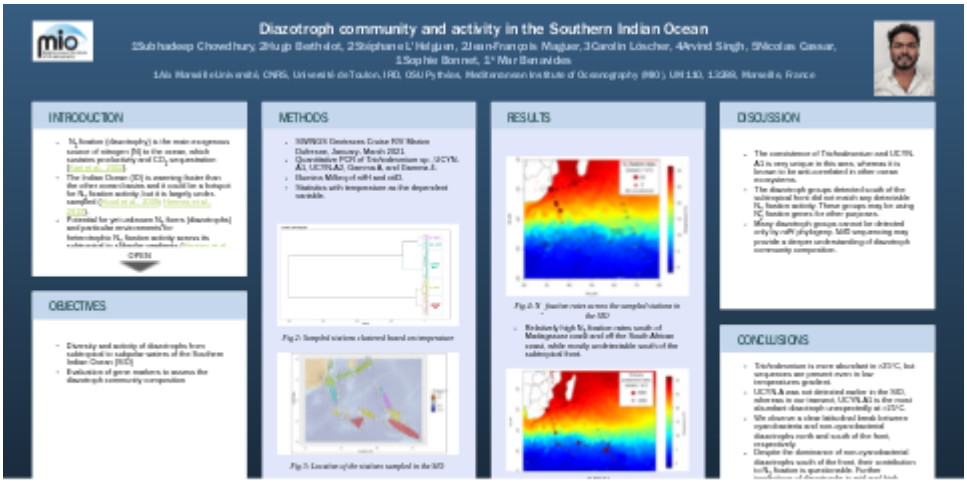
Diazotroph community and activity in the Southern Indian Ocean



1Subhadeep Chowdhury, 2Hugo Berthelot, 2Stéphane L'Helguen, 2Jean-François Maguer, 3Carolin Löscher, 4Arvind Singh, 5Nicolas Cassar, 1Sophie Bonnet, 1*Mar Benavides

1Aix Marseille Université, CNRS, Université de Toulon, IRD, OSU Pythéas, Mediterranean Institute of Oceanography (MIO), UM 110, 13288, Marseille, France

PRESENTED AT:

INTRODUCTION

- N_2 fixation (diazotrophy) is the main exogenous source of nitrogen (N) to the ocean, which sustains productivity and CO_2 sequestration (Karl et al., 2002 (https://link.springer.com/article/10.1023%2FA%3A1015798105851)).
- The Indian Ocean (IO) is warming faster than the other ocean basins and it could be a hotspot for N_2 fixation activity, but it is largely under-sampled (Hood et al., 2009 (https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2007GM000714); Hermes et al., 2019 (https://www.frontiersin.org/articles/10.3389/fmars.2019.00355/full)).
- Potential for yet unknown N_2 fixers (diazotrophs) and particular environments for heterotrophic N_2 fixation activity across its subtropical to subpolar gradients (Hermes et al., 2019 (https://www.frontiersin.org/articles/10.3389/fmars.2019.00355/full)).

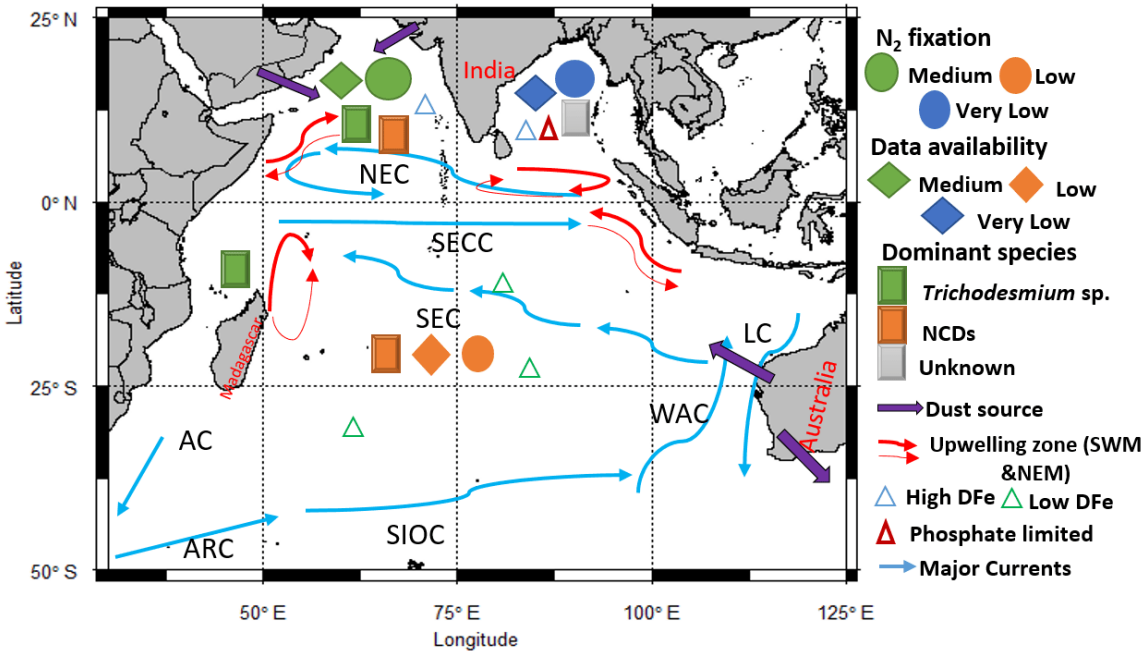


Fig 1: Summary of distribution of N_2 fixation, currents, biogeochemical parameters, data, dominant species, and dust source in the Indian Ocean (IO)

Major Currents: AC, ARC- Agulhas & Agulhas Return Current; SIOC- South Indian Ocean Current; LC- Leeuwin Current; WAC- West Australian Current; SEC, SECC- South Equatorial & South Equatorial Counter Current; NEC- North Equatorial Current

SWM: South West Monsoon; NEM: North East Monsoon

OBJECTIVES

- Diversity and activity of diazotrophs from subtropical to subpolar waters of the Southern Indian Ocean (SIO)
- Evaluation of gene markers to assess the diazotroph community composition

METHODS

- SWINGS Geotraces Cruise R/V Marion Dufresne, January- March 2021.
- Quantitative PCR of *Trichodesmium sp.*, UCYN-A1, UCYN-A2, Gamma A, and Gamma 4.
- Illumina MiSeq of *nifH* and *nifD*.
- Statistics with temperature as the dependent variable.

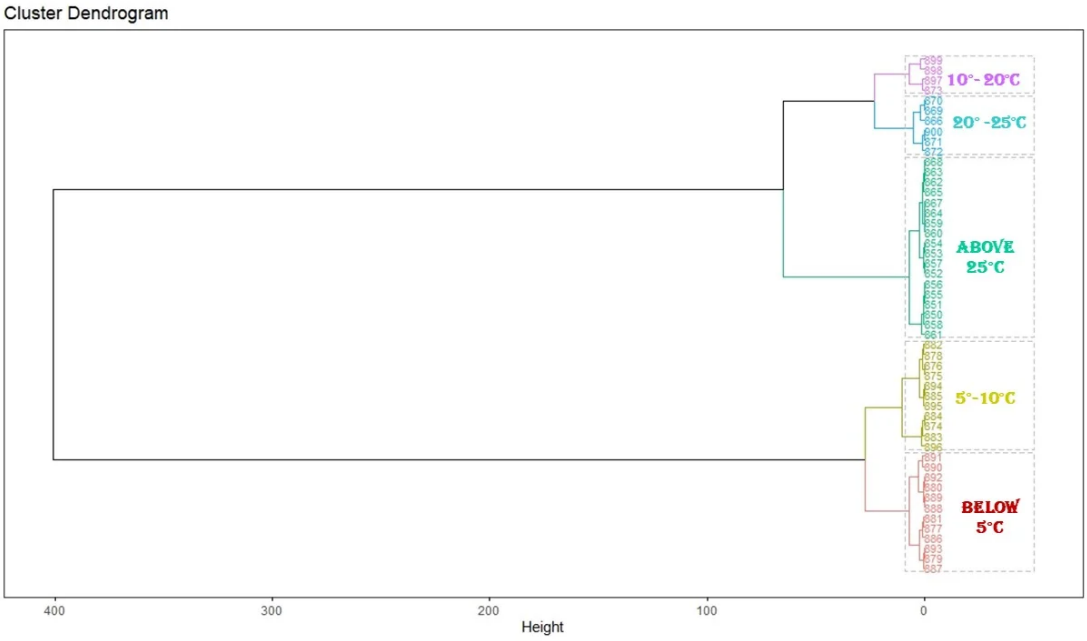


Fig 2: Sampled stations clustered based on temperature

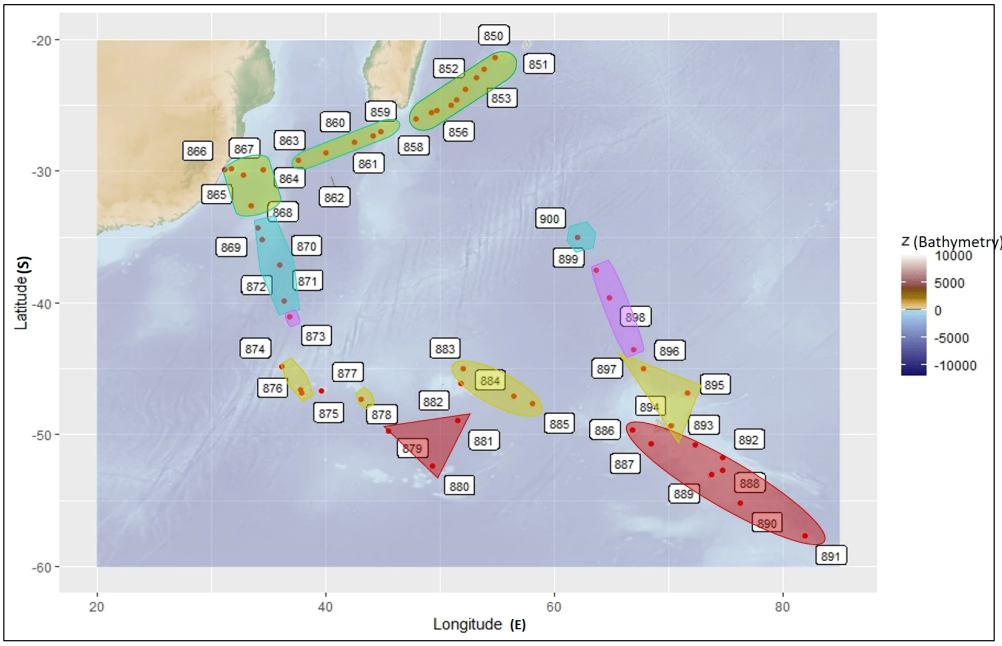


Fig 3: Location of the stations sampled in the SIO

RESULTS

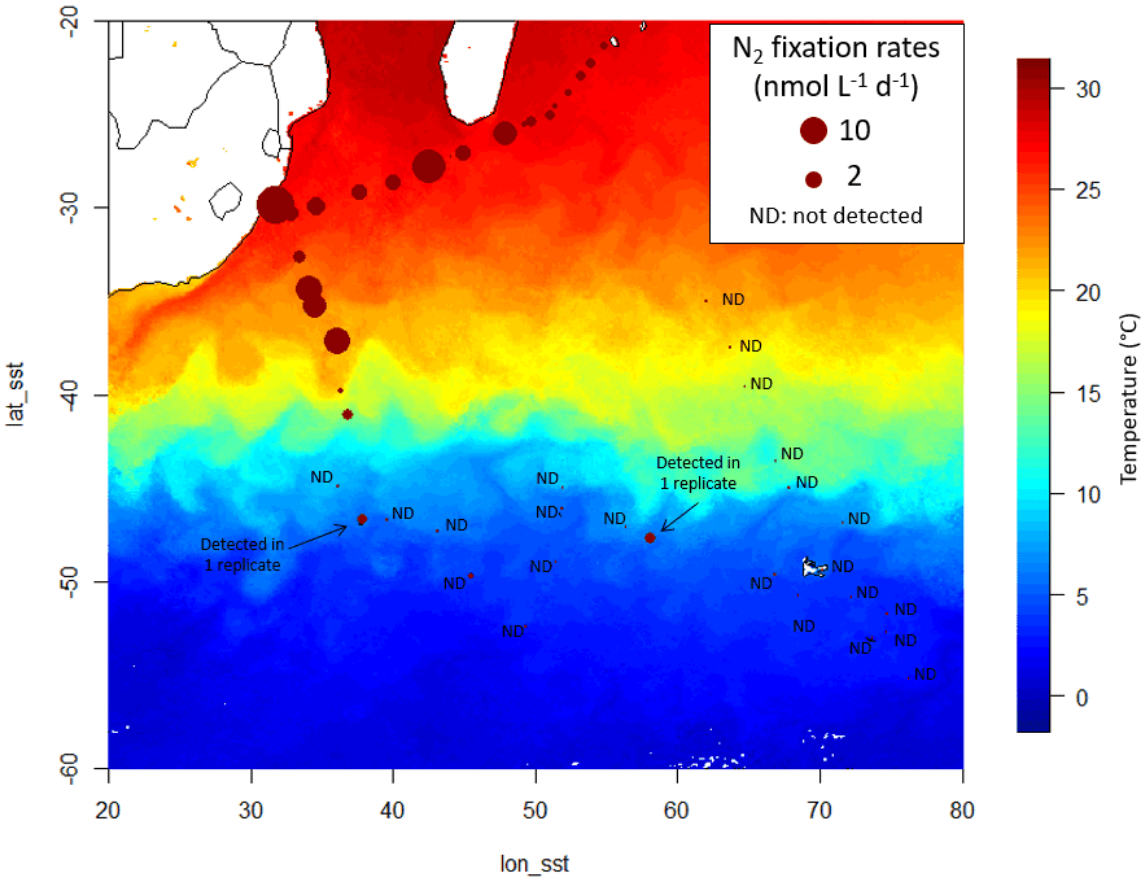


Fig 4: N_2 fixation rates across the sampled stations in the SIO

- Relatively high N_2 fixation rates south of Madagascar coast and off the South African coast, while mostly undetectable south of the subtropical front.

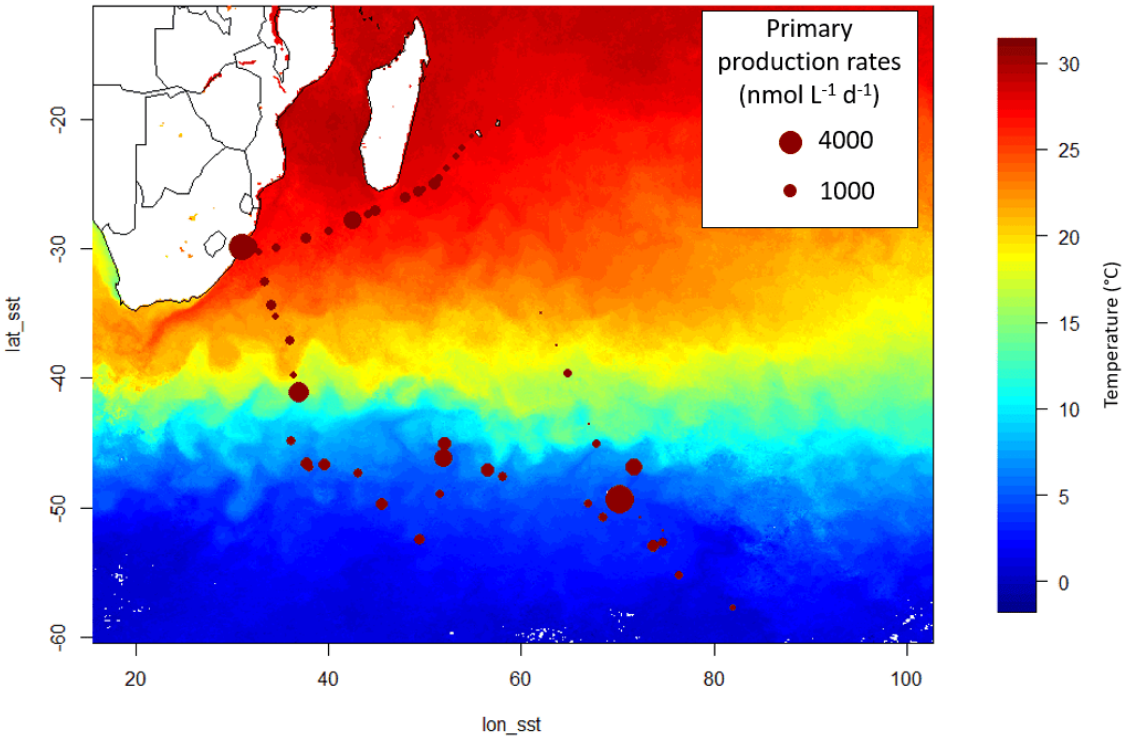


Fig 5: Primary productivity across the sampled stations in the SIO

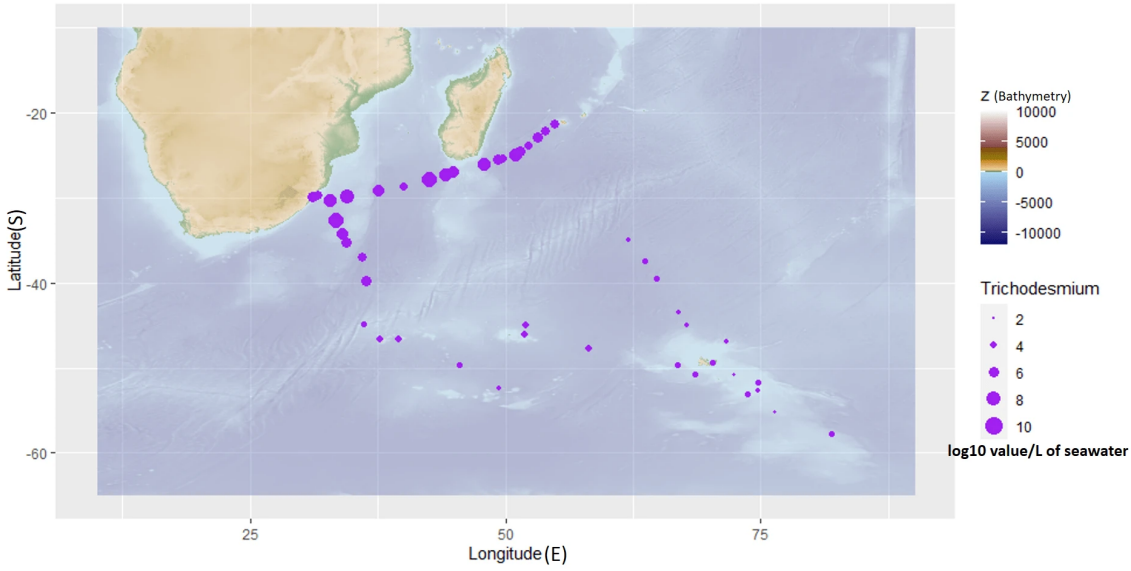


Fig 6: qPCR abundance of the nifH gene of Trichodesmium in the SIO

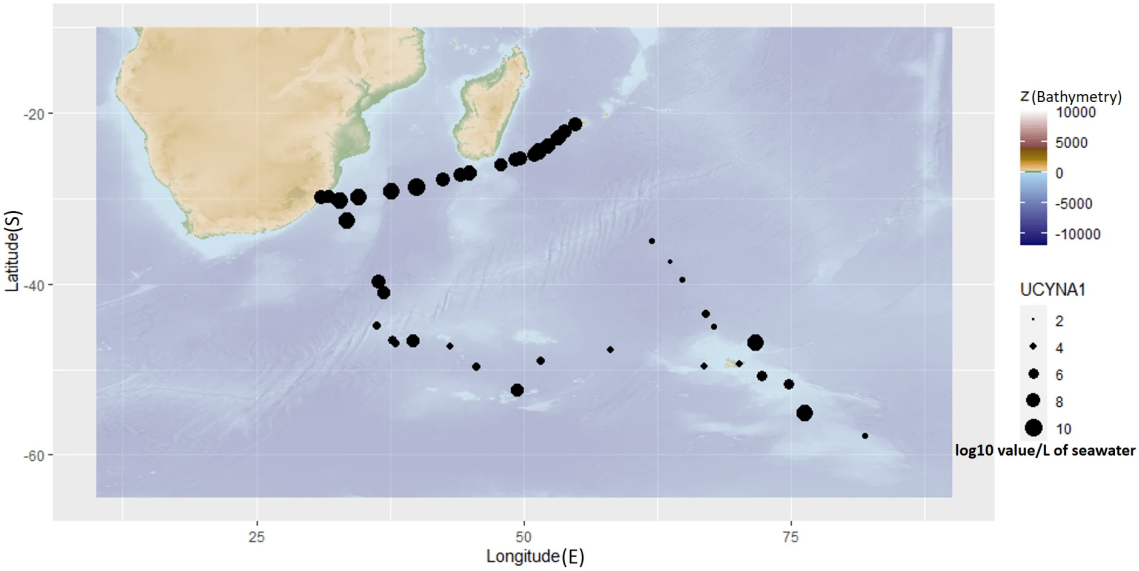


Fig 7: qPCR abundance of the nifH gene of UCYN-A1 in the SIO

- *Trichodesmium* and UCYN-A1 are more abundant in higher temperature

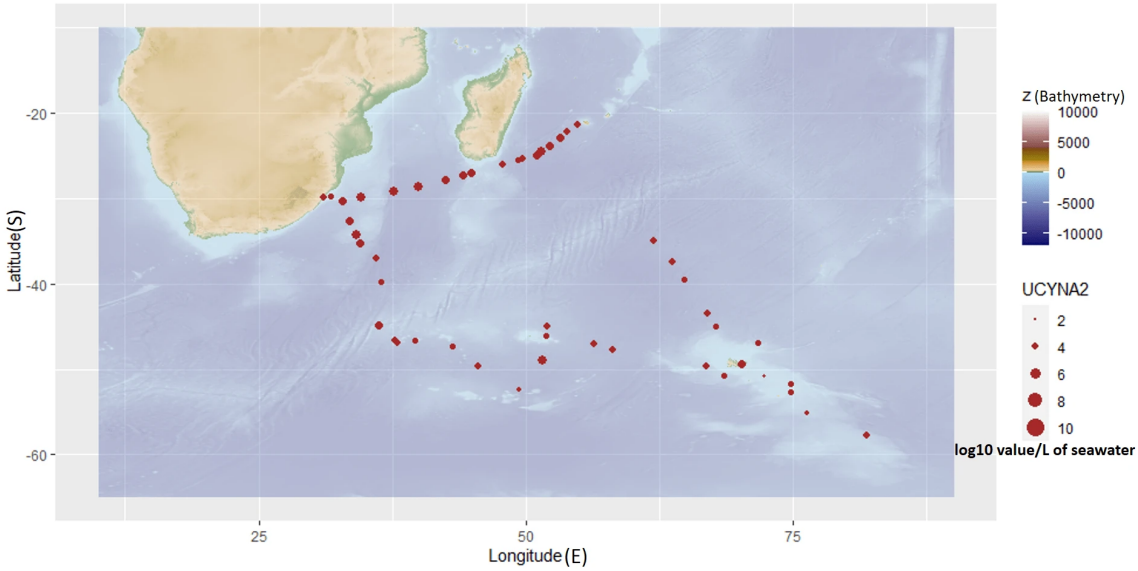


Fig 8: qPCR abundance of the nifH gene of UCYN-A2 in the SIO

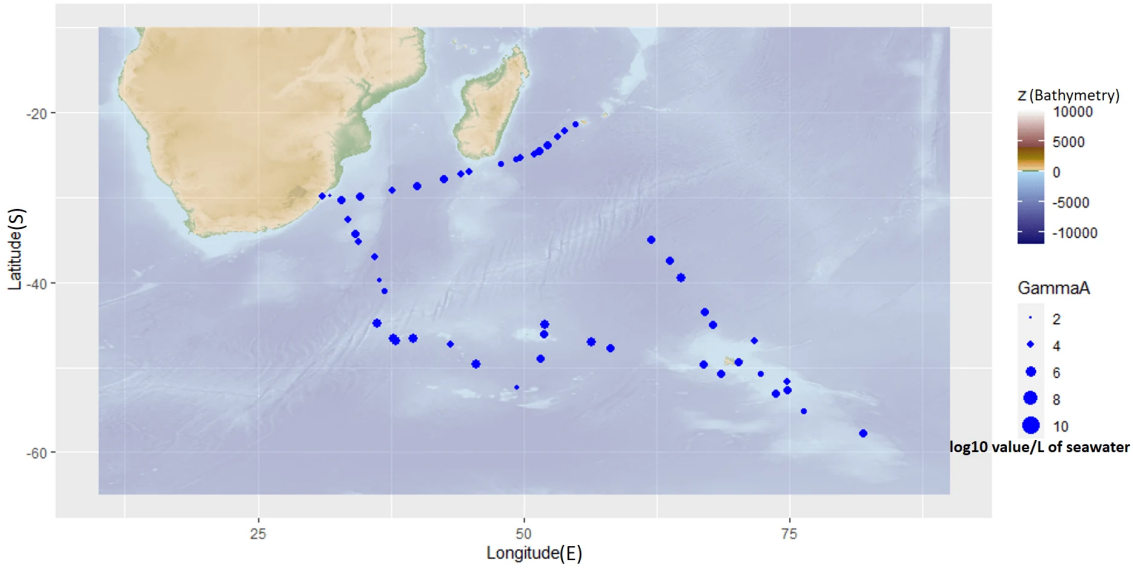


Fig 9: qPCR abundance of the nifH gene of Gamma A in the SIO

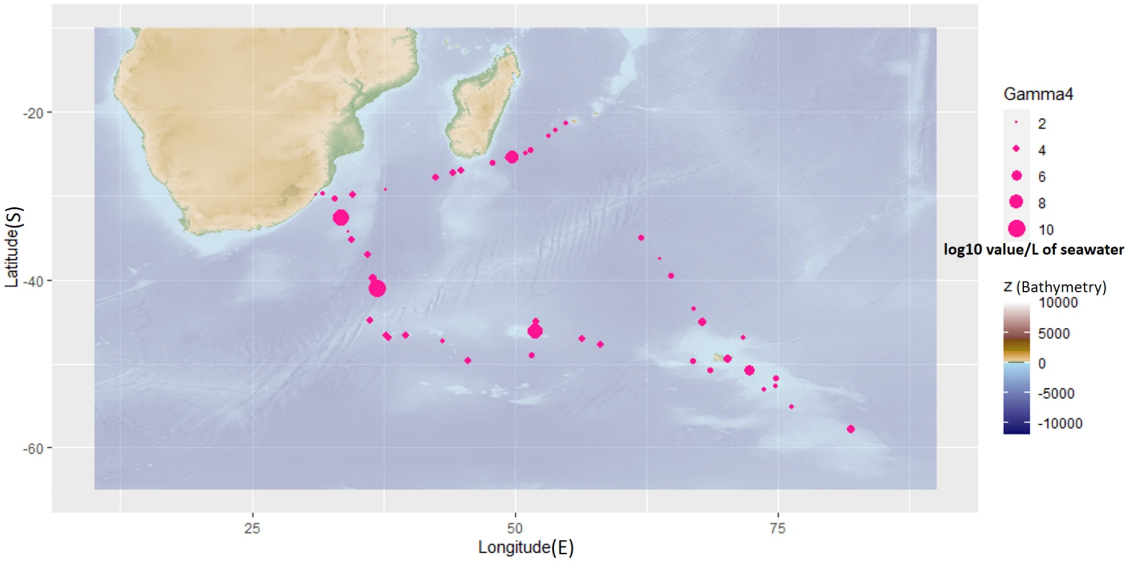


Fig 10: qPCR abundance of the nifH gene of Gamma 4 in the SIO

- Spatial gradients of diazotrophs abundance are well observed in *Trichodesmium* and UCYN-A1 across the transect.
- UCYN-A2, Gamma A, and Gamma 4 are more evenly distributed across SIO.

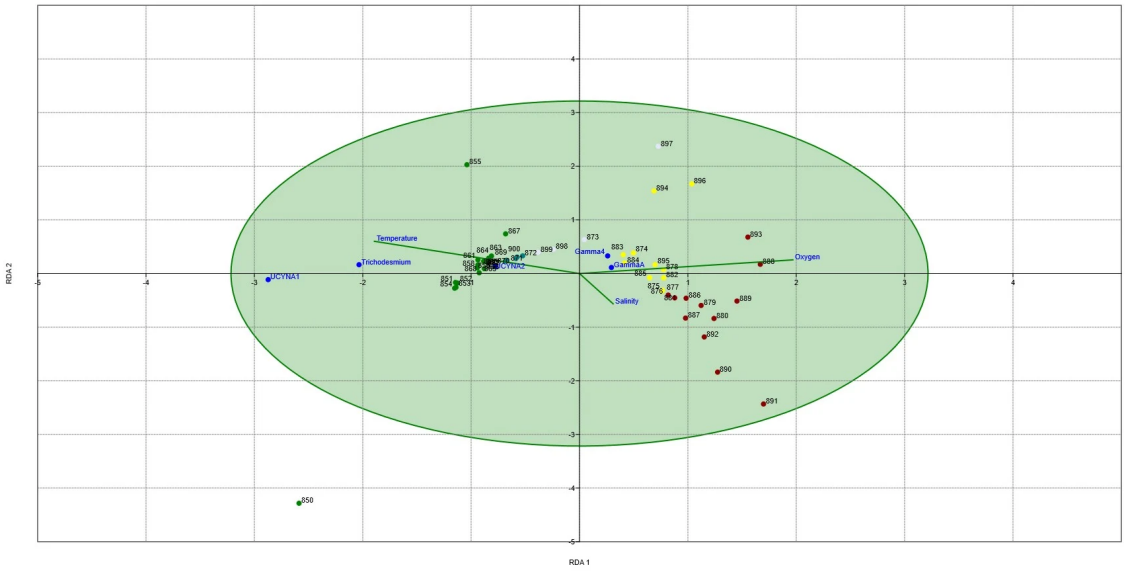


Fig 11: Redundancy analysis (RDA)

- RDA shows the most important environmental factor is temperature, influencing *Trichodesmium* abundance and Oxygen for Gamma A and Gamma 4 abundance.

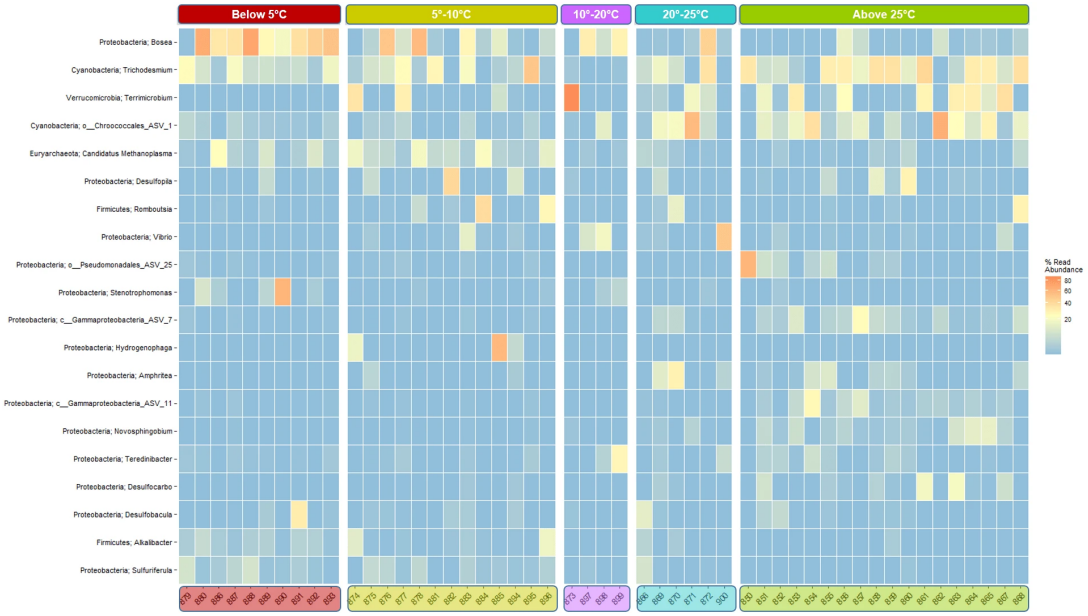


Fig 12: Diazotrophs community composition across temp. gradients in the SIO (top 20 most abundant ASVs based on Illumina nifH data)

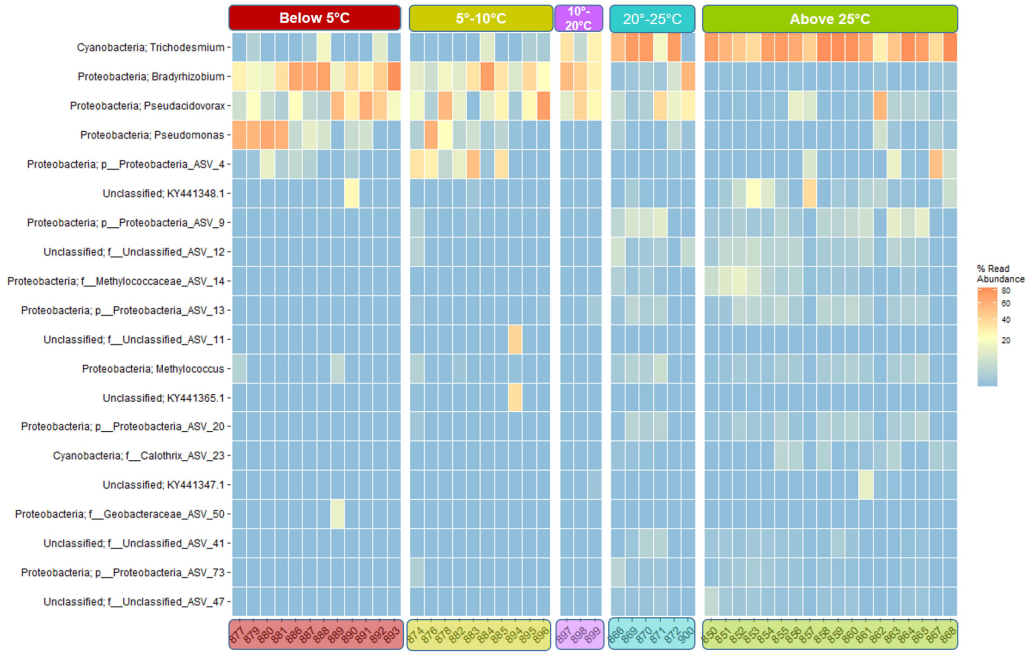


Fig 13: Diazotrophs community composition across temp. gradients in the SIO (top 20 most abundant ASVs based on Illumina nifD data)

- *Trichodesmium* was dominant on the north of the subtropical front and Proteobacteria with putative sulfate and iron-reducing metabolism were dominant south of the subtropical front

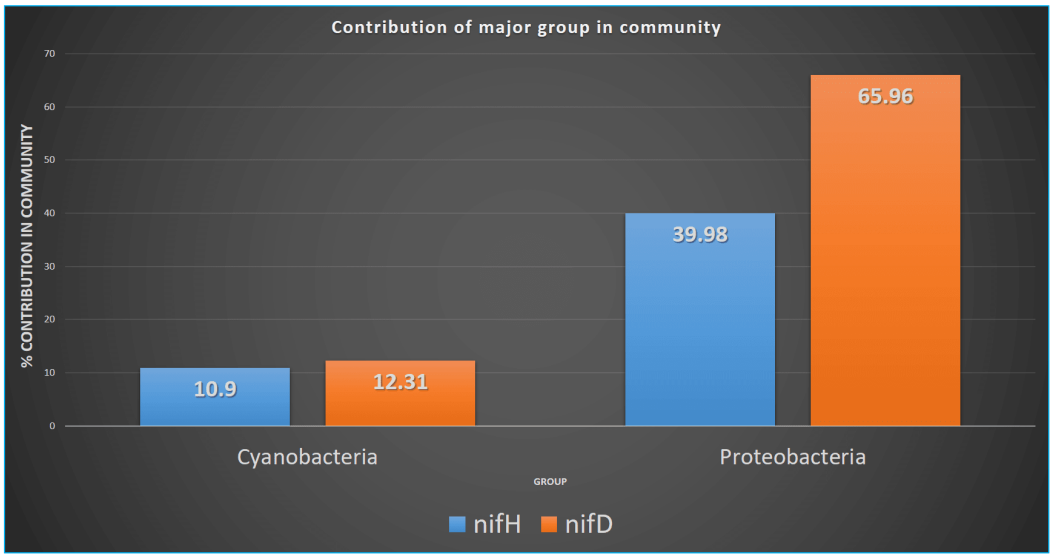


Fig 14: Comparison of major phylum group contributing to the diazotroph community in the SIO based on nifH and nifD dataset

- The contribution of nifD is much higher for Proteobacterial diazotrophs (compared through phylum level ASVs)

DISCUSSION

- The coexistence of *Trichodesmium* and UCYN- A1 is very unique in this area, whereas it is known to be anti-correlated in other ocean ecosystems.
- The diazotroph groups detected south of the subtropical front did not match any detectable N_2 fixation activity. These groups may be using N_2 fixation genes for other purposes.
- Many diazotroph groups cannot be detected only by *nifH* phylogeny. *nifD* sequencing may provide a deeper understanding of diazotroph community composition.

CONCLUSIONS

- *Trichodesmium* is more abundant in >25°C, but sequences are present even in low temperatures gradient.
- UCYN-A was not detected earlier in the SIO, whereas in our transect, UCYN-A1 is the most abundant diazotroph unexpectedly at >25°C.
- We observe a clear latitudinal break between cyanobacteria and non-cyanobacterial diazotrophs north and south of the front, respectively.
- Despite the dominance of non-cyanobacterial diazotrophs south of the front, their contribution to N_2 fixation is questionable. Further inspections of diazotrophs in mid-and high-latitudes are needed.

DISCLOSURES

- IFCPAR/CEFIPRA for the grants of the projects “DINDE” endorsed by IIOE-2
- PURE OCEAN for the grants of the projects “IDEFIX”
- SC would also like to thank the Mediterranean Institute of Oceanography (MIO), Aix Marseille University (AMU), and Institut de recherche pour le développement (IRD) for the facilities and support.
- Special thanks to Hugo Berthelot and Christian Furbo Reeder

AUTHOR INFORMATION

[1]Presenting Author: Subhadeep Chowdhury

Aix Marseille Université, CNRS, Université de Toulon, IRD, OSU Pythéas, Mediterranean Institute of Oceanography (MIO), UM 110, 13288, Marseille, France

subhadeep.chowdhury@mio.osupytheas.fr (mailto:subhadeep.chowdhury@mio.osupytheas.fr)

www.oceanbridges.net (http://www.oceanbridges.net/)

[2]*Hugo Berthelot, Stéphane L'Helguen, Jean-François Maguer*

Laboratoire des sciences de l'environnement marin, IUEM, Université de Brest-UMR 6539 CNRS/UBO/IRD,Technopole Brest-Iroise,29280 Plouzane, France

[3]*Carolin Löscher*

Nordcee, Department of Biology, University of Southern Denmark, Odense 5230, Denmark

[4]*Arvind Singh*

Geosciences Division, Physical Research Laboratory, Ahmedabad 380009, India

[5]*Nicolas Cassar*

Division of Earth and Climate Sciences, Nicholas School of the Environment, Duke University, Durham, NC 27708, USA

[1] Sophie Bonnet, Mar Benavides (corresponding author, Email- mar.benavides@ird.fr)

Aix Marseille Université, CNRS, Université de Toulon, IRD, OSU Pythéas, Mediterranean Institute of Oceanography (MIO), UM 110, 13288, Marseille, France

ABSTRACT

Dinitrogen (N_2) fixers (diazotrophs) fuel primary productivity by providing reactive nitrogen into the ocean ecosystem and promoting CO_2 sequestration. N_2 fixation has been extensively studied in the low latitudes of the Atlantic and Pacific Oceans. By comparison, the Indian Ocean remains the least explored and most enigmatic ocean basin. This is particularly the case for the Southern Indian Ocean (SIO). Here we explore N_2 fixation activity and diazotroph community composition, diversity and abundance from 20 to 60ºS in the SIO. While this region plays a key biogeochemical role serving as a link between the Atlantic and South Pacific Ocean waters, its N_2 fixation potential remains unknown. Our results provide new insights into diazotrophy in a poorly studied region, and expand the range of biomes where diazotrophy may be observed.

REFERENCES

Karl, D., Michaels, A., Bergman, B., Capone, D., Carpenter, E., Letelier, R., Lipschultz, F., Paerl, H., Sigman, D., & Stal, L. (2002). Dinitrogen fixation in the world's oceans. Biogeochemistry, 57–58, 47–98. https://doi.org/10.1023/A:1015798105851

Hermes, J. C., Masumoto, Y., Beal, L. M., Roxy, M. K., Vialard, J., Andres, M., Annamalai, H., Behera, S., D'Adamo, N., Doi, T., Feng, M., Han, W., Hardman-Mountford, N., Hendon, H., Hood, R., Kido, S., Lee, C., Lee, T., Lengaigne, M., … Yu, W. (2019). A sustained ocean observing system in the indian ocean for climate related scientific knowledge and societal needs. Frontiers in Marine Science, 6(JUN), 1–21. https://doi.org/10.3389/fmars.2019.00355

Hood, R. R., Wiggert, J. D., & Naqvi, S. W. A. (2009). Indian ocean research: Opportunities and challenges. Geophysical Monograph Series, 185(January), 409–428. https://doi.org/10.1029/2008GM000714