Carbon-limitation in a carbon-rich system: seasonal limitation of benthic denitrification in the coastal northern Baltic Sea

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Background

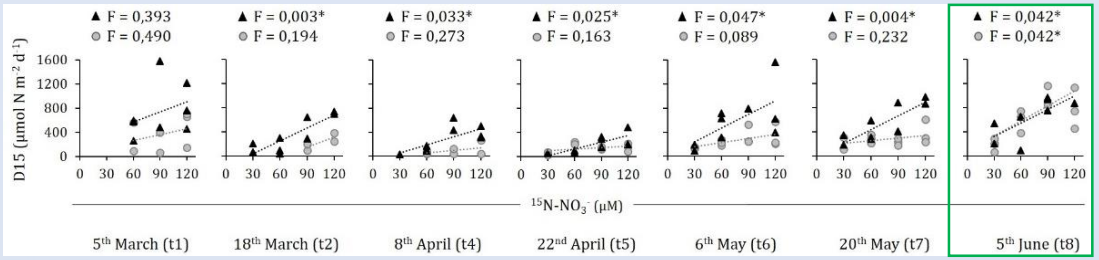
Early spring organic carbon (OC) limitation of benthic denitrification at the northwestern Gulf of Finland has been suggested by Hellemann et al. 2020, Bartl & Hellemann et al. 2019, Jäntti et al. 2011, and Hietanen & Kuparinen 2008, based on **non-significant correlation of D15-denitrification with $^{15}N\text{-}NO_3^-$ tracer when applying the Isotope Pairing Technique** (Nielsen 1992), indicating that (i) the denitrification layer was not NO_3^- limited, thus (ii) denitrifying bacteria were not properly active. We hypothesize, that the available OC in this OC-rich system degrades over winter in such a way that it limits heterotrophic microbial metabolism until fresh OC becomes available again, e.g. via the annual spring bloom.

Approach

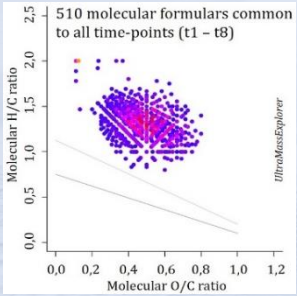
Samples were taken bi-weekly from photic and aphotic sites in the Tvärminne Archipelago pre- to post-spring bloom (March–June 2020) to follow the effect of fresh OC availability on denitrification, measured both 'in situ' and after addition of 1 mM glucose as very labile OC source. Benthic OC-quality was analyzed via natural isotopes, Fourier-transform mass spectrometry (FTMS), and optical measures.

Results & Discussion

Aphotic site (phytoplankton is main source of benthic OC):



D15-denitrification in unamended 'in situ' sediment did not correlate significantly with $^{15}N\text{-}NO_3^-$ tracer until beginning of June, whereas D15-denitrification in glucose-amended sediment correlated significantly with tracer from 18th March onwards ($F \leq 0{,}05$*), **proving OC-limitation of denitrifying bacteria throughout early spring**. The end of limitation in June followed the peak concentration of sediment Chl a on 20th May, suggesting that the bacteria were lacking sufficient availability of high quality OC, which, however, was not visible in CN-ratio (7,6 ± 0,1) or $\delta^{13}C$-POC (-23,2 ± 0,2 ‰).



Currently, the FTMS-derived molecular composition of pore-water dissolved organic matter is used to characterize the benthic OC-quality at each time-point, using the molecular formulars common to all time-points as base for comparison. *Preliminary* results indicate differences in the nominal oxidation state of OC (LaRowe & Van Cappellen 2011), which leads to differences in the energy gain during OC oxidation, affecting heterotrophic microbial metabolism.

Photic sites (phytoplankton and microphytobenthos are sources of benthic OC):
Denitrifying bacteria were not limited by labile OC.

Conclusion

Denitrification in coastal sediments that receive OC mainly from phytoplankton was OC-limited in early spring before the input of fresh spring bloom matter, likely due to molecular-level degradation of OC-quality over the winter.

Denitrification in coastal sediments that receive OC from both phytoplankton and microphytobenthos was not OC-limited in early spring, likely due to a more constant fresh OC supply from microphytobenthos.

Microbial bioavailability of OC cannot necessarily be derived from traditional measures of OC-quality, such as natural isotopes or CN-ratios.

The shown seasonally limited denitrification activity in a substantial part of coastal sediments needs to be taken into account when calculating annual budgets of nitrogen-turnover in the northern Baltic Sea.

All results shown are still unpublished.

Acknowledgement

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