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Limnobotics:
Understanding blooms of toxic freshwater cyanobacteria using an autonomous sampling platform and molecular strain typing

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Recurrent blooms of the microcystin-producing cyanobacterium *Planktothrix rubescens* (Fig. 1) are observed in Lake Zürich, where its recent proliferation (Fig. 3) seemed to be favored by changes in lake-wide hydrodynamic processes under global warming forcing[1].

Basic seasonal patterns of *P. rubescens* are known, but the basin-wide horizontal variability over the entire annual cycle is poorly understood.

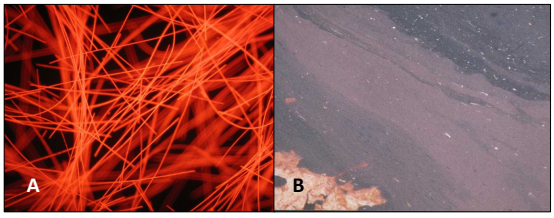

Fig. 1. A) Filaments and B) surface accumulation of *P. rubescens*

Automated sensing technologies are developing into an important tool for aquatic microbial ecology research, but few studies have applied them to limnology for long-term and basin-wide observational research[2].

We built an Autonomous Surface Vessel (ASV; Fig. 2) that is equipped with a variety of sensors, i.e., temperature, pH, light, oxygen, nutrients, and algal pigments (chlorophyll *a* and phycoerythrin).

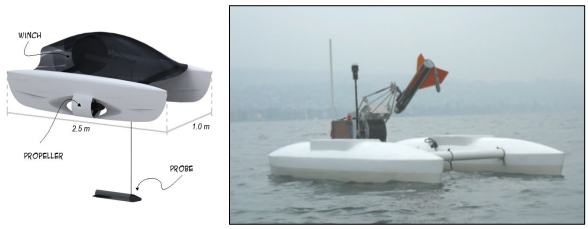

Fig. 2. Our Autonomous Surface Vessel to investigate Lake Zürich

Our project brings together limnology and robotics for the autonomous acquisition of limnological parameters. This would allow for an unprecedented spatial and temporal data resolution for a better understanding of the population dynamics of *P. rubescens* in Lake Zürich.

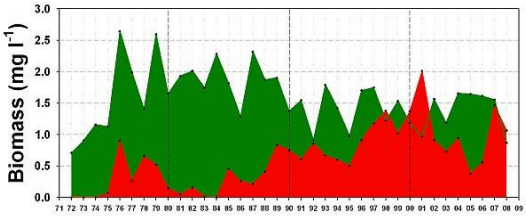

Fig. 3. Mean annual biomass of total phytoplankton (green) and *P. rubescens* (red) in the upper 20 m in Lake Zürich from 1973 to 2008[3]

Molecular approaches based on the microcystin (mcy) gene cluster (Fig. 4) will be combined to our large-scale sampling to address the co-existence and successions of mcy producing and non-producing strains of *P. rubescens* and their relationship with particular parameters or seasonal events. Specifically, we will:

1. Determine mcy-producing phenotypes at the level of single filaments using an enzyme-linked immunosorbent assay (ELISA).
2. Characterize mcy genotypes by single-cell approaches.
3. Use quantitative real-time polymerase chain reaction (qPCR) to quantify non-producing mcy strains and estimate their share of the total population.
4. Investigate the influence of environmental factors on mcy production and the proportions of mcy and non-mcy strains with *P. rubescens* cultures (Fig. 5).

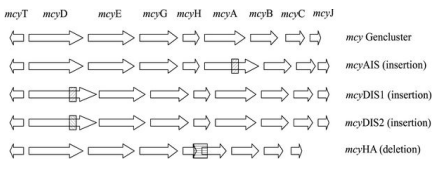

Fig. 4. Microcystin synthase gene cluster of *Planktothrix* and mutations resulting in the inactivation of the gene[4]

Fig. 5. *P. rubescens* culture

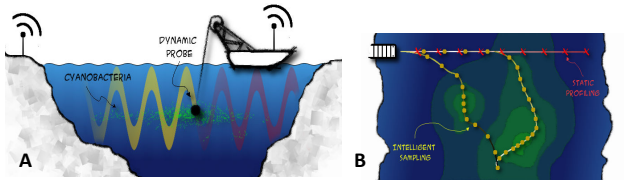

Fig. 6. A) Current profiling strategy and B) projected intelligent profiling

Our ASV allows for a high-frequency monitoring of cyanobacterial spatiotemporal distribution (Fig. 6) together with a comprehensive overview of environmental changes within the lake (Fig 7).

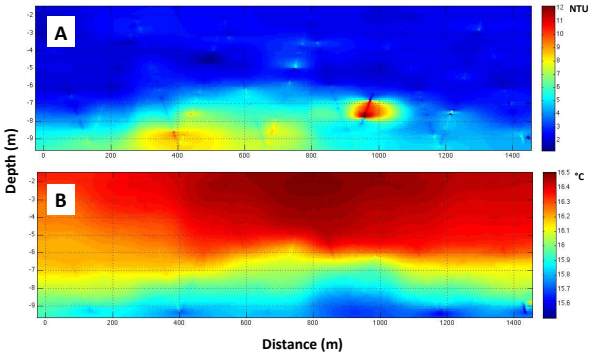

Fig. 7. A) Turbidity and B) temperature over a distance of 1.5 km in Lake Zürich

Ultimately, our ASV will provide an exhaustive collection of field data to identify environmental parameters that control blooms of mcy-producing strains of *P. rubescens* in order to develop a regional predictive model for Lake Zürich and other similar pre-alpine Swiss lakes.

References
1. Peeters et al. 2002 Limnol Oceanogr 47:186-
2. Caron et al. 2008 Limnol Oceanogr 53:2333-
3. Posch, unpublished
4. Ostermaier & Kurmayer 2009 Microb Ecol 58:1-

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