

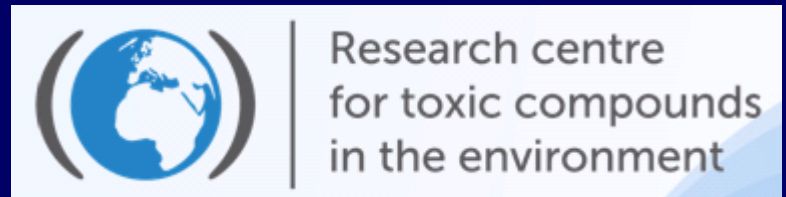
Cyanobacteria and their toxins: ecological and health risks

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www.recetox.muni.cz

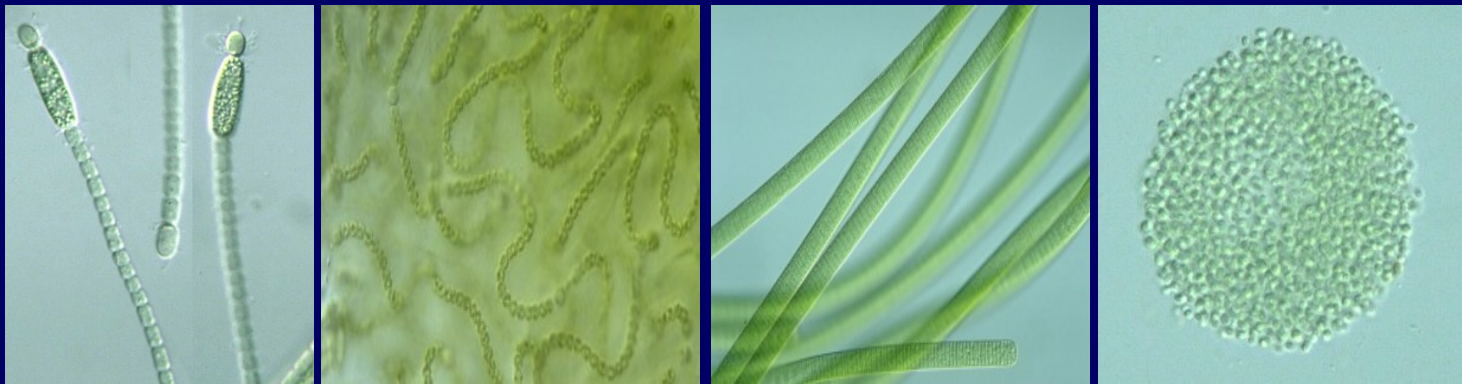
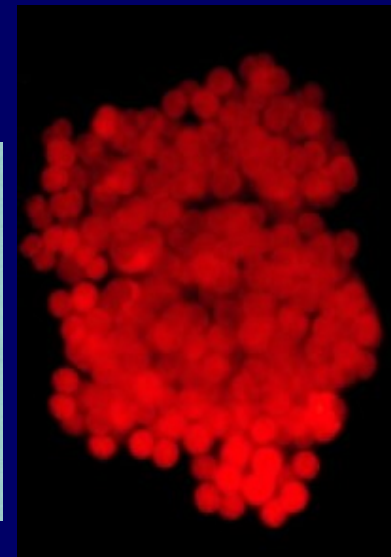
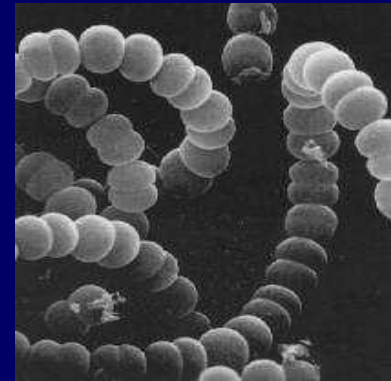
www.cyanobacteria.net



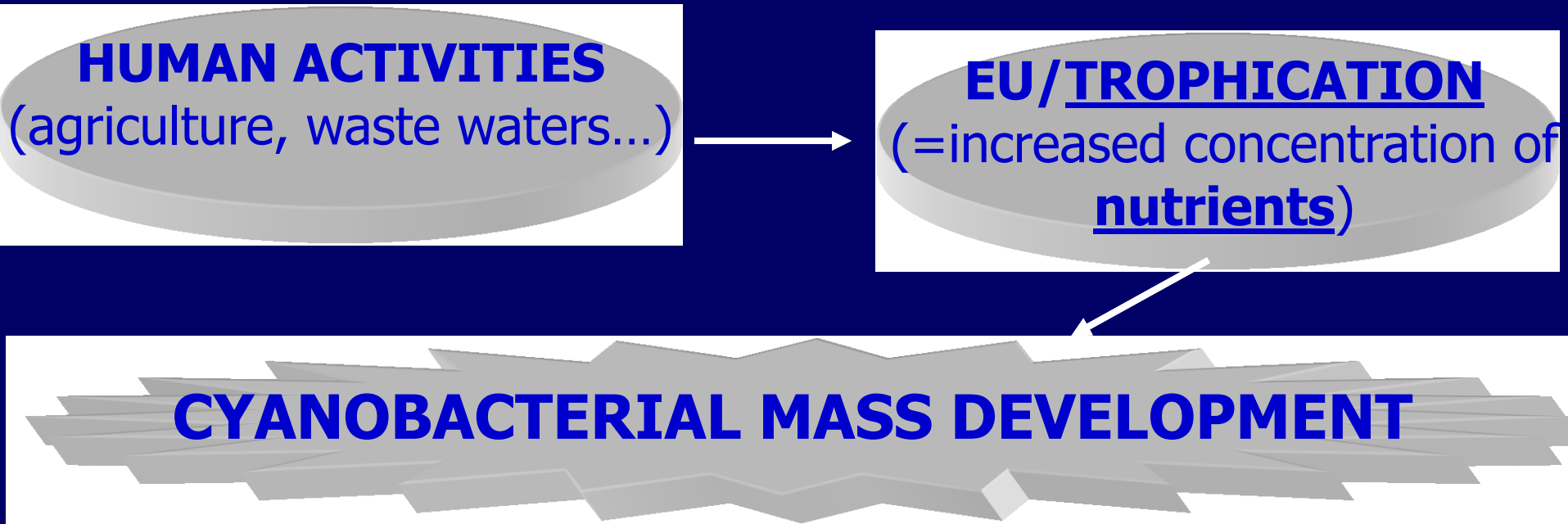
Blue green algae

(CYANOBACTERIA, CYANOPHYTA)

- photosynthetic **prokaryota**
 - live at **various biotops**
(**water**, soil, ice, rocks, lichens ...)
- cca 3×10^9 years old
- formation of the oxygen atmosphere



Cyanobacteria - current problem



Cyanobacterial water blooms – global problem



Upper Saranac River, USA



Bedetti Lake, Argentina



Neuse River, USA



Baltic sea, Europe



Nové Mlýny, Czech Rep.



Yellow sea, China



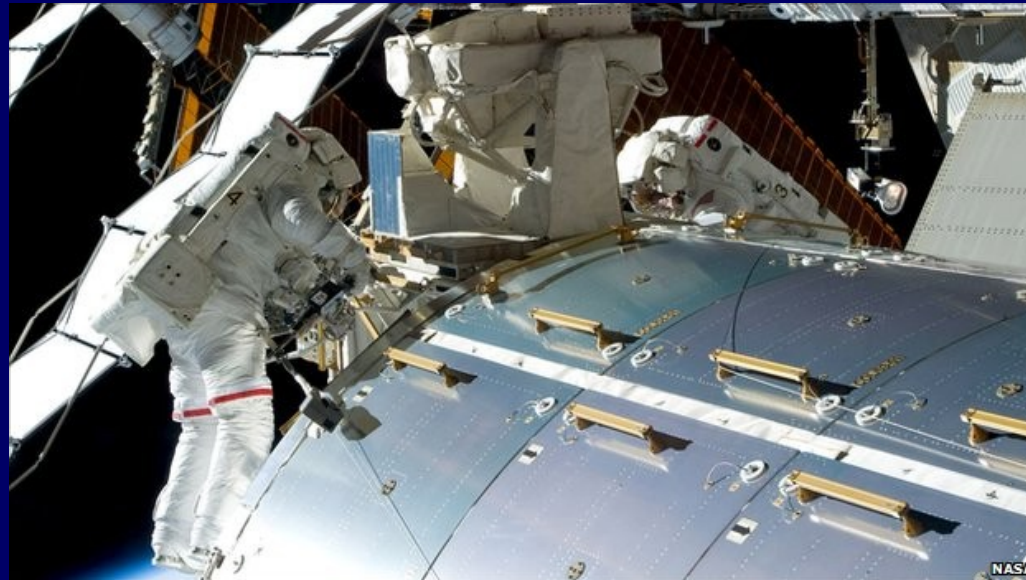
Lake Mokoan, Australia



South Africa

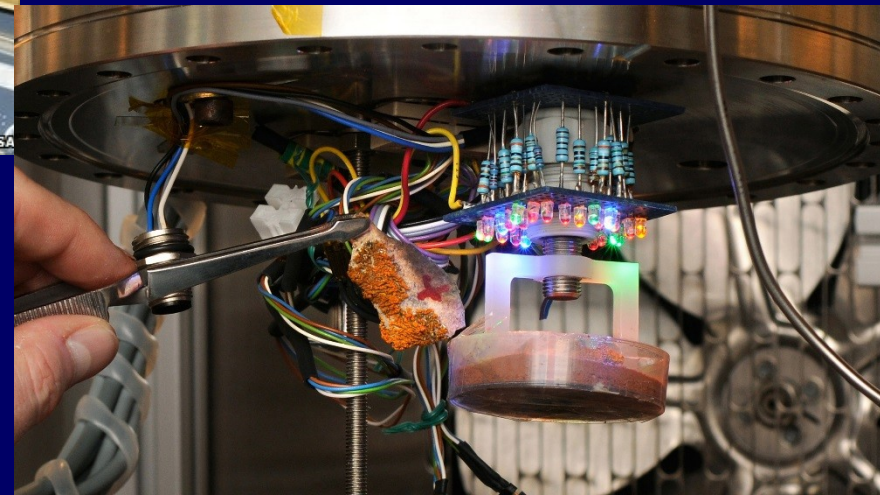


Cyanos in space



Astronauts retrieve cyanobacteria samples from the outside of the ISS

Space colonization, oxygen, fuel and biomass production, nutrient acquisition, and feedstock provisions.



Chamber used for simulating conditions on the martian surface.



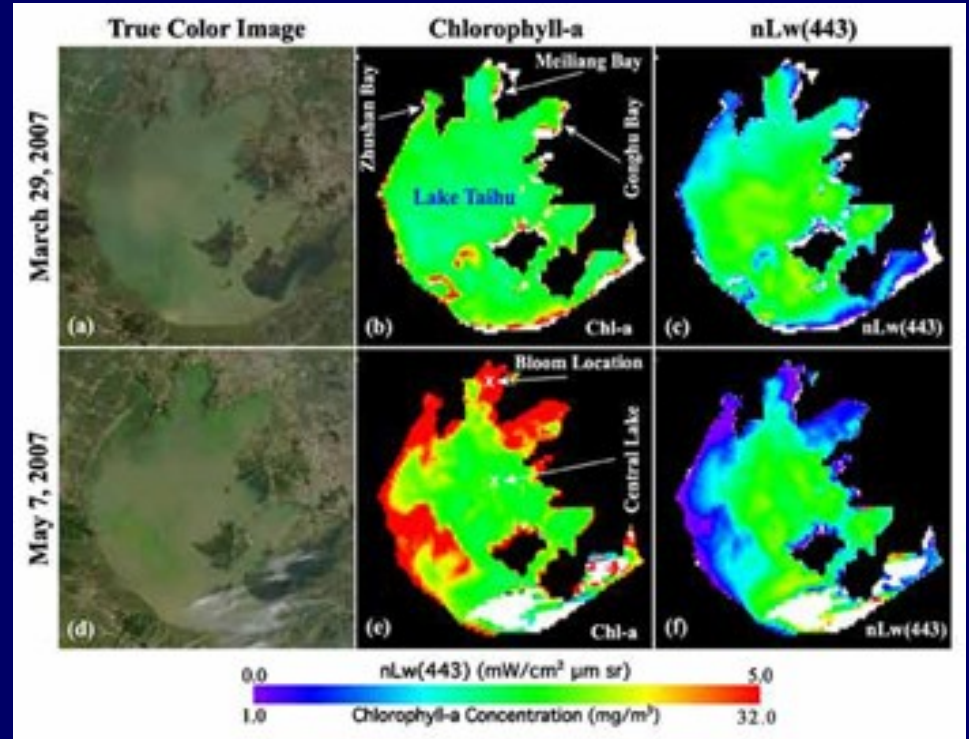
Cyanos from space



Cyanobacterial bloom in Lake Erie (satellite image, Sept. 27 2011)



The Great Lakes over Europe

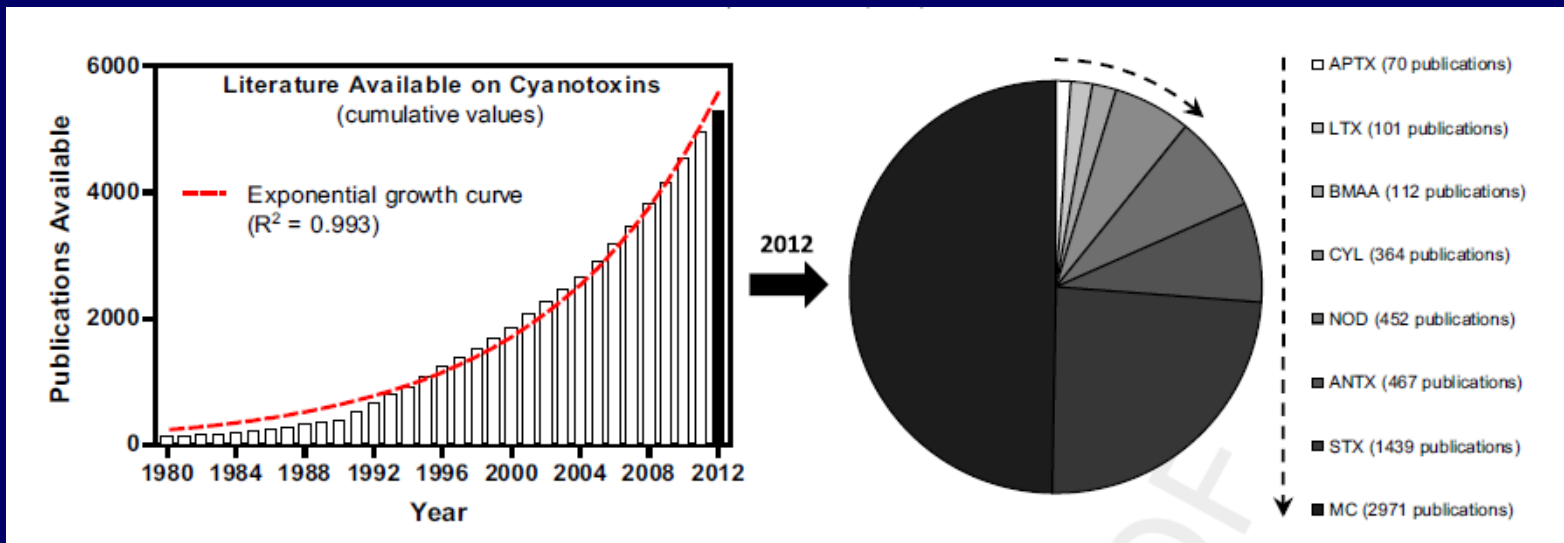
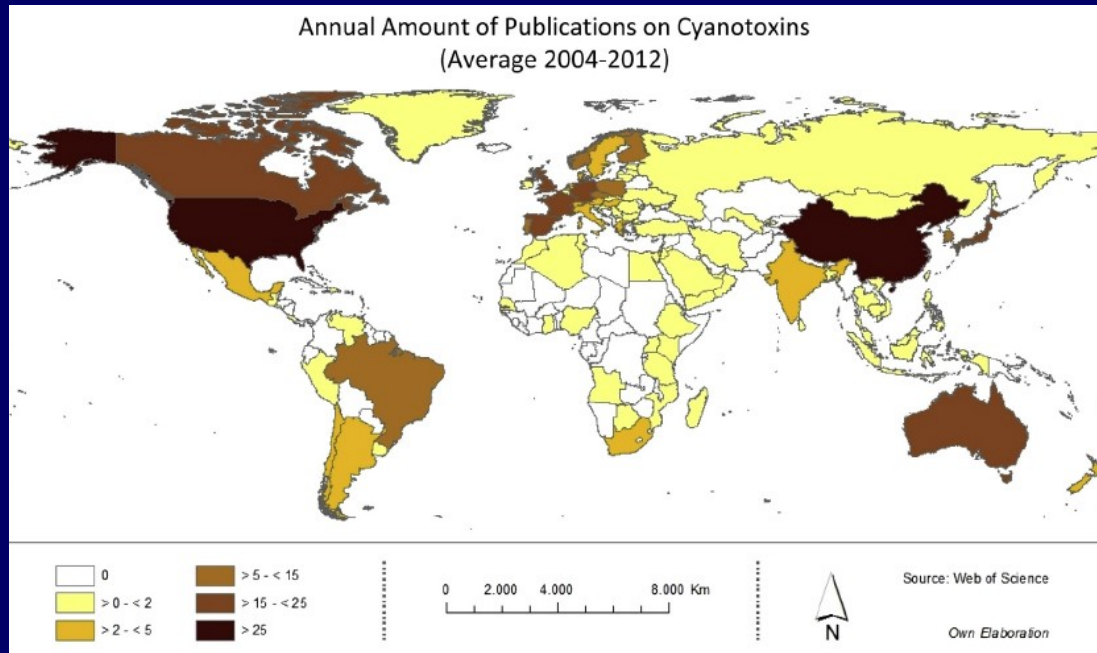


Satellite sensing of harmful algal blooms in Lake Taihu, China.



Research on cyanotoxins

Merel et.al (2013) *Toxicon* 76, 118-131



USA: The Toledo water crisis

- On August 2, 2014, the City of Toledo, Ohio, issued a “Do Not Drink – Do Not Boil” water notice, due to the presence of **microcystins**.
- The notice affected more than 400,000 people.
- Toledo water utilities abstract water from lake Erie, which suffers from cyanobacterial blooms.



Cyanobacterial bloom in Lake Erie (satellite image, Sept. 27 2011)

City of Toledo / News / 2014 / 08 / Urgent Water Notice

Urgent water notice!

URGENT NOTICE TO RESIDENTS OF TOLEDO & LUCAS COUNTY WHO RECEIVE WATER FROM THE CITY OF TOLEDO

DO NOT DRINK THE WATER
DO NOT BOIL THE WATER

Chemists testing water at Toledo's Collins Park Water Treatment Plant had two sample readings for microcystin in excess of the recommended "DO NOT DRINK" 1 microgram per liter standard. This notice applies to ALL customers of Toledo water.

Most importantly, water should not be consumed until an all clear is issued. It is important to state that this drinking water alert does NOT recommend boiling, and in fact, boiling water can worsen the situation. Water should not be given to pets.

Additional information as to where to obtain water will be forthcoming, steps will be taken to provide drinkable water if necessary.

What should you do?

DO NOT DRINK THE WATER. Alternative water should be used for drinking, making infant formula, making ice, brushing teeth and preparing food. Pets should not drink the water.

DO NOT BOIL THE WATER. Boiling the water will not destroy the toxins – it will increase the concentration of the toxins.

Consuming water containing algal toxins may result in abnormal liver function, diarrhea, vomiting, nausea, numbness or dizziness. Seek medical attention if you feel you have been exposed to algal toxins and are having adverse health effects. Contact a veterinarian immediately if pets or livestock show signs of illness.

The water notice issued by the City of Toledo

A screenshot of a USA Today news article. The headline reads "Ohio's 4th largest city has no drinking water". The byline is "Rick Jervis, USA TODAY" and the date is "1:50 a.m. EDT August 3, 2014". The article text states: "Residents of a large swath of northwestern Ohio are still without drinkable water after a dangerous toxin was discovered late Friday in an area water treatment plant." It also mentions that Gov. John Kasich declared a state of emergency and deployed the National Guard. A photo shows a man loading a shopping cart into the back of a red car. Social media sharing options for Facebook (4779), Twitter (530), LinkedIn (18), and Comment (97) are visible. A search bar is at the top right.

USA: Response to Toledo water crisis

Date	Time	Date Ohio EPA Notified	Location	Sample Water Type	Methodology	Results by Testing	
						Toledo	Ohio EPA
2/8/2014	12:20 μm	8/3/2014 - 10:28 PM	1474 Detroit, F.D.	Distribution System	ELISA - Unlysed Quenched	<0.30 ug/L	<0.30 ug/L
2/8/2014	12:45 μm	8/3/2014 - 10:28 PM	2566 Cass	Distribution System	ELISA - Unlysed Quenched	<0.30 ug/L	<0.30 ug/L
2/8/2014	12:25 μm	8/3/2014 - 10:28 PM	2616 Heatherdown	Distribution System	ELISA - Unlysed Quenched	0.31 ug/L	0.31 ug/L
2/8/2014	12:50 μm	8/3/2014 - 10:28 PM	3332 St. Lawrence	Distribution System	ELISA - Unlysed Quenched	0.54 ug/L	0.54 ug/L
2/8/2014	12:46 μm	8/3/2014 - 10:28 PM	4251 S. Clark TFD	Distribution System	ELISA - Unlysed Quenched	0.57 ug/L	0.57 ug/L
2/8/2014	1:10 μm	8/3/2014 - 10:28 PM	4710 Detroit	Distribution System	ELISA - Unlysed Quenched	0.53 ug/L	0.53 ug/L
2/8/2014	12:56 μm	8/3/2014 - 10:28 PM	6230 Summit	Distribution System	ELISA - Unlysed Quenched	0.34 ug/L	0.34 ug/L
2/8/2014	1:10 μm	8/3/2014 - 10:28 PM	6268 Edgewater	Distribution System	ELISA - Unlysed Quenched	0.68 ug/L	0.68 ug/L
2/8/2014	12:19 μm	8/3/2014 - 10:28 PM	8 ft	Distribution System	ELISA - Unlysed Quenched	<0.30 ug/L	<0.30 ug/L
2/8/2014	12:38 μm	8/3/2014 - 10:28 PM	Bahiamar and Suder	Distribution System	ELISA - Unlysed Quenched	0.53 ug/L	0.53 ug/L
2/8/2014	1:05 μm	8/3/2014 - 10:28 PM	BK/Secor	Distribution System	ELISA - Unlysed Quenched	<0.30 ug/L	<0.30 ug/L
2/8/2014	12:40 μm	8/3/2014 - 10:28 PM	Bob Evans Restaurant Reynolds	Distribution System	ELISA - Unlysed Quenched	<0.30 ug/L	<0.30 ug/L
2/8/2014	12:31 μm	8/3/2014 - 10:28 PM	BP	Distribution System	ELISA - Unlysed Quenched	<0.30 ug/L	<0.30 ug/L
2/8/2014	12:23 μm	8/3/2014 - 10:28 PM	BP Detroit/Alexis	Distribution System	ELISA - Unlysed Quenched	0.44 ug/L	0.44 ug/L
2/8/2014	12:25 μm	8/3/2014 - 10:28 PM	Bull Sheffieldd and Florence	Distribution System	ELISA - Unlysed Quenched	0.48 ug/L	0.48 ug/L
2/8/2014	2:37 μm	8/3/2014 - 10:28 PM	Bull Tracy and Andrus	Distribution System	ELISA - Unlysed Quenched	0.44 ug/L	0.44 ug/L
2/8/2014	1:15 μm	8/3/2014 - 10:28 PM	Bull Wakes Rd Pump and Hyd	Distribution System	ELISA - Unlysed Quenched	0.6 ug/L	0.6 ug/L
2/8/2014	12:15 μm	8/3/2014 - 10:28 PM	Burger King	Distribution System	ELISA - Unlysed Quenched	0.36 ug/L	0.36 ug/L

Open data for monitoring of lakes and drinking water supplies (US EPA)

Saturday, August 2, 2014

- Michael Johns
100,000+ searches
Related searches: michael johns american idol
American Idol Alum Michael Johns Dead at 35 RollingStone.com
Michael Johns was an incredible talent and we are deeply saddened b...
- Friendship Day
50,000+ searches
Friendship Day not so cool anymore. Times of India
PUNE: At a time when social media and technology are what is ruling rel...
- Michael Strahan
50,000+ searches
Related searches: andre reed
Lipic: Michael Strahan enters Pro Football Hall of Fame as one of New York's
New York Daily News
This was the night, this great Saturday night up in lights, when Michael ...
- Cheryl Hines
50,000+ searches
Cheryl Hines, Robert F. Kennedy Jr. are married Los Angeles Times
Sparks finally 'flaw' at a third meet-up, this time at a ski resort in Aspen, ...
- microcystin
20,000+ searches
What you need to know about microcystin, toxin prompting water ban in part of ...
WVYZ

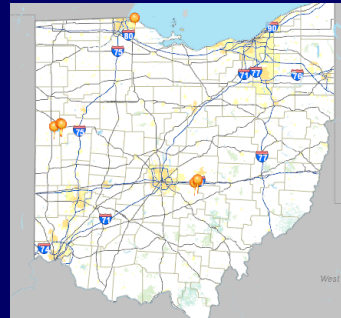
Google "Hot Searches", August 2, 2014

DRAFT June 2014

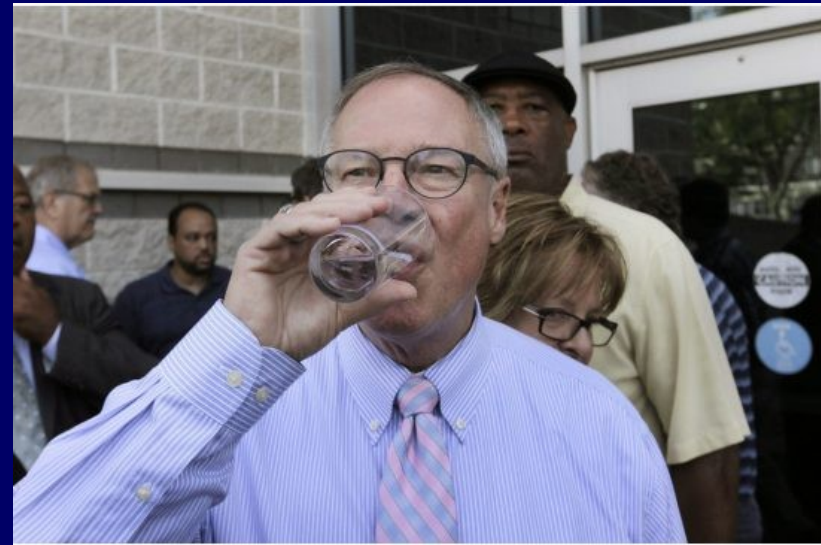
<http://epa.ohio.gov/ddagw/HAB.aspx>



Public Water System Harmful Algal Bloom Response Strategy



- **Short – term measures:** Continuous monitoring of water supplies for toxins
- **Long –term strategies:** limit nutrient runoffs in lake Erie (mainly phosphorus)



Toledo mayor, Dr. Michael Collins on August 4, when the water ban was lifted PAUL SANCYA / THE ASSOCIATED PRESS thestar.com

Serbia: The Uzice case

- In December 2013 there was a widespread bloom of *Planktothrix rubescens* in lake Vruci which is an artificial water reservoir serving the city of Uzice (ppl. 70.000).
- The use of water for drinking and preparation of food was forbidden.
- The WTP switched to an alternative source of water (groundwater).
- Data regarding the presence of cyanotoxins in water during the episode were not publicized.



МИНИСТАРСТВО ЗДРАВЉА
Република Србија

Print page

www.zdravlje.gov.rs

Data Since: 07.02.2014.

Water from Užice water supply is safe for drinking and for food preparation

Between 27 January and 6 February 2014, the Institute for Public Health of Serbia "Dr Milan Jovanović Batut" studied over 100 samples of drinking water supply from Užice for biological parameters. Parallel with the activities of the Institute, and in the Institute for Public Health Užice, physico-chemical and bacteriological examination of water was carried out.

The results of physico-chemical, bacteriological and biological studies, as well as their perception, showed that water from Užice water supply is safe for drinking and food preparation. Decision of Sanitary Inspection from 7 February 2014 showed that drinking water from Užice water supply is safe to be used for drinking and food preparation.

Since 26 December 2013, the water distributed by the PUC "Vodovod" in Užice with plants "Cerovića hill" was banned for drinking and food preparation because of the intense bloom of potentially toxic algae *Planktothrix rubescens* in Lake Vruci, which served as a source of water supply.



Water tank in Užice. Photo: Milos Cvetkovic

Talking about „risks“ of cyanobacteria

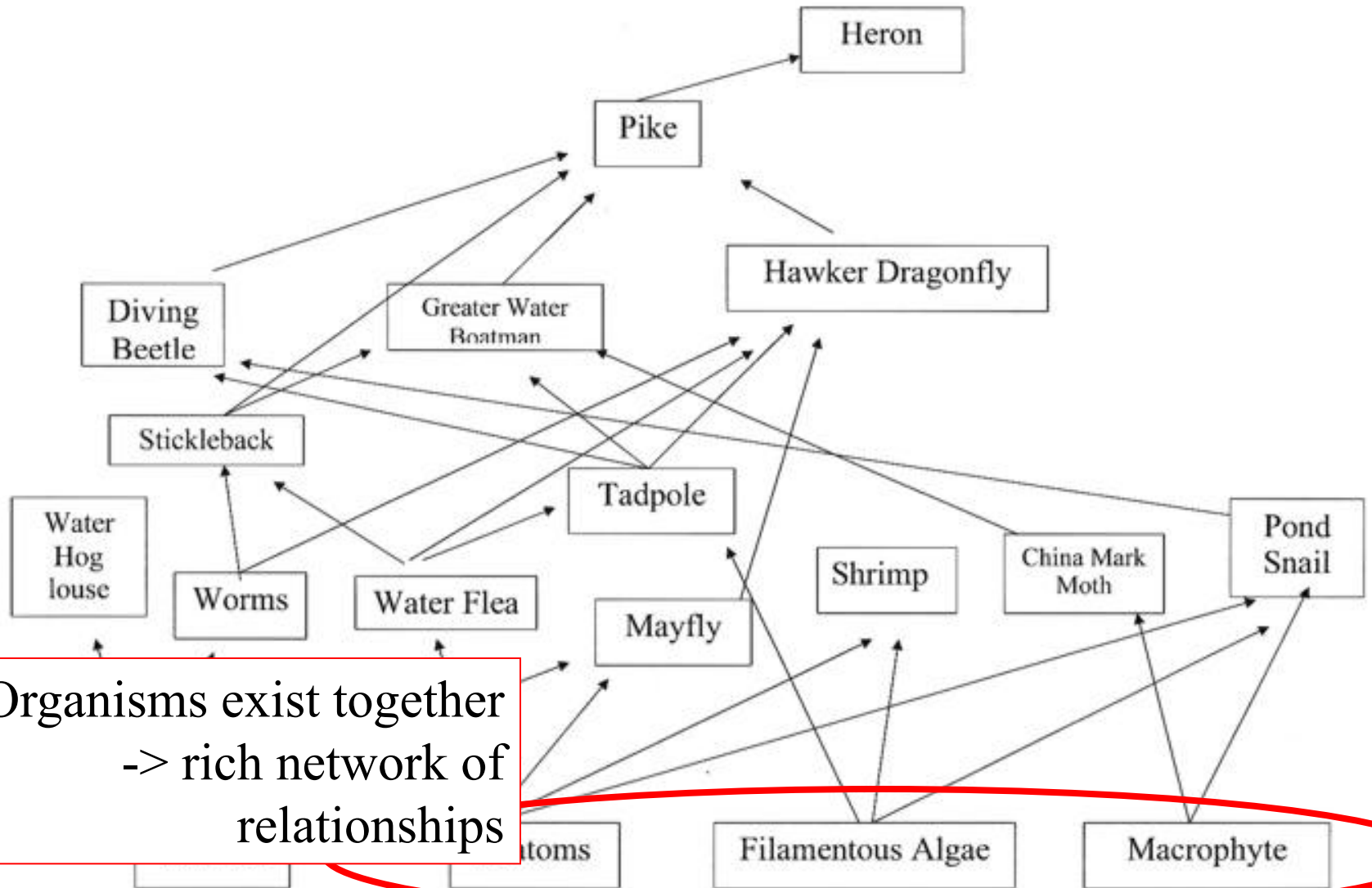
- **RISK = probability of the occurrence of HAZARDOUS event**
- „Hazardous events“ resulting from eu/trophication of the environment
 - **Primary** damage to structure and functioning of ecosystems
 - **Secondary** signs -> ecotoxicity and toxicity

Ecological „stability“

- **Stable and functioning ecosystem**
 - Complex and complicated structure (diversity)
 - Many links (food networks) among organisms = ecosystem functioning
 - *Including „ecosystem services“ to humans: supplies, regulations, cultural / aesthetic, supporting*

Complex ecosystem

Generalised Food Web of a Pond



Organisms exist together
-> rich network of
relationships

CYANOBACTERIAL BLOOMS: RISKS

BLOOM



ECOLOGICAL RISKS



TOXINS



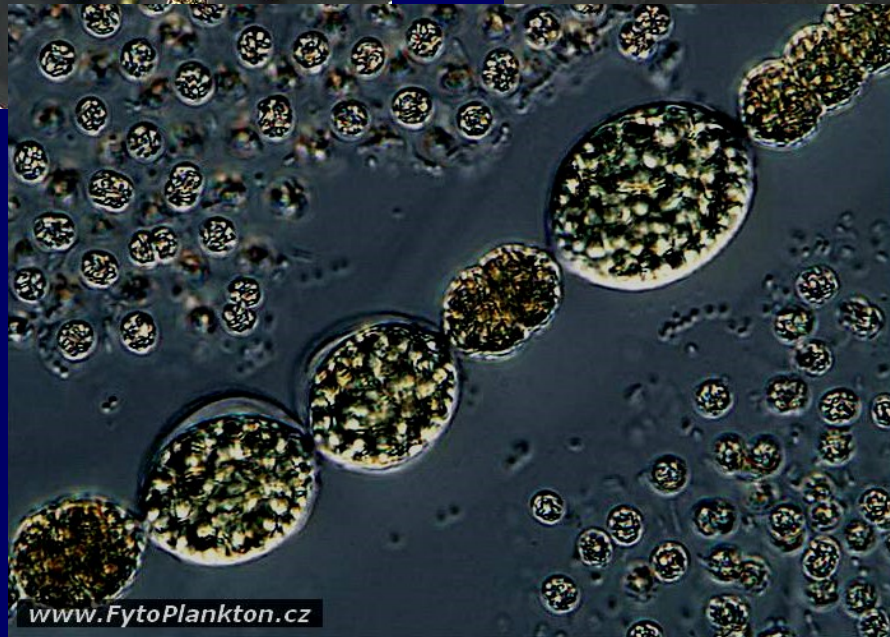
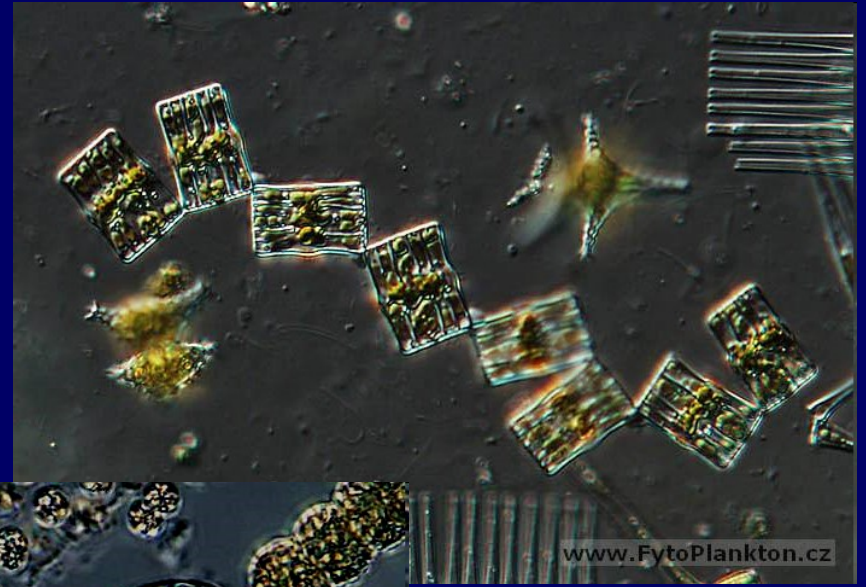
HUMAN
health risks



Ecological risk 1: Loss of phytoplankton biodiversity

- Anthropogenic changes in the environment (more nutrients - P,N)
 - > advantage for „some“ phytoplankton organisms
- Complex communities replaced with „monoculture“ (often *Microcystis aeruginosa*, *Planktothrix sp.*)
- „Monocultures“ **have secondary effects**
 - > changes in hydrochemistry (higher pH, transparency)
 - > further indirect impacts on other organisms

Ecological risk 1: Loss of phytoplankton biodiversity

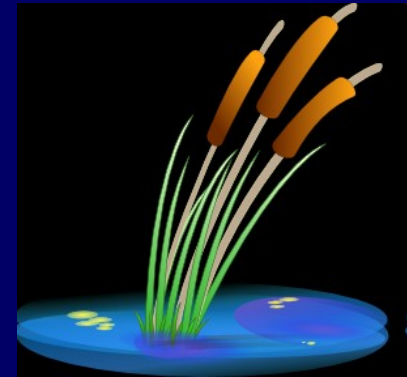


Ecological risk 1: Loss of phytoplankton biodiversity



Ecological risk 2: Further ecosystem changes

- **Phytoplankton -> changes in the whole network**
 - Reported examples ...
 - Changes in the **consumers communities**
zooplankton -> fish -> ...
 - **Makrophyte disappearance** (reed)
(shading -> no germination ...)
 - > **macrophytes**
= substrate for other organisms ...
- **New „expansive“ species**
 - cyanobacterium *Cylindrospermopsis raciborskii* (?)
- **Water blooms** = substrate for „associated bacteria“



Ecological risk 3: Ecosystem catastrophes

- Sudden disappearance of the producers „monoculture“
(*rapid environmental changes, „infections“ by viruses/phages*) -> **Ecosystem collapse**
- Seasonal changes
 - Cyanobacterial biomass lysis
 - > bacterial decay -> loss of O₂
 - > **anaerobic conditions - collapse**
 - Deaths of aquatic organisms (fish ...)
 - Pathogens (anaerobic Clostridium botulinum)

CYANOBACTERIAL BLOOMS: RISKS

BLOOM →

↓
↓
TOXINS →

ECOLOGICAL RISKS

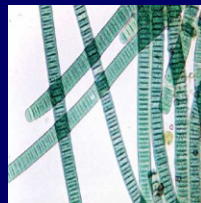
↓
HUMAN
health risks



Ecological risk 4: Cyanobacterial toxins

- **Cyanobacteria** - evolutionary old and important organisms (atmospheric oxygen)
- **G- bacteria** (10 mil. Cells / mL)
 - G- : cell walls contain lipopolysaccharides (LPS, *similar to E. coli, Salmonella sp...*)
- **Water blooms**
 - several complex problems (see previous slides...)
 - just one of the problems = **toxin production**

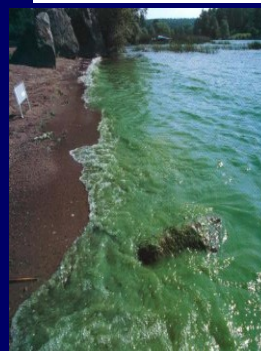
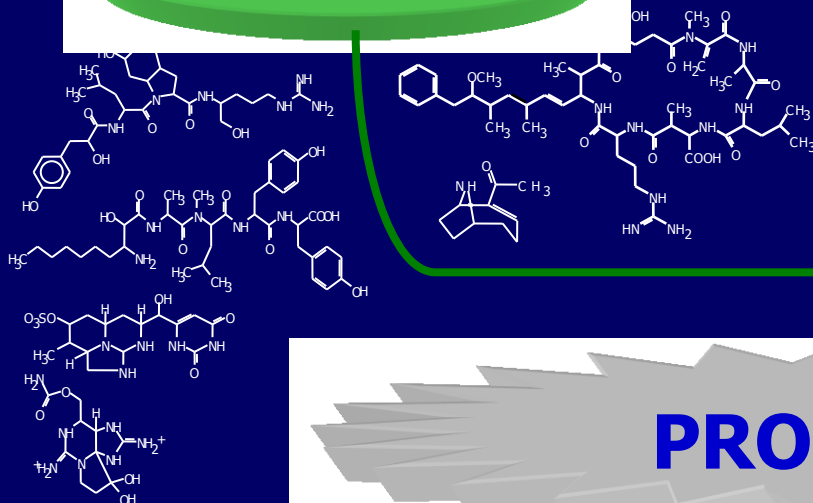
Cyanobacteria



(Eu)trophication

Water blooms

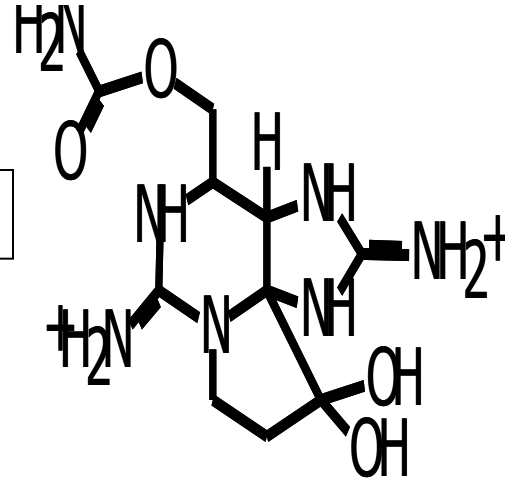
Cyanotoxins



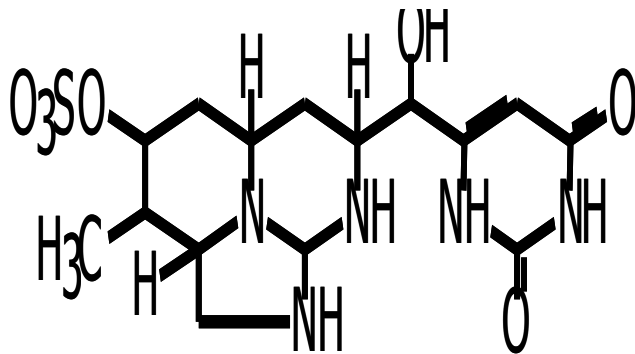
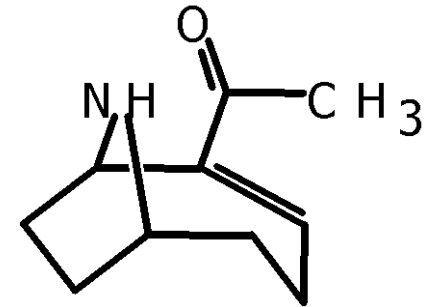
PROBLEM

Selected „known“ cyanotoxins

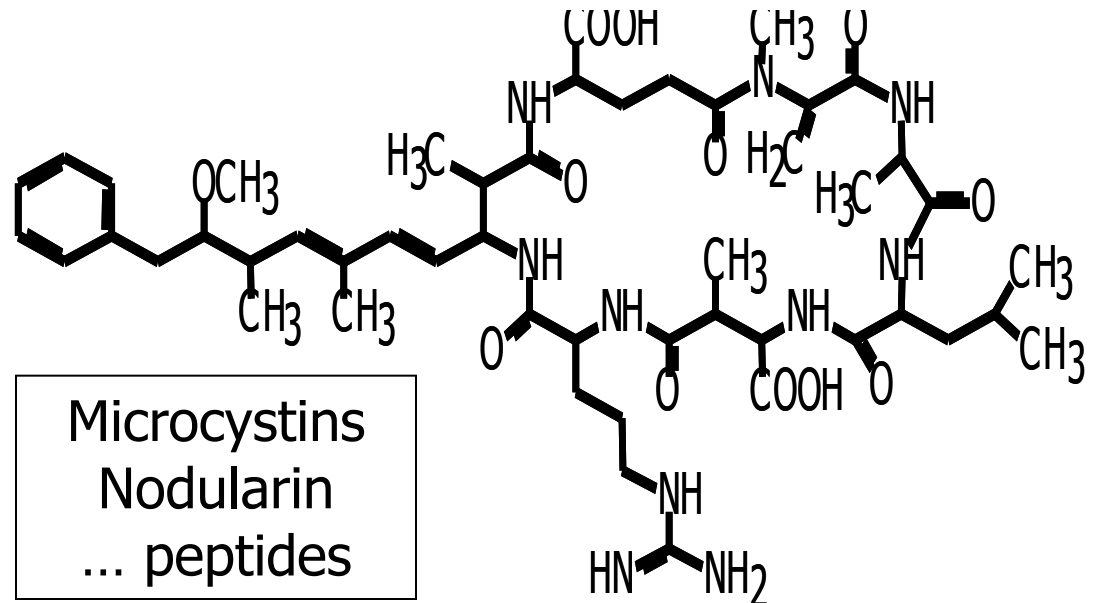
Saxitoxin



Anatoxin-a



Cylindrospermopsin



Microcystins
Nodularin
... peptides

Categorization of cyanotoxins

1. According to the chemical structure

- cyclic and linear peptides
- alkaloids
- lipopolysaccharides

2. According to biological activity

mechanisms of toxicity

- hepatotoxicity, neurotoxicity, cytotoxicity, irritating, immunotoxicity, genotoxicity ...

TOXIN	STRUCTURE	STRUCTURE VARIATION	LD50* ($\mu\text{g.kg}^{-1}$)	TOXICITY
Microcystin	cyclic heptapeptide	>60	50-1200	hepatotoxicity, tumor promotion, induction of oxidative stress
Nodularin	cyclic pentapeptide	7	50-2000	hepatotoxicity, tumor promotion
Anatoxin	alkaloide	2	200-250	neurotoxicity
Anatoxin-a(S)	methylphospho-ester N-hydroxy-guanine	1	20	neurotoxicity
Saxitoxin	carbamat alkaloid	19	10	neurotoxicity
Cylindrospermopsin	guanidin alkaloid	2	200**	cytotoxicity, target organs: liver and kidney
Aplysiatoxin		2		dermatotoxicity, tumor promotion
Lyngbyatoxin	modified cyclic dipeptide	1		dermatotoxicity, tumor promotion
Lipopolysaccharide				irritate effect

Cyanobacteria

Toxins produced

Anabaena

Anatoxins, Microcystins, Saxitoxins, LPS's

Anabaenopsis

Microcystins, LPS's

Anacystis

LPS's

Aphanizomenon

Saxitoxins, Cylindrospermopsins, LPS's

Cylindrospermopsis

Cylindrospermopsins, Saxitoxins, LPS's

Hapalosiphon

Microcystins, LPS's

Lyngbia

Aplysiatoxins, Lyngbiatoxin-a, LPS's

Microcystis

Microcystins, LPS's

Nodularia

Nodularin, LPS's

Nostoc

Microcystins, LPS's

Phormidium (Oscillatoria)

Anatoxin, LPS's

Planktothrix (Oscillatoria)

Anatoxins, Aplysiatoxins, Microcystins, Saxitoxins, LPS's

Schizothrix

Aplysiatoxins, LPS's

Trichodesmium

yet to be identified

Umezakia

Cylindrospermopsin, LPS's

THE COMPARISON OF TOXICITY OF THE NATURAL TOXINS

(i.p. injection, acute rat test, **LD50 in $\mu\text{g}/\text{kg}$**)

Bacteria-cyanobacteria- animals- fungi- plants

Amatoxin	<i>Amanita phalloides</i>	fungus	500
Muscarin	<i>Amanita muscaria</i>	fungus	1100
Aphanotoxin	<i>Aphanizomenon flos-aquae</i>	cyano	10
Anatoxin -A	<i>Anabaena flos-aquae</i>	cyano	20
microcystin LR	<i>Microcystis aeruginosa</i>	cyano	43
nodularin	<i>Nodularia spumigena</i>	cyano	50
botulin	<i>Clostridium botulinum</i>	bacteria	0,00003
tetan	<i>Clostridium tetani</i>	bacteria	0,0001
kobra	<i>Naja naja</i>	snake	20
kurare	<i>Chondrodendron tomentosum</i>	plant	500
strychnine	<i>Strychnos nux-vomica</i>	plant	2 000



Cyanobacterial EKOtoxicity ?

- Isolated microcystins - many toxicological studies
- HOWEVER: **Water blooms are more than microcystins**
 - complex mixtures of many compounds (toxins, lipopolysaccharides, non-toxic components...)
 - ? accumulated toxicants (metals, POPs ???)

Many studies:

tested complex water blooms BUT interpreted as „MCs“

Ecotoxicity of WATER BLOOMS to **bacterioplankton**

- highly relevant question (MCs are evolutionary old ... as well as bacteria)
- only few studies - in general **low toxicity** observed



Ecotoxicity of WATER BLOOMS to **algae (phytoplankton)**

- Algae = competitors to cyanobacteria
 - limited data
 - **weak direct toxicity** only at high (nonrelevant) concentrations
 - some studies indicate allelopathy between cyanobacteria & algae (*inhibition of growth, specific effects on dormant stages*)



Ecotoxicity of WATER BLOOMS to **zooplankton**

- invertebrates - **lower sensitivity** than vertebrates
- variable sensitivity of different (even closely related) invertebrate species
- one of the first hypotheses: „MCs are against predators“ (not confirmed - several contras...)

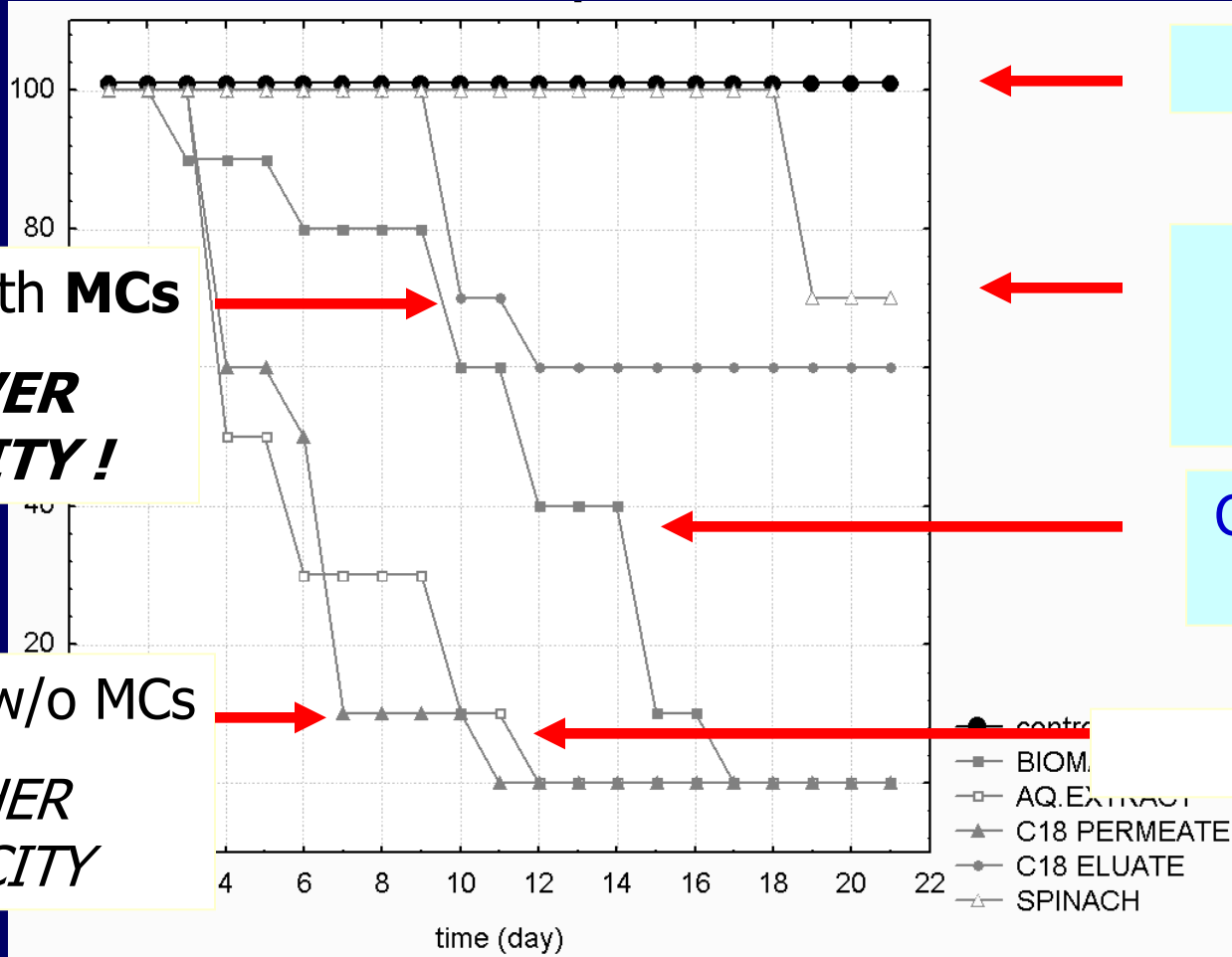
*BUT: zooplankton prefers nontoxic strains during feeding
(? -> indirect effects on development of toxic blooms ?)*



Ecotoxicity of cyanobacteria



Reproduction



Controls

Nontoxic biomass (spinach)

Complex water bloom

Extract

Fraction with **MCs**

! LOWER TOXICITY !

Fraction w/o MCs

HIGHER TOXICITY

Ecotoxicity of WATER BLOOMS to **fish and amphibians**

- Many studies ... toxin accumulations
 - + several effects observed (histology, biochemistry...)

**! Indirect effects (pH changes, oxygen content)
more important in toxicology !**



Ecotoxicity of WATER BLOOMS to **birds**

- deaths documented (with toxins in bird tissues)
- limited number of controlled experiments
 - low direct toxicity to model birds

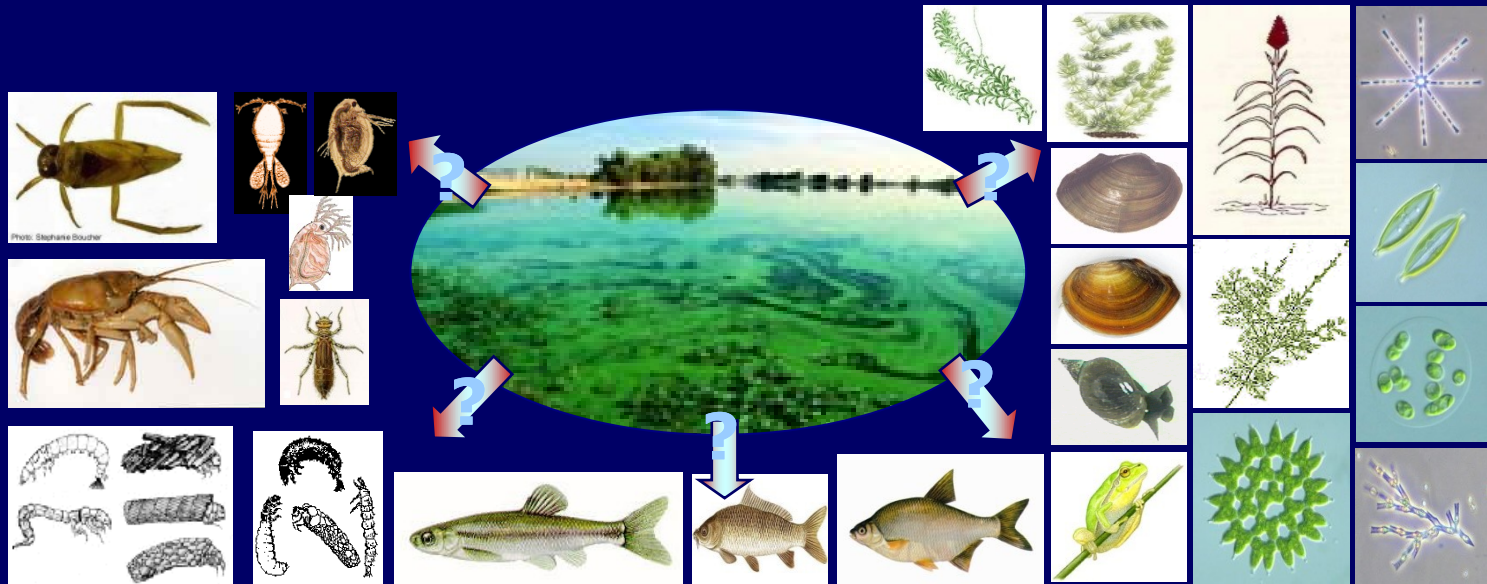
**! Water blooms stimulate effects of other agents
(lead toxicity, immunosuppressions)**



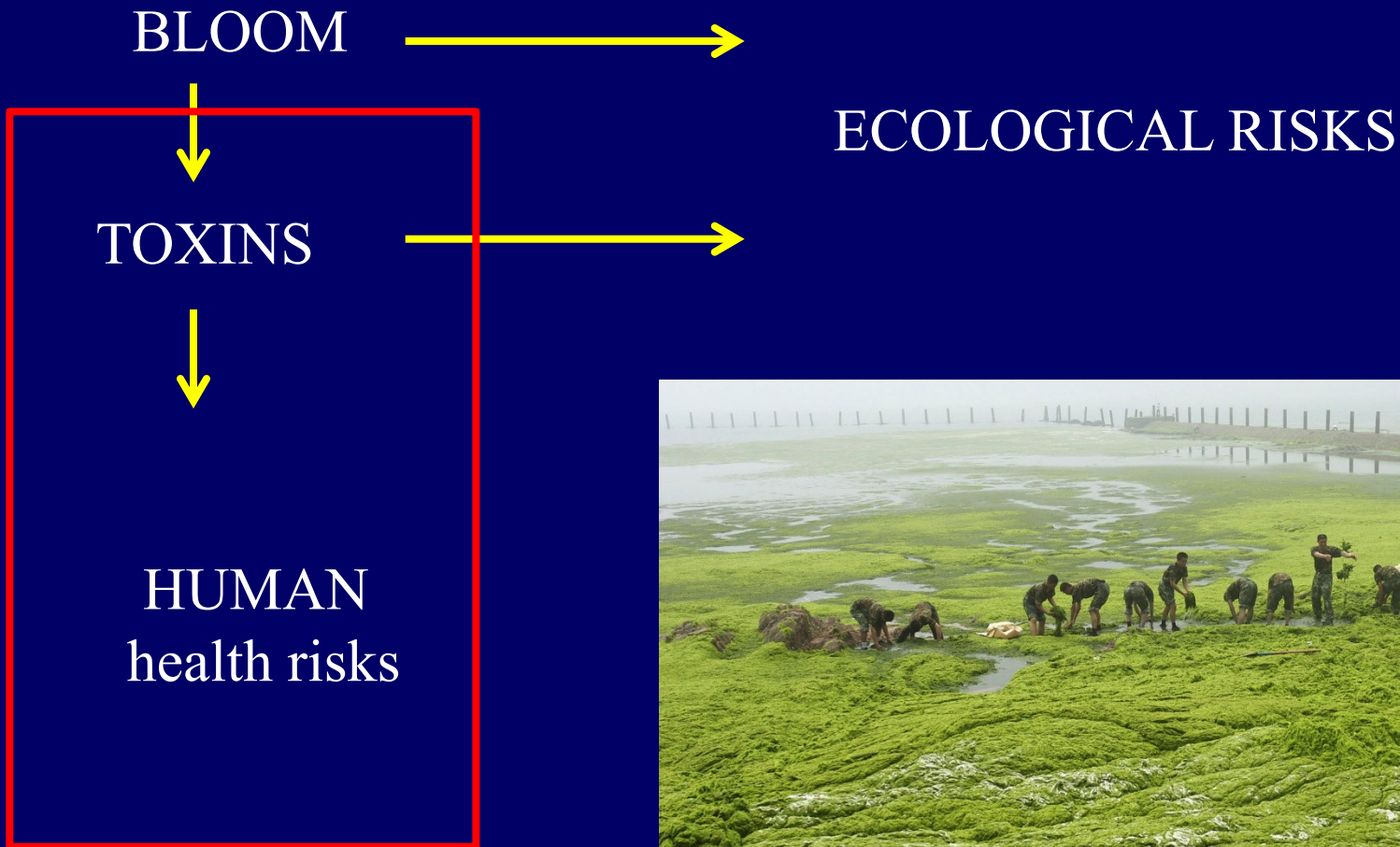
Summary

Ecotoxicological risks

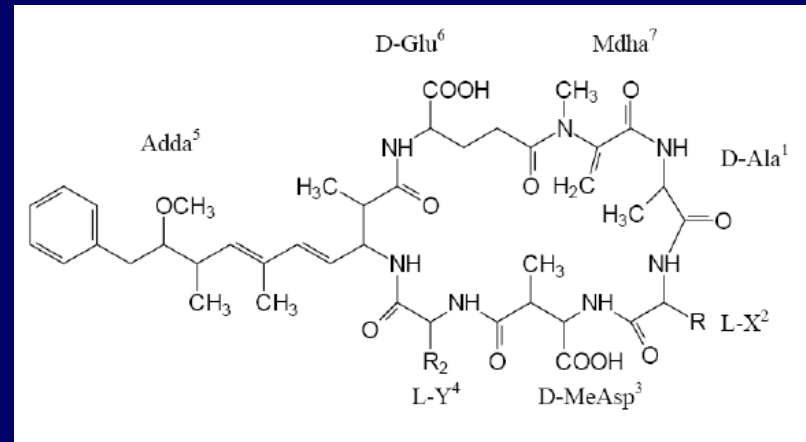
- **Only MCs studied** (*... results disputable ...*)
- **In general: Lower importance of „known“ isolated toxins (such as MCs)**
 - ! Complex bloom effects are more important !**



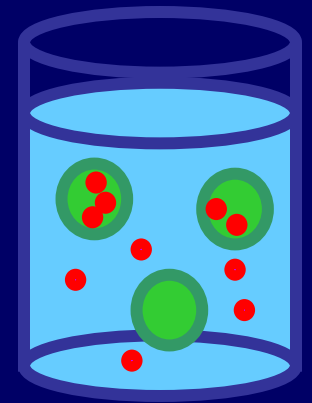
CYANOBACTERIAL BLOOMS: RISKS



MICROCYSTINS

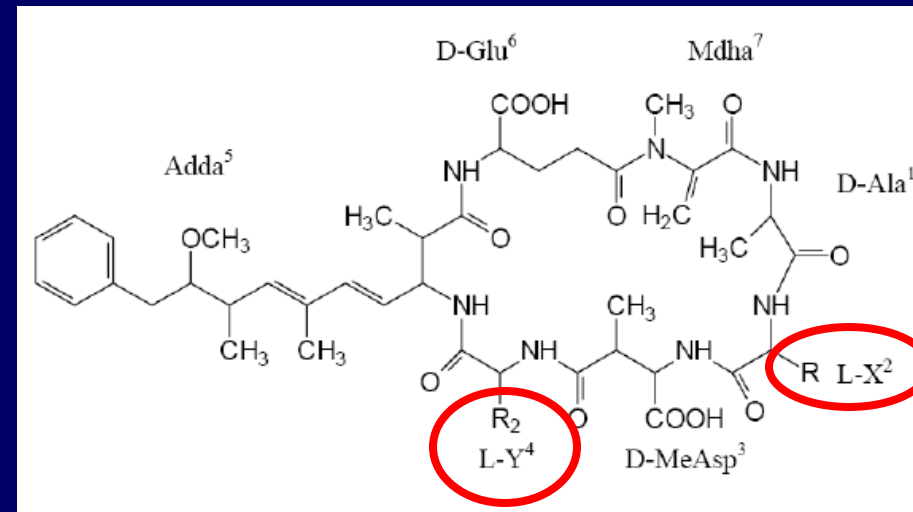


- **The most studied and most important**
- Produced and present inside cells:
 - **Intracellular:**
 - up to 10 mg/g d.w. of biomass
 - 1% dw -> tons / reservoir
 - **Extracellular** (dissolved): up to 10 ug/L
- Stable in water column, bioaccumulative (?)



MICROCYSTINS

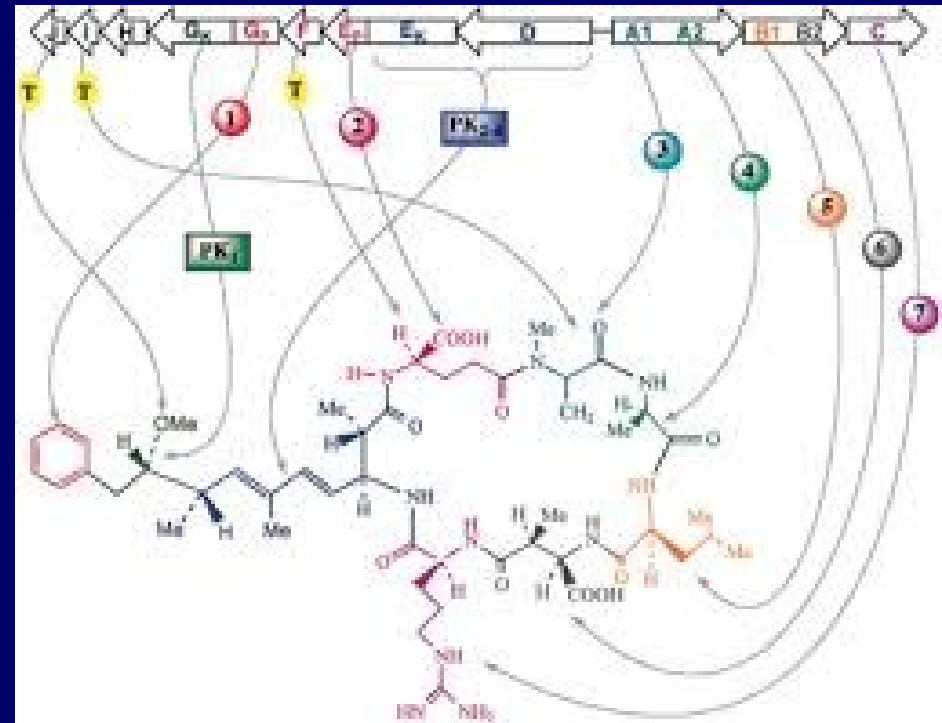
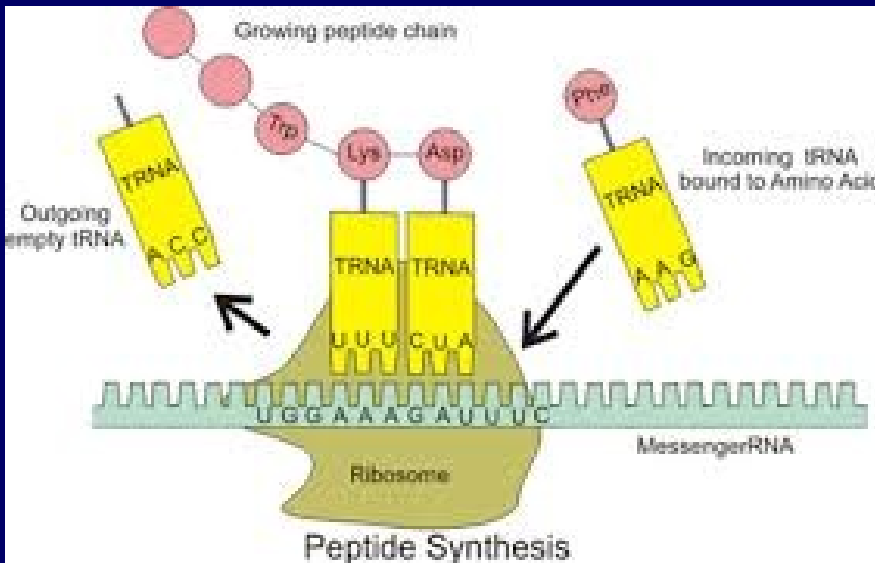
- Inhibit regulatory **protein phosphatases**
 - > tumor promoter
 - > hepatotoxic



- **70 variants**: MC-LR only considered by WHO
 - chronic TDI: 0.04 ug/kg b.w./day
 - drinking water guideline recommendation: 1 ug/L
- **Highly toxic to mammals and humans**
- Ecotoxicology ? Natural function ?

Microcystin synthesis

■ Non-ribosomal polyketide synthetases

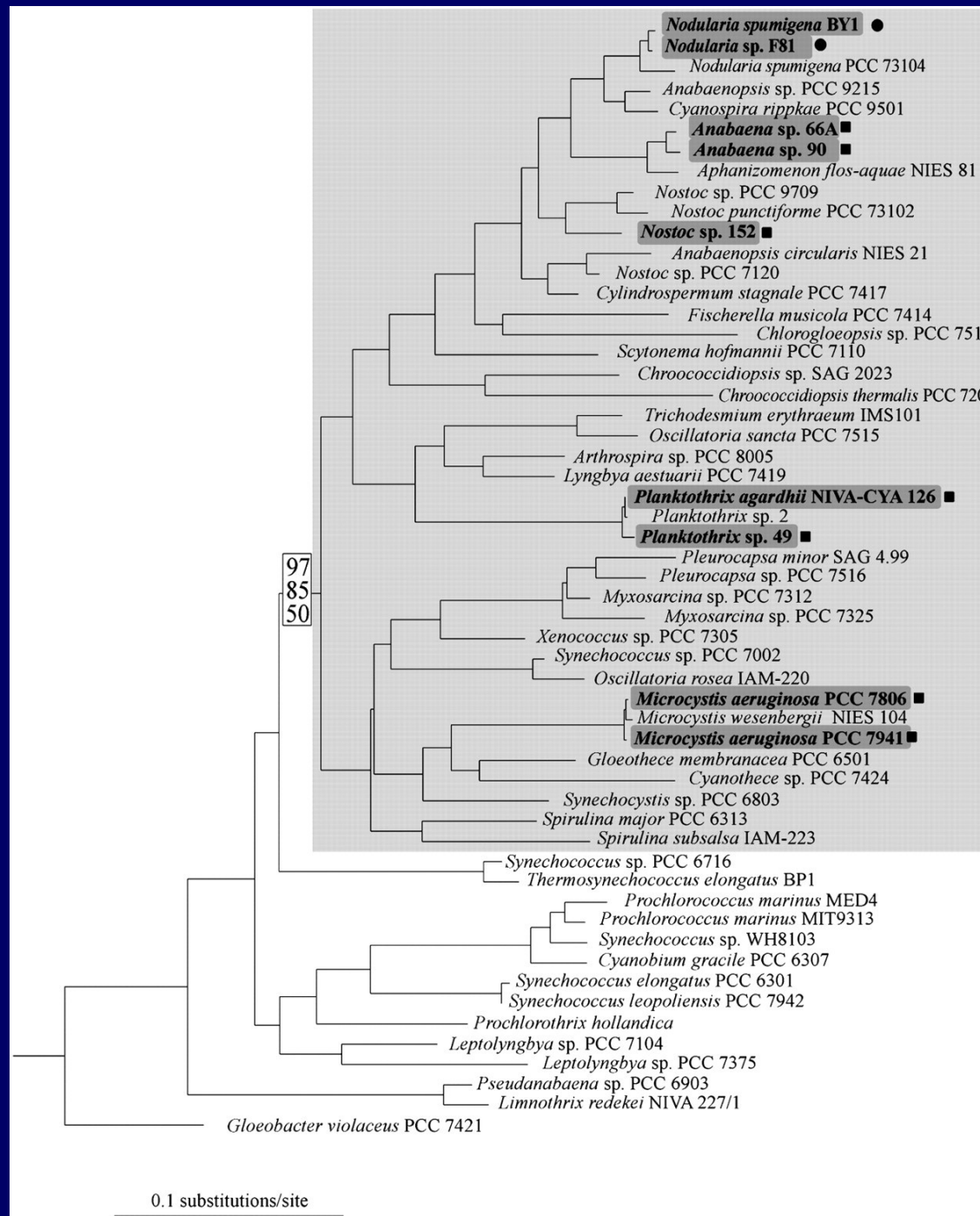


- ➡ 7 genes: 7 enzymes
- ➡ Enzymatic complex catalyzing binding of aminoacids (!!! Very high ATP demand)



Microcystin synthesis

- Evolution of non-ribosomal polyketide synthetases
- Evolutionary old genes
 - *Why remained?*

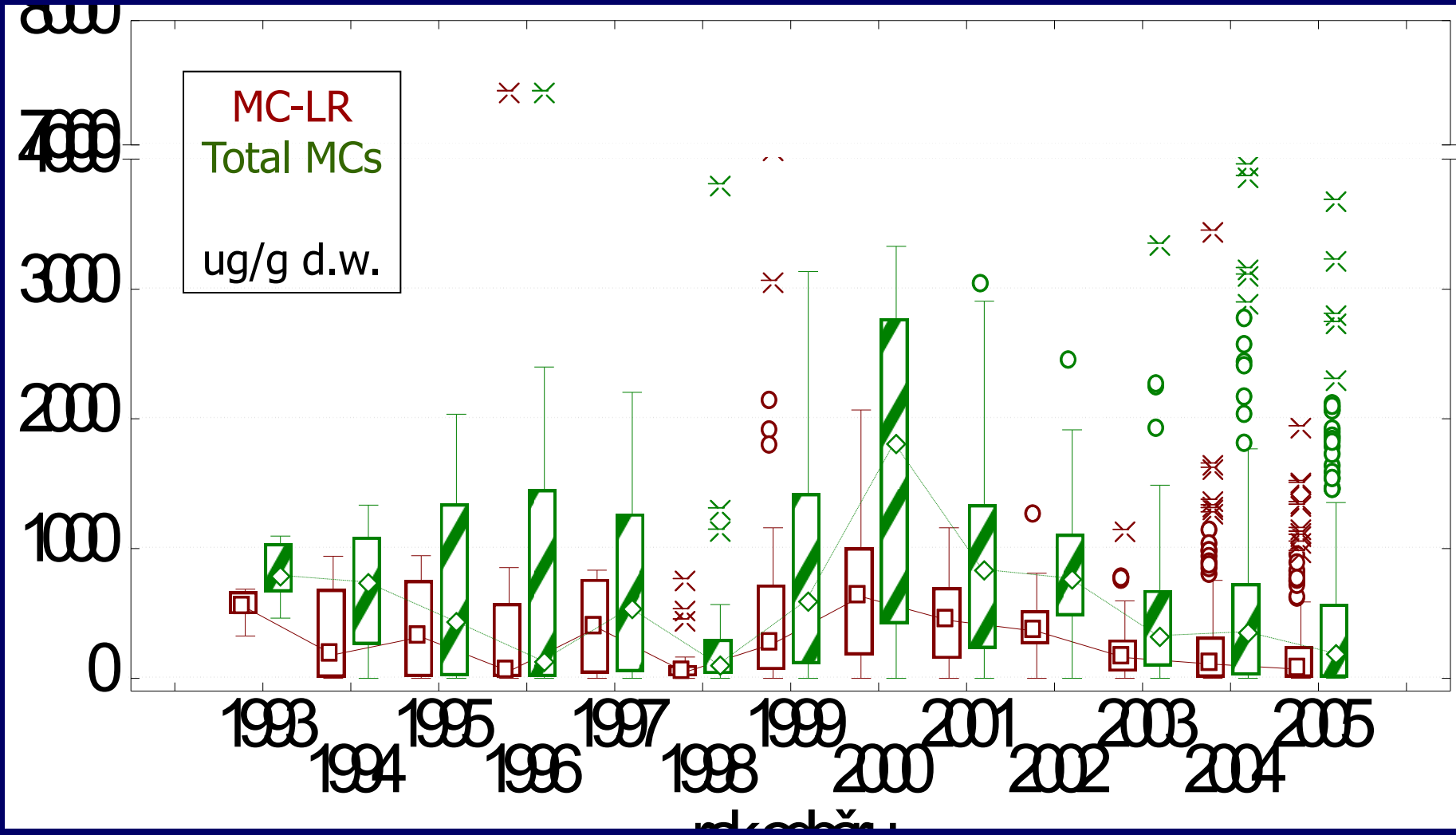


Rantala et al. (2004) PNAS 101:568

0.1 substitutions/site

Microcystins in the Czech Rep.

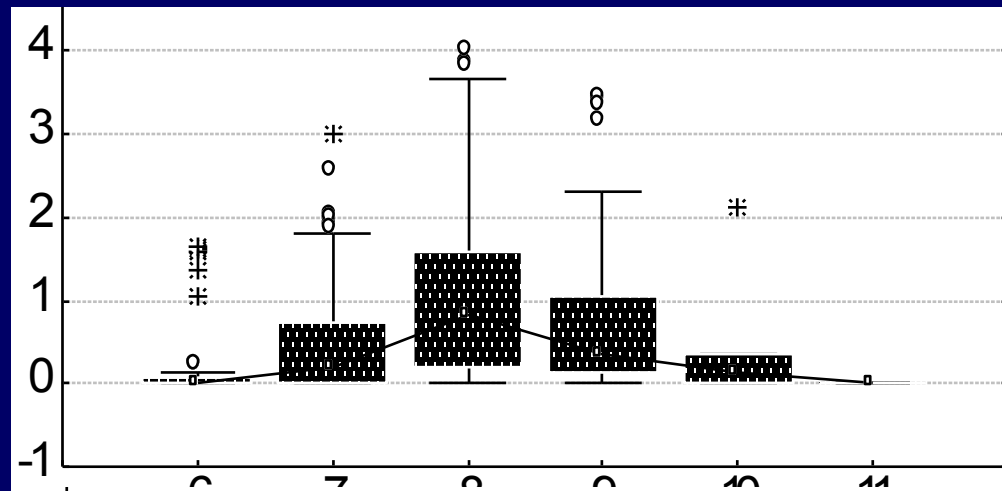
(Water bloom biomass concentrations
... up to several mg/g dry weight)



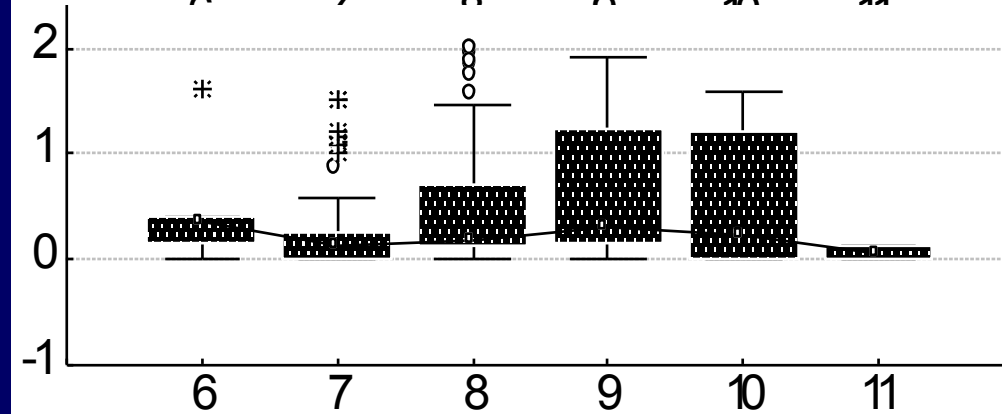
Seasonal variability

- **dissolved** microcystins in the C.R.
(water concentrations)

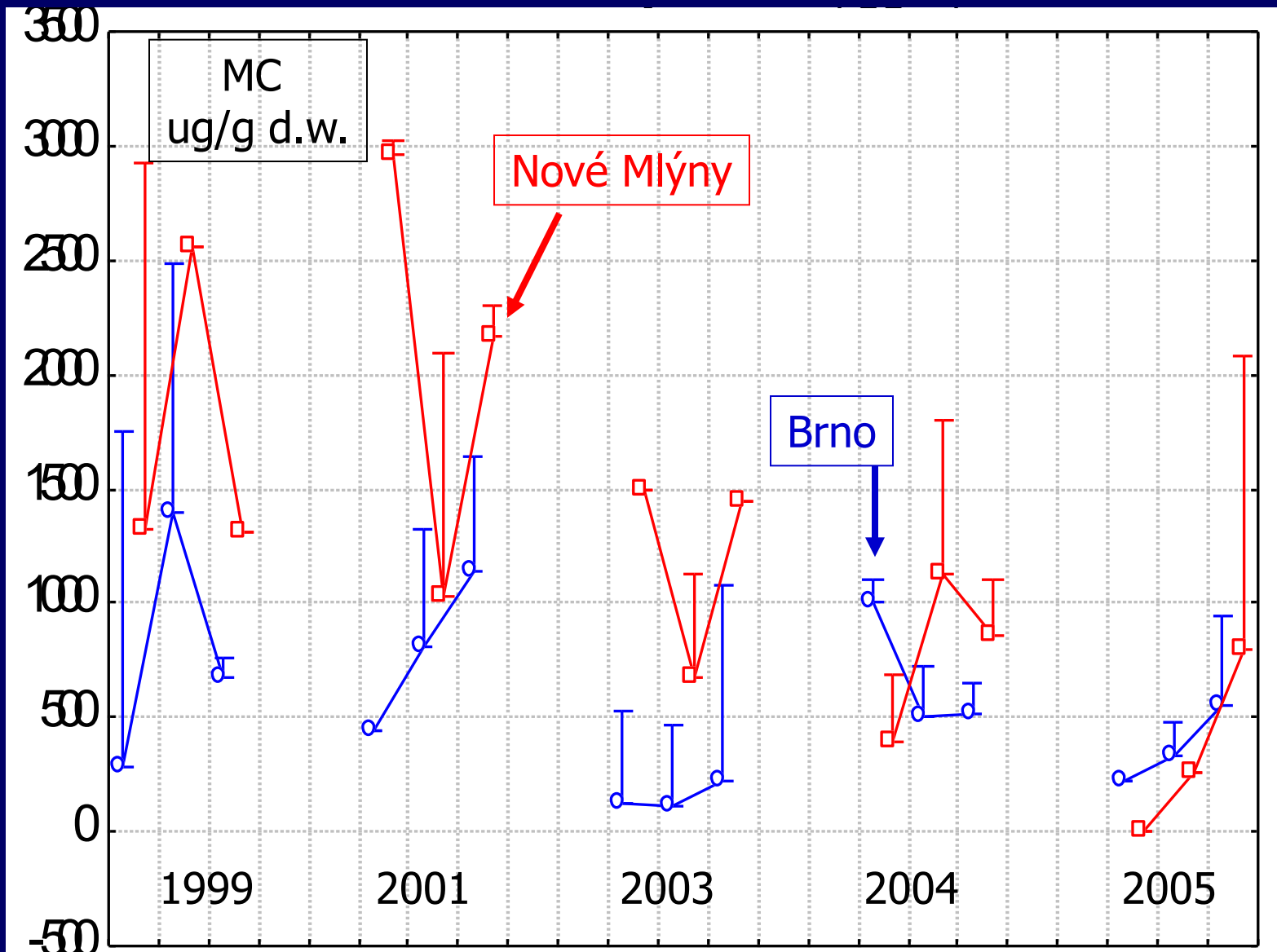
2004



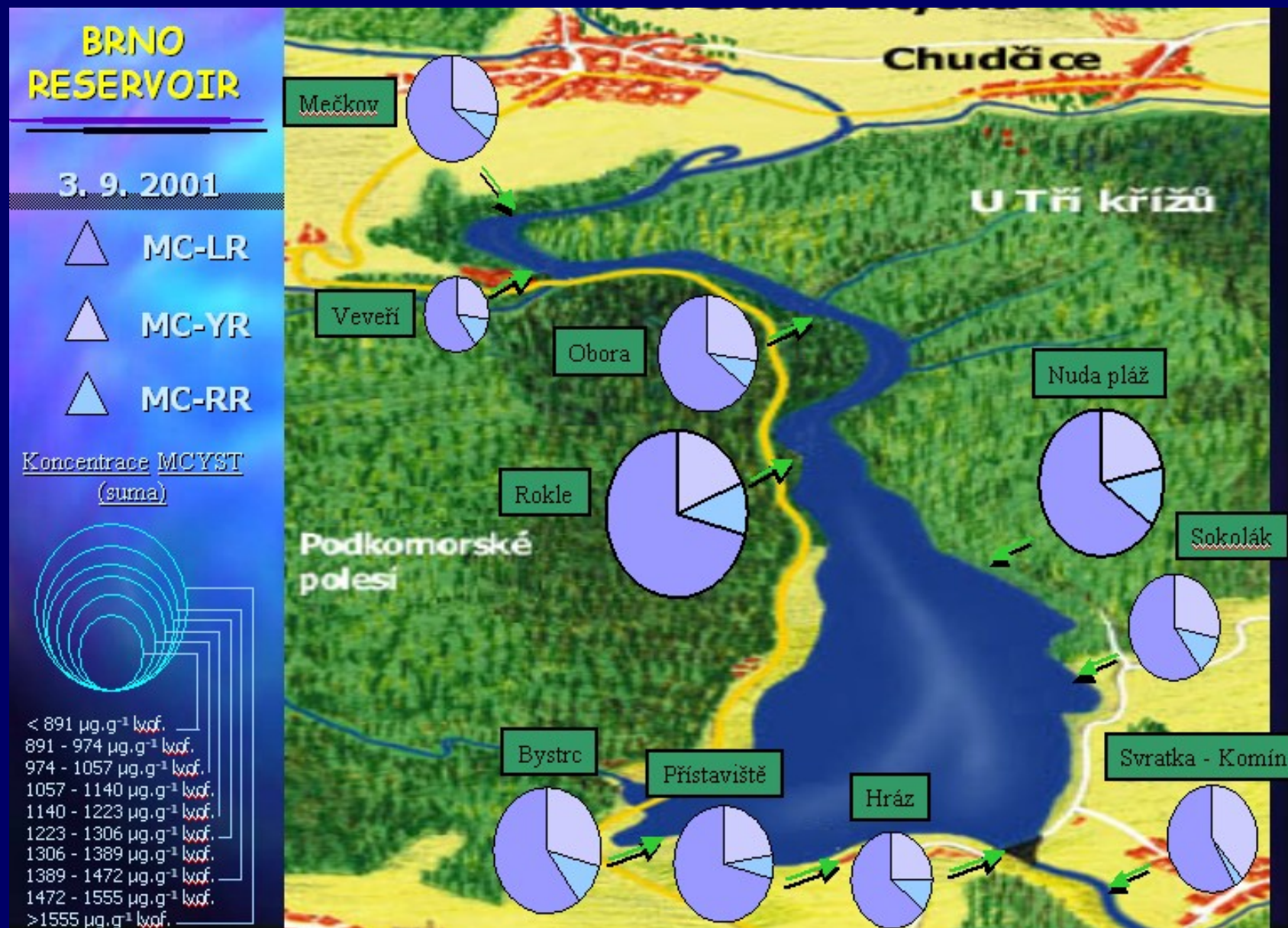
2005



Reservoir seasonal data



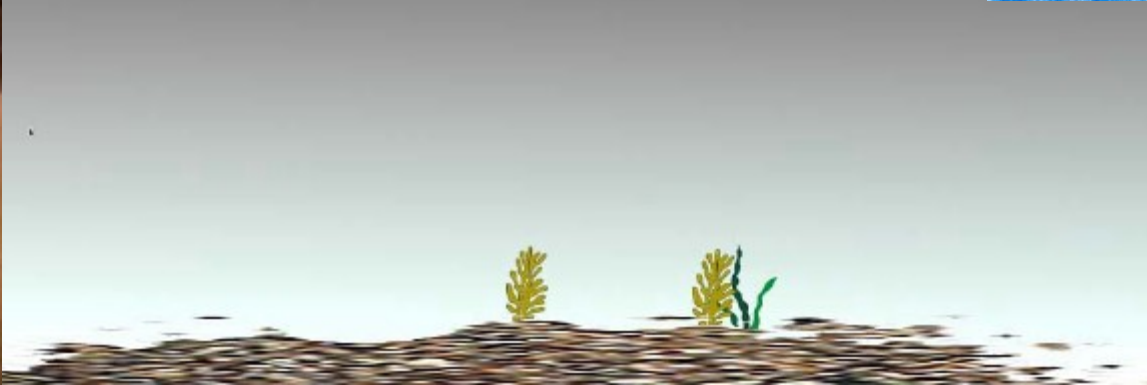
Reservoir spatial variability



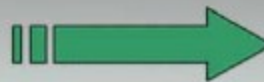
Microcystins

HUMAN HEALTH RISKS

EXPOSURE ROUTES

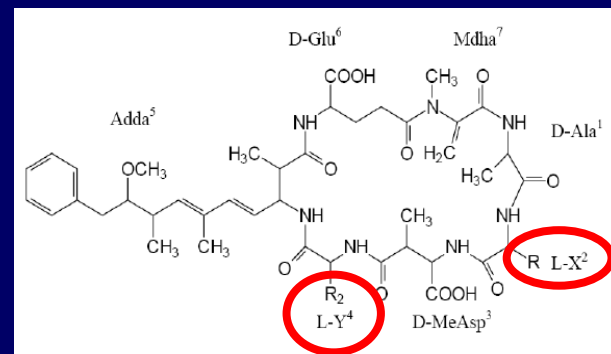


EXPOSURE ROUTES



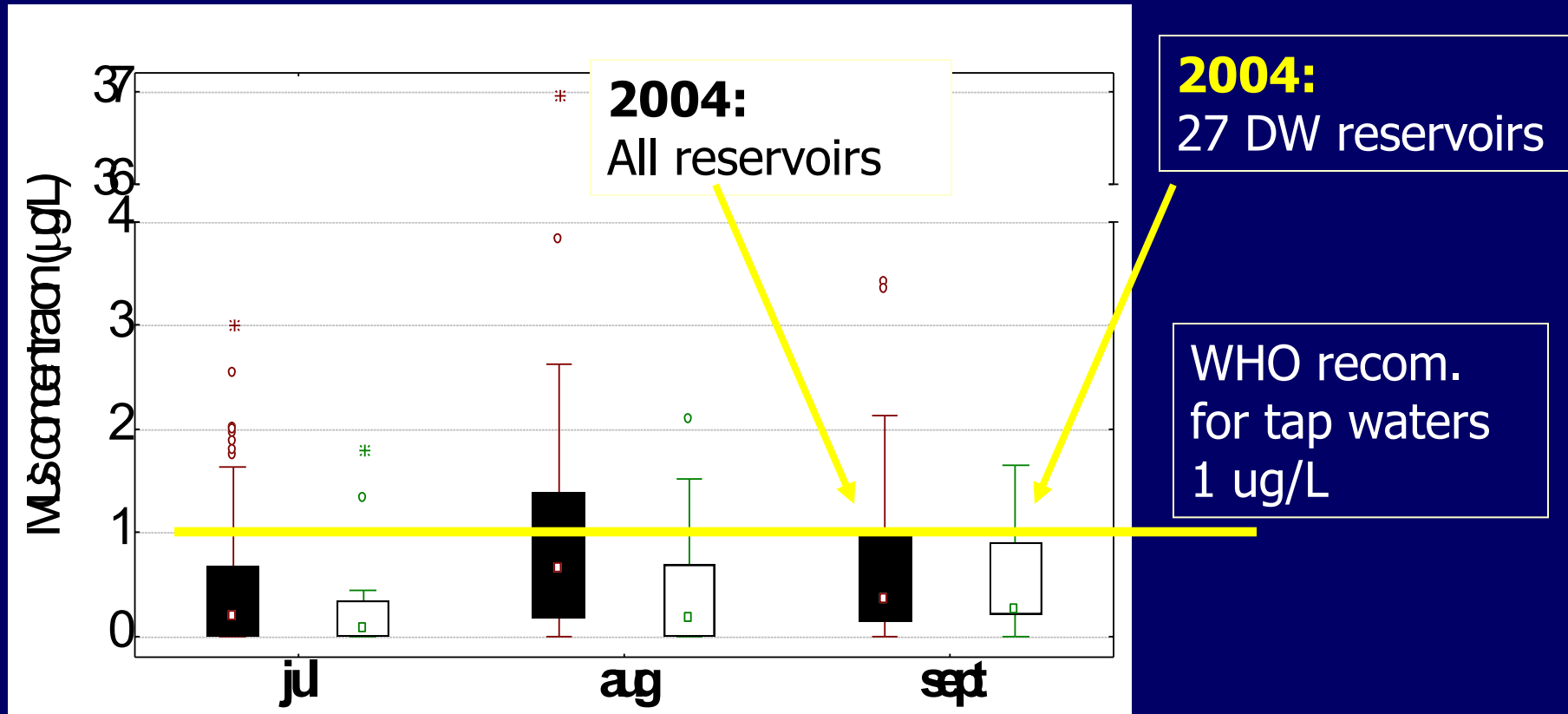
MICROCYSTINS

... brief reminder ...



- **70 structural variants:**
MC-LR only (about 30-50% of MCs) considered by WHO
- Human chronic TDI: **0.04 ug/kg b.w. daily**
 - drinking water guideline recommendation: **1 ug/L**
(usually accepted in national laws worldwide, incl. Czech Rep.)
- **High toxicity** - safety risks: **manipulation regulated**
United Nations - Bacteriological and Toxin Weapons Convention
Czech Rep. - Law no. 281/2002 Sb. and 474/2002 Sb.

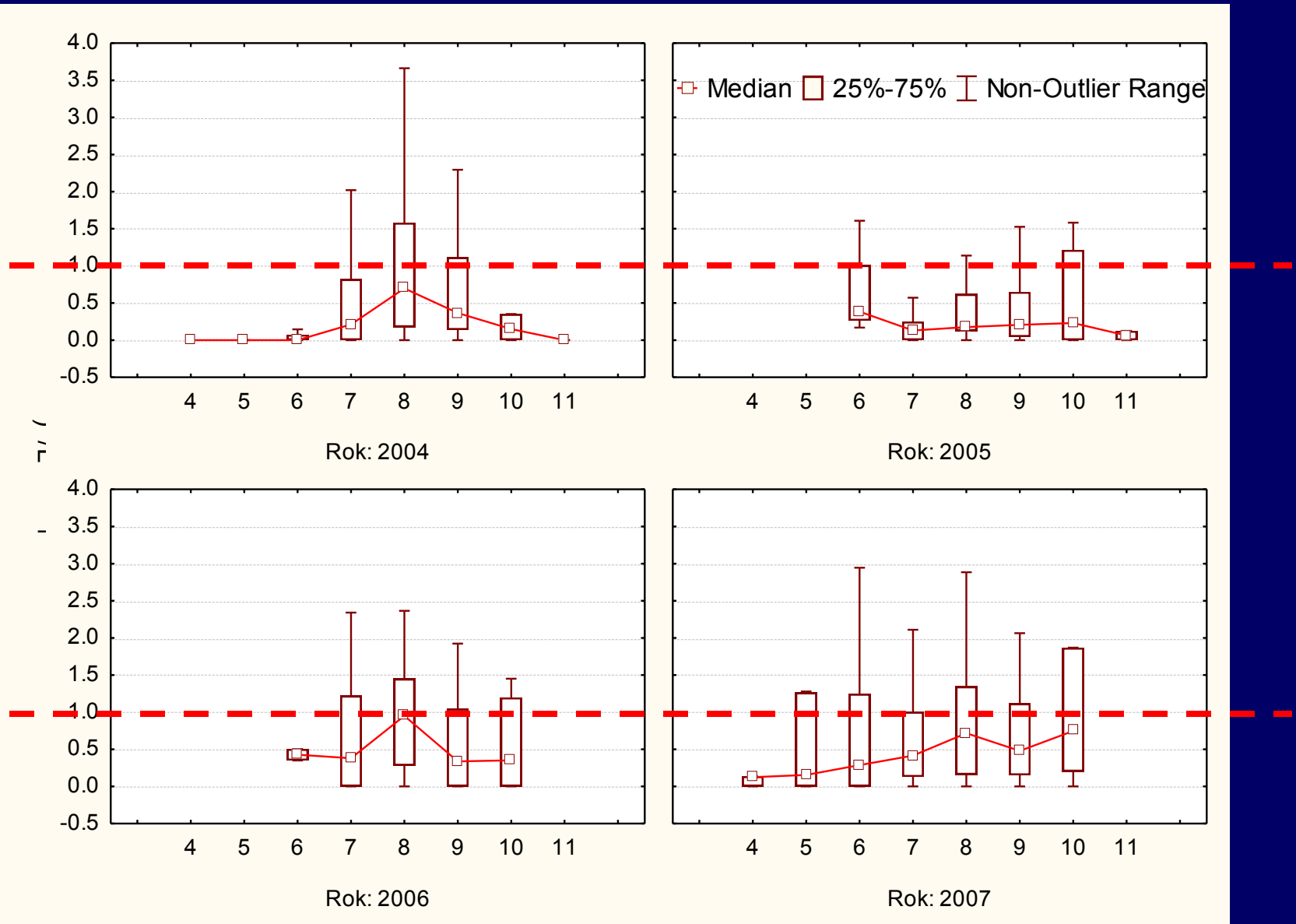
MCs in drinking water reservoirs



- **Tap waters up to 8 µg/L (1999)**

Bláha & Maršálek (2003) Arch Hydrobiol

MCs in drinking water reservoirs



"TOP" MCs **in waters** (Czech Rep. 2004-7)

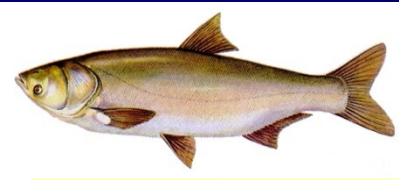
Lokalita	Datum odběru	MC [ug/L]
Velké Žernoseky (pískovna)	1.8.2004	37.0
Nechranice	31.7.2004	19.0
Dubice, Česká Lípa	8.9.2004	15.1
Prostřední, Lednice	6.9.2005	18.7
Lučina	19.7.2005	17.3
České údolí VN	8.8.2005	9.3
Plumlov	15.8.2006	24.8
Dalešice	14.7.2006	16.3
Hracholusky	21.8.2006	16.3
Nechranice	26.7.2007	29.8
Skalka	22.8.2007	19.9
Novoveský	2.10.2007	16.3

Risks of MCs in drinking water supplies

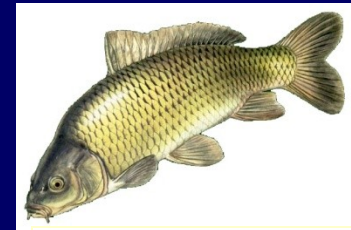
concentration of dissolved MC	20% daily intake from sources of drink.w.		100% daily intake from sources of drink.w.	
	child (25kg)	adult (70kg)	child (25kg)	adult (70kg)
	dose MC($\mu\text{g.kg}^{-1}$ live wt. day $^{-1}$)	dose MC($\mu\text{g.kg}^{-1}$ live wt. day $^{-1}$)	dose MC($\mu\text{g.kg}^{-1}$ live wt. day $^{-1}$)	dose MC($\mu\text{g.kg}^{-1}$ live wt. day $^{-1}$)
	HI	HI	HI	HI
median 0.205 $\mu\text{g/L}$	0.0015 0.038	0.0005 0.014	0.0075 0.189	0.0027 0.067
extreme 17.27 $\mu\text{g/L}$	0.1272 3.180	0.0454 1.136	0.6359 15.898	0.2271 5.678

- SIGNIFICANT HEALTH RISKS EXIST !
- To minimize risk
 - Adopt appropriate technologies and treatments
 - Establish routine monitoring of MCs during the season

Accumulation of MCs in fish



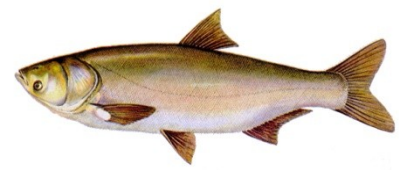
Silver carp



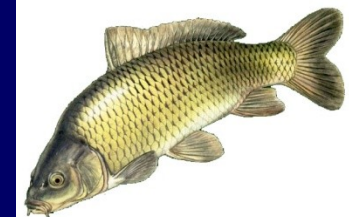
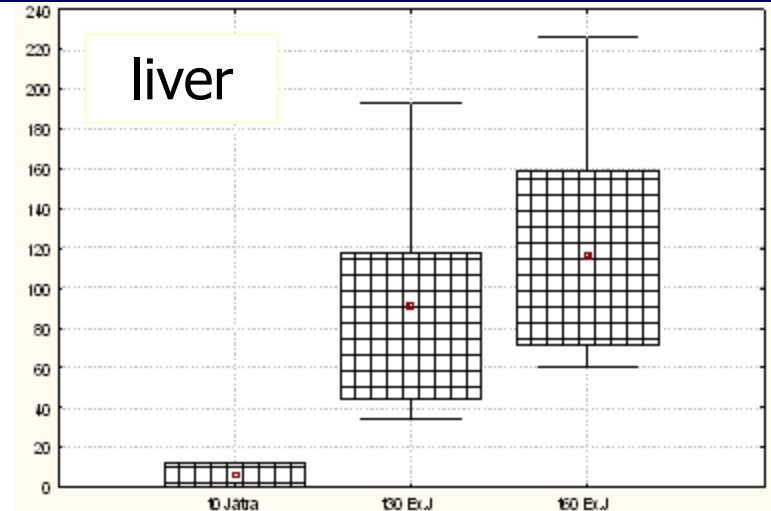
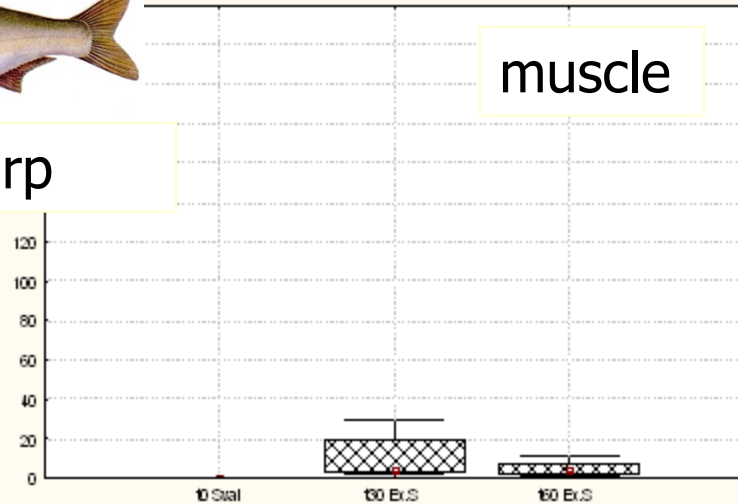
Common carp



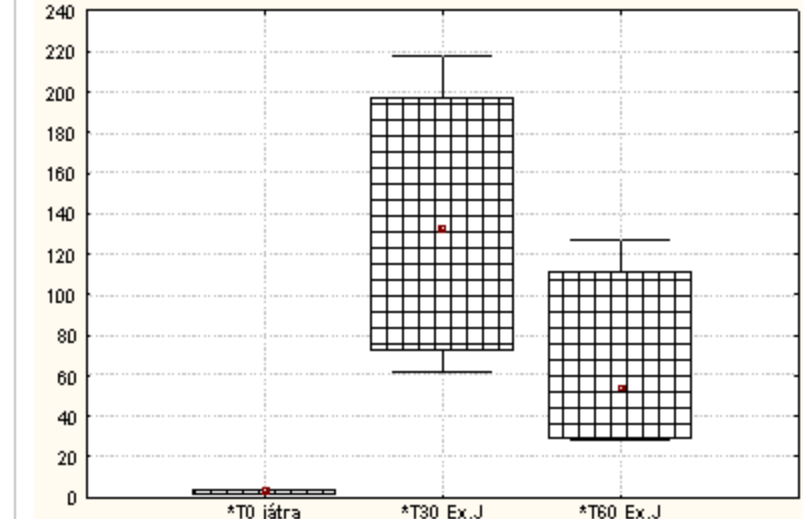
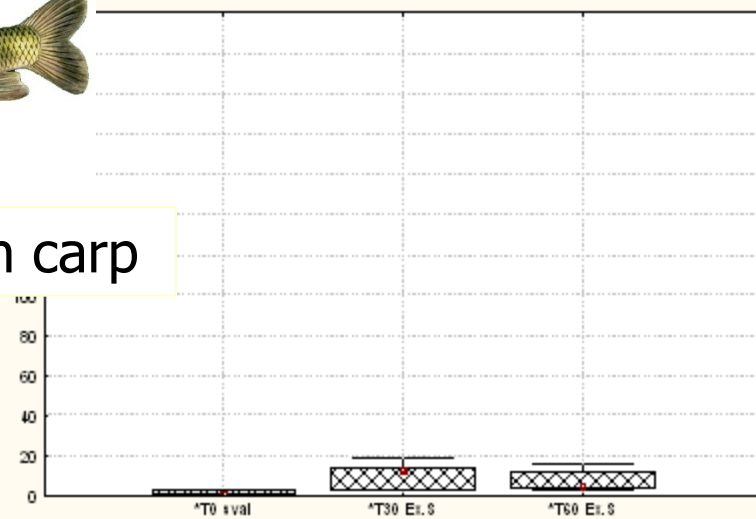
Accumulation of MCs in fish



Silver carp



Common carp



Control

30 d

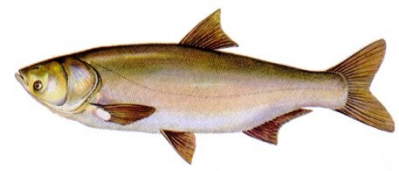
60 d

Control

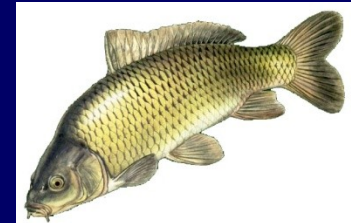
30 d

60 d

Risk of MCs in edible fish



Silver carp



Common carp

	Max. conc. (dose)	Max. HI	Average conc. (dose)	Average HI
SC: liver	226 ng/g 68 ug	28	106 ng/g 32 ug	13.2
muscle	29 8.8	3.7	8.4 2.5	1.1
CC: liver	217 65	27	132 39	16.5
muscle	18.8 5.6	2.4	8.5 2.6	1.1

*100% of food from the contaminated source
avg. person: 60kg, food - 300g*

TDI: 0.04 ug/kg/day

MCs in fish [ng/g f.w.] (Czech Republic reservoirs, 2008)

	Liver		Muscle
	Average	Maximum	
Pike perch	15.6	22.7	0
Amur	2.02	6.1	0
Carp	0.57	1.8	0
Catfish	0	0	0
Silver salmon	4.14	9.5	0

- Exposure to MCs from fish

Less (if any) significant health risks

RECREATIONAL EXPOSURE

- **Contact dermatitis**

*non-specific (!!!!)
responsible agents
(? MCs, LPS?)*



- **Toxins enter the body**

(MCs risk assessment possible)



Risks of MCs: recreational exposure (US EPA R.A.methodology)

biomass-bound MC	7 days per year (chronic exposure)				1 day acute exposure			
	Guidance level 2 100 000 cells/mL		Guidance level 3 2 000 000 cells/ml		Guidance level 2 100 000 cells/mL		Guidance level 3 2 000 000 cells/ml	
	child (25kg/80ml.h ⁻¹)	adult (70kg/50ml.h ⁻¹)	child (25kg/80ml.h ⁻¹)	adult (70kg/50ml.h ⁻¹)	child (25kg/80ml.h ⁻¹)	adult (70kg/50ml.h ⁻¹)	child (25kg/80ml.h ⁻¹)	adult (70kg/50ml.h ⁻¹)
	MC dose ($\mu\text{g.kg}^{-1}\text{bw.day}^{-1}$) HI	MC dose ($\mu\text{g.kg}^{-1}\text{bw.day}^{-1}$) HI	MC dose ($\mu\text{g.kg}^{-1}\text{bw.day}^{-1}$) HI	MC dose ($\mu\text{g.kg}^{-1}\text{bw.day}^{-1}$) HI	MC dose ($\mu\text{g.kg}^{-1}\text{bw.day}^{-1}$) HI	MC dose ($\mu\text{g.kg}^{-1}\text{bw.day}^{-1}$) HI	MC dose ($\mu\text{g.kg}^{-1}\text{bw.day}^{-1}$) HI	MC dose ($\mu\text{g.kg}^{-1}\text{bw.day}^{-1}$) HI
median concentration 348 $\mu\text{g/g dw}$	0.00019 0.005	0.00004 0.001	0.00389 0.097	0.00087 0.022	0.01013 0.253	0.00226 0.057	0.20268 5.067	0.04524 1.1310
extreme concentration 3945 $\mu\text{g/g dw}$	0.00220 0.055	0.00049 0.012	0.04406 1.102	0.00984 0.246	0.11488 2.872	0.02564 0.641	2.29757 57.439	0.51285 12.823

- Recreation exposure
-> significant risks of MCs

Lipopolysaccharides ?

- **Pyrogenicity of LPS**

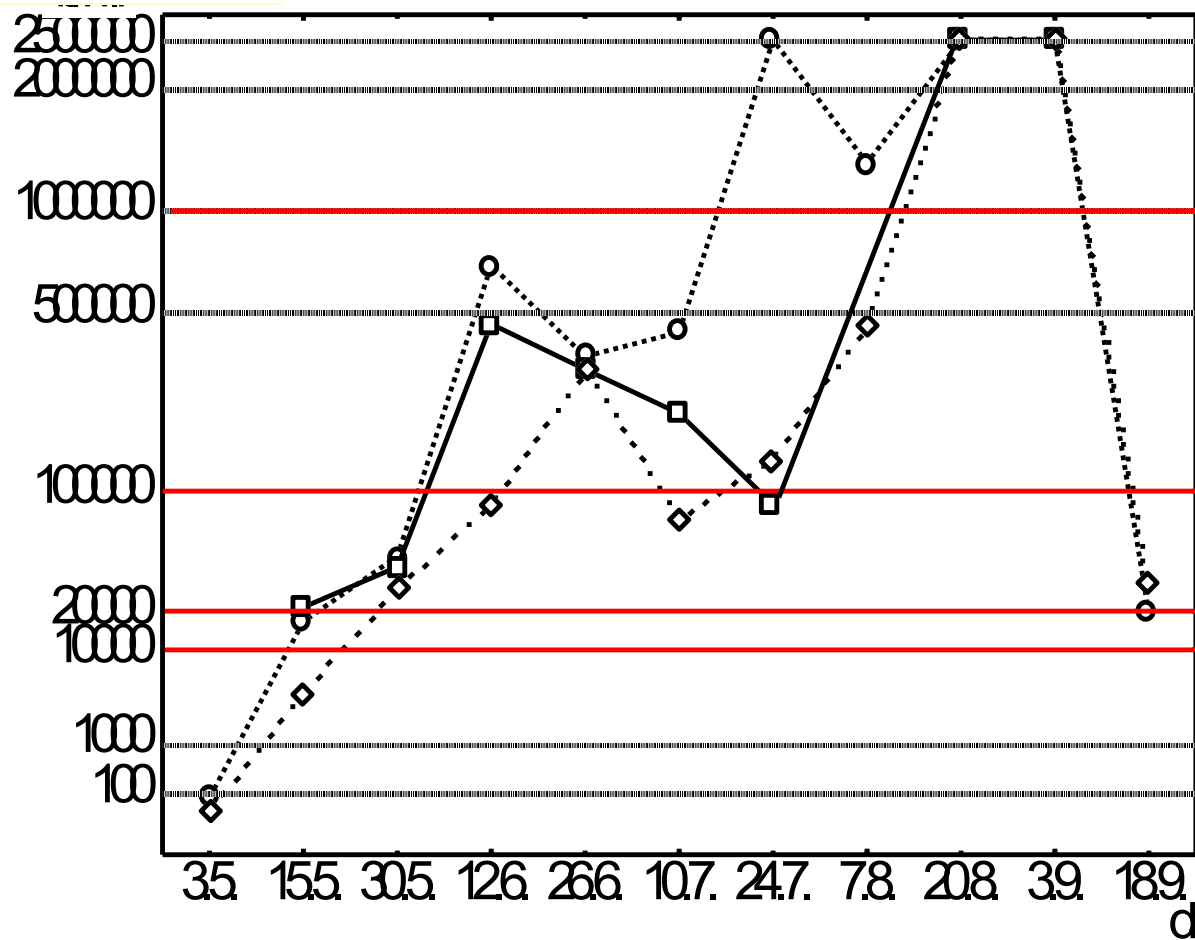
significant in water blooms
(less in lab cultures)

Sample	Endotoxin activity	
	(EU mg ⁻¹ d.w.)	(EU mg ⁻¹ LPS)
Green alga		
<i>P. subcapitata</i>	0	0
Cyanobacterial culture		
<i>P. agardhii</i>	301	35 456
<i>A. flos-aquae</i>	426	38 399
<i>M. aeruginosa</i>	257	36 809
<i>T. variabilis</i>	2 518	270 848
Water bloom		
<i>Planktothrix sp.</i>	61	46 959
<i>Aphanizomenon sp.</i>	7 895	918 118
<i>M. aeruginosa</i>	799	199 895
<i>Microcystis sp.</i>	989	449 576
<i>Anabaena sp.</i>	277	48 699
Heterotrophic bacteria		
<i>E. coli</i>	14 692	1 347 959
<i>K. intermedia</i>	1 702	239 770
<i>P. putida</i>	11 392	1 294 592
<i>P. fluorescens</i>	55	6 669

Bernardová et al.
2008 J Appl Toxicol

Toxic cyanobacteria in recreational reservoirs (WHO approach - „preliminary caution“)

Cells / mL

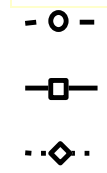


High risks

Swim. not recommended

Risk for sensitive

Warning

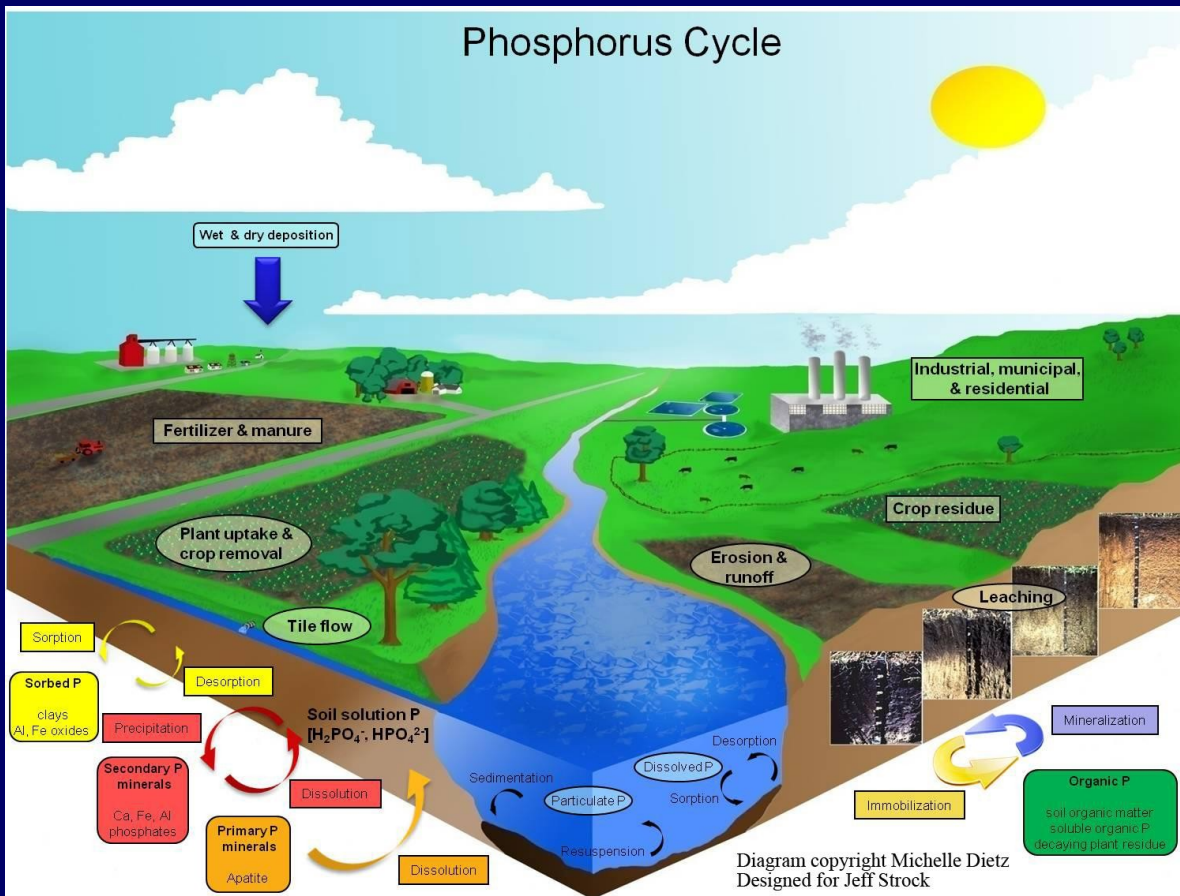


Summary

MCs and the health risks

- MCs present in 80-90% of reservoirs
- High MCs concentrations
- **All exposure routes pose significant health risks** under certain scenarios
 - ! Recreation, Drinking water
 - (MCs accumulated in fish - less important)*

How to „manage“ toxic blooms

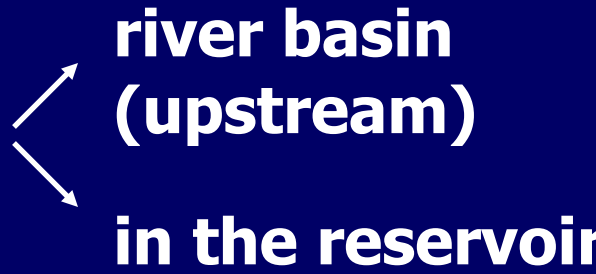


Successful solution:

Always
reservoir-specific

Combinations
of methods
of **PREVENTION**
+ **REMEDIATION**

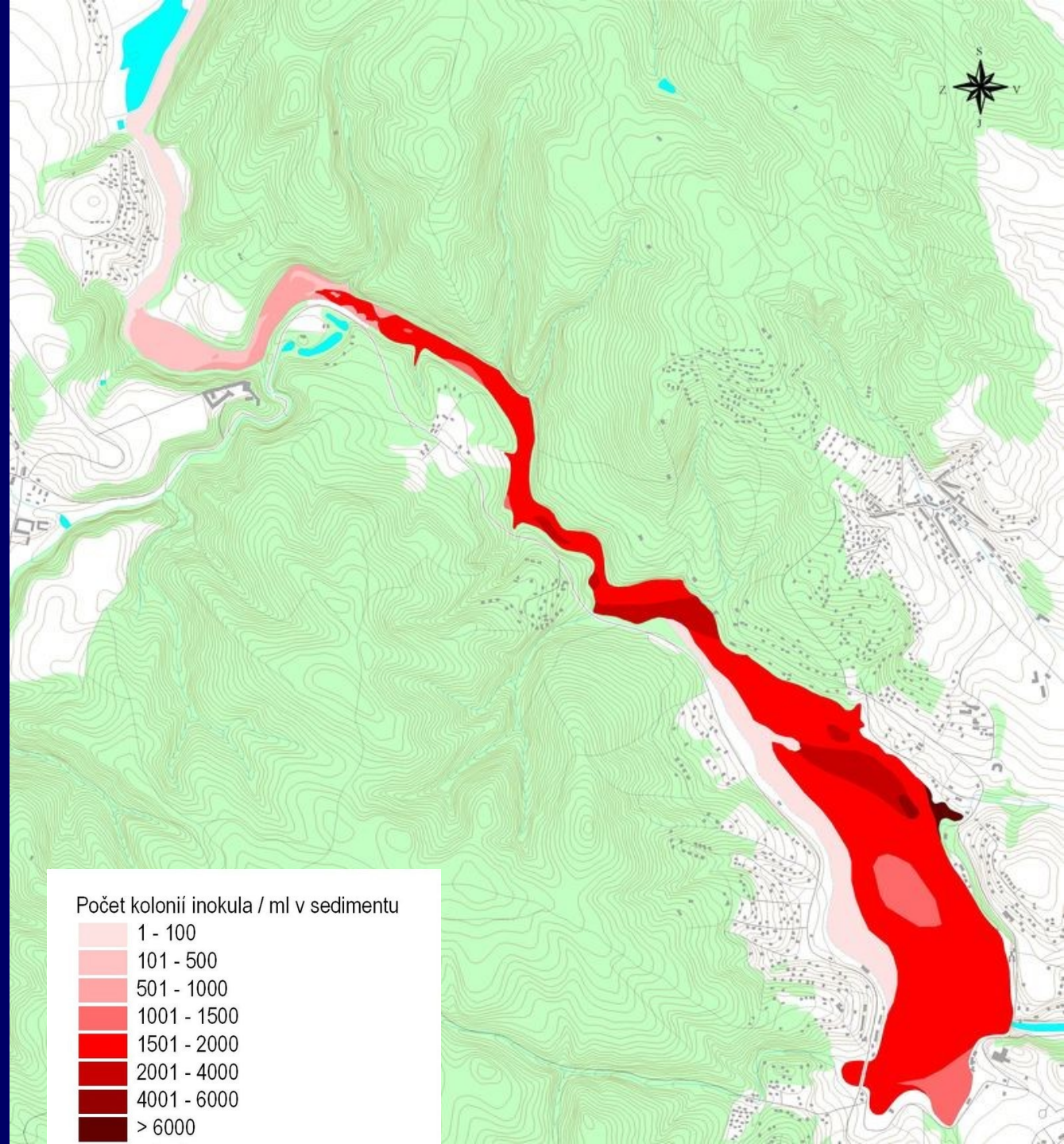
How to manage toxic blooms?

- Limit **nutrient sources** 
 - river basin (upstream)
 - in the reservoir
- **Cyanocides** (chemical, natural - e.g. Humic acids)
- **Flocculants** $\text{Al}(\text{OH})_3$...
- **Biological control** (... planktophagous fish)
- **Others** (mechanical removal, ultrasonic ...)

Example

Brno reservoir

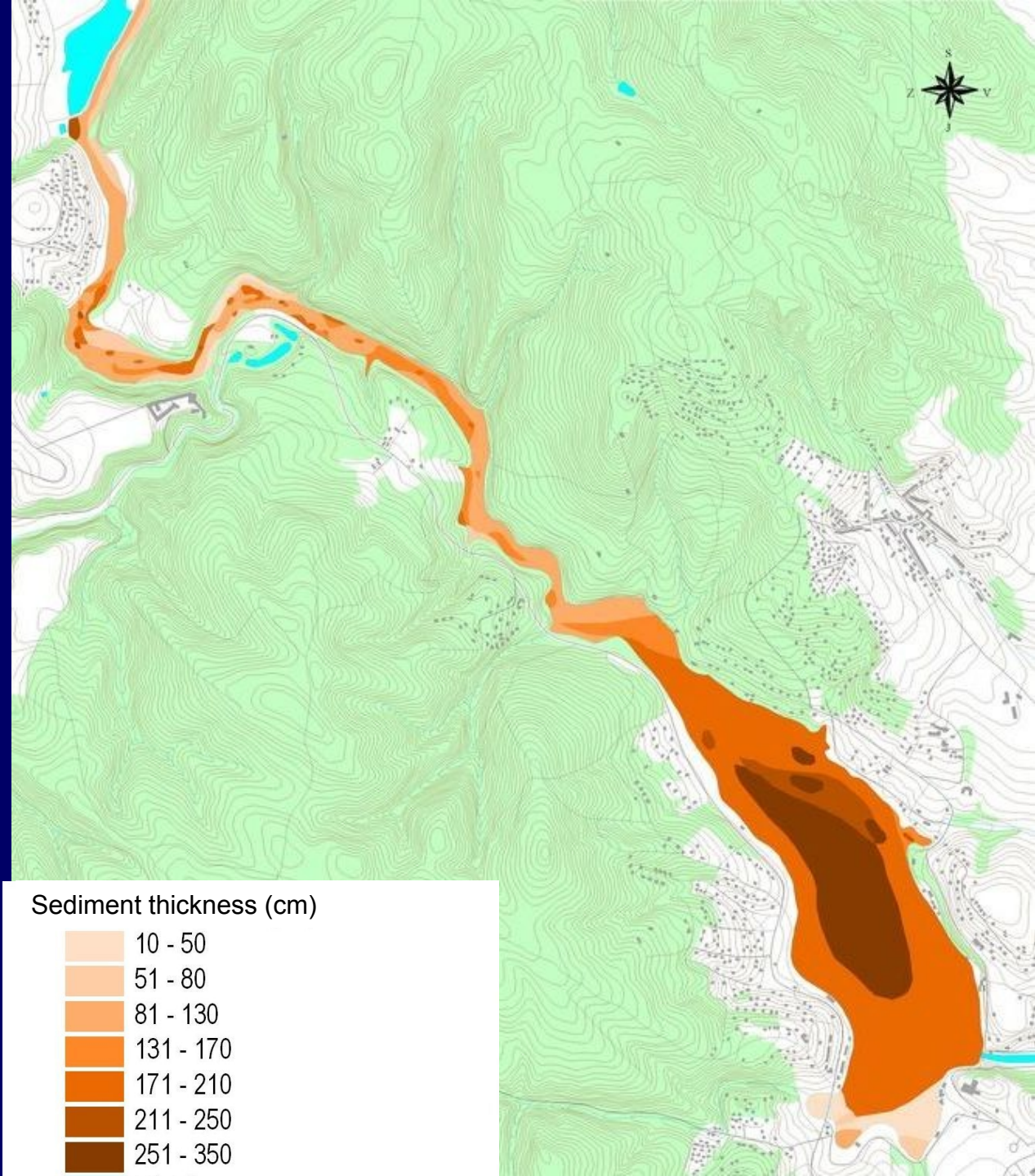
sources of
cyanobacteria
(colonies
in sediment)



Sources of nutrients

... in the
reservoir

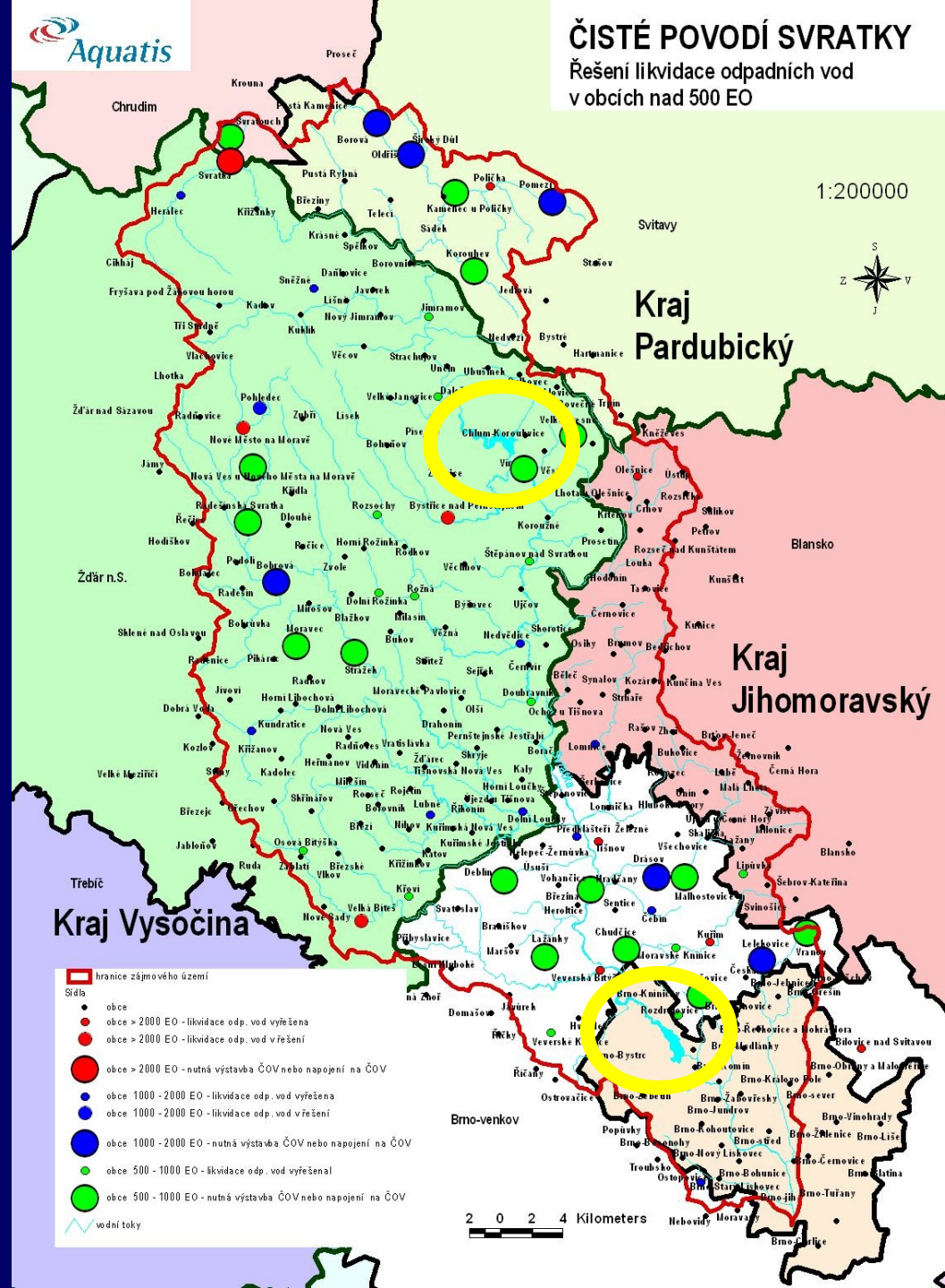
*(sediments
up to 3 m
thickness)*



Sources of nutrients

... upstream

- several small towns & villages (no WWTPs)



- REMOVAL OF Phosphorus from river basin

Lower
contamination
(P-free)



Bulding
+ improvements
of WWTPs



Revitalizations
(wetlands)

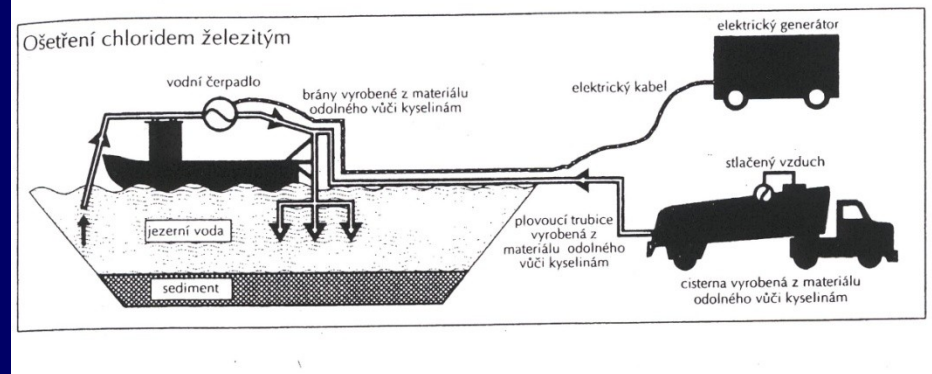
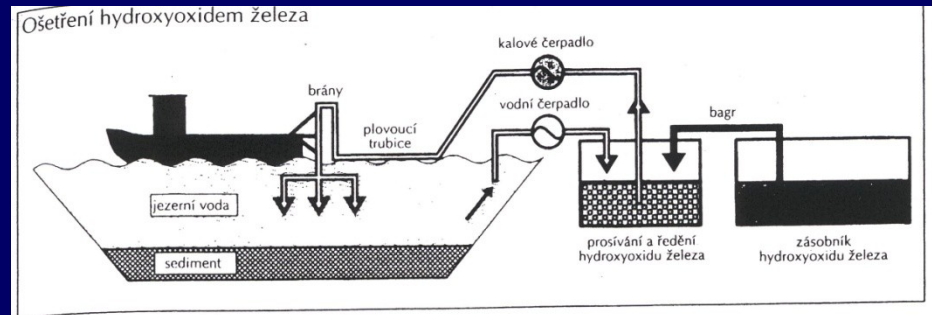


- Phosphorus immobilization „within“ the lake

**Draining the lake:
Surface chemistry at sediments**

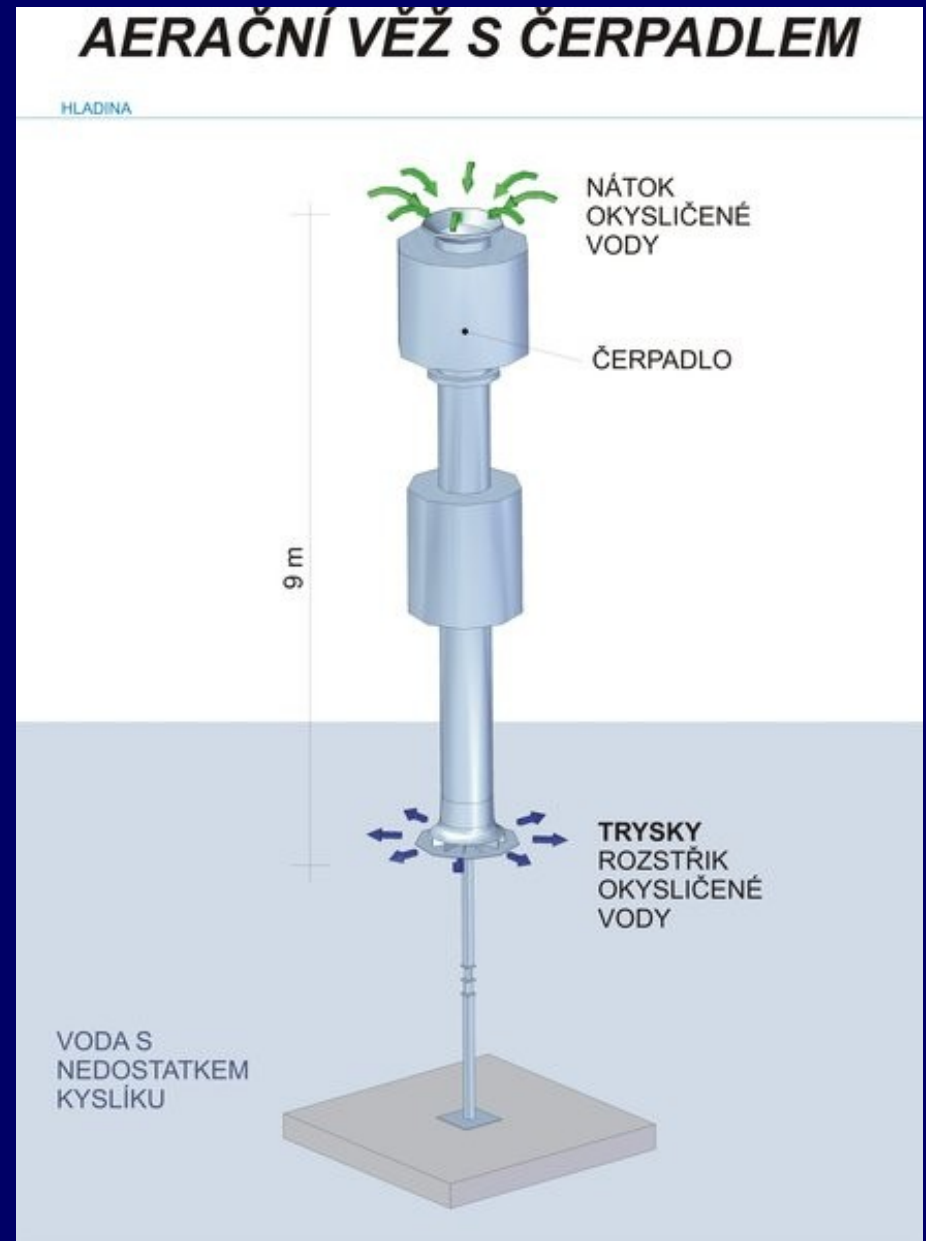


**Flocculation of P
in the river or lake**

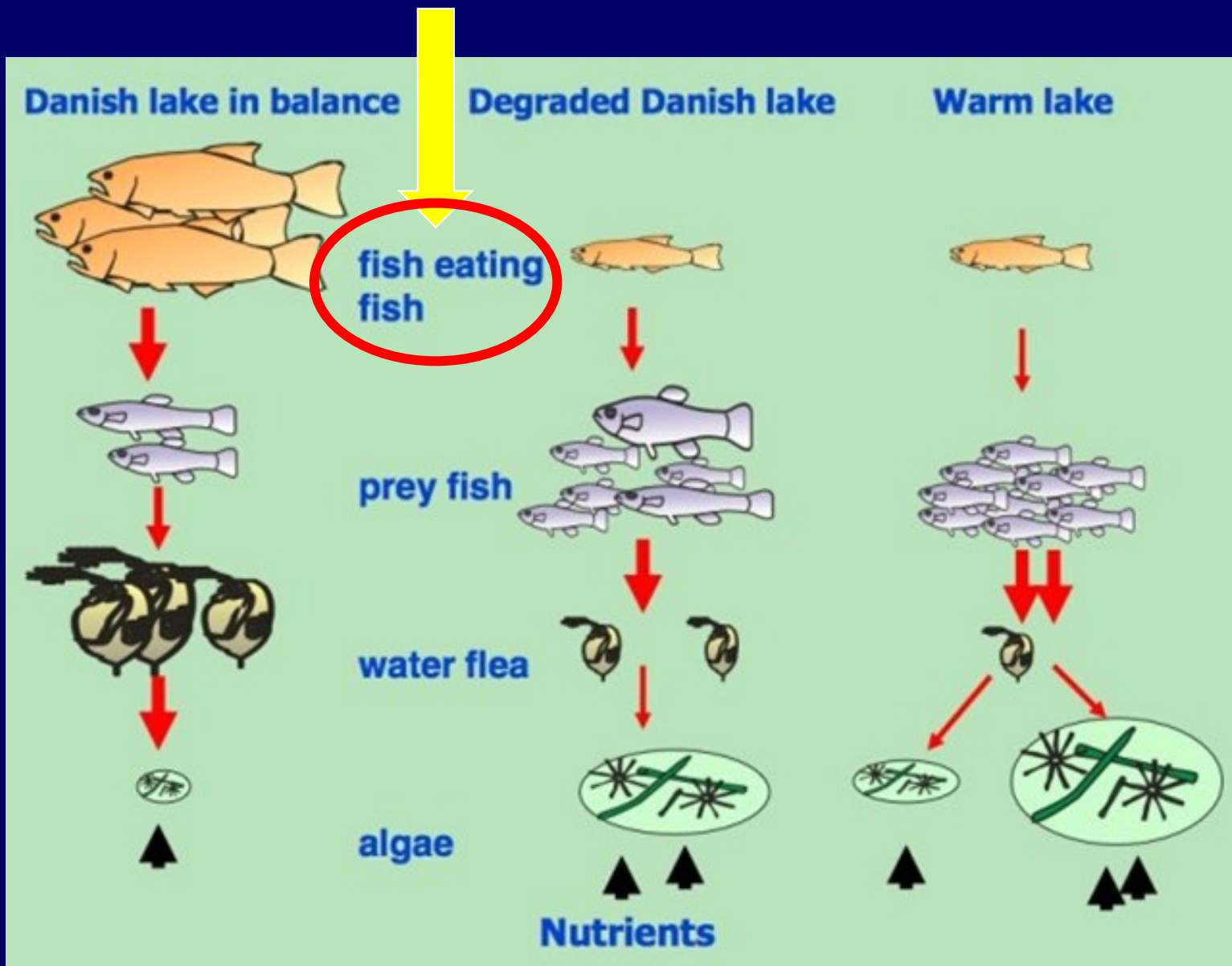


- Aeration towers

**Mechanical mixing,
deep water oxidation**



- Biological control: manipulation of food chains



- Mechanical collection of water blooms



CONCLUSIONS

- Eutrophication causes complex risks with complicated management

1) Ecological risks

- Loss of diversity ... followed by losses of functioning
- Secondary changes in the environment
 - hydrochemistry (pH, O₂)
 - loss on natural habitats (makrophytes...)
 - new conditions (associated bacteria - pathogenic ?)
- Susceptibility to catastrophes
- Direct ecotoxicity of individual (known) cyanotoxins seems to be less important

CONCLUSIONS

2) HEALTH RISKS OF CYANOTOXINS

- Lower importance - known toxins (MC) in food chains (*fish*)
- MC in drinking water - higher costs needed for management and control
- Important risk - recreation !

- New and less explored risks
 - new toxins (and their mixtures) - LPS, CYN ...
 - water blooms as „sorbents“ of other toxins (metals, POPs)