PHD COURSE IN LIFE AND ENVIRONMENTAL SCIENCES

Report Form for PhD student annual evaluation (XXXVII and XXXVIII cycles)

Name of PhD student: LORENZO SCENNA

Title of PhD research: Micro-macro interactions in the global ocean through the formation of habitats by microbes

Name of PhD supervisor: Prof. Roberto Danovaro
Research lab name: Marine Biology and Ecology Lab

Cycle:
[ ] XXXVI
[ ] XXXVII
[X] XXXVIII

PhD Curriculum::
[X] Marine biology and ecology
[ ] Biomolecular Sciences
[ ] Civil and environmental protection

DISVA instrumentation labs/infrastructure eventually involved in the project:
[ ] Actea Mobile Laboratory
[ ] Advanced Instrumentation lab
[ ] Aquarium
[ ] MassSpec lab
[ ] MaSBiC
[ ] Simulation/informatics lab
[X] Marine Biology and Ecology lab facilities.

ABSTRACT (1000 characters, including spaces)
The global ocean hosts a great variety of habitats, some of which are produced by geological processes, while others are created by habitat forming species. The research on habitat forming species has focused on larger organisms (e.g., from shallow water coral reefs, macroalgal forests, and seaweeds, to deep-sea animals like deep-sea corals and sponges). There are several observations that marine microbes (including prokaryotes and eukaryotes) can create complex habitats widespread at all depths, including at extreme environments. The exploration of habitats formed by microbes is fundamental for achieving the Sustainable Development Goal 14, because of their role in supporting biodiversity and providing ecosystem services at a global scale. In my PhD research, I investigate the role of marine microbes in habitat formation at various sites from the global ocean (from the Mediterranean Sea and the Celebes Sea near the Pacific Ocean). My research focuses on systems influenced by hydrothermal processes as well as systems that are poorly characterized.

Part 1. Scientific case of the PhD Research

- BACKGROUND

The ocean contains a huge variety of habitat types, some of which are due to topographic heterogeneities of geological/sedimentological origin, while others are created by habitat-forming species, which with their corporeal volume and structural complexity provide new opportunities for colonization and other ecological interactions (Buhl-Mortensen et al., 2010; Gómez-Gras et al., 2021). Complex habitats, with unique morphologies and substrates support species diversity and ecological functions (refuge, feeding, resting, nesting and other reproductive needs) thus contributing significantly to biogeochemical cycles (York et al., 2018). Such specific habitat complexity can also promote the speciation processes (Badgley et al., 2017; Kovalenko et al., 2012), while the distribution of these habitats across the ocean, can increase species connectivity across biogeographic regions (Breusing et al., 2016; Caldwell et al., 2013; Van der Stocken et al., 2019).

Most studies on habitat forming species have focused on larger organisms, like coral reefs, seaweeds (e.g., kelp forests), seagrasses, and oyster reefs among others (Cerrano et al., 2010; Thomsen et al., 2022). The role of microbes in creating complex habitats and in contributing to macro-scale habitat heterogeneity has been so far ignored (Levin et al., 2016). Most studies of microbe-habitat interactions have focused on small-scale processes at the scale of the individual animal or for example, on the structures animals make inside sediments (Aller, 1982; Bertics et al., 2009; Kristensen et al., 2005).

The census and conservation of habitats is one of the big human challenges and a priority of the UN (Sustainable Development Goals 14). In my PhD research, I summarized the available information on habitat forming microbes and investigated their role in supporting biodiversity as well as their potential wider ecological effects. I conducted a global-scale review of the scientific literature about microbial habitat formers and concluded that besides their well-known functions at the base of the marine food web, and their role in biogeochemical cycles, microbes can create large and widespread habitats from shallow waters to the deep sea, including extreme environments. In the following PhD years, I will investigate the role of marine microbes in habitat formation at various sites from the global ocean (from the Mediterranean Sea and the Celebes Sea near the Pacific Ocean). My research focuses on systems influenced by hydrothermal processes as well as systems that are poorly characterized.

- SCIENTIFIC AIMS

The aims of my PhD include characterizing the diversity and features of habitats created by microbes at various sites, as well as investigating the role of microbes in habitats that haven't been characterized yet. Moreover, I will also study the diversity of larger organism colonizing habitats created by microbes.

- WORKPLAN AND RESEARCH ACTIVITIES

WP 1. **Objective.** Collecting and summarizing available bibliographic information on habitats generated by microbes of the global ocean, including their features, geographic distribution, and the ecological roles of microbes that contribute to creating such complex habitats.

Methods. Bibliographic research on major databases (e.g., Scopus, the Web of Science) as well as other literature sources (e.g. Google Scholar and scientific project websites). Mapping and categorizing the different types of information (e.g., major characteristics, geographic distribution, associated diversity).

Obtained Results. A comprehensive review covering the topic of habitats created by microbes submitted to a scientific journal with a high impact factor.

WP 2. **Objective.** Investigating the role of microbes in creating habitats at two marine systems under hydrothermal influence of the Mediterranean Sea (Aeolian Islands and Naples Bay, Italy).

Methods. Samples were collected at several sites and characterized in order to investigate the role of microbes in the formation of marine habitats. The methods applied included electron microscopy, organic matter characterization, and molecular analyses in order to characterize the environmental properties of the different sites and to describe the microbial communities associated with these habitats.

Expected Results. The investigation will contribute to our understanding of marine habitats and the ecology of extreme environments, like hydrothermal vents. At least three publications in international journals with high impact factors.

WP 3. **Objective.** Contributing to the objectives of the Gombessa 6 expeditions and increasing our knowledge on the coralligenous "atolls" found off the island of Corsica in the Mediterranean Sea.

Methods. A systematic map of marine fairy circles and other spatially self-organized structures was conducted in order to collect bibliographic information on the distribution and on the proposed origins of these habitats. New samples from Gombessa 6 expeditions will be analysed in order to complete the dataset already available on the coralligenous "atolls" from Corsica. The methods include laboratory analyses to characterize the environment and to describe the viral, prokaryotic, and eukaryotic communities of these habitats.

Expected Results. An increased understanding of the origin of coralligenous "atolls" from Corsica and at least one publication in a high impact journal.

WP 4. **Objective.** Characterize the habitats formed by microbes from the Celebes Sea near the Pacific Ocean. This area is characterized by widespread submarine volcanic activity.

Methods. Samples were collected from the area and a new expedition will be organized. Laboratory work included electron microscopy in order to describe the features of microbially formed habitats and molecular analyses to determine the microbial communities associated with these habitats.

Expected Results. Characterization of extreme environments, potentially hosting new microbial taxa adapted to conditions at the limits of life. At least one publication in a high impact journal.

- REFERENCES

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Badgley, C. et al. Biodiversity and Topographic Complexity: Modern and Geohistorical Perspectives, Trends Ecol. Evol. 32, 211–226 (2017).

Bertics, V. J. & Ziebis, W. Biodiversity of benthic microbial communities in bioturbated coastal sediments is controlled by geochemical microniches. ISME J. 3, 1269–1285 (2009).

Breusing, C. et al. Biophysical and Population Genetic Models Predict the Presence of "Phantom" Stepping Stones Connecting Mid-Atlantic Ridge Vent Ecosystems. Curr. Biol. 26, 2257–2267 (2016).

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Caldwell, I.R. & Gergel, S.E. Thresholds in seascape connectivity: influence of mobility, habitat distribution, and current strength on fish movement. Landscape Ecol. 28, 1937–1948 (2013).

Cerrano, C. et al. Gold coral (Savalia savaglia) and gorgonian forests enhance benthic biodiversity and ecosystem functioning in the mesophotic zone. Biodivers. Conserv. 19, 153–167 (2010).

Gómez-Gras, D. et al. Population collapse of habitat-forming species in the Mediterranean: a long-term study of gorgonian populations affected by recurrent marine heatwaves. Proc. Royal Soc. B. 288, 20212384 (2021).

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Kristensen, E. & Kostka, J. E. in Interactions Between Macro-and Microorganisms in Marine Sediment Vol. 60 (eds. Kristensen, E., Haese, R. R. & Kostka, J. E.) 125–157 (American Geophysical Union, 2005).

Levin, L. A. et al. Hydrothermal Vents and Methane Seeps: Rethinking the Sphere of Influence. Front. Mar. Sci. 3, 72 (2016).

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Van der Stocken, T., Carroll, D., Menemenlis, D., Simard, M. & Koedam, N. Global-scale dispersal and connectivity in mangroves. Proc. Natl Acad. Sci. USA 116, 915–922 (2019).

York, A. Marine biogeochemical cycles in a changing world. Nat. Rev. Microbiol. 16, 259 (2018).

Part 2. PhD student information on the overall year activity (courses/seminars/schools, mobility periods, participation to conferences)

List of attended courses/seminars/schools

1. International Summer School on the Study of Extreme Environments through Integrated Approaches (ISS-SEEA) organized by the SZN Sicily Marine Center at Messina, Italy (18-22 September 2023).

2. Course by Prof. Nicola Paone at UNIVPM for PhD transdisciplinary credits on "Design of Research: European Projects" (academic year 2022/2023, 16 hours, 2 CFU).

3. Course by Prof. Donato Iacobucci at UNIVPM for PhD transdisciplinary credits on "Technology Transfer and Innovation" (academic year 2022/2023, 16 hours, 2 CFU).

4. Seminar of one hour on CAS SciFinder by Sofiem Garmendia organized at UNIVPM (07 February 2023).

5. Seminar of 30 minutes by Giulia Lucia on "Toxicological effects of cigarette butts for marine organisms", organized as part of the "Shot of Science" events at DiSVA by Prof. Di Marino (20 December 2022).

6. Course by Prof. Beolchini on "Regression analysis" as part of UNIVPM PhD transdisciplinary credits on informatics (academic year 2022/2023, 1 CFU).

7. Course by Prof. Spinozzi on "LATEX: a typesetting system for scientific documents" as part of UNIVPM PhD transdisciplinary credits on informatics (academic year 2022/2023, 1 CFU).

8. Course by Prof. Falco on "Climate-related risks" as part of UNIVPM lessons for PhD students (academic year 2022/2023, 1 CFU).

List of periods spent abroad

1. Mission abroad in Greece for the Project GLIDE (PRIN program) oceanographic campaign in the Aegean Sea (from 19 April 2023 to 12 May 2023).

List of conferences/workshops attended and of contributions eventually presented

1. Conference by the NBFC at Padova for the "Biodiversity PhD day" (31 May 2023 – 01 June 2023).

2. PhD week at DiSVA with poster presentation and talk (12-16 June 2023).

Part 3. PhD student information on publications

List of publications on international journals

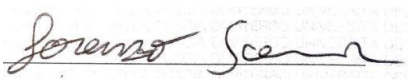
J1. Bouchachi, N., Obernosterer, I., Carpaneto Bastos, C., Li, F., Scenna, L., Marie, B., Crispi, O., Catala, P. and Ortega-Retuerta, E. “Effects of phosphorus limitation on the bioavailability of DOM released by marine heterotrophic prokaryotes” Microbial ecology, 86, 1961–1971 (2023).

J2. Danovaro, R., Levin, L. L., Fanelli, G., Scenna, L. and Corinaldesi, C. “Microbes as marine habitat formers and ecosystem engineers” SUBMITTED.

J3. Scenna, L., Perneel. M., Vlaeminck, B., De Troch, M. and Hablützel, P. “Combining multi-omics data to study *in situ* biosynthesis in natural plankton communities” IN PREPARATION.

13/10/2023

Student signature



Supervisor signature