Corso di Dottorato di Ricerca in Scienze della Vita e dell'Ambiente - Ciclo XXXVIII

Ecology of marine fairy circles and seepages

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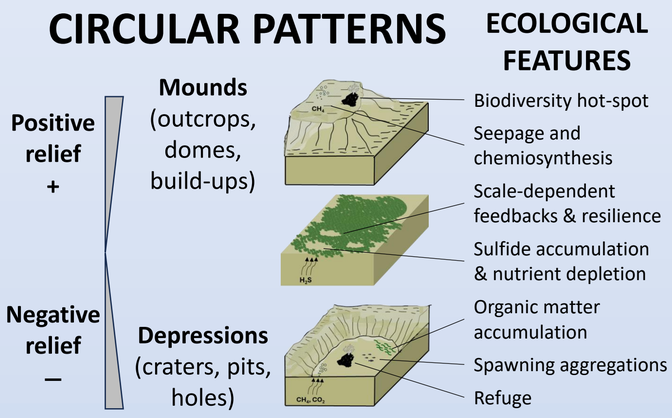
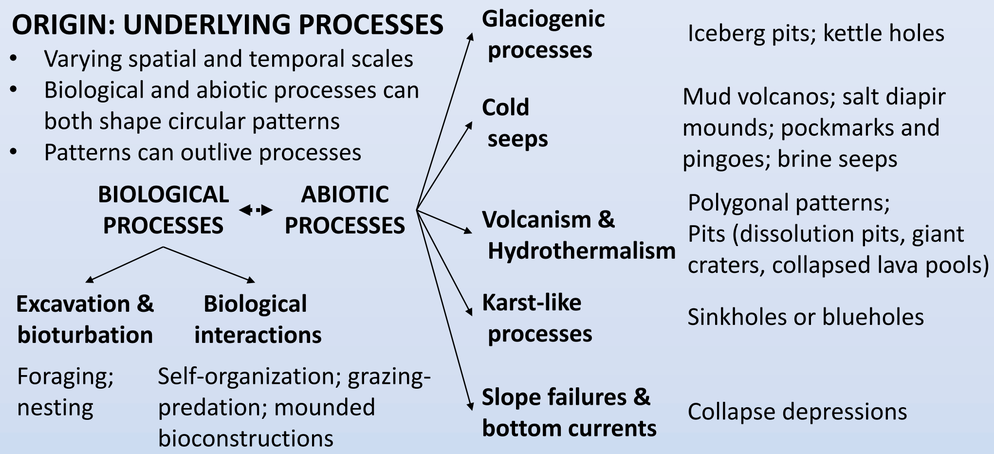
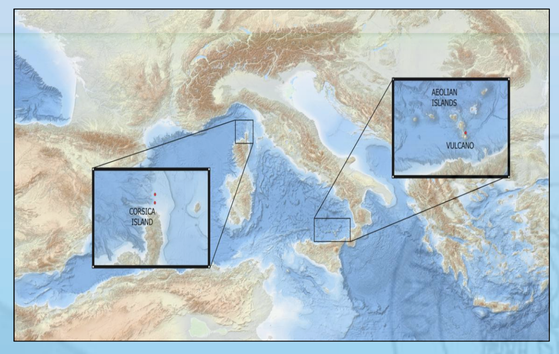
Circular structures on the seafloor are found in different habitats, from coastal ecosystems to the deep sea. For example, circular structures inside seagrass meadows, known as fairy circles, are related to ecosystem resilience[1]. Both biological processes and abiotic processes can generate circular patterns and the relation between spatial patterns and ecosystem resilience is not always clear. Therefore, the description of mechanisms originating spatial patterns is important to understand their ecological consequences.

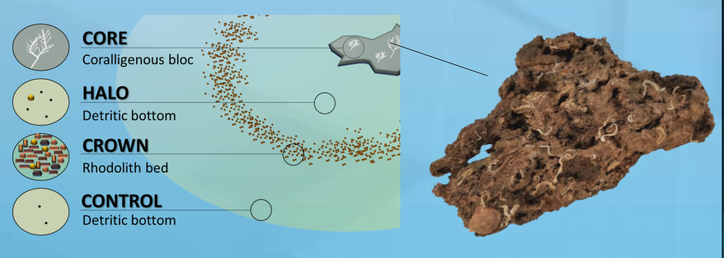


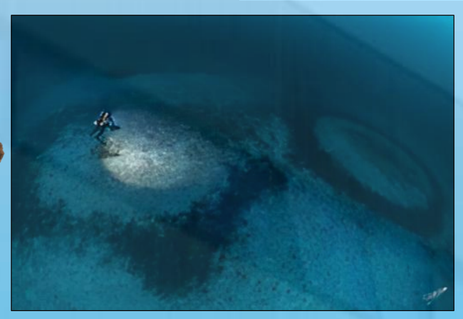


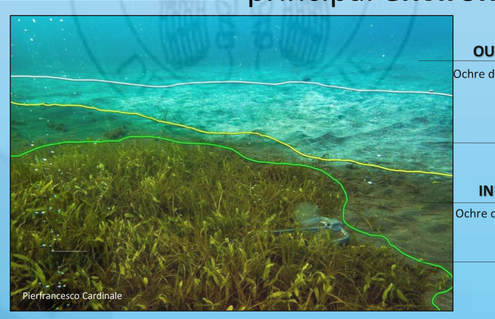
Hundreds of **coralligenous rings** cover the continental shelf off **Cap Corse** in the mesophotic zone[2]. They are domes with a coralligenous core surrounded by a halo of sediments and an external crown of rhodoliths. In summer **2021** and **2023**, sediment samples were collected from **four different rings** in two different areas at **120 m depth** by the **GOMBESSA 6** team. Our **objectives** are to characterize their **trophic status** and their **microbial communities** to investigate their origin.



Vulcano Island (Aeolian Archipelago) hosts underwater seepage resulting from hydrothermal activity. Several **vegetated fairy circles** are present in Levante Bay. Their origin might be related to a well-structured subseafloor flow organization[5]. The **main aims** of this study are to characterize their **trophic status** and their **microbial communities** to describe their ecological functioning. We measured the principal **environmental variables** using a CTD probe.



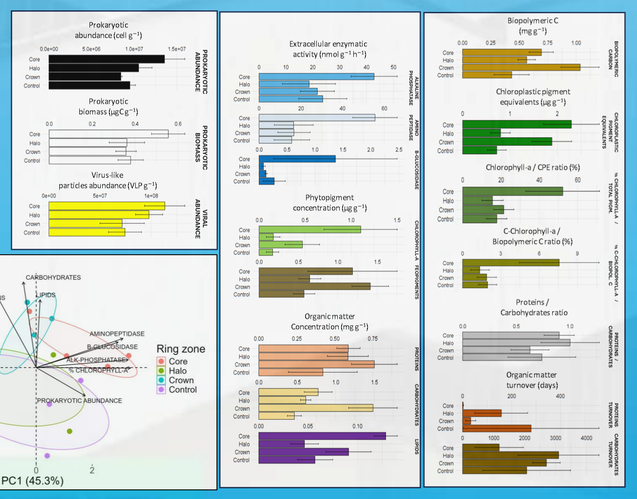




Methods included analyses on phytopigments and organic matter composition, extracellular enzymatic activities, microbial abundances, scanning electron microscopy and molecular tools[3].

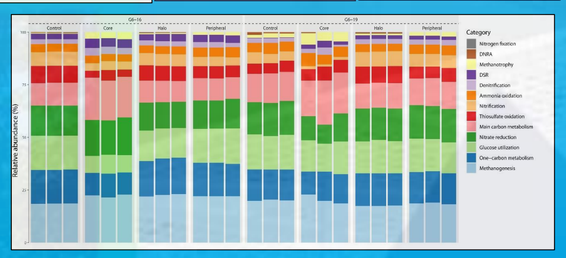
Main results:

- Similar values of controls and halos
- Highest activities and abundances within coralligenous cores
- Greatest organic matter content within rhodolith crowns

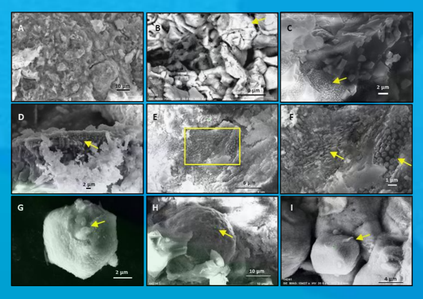


Principal component analysis (PCA) showed an overlap between halos and controls confidence intervals.

The metabolic reconstruction from **metagenomics** highlighted that methanotrophic microrganisms and nitrate reducers were more abundant within the coralligenous cores.



Magnetic aggregates from the sediments showed high iron content and differed in size from the magnetite produced by magnetotactic bacteria or detrital sources. The presence of particle alignments is similar to methanogenic archaea authigenic magnetite formations found in cold seeps[4].



Discussion

In our study, we highlighted different patterns in the trophic status and microbial communities of the coralligenous rings. In particular, the coralligenous cores are a hot-spot of primary production and microbial activities. Concerning the origin of the rings, our results suggest that methane seepage might have contributed to their formation though more evidence is warranted for drawing conclusions. Further analyses will include the study of biodiversity in the different parts of the rings and how the microbial metabolism might influence it.

Acknowledgements

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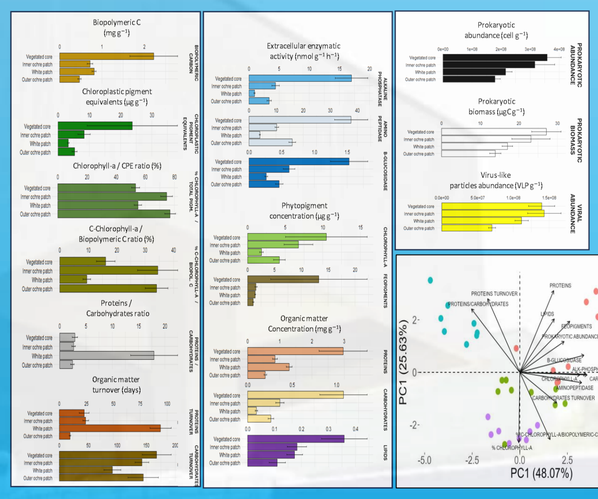
Methods included analyses on phytopigments and organic matter composition, enzymatic activities, and microbial abundances. Molecular analyses are on-going.

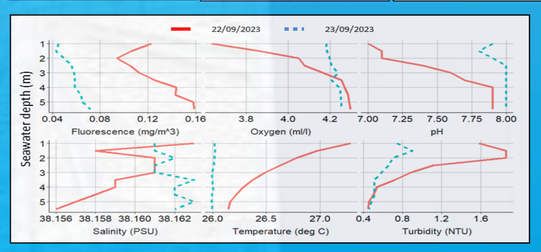
Main results:

- Highest values in the vegetated core
- Higher values in ochre patches inside the rings than outside them
- White patches showed highest protein/carbohydrates ratio

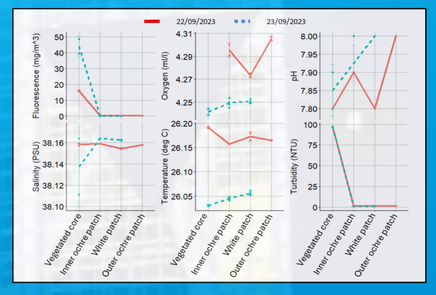


Principal component analysis (PCA) showed a separation between the different zones of the rings except for some vegetated core samples.

The **environmental parameters** along the **water column** showed daily variations due to the changing currents and the inflow of the less dense acidified-water coming from the main vent in Levante Bay close to the rings.



Bottom seawater environmental parameters showed a different pattern in the two days, except for fluorescence and turbidity. As expected, temperature was high at the white patch. The highest temperature at the vegetated core might be influenced by the overlying warmer water column.



Discussion

The vegetated rings of Vulcano showed a differentiation of the trophic status and microbial communities between their different parts. In particular, the vegetated core is a hot-spot of primary production and microbial activities. Concerning the origin of the rings, our results suggest that temperature shows daily variations. Therefore, a well-structured subseafloor flow might not be stable due to changing currents. Further analyses will include the study of biodiversity in the different parts of the rings and how the microbial metabolism might influence it.

References

1. Ruiz-Reynés, D., Gomila, D., Sintes, T., Hernández-García, E., Marbà, N., & Duarte, C. M. (2017). Fairy circle landscapes under the sea. Science Advances, 3(8), e1603262.
2. Bonacorsi, M., Pergent-Martini, C., Clabaut, P. & Pergent, G. Coralligenous "atolls": Discovery of a new morphotype in the Western Mediterranean Sea. Comptes Rendus. Biologies vol. 335 668–672 (2012).
3. Danovaro. Methods for the study of deep-sea sediments, their functioning and biodiversity, 1st Edition (2009).
4. Lin, Z., et al (2024). Methanogenic Archaea as Catalysts for Magnetite Formation in Iron-Rich Marine Sediments. Journal of Geophysical Research: Solid Earth, 129(6).
5. Puzenat et al (2021)Shallow-water hydrothermalism at Milos (Greece): Nature, distribution, heat fluxes and impact on ecosystems. Marine Geology, 438, 106521.