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Uncovering mercury methylation potential and microbial communities involved in Subarctic thermokarst lakes

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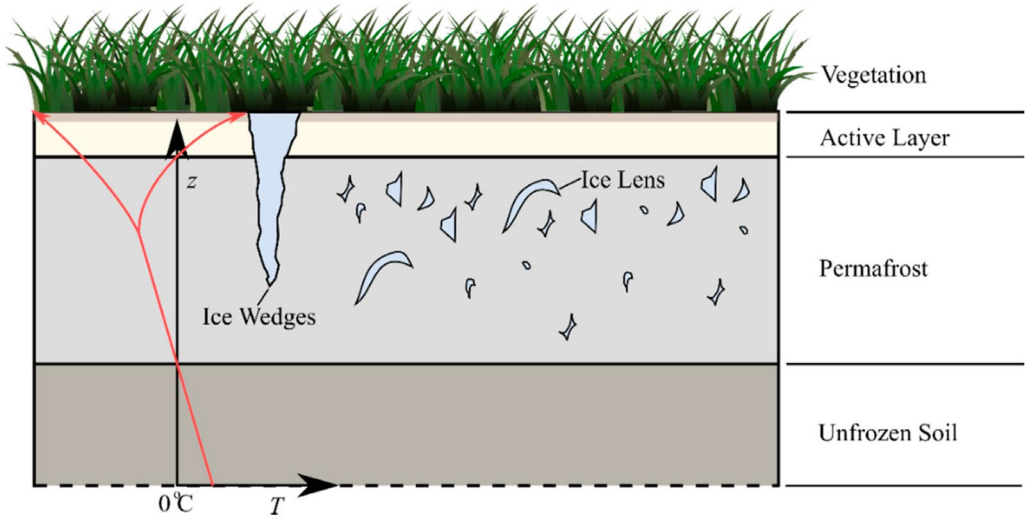
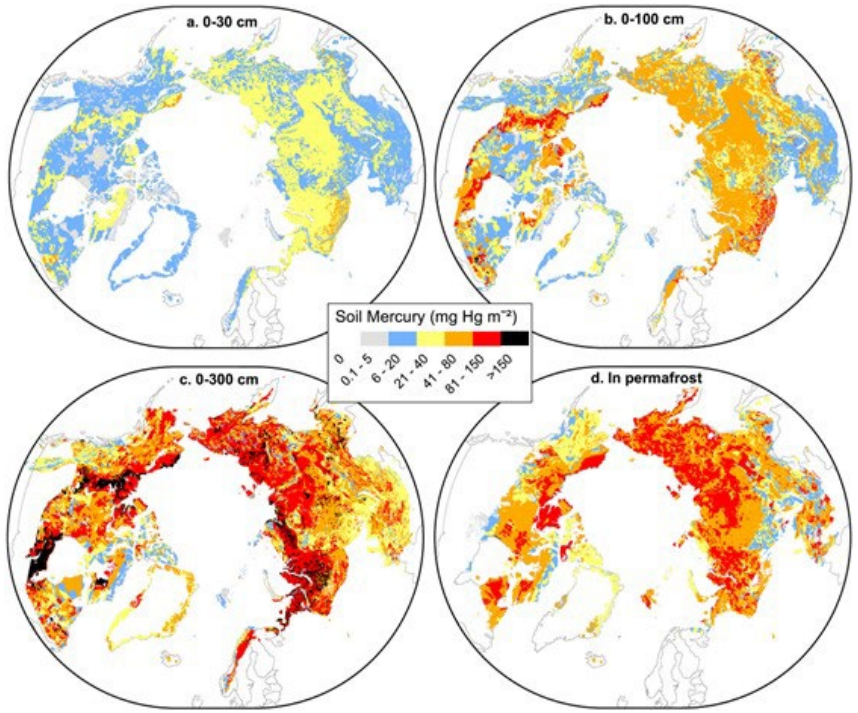


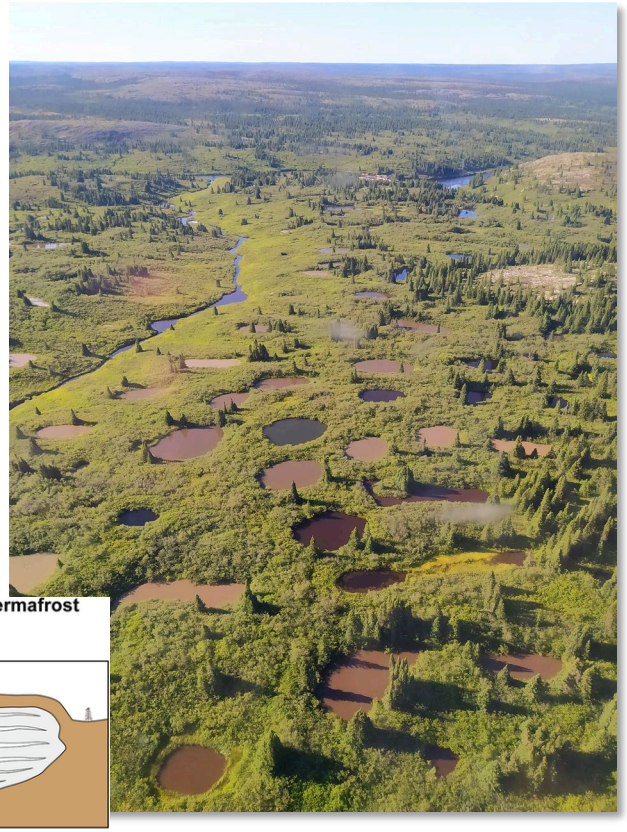
Korte et al. (2020) *Water*



Shuster et al.(2018) *Geophysical Research Letters*

INTRODUCTION

- **Permafrost:**
  - **Perennial frozen soil;**
  - **Pool of carbon, nutrients and contaminants;**
- **High mercury (Hg) content in permafrost;**
- Permafrost degradation;
- Impact on the Hg cycle.



KWAK valley
Whapmagoostui-Kuujjuarapik, Nunavik, Quebec

INTRODUCTION

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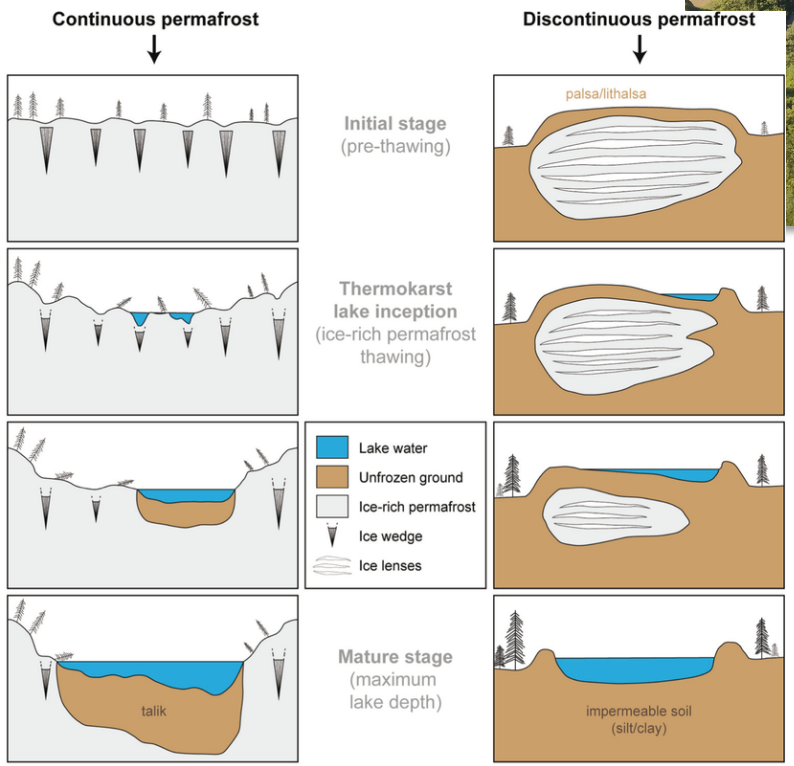
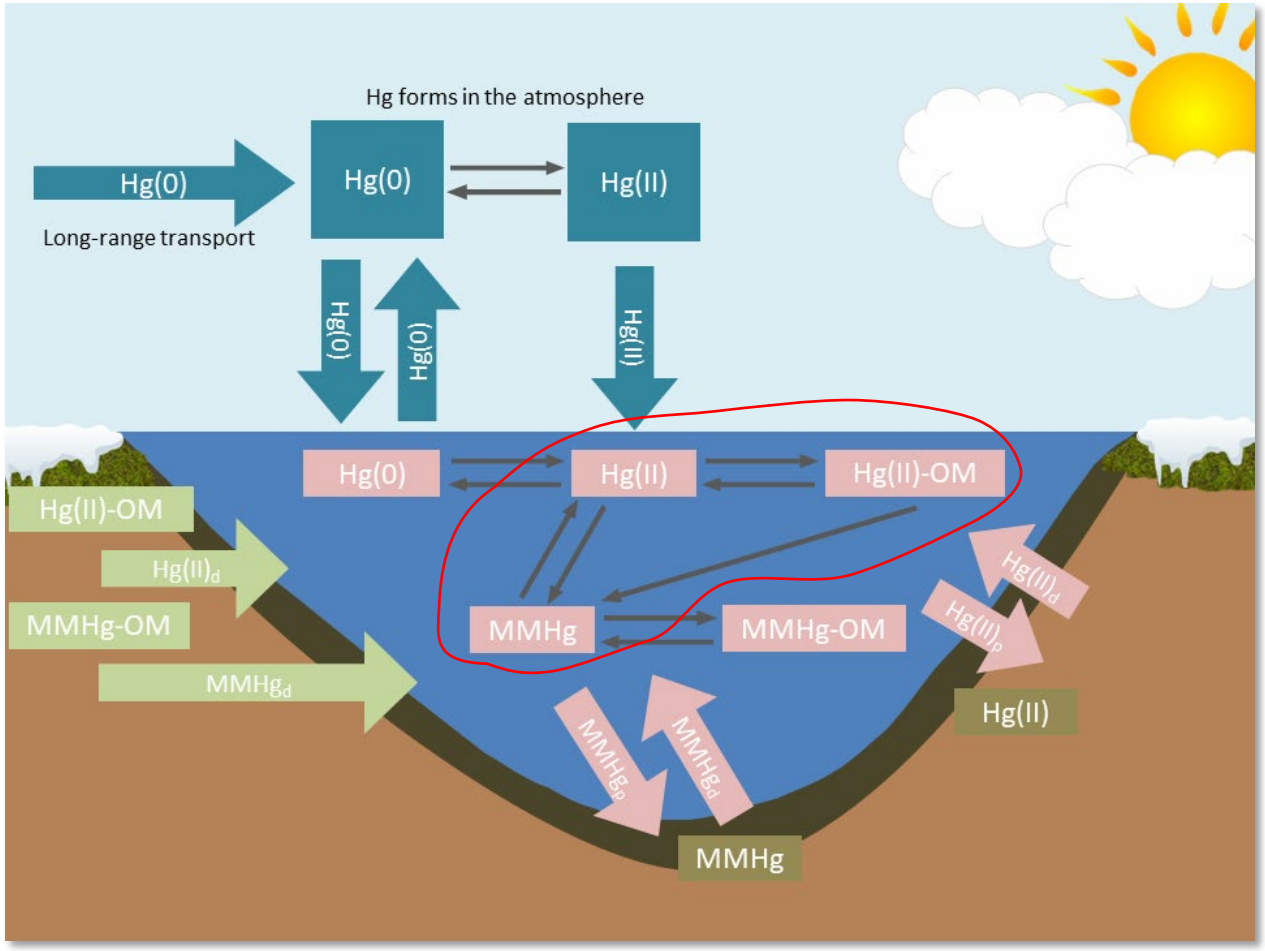


Bouchard et al.(2017) *Arctic Science*



INTRODUCTION

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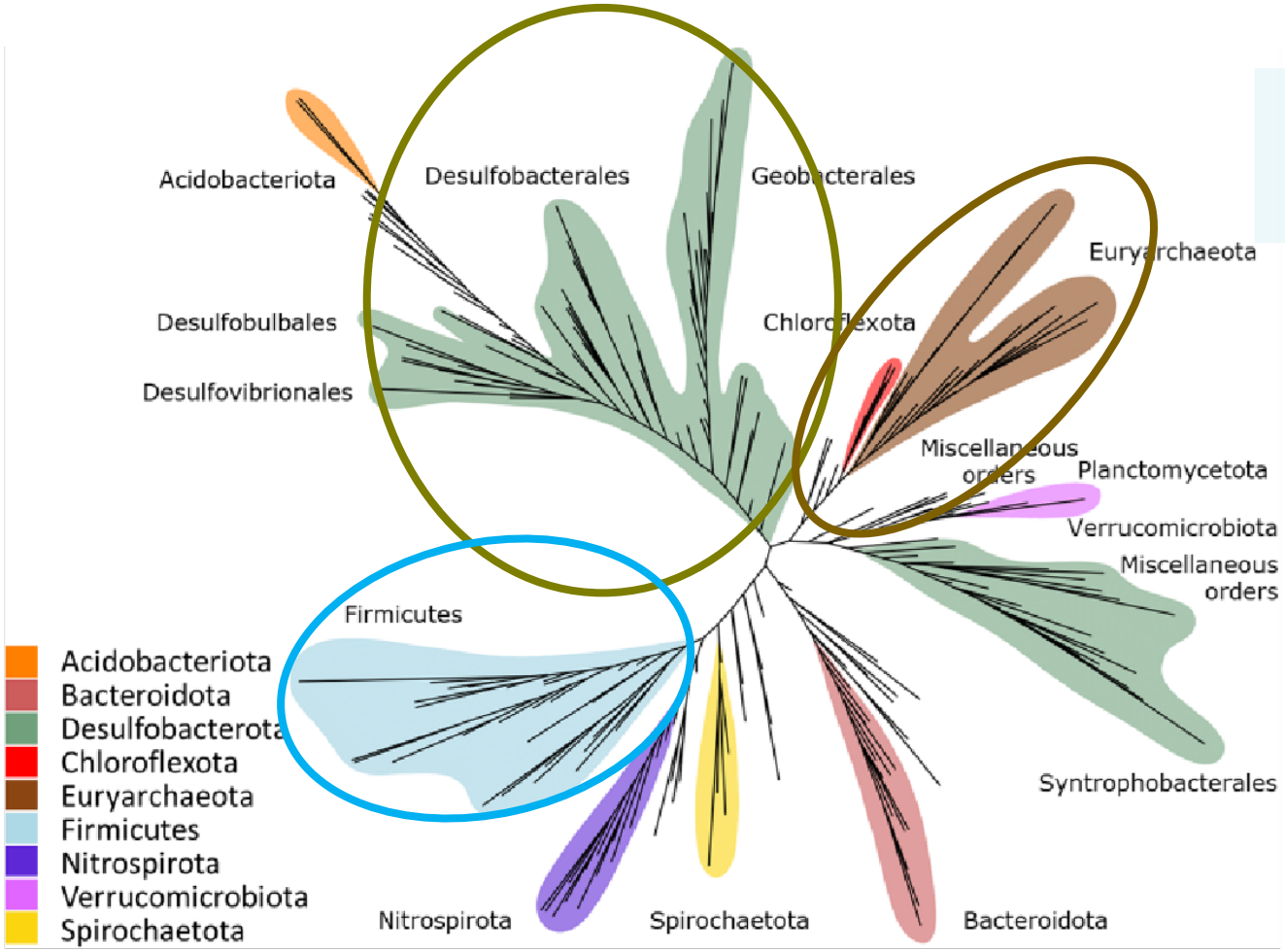
- High mercury (Hg) content in permafrost;
- Permafrost degradation;
- **Impact on the Hg cycle.**

Christiansen et al. (2016) *Applied and Environmental Microbiology*



Capo et al. (2023), *Molecular Ecology Resources*

INTRODUCTION

- Permafrost:
  - Perennial frozen soil;
  - Pool of carbon, nutrients and contaminants;
- High mercury (Hg) content in permafrost;
- Permafrost degradation;
- **Impact on the Hg cycle:**
  - **Methylmercury formation → 3 main clades of methylators: Desulfobacterota; Firmicutes; Methanomicrobia.**

STUDY SITE

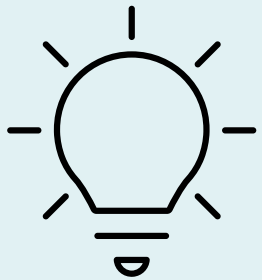
- Area of sporadic permafrost
- First fieldwork → March 2022 (**Winter**)
- Second fieldwork → August 2022 (**Summer**)

	SAS 1A	SAS 2A	
Snow depth (cm)	14	29	
Ice thickness (cm)	67	79	
Lake depth (m)	0.85	2.25	
Temperature (ºC)	0.2-1.3	0.3-3.5	**Winter**

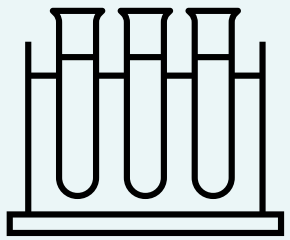
	SAS 1A	SAS 2A	
Lake depth (m)	1.75	2.25	
Surface area (km^2)	1661	104	
Temperature (ºC)	10.5-13.8	4.9-11.9	**Summer**

OBJECTIVES

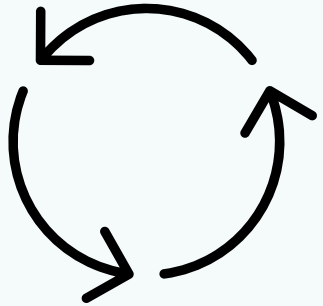
Assess total mercury (THg) and methylmercury (MMHg) and study seasonal variability



Evaluate methylation rates using isotope enriched Hg



Complement Hg assessment with microbiological analysis



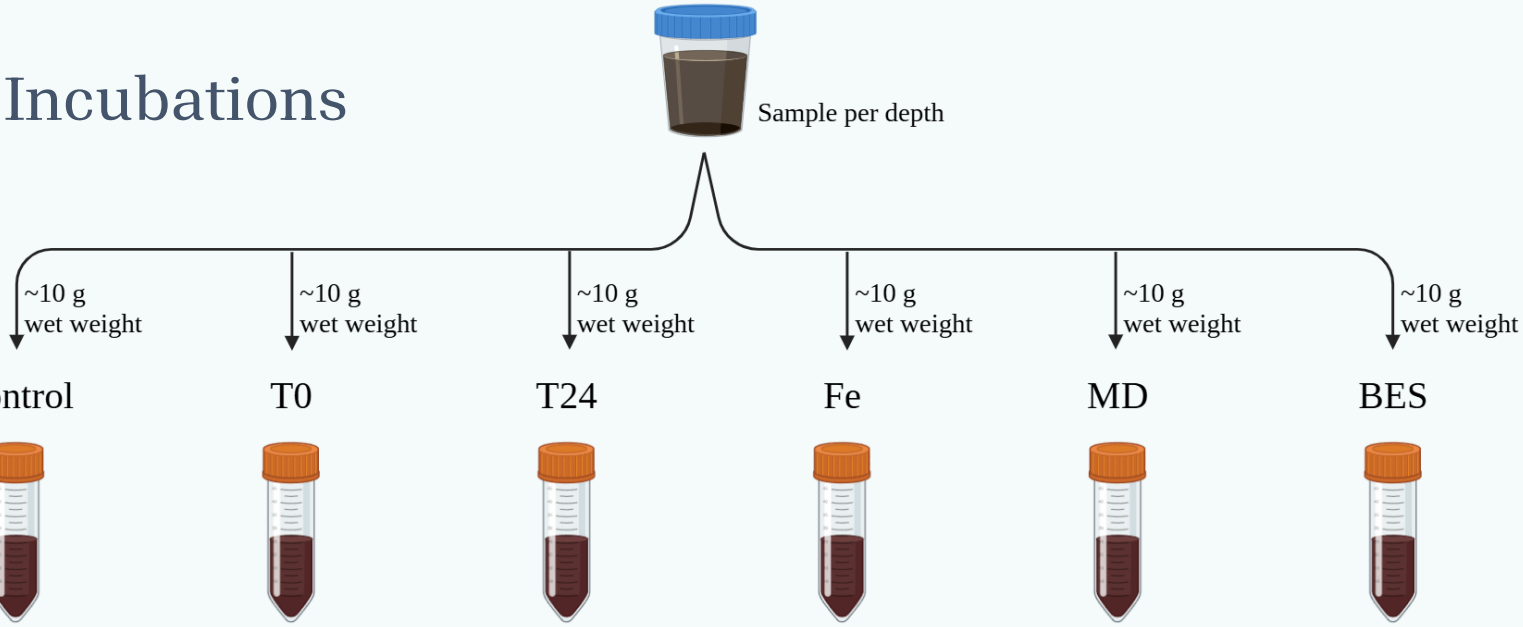
METHODOLOGY

Sediment Samples

- Uwitec Corer USC 0600;
- Divided in three depths:
  - Surface (0-5 cm);
  - Middle (5-10 cm);
  - Bottom (10-15 cm);
- Prepare sediment incubations;
- Analyze THg and MMHg concentrations;
- Metagenomic sequencing.

METHODOLOGY

Sediment Incubations



	Control	T0	T24	Fe	MD	BES
Spike	—	$^{200}Hg(II)$ + $MM^{198}Hg$	$^{200}Hg(II)$ + $MM^{198}Hg$	$^{200}Hg(II)$ + $MM^{198}Hg$	$^{200}Hg(II)$ + $MM^{198}Hg$	$^{200}Hg(II)$ + $MM^{198}Hg$
Amendments	—	—	—	Fe → IRB (+)	MD → SRB (-)	BES → Methan. (-)
Incubation time (h)	0	0	24	6	6	6

METHODOLOGY

Sediment Samples

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- Divided in three depths:
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- Prepare sediment incubations;
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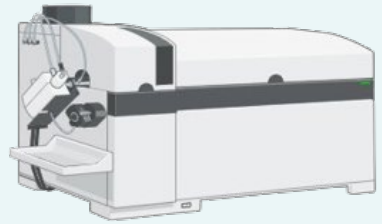
THg

Digestion with acid mixture → **CV-ICP-QQQ-MS**

Cold vapor system coupled with Agilent 8800 ICP-MS



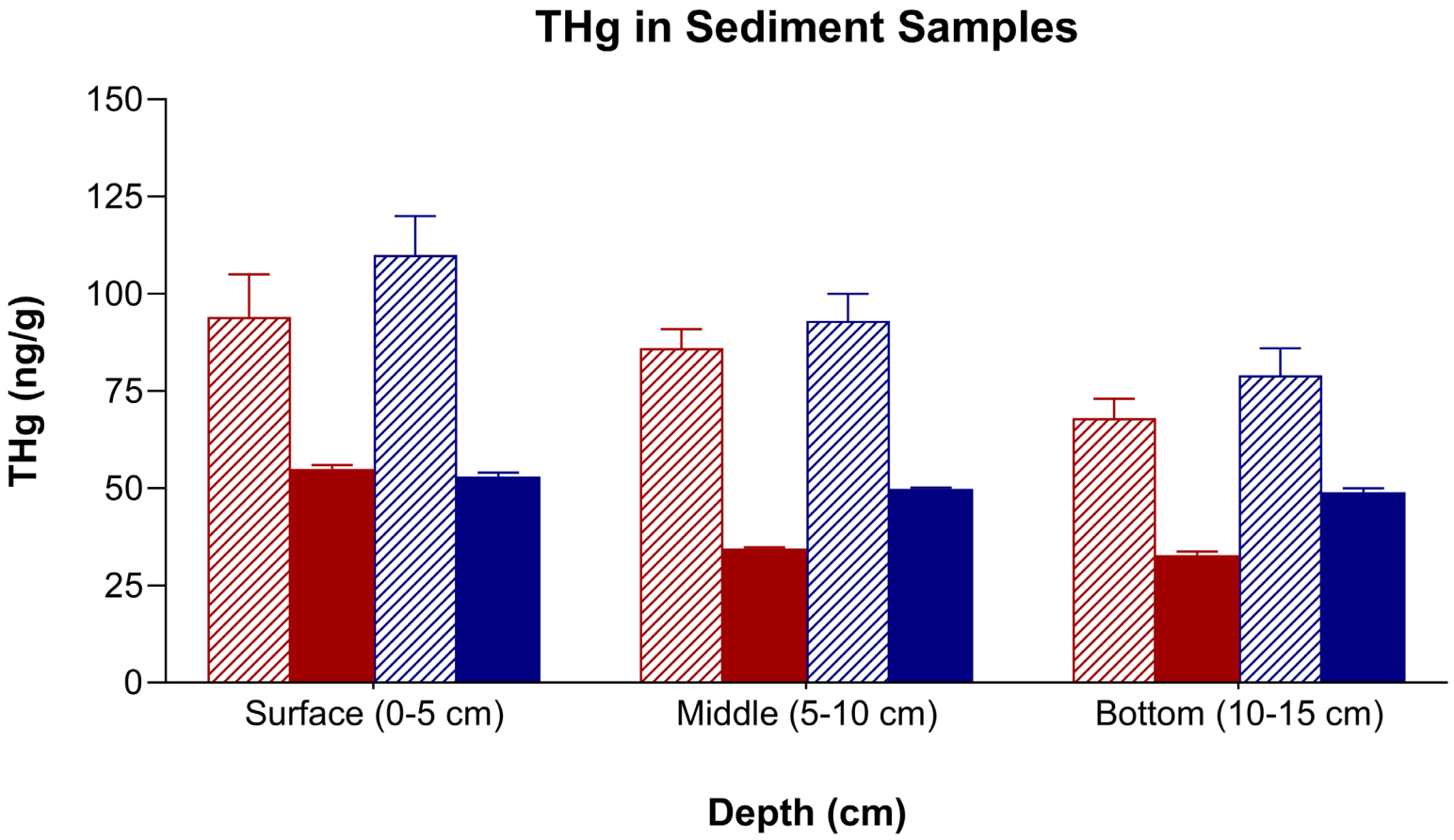
MMHg

Distillation → **GC-ICP-QQQ-MS**

Tekran 2700 (GC) coupled with Agilent 8800 ICP-MS

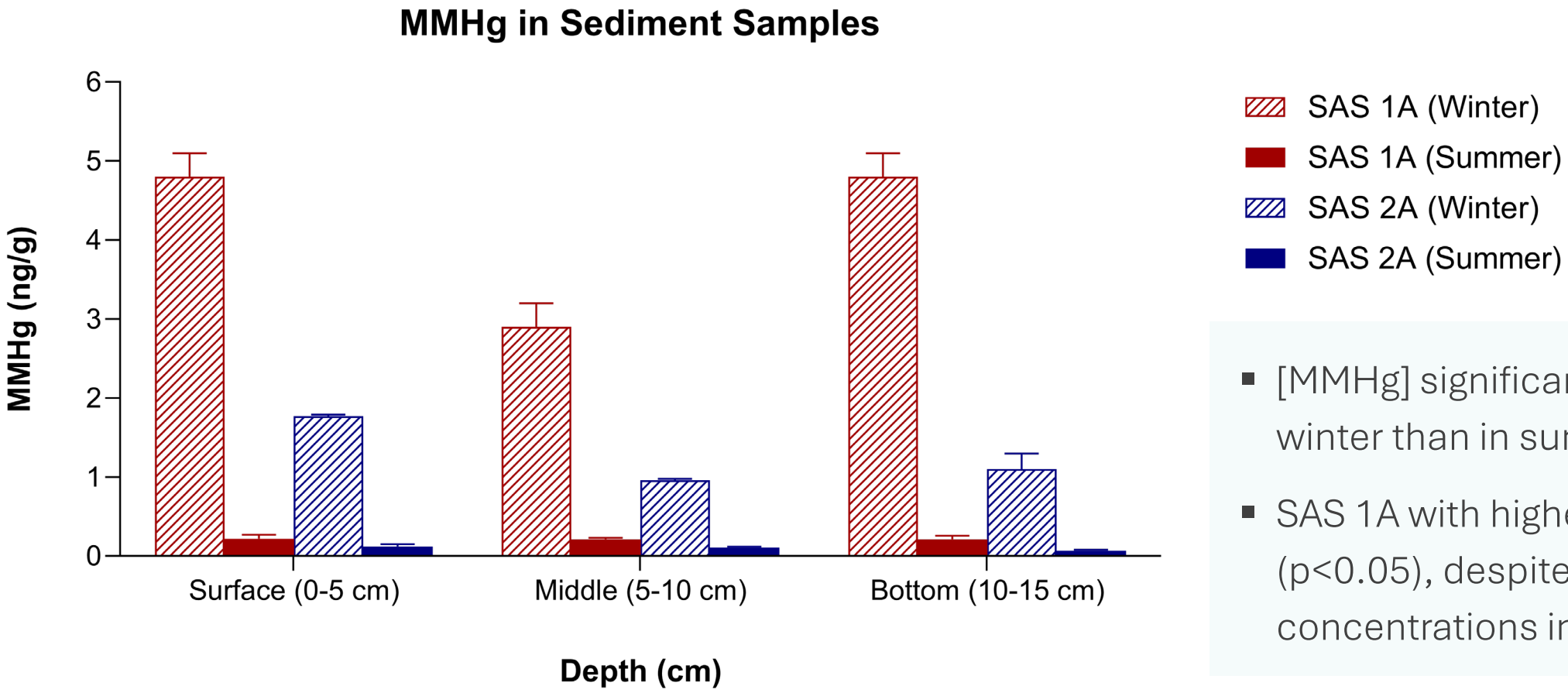
RESULTS

THg IN SEDIMENT SAMPLES



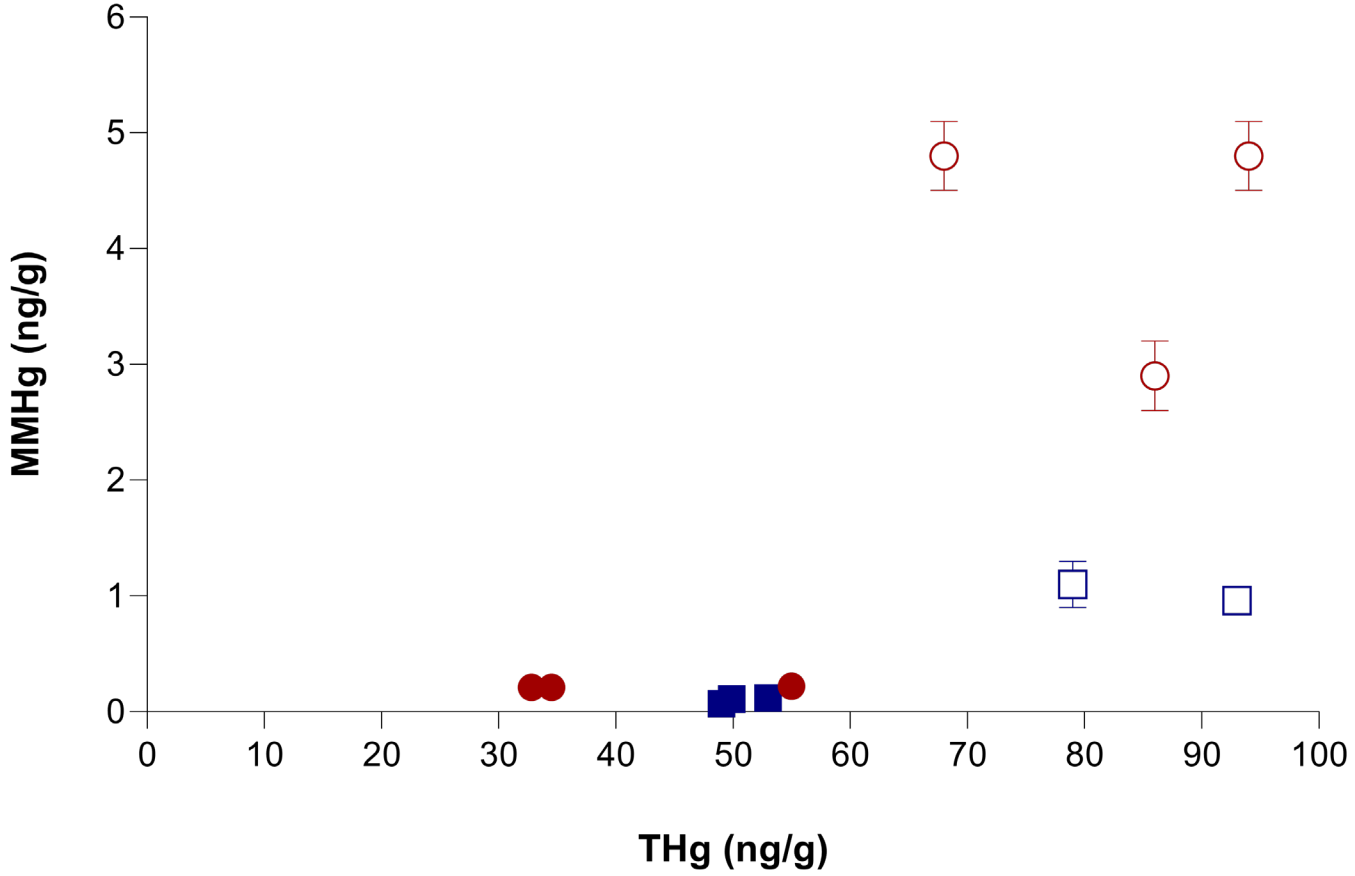
- In each season, similar THg concentrations ($p<0.05$);
- Higher THg in winter samples:
  - Sampling at the end of winter;
  - Closed system.

MMHg IN SEDIMENT SAMPLES



- [MMHg] significantly higher in winter than in summer ($p<0.05$);
- SAS 1A with higher [MMHg] ($p<0.05$), despite similar THg concentrations in each season.

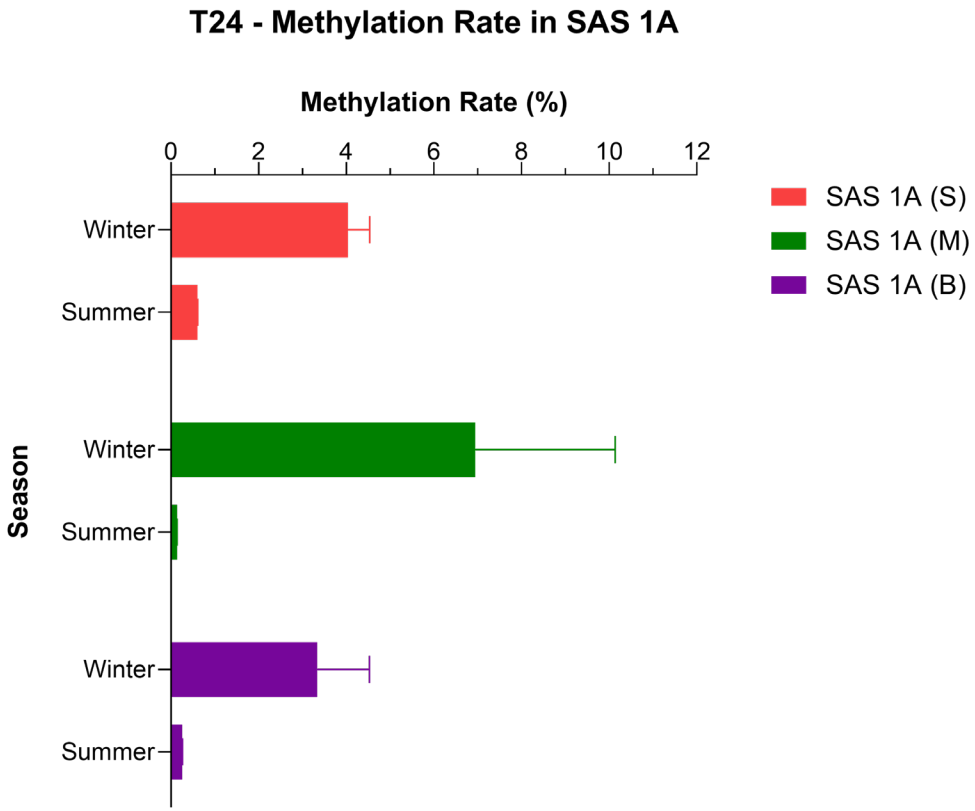
THg VS MMHg

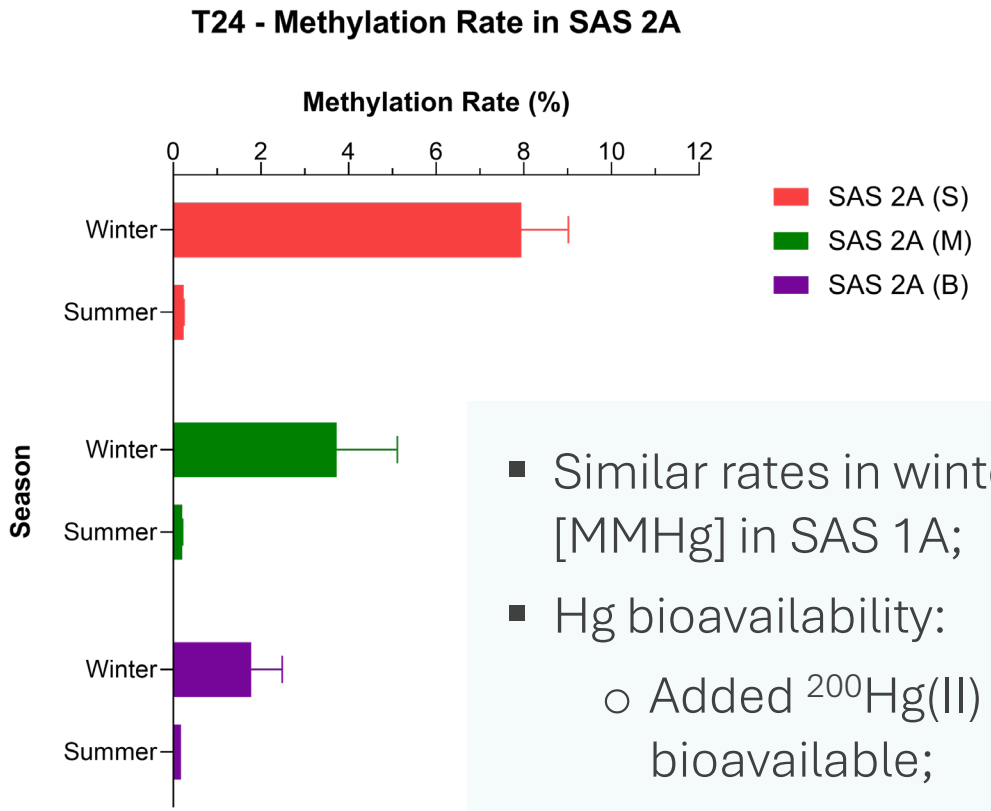


- SAS 1A (Winter)
- SAS 1A (Summer)
- SAS 2A (Winter)
- SAS 2A (Summer)

- Similar Hg pool in winter does not correspond to similar [MMHg];
- Other aspects are influencing:
  - Hg bioavailability;
  - Organic matter composition → thaw progression;
  - Bacterial communities.

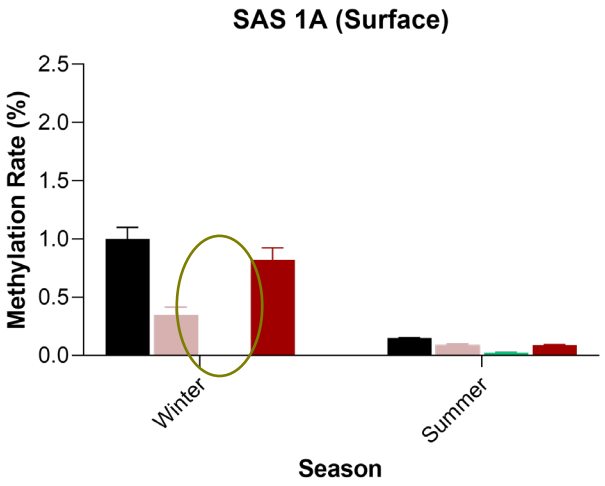
METHYLATION RATES - 24 HOURS

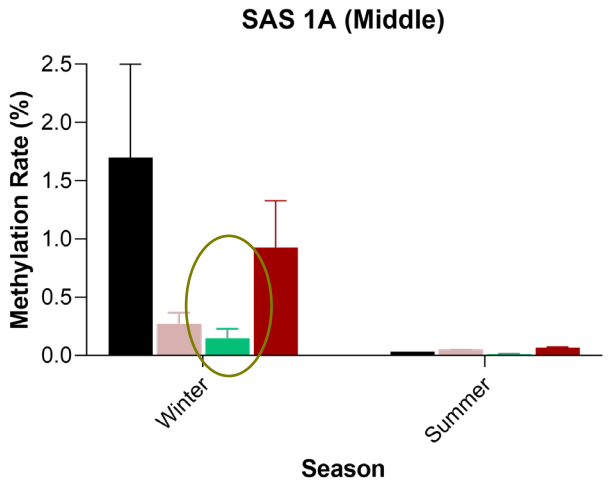


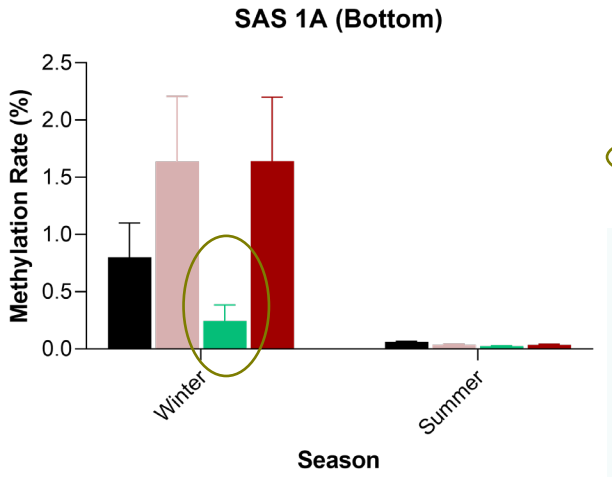


- Similar rates in winter but higher [MMHg] in SAS 1A;
- Hg bioavailability:
  - Added $^{200}Hg(II)$ is highly bioavailable;
  - Hg in ecosystem might be complexed with other elements → ≠ capacity to methylate.

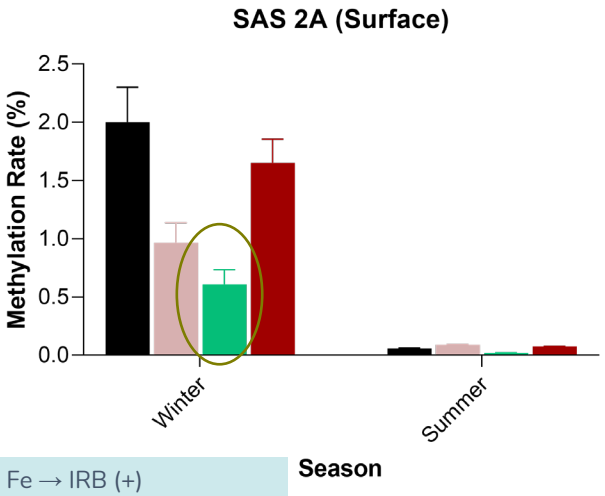
METHYLATION RATES - AMENDMENTS

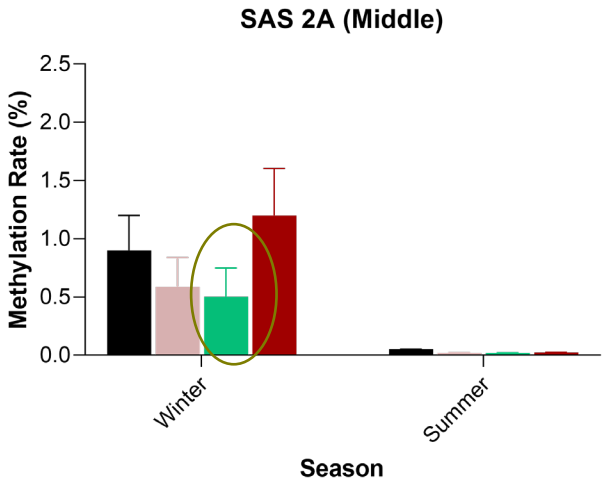


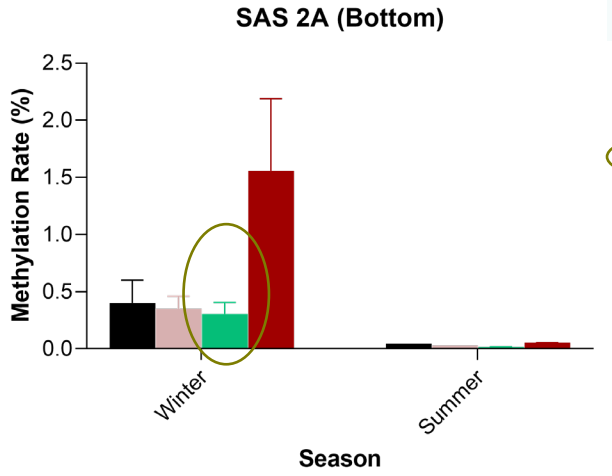




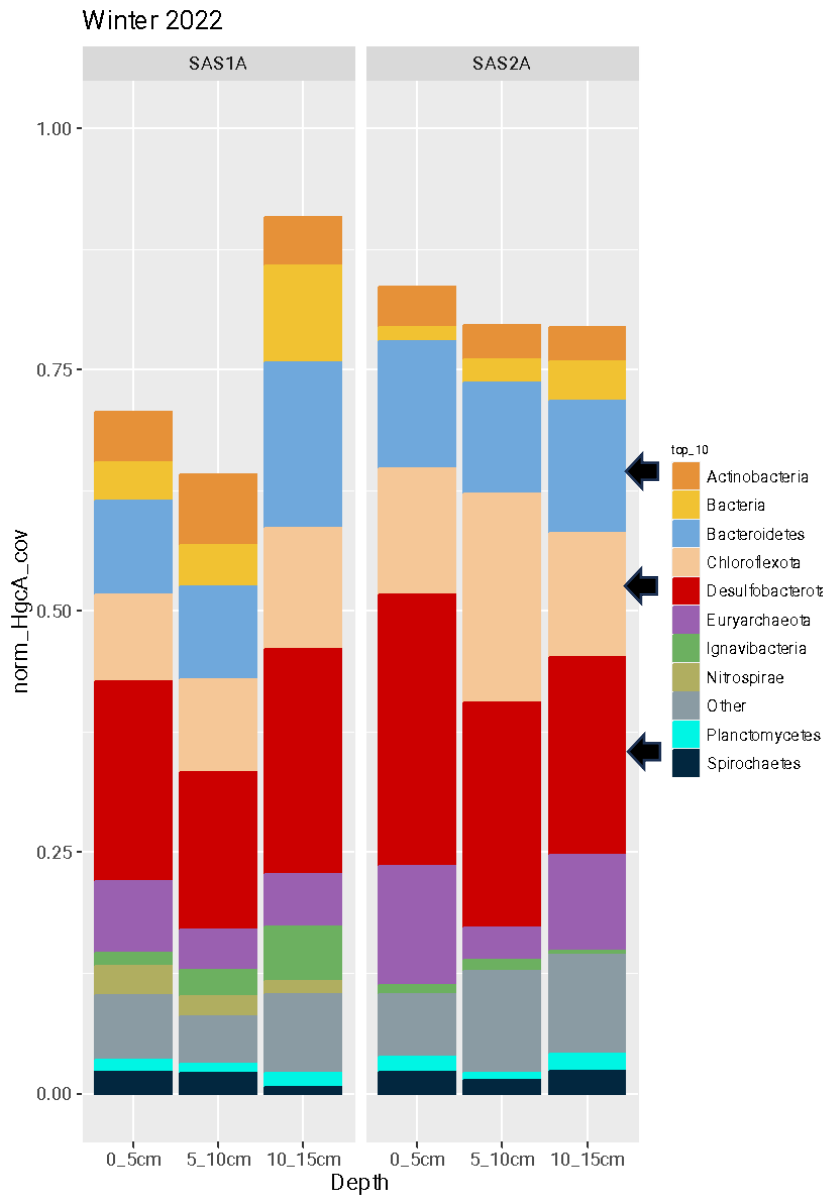
- Importance of SRB;
- Competition with other bacteria.

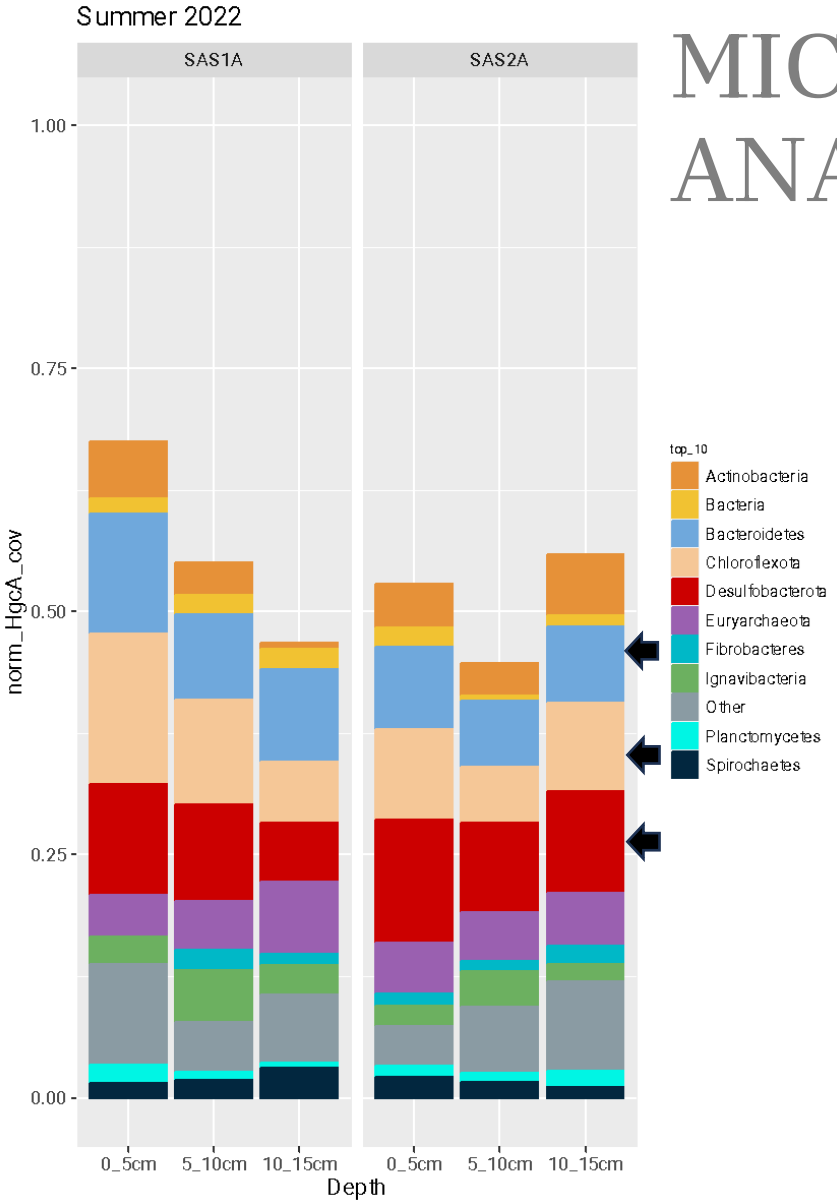






- ❑ Fe → IRB (+)
- ❑ MD → SRB (-)
- ❑ BES → Methanogens (-)



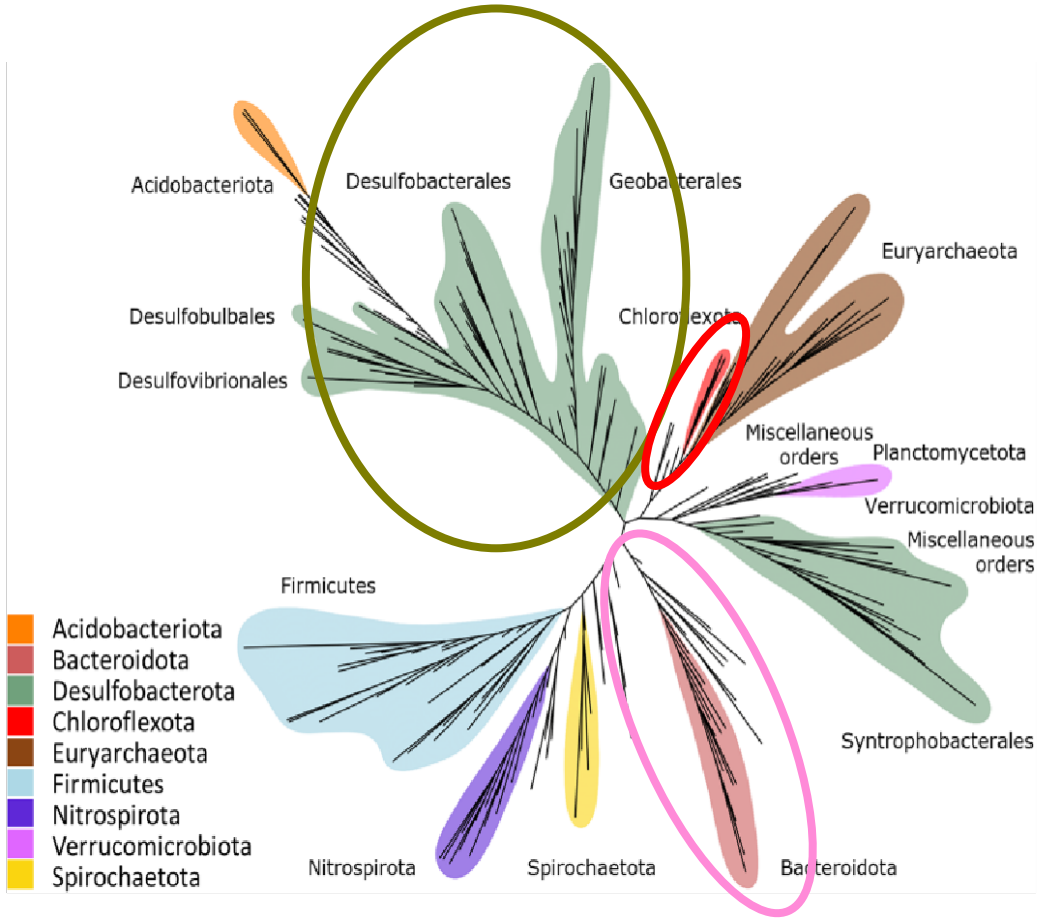


MICROBIOLOGY ANALYSIS

- Lakes with similar communities in each season;
- Main group found in samples:
  - **Desulfobacterota → SRB;**
  - Chloroflexota;
  - Bacteroidetes;
- Gene abundance higher in **winter;**
- Main reduction of Desulfobacterota between winter and summer.

Capo et al. 2022

MICROBIOLOGY ANALYSIS

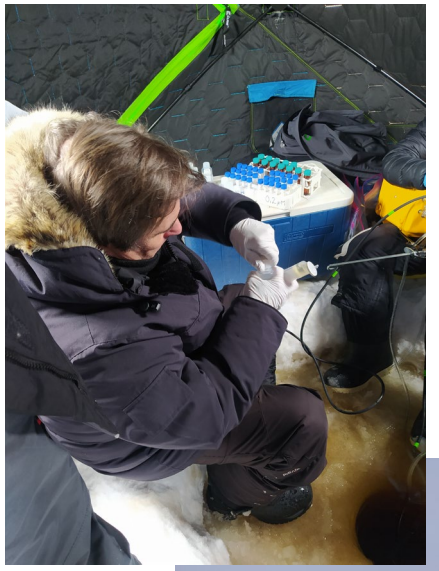


Capo et al. (2023), *Molecular Ecology Resources*

- Capo et al. (2023) found 3 main clades of methylators:
  - Desulfobacterota;
  - Firmicutes;
  - Methanomicrobia;
- Different in the sediments of Subarctic thermokarst lakes:
  - Desulfobacterota;
  - Chloroflexota;
  - Bacteroidetes;
- **Unique ecosystem.**

MAIN CONCLUSIONS

- Sediment samples show higher THg in winter → closed system;
- Higher [MMHg] and methylation rates also occur in winter:
  - Higher Hg pool;
  - Different microbial communities → in line with microbiological analysis (gene abundance);
- Important factors on MMHg concentrations → Hg pool and Hg bioavailability to be methylated;
- SRB seem to be important in the methylation process → in line with microbiological analysis;
- Thermokarst lakes are unique ecosystems.



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