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Indications of Enhancement of Reef Fish Community Richness at Selected Coral Rehabilitation Sites in the Philippines

ABSTRACT

Reef deterioration is a chronic issue that has persisted over the past decades. Much effort has been invested into research and development of reef rehabilitation technologies. Reef rehabilitation via coral fragment transplantation was initiated in 2012 at selected areas across the country. Assessments of its impacts on the diversity of reef fishes in Batangas, Tawi-Tawi, Aklan and Bohol in the Philippines using the fish visual census technique were conducted in 2017, five years after coral transplantation. Significant positive results were found at the treatment sites in Mabini, Batangas and in Bongao, Tawi-Tawi. Mean fish species richness were 56 and 43 species 250 m^{-2} at the treatment and control sites in Batangas, respectively, and 74 and 48 species 250 m^{-2} at Bongao, Tawi-Tawi. In contrast, the numbers of fish species at the control sites in Aklan and Bohol were slightly higher, but these were not statistically significant. Coral transplantation can potentially enhance fish diversity; but the effects of coral transplantation on fish communities may be difficult to demonstrate and detect. Sound scientific design and efficient application of the technology are needed to unambiguously present their potential benefits. Issues, challenges, and recommendations to advance the conduct of such reef enhancement initiatives are discussed.

Keywords: *coral transplantation, reef fish, diversity*

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INTRODUCTION

The deterioration of coral reef ecosystems is a global concern. Coral loss of up to 40% in the Indo-Pacific and over 80% in the Caribbean have been recently documented (*GREFP 2021*). In the Philippines, it has been reported that coral reefs have significantly deteriorated over the last 4 decades (*Licuanan et al. 2017; Licuanan et al. 2019*), with most reefs falling under the "poor" (0-22%) to "fair (22-33%)" live coral cover categories. The current situation underscores the pressing need for effective management, and active intervention actions to conserve and rehabilitate coral reefs.

Assisted reef rehabilitation techniques are important tools that aid in facilitating reef recovery. Reef restoration approaches are gaining greater importance and appreciation in addressing the current situation of reefs (*Suggett and Oppen 2022*). Aside from improving the condition of various benthic invertebrate fauna in a reef, rehabilitation will also benefit reef fish communities, a primary associate of these habitats, and an important component of the protein supply and the socio-economic matrix of coastal communities.

Features of natural reefs such as live coral cover, lifeform variety, and physical complexity are known to improve the diversity of invertebrate reef fauna (*Yap 2009*), as well as influence fish diversity, abundance and biomass (*Setiawan et al. 2021; Ghiffar et al. 2017; Yap 2009; Samaniego et al.*, in prep). With improvements in the reef framework resulting from protective management that promote coral growth, or through rehabilitation efforts such as coral transplantation (*Boström-Einarsson et al. 2018; Boström-Einarsson et al. 2020*) which attempt to bypass the growth and development processes, it is expected that fish communities should likewise exhibit concomitant positive changes in structure.

The Filipinnovation on Coral Reef Restoration Program of the Department of Science and Technology (DOST) and the Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development (PCAARRD), commenced in 2012. It utilized asexually propagated coral fragments that were transplanted to sites with the goal of rehabilitating coral reefs in selected localities in the country. An impact assessment of the program highlighted significant improvements in fish abundance and biomass within the treatment areas compared to the control sites (*Ancog et* *al. 2019*). These findings demonstrate the importance of assisted reef rehabilitation efforts utilizing coral transplantation in promoting reef recovery, health and resilience.

Fish abundance and biomass are important indicators of the value of reefs and fish communities in terms of harvestable biomass in fisheries which translate to economic value. However, fish species richness and diversity are equally important. Especially in locales where marine-based tourism is considered to be a central element of the economy, the diversity of marine fauna such as fishes is a major attraction, thereby directly supporting the tourism industry. In this context, investigations into how reef restoration efforts improve the diversity of associated fauna are important because they may contribute to formulating and implementing appropriate blue techniques and strategies. This study utilized data from the PhilCora project to look into the changes in the richness of fish communities between treatment and control sites of selected restoration sites under the Filipinnovation on Coral Reef Restoration Program.

MATERIALS AND METHODS

Study locations

Impact assessments of the Filipinnovation on Coral Reef Restoration Program (coral transplantation) were conducted in four locations, namely: Bongao, Tawi-Tawi; Boracay, Aklan; Mabini, Batangas; and Panglao, Bohol in the Philippines. Except for Bongao, Tawi-Tawi, these sites are well-known sea-based tourist destinations. As such, fisheries impacts were nil to minimal at the study sites, and tourism impacts were assumed to be minimal as well (i.e., no fish feeding activities were observed and noted). The assessments were conducted from June 2017 to April 2018. At each of these four locations, treatment sites (with coral transplantation) and control sites (no transplantation) were identified. The coral communities and associated fish communities were surveyed at each of these sites (**Figure 1**).

Reef fish survey and assessment

The coral reef fishes at each of the study sites were surveyed along transects within the 25 m x 75 m sampling area established for benthic community surveys (*van Woesik et al. 2009*). Within each sampling area, five 50-m transects were laid randomly and parallel to the shore. In the case of Panglao Island, Bohol, 25 m x 75 m quadrats were not established due to the narrow widths of the survey reefs. Here, only four survey transects were deployed. The depths of the survey transects at the study locations were similar and ranged from 3 to 7 meters, except for some transects in Mabini, Batangas which were about 6-9 meters.

Fishes were surveyed using the fish visual census technique (*English et al. 1997*). Fish within 2.5 m at each side of the transect were identified to species level with the aid of photographic field guides (i.e., *Randall 2005; Kuiter and Debelius 2006; Allen et al. 2012*).

Fish species were categorized as target, indicator or major species based on diet and important information found in FishBase.org. Briefly, target species are fishes that have some commercial value and are taken in fisheries. They include high value species such as groupers, jacks and snappers, and other lower value species such as some wrasses and triggerfish among others. Indicator species are highly specialized fish that feed on coral polyps.

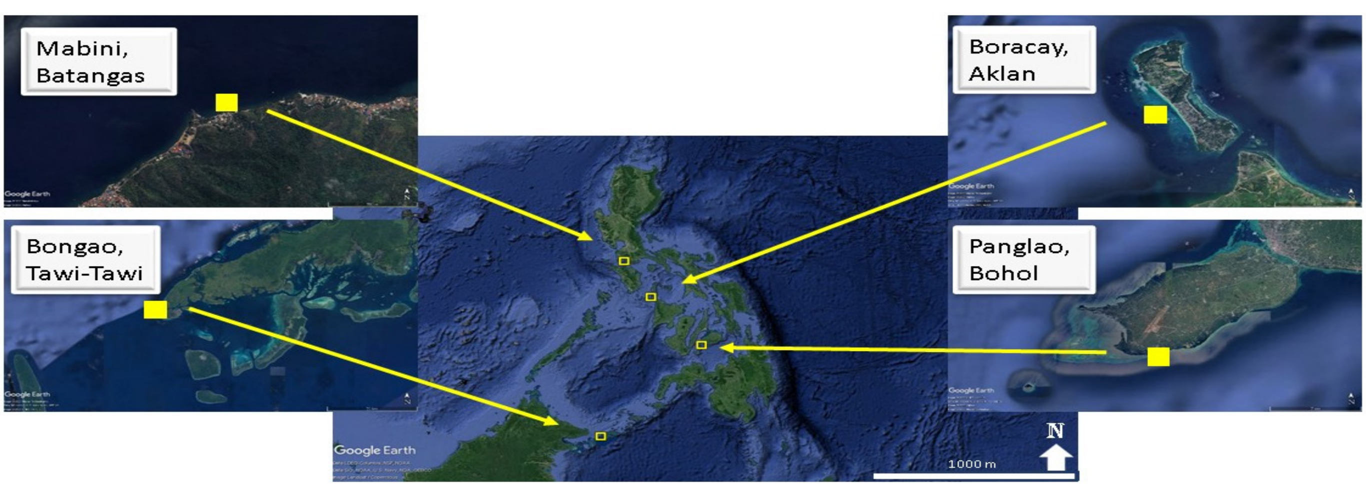

Figure 1. Locations of the study areas in (a) Mabini, Batangas, (b) Panglao, Bohol, c) Boracay, Aklan, and (d) Bongao, Tawi-Tawi in the Philippines.

These fish are closely associated with live corals, hence their variety and abundance in a reef give an indication of the condition of the reef in the area (*Labrosse et al. 2002; Nañola and Aliño 1999; Crosby and Reese 1996*). Indicator fish are mostly butterflyfishes, together with several wrasses and damselfishes. Major fishes are all other fish that do not fall under the target and indicator fish categories. They are often the dominant suite of fish on the reef in both richness and abundance, and are ecologically very important as they serve as trophic links.

Baseline and monitoring data on fish communities at the study locations were unavailable (i.e., either not collected, not secured, or not stored). As such, control sites with similar reef features (depth, coral community condition and composition) were identified and surveyed at each of the study locations to serve as non-treatment sites for comparative analyses (*Ancog et al. 2019*). Fish species density data collected from the treatment and control sites at each location were tested for significant differences using one-way ANOVA.

RESULTS AND DISCUSSION

A total of 275 unique species of fish belonging to 41 families were observed and identified across the four study locations (**Table 1**). The total number of species at each of the survey sites varied from 93 species 250 m^{-2} in the treatment site in Boracay, Aklan up to 138 species 250 m^{-2} in Panglao, Bohol. The total fish list was comprised of 91 target species, 20 reef-health indicator species, and 164 major or ecologically important species. Among the major fishes, the damselfishes (Pomacentridae) and wrasses (Labridae) were the most species-rich with 53 and 44 total species, respectively. The most diversetarget fish families were the parrotfishes (Labridae: Scarinae) with 19 species, followed by wrasses with 14, the surgeonfishes (Acanthuridae) with 11, and goatfishes (Mullidae) with eight species. The 20 reef-health indicator species included 17 species of butterflyfishes (Chaetodontidae) and three coral-feeding wrasses.

Estimates of fish species richness varied between the treatment and control stations across all the study locations. However, fish were only significantly more diverse in the treatment sites compared to the control sites in Batangas (p = 0.03) and Panglao (p = 0.005). The Batangas treatment site had a mean species richness of 56 species 250 m^{-2} while its control site had 43 species (**Figure 2**). As many as 74 species 250 m^{-2} were recorded in the treatment site in Panglao and only 48 species in the control site.

In contrast, numbers of fish species in the control sites of Tawi-Tawi and Aklan were higher but these were not statistically higher than the species density estimates at their corresponding treatment sites (p = 0.799 and p = 0.560, respectively). There were 48 species 250 m^{-2} at the control site in Tawi-Tawi and only 46 species at the treatment site; and there were 51 species 250 m^{-2} in the control site in Boracay, and about 46 species at the control site (**Figure 2**).

The data suggest that, at least for Panglao and Batangas, enhancements of coral reefs may have contributed to the higher diversity of the fish communities compared to areas with no intervention. Indeed, estimates of hard coral cover in the treatment sites at these two locations were relatively greater than at the control sites, and in Bohol the difference was significant (p= 0.019) (*Ancog et al. 2019*).

In Aklan and Tawi-Tawi, where there were more fish species counted in the control sites compared to the treatment areas, and it may be argued that the coral transplantation effort did not result in the improvement in the diversity of fishes. However, fish abundance and biomass improved at the treatment sites (*Ancog et al. 2019*). The apparent non-improvement in species richness at the treatment sites in Aklan and Tawi-Tawi may be due to numerous confounding factors. Factors that may influence

Table 1. Summary of the total number of fish species identified from the survey sites at each study location (Philippines) and the composition of indicator, major and target species.

Location	Site	Indicators	Majors	Targets	Total species
Mabini, Batangas	Control	10	62	29	109
	Treatment	8	68	43	123
Bongao, Tawi-Tawi	Control	7	76	26	117
	Treatment	10	66	29	109
Boracay, Aklan	Control	14	61	29	112
	Treatment	9	59	25	97
Panglao, Bohol	Control	5	65	29	107
	Treatment	8	85	45	142
Total species by category		20	164	91	279

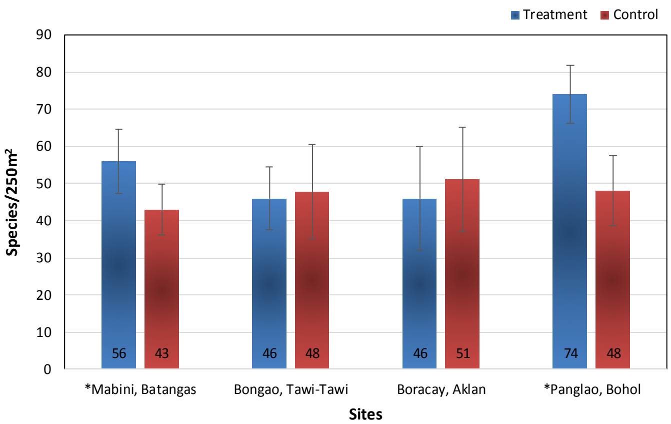

Figure 2. Mean estimates of species richness (species 250 m^{-2}) at the four study locations for coral transplantation. Species density estimates at the treatment sites were significantly higher than in the control sites in Batangas (0.03) and Bohol (0.005), Philippines.

the results of the transplantation efforts include: physical dislodgement caused by wave action (*Garrison and Greg 2008*), tourism activities, timing of transplantation, the degree similarity of environmental conditions at donor and transplantation sites, monitoring and maintenance activities after transplantation, attachment methods, size and growth form of coral transplants, species of coral transplants, control of chronic anthropogenic impacts that contributed to the deterioration of the site, and site selection for limited fishing activities (*Edwards 2010; Edwards and Gomez 2007*).

Whereas the impacts of coral transplantation on the benthic communities may be direct and immediately obvious, its effects on fish community structure may be more difficult to detect. Various confounding factors and their interactions drive different trajectories of change. Drivers may include higher natural spatio-temporal variability of fish communities compared to the benthos brought about by fish movement, protracted accumulation rates of species, abundance and biomass relative to the baseline community conditions, fisheries impacts, and community responses to changes in habitat structure (i.e., loss of prey species associated with high complexity reefs, and increased rate of mortality due to reduced refuge availability (*Ticzon et al. 2015; Ticzon et al. 2012*). A review of fish-habitat interactions in reef rehabilitation areas summarized the important concepts of fish-coral associations that reef rehabilitation projects "should consider in order to optimize order to optimize the benefits to be gained from such efforts (*Seraphim et al. 2020*). Among these are physical complexity, nutrient provision, and the roles of herbivorous, predatory and coral-feeding fishes groups. In Anda, Bohol, where a similar rehabilitation project was implemented, they reported improvements in the condition of fish communities after coral transplantation, with 52 fish species from 38 families in the coral transplantation sites (*Gulayan 2017*). These are important information and observations that emphasize the need for assisted reef rehabilitation efforts to off-set the continuous degradation of our natural reefs.

There was significant improvement in fish species richness at the treatment sites in Batangas and Bohol, but slightly higher fish species numbers in the control sites in Aklan and Tawi-Tawi (albeit not statistically significant). It is problematic to attribute changes in fish communities, whether positive or negative, to the coral transplantation and reef rehabilitation intervention alone. Emergent patterns in reef fish communities may reflect intervening events and externalities that have occurred over the entire study period. These may include habitat protection, fish growth, immigration, and recruitment; as well as diver/tourist impacts, fishing pressure, and natural disturbances.

Regimens of anthropogenic activities, such as fishing, improper waste management and tourism activities (i.e., snorkeling and SCUBA diving), as well as natural drivers, such as typhoons, disease, predation/COT, may have differentially impacted the study locations over the course of about five years since the coral transplantation project. And these disturbances can impose significant changes in the coral reef habitats (i.e., percentage cover, composition, complexity) that in turn would drive changes in fish communities. Nevertheless, the findings from this study support the body of knowledge that assisted reef rehabilitation efforts can contribute to the enhancement of reef health recovery and resilience through the improvement of reef fish diversity.

There are critical knowledge gaps in relation to fish and reef restoration interactions, and studies looking into the role of reef fishes in restoration projects are needed. Better understanding of the roles of reef fishes might help inform whether restoration projects can drive fish assemblages back to their natural compositions or whether alternative species compositions might develop (*Seraphim et al. 2020*).

While coral transplantation holds potential benefits and utility in reef restoration and improving fish community structure, careful thought must be given before undergoing such efforts. Some of the environmental and economic implications of coral transplantation efforts include the impacts on donor sites (i.e., need to have good coral cover), high mortality rates at transplantation sites, uncertain suitable environmental conditions at the transplantation sites, and the very high cost of these effort (i.e., materials and methods, transport from donor to transplantation site, nursery, human resources) (*Reyes et al. 2017*).

Given due consideration of the many challenges of coral transplantation efforts for reef recovery, this technology can yield unique benefits beyond fisheries enhancement and improvement of coral cover. Enhanced species diversity is valuable especially in tourism areas (*Bessa et al. 2017*). Perhaps species diversity might even improve at a faster rate compared to fish abundance and biomass that might support fisheries because species richness will depend largely on larval supply and recruitment, while count and biomass require time for growth, reproduction and survival on top of larval supply and recruitment.

CONCLUSIONS AND RECOMMENDATIONS

Transplantation projects for reef rehabilitation can offer immediate benefits, such as livelihood and educational opportunities, and increased awareness of stakeholders. However, careful scientific grounding is needed for ecological benefits to be gained in the long term. Fish diversity and marine biodiversity in general, is a major feature or attraction especially in tourist development sites, such as Mabini in Batangas, Panglao in Bohol and Boracay in Aklan. Improving fish diversity through assisted reef rehabilitation can support and enhance the tourism value of such locations.

The data collected from this study showed that coral reef restoration through the transplantation of coral fragments can have potential benefits in enhancing reef fish community diversity at least in Mabini, Batangas, and in Panglao, Bohol where statistically higher mean fish species richness were observed at the treatment sites. However, the mechanisms by which this may have occurred are complex and need to be understood and enhanced in order to gain consistency in the delivery of positive impacts of reef restoration efforts. A scientifically sound project design to set the direction, careful execution of restoration technologies, and a sustained monitoring and maintenance program are but some of the measures that need to be in place.

Impacts of reef restoration on fish community structure may be difficult to detect, and is largely contingent on a series of factors such as reef protection, fish growth, immigration, recruitment, diver/tourist impacts, and fishing pressure. However, there are steps to improve the probability of achieving the desired results and objectives of such projects. For studies of the same nature, it is recommended: to standardize methods, observers' skills (benthic and fish surveyors); database management: geo-references, unified database format, and a clear and dependable repository of data; intermittent project engagement through the project duration (actual or remote monitoring, communication); and secure (promissory) funding for 10 years.

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