Vertical structure and horizontal variations in the cycling of methane in the sediment of Lake Onego, Russia

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Introduction and framework

- Multidisciplinary project on ice-covered lake.
- Physical, chemical, biological characteristics of a seasonally ice-covered Great European Lake.
- International team: Russia, Switzerland, France, Germany
- Petrozavodsk Bay, 19km long, 18m average depth
- March 2015 : time coverage, testing light and convection influence
- March 2016 : spatial resolution along the bay, testing influence of allochtonous inputs.

Goals of the microbiology-methane team

- Understand the structure of microbial communities in the sediment & the actors involved in CH_4 production and degradation on a vertical scale, as well as on a horizontal scale
- Estimate the stability of the winter methane cycle over the years
- Assess the contribution of the winter sedimentary microbial communities to CH_4 cycling in lake Onego

Hypothesis

- Deep zone of methane production and shallow aerobic methane oxidation in the sediment
- Weak influence of AOM as poorly documented in lakes
- Influence of the quantity and origin of OM on the CH_4 cycle.
- Limited impact of temperaure and other environmental factors.
- Almost no change from one year to another & limited CH_4 efflux to the lake

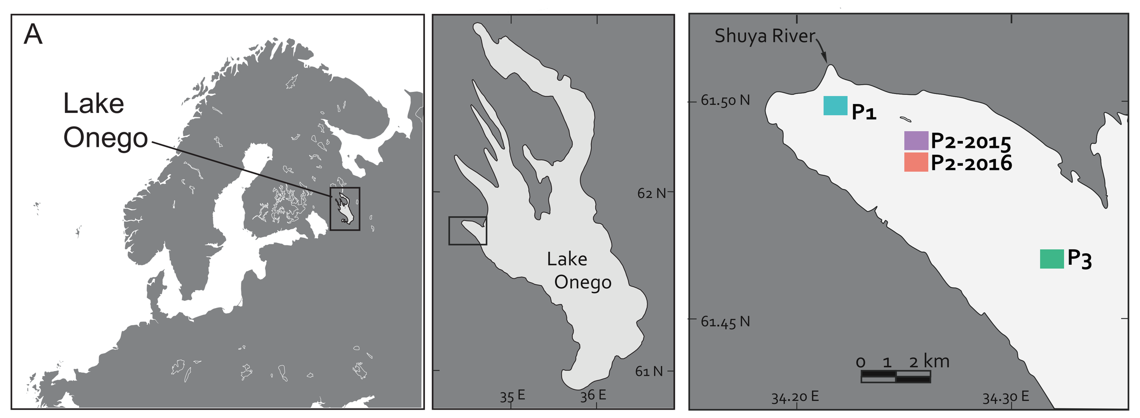
Methods

- Two winter campaigns, one transect from the river to the open lake
- Coring and measurements of sediment parameters (XRF, TOC, S, grainsize)
- CH_4 concentrations and isotopes
- DNA extraction, qPCR of pmoA and mcrA genes
- Incubation for CH_4 prod and degradation
- T-RFLP and sequencing of mcrA gene

Results and conclusions

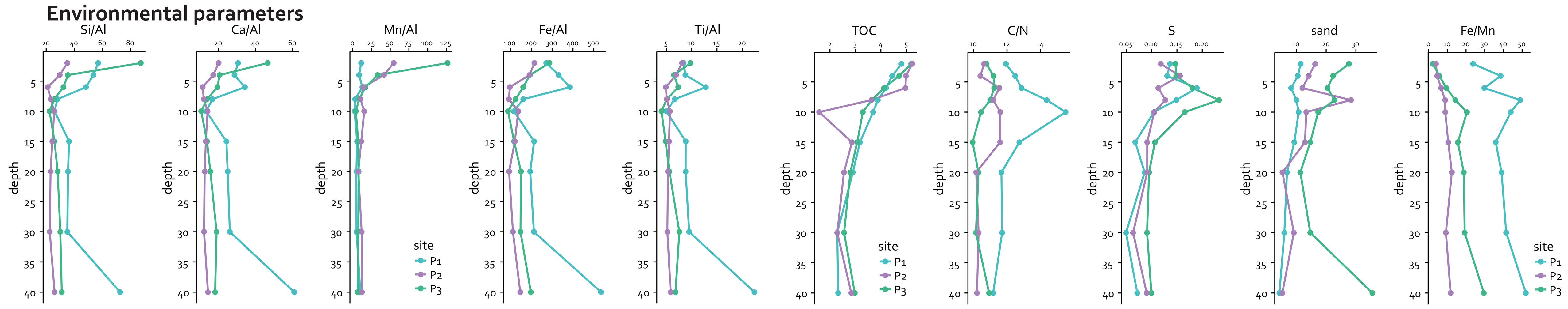
- CH_4 produced below 10 cm. AOM linked to nitrate and nitrite reduction and almost complete CH_4 oxidation in sed.
- Higher CH_4 concentration, production and degradation potential in P1: linked to specific mcrA community ?
- Methanoregula (H_2/CO_2) & Methanosarcina (acetate)
- Horizontal and vertical difference in mcrA communities, structured by redox & sediment and OM inputs
- Difference between 2015 and 2016. Limited CH_4 release

Site overview



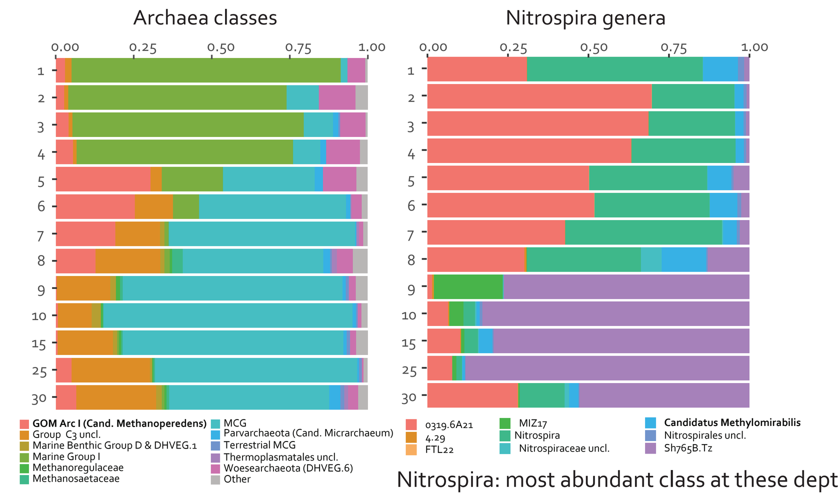
Coring on the ice-covered lake Onego. Site P2 sampled in 2015. P1, P2 and P3 sampled in 2016

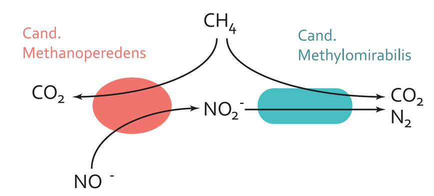
Environmental parameters



Sediment characteristics measured for site P2 from the 2015 cores. Differences are observed for P1 in C/N and Fe/Mn ratios. Variability in the first 10 cm, and overall strong inter-site similarities below 10 cm

Microbial diversity (16S rRNA gene) linked to methane cycle (site P2)

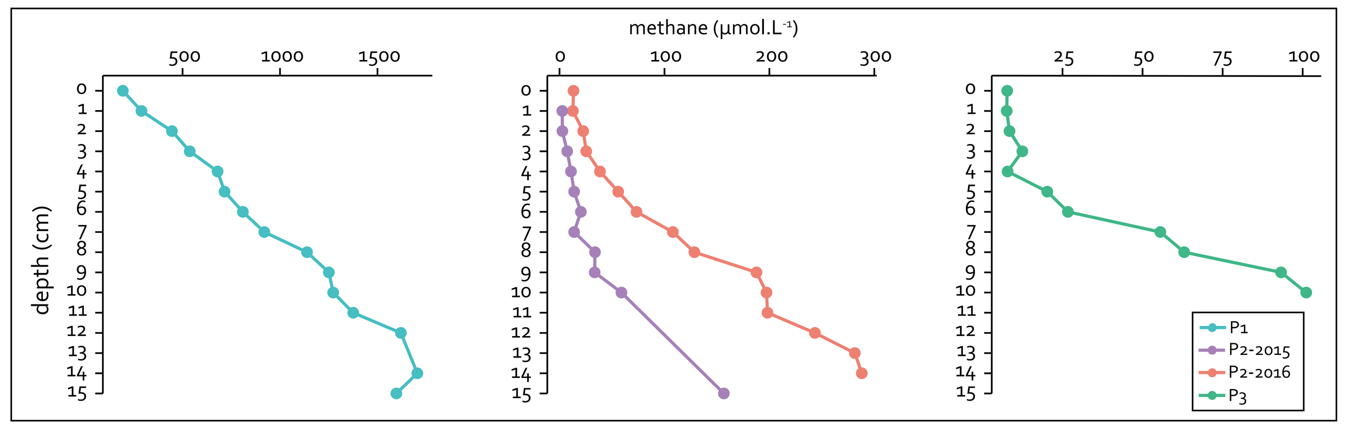


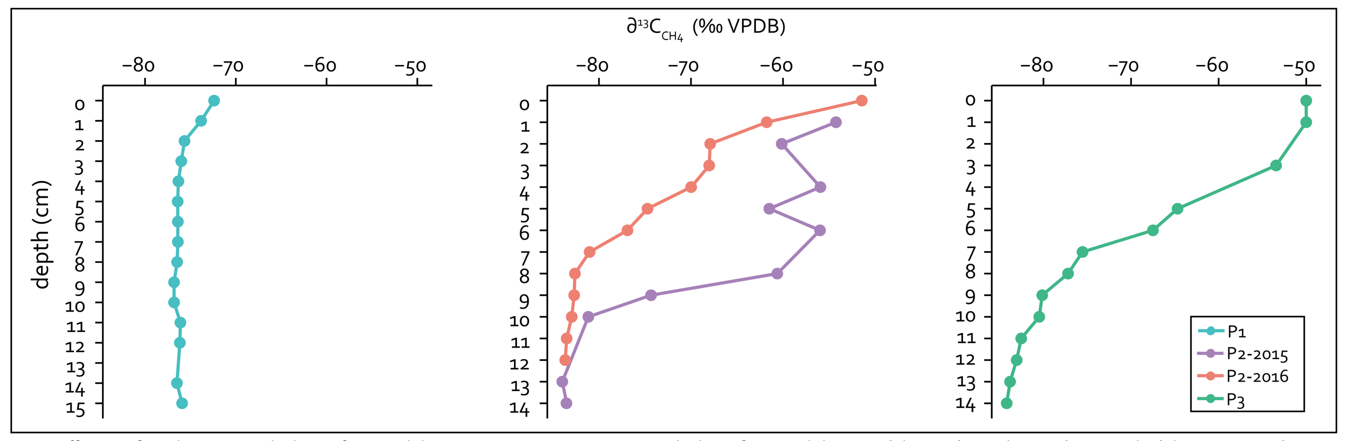


Correlated presence of RNA-derived 16S rRNA gene sequences of Cand. methanoperedens and Cand. methylomirabilis
--> AOM consortia dependent on nitrate and nitrite
(Haroon et al., 2013)

Nitrospira: most abundant class at these depths (>50% at 6-7 cm)

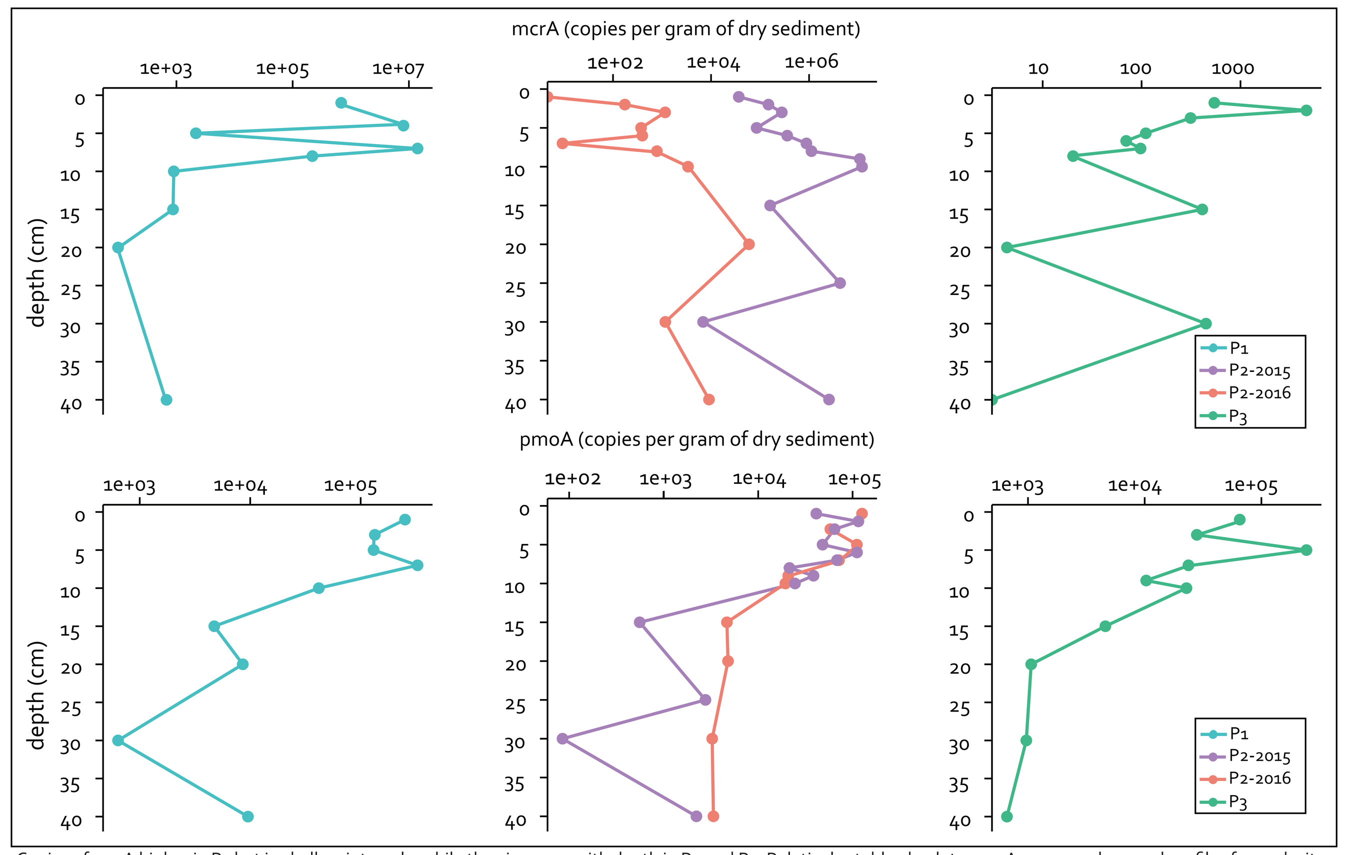
Methane concentrations and isotopes for each site of Onego lake





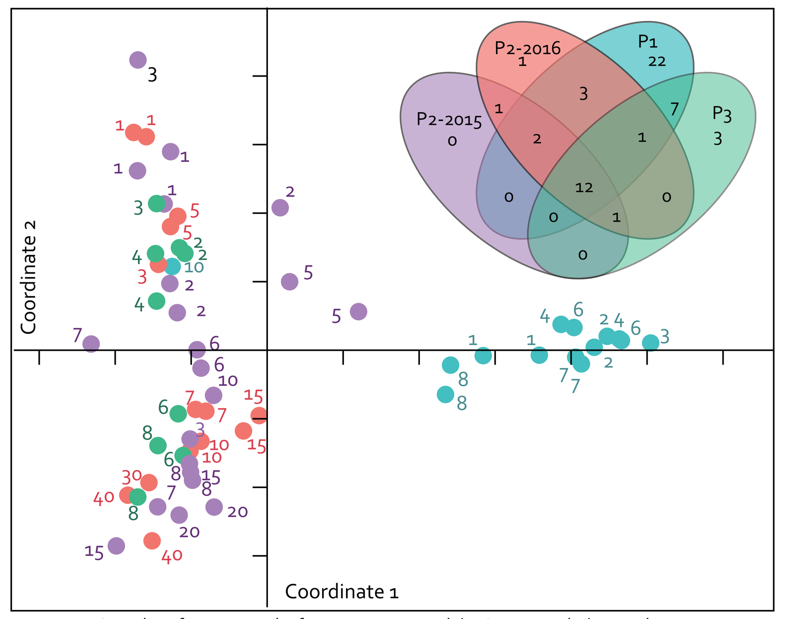
Diffusion of methane towards the surface, and decreasing concentrations towards the sufrace and the open lake. Little methane release to the lake (in P1 mainly). Methane production zone below 10 cm for P2 and P3, below 15 cm in P1. AOM zone between 10 and 4 cm in P2 and P3 ((narrower in 2015). Higher fluxes in P1.

Quantification of mcrA and pmoA genes for each site of Onego lake

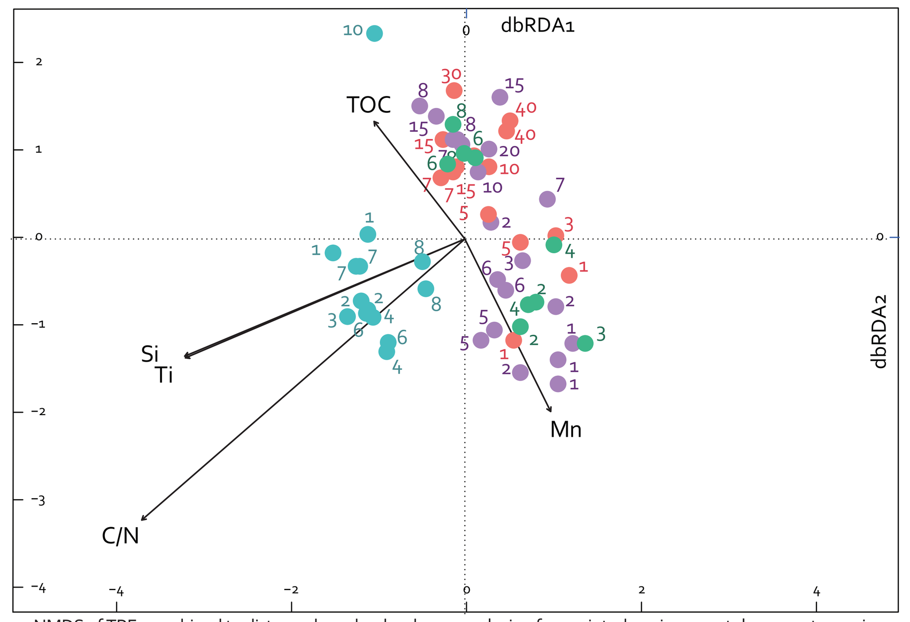


Copies of mcrA higher in P1 but in shallow intervals, while they increase with depth in P2 and P3. Relatively stable absolute pmoA copy numbers and profiles for each site

Analysis of mcrA structure and relation to environmental parameters

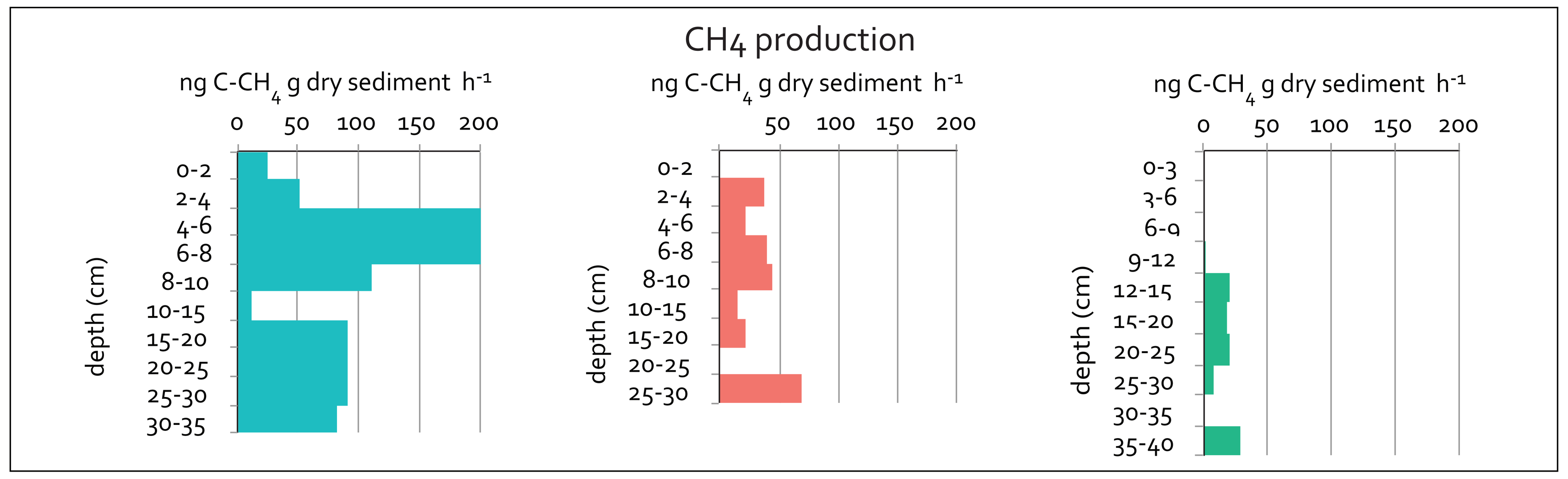


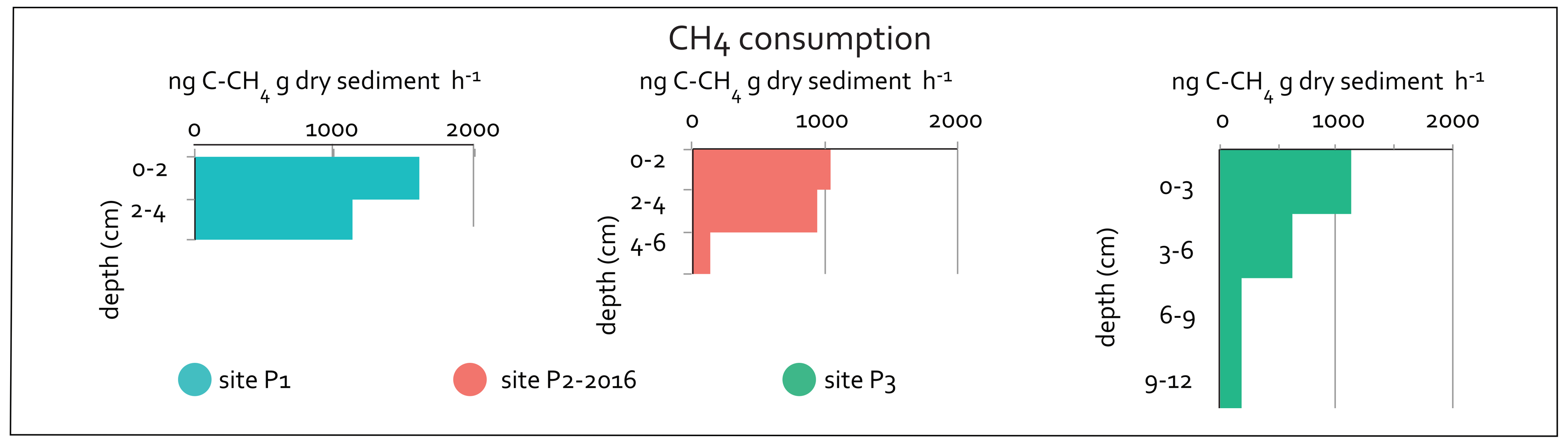
PCoA plot of TRFLP results from mcrA gene in lake Onego (including replicates)
Site P1 significantly different from P2 and P3 (ANOSIM pairwise significance of 0.0001)
2 groups along depth for the P2-P3 cluster (0.0002). Venn diagram shows shared TRFs per sites.



NMDS of TRFs combined to distance-based redundancy analysis of associated environmental parameters using step-across dissimilarities and permutation test under reduced model (999 permutations)
Only significant variables were plotted on the dbRDA (Pr<0.05 from ANOVA test)

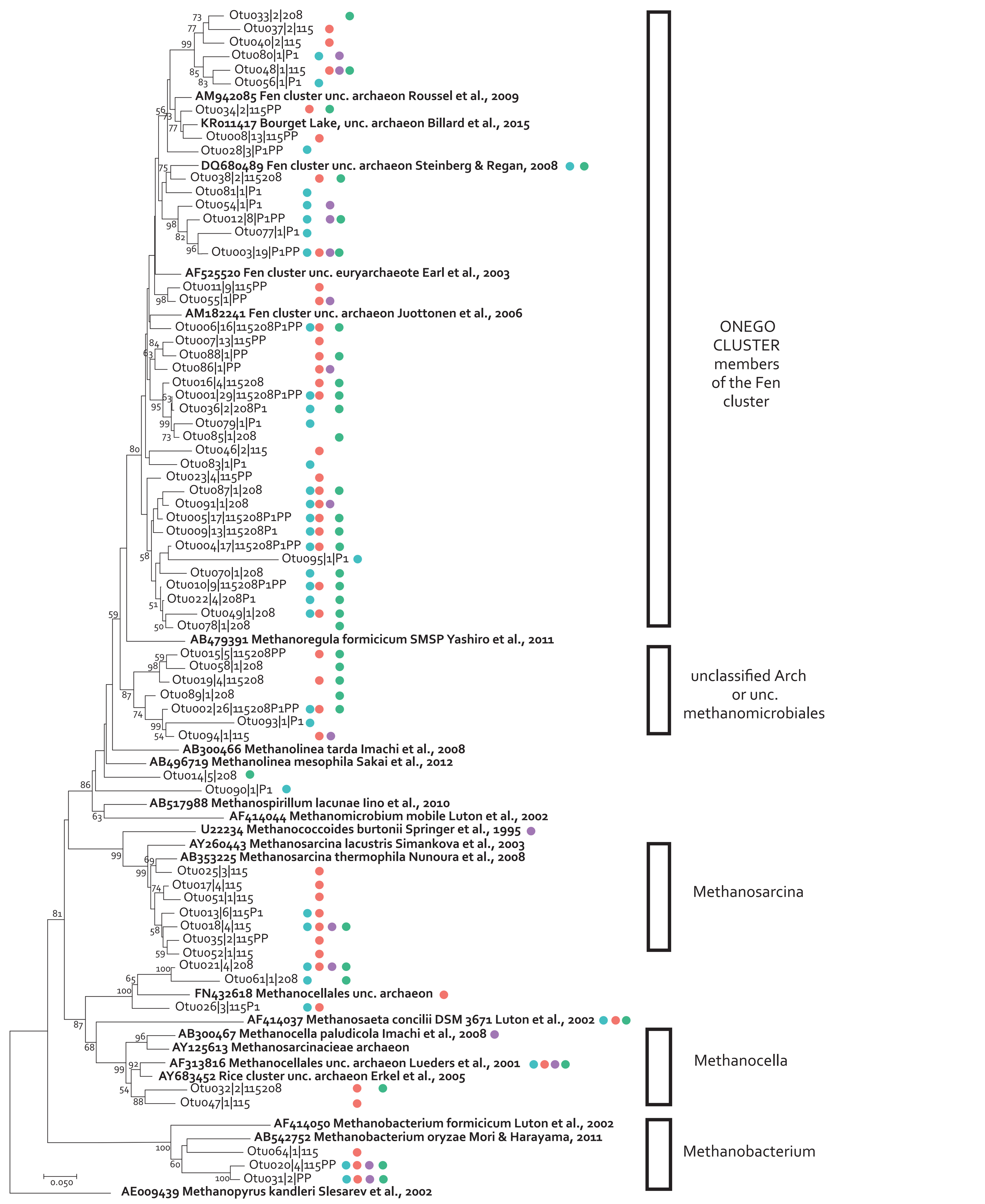
Methane production and consumption potential for each site of Onego lake





Methane production potential is higher in P1, especially between 4 and 10 cm. it decreases as we move offshore to P2 and P3. This production zone probably extends below the measured intervals in each sites.
On the contrary, methane consumption potential is relatively stable between each sites, although the shallowest intervals of P1 exhibit higher consumption rates.

Phylogenetic tree of mcrA sequences (and in silico T-RFLP identification)



High diversity of members of the Fen cluster (Methanoregula) in lake Onego (regardless of the sites. Specific OTUs for P1 within this Fen cluster.
P2 exhibits higher Methanosarcina diversity (acetoclastic methanogens) compared to P1 and P3. No ANME or Cand. methanoperedens.

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Reference : Haroon MF, Hu S, Shi Y, Imelfort M, Keller J, Hugenholtz P, Yuan Z and Tyson GW (2013) Anaerobic oxidation of methane coupled to nitrate reduction in a novel archaeal lineage. Nature, 500, 567–70.