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Nitrogen Fixation in two eutrophic polymictic lakes

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Aim of the study

The ability to fix molecular nitrogen is considered to be a competitive advantage of Nostocales cyanobacteria to overcome periods of nitrogen shortage. There is some concern that they are able to compensate the efforts of reducing anthropogenic nitrogen input.
We quantified cyanobacterial N_2-fixation over 3 years in 2 lakes and studied its possible limitation by light and nutrients.

Methods

Nitrogen fixation was measured fortnightly by acetylene reduction assay (ARA, 2012) or ^{15}N stable isotope technique (2013, 2014) in two eutrophic and polymictic lakes in the lowlands of Northern Germany (details see fig. 1). Lake water samples were incubated at *in-situ* temperature under controlled light conditions in a climate chamber.

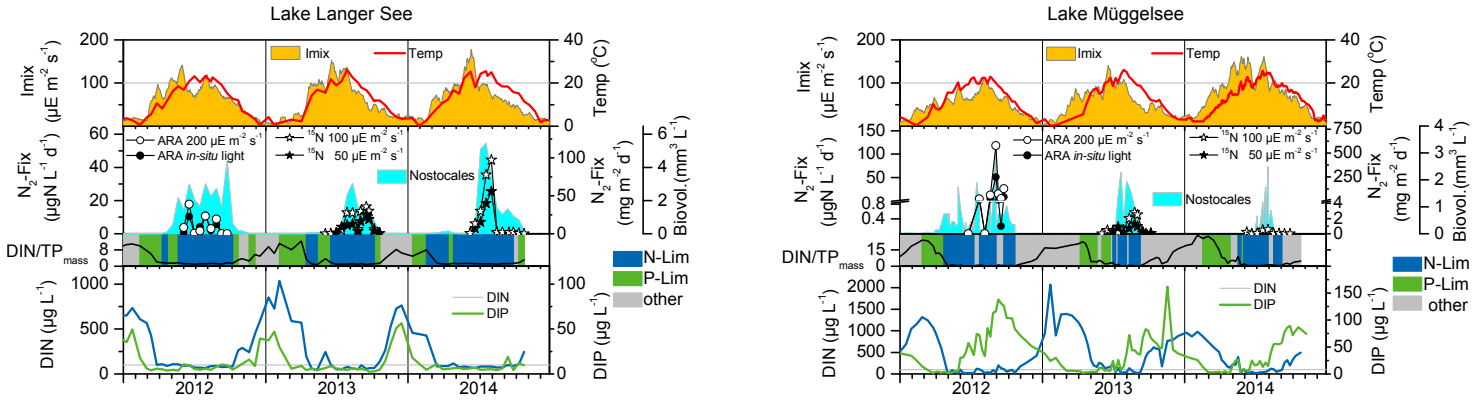

Fig. 1: Light in the mixed water column (Imix), water temperature (Temp), biovolume of Nostocales (cyanobacteria) and N_2-Fixation at different light intensities measured by acetylene reduction assay (ARA) or stable isotopes (^{15}N), concentrations of dissolved inorganic N (DIN) and P (DIP), limitation status of phytoplankton in Lake Langer See (left) and Lake Müggelsee (right) 2012 - 2014.

Limitation status of phytoplankton was derived from DIN <>100 µg L^{-1}, DIP <>10 µg L^{-1} and DIN/total phosphorus (TP) <>2.2 (Kolzau et al. 2014; PLoS ONE 9(4): e96065. doi:10.1371/journal.pone.0096065) .

Characteristics	Lake	Z_{mean} (m)	Area (km²)	Total P (µg L^{-1})	Chla (µg L^{-1})
Vegetation mean	Langer See	2.1	1.6	67	62
Apr-Sep.2012-14	Müggelsee	4.8	7.5	92	26

Quantification of Nitrogen Input

We found a high variation in N_2-fixation rates between the two lakes and the years, which could neither be explained by total Nostocales biovolume nor heterocyte numbers.
Although Nostocales were present from April to November N_2-fixation was found only from June/July to September.
Annual N-input by N_2 fixation is in the range of 0.2 – 9.2 g N m^{-2} a^{-1} given by Howart et al. (1988; L&O 33: 669-687) for eutrophic lakes (Tab. 1).

Tab. 1: Annual maxima of N_2 fixation and resulting annual N-input based on fixation rates measured at 100 µmol phot. m^{-2} s^{-1}.

Year	Langer See		Müggelsee	
	Maximum	Annual N-input	Maximum	Annual N-input
	µg N L^{-1} d^{-1}	g N m^{-2} a^{-1}	µg N L^{-1} d^{-1}	g N m^{-2} a^{-1}
2012	17.8	1.4	118.0	8.0
2013	16.3	2.0	0.6	0.1
2014	44.5	3.2	0.4	0.01

Factors controlling Nitrogen fixation

Light

N_2-fixation was light limited throughout the year. Saturation values (I_k) were 130 - 300 µmol phot. m^{-2} s^{-1}, i.e. above light intensities in the mixed water column (Imix mostly <100 µmol phot. m^{-2} s^{-1} (see fig.1).

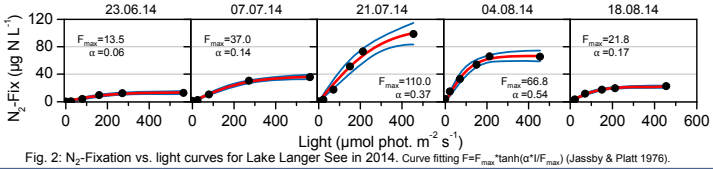

Fig. 2: N_2-Fixation vs. light curves for Lake Langer See in 2014. Curve fitting F=F_{max}*tanh(α*I/F_{max}) (Jassby & Platt 1976).

Nutrients

Nitrogen fixation and growth of Nostocales (mainly *Aphanizomenon* species) was highest during phases of minimum concentrations of dissolved inorganic nitrogen (fig. 1). Both were more pronounced in years with long lasting periods of N-limitation (fig. 1)

For Lake Langer See P-limitation of Nostocales and N_2-Fixation was proved by enrichment experiments in 2012 and 2013 (Kolzau et al. 2014; PLoS ONE 9(4): e96065. doi:10.1371/journal.pone.0096065).
→ **See presentation** of S. Kolzau, Session 095, Thursday 26th 11:15 room D (Floor-3).

Conclusion & Outlook

Substantial N-input by N_2-fixation occurs only sporadically in summer when concentrations of dissolved inorganic N are low. During these periods N_2-fixation can cover the N demand of primary production.
Most of the year N_2-fixation is limited by availability of light and phosphorus.
A mathematical model will be developed to estimate N_2-fixation in dependence of light, N and P availability and temperature.

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