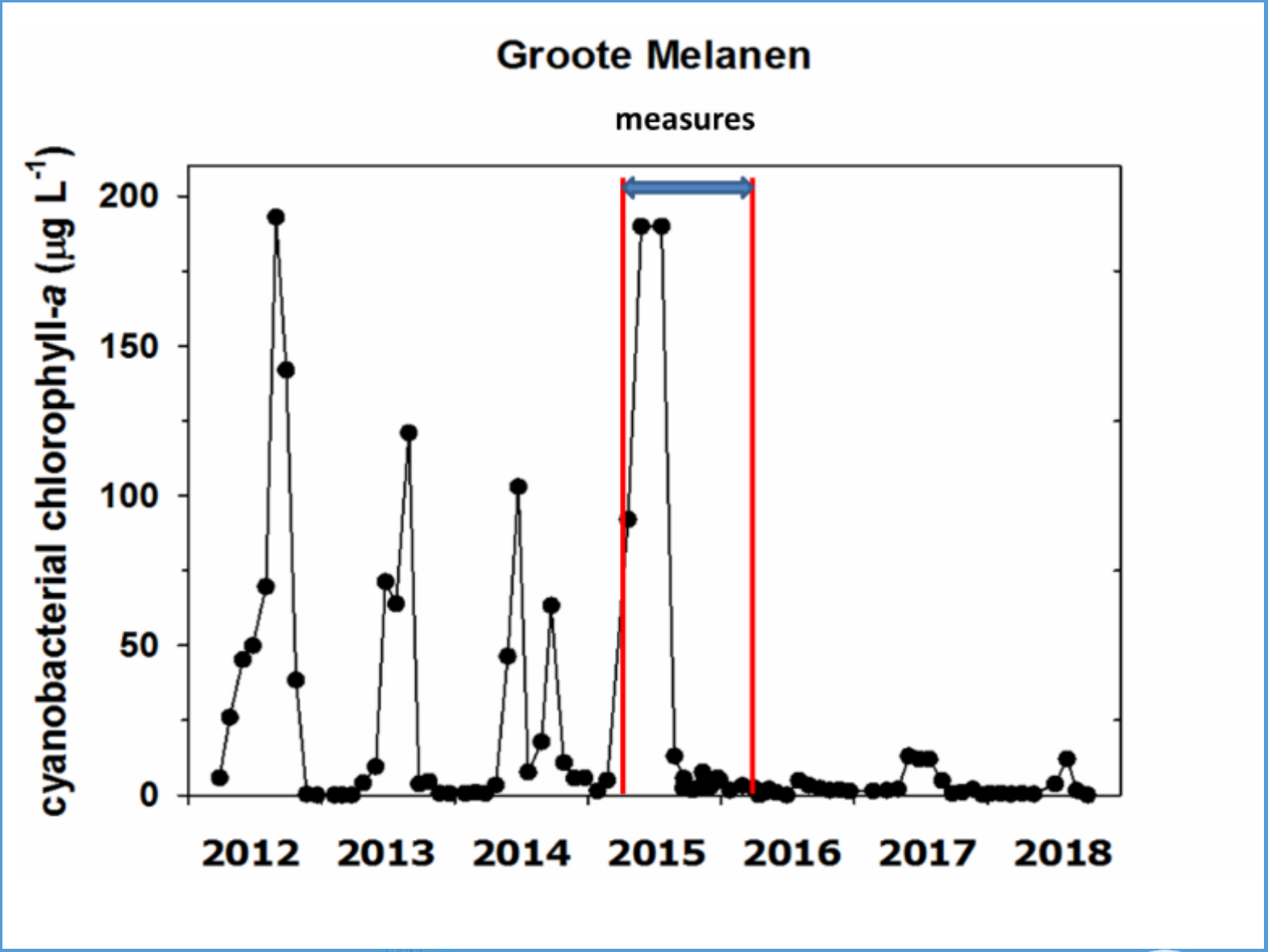


Lake Groote Melanen – The Netherlands

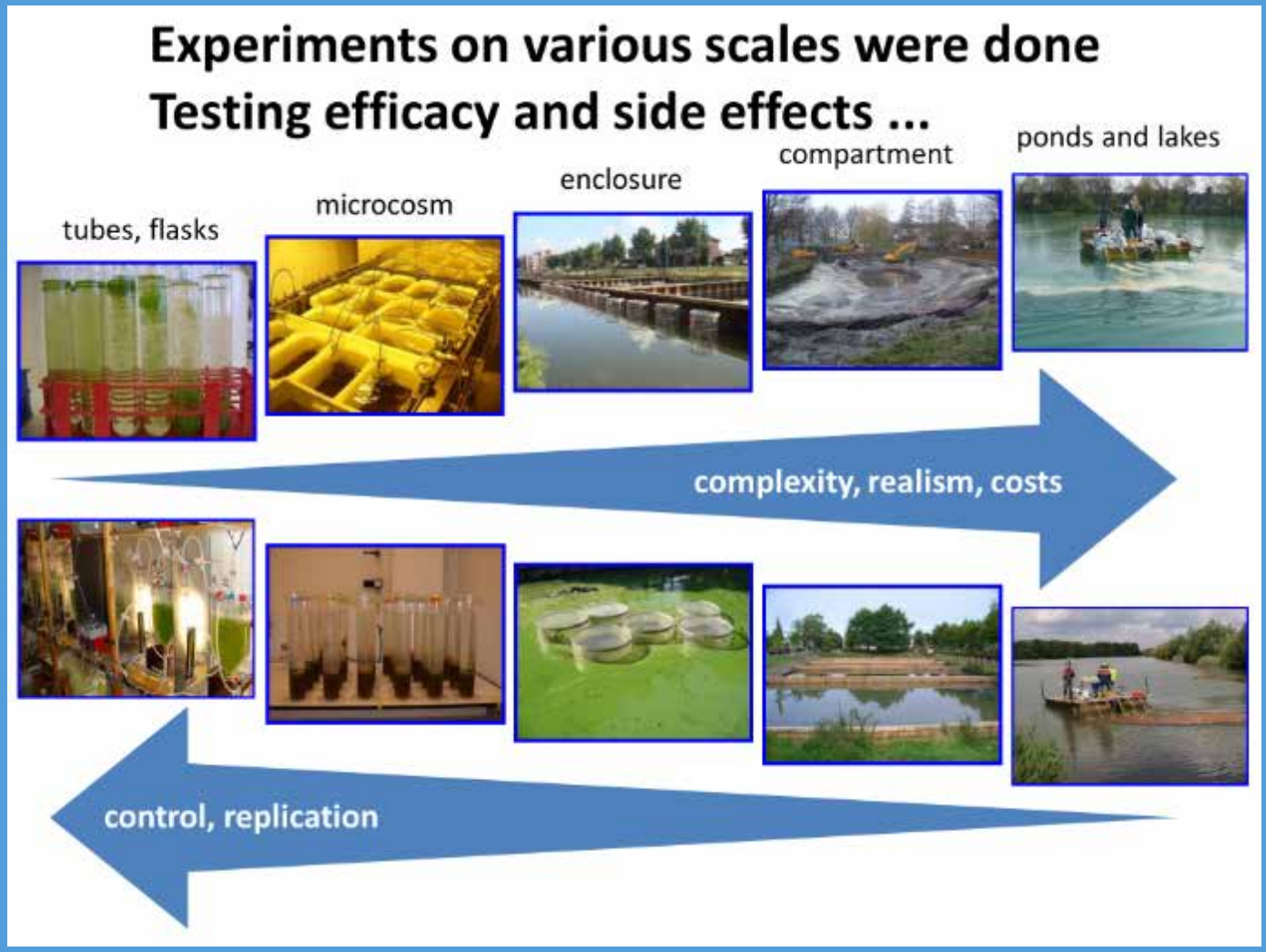
Dr Guido Waajen – Water Authority Brabantse Delta

Lake Groote Melanen

- **External P-load > critical P-load (inflow two streams = main P-source)**
- **Sediment P-release (mud, underlying sediment)**
- **Fishstock dominated by carp**
- **Absence of macrophytes**


Groote Melanen
measures
cyanobacterial chlorophyll-a (µg L-1)
200
150
100
50
0
2012
2013
2014
2015
2016
2017
2018

Lake restoration research in Netherlands



Lake restoration research in Netherlands

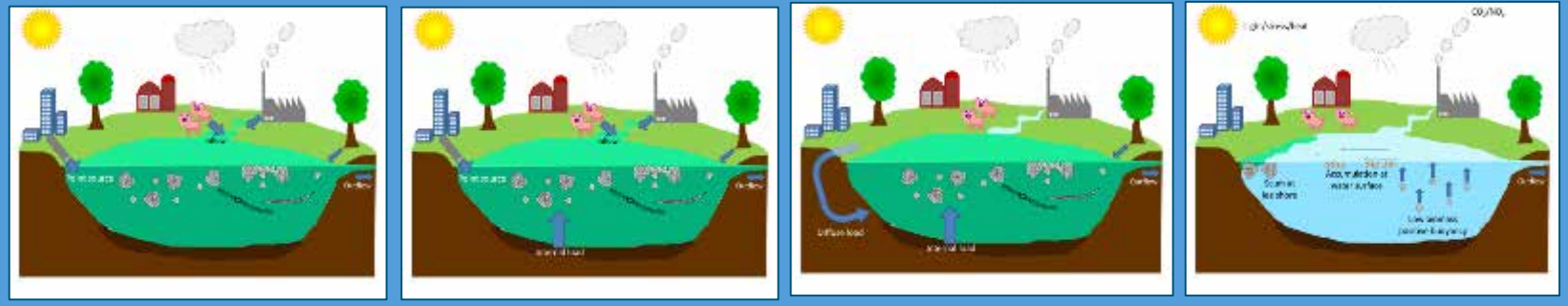
- We love to pull op warning signs, yet action is needed…
- …lots of action to show tax payer something is done…
- …but quacks are offered a rather free playing ground:
- Many commercial “magic solutions” don’t do the work:
  - Ultrasound
  - “effective microbes”
  - Virtually all plant extracts, barley, golden algae…

Don’t put your money on these

- System analysis is essential to determine which set of measures will be most promising (no copy-paste!)

Lake restoration: system analysis is crucial

§ In-lake measures are inevitable (legacies, diffuse pollution)



1) External load as main driver 2) External + internal load 3) Internal load as key driver 4) Not external nor internal load

§ Targeting cyanobacteria directly:

- algaecides, peroxide
- coagulants

§ Targeting phosphate = removing fuel for blooms

- Phoslock is a very powerful P-fixative

P-fixation intervention in Canada

CBC

Bromont Lake gets rid of blue-green algae, as experimental treatment takes hold

A chemical treatment was poured into the lake in November to trap the phosphorous that algae feeds on

CBC News · Posted: Jul 31, 2018 4:00 AM ET | Last Updated: July 31, 2018

Bromont Lake, in Quebec's Eastern Townships region, has been dealing with an abundance of blue-green algae for decades. (Radio-Canada)

Last year, the city spent $615,000 on an experimental treatment, and in November, 175 tons of a product called Phoslock was poured into the lake, located in Quebec's Eastern Townships region.

- **Bromont to use clay mixture to stave off blue-green algae growth**

The experiment was carried out under the supervision of Philippe Juneau, a biology professor at the Université du Québec à Montréal, who said it appears to be working as planned.

"So far, we didn't see any [algae] blooms," and the beach has been open all summer, Juneau told CBC News.

"That's very promising."

It works well in Bromont Lake because the phosphorous there is caused by sediments, he explained. In a lake where the main source of phosphorous is a river, it won't be as successful.

"You need to understand your lake. You need to understand that the phosphorous source comes from the sediment, and not from the external source," he said.

Thank you!

Like our Facebook site
"Lake Restoration Research"

Tweet about your lake restoration works
#LakeRestoration @SilWorking

Blooms also occur in oligotrophic water

If cyanobacteria nuisance can occur in eutrophic and oligotrophic waters, a proper diagnosis prior to intervention is essential

International Review of Hydrobiology 2016, *101*, 57–68 DOI 10.1002/iroh.201401780

RESEARCH PAPER

First record of toxins associated with cyanobacterial blooms in oligotrophic North Patagonian lakes of Chile—a genomic approach

Jorge Nimptsch[1], Stefan Woelfl[1], Sebastian Osorio[1], Jose Valenzuela[1], Cristiana Moreira[2], Vitor Ramos[2], Raquel Castelo-Branco[2], Pedro Nuno Leão[2] and Vitor Vasconcelos[2]

OPEN ACCESS Freely available online PLOS ONE

Lake Level Fluctuations Boost Toxic Cyanobacterial "Oligotrophic Blooms"

Cristiana Callieri[1]*, Roberto Bertoni[1], Mario Contesini[1], Filippo Bertoni[2]

1 Institute of Ecosystem Study – CNR, Verbania, Italy, 2 Centre for Social Science and Global Health – University of Amsterdam, Amsterdam, The Netherlands

Aquat Ecol (2012) 46:395–409
DOI 10.1007/s10452-012-9409-9

Occurrence and toxicity of the cyanobacterium *Gloeotrichia echinulata* in low-nutrient lakes in the northeastern United States

Cayelan C. Carey · Holly A. Ewing · Kathryn L. Cottingham · Kathleen C. Weathers · R. Quinn Thomas · James F. Haney