

# ***"Do fish adapt to cyanobacterial blooms"***

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## **Summary**

In the past decades, increasing eutrophication has led to frequent outbreaks of cyanobacterial blooms both in freshwater and in marine environments. Toxins produced by cyanobacteria threaten not only aquatic animals, including fish in which they may accumulate, but also people who may be exposed to cyanotoxins by consumption of contaminated fish. Shallow lowland dam reservoirs are particularly vulnerable to eutrophication followed by harmful algal blooms, it is why we choose as a study place the Sulejowski Reservoir, in which blooms occur regularly during summer time. Measurements were conducted during summer seasons of 2013-2015. Project aimed at assessing the fish spatial distribution in relation to cyanobacterial bloom occurrence and its toxicity. We hypothesize that fish can actively escape from the areas covered by blue-green algae blooms, and in this way avoid or substantially limit their intoxication. Both fish and cyanobacteria spatial distributions were measured with hydroacoustics, a non invasive method, which is safe for the environment and provides high resolution spatial data at a high speed. The main aim of the project has been fully reached and confirmed our hypothesis that fish can escape from cyanobacterial bloom. The echograms of the "bloom border" have shown in a spectacular way, that fish crowded in a clean water just at the border, while very few fish were found within the bloom. Estimated acoustically fish and cyanobacterial biomass were showing opposite trends with less fish encountered as intensity of bloom was increasing. There was a clear mismatch in spacial distribution of the maxima of fish and cyanobacterial biomass. Mean fish density for the investigated area was nearly three times lower in 2013 and 2015 (230 and 188 fish ha<sup>-1</sup> accordingly), when cyanobacterial blooms were present, than in 2014 (623 fish ha<sup>-1</sup>) when the bloom was absent. This difference could be caused by the migration of some fish into the upper part of the reservoir (not covered by our measurements due to too shallow depths), where as a result of dominating wind directions blooms usually are not observed and environmental conditions are much better. The highest biomass of cyanobacteria including toxic genotypes was recorded in 2015, while the lowest in 2014. Microbiological analyses confirmed that in years 2013-2015 intracellular toxins were present, but no toxins were detected in water. Also no microcistins were discovered in the tissue of dominating fish species, roach and bream, neither in muscles no in such sensitive organs like liver and kidney. This means that either fish were able effectively avoid the intoxication by cyanobacterial bloom, or toxin concentrations were too low to be detected with the methods applied (HPLC with diode array detection). It has been shown for the first time in this project that cyanobacteria can be measured by the scientific echosounder simultaneously with fish (until now they were removed as unwanted noise), which in the future should allow better understanding of the relationships between fish and cyanobacteria. Additionally results of the project suggest that ultrasound can have some negative effects on cyanobacteria (we have observed diminishing area covered by the bloom in consecutive days of measurements, reason for which at present is unknown and ultrasound is one of the hypotheses). There are some reports about the destructive effects of ultrasound on cyanobacteria, but proved only in laboratory conditions (Wu et al. 2011). Confirmation that it works also in natural ecosystems would give the managers an effective tool for cyanobacteria removal. Thus, hydroacoustics could be used not only to monitor presence and development of the cyanobacterial bloom, but also to control/remove it. This issue is very important in the light of existing world problems with eutrophication and expected negative changes due to global warming.

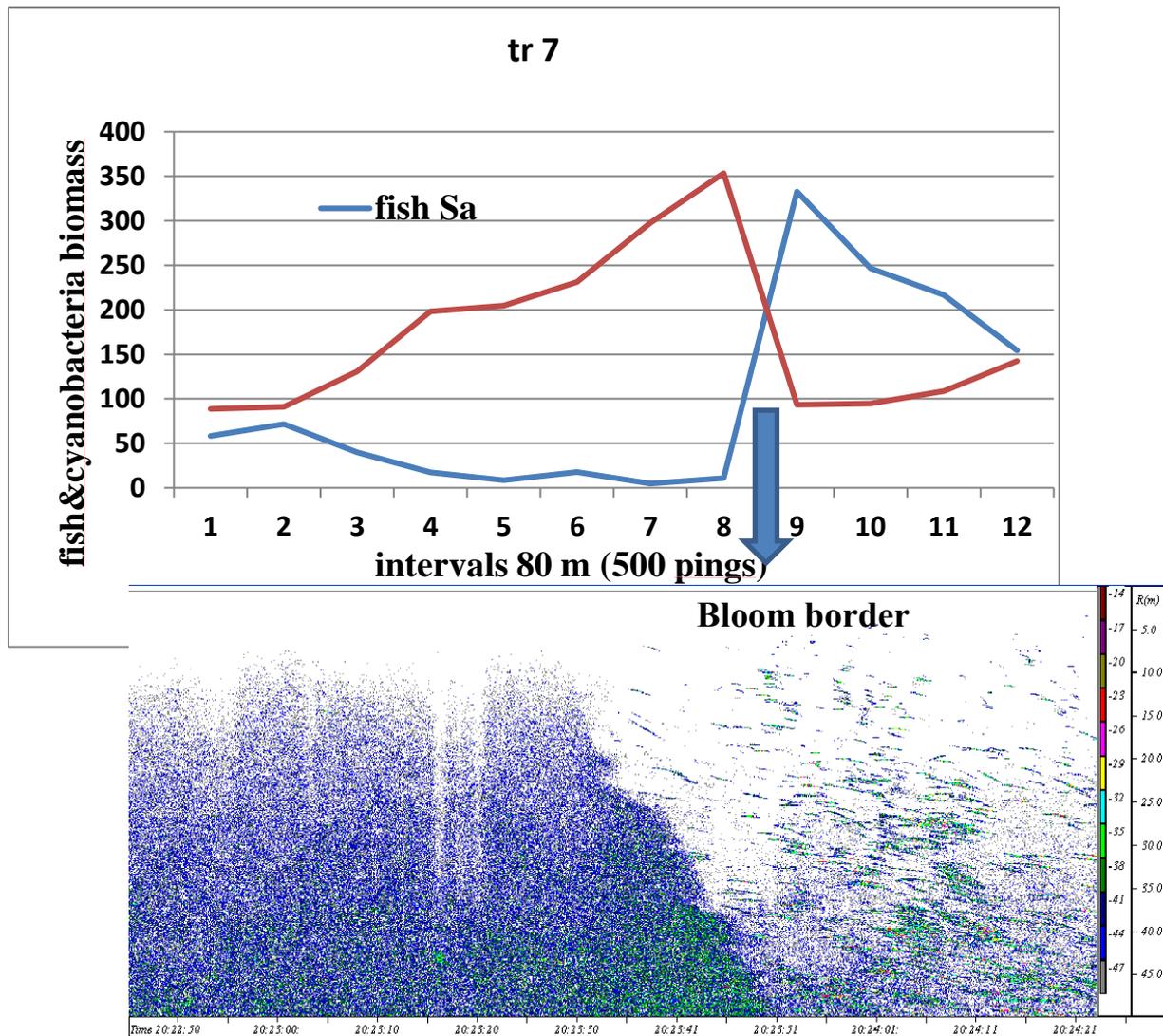


Fig. 1. Fish and cyanobacterial biomass expressed in acoustic units as coefficient of sound reflection per unit area  $S_a$  [ $\text{m}^2\text{ha}^{-1}$ ] in a function of distance. Arrow shows the bloom border with cyanobacteria on the left and numerous fish tracks on the right.

### Publications

1. Godlewska M., Izydorczyk K., Kaczkowski Z., Jóźwik A., Długoszewski B., Ye S. Lian Y. and Guillard J. 2016. Do fish and blue-green algae blooms coexist in space and time? *Fish. Res.* 173: 93-100, IF 1.903
2. Kaczkowski Z., Wojtal-Frankiewicz A, Gągała I., Mankiewicz-Boczek J., Jaskulska A., Frankiewicz P., Izydorczyk K., Jurczak T., Godlewska M., 2017. Relationships between cyanobacteria, zooplankton and fish in sub-bloom conditions in the Sulejów Reservoir. *Journal of Limnology*, DOI:10.4081/jlimnol.2017.1521, IF 1.178
3. Godlewska M., Balk H., Kaczkowski Z., Jurczak T., Mankiewicz-Boczek J., Fish escape from *Microcystis* bloom – evidence from simultaneous hydroacoustic measurements of fish and cyanobacteria and gillnet catches, *Fish Res.* submitted

## Presentations at the conferences

- **XXXII Congress of the International Society of Limnology (SIL), Budapest, Hungary, 4-9 August 2013**

Oral presentation: Do microcistis bloom affect fish spatial distribution and their migrations? An example of the Sulejów Reservoir, Poland (Małgorzata Godlewska, Katarzyna Izydorczyk, Piotr Frankiewicz, Tomasz Jurczak, and Jakub Wojtalik)

- **The 2nd International Conference and Exhibition on Underwater Acoustics (UA2014), 22-27 June 2014, Rhodes, Greece**

Referat zaproszony: Do fish and blue algae blooms coexist in space? (Małgorzata Godlewska, Katarzyna Izydorczyk, ShaowenYe, Bronisław Długoszewski, Marta Cendrowska)

- **Ecology of Fish in Lakes and Reservoirs EcoFiL 2014, 8-11 September 2014 Ceske Budejovice, Czech Republic**

Oral presentation: Do fish and blue-green algae blooms coexist in space and time? (Małgorzata Godlewska, Katarzyna Izydorczyk, Bronisław Długoszewski, ShaowenYe and Yuxi Lian)

- **8-th ShallowLakes Conference, 12-17 Oct. 2014, Antalya, Turkey**

Oral presentation: Dynamics of cyanobacterial bloom, zooplankton and fish biomass and spatial distributions in shallow Sulejów Reservoir, Poland (Małgorzata Godlewska, Joanna Mankiewicz-Boczek, Ilona Gągała, Katarzyna Izydorczyk, Adrianna Wojtal-Frankiewicz, Zbigniew Kaczkowski, Tomasz Jurczak, Bronisław Długoszewski, Aleksandra Jaskulska and Sebastian Ratajski)

- **10<sup>th</sup> Symposium on Cladocera, 28 September – 3 October 2014, Lednice, Czech Republic**

Poster with presentation: Response of antioxidant systems of *Daphnia* under spatial differences of toxic cyanobacteria concentrations in the eutrophic reservoir (Wojtal-Frankiewicz A., Bernasińska J., Gwoździński K., Frankiewicz P., Jurczak T., Godlewska M.)

- **XXXIII Int. Conference of the Polish Phycological Society, 19-22.05.14, Gdynia – Cetniewo, Poland.**

Oral presentation: Toxic cyanobacteria in the Sulejow Reservoir – the occurrence and threat (Gągała I., Pawełczyk, J., Jurczak, T., Jaskulska, A., Izydorczyk, K., Jaros, D., Karwaciak, I., Kokociński, M., Godlewska, M., Pułaski, Ł., Dziadek, J., Mankiewicz-Boczek, J.) ISBN 978-83-7865-222-9.