Limestone Autonomous Reef Monitoring Structures (ARMS): A Preliminary Study Of A New Low-cost Tool To Restore Coral Reef Biodiversity In Madagascar

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Background

Coral reefs represent less than 0.2% of the ocean, yet are one of the most valuable ecosystems on earth. Coral reefs protect shoreline communities and infrastructure, provide food and income for approximately 1 billion people, and are the source of important medical and industrial compounds. Nowhere are coral reefs more relied upon for food and income than in southwest Madagascar, particularly in the Bay of Ranobe (BoR). In recent decades, coral reef ecosystems in the BoR have been increasingly degraded by human impacts such as overfishing, pollution, sedimentation and climate change. The multi-year drought occurring in the region has also depleted already-low agricultural production, driving a large migration of people to the coasts in search of food. Reef decline, agriculture decline, and growth in coastal populations has heightened the risk of malnutrition and physical vulnerabilities due to storm damage, leading the UN Food Programme to call the situation the first climate-induced famine.

The primary goals of the ARMS Restore project, implemented in the BoR (2021-2024), are to (1) increase the number of fish and other marine species that can be harvested for food and income and (2) better protect shorelines with living reefs. Artificial reefs are a common tool used to build coral reefs. We are advancing this tool by adding the biological components required to form a thriving coral reef. Autonomous Reef Monitoring Structures (ARMS) are small structures affixed to the benthos that passively accumulate reef biota from their surroundings via larval dispersal, adult movement, and overgrowth. They have been shown to collect representatives of up to 85% of reef biodiversity. ARMS “seeded” on healthy natural coral reefs in the BoR for one year will be moved to artificial reefs to jumpstart reef growth.

In response to the COVID-19 pandemic, the team pivoted ARMS production on-site in Madagascar to employ local people and stimulate the economy. In doing so, the team redesigned the ARMS to transition from a PVC and stainless-steel design, to one that uses limestone and epoxy. The limestone was sourced locally and the transition lowered costs and used a natural material, providing additional benefits. Low cost, unit limestone ARMS price is $50 USD. Original ARMS unit is currently invoiced at $115 USD. The new pyramid design (instead of a cube) maximizes light penetration. They are composed of six square limestone plates with a thickness of 40mm, epoxied together with limestone spacers and connected by a long steel bolt in the middle to form a single structure. Each plate is stacked apart of 30mm. From the base to the top, plates sizes are respectively: 320mm x 320mm; 290mm x 290mm; 260mm x 260mm; 230mm x 230mm; 190mm x 190mm; 160mm x 160mm.

The first objective of the present study is to find the best sites in the Bay to collect diverse reef biota using limestone ARMS (termed “seeding ARMS”). Our first hypothesis is that there is an accessible healthy reef site inside the lagoon of BoR to seed the ARMS. The second objective is to test and quantify the effectiveness of limestone ARMS for collecting a large proportion of local reef biodiversity using a subset of ARMS for their original purpose, to census biodiversity (termed “census ARMS”). Our second hypothesis is that limestone ARMS can collect reef biodiversity.

Method

We are building 1-hectare artificial reefs and seeding them with biota from health coral reefs using limestone seeding ARMS. The experimental design consists of building 6 artificial reefs inside the lagoon of the BoR: 3 artificial reefs will be seeded with ARMS, 3 without seeded ARMS and 3 natural coral reef sites as control (without ARMS and artificial reef).

From the north to the south of the lagoon of the BoR, 23 sites have been explored using Manta tows to characterize the benthos in areas with coral reefs, seagrasses, and sand flats. Reef Health Index (RHI), based on 3 metrics (live coral coverage, fleshy macroalgae coverage and fish biomass) developed by the Healthy Mesoamerican Reef Ecosystem program (HMRE, 2006) was adopted to assess the health of reef ecosystems. Underwater biological surveys from all site provided information used to decide which site will be used as the “healthy” reef to seed the ARMS.

Results

The Manta tows identified 18 coral reef sites and 4 seagrass beds. One “healthy reef” site was identified as a seeding ARMS location (Site 1) and seven additional sites were selected for census ARMS: Site 1 (live coral cover 86.1%, fleshy macroalgae index 3.45%, fish biomass 302 kg/ha) and Site 2 (live coral cover 52.05%, fleshy macroalgae index 37.12%, fish biomass 237 kg/ha) as healthy reef, Site 3 (live coral cover 24.13%, fleshy macroalgae index 43.67%, fish biomass 63 kg/ha) and Site 4 (live coral cover 6.92%, fleshy macroalgae index 43.54%, fish biomass 47 kg/ha) as degraded reef, Site 5 a marine reserve as control site (live coral cover 69.63%, fleshy macroalgae index 12.31%, fish biomass 165 kg/ha), Site 6 is an old aggregation of artificial rock reefs (coral juvenile 59.86 ± 13.17 density per structure, fish biomass 43.06 Kg/ha) and Site 7 as sandy area (empty area : no coral reef and seagrass bed).

One hundred twenty “seeding ARMS” were deployed in Site 1(heathy reef) and will be left undisturbed for 12 months alongside 3 “census ARMS” to monitor their accumulation of biodiversity. ARMS units are located at least 2m apart from each other at depths of 4-16m. Monthly surveys will be used to survey benthic succession on ARMS plate and after 12 months will be recovered for full disassembly, species identification and analysis. Environmental factors (bottom temperature, luminosity, sedimentation rate) will also be monitored at all sites.

Conclusion

Data describing the colonization and succession of benthic organisms on ARMS and any changes in the surrounding natural reef will be collected before October. The application of molecular techniques such as metabarcoding will be used to identify cryptic species diversity on ARMS plates after 12 months of deployment (March 2023).