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Preliminary results of the community structure of reef fishes in coral reef restoration sites in the Tun Sakaran Marine Park, Semporna, Sabah

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Abstract

Restoration of coral reefs at the Tun Sakaran Marine Park (TSMP) started in 2009. Various methods are adopted, although the Coral Frame method is preferred mainly due to the low maintenance cost, its durability and is currently still being used. However, since the beginning of its deployment, there has been little study on the effectiveness of the coral restoration project. Thus, this study was conducted to determine the community structure of coral reef fish around the coral frames. Two study sites (Site 1: Bohey Dulang; Site 2: Mantabuan) with existing coral frames within the TSMP were selected. At each site, a baited remote underwater video system (BRUVS), was deployed, and each was set to capture approximately one-hour footage. The first BRUVS deployment of this 24-month project was made on 21 July 2020, during the peak of the southwest monsoon. A total of 20 families (32 species) and 19 families (42 species) were recorded at Site 1 and Site 2, respectively. The Small-tooth whiptail, *Pentapodus caninus* (MaxN:14) and fusilier, *Caesio* sp. (MaxN: 101) are the most abundant species at Site 1 and Site 2, respectively. The preliminary findings reveal a low abundance and diversity counts of indicator reef fish (Serranidae, Labridae, Scaridae and Lutjanidae) at the coral restoration sites within TSMP. However, it is suspected that opportunistic local fishermen indulge in fishing in restricted parts of the Park (pers. Observ.) and try to evade detection the Park's Law Enforcement.

Keywords: Coral frame, Reef fish, Tun Sakaran Marine Park, Sabah, CTI, Coral restoration

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Introduction

Tun Sakaran Marine Park (TSMP) gazetted in 2004 as a marine protected area (MPA) is located at the heart of Coral Triangle (CT) - a region well-known for its outstanding marine biodiversity. Coral and fish diversity in TSMP are recorded to be the highest in Malaysia (Semporna Island Project, 2001). The CT area has diverse coral reefs which is home to 605 zooxanthellate coral species (66% are common to all ecoregions) that is equivalent to 76% of the world's total coral species (Veron et al., 2009). The CTI area contains 52% of Indo-Pacific reef fish species (37% of reef fishes of the world). This area includes eastern Indonesia, Sabah (Malaysia), the Philippines, Papua New Guinea, and the Solomon Islands (Allen, 2008).

Coral reef ecosystems are important in various ecological, aesthetic, economic, and cultural functions (Maragos et al., 1996). They protect shoreline, which acts as the first line of defence against erosion by reducing the force of waves and the production of sediment (Elliff and Silva, 2017). Energy from ocean waves could be dispersed by crests of fringing reefs which act as breakwaters (Gallop et al., 2014; Rogers et al., 2016). Coral reefs provide critical ecosystem services, including fisheries, coastal protection and tourist income, to millions of people (de Groot et al., 2012; Barbier, 2017; Woodhead et al., 2019). However, coral reef faces significant threat from anthropogenic factors such as overfishing, global climate change, coral disease, sedimentation, extensive coastal developments, the introduction of invasive species and the release of pollutants (Hughes et al., 2003; Hoegh-Guldberg et al., 2017).

Unfortunately, TSMP itself is facing threats from events that happened recently such as bleaching in 2017 (unpublished), Crown of Thorns starfish outbreak in 2018 (unpublished) and unsustainable fishing practices that occurred long before the gazettement of the park in 2014 (Semporna Island Project, 2001). An annual survey of the health of coral reefs by RCM in 2017 showed that 25% of the natural reefs within TSMP were in excellent condition, 33% were in good condition, and 25% were in fair condition while the remaining 17% were in poor condition (Reef Check Malaysia, 2018).

In TSMP coral reef restoration is also carried out. The coral frame method which adopts the techniques and technology of Seamarc Ptv. Ltd. from the Maldives, has been used here since 2011. This strategy is to repair damaged coral reefs on a small-scale and is expected to eventually make a significant difference, versus a big-scale restoration projects that are not only difficult but expensive and time-consuming (Wood and Ng, 2014).

The restored coral reefs are hypothesized to build important habitats for many marine organisms, mostly coral reef fishes that support the livelihood of communities. However, since the beginning of these coral reef restoration efforts, monitoring of the 'recovery' phases on the population structure of coral reef fish has been minimal, and mainly done to monitor whether the coral frames are intact. Thus, this study was initiated to evaluate the effectiveness of the TSMP coral restoration project by determining the community structure of indicator coral reef fish (species richness, abundance and ecological grouping) around the coral frames.

Materials and Methods

Study site

The study site is the Tun Sakaran Marine Park (TSMP) in Semporna, Sabah, Malaysia which is situated on the east coast of Sabah, about 18 km northeast of Semporna town. TSMP is located between latitude 4°33′N to 4°42′N, and longitude 118°37′E to 118°51′E with an area of 350 km2 (Figure 1). It was established on 24 July 2004, and comprises eight islands (Bodgaya, Bohey Dulang, Maiga, Mantabuan, Selakan, Sebangkat, Sibuan and Tetagan) and two coral reefs areas (Church Reef and Kapikan Reef) (Figure 1).

Currently, there are 35 and 95 coral frames deployed at Death End Channel and Mantabuan, respectively. This reef at Death End Channel is based on the sunken southern rim of the Bodgaya Island volcano. It has about 10 km length and a depth of about 30 m at the east end and 20 m at the west. Towards the southern tip of the reef, almost mid-way along its length, there is a channel (Dead End Channel) about 100 m wide and approximately 1.5 km in length. The channel is open to the seaward side but does not lead into the lagoon. Whereas, the stretch of reef on the west side from Mantabuan island up to the northern end has wide shallow reef top and a gently-sloping profile overall. There is an indistinct rim at about 10m depth. The main reef slope is at an angle of about 30° and continues to at least 33 m, but is mainly rubble and sand below 17 m (Semporna Island Project, 2001).

The study focused on reef rehabilitation sites using coral frames which act as artificial reefs. Sabah Parks had used coral frames as a tool for its reef rehabilitation programmes since 2011, which were first started by the Semporna Island Darwin Project with the collaboration of Sabah Parks (Wood and Ng, 2012).

TSMP is a unique multiple-use MPA which allows local communities to live inside the park boundary. Zoning scheme is practiced here where areas are divided into Pelagic use/ Buffer Zone, General Use Zone, Sanctuary Zone and Preservation Zone (Semporna Island Project, 2001). Both of the study sites are located at the border of the Sanctuary Zone and General Use Zone.

Coral reef restoration using coral frame

Since the establishment of TSMP, several coral reef restoration programmes using various methods have been conducted at the park. Of the various methods the coral frame is the most successful and feasible one. The frames were built from metal bars that formed a hexagonal structure with a dimension of 59 cm in height and 130 cm width (Figure 2). The frames were covered with three layers of sea sand using fibreglass glue to protect the metal bar from corroding and provided suitable attachment for coral's fragments. Each frame was planted with around 60 – 70 coral fragments (3-4 inch) from a branching coral species such as *Acropora* spp., *Pocilopora* spp. and *Porites* spp. Over time, corals fragments grew on the frame and made habitats that support various marine species. These coral frames were placed at depths of 4 – 10m. Coral frames at Site 1 have been deployed relatively recent in 2016 (Figure 3) compared to Site 2 in 2012.

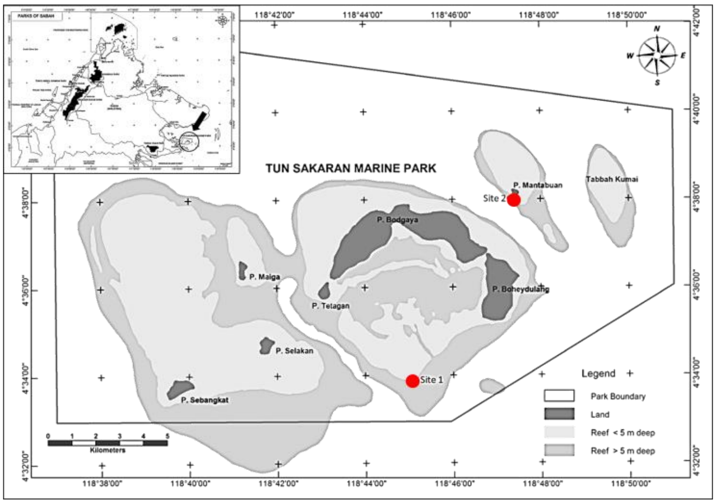

Figure 1. Map of study sites marked with red dots located at Death End Channel (Site 1) and Mantabuan Reef (Site 2) within TSMP. Insert is map of Parks of Sabah where the Tun Sakaran Marine Park, Semporna (circle and marked with black arrow) is located at South East of Sabah. (Map: Sabah Parks)

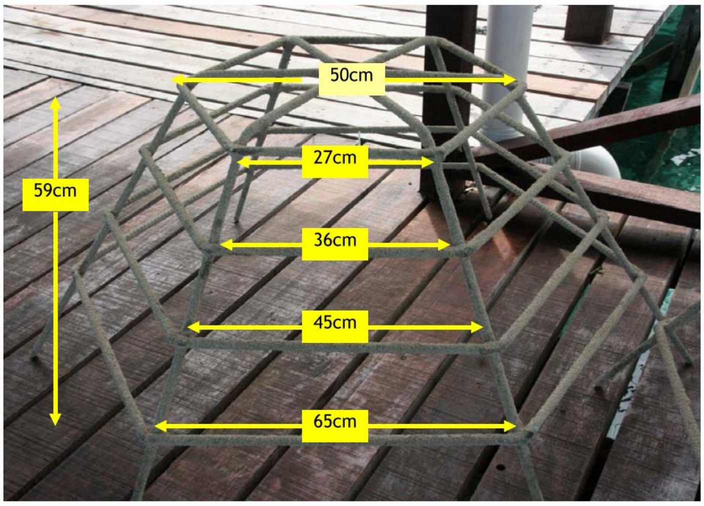

Figure 2. Hexagonal shaped coral frame structure made with iron bars that were covered with three layers of sea sands. (Picture: Wood and Ng, 2014).

Figure 3. Coral frame at Site 1 deployed at a damaged coral reef area that was covered with rubbles which has been overgrown by planted corals from *Acropora* spp.

Field surveys

This study is a projected 24-month investigation, with field data collection starting from July 2020. In this preliminary report, the data presented are based on field surveys carried out on 21 July 2020 at two sites which were at Death End Channel (Site 1) and Mantabuan Reef (Site 2).

Baited remote underwater video system (BRUVS)

Baited remote underwater video systems (BRUVS) were deployed during daylight hours (8.00 am to 3.00 pm) in both study sites at depths from 4.0 m to 10 m. BRUVS used in this study consisted of steel frame with the shape of a cross that housed a GoPro Hero 8 Black Edition camera with a wide-angle view (approx. 170° in the air), (1920×1080 video format, 60 frames/s) housed in a HERO 8 Black Protective Housing, and at 1 m from the camera is the bait housing (Figure 5). The bait housing consisted of a mesh bag containing approximately 200 g of roughly minced small tropical pelagic fish, *Decapterus* spp. BRUVS were manually lowered from the boat to the seafloor and oriented in a diagonal recording position facing the coral frames by a diver. Once the position was established, the diver started video recording and swam away from the BRUVS. The BRUVS was tied with a surface buoy to mark the deployment site and for easy recovery. Only one BRUVS was deployed at one time at each site with each BRUV recording video footage for a minimum of 60 minutes. Throughout the underwater video recording period, the boat maintained a distance of at least 200 m from the BRUVS to reduce any effects of the boat movement or presence on fish behaviour.

Figure 4. BRUVS steel structure equipped with GoPro Hero 8 camera and a bait's housing at 1 m in front of the camera.

Fish identification and data analysis

In order to establish the species richness of coral reef fish found at the coral frame, all the visible species observed from the BRUVS video footage were identified to the lowest taxonomic position possible. Several references were used to help the identification process. These reference materials included Fish Base website (www.fishbase.org) and other some books (Kong, 1998; Allen et al., 2004; Debelius, 2007; Bergbauer and Kirschner, 2014).

In order to observe the fish relative abundance in BRUVS footage, MaxN, which is a metric of species local abundance based on the maximum number of individuals observed in a single frame of video (Ebner et al., 2008, Louiseau et al., 2016) was used. It is the most commonly used technique for BRUVS footage analysis (Cappo, 2010; Whitmarsh et al., 2017) because it is quite simple, fast, and easily comparable with other BRUVS analyses due to its wide use (Cappo, 2010). The usage of MaxN to estimate the total number of individuals from single species in a single BRUVS deployment is the most conservative tool (Whitmarsh et al., 2017) and it is also designed to remove double counting and an overestimate of abundance (Sherman et al., 2018).

Besides recording all species, this study emphasized on abundance as an important indicator for coral reef fishes based on Hodgson and Torres (2006) which is extensively used in Reef Check surveys worldwide. Fishes from the families of Chaetodontidae, Haemulidae, Lutjanidae, Scaridae, Murraenidae, Seranidae and Labridae were the main priority. Note that in Hodgson and Torres (2006) indicator coral reef fish for the families of Scaridae and Serranidae were only collected for sizes larger than 20 cm and 30 cm, respectively. However, in this study, all fish sizes from both families were recorded. In addition, for Reef Check survey only *Cheilinus undulatus* of Labridae family was recorded but this study recorded every species from this family (Table 1).

Table 1. Target species in this study modified from Hodgson and Torres (2006).

No.	Common name	Family		Indicator of
1.	Butterflyfish	Chaetodontidae	Any species	Overfishing and aquarium trade
2.	Grunts/ sweetlips	Haemulidae	Any species	Overfishing
3.	Snapper	Lutjanidae	Any species	Overfishing
4.	Parrotfish	Scaridae	*Bolbometopon muricatum* and any species	Overfishing
5.	Moray eel	Muraenidae	Any species	Overfishing
6.	Grouper/ coral trout	Seranidae	*Cromileptes altivelis* and any species	Overfishing, live fish trade and spearfishing
7.	Wrasse	Labridae	*Cheilinus undulatus* only	Overfishing and live fish trade

Each species was categorized based on ecological groups as suggested by Nakamura (1985) which had been used in several other studies (Lowry, 2010; Tessier et al., 2013) that classified them by their horizontal distribution in the water column as well as their position relative to the reef. The first group (Type A) classified fish that were observed to have direct contact with the reef and often seen in crevices, holes or gaps in the structure. They are dominantly benthic dwellers. The second group (Type B) are fish species that were found in the immediate vicinity, but not coming into direct contact with the structure. Type B fish were seen swimming around the reef while remaining ones near the bottom. Lastly, the third group (Type C) included fish species that did not show any site associated attachment to the reef but were observed moving through the coral frame area. These fish tended to hover above the reef while remaining in the middle and upper parts of the water column.

Results

Species richness

A total of 120 minutes of video footage from two BRUVS were used for analysis (60 minutes on each study site). The preliminary results showed a total of 20 families (32 species) and 19 families (41 species) recorded at Site 1 and Site 2, respectively. Results presented in Figure 5, show that the family of Serranidae recorded highest number of species (4 species) in Site 1 whereas in Site 2, the family of Chaetodontidae was represented by the largest number of species (7 species).

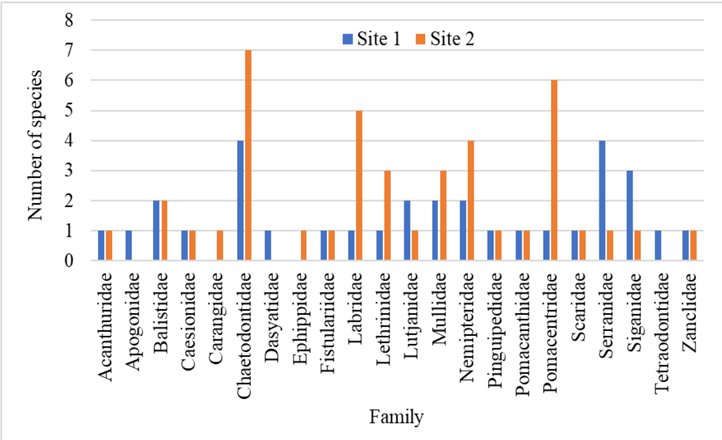

Figure 5. Number of coral reef fishes belonging to different families found in both study sites within coral restoration area in TSMP.

Relative abundance

In terms of relative abundance, small toothed whiptail, *Pentapodus caninus* (MaxN: 14) and Fusilier, *Caesio* spp. (MaxN: 101) were highest at Site 1 and Site 2, respectively. Low abundance of important coral reef fish indicators for overfishing for food fish (Family of Serranidae, Labridae, Scaridae and Lutjanidae) was recorded at both the sites. Families of Haemulidae and Muraenidae were not seen on the survey sites. At site 1, targeted species recorded were only *Lethrinus* spp., *Scarus* spp., *Lutjanus carponotatus, L. decussatus, Chephalopolis argus, C. cynostigma* and *Epinephelus sexfaciatus*. While in Site 2, reef species seen were *Cheilinus fasciatus, Hemigymnus malapterus, Lethrinus harak, Lethrinus microdon* and *Lutjanus decussatus.*

Ecological grouping

The fish categorization based on ecological grouping revealed that Type B fish were the most abundant at both sites, with more than half of the fish abundance recorded (Figure 6). Type A fish were 31.25% at Site 1; however, it is slightly lower at Site 2 with 26.19%. Higher percentages were seen for fish species in Type B group with a percentage of 62.5% and 66.67% at Site 1 and 2, respectively. Type C fish occurred sin lower percentages at Site 1 (6.25%) than Site 2 (7.14%).

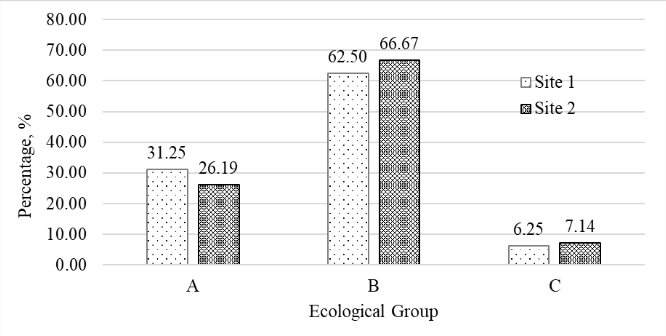

Figure 6. Percentage of reef fish found at both study sites based on their ecological groups (A, B and C).

In Site 1, there were six fish families categorized as Type A which were from the family of Apogonidae, Mullidae, Pinguipedidae, Pomacentridae, Serranidae and Zanclidae (Figure 7). Type B fish (12 families) belonged to Acanthuridae, Balistidae, Chaetodontidae, Dasyatidae, Labridae, Lethrinidae, Lutjanidae, Nemipteridae, Pomacanthidae, Scaridae, Siganidae and Tetraodontidae. In contrast, Type C fish (two families) were from families of Caesionidae and Fistulariidae.

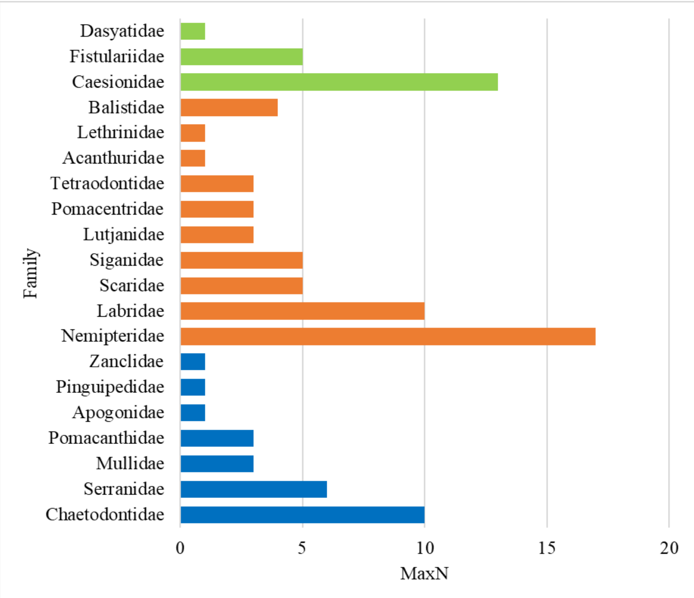

Figure 7. Relative Abundance (MaxN) of coral reef fish families categorized into different ecological groups (Green: Type A; Red: Type B and Green: Type C) at Site 1.

At Site 2, Type A fish belonged to the families of Mullidae, Pinguipedidae, Pomacentridae, Serranidae and Zanclidae (Figure 8). Type B fish were from the families of Acanthuridae, Balistidae, Chaetodontidae, Ephippidae, Labridae, Lethrinidae, Lutjanidae, Nemipteridae, Pomacanthidae, Pomacentridae, Scaridae and Siganidae. Type C fish at Site 2 were represented by families of Caesionidae, Carangidae and Fistulariidae.

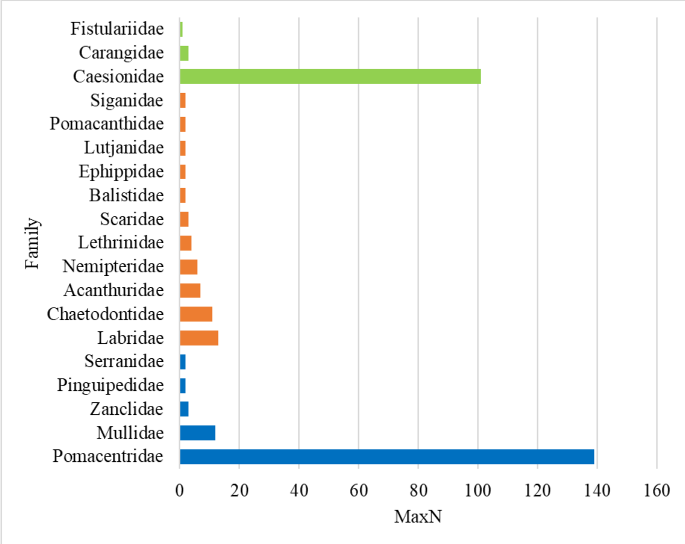

Figure 8. Abundance (MaxN) of coral reef fish families categorized into different ecological groups (Green: Type A; Red: Type B and Green: Type C) at Site 2.

Discussion

Species richness

The results showed higher species richness at Site 2 than in Site 1. This might be due to the fact that coral restoration at Site 2 started since June 2011 where 90 coral frames were deployed (Elizabeth Wood and Ng, 2014). At Site 1 the efforts were initiated in February 2015 with 35 unit of coral frames (Abdullah, et. al. 2018). Coral frame areas were not large enough to support higher species richness of fish. It is estimated that each coral frame could cover a surface area of only 1.42 m2. So, it could be estimated that the area covered by the coral frames at Site 1 is 49 m2 (35 frames x 1.42 m2) and at Site 2 is 67 m2 (90 frames x 1.42 m2). Coral restoration by coral frames could only restore a small portion of the damaged area. Larger areas need to be included for restoration to provide artificial habitats for more species. At this point the assemblages' pattern of coral reef fish at the coral frame is still unclear as the data from other BRUVS video footage are currently under analysis. Interestingly one individual elasmobranch species was observed so far (Site 1), which was the blue spotted Fantail Ray (*Taeniura lymma*). This species is currently categorized as Near Threatened in the IUCN Red List in 2009 (Compagno, 2009).

Relative abundance

Low abundance of indicator coral reef fish is likely due to overfishing. Since the study sites are located near the General Use Zone (Semporna Island Project, 2001) where traditional fishing (long line and hook) practices by local communities are allowed. This could have affected the abundance of indicator coral reef fishes. Nearby Site 1 is a common fishing spot for local communities since before the gazettement of the Park. The local communities from nearby villages within the Park continue the fishing activity in the area. During the survey, a few wooden boats with small engines were encountered around the area for fishing purposes. However, the presence of Sabah Parks personnel had a deterrent effect. Based on the preliminary findings, it is believed that the lack of ecological indicators of overfishing of coral reef fish in the study site requires regular long-term programs for monitoring and regulation.

The demand for coral reef fish especially the species common in the Live Reef Food Fish Trade (LRFFT) in Sabah has been increasing in the district of Semporna. The influx of tourists seeking 'fresh seafood' has increased pressure on local fisheries. Tourists go to Semporna not just for viewing the beautiful marine life and white sandy beaches, but also to taste the seafood. State Government is also promoting Sabah as a seafood destination on their website (Sabah Tourism Board, 2020). Increasing seafood restaurants in Semporna town points to the increasing tourist flow and seafood demand. Most restaurants in Semporna have aquarium facilities for maintaining live reef fish, molluscs, shells, lobsters and crabs to display an array of seafood available. Local fishermen are tempted to increase the fishing activity for earnings. Fishers are targeting the MPA to get expensive fish to supply to the restaurants. The low abundance of indicator coral reef fish was not just seen at coral frame areas only. A survey done in TSMP found that the indicator coral reef fish abundance was low (0.13 – 9.02 individual/m2) which showed Lutjanidae as the most abundant indicator fish recorded during surveys, followed by Chaetodontidae and Scaridae. Barramundi cod, Humphead wrasse and Bumphead parrotfish that were not encountered during surveys while other indicator species were present in low numbers (Reef Check Malaysia, 2018). The presence of elasmobranch in the study site indicates that this area provides habitat for these species. Efforts towards restoring the reefs should, therefore, continue.

Ecological grouping

Type A fish make up a small percentage of species found on coral frames compared to Type B fish. Type A fish on the coral frame were dominated by the Pomacentridae family. Coral frame planted with mainly branching corals such as Acropora spp. and *Pocilopora* spp. have become an important habitat for Pomacentrid. *Pocilopora* spp. have higher survival rates. and are prevalent on reefs in TSMP and were used quite extensively on the frames because of their excellent survival and growth (Elizabeth Wood and Ng, 2014). *Pocilopora* spp. have a compact form to provide shelter to Pomacentrid as the fish could easily fit in the crevices to from larger predators. It was noted that after about six years of coral frame deployment at Mantabuan Reef, two species of Dascyllus (*D. trimaculatus*, and *D. reticulatus*) are still seen on coral frames. This finding indicates that the coral frames had provided these species with a suitable habitat to reside.

Conclusion

Coral reef restoration in TSMP is a vital tool in improving the structure and health of damaged coral reefs as habitats for reef fishes. Restoring damaged coral reefs through the coral frame program is beneficial in improving the live coral cover of damaged reefs and providing habitats for reef fish that are important for local communities in the Park. The preliminary findings reveal a low abundance, and low diversity for indicator reef fish at the coral restoration sites within TSMP. It seems that fishing activities need to be managed more effectively to provide healing touch to depleted populations and the marine ecosystem. However, as the survey is still ongoing, further observations might provide a more comprehensive information on reef assemblages. It is important to know the success of the coral restoration program for the community structure of coral reef fish as it provides the livelihood of populations that rely on this vital ecosystem service.

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References

Allen, G. R. (2008). Conservation hotspots of biodiversity and endemism for Indo-Pacific coral reef fishes. **Aquatic Conservation Marine and Freshwater Ecosystems** (18). https://dx.doi.org/10.1002/aqc.880.

Allen, G., Steene, R., Humann, P., & Deloach, N. (2004). Reef fish identification: tropical Pacific. In Choice Reviews Online (2nd Ed., Vol. 41, Issue 07). New World Publication. https://doi.org/10.5860/choice.41-4050.

Barbier, E. B. (2017). Marine ecosystem service. **Current Biology** 27(11), R507–R510.

Bergbauer, M., & Kirschner, M. (2014). Diving and snorkelling guide to tropical marine life of the Indo-Pacific Region. **John Beaufoy Publishing Limited**, 224pp. John Beaufoy Publishing Limited, Oxford, England, UK.

Cappo, M. (2010). Development of a baited video technique and spatial models to explain patterns of fish biodiversity in inter-reef waters 2010. PhD thesis, James Cook University, Australia. Access on 17 February 2020

De Groot, R., Brander, L., van der Ploeg, S., Costanza, R., Bernard, F., Braat, L., Christie, M., Crossman, N., Ghermandi, A., Hein, L., Hussain, S., Kumar, P., McVittie, A., Portela, R., Rodriguez, L. C., ten Brink, P., & van Beukering, P. (2012). Global estimates of the value of ecosystems and their services in monetary units. **Ecosystem Services** 1(1), 50–61. https://doi.org/10.1016/j.ecoser.2012.07.005

Compagno, L.J.V. 2009. Taeniura lymma. The IUCN Red List of Threatened Species 2009: e.T39412A10229354. https://dx.doi.org/10.2305/IUCN.UK.2005.RLTS.T39412A10229354.en. Downloaded on 07 November 2020.

Debelius, H. (2007). Asia Pacific Reef Guide (3rd Ed.). **Hollywood Import & Export**, Inc., 321pp. Florida, USA.

Ebner, B., Clear, R., Godschalx, S., & Beitzel, M. (2008). Monitoring, in-stream behaviour of threatened fish and their food organisms based on remote video. **Aquatic Ecology** 43, 569–576.

Elliff, C. I., & Silva, I. R. (2017). Coral reefs as the first line of defense: Shoreline protection in face of climate change. **Marine Environmental Research** 127, 148–154.

Gallop, S. L., Young, I. R., Ranasinghe, R., Durrant, T. H., & Haigh, I. D. (2014). The large-scale influence of the Great Barrier Reef matrix on wave attenuation. **Coral Reefs** 33(4), 1167–1178.

Hodgson, G., Hill, J., Kiene, W., Maun, L., Mihaly, J., Liebeler, J., Shuman, C. and Torres, R. (2006). Reef check instruction manual: **A guide to reef check coral reef monitoring**. Reef Check Foundation, Pacific Palisades, California, USA

Hoegh-Guldberg, O., Poloczanska, E. S., Skirving, W., & Dove, S. (2017). Coral reef ecosystems under climate change and ocean acidification. **Frontiers in Marine Science** 4, 158.

Hughes, T. P., Baird, A. H., Bellwood, D. R., Card, M., Connolly, S. R., Folke, C., & Lough, J. M. (2003). Climate change, human impacts, and the resilience of coral reefs. **Science** 301, 929–933.

Kong, C. P. (1998). Marine food fishes and fisheries of Sabah. Natural History Publication (Borneo) Sdn. Bhd., Kota Kinabalu, Sabah, Malaysia.

Louiseau, N., Kiszka, J. J., Bouveroux, T., Heithaus, M. R., Soria, M., & Chabanet, P. (2016). Using an unbaited stationary video system to investigate the behaviour and interactions of Bull shark *Carcharhius leucas* under an aquaculture farm. **African Journal of Marine Science** 38, 73–79.

Lowry, M., Folpp, H., Gregson, M., & McKenzie, R. (2010). Assessment of artificial reefs in Lake Macquarie NSW. August 2010. Fisheries Final Report Series No. 125. Industry and Investment NSW. Nelson Bay, NSW 2315 Australia.

Maragos, J. E., Crosby, M. P., & Mcmanus, J. W. (1996). Coral reefs and biodiversity: A critical and threatened relationship. **Oceanography** 9(1), 83–99.

Nakamura, M. (1985). Evolution of artificial fishing reef concepts in Japan. **Bulletin of Marine Science** 37(1), 271–278.

Reef Check Malaysia. (2018). Status of Coral Reefs in Malaysia, 2018. Reef Check, Malaysia. 94pp. Available at http://www.reefcheck.org.my/media-information/annual-survey-reports.

Rogers, J. S., Monismith, S. G., Koweek, D. A., & Dunbar, R. B. (2016). Wave dynamics of a Pacific Atoll with high frictional effects. Journal of Geophysical Research: **Oceans** 121(1), 350–367. https://doi.org/https://doi.org/10.1002/2015JC011170.

Sabah Tourism Board. (2020). Fresh Seafood | Sabah, Malaysian Borneo. Retrieved October 2020, 3.18 pm from https://www.sabahtourism.com/what-to-eat/fresh-seafood/

Semporna Island Project. (2001). Management Plan for the Semporna Island Park, Sabah, Malaysia (Elizabeth Wood (ed.)). **Marine Conservation Society and Sabah Parks, Sabah, Malaysia**. 167pp.

Sherman, C. S., Chin, A., Heupel, M. R., & Simpfendorfer, C. A. (2018). Are we underestimating elasmobranch abundances on baited remote underwater video systems (BRUVS) using traditional metrics? **Journal of Experimental Marine Biology and Ecology** 503, 80–85. https://doi.org/10.1016/j.jembe.2018.03.002

Tessier, A., Pastor, J., Francour, P., Saragoni, G., Crec'hriou, R., & Lenfant, P. (2013). Video transects as a complement to underwater visual census to study reserve effect on fish assemblages**. Aquatic Biology** 18(3), 229–241. https://doi.org/10.3354/ab00506

Veron, J. E. N., Devantier, L. M., Turak, E., & Green, A. L. (2009). Delineating the Coral Triangle. Galaxea, **Journal of Coral Reef Studies** 11, 91–100.

Whitmarsh, S. K., Fairweather, P. G., & Huveneers, C. (2017). What is Big BRUVver up to? Methods and uses of baited underwater video. **Reviews in Fish Biology and Fisheries** 27(1), 53–73. https://doi.org/10.1007/s11160-016-9450-1

Wood, E, & Ng, J. V. (2012). Progress Report: Coral Frame Programme. Semporna Island Project / Marine Conservation Society, UK. 20pp.

Wood, E., & Ng, J. V. (2014). Coral Frame Programme. Progress Report 2014. **Semporna Islands Project / Marine Conservation Society,** UK. 30 pp.

Woodhead, A. J., Hicks, C. C., Norström, A. V., Williams, G. J., & Graham, N. A. (2019). Coral reef ecosystem services in the Anthropocene. **Functional Ecology** 33(6), 1023–1034.