From Natural to Artificial Reefs: Using SfM Modeling To Study Coral Community Functioning And Tune Restoration Solutions In Mayotte

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Submission:
Trait-based approaches help to understand the dynamics and trajectories of reef ecosystems. With resilience-based management, they represent the most effective conservation approaches in the context of the accelerating environmental change over the last decades. The biodiversity of reef-building corals is key to sustaining reef ecosystem functioning. Functional approaches for corals have improved proxies for key biological and ecological processes and already help fill data gaps by prioritizing easily measurable traits. The quantitative study of the functional structure of coral communities on natural reefs provides relevant information to propose functional goals of restoration and can optimize restoration efforts. Underwater photogrammetry by Structure from Motion (SfM) allows the accurate quantification of physical and ecological characteristics of reef organisms by 3D modeling. Nowadays, this technology is used to monitor the dynamics of reef benthic communities and their structural temporal changes. The interdisciplinary project “Future Maore Reefs” supported by France Relance and coordinated by A. Tribollet & F. Guilhaumon (IRD) with the support of the Marine Park Authority of Mayotte applies these new tools in a comparative study between natural and artificial reefs. Our goals are: (i) to understand the functional composition of reef-building corals and their contribution to reef structural complexity in three natural reef (with contrasted environmental conditions); (ii) to settle diverse nubbins communities on artificial reefs structures; (iii) to monitor growth and calcification of coral (colonies or nubbins) in natural vs artificial reefs. In the end, the project aims to understand the functional dynamics of coral communities and identify the most resilient and efficient coral assemblages allowing the creation of reef structural complexity and functioning representative of nature, this, to help reef managers to improve their restoration or compensation plans. In the present paper, data collected only on natural reefs will be presented. The results of artificial reefs will be presented elsewhere.
Methods
The study is currently conducted on Mayotte island, French oversea territory, part of the Comoro archipelago situated in Mozambique Chanel in the western Indian Ocean. Three sites were selected: Île Blanche (IB - fringing reef), Airport (AI - lagoon reef), and Surprise (SU - inner barrier reef) within 3-6m depth. The sites encompassed natural well-developed reefs with strong environmental contrasts and a range of anthropogenic pressures. Artificial reefs which will be implemented next to those natural reefs, will be

basaltic blocks (~1m3; local production) on which “coral garden experimental boards” will be affixed. The three natural reefs (represent a total surface area of ~ 620 m²) and 45 coral colonies (15 per site) were 3D modeled by photogrammetry using a consistent protocol allowing collection of images using SCUBA. Three-dimensional models were constructed using Agisoft Metashape Professional (version 1.8.2). Those models, together with digital elevation models (DEM), and orthomosaics were generated to perform physical and ecological analyses. DEM analyses were conducted with R to get physical descriptors (e.g. fractal dimension, surface complexity, mean slope) while orthomosaic analyses were conducted using QGIS (version 3.24.1) to describe reef-building corals, colonies are manually delineated as polygons (by drawing edges of colonies) considering an individual as a colony growing independently from its neighbor. Each colony was classified by genus/species and categorized into four groups of Life History Traits (LHT): competitive (COM), stress-tolerant (STO), weedy (WEE), and generalist (GEN) following (Darling et al., 2012).

Results

Results of abundance (number of coral colonies) revealed three different coral communities in terms of LHT: a dominance of competitive species for SU: COM= 370 > STO= 71 > GEN= 19 > WEE= 5; weedy species were more abundant at AI: WEE= 108 > STO= 97 > COM= 93 > GEN= 10, and stress-tolerant species were more represented at IB: STO= 184 > COM= 144 >WEE= 42 > GEN= 0. However, overall abundances showed a dominance of competitive species (=607), followed by stress-tolerant species (=352) which in turn was followed by weedy species (=155), generalist species being the least abundant (=29). Physical analyses showed that SU had a higher surface complexity than IB and AI (3.2 > 2.7 > 2.4, respectively). A similar trend was obtained for the fractal dimension descriptor (SU= 2.18> IB= 2.17> AI= 2.11). Mean slopes of three reefs were similar throughout the sites IB= 35,4~ SU=33.2 ~AI=33,9. LHT composition of coral communities responded directly to environmental conditions. Our results showed indeed that natural factors (such as hydrodynamic conditions and clear water conditions at SU) selected competitive species (mainly branching forms) while local anthropogenic disturbances like at IB such as terrigenous inputs and pollution), selected in priority stress tolerant species (mainly represented by massive forms). Also correlated to this natural conditions and species composition, SU reef site beared the highest reef surface complexity. Fractal dimension descriptor could be more sensitive to the diversity of species presented and exposed a lower gap between sites. Other ecological descriptors such as the shelter capacity and Shannon Shelter Index (Urbina-Barreto et al., 2020), will tune these findings. Those results will guide the in situ experimental design for the artificial reefs and coral nubbins following the laboratory experiment conducted by McWilliam et al. (2018) in the next few months.

Conclusion

Maintaining the main functional processes of coral reefs is vital for the persistence of these ecosystems as well as for securing the goods and services that they provide to local populations. Until now, our study showed promising preliminary findings that enhance the relevance of fundamental sciences to contribute to optimizing restoration efforts to support the resilience of reef ecosystems. This can be of particular interest to conservation planners, decision-makers, and developers regarding the avoidance, reduction, or compensation measures often required by environmental laws for coastal and seascape works. Together, these types of initiatives and efforts can partially offset man-made impacts and relieve some stress induced by increasing natural pressures related to global climate change.

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