Ecophysiology, Phylogeography and Environmental Sociology on Water Blooms of the Globally Distributed Cyanobacterium *Microcystis aeruginosa*

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Abstract. In the present report, we would like to introduce the project "Ecophysiology, Phylogeography and Environmental Sociology on Water Blooms of the Globally Distributed Cyanobacterium *Microcystis aeruginosa*", together with some additional/subsequent project on *Microcystis*. Blooms of cyanobacteria are notorious symptoms of eutrophication in freshwaters all over the world, deteriorating water quality as well as the health of human and natural resources. The genus *Microcystis* is the most frequently found cyanobacterial bloom. The present project has been elucidated the following issues on *Microcystis aeruginosa* blooms in eutrophic lakes: dispersal of *M. aeruginosa* into various lakes, ecology and phylogeography of particular genotypes of *M. aeruginosa*, and the relationship between human activity and *Microcystis* bloom.

Key Words: *Microcystis aeruginosa* blooms, Ecology, Phylogeography, Genetic diversity, Environmental sociology

1. INTRODUCTION

Blooms of cyanobacteria are notorious symptoms of eutrophication in freshwaters all over the world, deteriorating water quality , as well as the health of human and natural resources. The genus Microcystis is the most frequently found cyanobacterial bloom. We already have numerous reports on the physiological and ecological characteristics of Microcystis, and their bloom-forming mechanisms have been clarified. However, the following items still have not yet been fully understood: dispersal, phylogenetic distribution, physico-chemical environments favorable for growth, and genotype succession of Microcystis species.

2. RESULTS AND DISCUSSIONS

Cyanobacteria in lakes: dispersal and phylogenetic distribution

We examined survival of *Microcystis* in the digestive tract of mallard duck (*Anas platyrhynchos*). We kept mallard ducks in cages for some months, forced those ducks to drink a *Microcystis* liquid culture and followed temporal changes in living *Microcystis* cells in the ducks' fecal pellets. About 10% of living *Microcystis* cells were excreted in those pellets after four hours of the ducks' ingestion, having growth ability.

Assuming the flight speed of the duck as 65 to 80 km h^{-1}, four hours would be enough for ducks to fly 300 km which roughly accounts for the distance between Korean Peninsula and Japanese Kyushu Island.

We identified the genotypes of 221 *M. aeruginosa* strains of Japanese lakes and Southeast Asian lakes, using a multilocus sequence typing (MLST) (Tanabe and Watanabe 2011, Nguyen et al. 2012). We found 124 new MLST genotypes out of 155 (Tanabe and Watanabe 2011, Nguyen et al. 2012). Population, genetic, and phylogenetic analyses showed negligible differences among the genotypes, suggesting the transport of *M. aeruginosa* among those countries (Tanabe and Watanabe 2011, Nguyen et al. 2012). A specific strain belonging to a panmictic cluster was found only in Lake Kasumigaura of 2009 (Tanabe and Watanabe 2011). We also found a halotolerance strain of *M. aeruginosa* in brackish Lake Shinji (Ohbayashi et al. 2013). Using 16s-23s rDNA ITS region, high genotypic diversity of *M. aeruginosa* collected in Western Japan was also found without geographical differentiation (Ohbayashi et al. 201).

Anatoxin-a-producing *Cuspidothrix issatschenkoi* strains were misidentified as *Raphidiopsis mediterranea* var. *grandis*. So, we have developed specific primers and a probe for quantitative PCR of anatoxin-a-producing *C. issatschenkoi*, and applied them to water samples collected from Japanese lakes (Hodoki et al. 2012 and 2013). We detected anatoxin-a-producing *C. issatschenkoi* strains in some Japanese lakes, and this was the first report in Asia (Hodoki et al. 2012 and 2013).

Microcystis ecology: growth and grazing

In outdoor mesocosms, we successfully had artificial *M. aeruginosa* blooms with diverse, ephemeral dominant genotypes. We conducted experiments to see the effects of nutrients on growth of *M. aeruginosa* strains in the systems with various nitrogen:phosphorus ratios. The results suggested that high N:P ratio of nutrient supply is favorable to *Microcystis* growth. In laboratory experiments, we also examined *Microcystis* growth rates under various nitrogen availabilities, and found high nitrogen requirement by *Microcystis*.

In ourdoor mesocosms, we found the flagellate *Collodictyon triciliatum* as grazers of *Microcystis* during its bloom (Kobayashi et al. 2013). The flagellate had grazing impact on *M. aeruginosa* as up to 25% standing stock day^{-1}, suggesting the high potential of protistan grazing on *Microcystis* blooms (Kobayashi et al. 2013).

Cyanobacterial blooms and humans

Further, in the mesocosms,we developed the method which predicts massive growth of cyanobacteria, using autofluorescence with or without DCMU (3’-(3,4-dichlorophenyl)-1’, 1’-dimethyl urea) (Hodoki et al. 2011). This method has been examined its application to cyanobacterial blooms in the dam reservoirs which managed by the Ministry of Land, Infrastructure, Transport and Tourism. In the future, we have the possibility of “cyanobacterial bloom forecasts” or “*Microcystis* forecasts” for dam reservoirs.

Risk control on cyanobacterial blooms has been well organized in Australia (Figure 1). In Japan, the information about cyanobacterial blooms has been collected by researchers and local/national governments (Figure 1). However, the information is not shared with other stakeholders such as ordinary people, NGO, NPO and industries (Figure 1). Unfortunately, the information about cyanobacterial blooms is still limited in many developing countries (Figure 1), and ordinary people in these countries directly drink “cyanobacterial soup” from lakes with blooms (Figure 2 and 3). To supply safe water for those people, we first have to provide information about how cyanobacterial blooms are harmful, together with necessary financial and technology support.

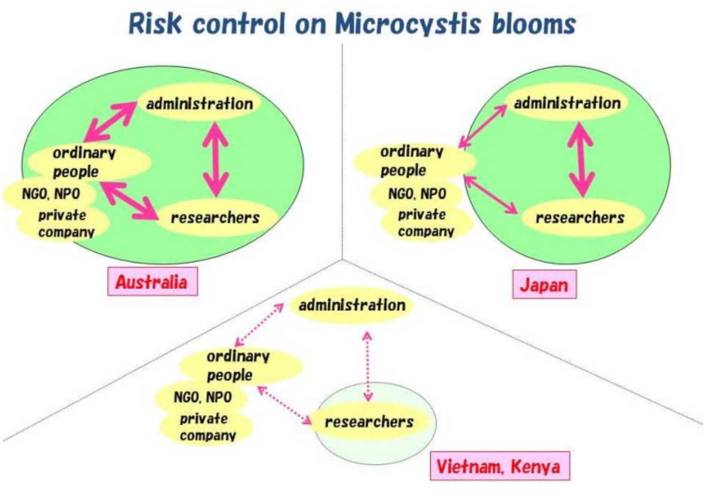

Figure 1: Risk control on Microcystis blooms in some countries.

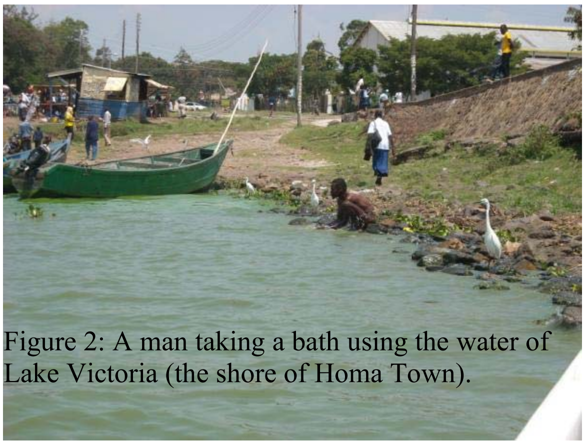

Figure 2: A man taking a bath using the water of Lake Victoria (the shore of Homa Town).

Figure 3: The “cyanobacterial soup” in Lake Victoria (the shore of Homa Town).

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