



Development of bioremediation and natural attenuation strategies for Arctic marine beaches contaminated with hydrocarbon

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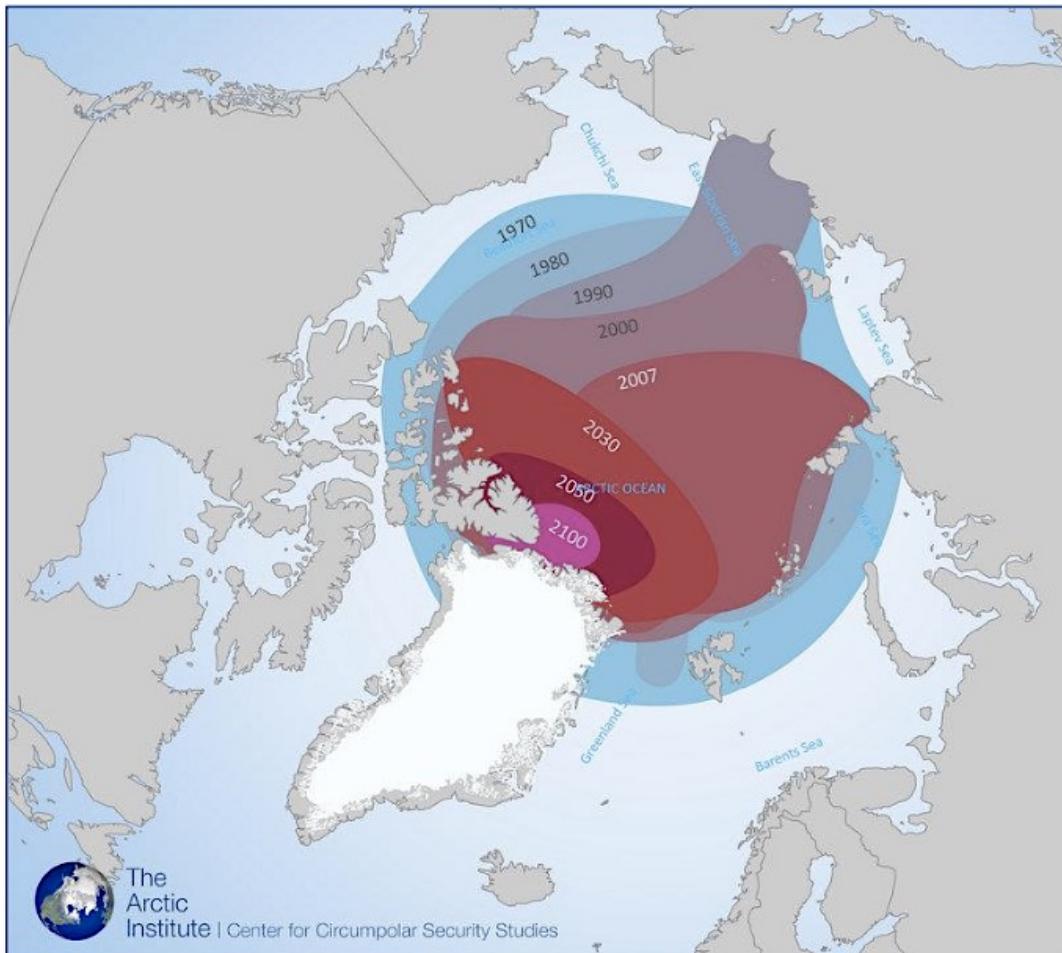
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DFO & NRCan MPRI projects

September 6th, 2023

What is the prediction of the Arctic Ocean's state?

Recorded and projected minimum ice coverage
of the Arctic Ocean by years



The future of navigation in
arctic waters



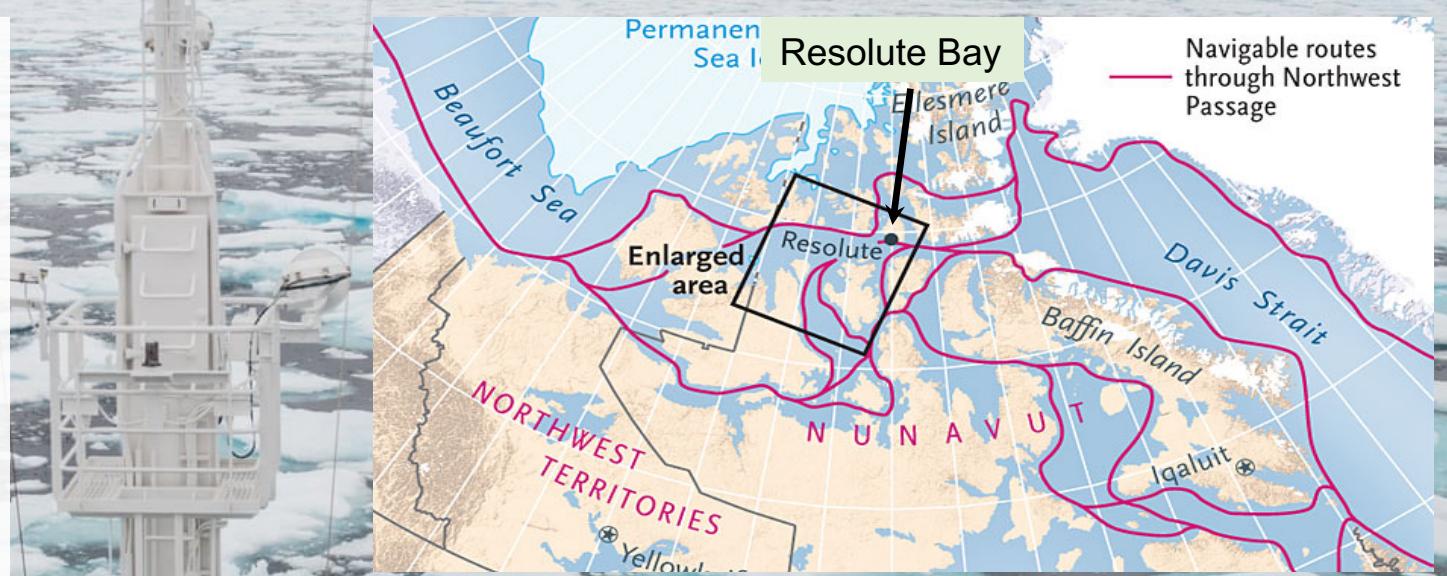
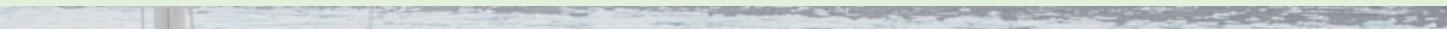
The Northwest Passage, an easy route?

Network of **gulfs, straits, and channels** within Canadian Arctic Archipelago

Ice free summers are projected by mid century due to **global warming**:

- Increased ice-free zones - Polynyas
- Increased shipping activity in the NWP
- Increased risk of introduced fuel & oil to the environment

What happens to that fuel and oil that is washed up to the shores?



Studies goals?

Our lab aims to optimize hydrocarbon bioremediation on Arctic beaches:

- Genomic surveys of Arctic shorelines
- In-situ microcosm experiments
- Ex-situ lab mesocosm experiments

**DFO and NRCan MPRI projects:
2018 to present**



Tupirvik Beach, at Resolute Bay, July 2021

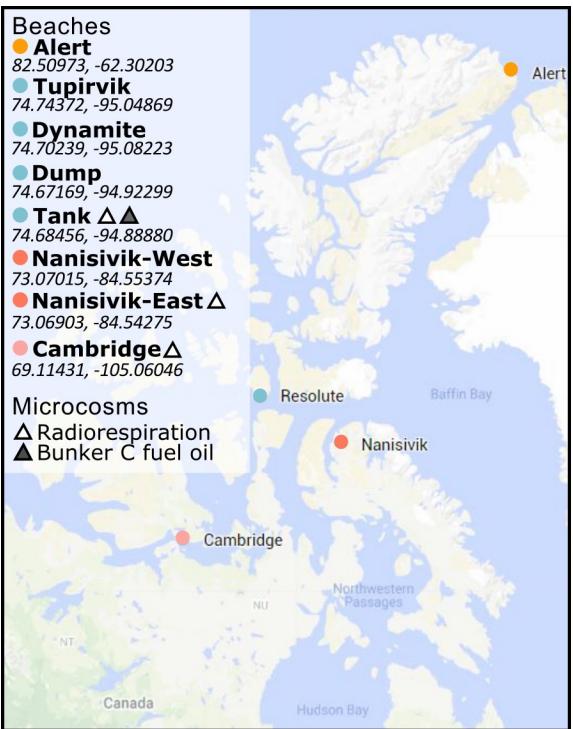
Genomic survey: First glimpse of microbial communities and the potential for biodegradation along High Arctic shorelines?

Ellis et al., 2022. *Marine Pollution Bulletin*



Madison Ellis, MSc Candidate

Intertidal sediment sample sites in 2018



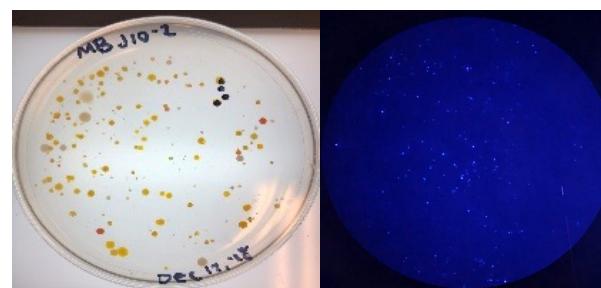
Objective 1:
Characterize intertidal sediments from 8 beaches

Environmental variables

- Available nutrients

Abundance

- Culturable + unculturable microorganisms



Fuel constituents

- Hexadecane & naphthalene degradation over time +/- nutrients



Objective 2:
Screen for hydrocarbon biodegradation activity

Fuel

- ULSFO degradation over time +/- nutrients
- Community composition
- Biodegradation genes



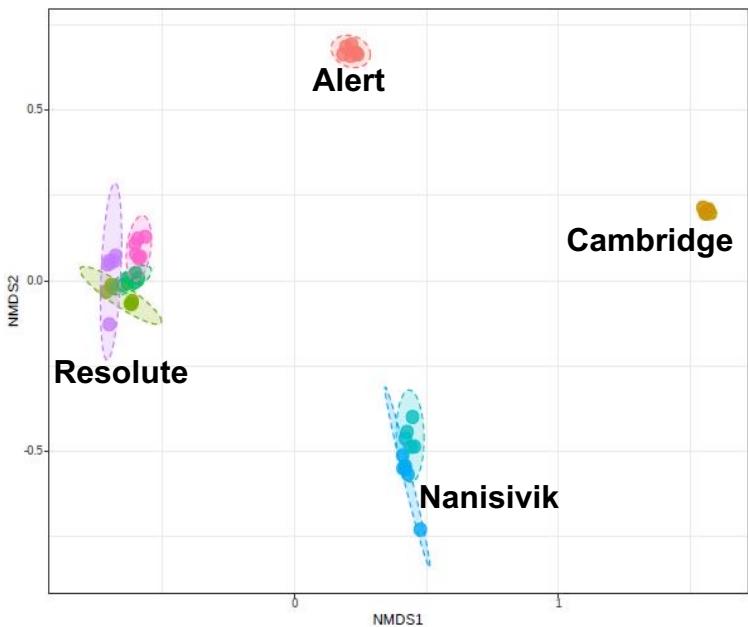
Genomic survey: First glimpse of microbial communities and the potential for biodegradation along High Arctic shorelines?

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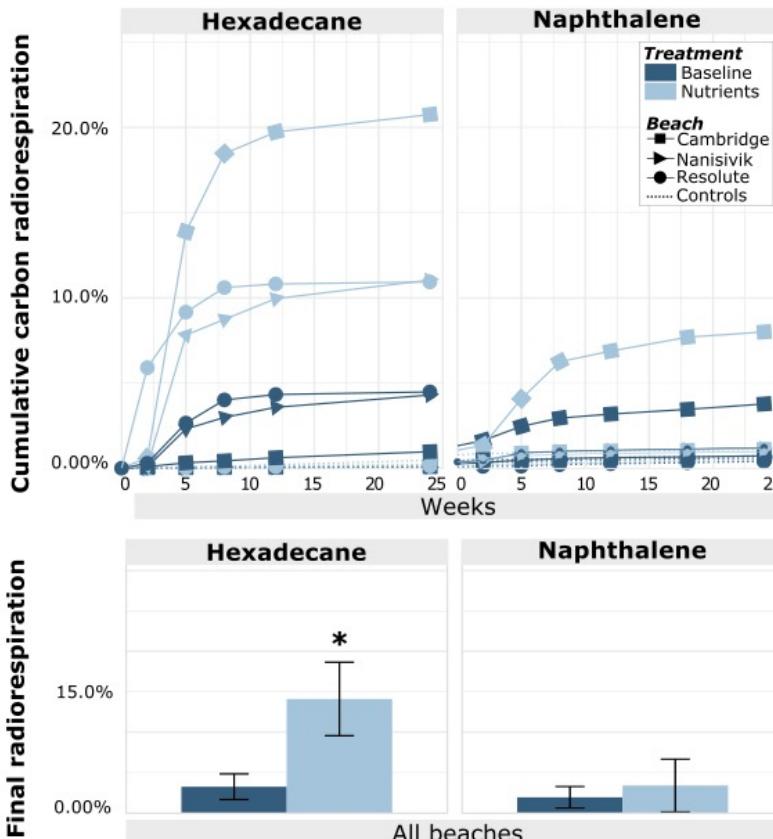


Madison Ellis, MSc Candidate

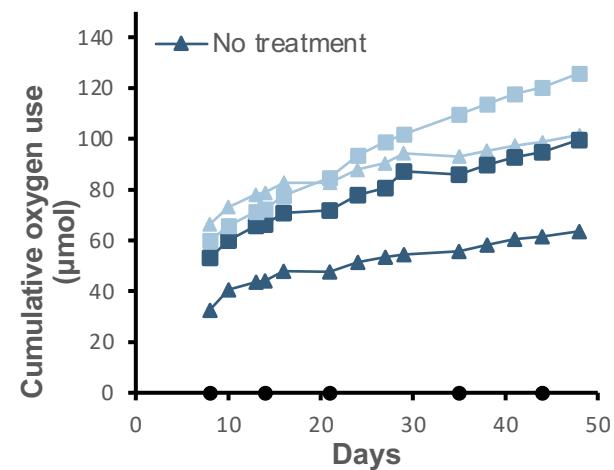
NMDS ordination show distinct bacterial community composition in each site



Fuel constituent biodegradation



Oxygen use over time of fuel microcosms

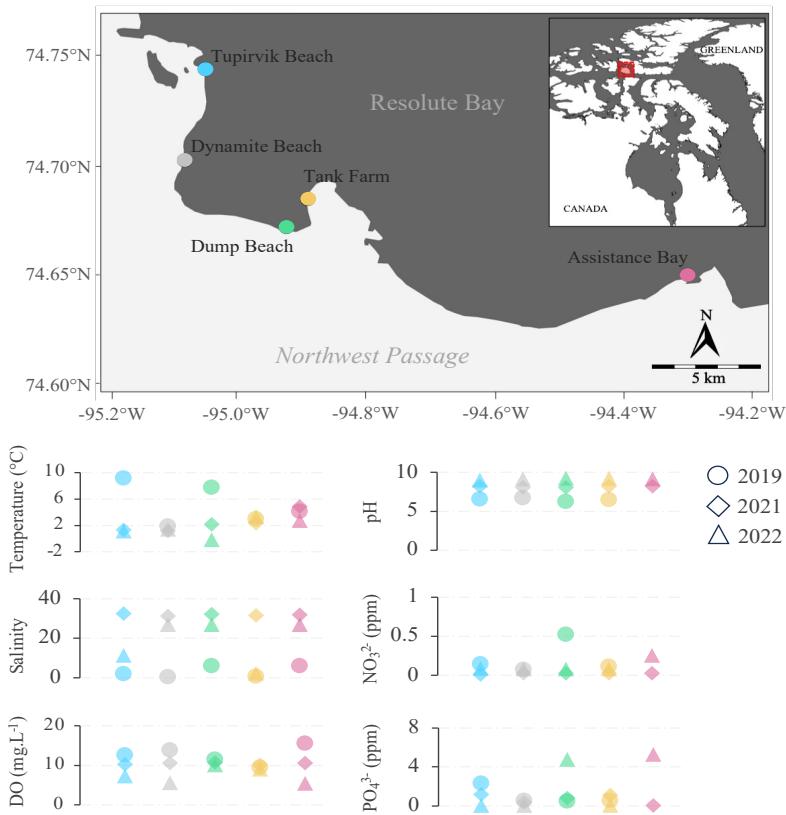
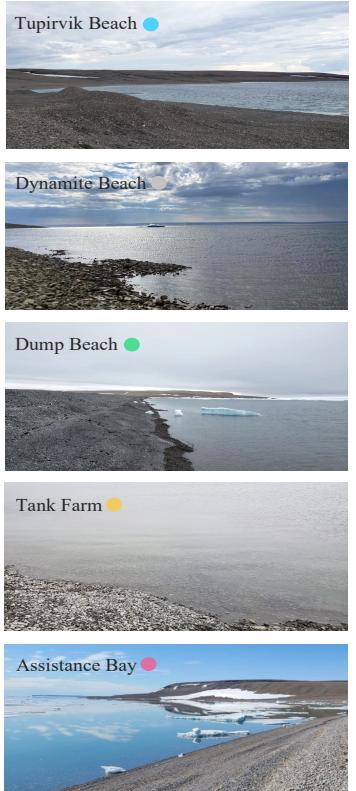


Summer genomic surveys of microbial community and screening of hydrocarbon degradation genes

Freyria et al., *in prep.*



Nastasia Freyria, PDF



4 years of summer sampling from 5 beaches along Resolute shorelines:

- 2018, 2019, 2021 and 2022

Measurements of environmental variables:

- Temperature, salinity, nutrients ...

**Objective 1:
Characterize intertidal sediments and surface seawater from 5 beaches**

Community composition

- 16S and 18S rRNA gene sequencing



Environmental influence

- Functional annotation
- Binning



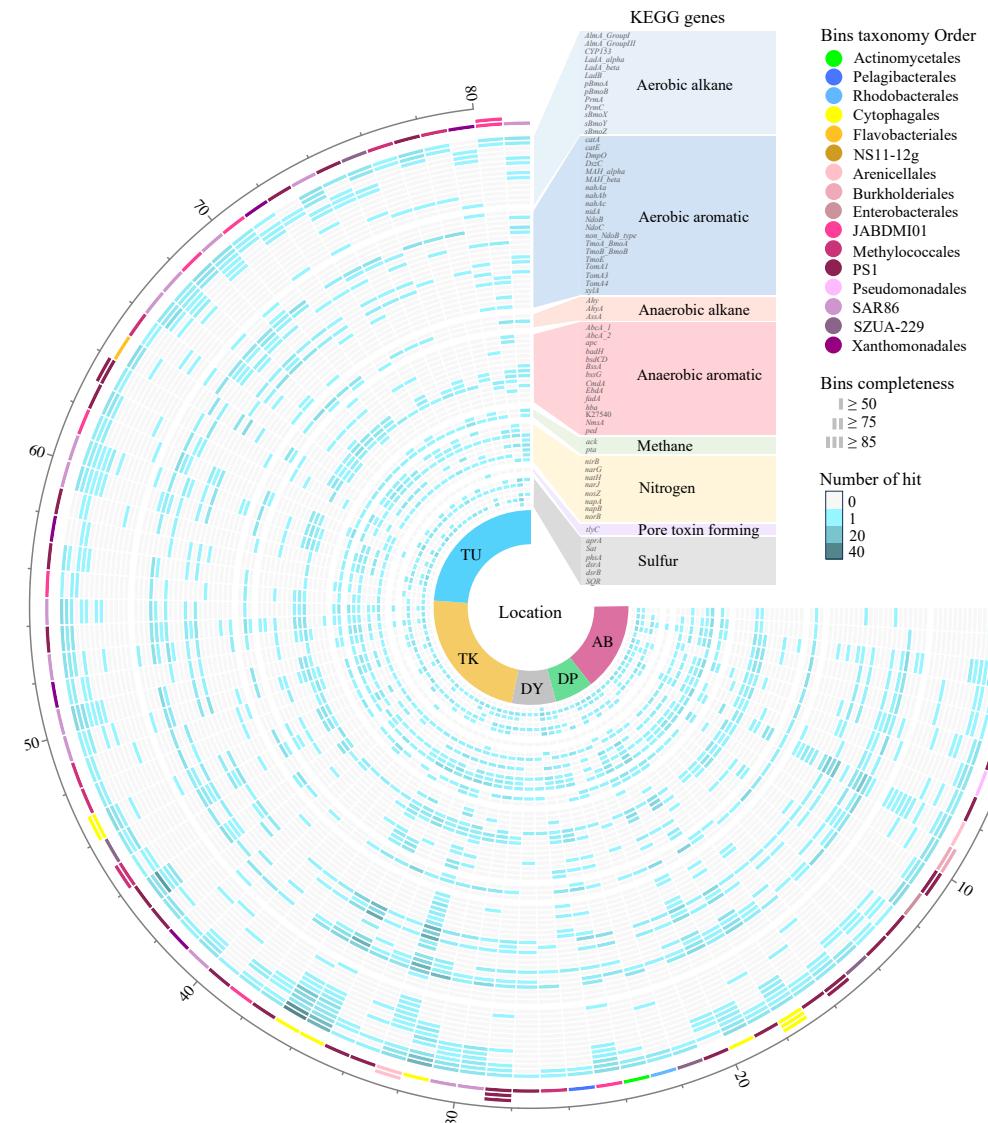
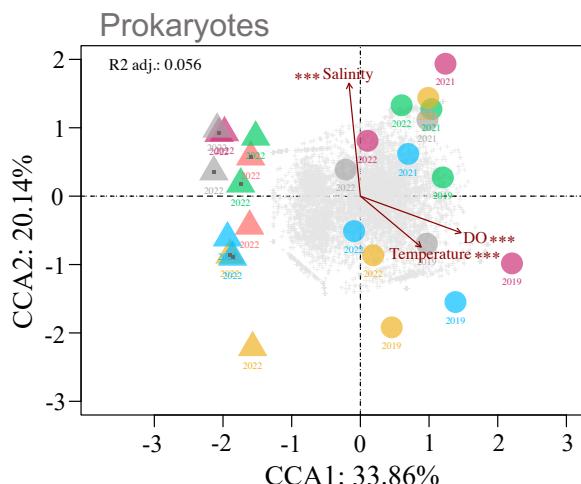
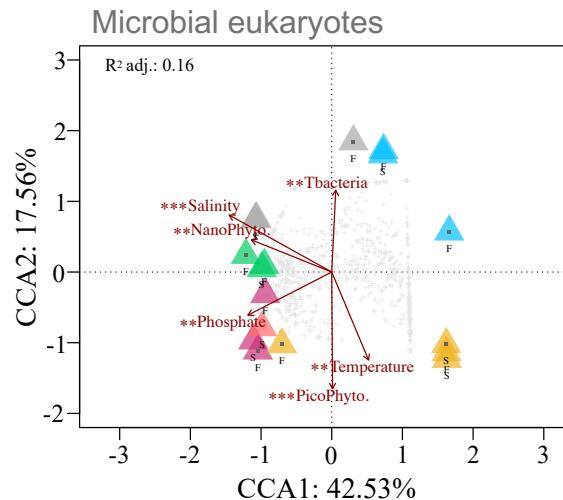
**Objective 2:
Screen for hydrocarbon degradation genes**

Summer genomic surveys of microbial community and screening of hydrocarbon degradation genes



Freyria et al., *in prep.*

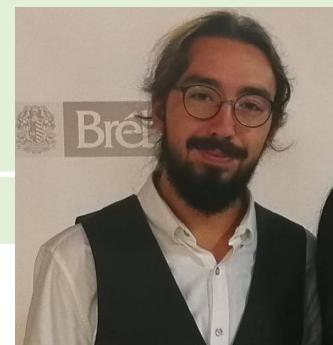
CCA ordination of community composition by beach using Bray-Curtis distances



Bins from Nanopore sequencing and functional annotation of key degradation pathways

Bioremediation properties of hydrocarbon degrading bacteria isolated from Arctic beaches

Lurette et al., 2023. Submitted at CSMJ

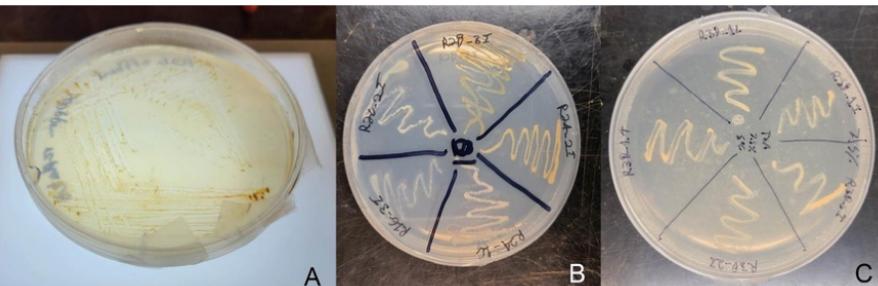


Antoine Lurette, MSc
Candidate

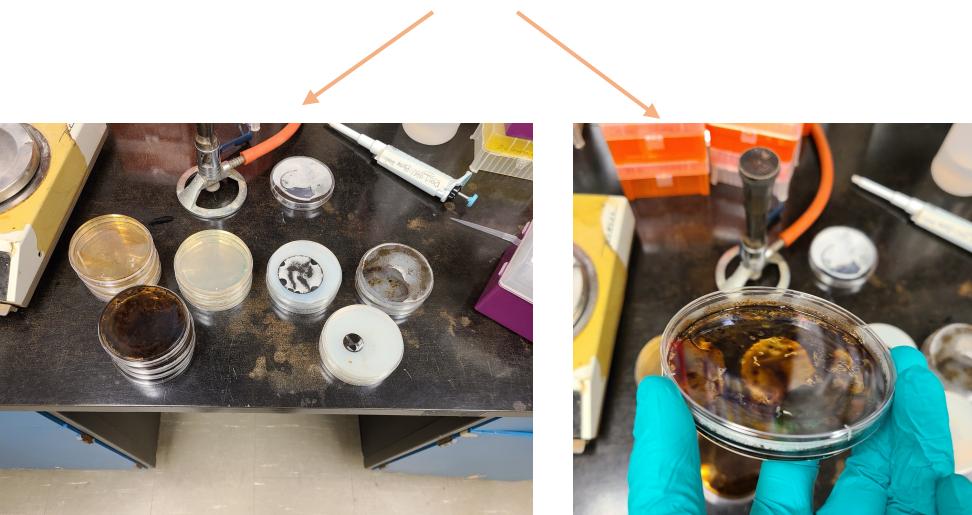
Objective 1: **Isolating Novel hydrocarbon degraders from Northwest Passage beach sediments**



- Sampling Arctic beach sediment
- Solid culture for isolation and growth of isolates
- Identify the taxonomy of those isolates (16S sequencing)



Objective 3: **Assessing the bioremediation potential of hydrocarbon degraders**



- Adding 500 ppm of Ultra low sulfur fuel oil (ULSFO)
- Total Petroleum Hydrocarbon analysis (TPH) using GC-MS

Objective 2: **Whole genome sequencing and screening for hydrocarbon degradation genes**



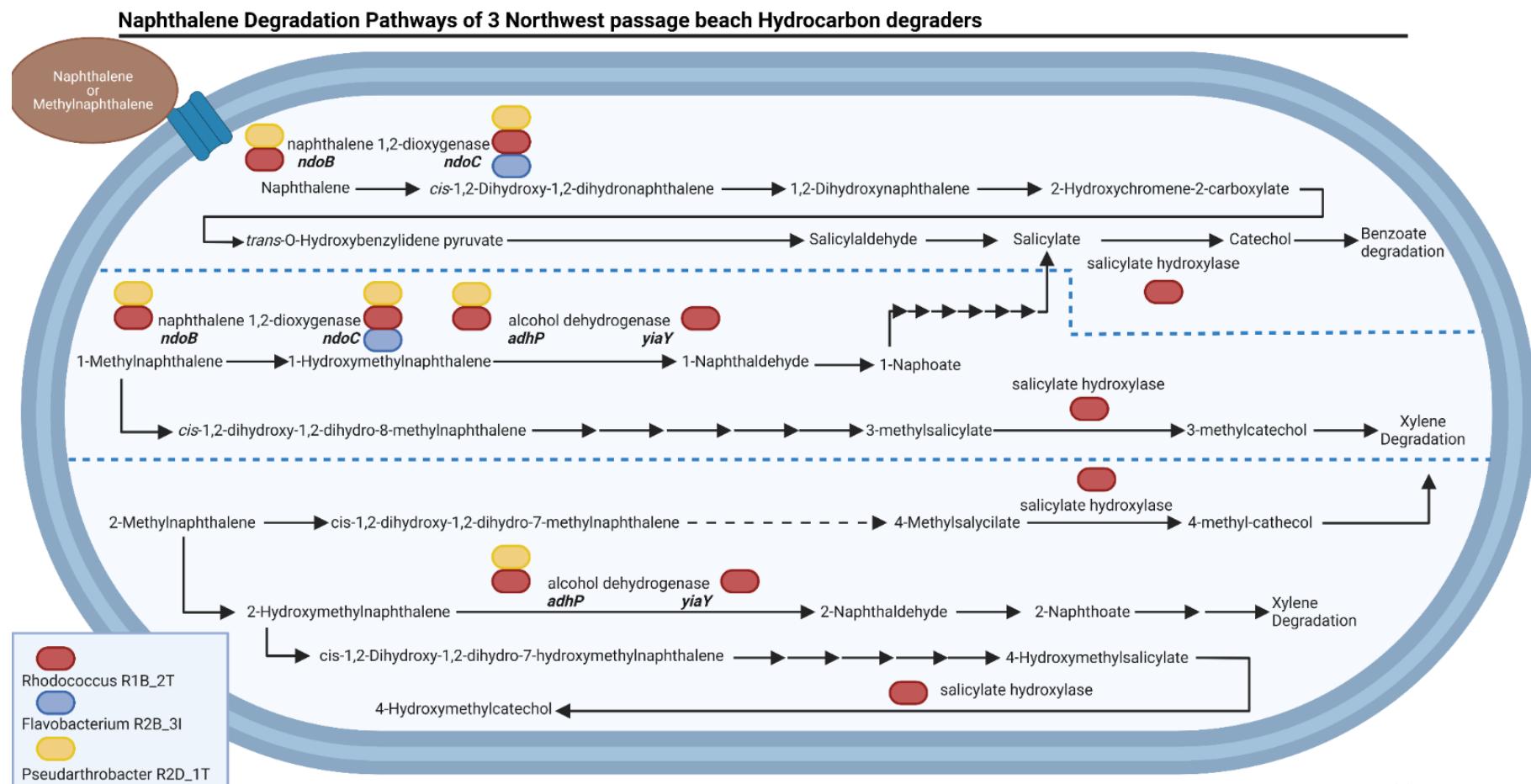
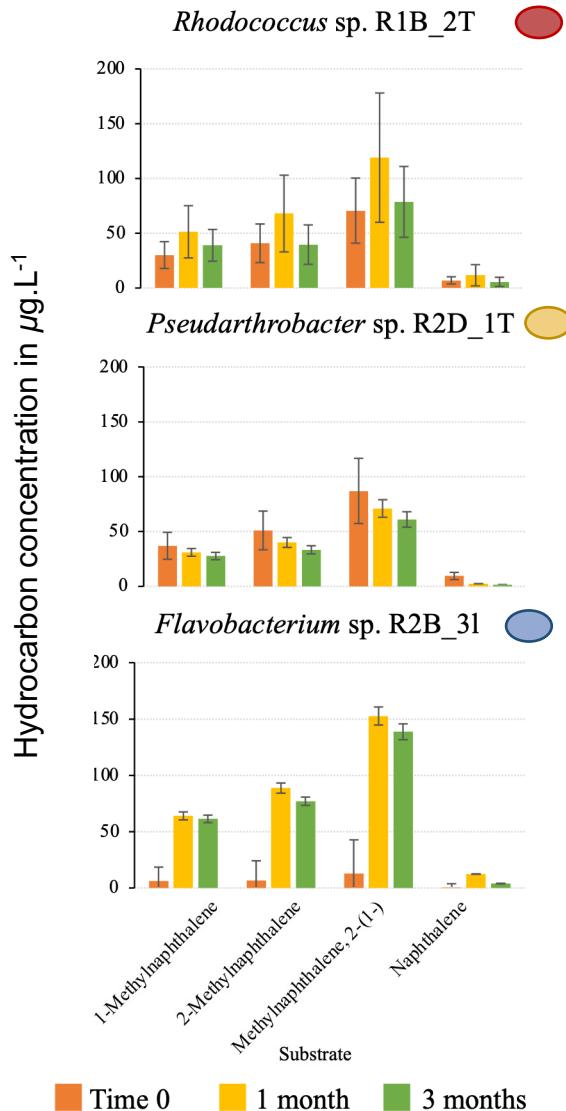
Illumina Novaseq

Bioremediation properties of hydrocarbon degrading bacteria isolated from Arctic beaches

Lurette et al., 2023. Submitted at CSMJ



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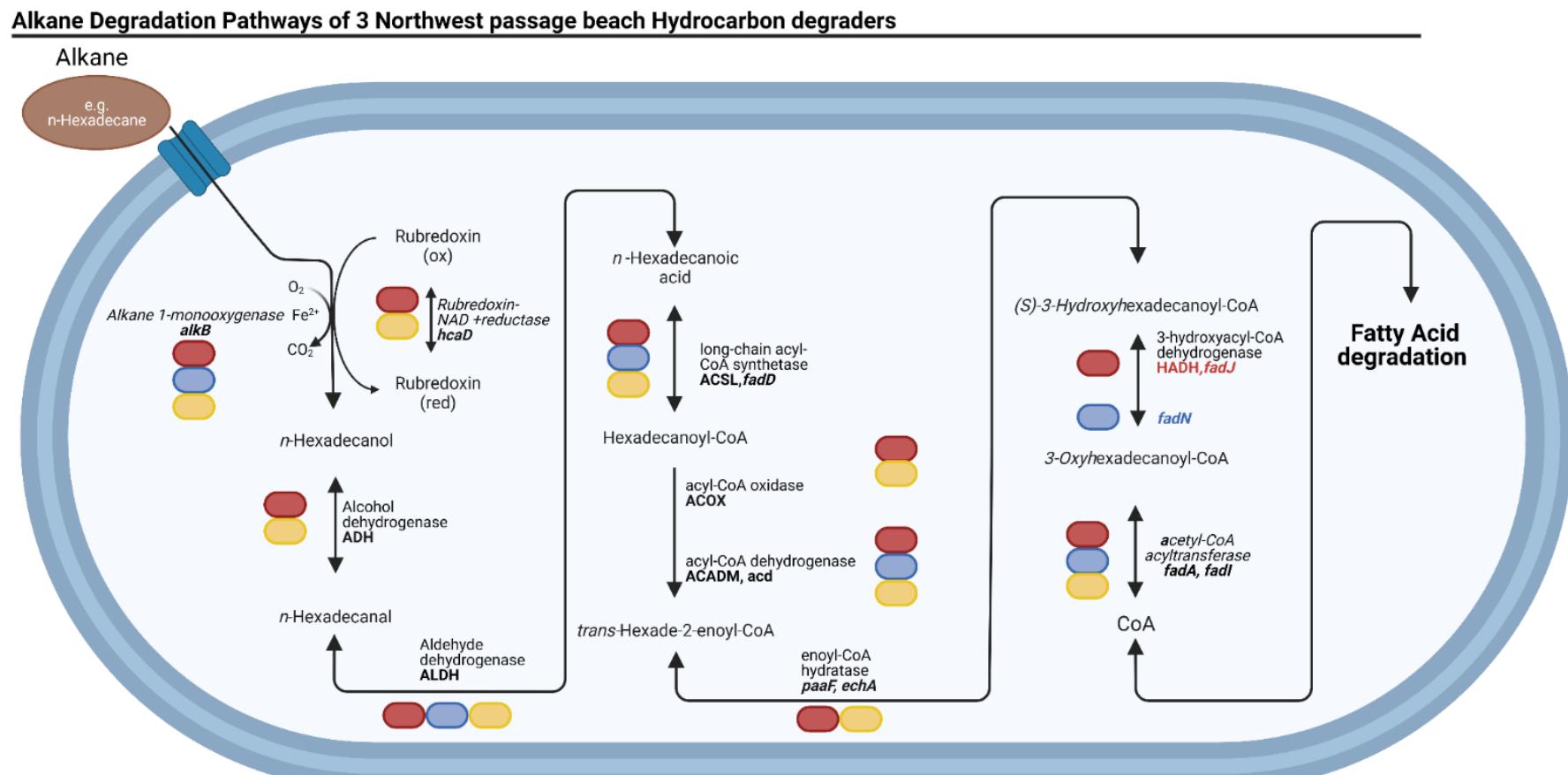
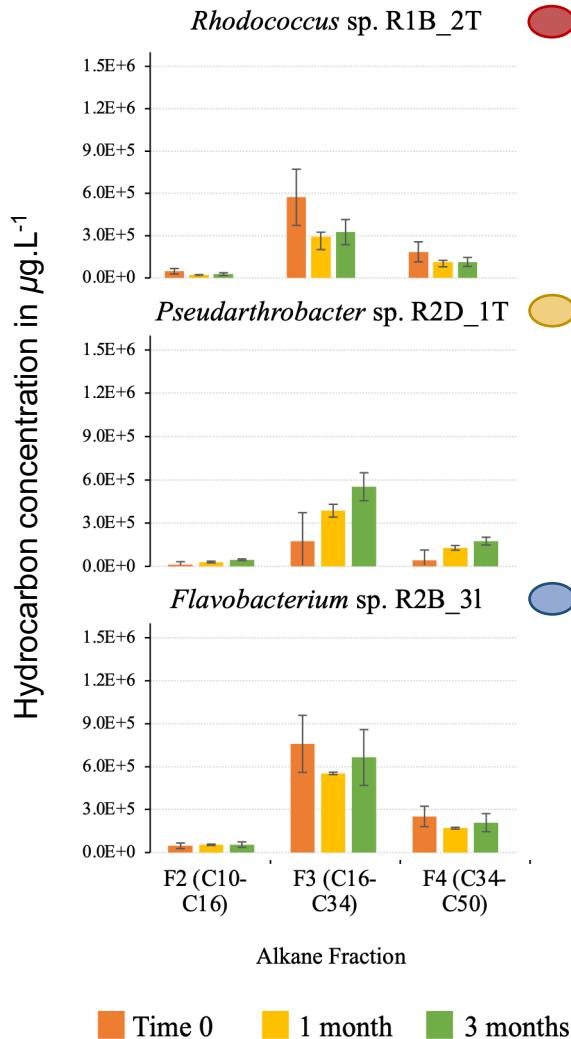


Bioremediation properties of hydrocarbon degrading bacteria isolated from Arctic beaches

Lurette et al., 2023. Submitted at CSMJ



Antoine Lurette, MSc
Candidate



Transcriptomic analyses of 3 representative hydrocarbon degraders from Arctic intertidal beach

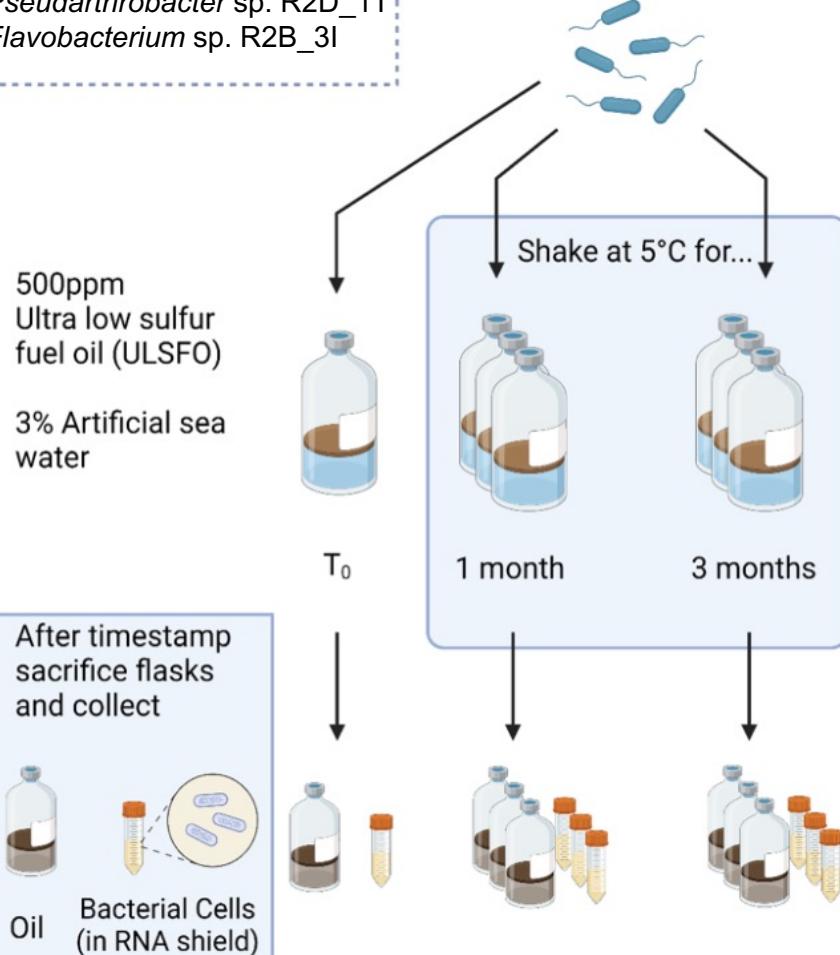
Freyria et al., *In prep.*



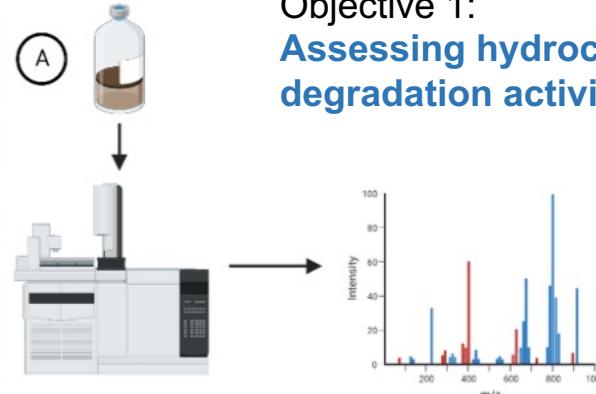
Nastasia Freyria, PDF

- Bacterial strains of interest
- Rhodococcus sp. R1B_2T
 - Pseudarthrobacter sp. R2D_1T
 - Flavobacterium sp. R2B_3I

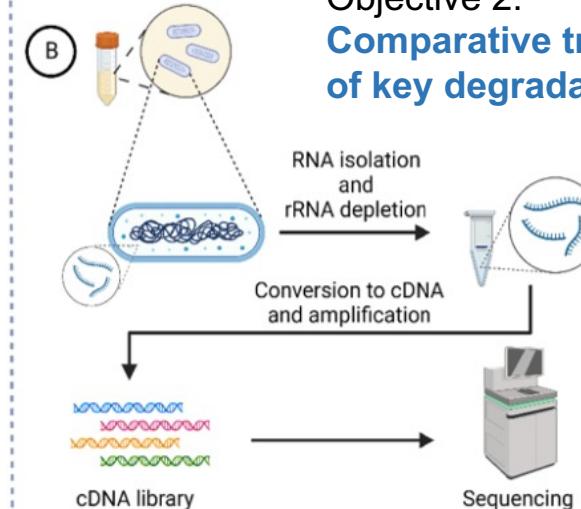
1 copy of this setup
for each strain



Objective 1: Assessing hydrocarbon degradation activity



Objective 2: Comparative transcriptomic and screening of key degradation genes and pathways



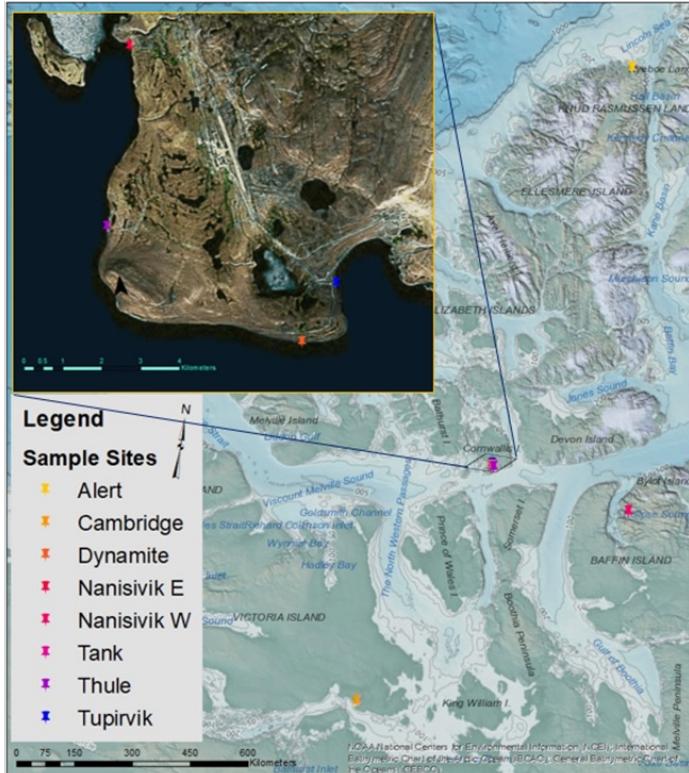
Molecular description of the bioremediation process in-situ and in vitro

Góngora et al., *In prep.*



Esteban Góngora, PhD Candidate

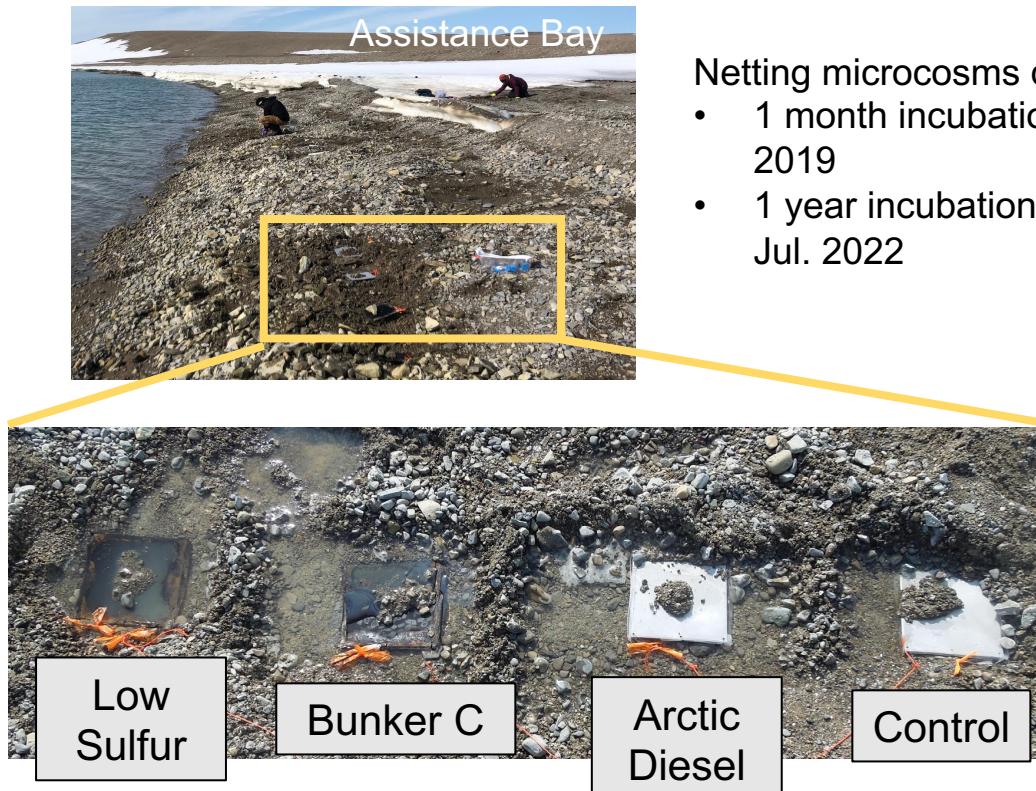
Objective 1: Genomic survey of Arctic beach across the Northwest Passage



Illumina Novaseq sequencing:
• Metagenomes
• Metatranscriptomes

Objective 2: Screen for hydrocarbon degradation genes

Objective 3: In-situ microcosms experiments



Objective 4: Identify taxonomy and assessing hydrocarbon degradation activity

Netting microcosms deployed for:
• 1 month incubation Jul. to Aug. 2019
• 1 year incubation Aug. 2021 to Jul. 2022

- Metagenomic
- TPH analysis using GC-MS



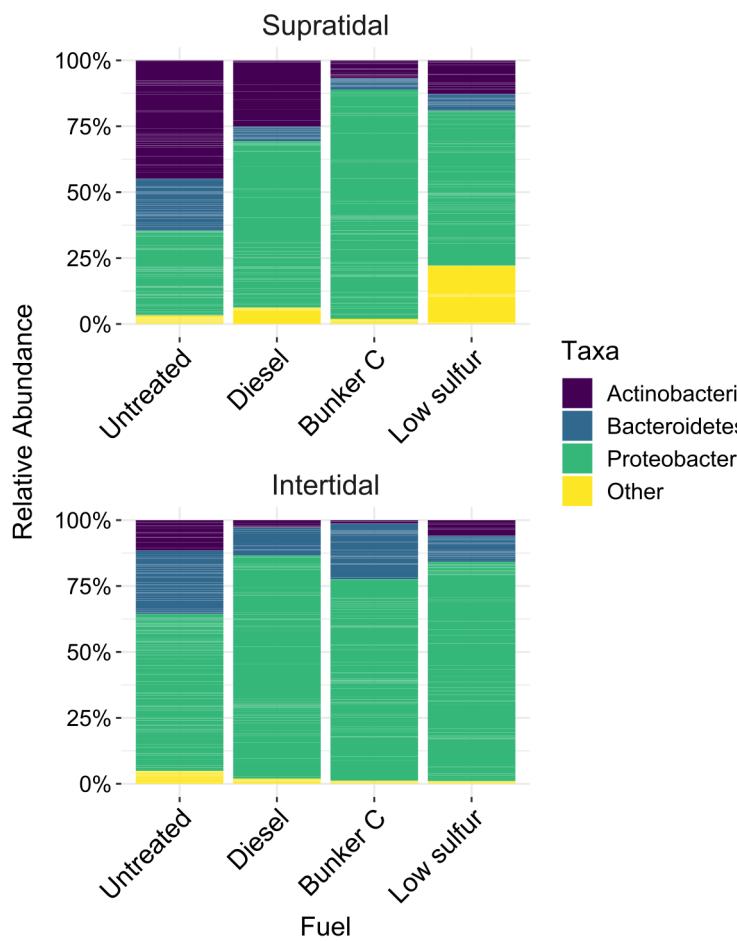


Molecular description of the bioremediation process in-situ and in vitro

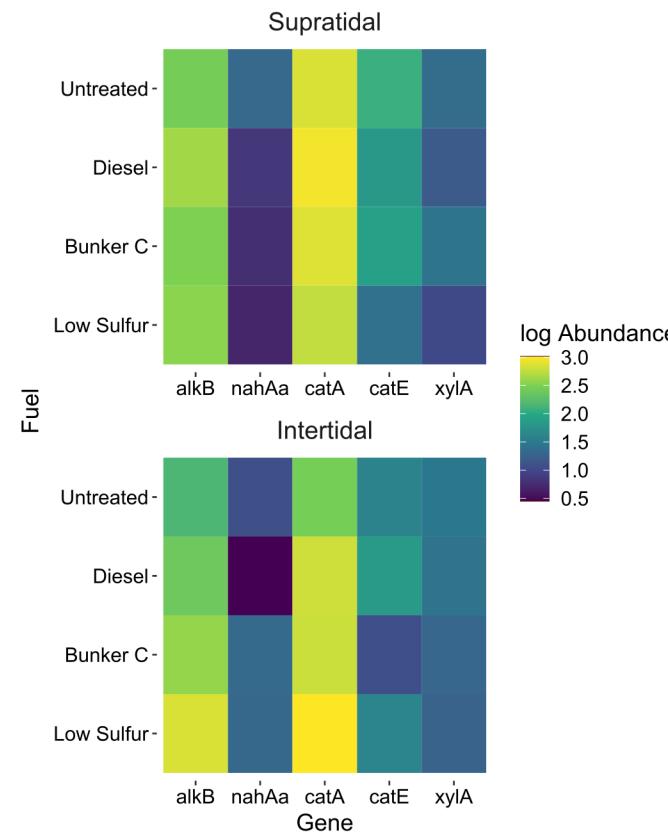
Góngora et al., *In prep.*



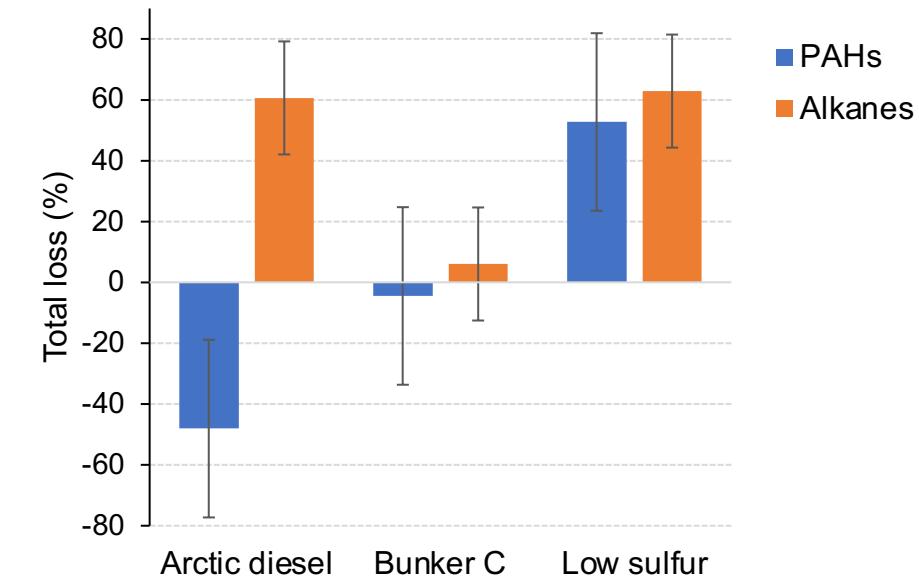
Relative abundance of one month netting
microcosms bacterial community



Abundance of key
hydrocarbon degradation
genes



TPH analysis of intertidal one month in situ microcosms



Column experiment to test effectiveness of nutrient amendment for oil biodegradation on Arctic beach

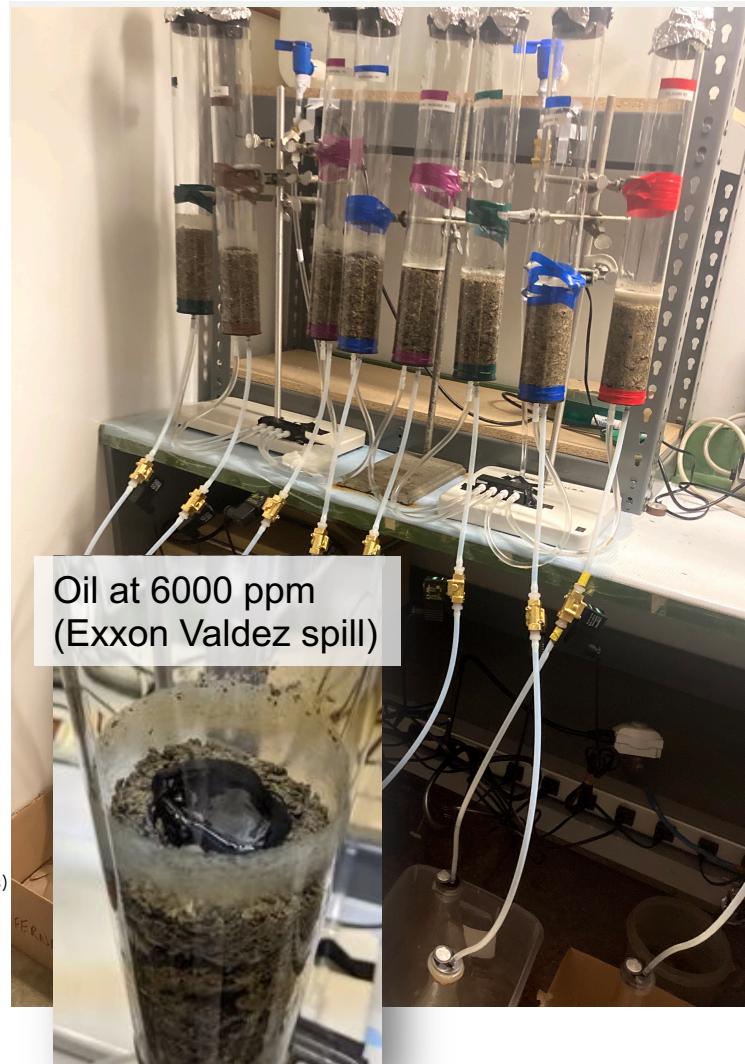
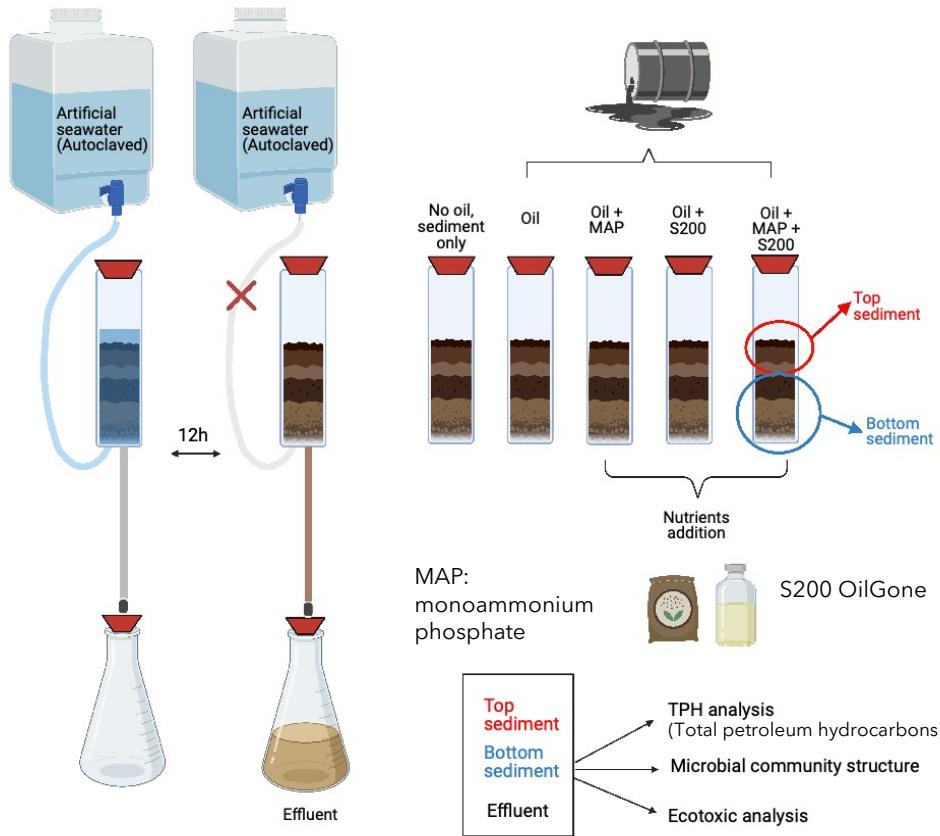
Chen et al., *in prep*



Ya-Jou Chen, PDF

Ex-situ mesocosm experiments used to mimic tidal cycle

- One month incubation: with 2 types of nutrient
- Three months incubation: with nutrient + washing agent



Objective 1:
Assess the hydrocarbon degradation activity

- TPH analyses using GC-MS

Objective 2:
Identify microbial degraders and whole sediment community

- 16S amplicon sequencing
- Metagenomic sequencing



Objective 3:
Screen for hydrocarbon biodegradation genes

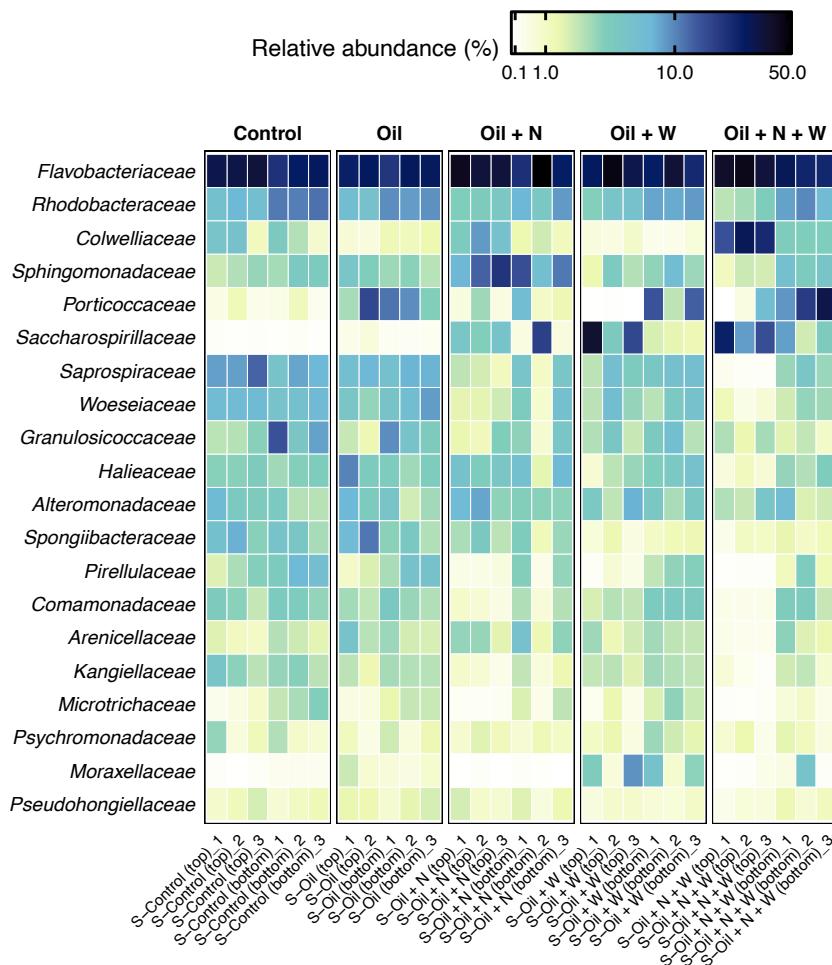
Column experiment to test effectiveness of nutrient amendment for oil biodegradation on Arctic beach

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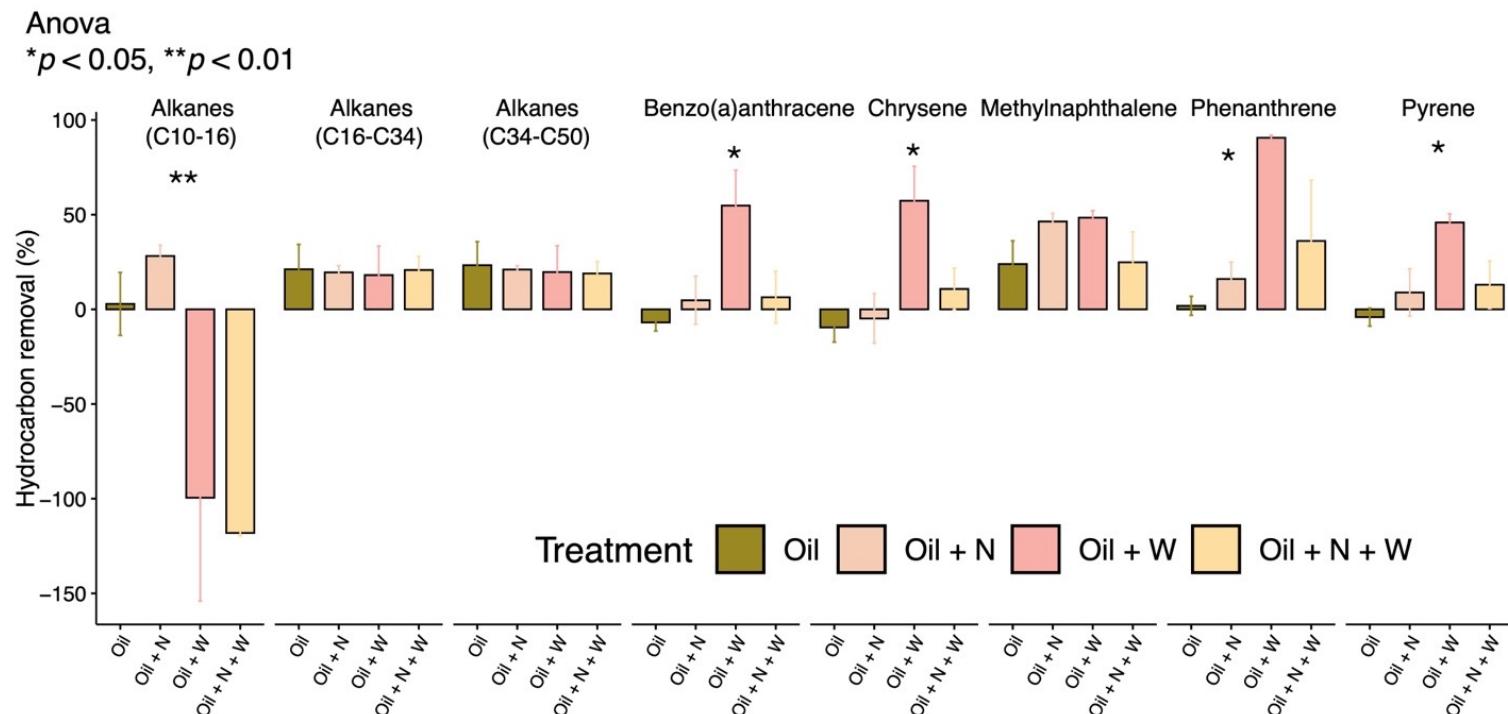


Ya-Jou Chen, PDF

Microbial community structure among the different treatments



TPH analysis compared across different treatments



In conclusion

Genomic surveys of Arctic shorelines

- Solid knowledge of naturally-occurring Arctic shoreline microbial community, their abundance and composition over time
- Evaluate physicochemical properties of sediments and surface seawater and its influence on microbial community

Culture, in-situ microcosm and ex-situ mesocosm

- Isolation of potential novel species
- Assess the potential biodegradation activity directly in the field and recreating the environmental condition in the lab
- Selection of key microbial organisms capable of biodegradation
- Observation of the behavior of microbial organism using different types of oil and with or without nutrient-amendment and washing agent





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Thank you!
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