

Metagenomic insights into diazotrophic communities in the Estuary of the Saint Lawrence: the missing links to understand the nitrogen cycle

Description: We are looking for a motivated student to complete a two-year MSc research project in metagenomics and sedimentary biomarker analysis to unravel past and present diazotrophic dynamics under hypoxia and climate change in the Estuary of the Saint Lawrence.

Background: The Estuary of the Saint Lawrence occupies a pivotal position at the interface between freshwater inputs from the Great Lakes and the North Atlantic, making it a dynamic laboratory for studying nitrogen cycling under rapidly changing environmental conditions. Over the past two centuries, human activities have transformed this once well-oxygenated system into one characterised by seasonal surface nitrogen limitation and persistent deep-water hypoxia. Such shifts not only constrain primary productivity but also alter carbon sequestration and greenhouse-gas fluxes, with consequences that reverberate far beyond the estuary itself. By exploring how diverse diazotrophic assemblages, from phototrophic symbioses in sunlit surface waters to anaerobic microbes thriving in low-oxygen bottom layers, contribute to the estuarine nitrogen budget, this project addresses fundamental questions about ecosystem resilience and biogeochemical feedback in a warming world.

Despite growing recognition that biological nitrogen fixation occurs outside tropical gyres in temperate estuaries, subarctic seas and oxygen-depleted zones, the Estuary of the Saint Lawrence remains virtually unexplored. No study has yet combined sedimentary biomarker records (including *nifH* gene, hopanoid lipids and isotopic signatures) with modern metagenomic surveys to reconstruct how diazotrophic activity has evolved from the pre-industrial era to the present day. By filling this critical gap, the project will reveal how hypoxia and anthropogenic nutrient loading have reorganised nitrogen-fixing communities over time, establishing a robust framework for predicting how these processes will respond to future climate change and informing strategies to safeguard estuarine health.

Project Objectives: This project aims to uncover the diversity of diazotrophic communities across oxygen and salinity gradients in the Estuary of the Saint Lawrence using metagenomics and sedimentary biomarkers.

A dual approach will consist in:

1. Amplify, sequence, and analyse *nifH* gene amplicons from surface and hypoxic bottom waters to characterise diazotroph diversity, distribution, and community shifts across environmental gradients. This will provide insights into the relative contribution of distinct lineages and their ecological partitioning.
2. Analyse sedimentary biomarkers (*nifH* gene copies, hopanoid lipids) to reconstruct historical shifts in diazotrophic activity from the pre-industrial era to the present.

Framework: This MSc project will be carried out at the Institut des sciences de la mer (ISMER) at the Université du Québec à Rimouski (UQAR). The student will be part of a dynamic, multidisciplinary research environment, and will have the opportunity to develop knowledge and practical skills in bioinformatics, marine microbiology and biogeochemistry. In addition, the student will participate in oceanographic fieldwork at sea as part of their training, gaining hands-on experience in sampling and environmental data collection.

This project is embedded within the CFREF – Transforming Climate Action (TCA) programme and is carried out in collaboration with Dalhousie University. It draws upon shared expertise in marine biogeochemistry, microbial ecology, and metagenomics. Sequencing and bioinformatics analyses will be conducted with support from Dalhousie's genomics core facility.

Funding: A fully funded two-year scholarship is available for the successful candidate. Research costs are fully covered by the project. Other funding opportunities are available for dissemination and development activities through TCA, UQAR student support funds, and the Québec-Océan research cluster.

Research areas: biomarkers, metagenomics, microbiology, molecular ecology, oceanography

Requirements and conditions:

- Bachelor's degree in biology, ecology or other related disciplines .
- Demonstrate a strong interest for research in oceanography.
- Experience in computer science or molecular biology would be an asset.
- Candidates with atypical academic backgrounds are encouraged to apply and should detail what they learned from their experience in their cover letter.

Application: Please send your CV, transcripts and a letter of motivation including the contact details of two referees, to the attention of Prof. El Mahdi Bendif, elmahdi_bendif@uqar.ca, before the 5th of Décembre 2025.

Please note that ISMER is able to offer assistance during the recruitment process. We invite you to share your needs with us if necessary. ISMER places great importance on the diversity of its student community where individual differences are recognized, appreciated, respected and valued, with the aim of fostering the full potential of each person and building on their unique talents and strengths.

Relevant bibliography:

Bonnet, S., Benavides, M., Le Moigne, F.A.C. *et al.* (2023) Diazotrophs are overlooked contributors to carbon and nitrogen export to the deep ocean. *ISME J* 17, 47–58. <https://doi.org/10.1038/s41396-022-01319-3>

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Hagino, K., Onuma, R., Kawachi, M., & Horiguchi, T. (2013). Discovery of an endosymbiotic nitrogen-fixing cyanobacterium UCYN-A in *Braarudosphaera bigelowii* (Prymnesiophyceae). *PloS one*, 8(12), e81749.

Pascal, L., Cloutier-Artiwat, F., Zanon, A., Wallace, D. W. R., & Chaillou, G. (2025). New Deoxygenation Threshold for N₂ and N₂O Production in Coastal Waters and Sediments. *Global Biogeochemical Cycles*, 39(8), e2024GB008218. <https://doi.org/10.1029/2024GB008218>

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