PHD COURSE IN LIFE AND ENVIRONMENTAL SCIENCES

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

Name of PhD student: .....Teo Marrocco.....

Title of PhD research: ...Bioerosion: which effect on habitat complexity and biodiversity?...

Name of PhD supervisor: .....Barbara Calcinai.....
Research lab name: .....Zoology laboratory.....

Cycle:
[ ] XXXVI
[X] XXXVII

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

DISVA instrumentation labs/infrastructure eventually involved in the project:
[X] Actea Mobile Laboratory
[ ] Advanced Instrumentation lab
[ ] Aquarium
[ ] MassSpec lab
[ ] MaSBiC
[ ] Simulation/informatics lab
[ ] Other. Please, indicate: .....

ABSTRACT (1000 characters, including spaces):
Spatial heterogeneity is a fundamental factor driving the ecosystem dynamics and stability and providing the habitat a structural level of complexity to support hotspots of biodiversity for fishes, sponges, cnidarians, ascidians, bivalves and many other species. Organisms able to modify the benthic seascape are divided into two major groups: autogenic and allogenic engineers [1].
While the autogenic engineer group, mainly represented by sponges, coral and macroalgae, is capable to create epibenthic three-dimensional structures, and thus enhancing microhabitats availability (e.g. animal forests and canopy), the allogenic one can erode and deeply modify the substrate, creating a three-dimensional complexity by holes and crevices, which can be used by infauna species, providing new habitats for a multitude of organisms such as fishes, gastropods, crustaceans and cnidaria, especially during their early life stages.
Both groups can create a mosaic of conditions which support crucial ecosystem services, but while for autogenic engineers there is a wide scientific literature, the knowledge on autogenic organisms and on their role and function is still scant [2].

Part 1. Scientific case of the PhD Research (2 to 3 pages, including figures)

- BACKGROUND

Bioerosion and biocalcification are the major processes involving carbonate recycling but, while biocalcification has a long tradition of scientific studies, even regarding its relationship with climate change, the information about the bioerosion mainly focuses on the damages triggered by bioeroders activity. Coral reef destruction, weakening of calcareous rocks and ancient manufactures are the main problems that attract interest towards boring organisms and their actions. Furthermore, very few studies are conducted in temperate water and even less of them are in the Mediterranean Sea province [3].

- SCIENTIFIC AIMS

The aim of my Ph.D. is to evaluate the bioerosion processes as potential local biodiversity enhancers.
The coasts of the Mediterranean Sea, and particularly in the Adriatic Sea the hard bottom of the Conero Promontory, are deeply influenced by eroding organisms belonging to several taxa. Porifera and Bivalvia are the endolithic taxa that erode the highest volumes of carbonate rocks, but also Polychaetas, Echinoderms, microalgae and fungi participate in the erosion process [2].
The project aims to assess the role of the date mussel *Lithophaga lithophaga,* one of the most abundant boring species of the Conero Promontory, in influencing the biodiversity of the area. The species has a high conservation value inhabiting had substrate of limestone from a few meters to 20 meters of depth; it excavates holes into the substrate thanks to chemical reaction, and its illegal fishing conducted by highly destructive methods affects the community altering the biotic interaction, but also eradicating the sessile animals and the rock itself. *Pholas dactylus,* another species of boring bivalve, creates similar burrows making the distinction with *L. lithophaga* complex [4].
The goal of my Ph. D. is to quantify the abundance and distribution of these bioeroding species and assess the diversity of organisms inhabiting holes left by these bivalves when dead [5].
Both *P. dactylus* and *L. lithophaga* are protected under international conventions, but their illegal fishing is still frequent along the Italian coasts. This activity endangers not only the coastal integrity but also the microhabitats provided by boring activity, due to the extremely impacting collecting methods. Therefore, it is extremely urgent to know the distribution of *L. lithophaga* and *P. dactylus* to better estimate their density and so the potential microhabitats enhancing biodiversity along the Adriatic coast. Gathering more information about their distribution and role in the benthic community, would be also helpful to their conservation management [6] [4].
It is also very important to have a clear picture of the actual knowledge about the influence of bioerosion in promoting biodiversity. For this reason, a review of actual knowledge on bioerosion effects is needed and is necessary to understand which is the knowledge of his role in affecting the ecosystems' function and diversity.

- WORKPLAN AND RESEARCH ACTIVITIES

WP 1. Objective.

Review on current knowledge on bioerosion effects focusing on facilitation, in order to select papers that contain information on bioeroding taxa, and how their capability to erode the substrate affect the ecosystems or the species considered in the paper.

Methods.

A systematic review with Scopus and Web of science database using the following keywords was conducted:

bioero* OR boring OR *borer OR endolithic* OR epilithic* OR excavating OR grazing OR grazer* OR borehole
AND

cryptic OR fragmentation OR rubble OR facilitation OR recruit* OR biodiversity OR dissolution
AND
ocean OR ecosystem-engineer OR vacant

Expected/Obtained Results.

The purpose of the review is to demonstrate that information on bioerosion effects is geographically circumscribed and very scant, the actual scientific bibliography only focusing on a few aspects of the bioerosion and not considering its facilitation capability.
Before starting the review, we expected a lot of scientific publications from tropical regions, as the research activities, due to climate change and ocean acidification problems affecting coral reefs are numerous.
A total of 187 effects were selected within the screened bibliography, and when a single publication analyzed more than one effect, every one of them was added as single to the total effect list. Lastly, all the effects were regrouped in 10 categories, based on the obtained results and with the previous described keywords as main drivers of the effect:
"Grazing controlling the algal communities, damage on coral reef structure, grazing control coral settlement, sediment production, damage to shells, carbonate erosion, chips production, microhabitat formation, nutrient recycling, substrate modification."

The preliminary result of the review clearly shows a scarcity of papers on bioerosion in the temperate regions: out of the total 161 screened works, only 26% (n=42) are in temperate regions, and just a few of them in the Mediterranean Sea, 2 of which conducted in the Adriatic Sea.
Grazing and coral reef threats groups are the major topics of the papers, 26% (n=50) and 22% (n=42) respectively, followed by "erosion of calcium carbonate" and "sediment production" categories. Microhabitat formation category gets only the 3.7 %, with 7 effects on 187 in total.
Concluding, these preliminary results clearly underline not only the lack of information on bioerosion in the Mediterranean Sea but emphasize the necessity to widening the knowledge on bioerosion as biodiversity enhancer, overstepping the interest on its impoverishing activity on coral reef ecosystems.

WP 2. Objective.

Colonization of artificial holes having different volumes.

Methods.

In order to evaluate if vacant holes provide a potentially exploitable substrate by many species, standard house bricks, with holes, which mimic the vacant boreholes, were fixed against the substrate with cables; moreover, solid bricks, like the substrate, were also installed to evaluate the influence of the holes on colonization. In total 13 bricks were disposed, (9 holed and 4 solid bricks, Fig. 1), allowing a statistical comparison between different kind of substrates in terms of habitat availability.

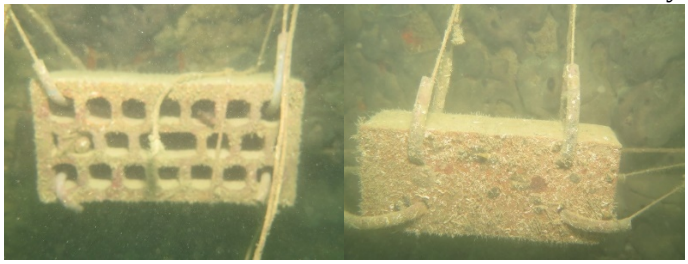

Fig. 1. Some of the different bricks installed undewater

The bricks will be periodically sampled to analyze the sediments accumulated in the holes and monitored by time-lapse. They will be removed and analyzed in the laboratory to identify the species exploiting these artificial substrates and evaluate if the holes may produce a positive effect in enhancing the local biodiversity.

Before collecting the bricks, they will put in bags avoiding vagile fauna to escape. Species present inside the holes and on the surface, will be removed and classified at the possible, lowest taxonomic level.

Expected/Obtained Results.

What we expect is to collect different taxa inhabiting the two groups of bricks. Meiofauna living in the accumulated sediments will be analysed and compared with surrounding sediments. Pisces, Decapoda, Crustacean, Porifera, Cnidaria are described in literature as groups which could rely on *Lithophaga* microhabitat to fulfill different ecological necessities; the holes are expected to attract these taxa and organisms typical of soft sediments likely to fill the holes of the bricks. On the other hand, the solid bricks are expected to recruit lesser quantity of organisms, typical of the surrounded habitat

WP 3. Objective.

Boring organisms' geographical distribution

In order to estimate the suitable substrate for *Lithophaga lithophaga* and *Pholas dactylus* along the Mediterranean Sea coastline, and so, to assess their geographical potential distribution, we need a first comparison between standard methods, represented by quadrats and transects, and the digital modern method, represented by the photogrammetry approach.

Methods.

The distribution and density of *L. lithophaga* and *P. dactylus* along the Conero Promontory was first assessed in the Grotta Azzurra cave (Ancona). Ten meters long transects have been extended along the two walls of the cave. For each meter of the transect, 2 quadrats were placed, one on the upper part of the cave and the other on the lower part; pictures have been taken in order to count the number and evaluate the size of *Lithophaga* holes with ImageJ (Fig. 2). To discriminate living and death *L. lithophaga* (i.e., occupied, or empty holes, respectively) the number of livings *Lithophaga* has been counted during the SCUBA surveys. Photogrammetry will be adopted to assess if this innovative methodology can complement or substitute traditional assessments. Once, collected enough information to select the most suitable *Lithophaga* assessments method, all the local coastlines will be guarded.

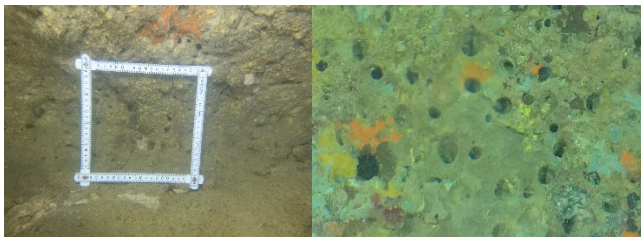

Fig. 2. Example of quadrat along 10 meters transect on the left; frame of the 3-D model of the cave on the right (Grotta Azzurra, Ancona)

Expected/Obtained Results.

Comparing the results obtained by visual census and photogrammetry will allow to select the most appropriate one to evaluate the density of living *L. lithophaga*, of *P. dactylus* and of their holes. Using also physico-chemical data of boring bivalves' distribution and coastline outcrops allow to build up a potential distribution map, helping the study and conservation programs of the two species.

- REFERENCES

1. Gratwicke, B., & Speight, M. R. (2005). The relationship between fish species richness, abundance and habitat complexity in a range of shallow tropical marine habitats. *Journal of fish biology*, *66*(3), 650-667.

2. Pinn, E. H., Thompson, R. C., & Hawkins, S. J. (2008). Piddocks (Mollusca: Bivalvia: Pholadidae) increase topographical complexity and species diversity in the intertidal. *Marine Ecology Progress Series*, *355*, 173-182.
3. Bagur, M., Gutiérrez, J. L., Arribas, L. P., & Palomo, M. G. (2016). Complementary influences of co-occurring physical ecosystem engineers on species richness: insights from a Patagonian rocky shore. *Biodiversity and conservation*, *25*(13), 2787-2802.
4. Fanelli, G., Piraino, S., Belmonte, G., Geraci, S., & Boero, F. (1994). Human predation along Apulian rocky coasts (SE Italy): desertification caused by Lithophaga lithophaga (Mollusca) fisheries. *Marine Ecology Progress Series*, 1-8.
5. Pinn, E. H., Richardson, C. A., Thompson, R. C., & Hawkins, S. J. (2005). Burrow morphology, biometry, age and growth of piddocks (Mollusca: Bivalvia: Pholadidae) on the south coast of England. *Marine Biology*, *147*(4), 943-953
6. European Commission, 2019a. The Habitats Directive [WWW Document]. URL https://ec.europa.eu/environment/nature/legislation/habitatsdirective/index_en.htm (accessed 4.27.20).

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. Design of research: European project

2. Technology transfer and innovation

List of conferences/workshops attended and of contributions eventually presented

1. SIBM 51° congress

Part 3. PhD student information on publications

If not yet published, please indicate the publication status (submitted, accepted, in preparation...)

List of publications on international journals

J1. Roveta, C., **Marrocco, T**., Pica, D. *et al.* The effect of substrate and depth on hydroid assemblages: a comparison between two islands of the Tuscan Archipelago (Tyrrhenian Sea). *Mar. Biodiverse.* **52**, 9 (2022). https://doi.org/10.1007/s12526-021-01254-0...

J2. Roveta, C**., Marrocco, T**., Calcinai, B., Pulido Mantas, T., Pica, D., Valisano, L., & Puce, S. (2022). Unravelling the sponge diversity of the Tuscan Archipelago National Park (Tyrrhenian Sea, Italy). *The European Zoological Journal*, *89*(1), 317-330.

[Date]

14/10/2022

Student signature

Supervisor signature