Benthic nitrogen processes and ecosystem functioning along environmental gradients in the Arctic marine system

(A Spitsbergen Fjord)

PhD Student : Politi Tobia

Klaipeda University ; Marine Research Institute

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Tobia Politi *[1], Mindaugas Zilius [1], Marco Bartoli [1,2], Sergej Olenin [1]

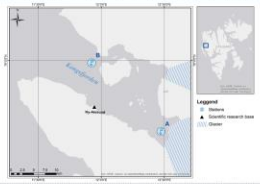
[1]Marine Research Institute, Klaipeda University, 92294 Klaipeda, Lithuania
[2]Department of Chemistry, Life science and Environmental Sustainability, Parma University, 43124 Parma, Italy

Introduction and Main Aim

- Benthic biogeochemistry, organic matter mineralization and the interactions between macrofauna and microbial communities along environmental gradients are poorly studied in arctic sediments. These issues are relevant due to ongoing global changes, in order to understand whether and in which direction they will affect benthic communities and processes.
- In this study we analyzed benthic processes, including oxygen and nitrate-based respiration and ammonium regeneration in bioturbated arctic sediments along an organic/disturbance gradient generated by a tidal glacier. Benthic fluxes where interpreted on the basis of the sedimentary organic content and of the galcies disturbance on the macrofauna community.

Study site

- Kongsfjorden (79N and 12E) is located on the northwest part of Spitsbergen Island in the Svalbard archipelago.
- It receives warm and cold water inflows from the Atlantic and Arctic currents, respectively as well as freshwater inflow from four tidal glaciers.
- Massive diatom bloom during the spring results in large inputs of labile organic matter to the seafloor.
- Two sites were contrasted: *Station A*, located 1.4 km from head of the fjord, is directly influenced by the glacier. *Station B*, close to the fjord mouth, is affected by the Atlantic Ocean.



Preliminary results

Bottom water physic-chemical conditions (mean ± st.err.; n=8)

Station	Dept (m)	Bottom water Salinity	Bottom water temp. (° C)	O_2 (µM)	NH_4^+ (µM)	NO_3^- (µM)	CH_4 (µM)
A	80	34	5.3 ± 0.7	379.5 ± 56	3.8 ± 0.1	1.19 ± 0.07	2.03 ± 0.43
B	75	37	6.6 ± 0.8	382.9 ± 77	2.4 ± 0.1	0.94 ± 0.04	4.19 ± 0.51

Sediment properties (0-5 cm ;mean ± st.err.; n=4)

Station	Organic matter (%)	C:N	Pelite fraction 63 < µm (%)
A	10.5 ± 0.9	8.59 ± –	90.59
B	6.5 ± 1.5	7.51 ± –	95.16

Macrofauna community (mean ± st.err.; n=8)

Station	Diversity (Species station^{-1})	Abbundance (Ind. m^{-2})	Total Biomas (g m^{-2})	Sediment dwelling, Bioturbators (%)	Others Func. groups (%)
A	9 ± 0.5	5525 ± 611	192 ± 53	61	39
B	12 ± 0.8	3225 ± 523	28 ± 11	73	27

- Opportunistic and fast growing species were found at *Station A*, in proximity of the glaciers.
- *Station B* is characterized by a more diversified macrofauna community , mainly composed by long life cycle burrowers species.

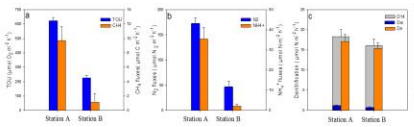
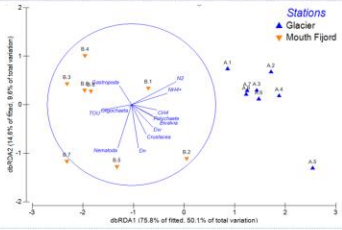


Figure 1. Fluxes of dissolved O_2 (TOU), CH_4 and N_2 and NH_4^+ measured across the sediment–water interface; Total denitrification rates (D14) and Denitrification coupled with nitrification (Dn) and denitrification of NO_3^- coming from the overlying water (Dw). (n= 8 ; average ± st. er.).

- Higher organic inputs, sedimentary pools and macrofauna abundance resulted in higher rates of aerobic and anaerobic metabolisms and ammonium regeneration at *Station A* (Fig.1 a , b).
- Denitrification rates calculated via the IPT and the N_2 fluxes calculated via N_2:Ar method suggest differences between stations (*A>B*), but rates are in disagreements (higher with the N_2:Ar) (Fig. 1 b , c).

- The *distLM* model explained 66.8% (sum of all canonical eigenvalues) of total variation in NO3– reduction processes (Dn, Dw) and fluxes using 6 groups of macrofauna (Fig. 2).
- Marginal test revealed that only Polychaetes (F=3.9, p=0.022) and Bivalvia (F=5.3, p=0.007) were significant parameters in the model.
- The first two axes were accounted for 89.9% of the tot. explained variance (Fig. 2).



←Figure 2. dbRDA triplot of the relationships between the modelled predictors (macrofauna functional groups) and response variables (Solute fluxes and Nitrogen reductive processes)

Material and Methods

1. In kongsfjorden
In Aug. 2018, sediments and water were collected from board of r/v 'Oceania'

2. Sampling
8 intact cores (i.d. 8 cm, length 30 cm) were randomly collected per station together with bottom water

3. Preincubation
Cores were left submersed overnight, under constant temperature and oxygen level

4a. Incubation I
Start-end, with measurement of benthic metabolism (O_2 , N_2, CH_4) and NH_4 fluxes

4b. Incubation II: r-IPT
$^{15}NO_3^-$ spike targeting Dn and Dw dark rates, annamox and DNRA

5. Macrofauna characterization
Sediment sieving (0.5 mm mesh size) to retrieve and analyze macrofauna

6. Chemical Analyses

7. Flux calculations
$F_x = (C_f - C_i) \times V) / (A \times t)$

8. Statistical Analyses
One-way ANOVA ;
Multivariate analysis (DistLM)

Distance-based linear model was used to quantify and test interactions between the dominant macrofaunal functional groups and specific NO_3^- reduction process and benthic fluxes at the water-sediment interface.

Discussion and Conclusions

- Results align with previous studies on biogeochemical dynamics at arctic sediments (i.e. Rysgaard et al. 2006) and on macrofauna community composition in Kongsfjorden (i.e. Wlodarska-Kowalczuk et al. 2005).
- Organic matter inputs, tidal glacier disturbance on macrofauna community at *Station A* and more stable conditions at *Station B* likely represent the main factors determining differences between the two sites and affecting their benthic functioning.
- Macrofauna community and associated bioturbation explains most of the variability in biogeochemical fluxes.
- Higher organic inputs and less diverse macrofauna community (poorly represented by long living burrowers in *St. A*) result in higher ammonium effluxes (less internal recycling) and lower percentage of denitrification efficiency with respect to NH_4^+ effluxes in *St. A* (33%) as compared to *St. B* (84%).

Acknowledgments

We gratefully thank for: G. Kilmonaite; I. Vybernaite-Lubiene; P. Forni; S. Medelyte; the crew of the Polish research vessel Oceania.

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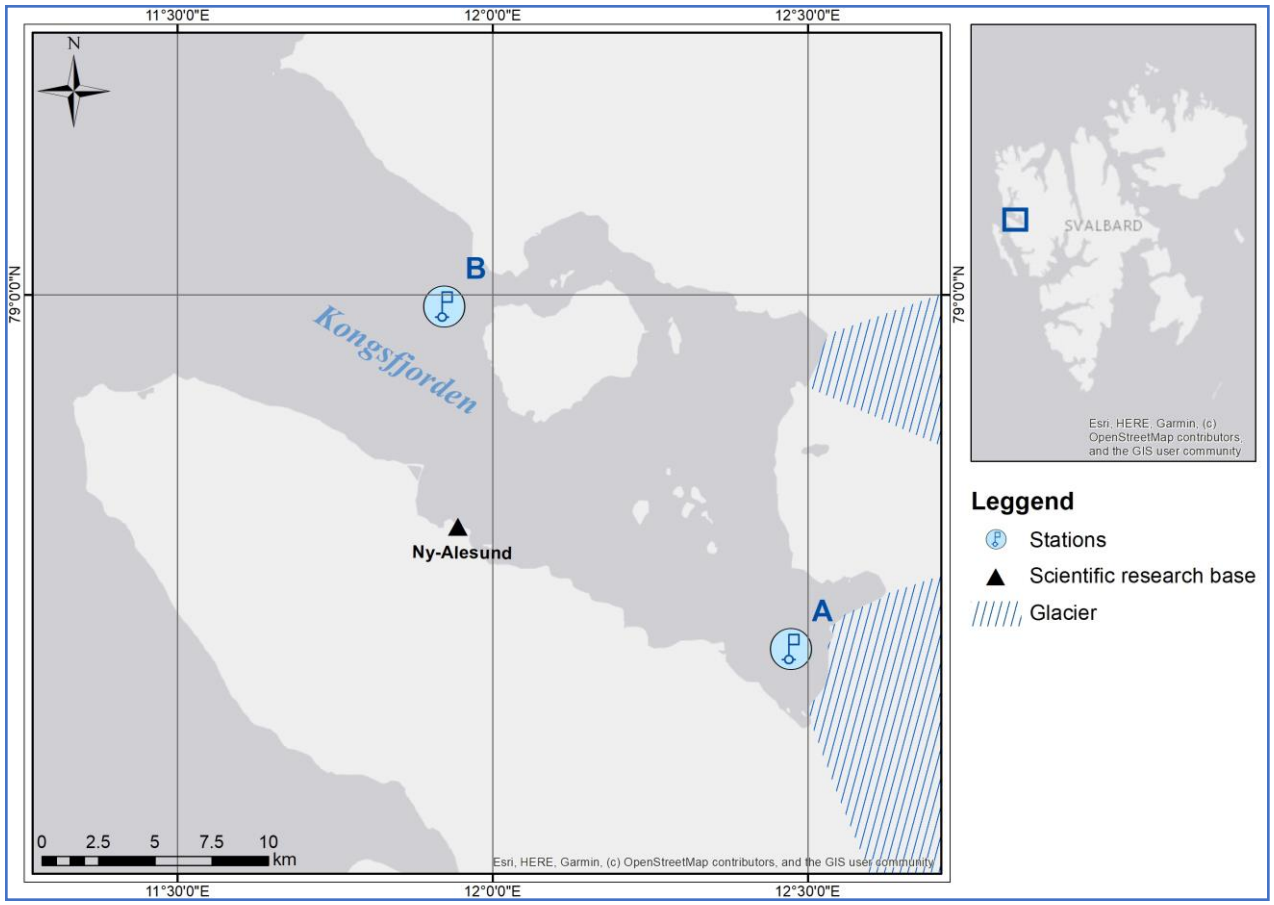
- Benthic fluxes where interpreted on the basis of the sedimentary organic content and of the glacier disturbance on the macrofauna community.

Ph: Kajetan Deja

Study Site and Material & Method



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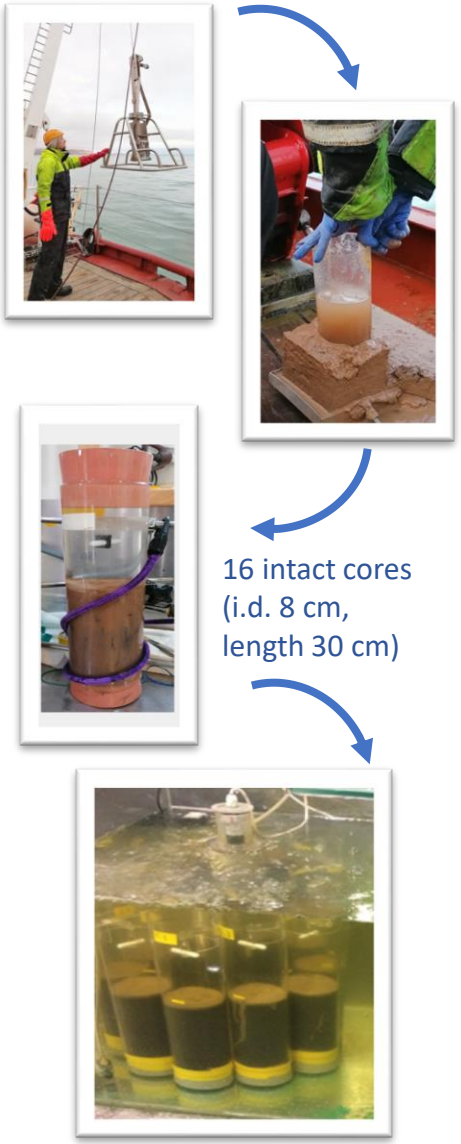
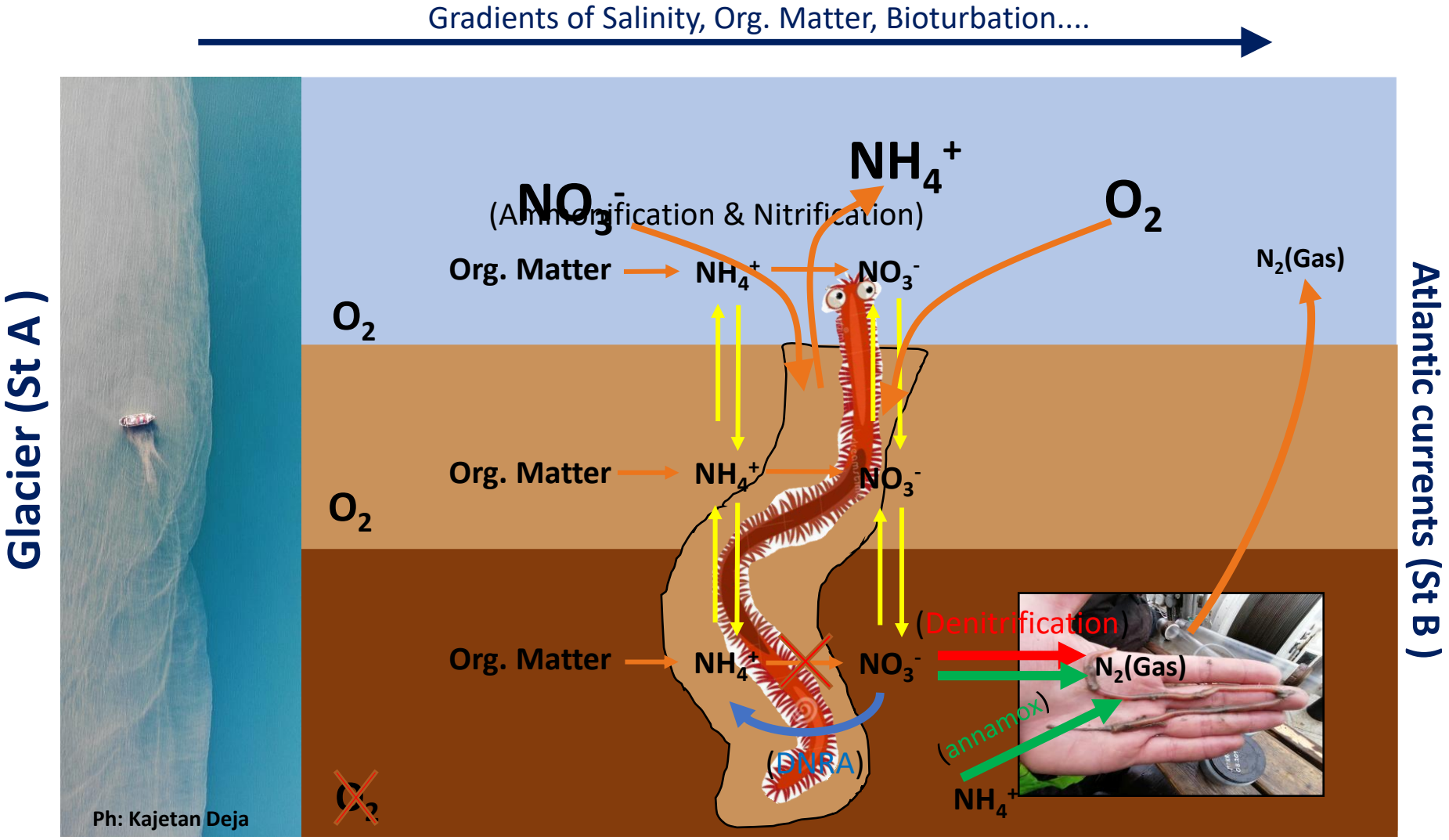


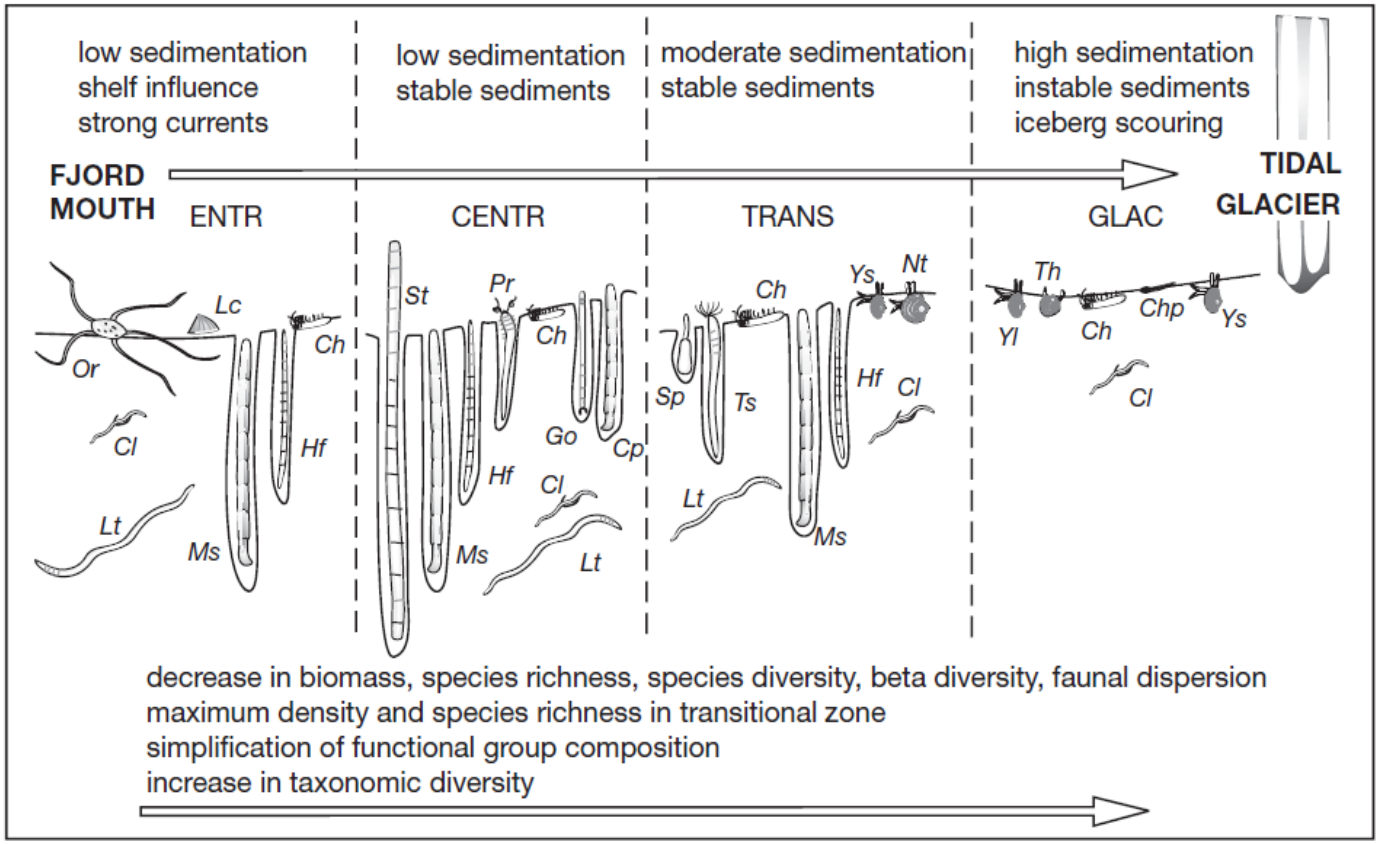
16 intact cores (i.d. 8 cm, length 30 cm)

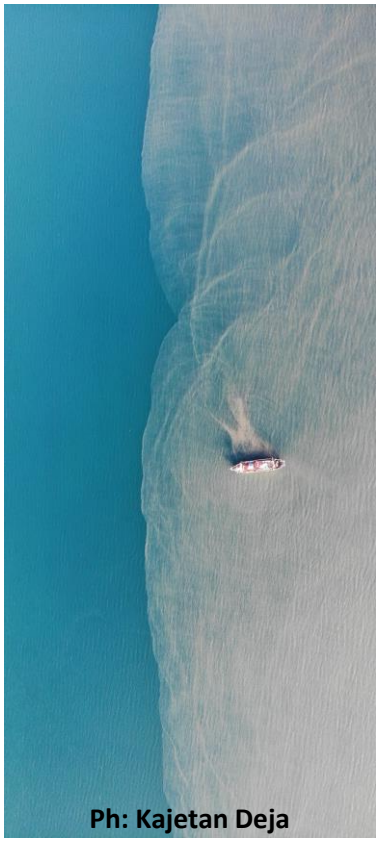
Start-end Dark Incubations:
- Metabolism
- R-IPT

Benthic nitrogen cycle & Bioturbation



Trends in macrobenthic abundance in Kongsfjord





Wlodarska-Kowalczuk et al. 2005

Wlodarska-Kowalczuk, M., Pearson, T. H., & Kendall, M. A. (2005). Benthic response to chronic natural physical disturbance by glacial sedimentation in an Arctic fjord. *Marine Ecology Progress Series*, *303*, 31-41.

Preliminary results 1: Benthic macrofauna

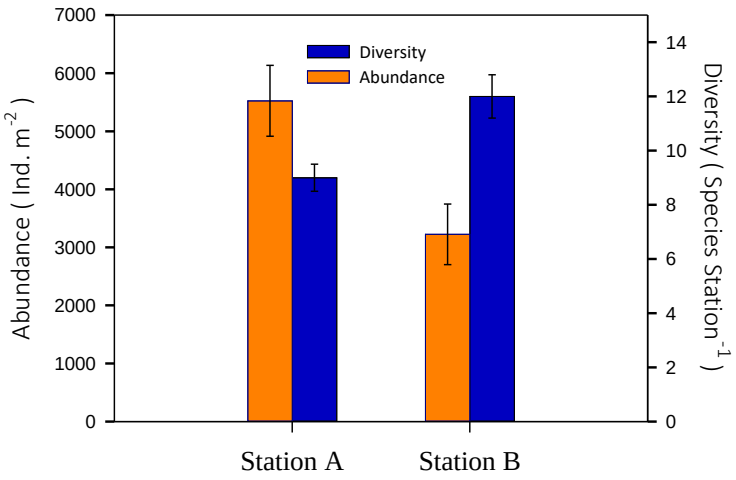


Figure. Taxonomic diversity (number of species per station) and total abundance of benthic macrofauna (ind. m^{-2}) in incubated cores at the 2 study sites (left). (n= 8 ; average ± st. error).

- Polychaetes; Bivalvia ; Nematodes; Crustacean (Crustacea) the most abbundant taxa.
- Polychaetes — 65 %, mollusks—30 % ; Nematoda + Crustacea — 4 %.
- Borrower as polycaetes, nematodes and oligochaetes were found exclusively at Station B.
- Functional group diversity become higher with distance from the glacier.

Macrofauna community (mean ± st.err.; n=8)					
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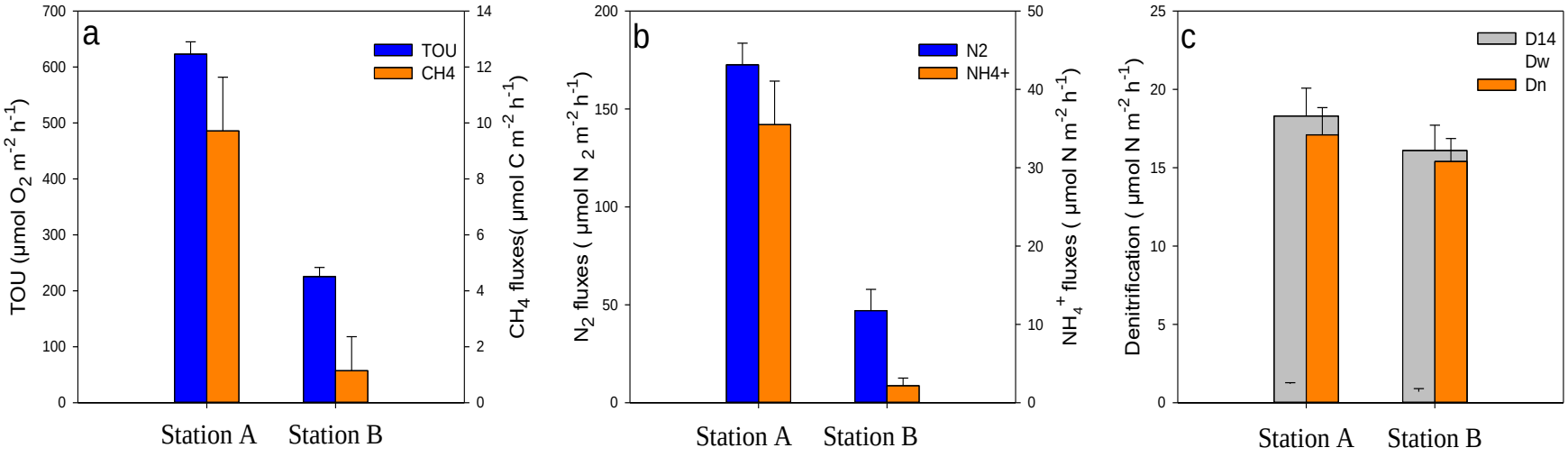
Preliminary results 2: Benthic fluxes



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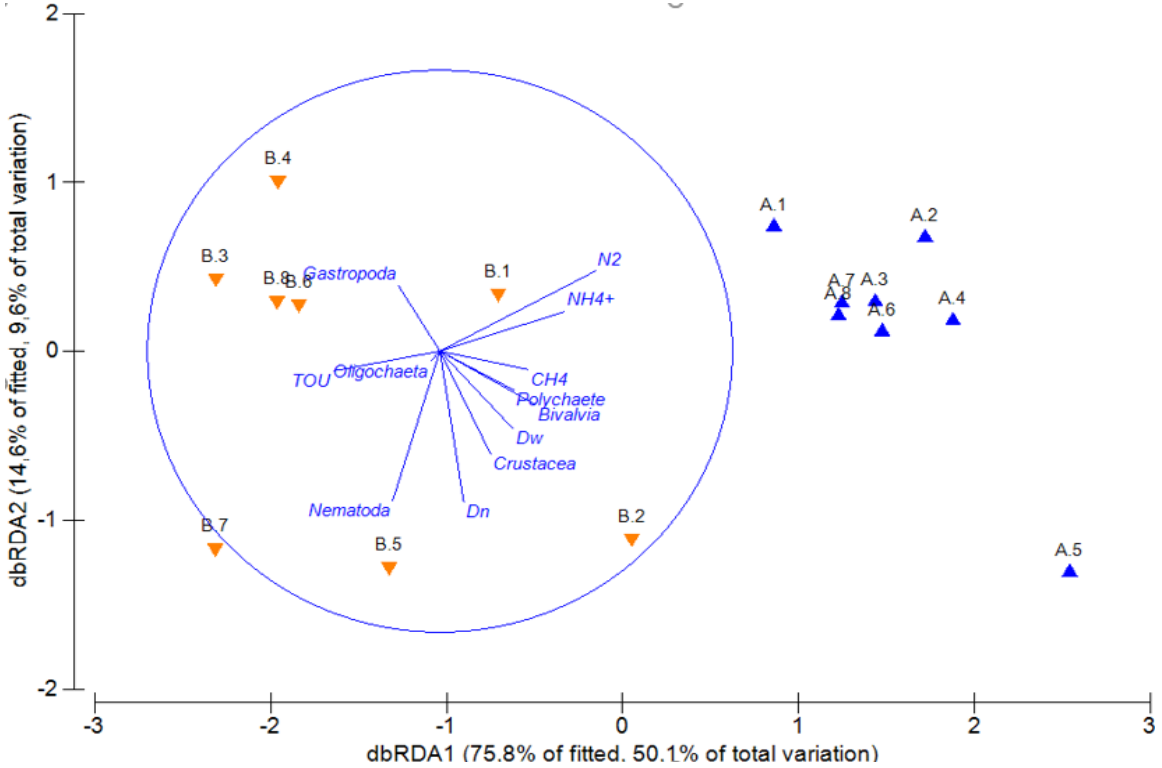
Preliminary results 3: Multivariate analyis



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Thank you!