**FINAL REPORT PROGRAM LEFE**

| **Program LEFE/ CYBER** | **Project Title**<br>Unveiling the ROle of rhizaria in the SIlicon cycle | **Years 2020-2022** |
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***Context*** *(2-3 lignes)*

Studies on the marine silicon biogeochemical cycle have focused mainly on pelagic diatoms, yet, the importance of other silicifiers is poorly documented. Recently, combination of data has evidenced that another group of silicifiers, the Rhizaria, have been largely underestimated and would represent an important part of zooplankton biomass (33%). This newly reported evidences stress the need for the community to assess the diatoms and Rhizaria relative contribution in pelagic ecosystems, in global picture, this is critical for both silica and carbon biogeochemical cycles.

***Objectives / scientific questions*** *(2-3 lignes)*

In this context the general objective of the ROSI project was to study Rhizaria in the ocean, in order to:
1- Describe their silicon-based physiology and its response to different environmental parameters, and
2- Characterize the biodiversity of Rhizaria and quantify the contribution of different taxa with respect to diatoms in order to understand their role in the biogeochemical Si and C cycle.
The financial support requested from LEFE concerned the costs of analysis of samples previously taken in the Southern and Atlantic Oceans and a contribution to additional sampling in the Mediterranean (MOOSE) in order to valorise the results.

***Main results***

The study in the Mediterranean Sea (Fig. 1) is one of the few that simultaneously analyses a planktonic compartment covering a wide size spectrum using a wide array of instruments and methods. We used three imaging methods and genetic analyses to investigate a broad section of the Rhizaria size range. While imaging data (cells $m^{-3}$) revealed that the most abundant organisms were the smallest, molecular results (number of reads) showed that the largest Rhizaria had the highest relative abundances. While this seems contradictory, relative abundance obtained with molecular methods appear to be closer to the total biovolume than to the total abundance of the organisms. This result reflects a potential link between gene copies number and the volume of a given cell allowing reconciling molecular and imaging data.
We found that the largest individuals (>1000 µm) contributed the most to the total Si stock in the water column (Fig. 1), from 5.2 to 70.3 µmol-Si $m^{-2}$. Overall, the small and medium-sized individuals (>64 – 1000 µm) contributed equally to the largest individuals at all stations, except at offshore stations leg2-36, leg2-56, where small-sized individuals dominated. These stations presented the deepest bottom depths. Small Rhizaria (<200 µm) contributed to the biogenic silica standing stock from 2 to 50% depending on the sampling stations, contributing from 1.1 to 39.9 µmol-Si $m^{-2}$.

Results from the Southern Ocean expedition reveal that Rhizaria cells are heavily silicified (up to 7.6 nmol Si $cell^{-1}$), displaying higher biogenic Si content than similar size specimens found in other areas of the global Ocean (Fig. 2), suggesting a higher degree of silicification of these organisms in the silicic acid rich Southern Ocean. Despite their high biogenic Si and carbon content, the Si/C molar ratio (average of 0.05 ± 0.03) is quite low compared to that of diatoms and relatively constant regardless of the environmental conditions.

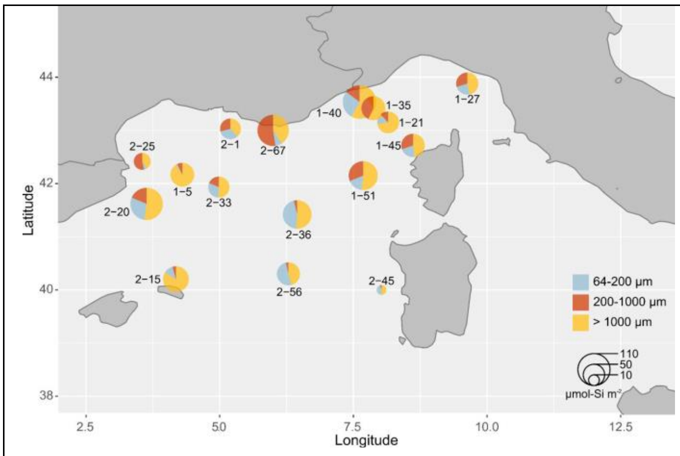


Fig.1: Overview of the bSi biomass of Rhizaria integrated into the upper 500 m of the water column (µmol-Si m$^{-2}$) in the Mediterranean Sea. Pie charts indicate relative contributions of the three studied size classes to the total bSi at each station and their size is proportional to their Si contribution.

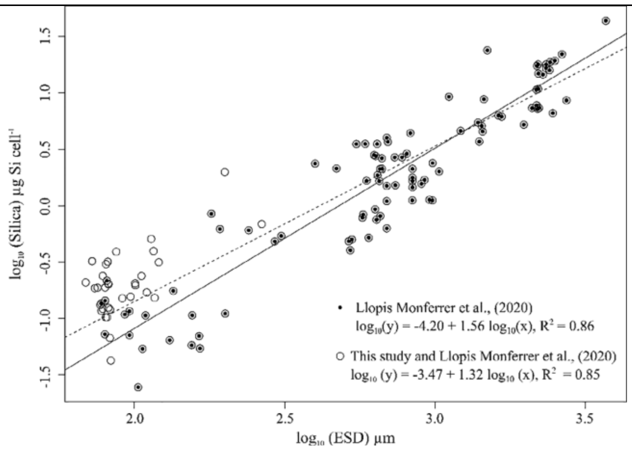


Fig.2: Relationship between the Si content of Polycystina and Phaeodaria and their equivalent spherical diameter (ESD, µm) across all the specimens assessed. Black dots represent data from Llopis Monferrer et al. (2020), which include data from Biard et al. (2018). White dots are all data including that of this study. The linear regressions correspond to Llopis Monferrer et al. (2020) data (solid line) and the combination of data from this study and Llopis Monferrer et al. (2020). (dashed line)

***Future of the project :***

This project has shed light on the potential role of siliceous Rhizaria in the biological carbon pump. A better understanding of the ecology and biogeochemistry of Rhizaria is a fundamental step towards estimating biomass and fluxes on a larger scale. The implementation of this project has brought young researchers together and given them the opportunity to have a leading role, essential for the pursuit of their careers as scientists. It has also fostered networking between LEMAR's Silica group and the Université du Littoral et Côte d'Opal, with Tristan Biard (ANR JCJC RhiCycle Role of Rhizaria in biogeochemical Cycles in the epi- and meso-pelagic ocean, 2021, 2 yr). N. Llopis Monferrer obtained a Marie Curie postdoctoral fellowship in 2022 and is currently working at the Monterey Bay Aquarium Research Institute to continue her work on silicification processes in Rhizaria (Si-ORHIGENS project). The Si-ORHIGENS project consolidates the dynamics established around the silica cycle and siliceous Rhizaria based on the LEMAR laboratory and ensures the continuity of the fruitful collaborations with Aude Leynaert and Jill Sutton.

*Number of publications, communications and theses*

***Publications***:

Llopis Monferrer N., **Leynaert** A., Tréguer P., Gutiérrez-Rodríguez A., Moriceau B., Gallinari M., Latasa M., L'Helguen S., Maguer J.F., Safi K., Pinkerton M.H., Not F., **2021**. Role of small Rhizaria and Diatoms in the pelagic silica production of the Southern Ocean. Limnology and Oceanography 66 (6), 2187-2202

Llopis Monferrer N., Biard T., Sandin MM., Lombard F., Picheral M., Elineau A., Guidi L., **Leynaert** A., Tréguer P. and Not F., **2022** Siliceous Rhizaria abundances and diversity in the Mediterranean Sea assessed by combined imaging and metabarcoding approaches. **2022**. Front. Mar. Sci., doi.org/10.3389/fmars.2022.895995

***Communications and theses:***

- Llopis Monferrer, B Moriceau, A Gutierrez-Rodriguez, F Not, P Tréguer, A. Leynaert. Rhizarians and diatoms: their relative impact in the silicon cycle in the Southern Ocean (Ross Sea). Oral communication at the Ocean Sciences Meeting, San Diego (USA), 2020.
- Llopis Monferrer, 2020. Rôle des Rhizaria dans le cycle biogéochimique du silicium. Thèse de doctorat, Ecole doctorale Sciences de la Mer et du littoral (Spécialité : Chimie Marine)

***Data availablility***

- Llopis Monferrer, N., Biard, T., Sandin, M. M., Lombard, F., Picheral, M., Elineau,A., Leynaert, A., Tréguer, P., Not, F. 2022. Merging imaging technologies and metabarcoding to assess Rhizaria abundances, diversity and contribution to the silicon cycle in the Mediterranean Sea. figshare. Dataset. *https://doi.org/10.6084/m9.figshare.19362374.v1*
- Llopis Monferrer, N., Leynaert, A., l'Helguen, S., Maguer, J-F. Biogenic silica and particulate organic carbon of siliceous Rhizaria during the MOOSE GE (2017 and 2018) and AMT28 cruise. *https://www.seanoe.org/data/00594/70596/*