Ecosystem Research and Monitoring Report 2019

Tubbataha Reefs Natural Park
and World Heritage Site

TRNP Ecosystem Research and Monitoring Report 2019

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Cover photo: Eric Madeja. Lined butterflyfish (*Chaetodon lineolatus*) swimming over branching corals (*Isopora bruggemanni)*

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Executive Summary

TRNP is the largest no-take marine protected area in the Philippines. To ensure that TRNP's biological diversity is maintained, the Tubbataha Management Office conducts annual ecosystem research and monitoring activities. Monitoring and research helps park authorities determine the efficacy of management interventions and formulate science-based policies. This report includes results from the monitoring of fish population and reef benthos, as well as special studies on coral recruitment and comprehensive fish inventory.

A total of 292 fish species belonging to 38 families were recorded this year. The total fish species richness across all sites was 63.5 species per 500 m^2, which was very high (>50 species per 500 m^2) according to the established categories for a healthy reef fish community. The number of species found in deeper transects was relatively higher than in the shallow transects. Overall, the mean biomass this year was 102 g/m^2, slightly higher than last year's estimate, which was at 94 g/m^2. Acanthuridae (surgeonfish), Scaridae (parrotfish), and Balistidae (triggerfish), were the prominent contributors to the mean biomass this year. These three families were also observed to increase remarkably in biomass compared to last year. The deep areas of all the sites have relatively higher biomass output at 112.5 g/m^2 than its shallow counterpart with biomass of 93 g/m^2. Target fish species constituted about 73 g/m^2 or 71% of the total mean biomass. The biomass alone of Acanthuridae (surgeonfish), Scaridae (parrotfish), and Carangidae (jacks and trevallies) made up 63% of the 73 g/m^2. Species with international conservation status recorded during the monitoring include Whitetip and Grey Reef Shark, Whaleshark, Eagle Rays, Green Sea and Hawksbill Turtles, Bumphead Parrotfish and Napoleon Wrasse.

Plate 1. School of jacks (Caranx sexfasciatus) is a usual sight in Tubbataha.

A total of 146 species under 26 families and subfamilies were identified in the USS Guardian (USSG) grounding site, while 163 species under 25 families were identified in the Min Ping Yu

(MPY) grounding site. The mean density of USSG was 1,231 individuals per 500m^2, while MPY was at 1,040 individuals per 500m^2.

The average hard coral cover in the deep areas this year was 22.9%, less than the 29.9% last year. All stations in the deeper areas have decreased in hard coral cover. Most of the decrease corresponded to increase in the cover of soft corals, algae and abiotic components. Algae in the deep areas of TRNP were mainly composed of coralline algae, which are important contributors to reef calcium carbonate that can facilitate coral recruitment. Turf algae, which has not been recorded anywhere in Tubbataha before, was noted in Stations 2A, 3A, 3B and 4A, where it occurred in minimal numbers.

Hard coral cover in the shallow areas was 35.2%, which is classified under 'good' condition. The occurrence of soft corals in the shallow transects was generally minimal, except for Station JBB. Like in the deep areas, algae in the shallow areas were mostly composed of crustose coralline algae. However, turf algae was noted in both stations of Sites 3 and 4, although in minimal numbers. The presence of turf algae and what could possibly be *Terpios hoshinota* sponge in the shallow areas is quite alarming because both suggest that some form of disturbance happened in the reefs.

Plate 2. Shallow areas of Tubbataha flourish with branching, tabular and massive coral formations.

A total of 40 coral Genera belonging to 16 Families were recorded in all the sites in TRNP in this year's monitoring. This correspond to a total of 52 TAUs in the deep and 50 TAUs in the shallow transects. The deep areas were dominated by Genus *Porites*, *Echinopora*, *Isopora* and *Montipora*. In the shallow areas Genus *Montipora, Isopora, Porites* and *Acropora* were the most common.

In July 2019, TMO received a report from one of the dive operators regarding bleaching of the branching corals in Jessie Beazley Reef. This coincided with the degree heating weeks (DHW) recorded for Tubbataha in June 2019.

The mean coral recruitment density in the deep areas was 42.28 individuals/m^2, which was higher than in 2018. A total of 12 coral families were recorded for the deep areas across all the sites. The three most common families were Agariciidae, Poccillopiridae and Poccillopiridae. The mean coral recruitment density in the shallow areas increased from 25.42 ind/m^2 in 2018 to 29.39 ind/m^2 in 2019. The densities at the shallow were lower than the deep areas, although the genera found at both depths were similar to each other. Fast growing *Acropora, Isopora and Montipora* were most frequently recorded in most of the shallow stations.

Plate 3. Goniastrea coral recruit thrives in the shallow areas of Tubbataha.

Coral recruitment rates were also determined in the two grounding sites. This year, the mean densities recorded at USSG site were 0.88 ind/m^2 in the impact zone, 0.81 ind/m^2 in the control zone and 0.69 ind/m^2 in the buffer zone. The quadrats were dominated by 16 genera, *e.g.*, *Goniastrea*, *Favites*, *Platygrya* and *Merulina*, which are more tolerant to disturbances. The permanent quadrats were also observed to have >5cm of Genus *Pocillopora* and *Porites*. The mean coral recruitment density recorded in MPY was 0.54 ind/m^2 in the impact zone, and 0.57 ind/m^2 in the control zone. A total of nine genera belonging to seven families were recorded. Dominant genus found in the quadrats were *Porites*, *Pocillopora* and *Millepora*. A consistently high number of juvenile recruits (>1cm to ≤4 cm) were found two years in a row suggesting that Tubbataha may have the capacity to replenish itself.

In the comprehensive reef fish inventory conducted by Dr. Kent Carpenter and Dr. Jeffrey Williams, a total of 338 species, including sharks and rays, were recorded. The highest number of species were identified under family Labridae (wrasses) with forty-nine (49) species recorded, followed by Pomacentridae (damselfish) (38 sp.), and Chaetodontidae (butterflyfish) (29 sp.). Sixty-seven (67) of the total species were not identified in the previous year's survey of the same method. This year, twenty-six (26) species not previously listed in the Tubbataha fish list of species were recorded. After only two years of survey, ninety-six (96) species not initially listed in the existing fish species list of the Tubbataha Management Office, were identified indicating the value of supplementing belt transect surveys with this roving census surveys.

Plate 4. Damselfish (Pomacentridae) hover on top of branching Acropora corals.

1 INTRODUCTION

1.1 Overview

According to the MPA Atlas, marine protected areas (MPAs) cover a total of 4.8% of our ocean. Only 2.3% of these are highly protected (Marine Conservation Institute, 2020). In the Philippines, there are 372 MPAs covering 1.66% of its territorial waters. These numbers, however, are not sufficient to protect our oceans. Studies show that fully protected marine reserves are the most effective type of protected area for restoring and protecting biodiversity (Malta Declaration, 2017).

TRNP is the largest no-take marine protected area in the Philippines. To ensure that TRNP's biological diversity is maintained, the Tubbataha Management Office conducts annual ecosystem research and monitoring activities. Research and monitoring, being one of its conservation programs, is designed to:

- determine ecosystem health;
- measure biophysical indicators of management effectiveness, and;
- provide scientific basis for the formulation of proactive strategies and responses to emerging issues.

The TMO annual ecosystem research and monitoring report includes the results of monitoring of fish and reef benthos. While considering comparability to previous years' data, TMO have also adopted the new methods recommended by DENR through Technical Bulletin 2017-05 in conducting fish and reef benthos monitoring.

This report presents the results of the reef fish and benthos monitoring in 2019. It also presents the long-term monitoring data of TRNP to identify trends.

Plate 5. Aerial shot of Black Rock dive site in South Atoll.

1.2 Monitoring design

Study Sites

TMO currently monitors five sites located in the North Atoll, South Atoll and the Jessie Beazley Reef (Figure 2) to describe the status of the fish and benthic communities. In each site, two replicate stations, approximately 200 meters apart, were established. The geographic location of each monitoring stations is provided in Appendix 2. The two ship grounding sites, USS Guardian (USSG) and Min Ping Yu (MPY), have been monitored since 2013 as they are ideal for assessing changes through time. In each of the stations, shallow (5meters) and deep (10meters) areas are assessed to acquire better understanding of the condition of the reefs at varying depths. This hierarchical sampling design is presented in Figure 1.

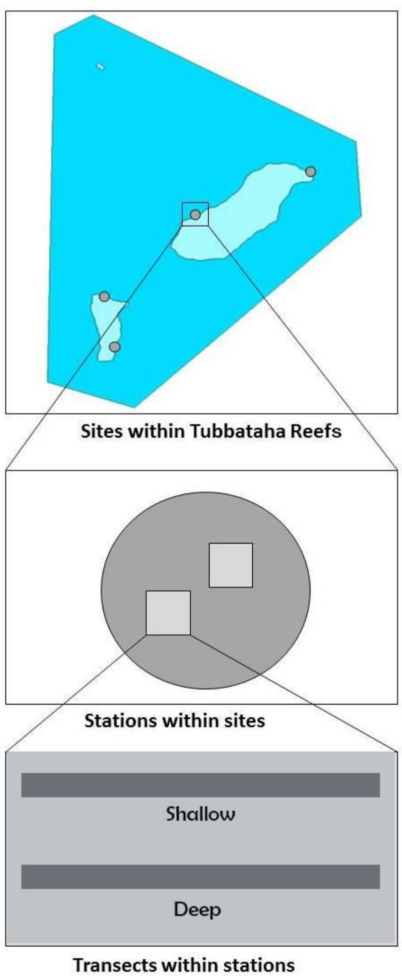

Figure 1. Hierarchical sampling design (Modified from Licuanan et al. 2016).

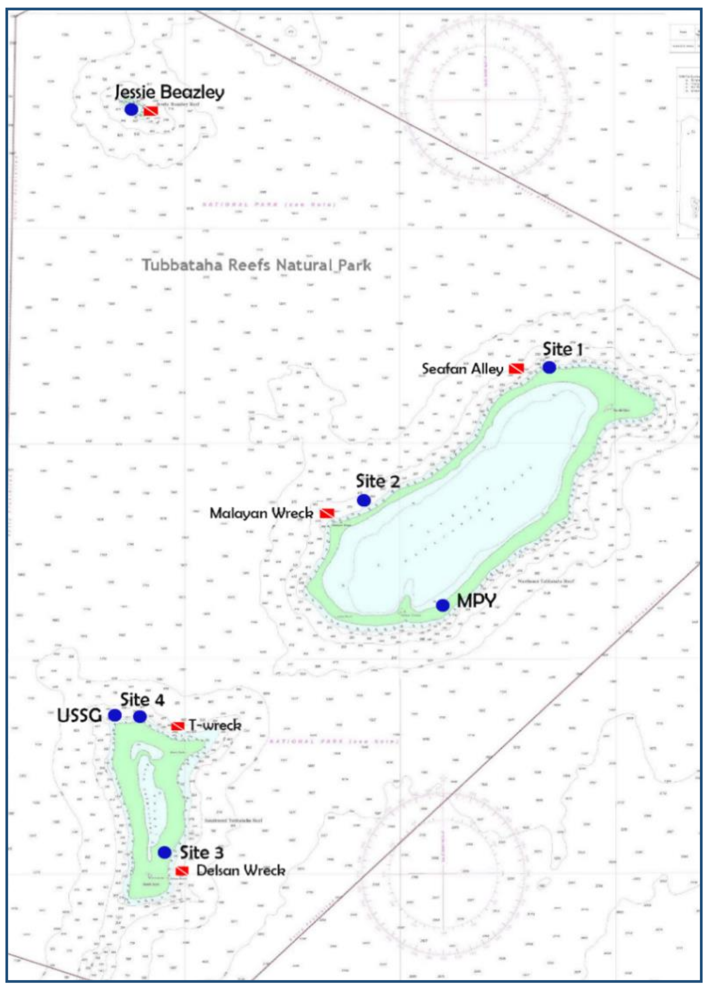

Figure 2. Location map of the monitoring sites (blue dots).

Field Surveys

The fish and benthos surveys were conducted on 2 to 9 May 2019. In-house researchers and marine park rangers were assisted by volunteer researchers from the UP-Cebu, Jose Rizal Memorial State University, De La Salle University and WWF – Philippines. The members of the monitoring team are listed in Annex 1.

1.3 References

Marine Conservation Institute. 2020. Atlas of Marine Protection. Accessed at mpatlas.org on 08 January 2020

Malta Declaration. 2017. Malta Declaration: Assessing real progress towards effective ocean protection. Accessed at https://www.nationalgeographic.org/projects/pristine-seas/malta-declaration/ on 08 January 2020

Licuanan W., Robles, R., Dygico, M., Songco, A., and van Woesik, R. 2016. Coral benchmarks in the center of biodiversity. Marine Pollution Bulletin. http://dx.doi.org/10.1016/j.marpolbul.2016.10.017

2 REEF FISH COMMUNITY

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2.1 Overview

Tubbataha Reefs Natural Park (TRNP) is an important source and sink of fish and other larval recruits which are carried by ocean currents to the reefs surrounding the Sulu Sea (Campos *et al* 2008; Alcala 1993; Dantis *et al* 1999; Nañola *et al* 2002). It helps secure the food source of the Filipino people by supplying degraded reef habitats with recruits. Being mobile animals, fishes can migrate from a well-protected reef to another as a result of spillover, thereby enriching fisheries in the nearby areas.

Annual monitoring is conducted to check variations in the spatio-temporal aspect of the reef fish community and to assess the condition of the reef, including damages caused by natural and anthropogenic disturbances (Wilkenson *et al* 2003). This survey aims to determine the spatial distribution of reef fish communities and its trend in terms of biomass and density through the years. Moreover, the result of this survey would help gauge the efficacy of policies formulated for the protection of the reefs. This year's survey was conducted with the help of expert volunteers from the University of the Philippines – Cebu and the Jose P. Rizal Memorial University.

2.2 Methodologies

Data Collection

Using the geographic coordinates of sampling locations, five (5) regular monitoring sites, plus the USS Guardian and Min Ping Yu grounding sites, were re-surveyed. Except for the grounding areas, all monitoring sites have two stations (A and B) each approximately 200 meters apart. Temporary markers were established using a buoy to mark the location of the first transect. Three (3) 50-meter replicate transects, separated by a 10-meter buffer, were laid in the deep (~10m) and shallow (~5m) areas of each station. Each transect had an imaginary 5-meter coverage on both sides, thereby establishing a 10 x 50-meter corridor. A transect was further segmented into 5-meter stops along its length and was surveyed one segment after another. Daytime Fish Visual Census (FVC) described by English *et al* (1997) was employed to determine the attributes of fish community such as biomass, density, and species richness.

Researchers recorded the scientific name, actual count, and estimated length/size of the fish encountered inside the established corridor. Highly mobile species were recorded first before the slower ones (i.e., transient and cryptic species). Four (4) divers completed the survey this year, assessing the deep areas first and the shallow afterwards. The same sampling design was replicated in the grounding sites.

Data Analysis

Data was collated and organized using the format adapted from Coral Reef Visualization and Assessment (CoRVA) system introduced by the DENR in 2014. Species richness was determined using the actual number of species identified during the survey while the fish density was expressed by the number of individuals per given area (individuals per 500m²). The biomass was simplified in grams per square meter (grams per m²) and was calculated with the existing length and weight model (Kulbicki *et al* 1993), using the formula:

$$W = aL^b$$

where ***W*** was derived weight (g), **L** was the estimated total length (cm), and **a** and **b** were regression parameter values obtained from CoRVA and FishBase databases (www.fishbase.org).

A paired t-test was applied to calculate significant variations in the density and biomass of reef fishes in varying depths, sites, and between this year and previous year's estimates at p=0.05. Two-factor analysis of variance (ANOVA) in Microsoft Excel 2016 was used to detect if there were significant differences in the overall biomass between sites and between years, from 2013-2019. The same statistical analysis was applied in the density and biomass outputs between depths of each of the grounding sites.

The fish species were further classified into the following groups to generate a clearer picture of the contribution of each group to the total biomass and density: (1) according to nature (pelagic or demersal); (2) target, indicator, and major; and (3) according to trophic groups.

2.3 Results and Discussions

Present conditions

Species richness and density

A total of 292 species belonging to 38 families were recorded this year. This was slightly fewer than the 306 species observed in 2018. Station 2A had the highest total number of species recorded with 176 species, while the lowest number was in Station JBB with 133 species.

Species richness per site varied from 47 species per 500 m² (Station JBB) to 85 species per 500m² (Station 3B). The number of species found in deeper transects was relatively higher than in the shallow transects. The total species richness across all sites was 63.5 species per 500 m², which was very high (>50 species per 500 m^2) according to the established categories for a healthy reef fish community (Hilomen *et al* 2000) (Appendix 1).

Biomass and Density

Overall, the mean biomass this year was 102 g/m^2, slightly higher than last year's estimate, which was 94 g/m^2. No significant difference was found between these two years' biomass estimates (t-test; $p>0.5$). Acanthuridae (surgeonfish), Scaridae (parrotfish), and Balistidae (triggerfish), were the prominent contributors to the mean biomass this year. These three families were also observed to increase remarkably in biomass compared to last year. The mean biomass value also exceeded the minimum established biomass yield for a healthy reef fish community (Nañola *et al* 2004) (Appendix 1).

The deep areas of all the sites have relatively higher biomass output at 112.5 g/m^2 than its shallow counterpart which has a biomass of 93 g/m^2. However, there was no significant variation (t-test; $p>0.5$) found between the deep and shallow sites. The biomass of deep transects were mainly attributed to Acanthuridae (surgeonfish), Pomacentridae (damselfish), and Balistidae (triggerfish). The shallow transects' biomass output was represented by Balistidae (triggerfish), Acanthuridae (surgeonfish), and Scaridae (parrotfish). Appendix 2 lists all the families with their mean biomass contribution for each depth.

Station JBB recorded the highest biomass output at 125 g/m^2, followed by Station 4B and Station 4A both at 118 g/m^2. There were no significant variations in the biomass output between Stations A and B. Site 1 recorded the lowest biomass output at 83.22 g/m^2, while the highest biomass was in Site 4. Site 4 was dominated by Scaridae (parrotfish) and Acanthuridae (surgeonfish).

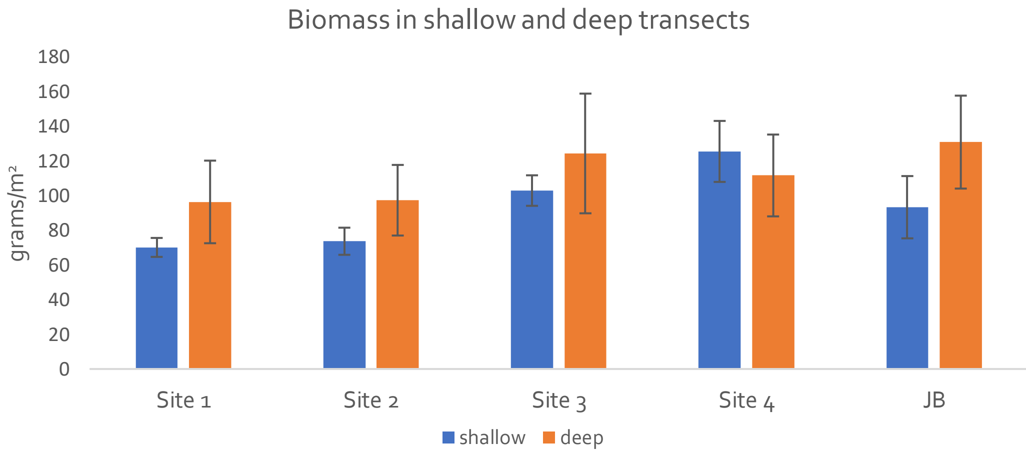

Figure 3. Distribution of mean biomass (grams per m2) per depth in all sites.

Threadfin anthias *Pseudanthias huchtii*, Bicolor chromis *Chromis margaritifer*, and Dispar anthias *Pseudanthias dispar* dominated the reefs in terms of numbers. The mean density this year was 1,678 individuals per 500m², higher than last year's value of 1,298 individuals per 500m². However, no significant difference was found between this year and last year's mean density estimates.

Deep density output contributed significantly (t-test; $p=0.05$) to the total density with around 1,027 individuals per 500 m² than its shallow counterpart with only 651 individuals per 500 m². In the deep areas, Station JBA had the highest mean density recorded at 3,276 individuals recorded, while Station 2A had the lowest with 1,352 individuals. Meanwhile, in the shallow portion, the greatest number of individuals were recorded in Station 4A with 1,662 individuals, while only 948 individuals were observed in Station 3B. Deep transects were dominated by Serranidae (fairy basslets), and Pomacentridae (damsels). Shallow sites, on the other hand, were dominated by Pomacentridae (damselfish) and Serranidae (fairy basslets). Bicolor chromis *Chromis margaritifer* and Threadfin anthias *Pseudanthias huchtii* comprised 25% of the total number of individuals recorded this year.

In general, Site JB had the highest mean density of reef fish at 2,155 individuals per 500 m². The lowest mean density was recorded in Site 2 at 1,101 individuals per 500m².

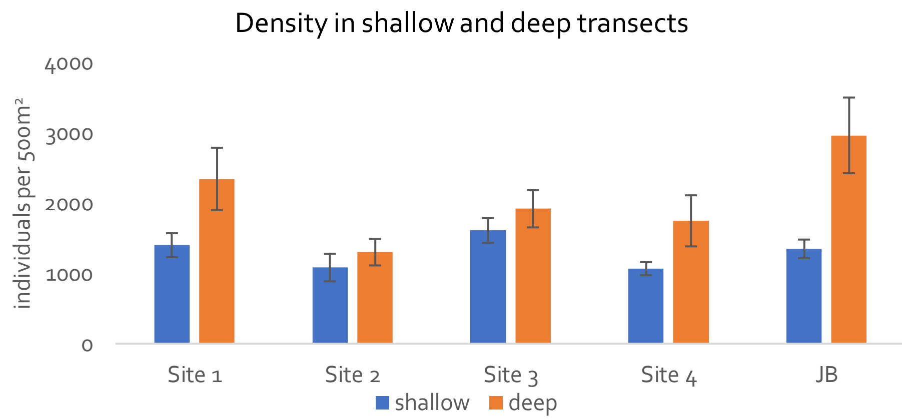

Figure 4. Distribution of mean density per depth in Tubbataha Reefs.

Patterns of fish community

Despite the erratic biomass estimates year after year, the polynomial trend appeared to be stable until 2015 (Figure 5). The decreasing biomass pattern was observed in 2016 until 2018. The most significant decrease in the presence of the Scaridae (parrotfish) was from 2016-2017). This year had the highest biomass of Scaridae since 2016 but is still not comparable to 2015 figures.

To test the source of variance in biomass estimates from 2013 to the present, two-factor analysis of variance (ANOVA) was used. Take note that this analysis was only applied from 2013 due to the change in the number of monitoring sites from seven to only five (5) sites.

Both temporal ($p<0.05$; df=6) and spatial ($p=0.05$; df=4) factors were revealed to strongly influence the variations between biomass values of the Tubbataha Reefs. This was evident in the fluctuating biomass estimates which could be clearly observed between 2014-2016. An abrupt increase in biomass was observed in 2015 and a decrease of more than one-third was recorded the following year. One factor that may have attributed to the fluctuations were the presence and absence of large-bodied species other than pelagic fishes. The presence of a school of Scaridae (parrotfish), specifically the Bumphead parrotfish *Bolbometopon muricatum* in 2015, which was not encountered the following years, contributed largely to these differing biomass outputs. Other notable families which were observed to fluctuate year after year and which largely influenced biomass outputs were the Nasinae (unicornfish), Balistidae (triggerfish), and Carangidae (jacks and trevallies).

Differences in biomass yields of regular monitoring sites from one another were also found to be a source of variance. Figure 6 showed the biomass estimates of regular monitoring sites from 2013. On average, Site 4 had relatively higher biomass outputs compared to other regular monitoring sites. Site JB had the lowest average biomass estimate during the last seven (7) years. The decreasing trend for Sites 1, 2, and 4 were greatly influenced by the significant number of Scaridae (parrotfish) recorded in 2015 but were absent in subsequent years. The downward trend in Site 3 was influenced by the absence of the pelagic groups Carangidae (jacks and trevallies) and Caesionidae (fusiliers). In Site JB, the main cause of the decrease from 2015 was attributed to the decrease in the number of Nemipteridae (bream) and Nasinae (unicornfish).

Most of the sites, however, showed an increase in biomass estimates from the previous year, except for Site 1. The decrease in this site was strongly influenced by the pelagic group Carangidae (jacks and trevallies). Although there was an increase in their number this year, the jacks and trevallies were of smaller sizes.

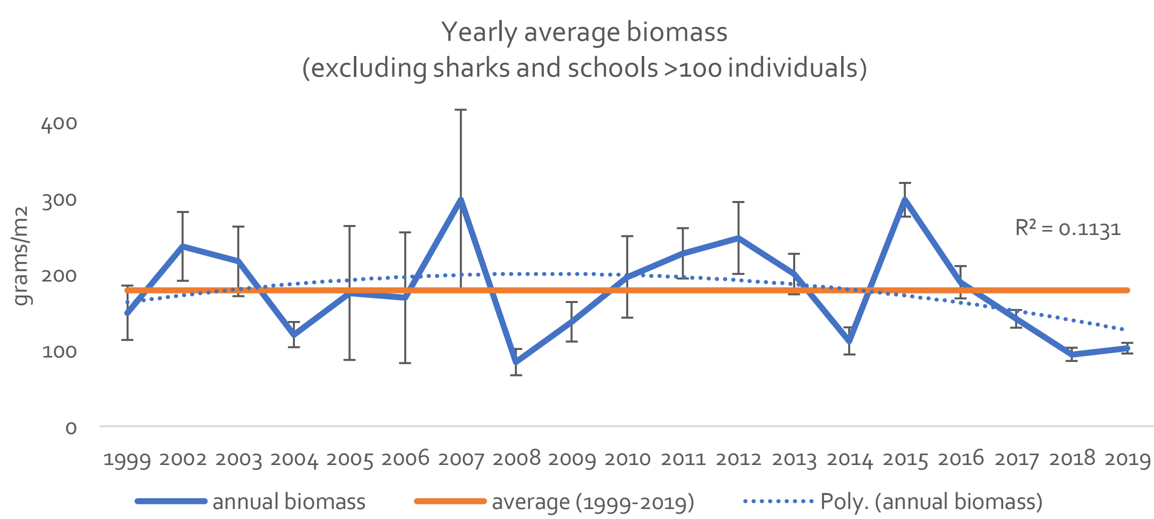

Figure 5. Temporal pattern of mean biomass (g/m²) in Tubbataha Reefs. Error bars represent the standard error of the mean.

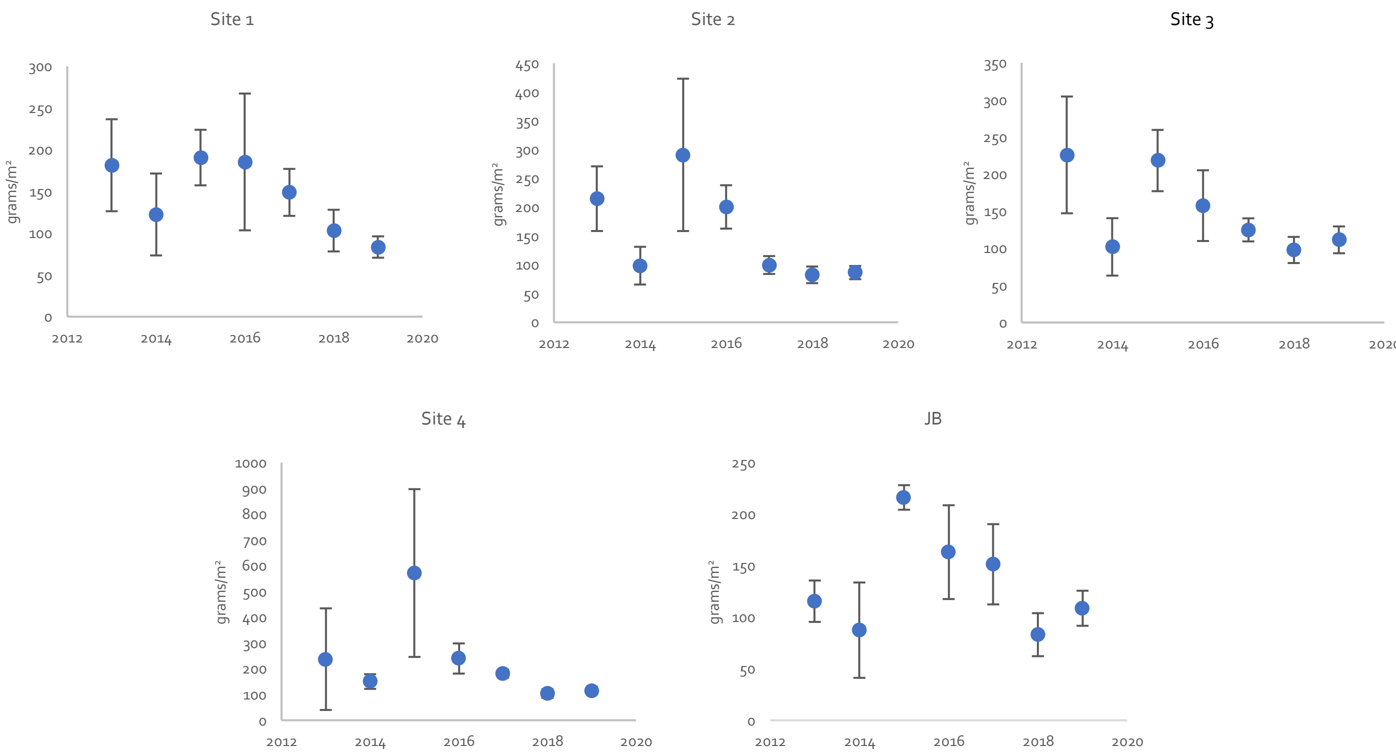

Figure 6. Biomass in regular monitoring sites from 2013-2019. Error bar represents the standard error of the mean.

Biomass in deep vs. shallow area

Annual biomass estimates in shallow areas showed more stable polynomial trend than its deep counterpart (Figure 7). Furthermore, it was also closer to the annual average. Variability in biomass values was more prominent in deep areas. The deep area also mirrors the trend of the annual biomass estimates in Figure 5. The major influencers of biomass estimates in the deep areas were the Acanthuridae: Nasinae (unicornfish), Caesionidae (fusiliers), and Carangidae (jacks and trevallies). In general, these three families contributed the most to the biomass estimates in the deep areas. They are pelagic species, often venturing and traversing the deeper part of the reefs. The declines in the biomass in deep sites in the last four (4) years may have been influenced by the absence of schooling large-sized (>30 cm) Red snapper (*Lutjanus gibbus)*, which were last recorded in 2014 (TMO 2014, unpub). The shallow stations were mainly influenced by Scaridae (parrotfish), Balistidae (triggerfish), Acanthuridae (surgeonfish), and the occasional visits of pelagic Carangidae (jacks and trevallies). The presence or absence of these families could determine the decrease and increase of biomass yields on each depth.

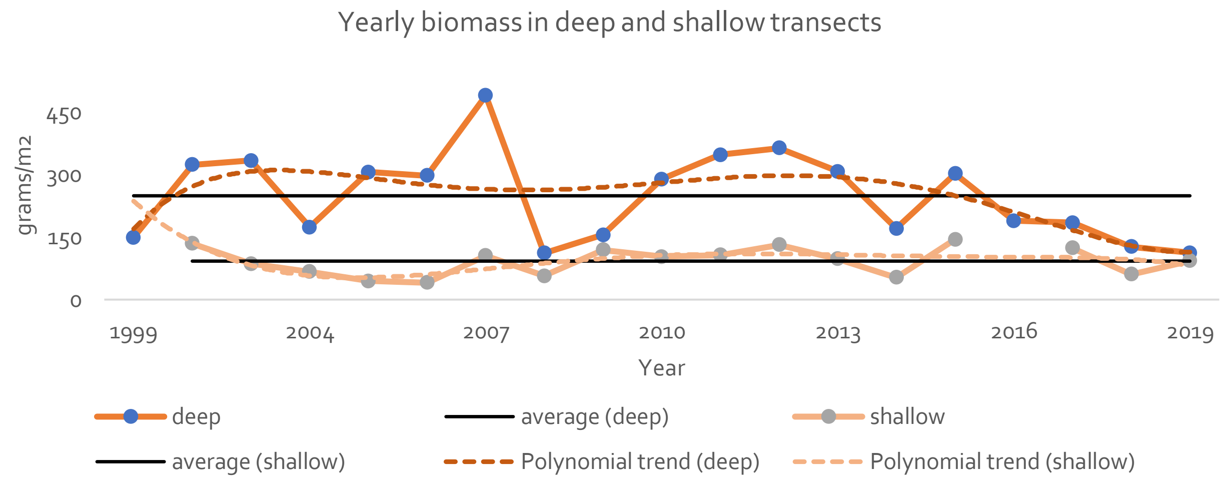

Figure 7. Biomass estimates in shallow (~5m) and deep (~10m) sites. Error bar represents the standard error of the mean.

Demersal vs. pelagic

Demersal species are fishes that live or feed on or at the bottom of coral reefs. They are highly associated with coral reefs, thus, there is a higher chance of encountering the same species in the same area in subsequent surveys. Hence, demersal species are better indicators of reef health than pelagic species. Pelagic fishes, in contrast, are those that inhabit and feed in the open water column of coastal and oceanic waters (Lal and Fortune 2000). They are usually larger than demersal fishes, are highly mobile, occasionally occur in schools, and more often traverse deeper part of the reefs.

Except in 2006-2007, demersal species contributed the most to the total mean biomass output in the Tubbataha Reefs. Decreasing trends were recorded in 2004-2006, 2007-2009, and 2016 to the present. The greatest downtrend was recorded in 2016. This follows the same trend for the annual mean biomass presented in Figure 5. Although the mean biomass values this year increased slightly from last year's, the increase did not compensate for the three-year decrease in biomass yields observed from 2016 to 2018. It was mentioned in the previous year's report that the very high biomass of demersal species in 2015 was influenced by the high number of Scaridae (parrotfish). The increase in biomass this year was attributed to an increase in both the density and biomass of Balistidae (triggerfish), Pomacentridae (damselfish), Serranidae (groupers), and Labridae (wrasses). However, the increase in these groups' values was still not as high as in 2016. This year, demersal fishes accounted for 71% of the total mean biomass and 98% of the total mean density. The total mean density was mostly attributed to Serranidae: Anthiinae (fairy basslets) and Pomacentridae (damselfish).

The trend for pelagic species could not be established and appears to be unpredictable. Pelagic fish rarely traverse the transects and their presence is more a function of chance. However, when observed in the transects, they could influence the biomass significantly. This was noted in 2006-2007 when more than 50% of the mean biomass was attributed to pelagic species. There were some years as well when fewer pelagics were recorded e.g., 2005, 2009, and 2014. The dominant influencers for these groups were the Nasinae (unicornfish), Carangidae (jacks and trevallies), and Caesionidae (fusiliers). This year, the mean biomass of pelagic fishes was mainly attributed to Nasinae (unicornfish) and Carangidae (jacks and trevallies) while mean density was attributed to Nasinae (unicornfish) and Caesionidae (fusiliers).

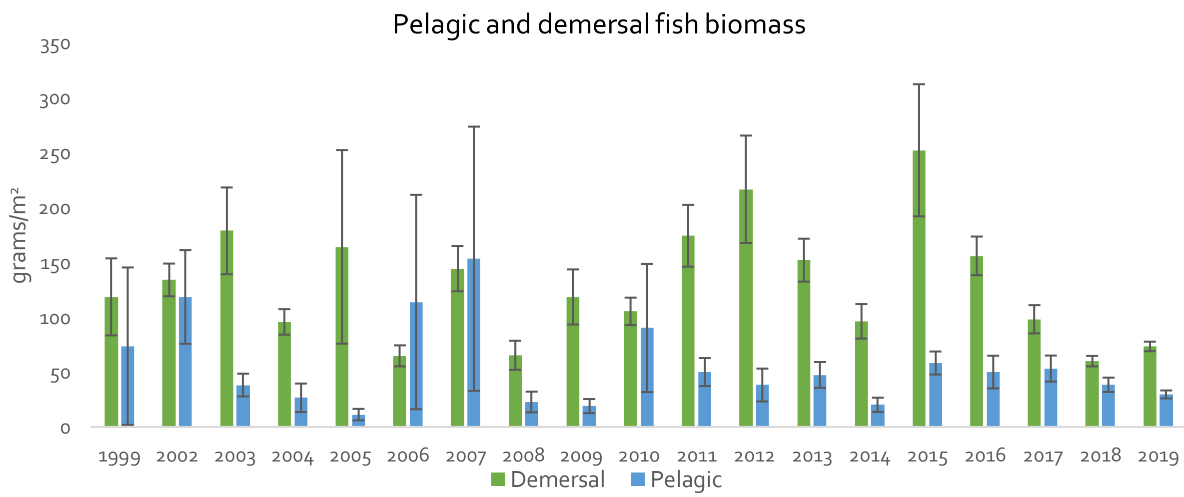

Figure 8. Temporal biomass of demersal and pelagic fishes of Tubbataha Reefs. Error bar represents the standard error of the mean.

Fish Group: Target, Indicator, and Major

Target species are fishes primarily sought by fishermen and are subject of fishing effort in a particular fishery (FAO 2003a) for their commercial value as food or ornament. This includes, but is not limited to Lutjanidae (snappers), Carangidae (jacks and trevallies), and Caesionidae (fusiliers). Indicator species often referred to as the corallivores, are fishes that are highly dependent on corals for food and shelter (Cole *et al* 2008). Thus, they could serve as a measure for determining the coral cover or condition of the reef in general (Crosby and Reese 1996; Ohman *et al* 1998). In this report, Pomacanthidae (angelfish), Chaetodontidae (butterflyfish), and some species of Scaridae (parrotfish), Balistidae (triggerfish), Tetraodontidae (pufferfish), Pomacentridae (damselfish), and Labridae (wrasse), were identified under this group. Lastly, the major group which usually occurs in high concentrations and does not belong to any of the two groups includes, but is not limited to, the Serranidae: Anthiinae (fairy basslets) and Pomacentridae (damselfish). They are targeted as ornaments rather than for human consumption. They also serve as food for other fish species.

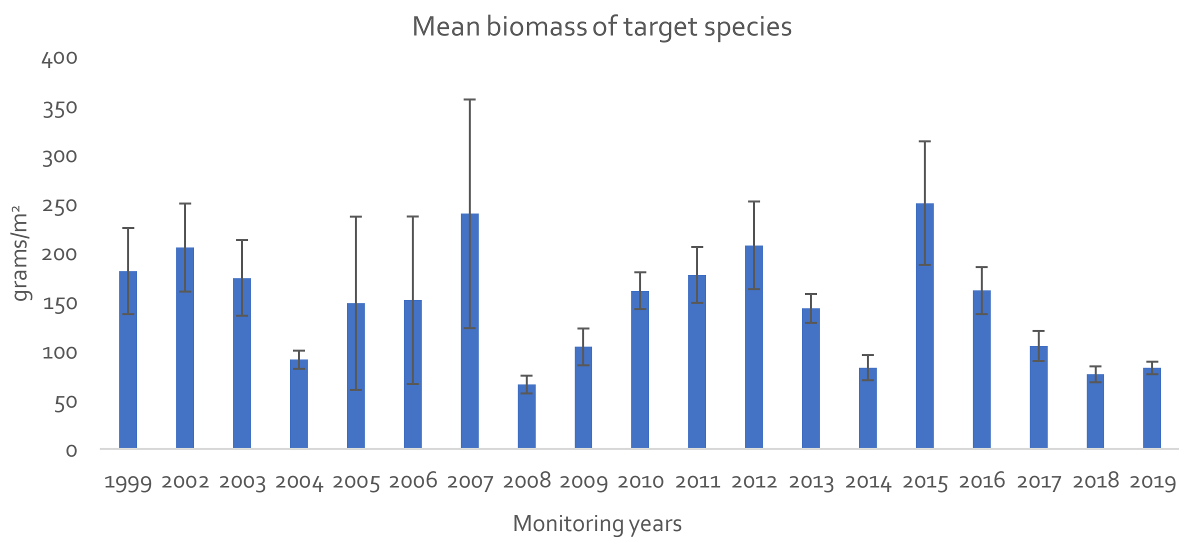

Figure 9. Temporal mean biomass (g/m²) of the target species.

The mean biomass of target fish exhibited an oscillating pattern. Pelagic groups, such as Acanthuridae: Nasinae (surgeonfish), Caesionidae (fusiliers) and Carangidae (jacks and trevallies), and demersal such as Lutjanidae (snappers), Scaridae (parrotfish), and Serranidae (groupers), were the top influencers of the biomass for target species. These groups' presence or absence dictates the fluctuations in the biomass yields for the target species. The biomass of target species ranged from 65 g/m^2 (2008) to as high as 250 g/m^2(2015).

Target fish made up 17.8% of the mean density this year. Acanthuridae (surgeonfish) was the dominant group recorded in all sites except in Site 4 where Scaridae (parrotfish) were larger. Indicator species constituted 1.45% of the mean density, dominated by Pomacanthidae (angelfish). Pearlscale angelfish (*Centropyge vroliki)* was the most dominant indicator fish this year, with 519 individuals recorded. Chaetodontidae (butterflyfish) and Pomacentridae (damselfish) were the most abundant groups. This year's value for indicator species was also the highest since 2008 monitoring. Although the increase in the presence of corallivorous/indicator species could indicate a healthy coral reef, available literature is still limited on whether their 'over' abundance could affect and limit the recovery of the coral they feed on and if it could lead to further stress to the corals especially after a disturbance (Cole *et al*, 1998; Glynn 1996; Bellwood, *et al* 2006). Major species constitute the bulk of the mean density. The group was dominated by Pomacentridae (damselfish) and Serranidae: Anthiinae (fairy basslets).

This year, target fish species constituted about 73 g/m^2 or 71% of the total mean biomass. The biomass alone of Acanthuridae (surgeonfish), Scaridae (parrotfish), and Carangidae (jacks and trevallies) made up 63% of the 73 g/m^2. The biomass of the indicator species was at 3.54 g/m^2 with prominent contributions from Scaridae (parrotfish), Chaetodontidae (butterflyfish), and Balistidae (triggerfish). Major species contributed 26 g/m^2 in the total mean biomass. Balistidae (triggerfish), specifically the Genus *Melichthyes*, dominated all sites except for Site 3, and it was also among the most abundant group in TRNP.

Trophic groups

Fishes could be also grouped according to their feeding niche. Feeding guild (Bone and Moore 2008), another term for trophic group, is a concept based on the similarity of diet specializations of each species, irrespective of their taxonomic affinities (Bellwood and Green 2009). The structure of these trophic categories could imply the availability and abundance of food sources in a site. The categories, also used in the 2018 report, are (Helfman *et al* 2009):

Benthic Carnivore:	Fishes that feed on benthic invertebrates
Corallivore:	Fishes that consume coral polyps (with or without skeleton)
Detritivore:	Fishes that feed on detritus (decaying organic matter)
Herbivore:	Fishes that feed and digest plant matter
Omnivore:	Fishes that feed on both plant and animal matter
Piscivore:	Fishes that feed on marine animals such as other fish or invertebrates; also called carnivorous fishes (top predators)
Planktivore:	Fishes that feed on phyto- and zooplankton

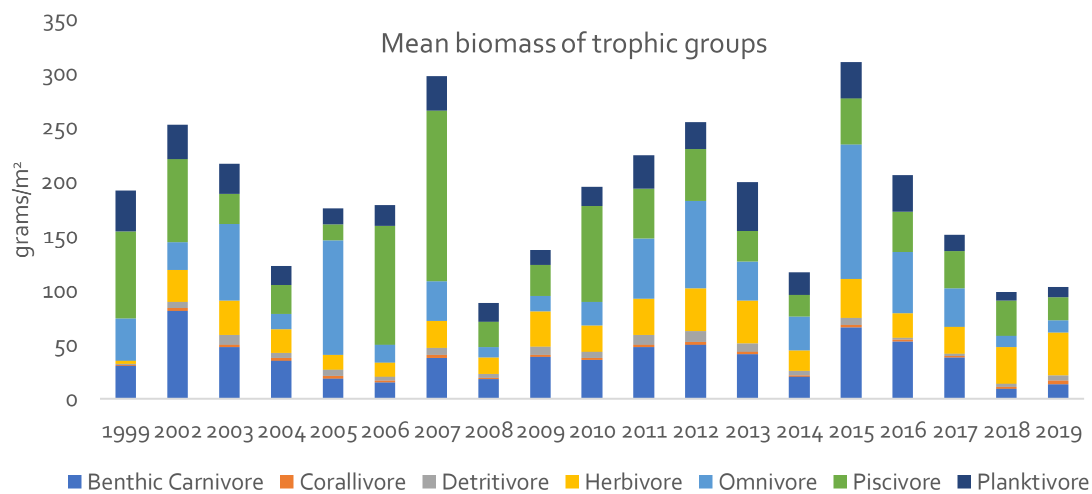

Figure 10. Temporal distribution of biomass per trophic group.

Among all trophic groups, detritivores and omnivores exhibited a general stable trend across time. Except for a slight decrease influence by low biomass values in the last two years, benthic carnivore appears to be stable as well. Herbivores and corallivores both exhibited an increasing trend, with the last two years yielding the highest biomass values of two decades of monitoring. Since 2014 the biomass estimates of herbivores showed a significant increase on each site (ANOVA; $p<0.05$). A notable increase in herbivore biomass was observed in Sites 1 and 3, and JB. Although there was a slight decrease in the biomass of herbivores this year compared to 2018 in Sites 2 and 4, the current values are still among the highest in the past six years.

Piscivores showed the most erratic fluctuations in biomass each year. Since fishes tend to move from one place to another, variations in biomass are expected. Piscivorous species are mostly the large-sized predators such as jacks and trevallies, groupers, snappers, and emperor fishes. Species at the top or near the top of the ecological food web, oftentimes the piscivores and benthic carnivores, are of special concern to conservation because their presence or severe losses/reduction could influence changes in ecological processes and diversity of an ecosystem (Steneck 1998). Based on the concept of 'fishing down the web', popularized by Pauly *et al* (1998), species at the top of the trophic level are the first to be fished, followed by smaller species (Christensen 1996). Thus, having a high abundance of top predators in an area could imply a balanced ecosystem. In the case of Tubbataha, top predators such as the piscivore and benthic carnivore exhibited a relatively high average biomass throughout the years.

Threatened Species

Aside from restoring fish stocks, one of the aims of establishing marine protected areas is to ensure the conservation of threatened species, especially those identified by the International Union for Conservation of Nature (IUCN). Tubbataha is known to host more than 180 threatened and near threatened marine species. Some of these species of interest were observed outside the transects. The Near Threatened (NT) Whitetip reef sharks (*Triaenodon obesus)* were recorded in all regular monitoring sites, while the NT Grey reef shark (*Carcharinus amblyrhynchos*) was noted in Site 2. The Green sea turtle (*Chelonia mydas*) were observed in Site 1, 3, and 4, while the Critically Endangered Hawksbill turtles (*Eretmochelys imbricata)* were seen in Site 1 and 2. Bumphead parrotfish (*Bolbometopon muricatum*) were also recorded in Site 1. Three (3) eagle rays (*Aetobatus sp*.) were noted in the USS Guardian site. The Endangered Napoleon wrasse (*Cheilinus undulatus)* was noted on most sites including the grounding sites. Whaleshark (*Rhincodon typus*) was noted in Site JB. The presence of these species could serve as an indication of recovery from disturbances, such as from overfishing, and of stringent protection. Hence, their presence implies a healthy and well-protected reef.

Grounding Sites

Present condition

A total of 146 species under 26 families and subfamilies were identified in the USSG grounding site. This was higher than the previous year's count of 136 species. Species richness was at 56.5 species per 500m². In the MPY grounding site, a total of 163 species under 25 families were identified this year, slightly higher than last year's 161 species. Species richness was at 64.8 species per 500m². Values for both grounding sites were considered very high (>50 species per 500 m²) according to the categories set for a healthy reef fish community in the country (Hilomen *et al* 2000) (Appendix 1).

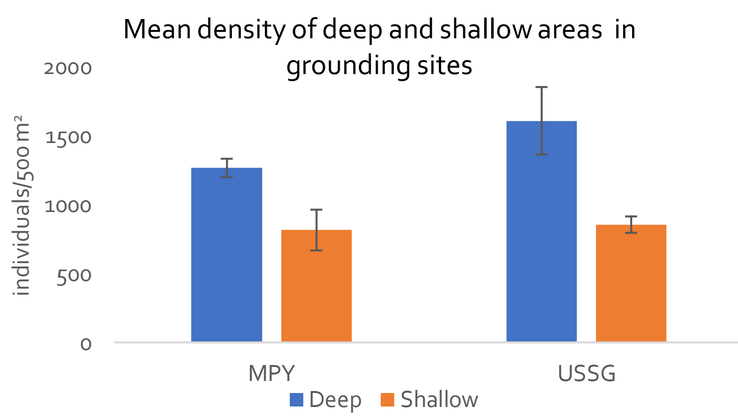

Figure 11. Relative distribution of mean density of reef fish communities in shallow (~5m) and deep (~10m) sites of MPY and USSG grounding site.

Overall, the mean density of USSG was 1,231 individuals per 500m², higher than 1,205 individuals per 500m² of the previous year. The deep area (1,608 individuals per 500m²) contributed most to the overall density of reef fish than the shallow (854 individuals per 500m²) (Figure 11). However, the difference in density between the deep and the shallow area was not significant (t-test, p>0.05). The deep site of the USSG area was dominated by Dispar anthias *Pseudanthias dispar* and Lyretail anthias *Pseudanthias huchtii*, while the shallow site was influenced by the presence of Bicolor chromis *Chromis margaritifer* and Lyretail anthias *Pseudanthias huchtii*. Ninety-five percent (95%) of the mean density was attributed to demersal fishes which were dominated by Anthiinae (fairy basslets) and Pomacentridae (damselfishes).

The total mean density of MPY was 1,040 individuals per 500m², slightly lower than the previous year's value (1,149 individuals per 500m²). Deep area (1,265 individuals per 500m²) is relatively higher in mean density than the shallow area (815 individuals per 500m^2) (Figure 11). However, no significant variations were found between the deep and shallow areas (t-test; p>0.05). Both depths were dominated by Ternate chromis *Chromis ternatensis.* Demersal species constituted about 95% of the total mean density in the area, mainly attributed to Pomacentridae (damselfish) and Anthiinae (fairy basslets).

Based on the category established by Hilomen *et al* (2000) for a healthy reef fish community, the mean density of USSG site falls under the 'high' category (>1134 individuals/500m^2) while MPY was considered 'moderate' (<1,133.5 individuals/500m^2).

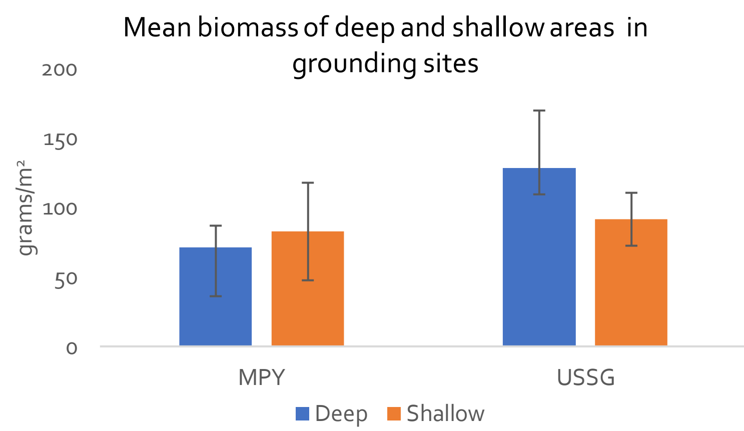

Figure 12. Relative distribution of mean biomass of reef fish communities in shallow (~5m) and deep (~10m) sites of MPY and USSG grounding sites.

The total mean biomass of USSG was 111.5 g/m^2, relatively higher than the 101.7 g/m^2 output of 2018. The mean biomass in the deep area (128 g/m^2) of USSG was relatively higher than its shallow (91 g/m^2) counterpart. However, the difference was not significant (t-test; p>0.05). Balistidae (triggerfish), Scaridae (parrotfish), and Acanthuridae (surgeonfish), and Carangidae (jacks and trevallies) dominated the USSG grounding site. Demersal fishes constituted about 72% of the total mean biomass in the site, mainly influenced by Balistidae (triggerfish) and Scaridae (parrotfish). Target fishes constituted 69% of the total mean biomass, while 28% were attributed to major species.

This year, the mean biomass of MPY was 70 g/m^2, slightly higher than the 56 g/m^2 of 2018. Biomass values in the deep area (81 g/m^2) contributed more to the total mean biomass than shallow area (71 g/m^2). Scaridae (parrotfish), Acanthuridae (surgeonfish), and Carangidae (jacks and trevallies) contributed the most to the biomass output in the deep transects, while

Acanthuridae (surgeonfish), Scaridae (parrotfish), and Labridae (wrasses) mainly influenced the biomass in the shallow station. Seventy-three percent (73%) of the biomass in this site was contributed by the demersal fishes, mainly by Scaridae (surgeonfish) and Labridae (wrasses). Target species constituted about 81% of the total mean biomass, major species were attributed to 15%, while indicator comprised the remaining four percent (4%).

In addition, biomass outputs of USSG and MPY grounding sites exceeded the minimum yield for the reef fish community to be considered healthy as established by Hilomen *et al* (2000).

Patterns of density and biomass

The mean density in the USSG increased in the last two years. Despite this increase, the mean density is still merely almost half of 2014 records. The downtrend was observed for Pomacentridae (damselfish) and Anthiinae (fairy basslets). Both groups are the top contributors to density in Tubbataha and occur in large concentrations, thus, the decrease in their numbers would greatly affect the density of the area. Other groups which also decreased from 2014 were the Acanthuridae (surgeonfish), Chaetodontidae (butterflyfish), and Balistidae (triggerfish).

In the case of the MPY, increasing trend from 2014 was observed. Only families of Anthiinae (fairy basslets), Holocentridae (squirrelfish), and Scaridae (parrotfish), showed a notable decreasing trend. Further, there was an observed increase in the number of Pomacentridae (damselfish) and Caesionidae (fusiliers) which for compensated for the decrease in other families.

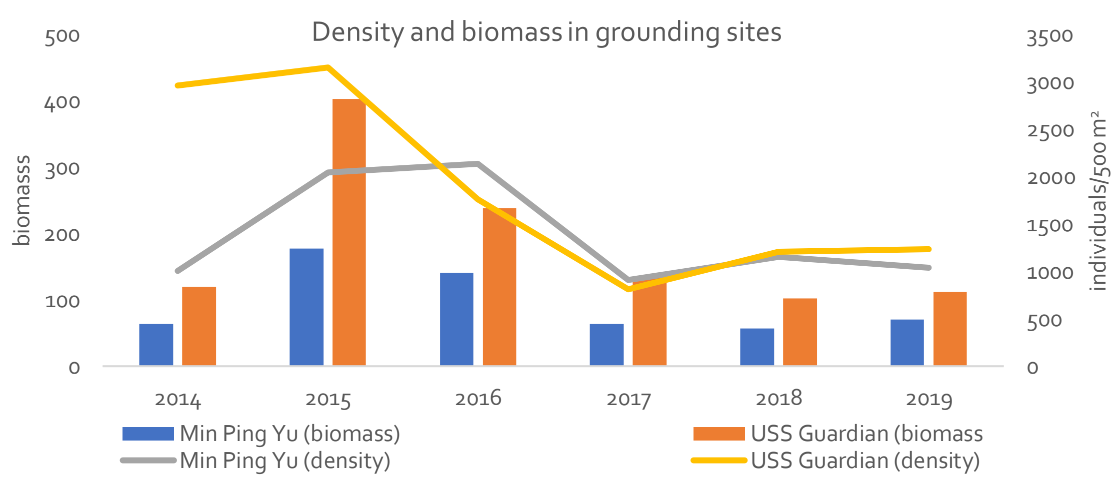

Figure 13. Temporal pattern of biomass (g/m²) and density (individuals/500m²) of USSG and MPY grounding sites.

The difference in biomass from 2014 to 2019 was almost negligible for the USSG grounding site. The spike in the biomass estimates in 2015 and 2016 was attributed to the high presence of Balistidae (triggerfish). The same group was also recorded after 2016 but in lesser numbers compared to 2015 and 2016. The biomass estimates of Chaetodontidae (butterflyfish) was also not as high as in 2014, with 2018 and this year having the lowest estimates. Acanthuridae (surgeonfish) was also one of the groups that exhibited a decrease from 2014.

MPY site showed an improvement in mean biomass from 2014. The six-year survey in this site revealed a decrease in Nemipteridae (breams). A slight decrease as much as 4 g/m^2 was noted for Serranidae (groupers) and Holocentridae (squirrelfish). However, these decreases in biomass were compensated for by the presence of Labridae (wrasses) and Balistidae (triggerfish), and the occurrence of pelagic groups such as Caesionidae (fusiliers) and Carangidae (jacks and trevallies), which did not exhibit a decrease in the last six years.

Although the last three years showed lower values of biomass and density for both grounding sites compared to the 2015-2016 values, it was still worth noting that the fish community in these disturbed areas remained healthy (Hilomen *et al* 2000; Nañola *et al* 2004) since 2014.

Despite the plunge in biomass outputs in some years, the values of the Tubbataha Reefs are still considered healthy according to the categories for healthy reef fish community set by Nañola *et al* (2004). Since stringent protection is applied in the Tubbataha Reefs, fishing may be ruled out as the cause of the decrease in biomass. The fluctuating biomass and density values could be influenced by the movements of fish species from one place to another, driven by various factors that affects and influences survival demands correlated with feeding, predator avoidance, spawning, and ontogenetic developments and shifts in habitat requirements (Dahlgren and Egglestone 2000; Helfman *et al* 2009; Sale 2002; Sale 1978; Bone and Moore 2008), tidal state (Choat and Robertson 1975), and time of the day (Hobson 1972). In some instances, much larger seasonal migrations occurred that were related to spawning and feeding that were depicted in the form of oscillatory movements (Bone and Moore 2008). Most coral reef fishes were sedentary and have small home ranges (Sale 1978; Russ 1991), but the factors mentioned above could also drive longer distance movements among these species (Kaunda-Arara and Rose 2004). This could be driven by the larger space needed by bigger individuals to provide for their requirements (Grant 1997) and the lesser effort they need to cover a given distance (Brett 1965). Further, variations in observers and lack of opportunity to standardize methods in the previous years may be one of the factors contributing to these fluctuations as presented in the standard error.

2.4 Conclusions

In summary, Tubbataha Reefs continued to display biomass values exceeding the minimum yield established for a healthy Philippine reef fish community. The estimates also showed an improvement from the previous year. The abundance of the species found in Tubbataha also clearly indicates a healthy fish population. Commercially important reef fish still constitutes two-third of the total biomass this year. The presence of the top predators and endangered species such as sharks, rays, napoleon wrasses, marine turtles, and whale shark indicates that Tubbataha Reefs has a balanced ecosystem and is therefore favored by these species.

The grounding areas of the USS Guardian and Min Ping Yu continually exhibited improvement in both abundance and biomass of reef fish community. The outputs recorded in these sites were of exemplary values according to the categories set for the Philippine reef fish community (Hilomen *et al* 2000; Nañola *et al* 2004). This may indicate that the healthy surrounding reef is seeding the damaged area with fish.

It is known that offshore reefs display higher fisheries potential than fringing reefs (Dantis *et al* 1999). Combined with vigilant enforcement through the years and limited inaccessibility, these factors are likely to contribute to the successful restoration and recovery of the fish population. This may be why Tubbataha is considered as one of the best marine protected areas in the Philippines (ADB 2014) and in the world (Marine Conservation Institute, 2017).

2.5 Recommendations

It is recommended that these practices be continued for the next surveys in Tubbataha:

- The practice of having dedicated personnel to lay and retrieve the transect lines to increase the efficiency of the survey;
- As much as possible, same observers need to be employed every year; and
- In case new observers join the survey, at least one dive should be dedicated for standardization of size and count estimates among the observers prior to the actual surveys to ensure uniformity in estimates.

2.6 References

Alcala, A. C. 1993. Ecological Importance of the Coral Reefs in the Cagayan Ridge, Sulu Sea, Philippines. Siliman Journal 36 (2): 1-3.

Allen G.R., Werner T.B. (2002). Coral reef fish assessment in the 'Coral Triangle' of Southeast Asia. Environ Biol Fish 65 (2):209–214

Asian Development Bank. 2014. Regional State of the Coral Triangle – Coral Triangle marine resources: Their status, economies, and management. Mandaluyong City, Philippines

Bone, Q. and Moore, R. 2008. Biology of Fishes. Third Edition.

Brett, J.R. 1965. The relation of size to rate of oxygen consumption and sustained swimming speed of sockeye salmon (Oncorhynchus nerka). J.fish. Res. Board Can. 22:1491-1501

Campos, E.L, Beldia II, P.D., Villanoy, C.L., Alino, P.M. 2008. Using phytoplankton distribution in selecting sites for an MPA Network in the Sulu Sea, Philippines. Proceedings of the 11th International Coral Reef Symposium, Ft. Lauderdale, Florida, 7-11 July 2008 Session number 23

Christensen, V. 1996. Managing fisheries involving predator and prey species. Reviews in Fish Biology and Fisheries 6(4):417–442. Hilborn, R. 2010.

Crosby, M.P. and E.S. Reese. 1996. A Manual for Monitoring Coral Reefs with indicator species: Butterflyfishes as Indicators of Change on Indo Pacific Reefs. Office of Ocean and Coastal Resource Management, National Oceanic and Atmospheric Administration, Silver Spring, MD. 45 pp

Dantis, A.L., Nañola, C.L., Castrence, F., Cabansag, J.P., Valles, D.C., Rañola, M.C., Campos, W.L., Hilomen, V.V., Hernandez, H.B. and P.M. Aliño. 1999. Distribution patterns and community structure of fishes in some offshore and shelf reefs of the Philippines. Proceedings of the Symposium on Marine Biodiversity in the Visayas and Mindanao. Miag-ao, Iloilo. Pp.86-93.

English, S. S., Wilkinson, C. C. & Baker, V. V. 1997. Survey manual for tropical marine resources. Australian Institute of Marine Science (AIMS).

Froese, R. and D. Pauly (eds.). Oct 2015. FishBase. www.fishbase.org.

Grant, JWA. 1997. Territoriality. Pp. 81-103. In: J-G.J. Godin (ed) Behavioral Ecology of Teleost Fishes. Oxford University Press, Oxford

Green, A.L. and Bellwood, D.R. (2009). Monitoring functional groups of herbivorous reef fishes as indicators of coral reef resilience – A practical guide for coral reef managers in the Asia Pacific region. IUCN working group on Climate Change and Coral Reefs. IUCN, Gland, Switzerland. 70 pages.

Halford, A.R. and Thompson A.A. (1994). Visual Census Survey: Long-term monitoring of the Great Barrier Reef. Standard Operational Procedure Number 3. Australian Institute of Marine Science

Hilomen, V.V, C.L. Nañola and A.L. Dantis, 2000. Status of Philippine reef fish communities. In Licuanan, W.Y. and E.D. Gomez. 2000. Philippine Coral Reefs, Reef Fishes and Associated Fisheries: Status and Recommendations to Improve Their Management. GCRMN Report. Appendix B.

Hourigan TF, TC Tricas, and ES Reese. 1988. Coral Reef Fishes as Indicators of Environmental Stress on Coral Reefs. In DF Soule and GS Kleppel (Eds.). Marine Organisms as Indicators (pp. 107 – 136). New York, NY: Springer – Verlag.

Kaunda-Arara B and GA Rose. 2004. Long-distance movements of coral reef fishes. Coral Reefs, 23 pp 410-412

Kramer, D. and Chapman, M. 1998. Implications of home range size and relocation for marine reserve function. Environmental Biology of Fihes. 55:65-79,1999. Kluwer Academic Publishers

Lal, Brij V.; Fortune, Kate (2000). The Pacific Islands: An Encyclopedia. University of Hawaii Press. p. 8. ISBN 978-0-8248-2265-1.

Lindman, R. 1942. The trophic-dynamic aspect of ecology. Ecology. Vol. 23, No.4., pp. 399-417

Nañola, C.L., A.C. Alcala, P.M. Aliño, H.O. Arceo, W.L. Campos, E.D. Gomez, W.Y. Licuanan, M.C. Quibilan, A.J. Uychiaoco, and A.T. White. 2004. Status of Philippines Reefs. In Global Coral Reef Monitoring Network (GCRMN) report.

Nañola, C.L., Aliño, P.M., Dantis, A.L., Rañola, M.C., Hilomen, V. and J. Cabansag. 2002. Understanding Philippine Reef Fishes: A key to fisheries manangement and marine biodiversity conservation. In P.M. Aliño, E.F.B. Miclat, C.L. Nanola, Jr., H.A Roa-Quiaoit and R.T. Campos (eds). 2002. Atlas of Philippine Coral Reefs. Philippine Coral Reefs

Information (Philreefs). Goodwill Trading Co., Inc. (Goodwill Bookstore), Quezon City, Philippines. xvi + 264 pp.

Ohman MC, Rajasuriya A and Svensson S. 1998. The use of butterflyfishes (Chaetodontidae) as bio-indicators of habitat structure and human disturbance. Ambio 27(8):708-716

Pauly, D. 1984. Fish population dynamics in tropical waters: a manual for use with programmable calculators. ICLARM Studies and Reviews 8, 325p. International Center for Living Aquatic Resources Management, Manila, Philippines.

Pauly, D., R. Froese and V. Christensen. 1998. How pervasive is "Fishing down marine food webs": response to Caddy et al Science 282: 183.

Pereira, M.A. and Videira, E. 2005. Distribution and Community Structure of Butterflyfishes (Pisces: Chaetodontidae) in Southern Mozambique. Western Indian Ocean J. Mar. Sci. Vol. 4, No. 1, pp. 39-46

Russ, G.R. .1991. Coral reef Fisheries: effects and yields. In: Sale PF(ed) The ecology of fishes on coral reefs. Academic press, Orlando, pp 601-635

Russ, G.R., Alcala, A.C., and Cabanban, A.S. 1992. Marine Reserves and fisheries management on coral reefs with preliminary modelling of the effects on yield per recruit. pp. 978-985. In: Proceedings of the Seventh International Coral Symposium, Guam.

Sabater M. 2002. Fish community structure in Tubbataha reefs and other sites along the Cagayan Ridge with emphasis on spatial and temporal variations and trophic relationships. Annual research and monitoring report 2002. WWF-Phils. Unpublished report.

Sale, PF. 1978. Coexistence of coral reef Fishes: a lottery for living space. Env Biol Fish 3(1) : 85Ð102

Steneck, R.S., 1998. Human influences on coastal ecosystems: does overfishing create trophic cascades? Trends in Ecology and Evolution 13, 429-430.

Thompson, John. "Guild (ecology)." Encyclopedia Britannica Online. Encyclopedia Britannica, n.d. Web. 15 Apr. 2014. http://www.britannica.com/EBchecked/topic/248611/guild

Tubbataha Management Office. 2015. Ecosystem Research and Monitoring Report 2015. Tubbataha Protected Area Management Board. Puerto Princea City, Palawan

Tubbataha Management Office. 2017. Ecosystem Research and Monitoring 2017. Tubbataha Protected Area Management Board. Puerto Princea City, Palawan

Tubbataha Management Office. 2018. Ecosystem Research and Monitoring Report 2018.

Tubbataha Protected Area Management Board. Puerto Princesa City, Philippines

Veron J.E. (1995). Corals in Space and Time: The Biogeography and Evolution of the Scleractinia. Univ. of New South Wales Press, Sydney, Australia

Wilkenson, C., Green, A., Almany, A. and Dionne, S. 2003. Monitoring Coral Reef Marine Protected Areas. A practical guide on how monitoring can support effective management of MPAs. Australian Institute of Marine Science and the IUCN Marine Program

3 REEF BENTHOS

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3.1 Overview

The Special Report on the Ocean and Cryosphere in a Changing Climate released by the Intergovernmental Panel on Climate Change (IPCC 2019) revealed that the ocean is continuing to acidify in response to ongoing ocean carbon uptake, the open ocean is losing oxygen, and net productivity will decline by 4-11%. The ocean provides much of the resources we need to survive. The benefits we derive from it is not limited to what we can harvest from it. Oceans take up approximately 20-30% of the total anthropogenic emissions of the recent two decades (IPCC 2017). The rate of ocean warming has also increased two-fold since 1993, which has contributed to observed changes in the biogeography of organisms ranging from phytoplankton to marine mammals consequently changing community composition, and in some cases, altering interactions between organisms (IPCC 2017). Coral reefs, containing a lot of organisms producing calcium carbonate, are greatly affected by these changes.

These changes call for continuous monitoring of coral reefs to ensure that management efforts are effective in maintaining the health of the marine environment. This chapter reports the status of the reef benthos in TRNP.

3.2 Methods

Data collection

Beginning in 2018, photo-transect method (following DENR Technical Bulletin 2017-05: Guidelines on the Coastal and Marine Ecosystem) was employed in the same transects previously monitored. As in the previous years, four 20-meter transects were laid on the substrate at each depth. Each transect was placed approximately five (5) meters away from each other to provide four independent transects and avoid pseudo-replication. Photographs were taken at every meter of the transect using a digital camera with an underwater casing mounted on an aluminum monopod. This produced 20 frames of photos per transect, or a total of 1,600 photos from all the monitoring sites.

Data Analysis

The photos were then processed using Coral Point Count with Excel extensions (CPCe) (Kohler and Gill 2006). The software overlaid ten random scoring points per image (1x1 meter frame), and benthos under each point was identified based on modified taxonomic amalgamation units

(TAUs), introduced by van Woesik *et al* (2009) which corresponds roughly to the common genera in TRNP (See Appendix 1). A total of 200 data points was scored per transect. Percent cover per TAUs and Shannon-Weiner diversity index (H) were compiled and analyzed in Excel. Further comparison of the benthic categories was only possible for 2018 and 2019 data due to difference in methods employed before 2018. Comparisons of hard coral cover between 2018 and 2019 and between stations were made using the Analysis of Variance (ANOVA two-factor without replication) in Excel.

The following categories were used to describe coral health in the shallow areas based on hard coral cover (Licuanan *et al* 2017):

Category	% Hard Coral Cover
A	>44%
B	>33 – 44%
C	>22 – 33%
D	0 – 22%

3.3 Results and Discussions

Present conditions

The average hard coral cover in the deep areas (10 meters) this year was 22.9% (±2.6 SE), less than the 29.9% last year (TMO 2018, *unpub.*). The highest hard coral cover was recorded in Station 1B (41.35%), followed by Station 4B (28.56%). Most of the corals recorded in these stations comprise of the Genus *Echinopora, Montipora* (encrusting) and *Porites* (encrusting). The lowest hard coral cover was recorded in Station JBA with 9.57%, which was composed of *Pocillopora* and *Porites* (encrusting). In general, coral genera in the deep areas were composed of *Porites* and *Echinopora*.

As in the previous year, soft coral cover was highest in Station JBA (74.53%). Algae in the deep areas of TRNP were mainly composed of coralline algae, which are important contributors to reef calcium carbonate that can facilitate coral recruitment (Dean *et al* 2015). However, an increase in algal assemblages in almost all the sites has also been recorded. This may suggest disturbances in the past year. Turf algae, which has not been recorded anywhere in Tubbataha before, was noted in Stations 2A, 3A, 3B and 4A, where it occurred in minimal numbers. The occurrence and increase in cover of turf algae may occur due to availability of space and limited number or grazers (herbivores), following a disturbance. Mortalities were still very low across all monitoring sites.

Among all the sites, the two stations of Site 3 had the highest percentage cover of abiotic components, mainly composed of rubble. Last year, the increase in rubble in Station 3B was already noted and this was attributed to the possible effects of strong waves exacerbated by the northeast monsoon. This year's increase in rubble in Site 3 might be a continuing effect of the eroding branching *Isopora bruggemanni*, which was very common in the Site. Other invertebrates recorded in the deep transects across all sites are composed mainly sponges, which are encrusting in form. Last year, the increase in sponges was already noted. Encrusting sponges are known to compete with corals for space at different rates depending on the angle at which the sponge approaches the coral (López-Victoria *et al* 2006).

Table 1. Characterization of reef benthos of the deep areas in 2019.

DEEP	Site 1	Site 2	Site 3	Site 4	JB	AVE
Hard Corals	32.13	20.58	20.82	23.53	17.42	22.9
Soft Corals	25.48	11.63	5.48	15.98	55.85	22.9
Algae	31.89	52.24	19.81	51.44	15.84	34.2
Mortalities	0.86	0.26	0.07	0.33	0.28	0.4
Abiotic components	2.82	3.07	45.46	1.42	2.22	11.0
Other invertebrates	6.83	12.22	8.37	7.30	8.39	8.6

The average hard coral cover in the shallow areas (5 meters) was 35.2% (±3.7 SE), which is classified under 'good' condition based on Licuanan *et al* (2017). The highest hard coral cover was recorded in Station JBA with 61.33%, followed by Station 1B with 54.55%. The hard corals that dominated these stations include Genus *Montipora*, *Echinopora*, and *Millepora*. The lowest hard coral cover was recorded in Stations 2B and 3B, with 20.34% and 20.79%, respectively. In general, coral genera in the deep areas were composed of *Montipora*, *Isopora* and *Porites*.

The occurrence of soft corals in the shallow transects was generally minimal, except for Station JBB (38.58%). Like in the deep areas, algae in the shallow areas were mostly composed of crustose coralline algae. However, turf algae was noted in both stations of Sites 3 and 4, although in minimal numbers. Mortalities recorded in the sites were still very low. Abiotic components were minimal in most sites except in Station 3. Since last year, rubble increased in both the deep and shallow areas of Site 3.

Table 2. Characterization of reef benthos of the shallow areas in 2019.

SHALLOW	Site 1	Site 2	Site 3	Site 4	JB	AVE
Hard Corals	38.66	25.54	33.42	31.07	47.19	35.2
Soft Corals	10.14	9.11	0.97	2.18	24.65	9.4
Algae	37.00	46.79	23.16	58.52	20.51	37.2
Mortalities	0.38	0.39	1.35	0.39	1.01	0.7
Abiotic components	7.58	10.11	36.33	1.09	3.89	11.8
Other invertebrates	6.24	8.07	4.76	6.75	2.76	5.7

Similar to the deep areas, sponges were also the main component of the other invertebrate category in the shallow areas. One type of sponge, possibly *Terpios hoshinota,* was recorded in the shallow areas of Site 3. This is quite alarming because *Terpios hoshinota* are known to encrust and kills corals as observed in coral reefs in the Philippines and in other parts of the world. This black-colored sponge is known to occur in reefs which have been subject to some disturbance, and they compete for space with corals and other benthos (Plucer-Rosario 1987, Liao *et al* 2007).

Figure 14. Sponges, possibly Terpios hoshinota, encrust rubbles in Site 3.

Temporal patterns

The graphs below show the long-term monitoring data of the reef benthos in the deep and shallow areas of TRNP. The broken vertical line demarcates the change in methods (Figures 1 and 2); therefore, comparison to earlier data is inconclusive.

This year, the hard coral cover of the deep and shallow areas were relatively low for TRNP, which averaged to 22.9% and 35.17%, respectively. Overall, hard coral cover in the deep areas exhibited a downward trend since 2015, while the same trend was observed in the shallow areas since 2018.

A decrease in hard coral cover in Station 3B resulting to the increase in rubble was recorded in 2018. This may be attributed to the effects of strong waves associated with the northeast monsoon and/or the five tropical storms that traversed the Sulu Sea from November 2017 to February 2018. This year's increase in rubble in Site 3 might be due to the attrition of the branching *Isopora bruggemanni*, aggravated by the strong monsoon winds and the storm that passed the Sulu Sea in November 2018.

Algae, composed of both crustose coralline algae and algal assemblages, has exhibited an increasing trend since 2014 in the deep areas and since 2018 in the shallow areas. This trend may be a manifestation of disturbances occurring in the reefs, such as prolonged exposure to stronger waves, increase in sea temperature and/or changes in water quality.

Figure 15 presents the maximum monthly mean sea surface temperature and degree heating weeks (DHW) in TRNP from January 2018 to September 2019. Although the marine park rangers did not record any bleaching incidents from June 2018 to May 2019, based on the data published by NOAA Coral Bleaching Watch, Tubbataha Reefs was under the categories Bleaching Watch and Warning, which coincided with the 4°C DHW from May – August of 2018 and 2019. Another bleaching warning was declared for TRNP in October to early November in 2018. These incidences may have affected the corals in TRNP but were unobserved due to intermittent monitoring which limits the detection of effects/changes in the reefs.

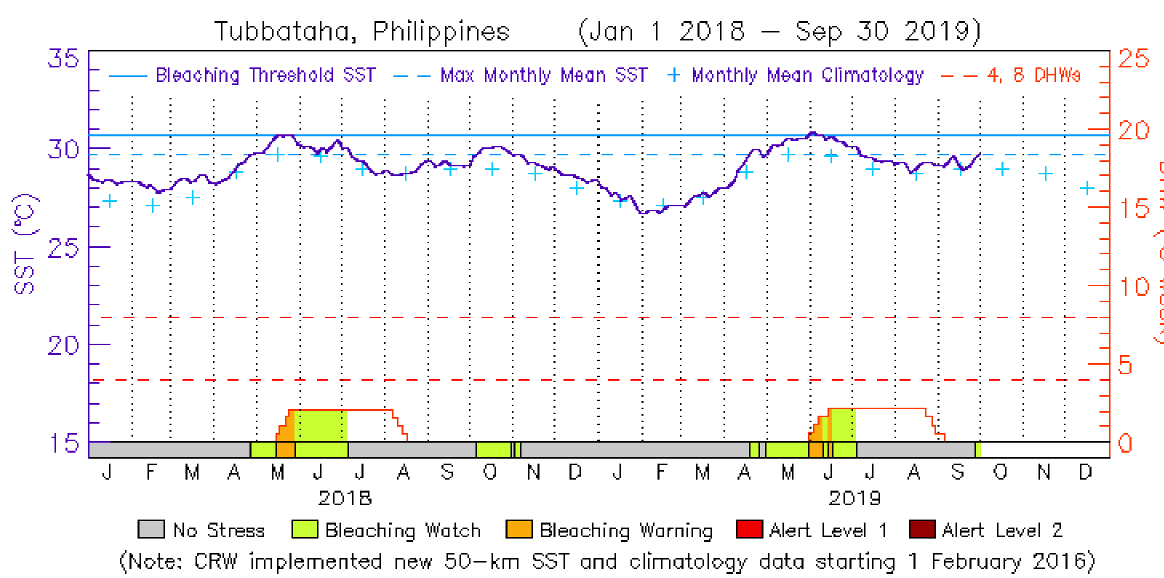

Figure 15. Maximum monthly mean sea surface temperature and degree heating weeks in TRNP from January 2018 to September 2019. Source: NOAA Coral Beaching Watch

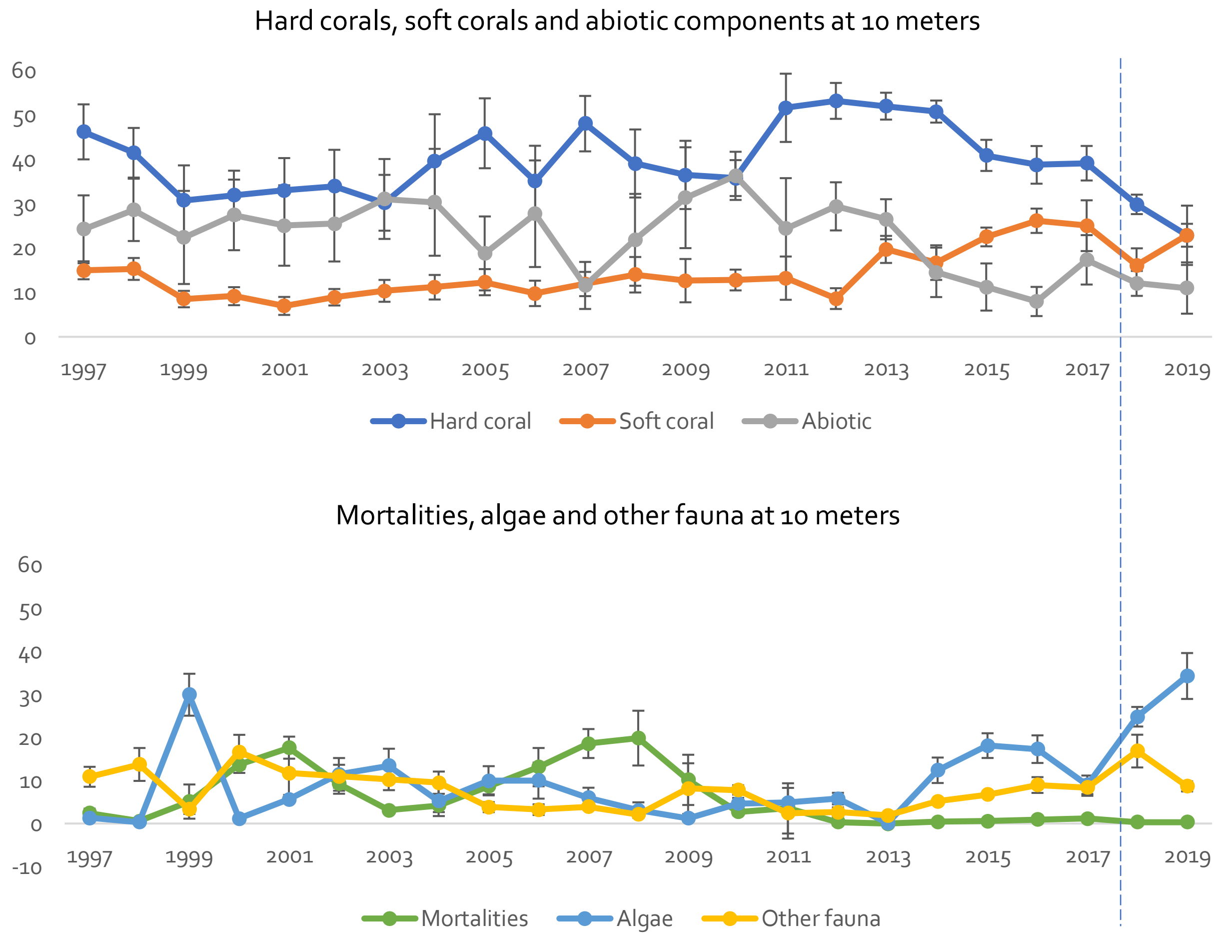

Figure 16. Characterization of reef benthos at the deep monitoring areas of TRNP. Error bars represent the standard error of the mean.

In July, TMO received a report from one of the dive operators regarding bleaching of the branching corals in Jessie Beazley Reef (See Figure 4). This coincided with the DHW recorded for Tubbataha in June 2019 (Figure 17).

Figure 18. Bleaching branching corals in Jessie Beazley Reef in June 2019. Photos: Pierlo Pablo

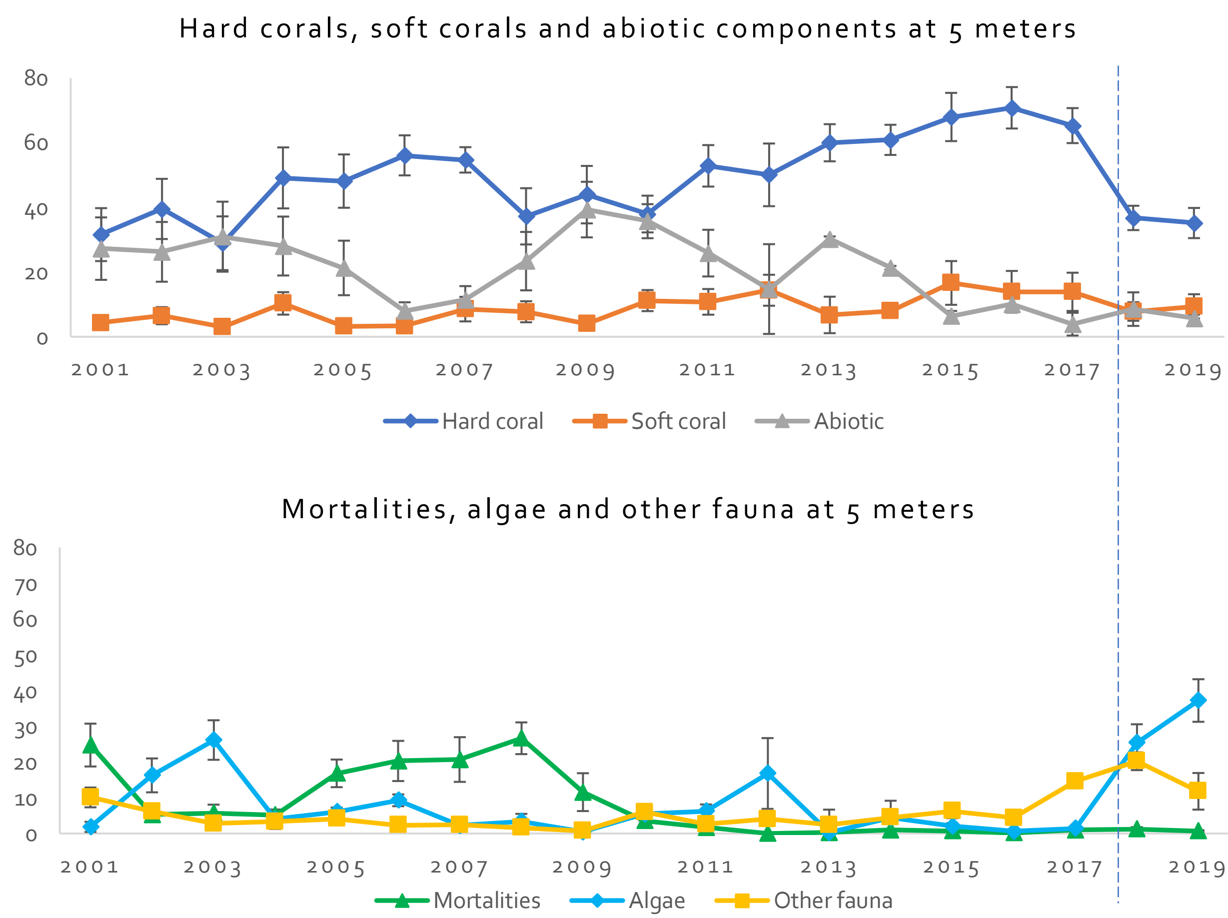

Figure 17. Characterization of reef benthos at the shallow monitoring areas of TRNP. Error bars represent the standard error of the mean.

Reports from other areas in the Philippines show that coral reef health is generally in decline. According to the initial results of the nationwide assessment published by Licuanan *et al* (2017), none of the coral reefs surveyed in the Philippines from 2015 to 2017 had live coral cover in 'excellent' condition following the scales of Gomez *et al* (1981). A new scale for categorizing hard coral cover proposed by Licuanan *et al* is now prescribed by the Department of Environment and Natural Resources and is used by TMO since 2018. Under this new scale, hard coral cover in the shallow areas are within category B, with more than 22% to 33% hard coral cover.

Results from last year and this year were further compared using ANOVA to determine significant differences between years and stations, at α=.05. Results for the deep areas revealed significant changes in hard coral cover for both between years (p=.0011) and stations (p=.003). The shallow areas, on the other hand, had significant changes between stations (p=.019), but not between years. This suggests that the deep areas have changed more significantly than the shallow areas.

Scleractinian Coral composition

A total of 40 coral Genera belonging to 16 Families were recorded in all the sites in TRNP during this year's monitoring. This correspond to a total of 52 TAUs in the deep and 50 TAUs in the shallow transects. The deep areas were dominated by Genus *Porites*, *Echinopora, Isopora* and *Montipora*. In the shallow areas Genus *Montipora, Isopora, Porites* and *Acropora* were the most common.

Table 3. Percent hard coral cover, number of TAUs and hard coral diversity indices.

	DEEP				SHALLOW			
Station	HCC (%)	TAUs	Shannon (H)	Simpson (1-D)	HCC (%)	TAUs	Shannon (H)	Simpson (1-D)
1A	22.92	28	2.924	0.929	22.77	27	2.641	0.89548
1B	41.35	32	2.684	0.869	54.55	30	2.124	0.73626
2A	20.74	27	2.671	0.899	30.73	27	2.465	0.85942
2B	20.41	31	3.013	0.932	20.34	24	2.556	0.88577
3A	22.25	22	2.072	0.742	46.04	26	1.813	0.69837
3B	19.38	24	2.751	0.918	20.79	19	1.877	0.68602
4A	18.49	27	2.867	0.917	22.58	23	2.822	0.92785
4B	28.56	29	2.95	0.932	39.55	29	2.783	0.91105
JBA	9.57	19	2.625	0.913	61.33	16	0.842	0.30123
JBB	25.26	21	2.121	0.761	33.05	25	2.272	0.79811

The hard coral cover in the deep transects of Sites 1, 2, 4, JB and Station 3B recorded this year were mostly composed of massive and encrusting coral formations. On the other hand, hard corals in Station 3A was mostly composed of branching *I. bruggemanni*. Shannon-Weiner and Simpson diversity indices were relatively high in all the stations indicating high coral diversity and evenness.

The hard corals in the shallow transects of Sites 1, 2, 4 and JB were mostly composed of encrusting and massive coral formations. Site 3, on the other hand, was composed of branching *I. bruggemanni.* Last year, a huge decline in the coral cover of Site 3 was reported, which resulted in the increase in rubble, in both the deep and shallow areas. Having monospecific stands of *I. bruggemanni* in the area may have contributed to its vulnerability. High percentage of mortalities, mainly dead corals with algae, was recorded in 2018. It is most likely that the dead corals observed last year were the rubbles recorded this year. Shannon-Weiner and Simpson diversity indices were relatively low in Site 3 and Station JBA, which suggests dominance *I. bruggemanni* and *Montipora*, respectively.

3.4 Conclusion

Changes in the benthic cover was more evident in the deep areas than in the shallow. This highlights the importance of monitoring both the deep and the shallow areas for better reef characterization. Although a decrease has been noted in most of the stations in the shallow areas, some stations have shown increase in hard coral cover (Stations 1B, 3A and JBB).

All stations in the deeper areas have decreased in hard coral cover. Most of the decrease corresponded to increase in the cover of soft corals, algae and abiotic components. The presence of turf algae and what could possibly be *Terpios hoshinota* sponge is quite alarming because both suggest that some form of disturbance happened in the reefs. Since we have not noted any particular phenomenon which may have caused this decline in coral cover, it is very important to continue the annual monitoring in TRNP. The method we now employ, which includes identification of corals to the Genus level, will give more robust results in the long-term. As we build on the database for corals in TRNP, we might be able to get more conclusive results in the coming years.

Tubbataha Reefs, being offshore and with limited anthropogenic activities, is not exempt from the effects of global phenomena. It is important to highlight that the management interventions being undertaken to protect this fragile ecosystem play an important role in ensuring that anthropogenic factors do not exacerbate the effects of the changing climate.

3.5 Recommendations

- Establish permanent markers showing the direction of the transect at each station, for the ease of looking for the monitoring sites every year. A mooring pin where the dinghy can tie while waiting for the survey to finish will also be advantageous.
- Study the possibility of completely shifting to the photo-transect methods employed by the team of De La Salle University to avoid duplication of monitoring efforts in the shallow area. However, careful consideration must be made in determining the appropriate method for the deep areas, which are mostly on the walls. Additional researchers and equipment will be needed next year if we are to employ this method at both depths.
- Continuous standardization of identification of corals following the TAUs codes must be observed to facilitate faster data processing.
- Include sponges, specifically *Terpios hoshinota,* in the monitoring conducted by the marine park rangers during the off-season.

3.6 References

Gomez ED, Alcala AC, San Diego AC. 1981. Status of Philippine coral reefs – 1981. Proceedings of the Fourth International Coral Reef Symposium; 1981; Manila. 1: 275-282

IPCC. 2019. IPCC Special Report on the Ocean and Cryosphere in a Changing Climate [H.- O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, M. Nicolai, A. Okem, J. Petzold, B. Rama, N. Weyer (eds.)]. In press.

Licuanan, A., Reyes, M., Luzon, K., Chan, MA., Licuanan, W. 2017. Initial Findings of the Nationwide Assessment of Philippine Coral Reefs. Philippine Journal of Science 146(2):177-185

Licuanan, W. Y., Robles, R., Dygico, M., Songco, A., & van Woesik, R. 2017. Coral benchmarks in the center of biodiversity. Marine Pollution Bulletin 114:1135-1140. https://doi.org/10.1016/j.marpolbul.2016.10.017

López-Victoria, M., Zea, S., and Weil, E. 2006. Competition for space between encrusting excavating Caribbean sponges and other coral reef organisms. *Marine Ecology Progress Series*. Vol. 312: 113–121.

Ming-Hui Liao, Sen-Ling Tang, Chia-Ming Hsu, Kou-Chang Wen, Henry Wu, Wen-Ming Chen, Jih-Terng Wang, Pei-Jie Meng, Wen-Hung Twan, Chung-Kuang Lu, Chang-Feng Dai, Keryea Soong, and Chaolun Allen Chen. 2007. The Black Disease of Reef-Building Corals at Green Island, Taiwan - Outbreak of a Cyanobacteriosponge, *Terpios hoshinota* (Suberitidae; Hadromerida). Zoological studies 46(4)

Plucer-Rosario G. 1987. The effects of substratum on the growth of Terpios, an encrusting sponge which kills coral. Coral Reefs 5:197-200

OTHER STUDIES

4 CORAL RECRUITMENT

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Tubbataha Management Office

4.1 Overview

Disturbance is part of the evolutionary history of coral reefs. However, the increasing frequency and intensity of anthropogenic and climate-related disturbances, particularly coral bleaching and altered storm regimes (Knutson *et al* 2010), are predicted to significantly reduce coral population sizes in the next few decades (Hoegh-Guldberg *et al* 2007). One of the approaches in understanding the capacity of the reef to recover from this disturbance is by monitoring coral recruitment. Recruitment is the process by which a new coral passes through the settlement stage, survives and becomes ready for the reproductive phase. The growth of a coral larvae into the adult phase, or coral recruitment, is critical to the health of coral reef ecosystems. This study intends to continue quantifying coral recruitment abundance, recruitment density, and distribution in TRNP. Furthermore, it aims to identify and understand factors, such as the variability of juvenile corals among sites and depths, that may have implications on the coral population as a whole.

4.2 Materials and Methods

Sampling Design

At each transect, a diver randomly placed a 34 x 34 cm (0.12 m^2) quadrat on the substrate along the transect to get representative samples of the station. The quadrats were marked with scale bars (2 and 5 cm) on both sides for size reference (Figure 33).

For each quadrat, five photos were taken (four close-up shots at each corner and one full quadrat shot) to provide more detailed images of juvenile corals (Figure 28-c). This process was repeated 10 to 20 times along the transects at both depths in each of the stations. Images were taken using a 12-megapixel camera with underwater casing and red filter for white balance. A total of 20 quadrats per station were processed, 10 from the shallow and 10 from the deep.

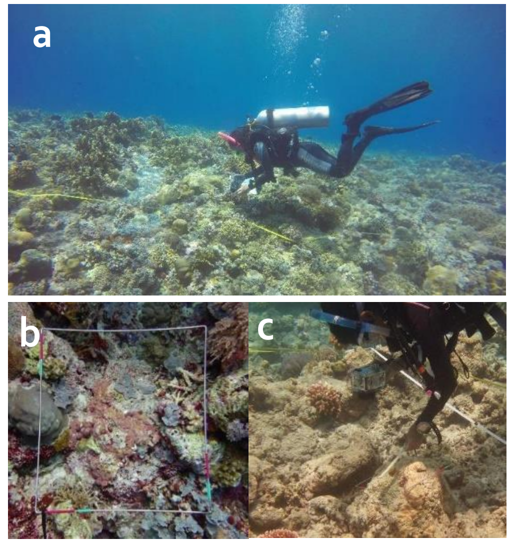

Figure 19. Coral recruitment sampling. (a) randomized quadrat sampling within the transect. (b) close-up shot of the quadrat with scale bars (c) multiple photos were taken using underwater camera.

For the grounding sites, quadrats were laid following the method described by Licuanan *et al* (2018). The two (2) ship grounding sites were surveyed using three 4m x 4m quadrat plots (Figure 20). They were strategically positioned to capture the impact of the ship groundings on the affected reefs. In each of the grounding sites, one quadrat was positioned in the impact zone (Quadrat 1), one quadrat in a buffer zone (Quadrat 2), and another quadrat in a control zone (Quadrat 3).

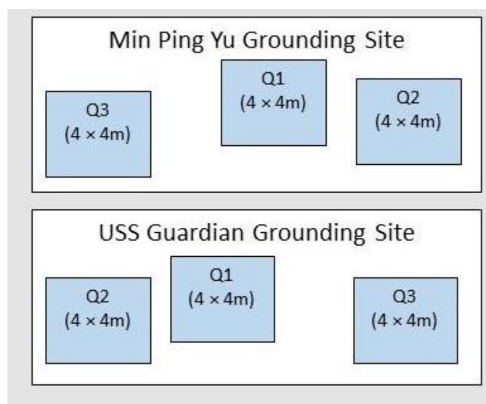

Figure 20. Permanent quadrats of the two grounding sites established in 2014 (Licuanan et al. 2014).

Sampling was done in the middle and at the four corners of the 4 x 4 meters permanent quadrats in the grounding sites. A total of 15 quadrats were sampled at each site.

All photos were downloaded, grouped, and labeled according to quadrat number per station and per site for the post-processing and scoring using the Coral Point Count with Excel Extension® (CPCe) software. Only coral colonies measuring <5cm were considered recruits (Burgess *et al* 2009).

Data Analysis

Quantitative data on coral recruits were obtained using CPCe 4.1 (Kohler and Gill 2006). In the CPCe software, each photo was calibrated using the 5-cm scale bar located on each side of the quadrat. This scale bar provided an adequate size estimate of the coral recruits. The identified recruits were classified to the closest possible taxonomic level (usually the genus level) provided in the modified Taxonomic Amalgamation Unit (TAUs). The Indo-Pacific Coral Finder version 3.0 and the Guide to the Corals of Bolinao Anda-Reef Complex served as references for coral identification. Small coral fragments that appeared to be remnants of adult corals were excluded.

Estimates of coral recruit density was then calculated for each quadrat as the number of recruits per 0.12m². Differences in the densities of recruits across stations and depths were tested using one-way Analysis of Variance (ANOVA). In addition, t-test (assuming equal variance) was performed when significant differences were found. Densities and mean percentage covers were plotted in Microsoft Excel across depths and stations. Pearson correlation was performed to determine the relationship of the mean sample across station and year.

4.3 Results and Discussion

Coral recruitment patterns

A total of 1,318 coral recruits from 1,140 photographs were processed, covering a total of 50m² for the whole park. This year's survey recorded 42 genera belonging to 12 families, higher than last year. The average coral recruitment density (all taxa) across all the regular monitoring sites was 42.28 ind/m² (±3.51 SE) with density ranging from 0.58 ind/m² (±0.11 SE) to 22.92 individuals/m² (±7.65 SE) at 10 meters. This is almost the same as last year's values (45.56 ind/m²). These results were higher compared to the estimates of Burgess *et al* (2013) in the Great Barrier Reefs (Cod Hole, Turner Reef and Lizard Island), where they recorded recruitment density at 37.67ind/m² (±2.92 SE). In the shallow area, the mean coral recruitment density was 29.93 ind/m² (±4.18) with values ranging from 0.63 ind/m² (±0.15 SE) to 14.58 ind/m² (±1.43 SE). Generally, a lower density of coral recruits was observed in the shallow compared to deep areas, coinciding with last year's results (paired t-test=0.034, α=0.05).

This year, the mean recruitment density in the USS Guardian (USSG) grounding site was recorded at 0.88 ind/m² (±0.36 SE) in Quadrat 1 (impact zone), lower than density in 2018. The Ming Ping Yu (MPY) grounding site had a mean density of 0.54 ind/m² (±0.35 SE) in its impact zone. Generally, the grounding sites had lower recruitment densities compared to the regular monitoring sites in Tubbataha.

Coral recruitment in the deep area

A total of 12 coral families were recorded across all the sites. The three most common families were Agariciidae, Poccillopiridae and Poritidae (Figure 1). Among the three, Agariciidae had the highest percentage cover at 29.72%, followed by Poritidae and Pocilloporidae at 17.41% and 17.26%, respectively.

Conversely, the lowest cover was observed in family Faviidae with 5.58% in 2019, from 19.39% in 2018. Other families such as Merulinidae and Dendrophylliidae have slightly increased this year. However, these variabilities were not statistically significant (paired *t*-test=0.949). Pearson

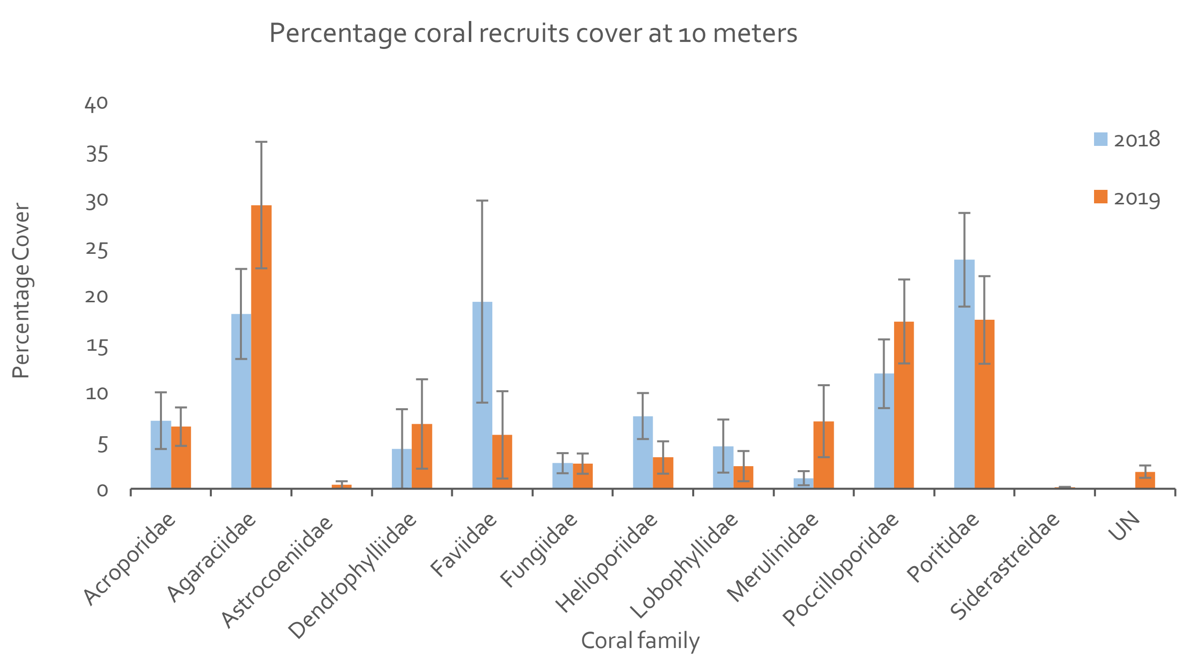

Figure 21. Mean Percentage cover of coral family at 10m deep. Error bar represent standard error of mean. Unidentified corals were group under category UN.

correlation revealed moderate positive correlation between the adult colonies and the coral recruits in the deep area at r=0.392.

Table 4. Mean recruitment density at 10 meters.

Station	2018	2019
1A	33.33 (± 2.42 SE)	48.61 (± 2.76 SE)
1B	41.67 (± 2.36 SE)	27.78 (± 4.50 SE)
2A	22.92 (± 1.23 SE)	22.22 (± 8.21 SE)
2B	34.03 (± 1.53 SE)	50.69 (± 8.21 SE)
3A	52.78 (± 3.51 SE)	42.25 (± 2.15 SE)
3B	68.06 (± 6.11 SE)	36.81 (± 6.12 SE)
S4A	41.67 (± 2.43 SE)	40.97 (± 7.02 SE)
S4B	47.22 (± 3.58 SE)	58.33 (± 3.06 SE)
JBA	33.33 (±1.59 SE)	43.06 (± 3.10. SE)
JBB	27.78 (±1.32 SE)	52.08 (± 8.91 SE)
Average	**40.28 (±33.96 SE)**	**42.28 (±3.51 SE)**

In this year's survey, the mean coral recruitment density (42.28 ind/m^2 ±3.51 SE) was higher than in 2018 (40.28 ind/m^2) (Table 4.) The highest densities were observed in Stations 4B and JBB. Station JBB had the highest density of genus *Tubastrea*, a non-reef building colony, fast growing zooxanthellate coral which are highly adaptable to different substrata and orientation (Miranda *et al* 2018). Genus *Tubastrea* were observed competing with the large cover of sponges and algal assemblages in the walls of Stations JBB and 2B. The dominance of genus *Tubastrea* in these areas may suggest that they are rapid colonizers of newly available habitat. The lowest recruitment density was observed in Station 2A at 22.22ind/m^2 (±8.21 SE). The recruitment density observed at Station 3B decreased from 68.06 ind/m^2 in 2018 to 36.81 ind/m^2 in 2019. This may be attributed to the large portion of unstable rubble in the area which may have abraded the recruits found last year. Loose rubble substrate might hinder recolonization and regeneration of sessile invertebrates such as coral recruits (Duckworth and Wolff 2011). The genus that dominated most of the stations were brooder type of corals, *e.g*. genus *Pavona*, *Porites encrusting*, *Pocillopora* and *Seriatopora*. The variability of coral recruitment density at this depth across stations and years did not show a significant difference.

The coral recruitment size-frequency distribution seemed to mirror the results of the last year's survey (Figure 5). The coral recruits <1cm in size were significantly lower in numbers (Chi-square test $p=0.002$, $\alpha=0.05$) compared other group sizes. Coral recruits that were less than 1 cm were rarely found in most of the stations. Sizes from this group are presumed to be newly settled coral recruits (Wilson and Harrison 2005; Acosta et al 2011) which might be a possible indicator of continuous coral propagation in the area. A more in-depth study is required to better understand this development.

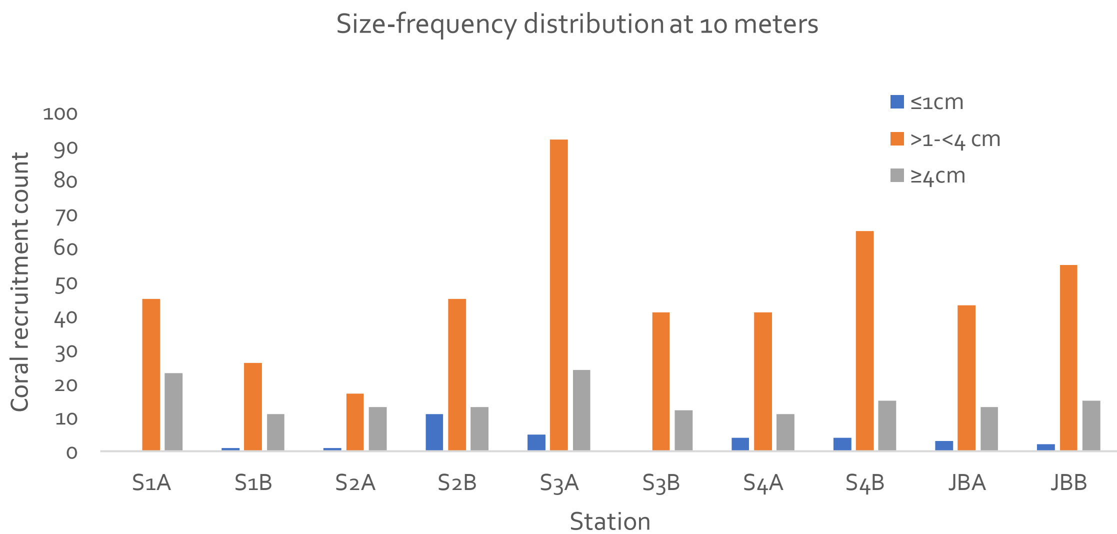

Figure 22. Size-frequency distribution of juvenile coral per site. Bars represent the number of recruits in each size class.

Coral recruitment in the shallow area

Generally, the shallow areas were dominated by family Agariciidae (25.67%), Pocilloporidae (17.15%), Acroporidae (15.71%), Poritidae (14.14%), and Merulinidae (12.23%). Similar to 2018, majority of the coral families that thrived in this area were encrusting to sub-massive corals. High densities of the genus *Pavona*, of the family Agariciidae, were observed in almost all the stations. Genera belonging to Acroporidae mainly composed of *Acropora* branching to sub-massive forming *Isopora* were frequent in most of the stations. The highest increase was observed in the family Faviidae, which are massive forming corals (*e.g. Hydnophora*, *Favia*, and *Montastrea)* that are tolerant to disturbances (Adjeroud *et al* 2013). There was a moderately positive correlation (r=0.394) between the recruitment densities and the adult colonies this year.

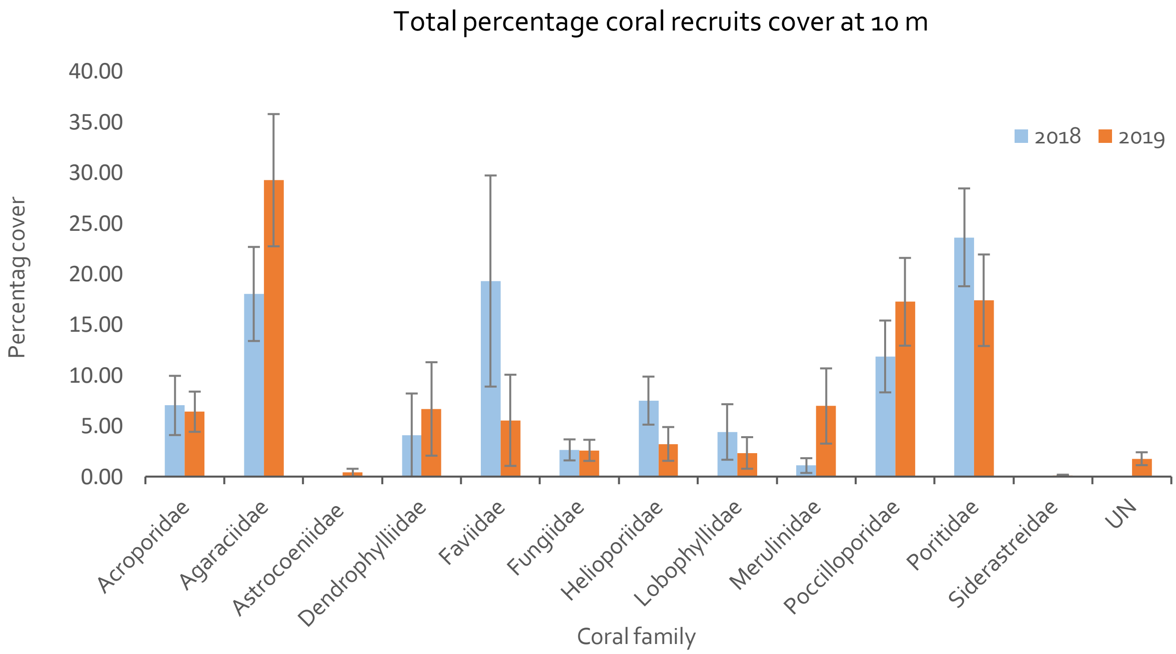

Figure 23. Mean Percentage cover of coral family at 5m deep. Error bar represent standard error of mean. Unidentified corals were grouped under category UN.

In total, the mean density in the shallow areas increased from 25.42 ind/m² (±4.96 SE) in 2018 to 29.39 ind/m2 (±1.17 SE) in 2019. The highest coral density at this depth was recorded in Station 2A (47.22 ind/m2 ±2.70) and the lowest was in Station JBA (5.56 ind/m2 ±0.44SE) (Table 5). The densities at this depth were lower than the deeper areas, although the genera found at both depths were similar to each other. Fast growing *Acropora, Isopora and Montipora* were most frequently recorded in most of the stations.

Table 5. Mean recruitment density at shallow area.

Station	2018	2019
S1A	16.67 (±3.27 SE)	36.11 (±2.39 SE)
S1B	48.61 (±9.07 SE)	46.53 (±1.94 SE)
S2A	47.92 (±8.82 SE)	47.22 (±2.70 SE)
S2B	35.42 (±6.83 SE)	30.56 (±1.67 SE)
S3A	11.81 (±2.27 SE)	18.75 (±1.22 SE)
S3B	11.81 (±2.30 SE)	30.56 (±1.59 SE)
S4A	8.33 (±1.86 SE)	34.72 (±2.60 SE)
S4B	23.61 (±1.86 SE)	31.25 (±1.70 SE)

JBA	29.17 (±6.48 SE)	5.56 (±0.44 SE)
JBB	20.83 (±3.92 SE)	18.06 (±1.24 SE)
Average	**25.42 (±4.96 SE)**	**29.93 (±1.75 SE)**

Massive forming corals e.g. *Favites, Goniastrea, and Porites* were noticeably thriving in both stations of Sites 1 and 2. The dominance of these genus could be influenced by their resistance to strong currents in these areas in Tubbataha. On the other hand, the abrupt drop in density in Station JBA may have been influenced by the growing stand of *Montipora* in this area. Due to the presence of mature colonies, it is likely that the lack of substrate to settle on was a factor in this development. Variability in this year's survey for all stations did not show a significant difference (paired t-test= 0.3452, α=0.05).

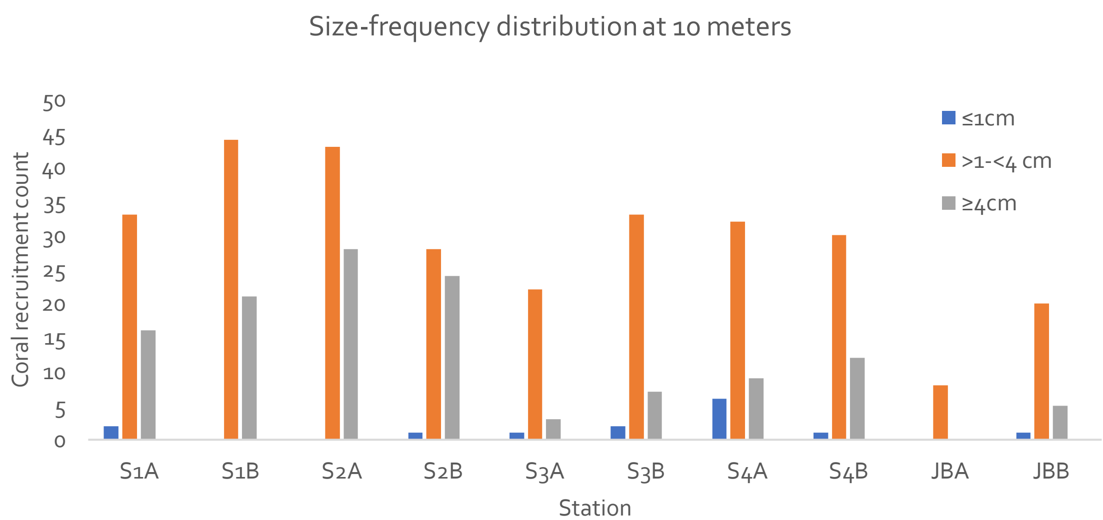

Figure 24. Size-frequency distribution of coral recruits by site. Bars represent the number of recruits in each size class for each site.

Ship grounding site

To determine the recovery of the two grounding sites, recruitment rates were determined. This year, the mean densities recorded at USSG site were 0.88 ind/m² (±.036 SE) in the impact zone, 0.81 ind/m² in the control zone and 0.69 ind/m² in the buffer zone. The recruitment density in this area was almost the same as the MPY grounding site, which was generally low. The quadrats were dominated by 16 genera, *e.g.*, *Goniastrea*, *Favites*, *Platygrya* and *Merulina*, which are more tolerant to disturbances. The permanent quadrats were also observed to have >5cm of Genus *Pocillopora* and *Porites*.

This was also reported by Licuanan *et al* in 2018 *(unpub)*, who found that the coral cover increased

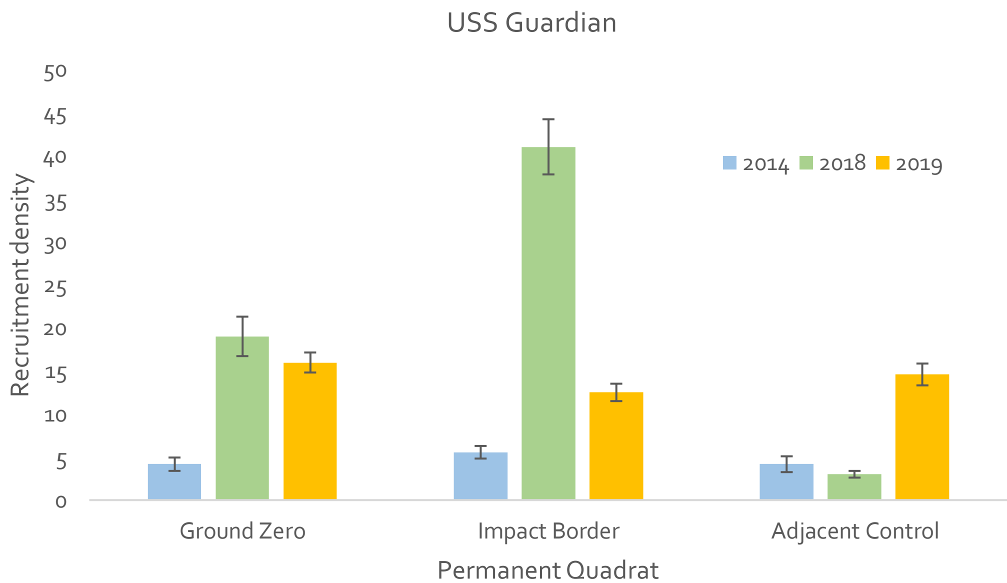

Figure 25. Mean coral recruitment density of US vessel grounding site. Error bar represent standard error of mean.

by 1.4% across all 4 x 4-meter permanent quadrats from 2014-2018. This suggests that the USSG grounding site has a better chance of recovery from disturbance compared to the MPY area.

The mean coral recruitment density recorded in Ming Ping Yu (MPY) was 0.54 ind/m^2 (±0.26 SE) in the impact zone, and 0.57 ind/m^2 (±0.24 SE) in the control zone. A total of nine genera belonging to seven families were recorded. Dominant genus found in the quadrats were *Porites*, *Pocillopora* and *Millepora*. Data variability among the quadrats did not show significant results ($p=0.293$, $\alpha=0.05$). The report of Eneria and Licuanan (2017 *unpub*), revealed that there was not enough evidence of recovery in this area mainly due to the high amount of rubbles and sand that inhibit the coral to recolonize.

The mean estimated coral recruitment density was recorded at 46.16/m^2 (±5.17 SE) at deep area and 29.93 ind/m^2 (±4.18) at the shallow area. The recruitment density estimates fall within the range recorded in the Great Barrier Reef (e.g. Lizard Island and Keppel) at 37.67/m^2 (±2.92 SE) (Burgess *et*. al 2009). The deep areas showed significantly higher densities as opposed to the shallow areas of Tubbataha (ANOVA p = 0.034, α.=0.05).

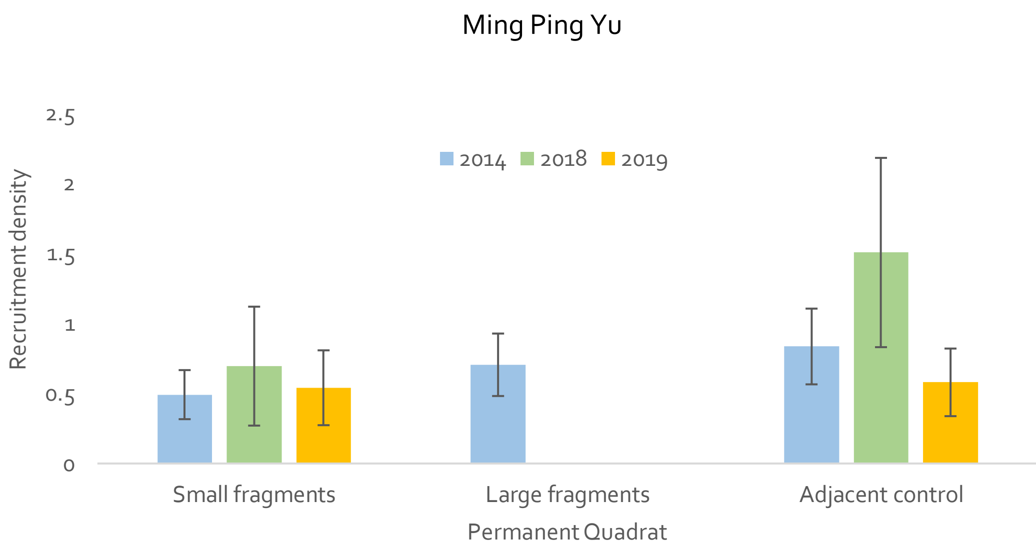

Figure 26. Mean coral recruitment density of Chinese vessel grounding site. Error bar represent standard error of mean.

The brooder type of corals composed almost 60% of the total recruit population observed, as opposed to 40% broadcast spawner at both depths. Brooder corals tend to have multiple chances of reproduction and disseminate fully formed larvae that settle in the substrate within hours (Underwood *et al* 2007). On the other hand, broadcast spawners release eggs and sperms that fertilize externally, and the larvae settle in the substrate after four to seven days (Figueiredo *et al* 2013). The high amount of brooder recruits found in Tubbataha could be related to the dominance of mature brooder corals the area.

A consistently high number of juvenile recruits (>1cm to ≤4 cm) were found two years in a row suggesting that Tubbataha may have the capacity to replenish itself. A study of Campos *et al (*2008) suggests that Tubbataha has the potential to enrich itself through local spawning and recruitment Several factors probably contribute to this. The study of Pizarro *et al* (2005) found that mortality during the early stages of settlement increase with time. They also found that colonies smaller than 0.5 cm would have a greater mortality rate in comparison to larger-sized juvenile recruits. These findings suggest that the mortality rate during the initial stage of the life cycle follows a normal curve – increasing mortality from larval settlement until the juvenile reaches about 5cm, then decreasing mortality as the individual reaches the minimum reproductive size. The group size >1cm to <4cm were observed to have high densities of encrusting and massive growing genus, which possibly contribute to the overall reef-building process (Moulding 2005). On the other hand, recruits >4cm found in most of the stations seemed to be low in proportion. In general, corals that reached these sizes most likely have almost reached their reproductive stages (Ritzon-Williams *et al* 2009).

Self-seeding seemed possible when correlation analysis was conducted on the adult versus the recruitment population, which resulted to positive moderate correlation found at both depths. This suggests that recruits found at both depths could possibly be supplied by the adult population in the area. More in-depth study should be done to validate this.

Licuanan *et al* (2018) recorded an increase in adult colonies in the USS Guardian site. This was not reflected in the results of this study due to the difference in sampling design. Note that this study only considered coral recruits measuring less than 5cm while the Licuanan *et al* study recorded adult colonies. Thus, the corals recorded by Licuanan *et al* (2018) are considered mature colonies based on our methods and were therefore not recorded.

4.4 Conclusion

The results of the coral recruitment survey of 2018 and 2019 show higher productivity in the deeper areas compared to their shallow counterparts. The higher recruitment population in the deep area may indicate higher potential for reef resilience and recovery in these areas. Furthermore, the correlation between adult abundance and successive coral recruitment density revealed a moderate positive correlation. This suggests that the recruits found have an important role in shaping the overall coral community in Tubbataha. With respect to the higher proportion of brooder type of corals coupled with a higher proportion of the successive recruits (>1 to ≤5 cm), the reef may have a potential to replenish itself after certain disturbances. Reliability and validation of this findings could be improved by continuing the coral recruitment study in the park and increasing the sampling sites.

4.5 Recommendations

Increasing the number of sampling sites from five (5) to ten (10) quadrats within the grounding sites will increase the statistical rigor of the study and is therefore recommended.

Recruitment studies the current monitoring sites is also recommended to determine trends.

4.6 References

Acosta A.D., Pizarro FL.V. 2011. Review on hard coral recruitment (Cnidaria: Scleractinia) in Colombia. Universitas Scientiarum 16:200–18.

Adjeroud, Mehdi & Briand, Marine & Kayal, Mohsen & Dumas, Pascal. 2013. Coral assemblages in Tonga: Spatial patterns, replenishment capacities, and implications for conservation strategies. Environmental monitoring and assessment. 185. 10.1007/s10661-012-2982-5.

Burgess, S.C., Osborne and Sfiligoj K.B. 2009. Environ Monit Assess. 171: 345. https://doi.org/10.1007/s10661-009-1282-1

Chiappone, M., & Sullivan, K. M. 1996. Distribution, abundance, and species composition of juvenile scleractinian corals in the Florida reef tract. Bulletin of Marine Science, 58, 555–569.

Campos W.L., Beddia PD., Villanoy CL., and Aliño PM. 2008. Using Ichthyoplankton Distribution in Selecting Sites for an MPA Network in the Sulu Sea, Philippines. Proceedings of the 11th International Coral Reef Symposium, Ft. Lauderdale, Florida, 7-11 July 2008

Duckworth AR, Wolff CW. 2011. Population dynamics and growth of two coral reef sponges on rock and rubble substrates. J Exp Mar Biol Ecol. 402(1):49–55. http://dx.doi.org/10.1016/j. jembe.2011.03.017

Figueiredo, Joana & Baird, Andrew & Connolly, Sean. 2013. Synthesizing larval competence dynamics and reef-scale retention reveals a high potential for self-recruitment in corals. Ecology. 94. 650-9. 10.2307/23436268.

Hoegh-Guldberg O, Mumby PJ, Hooten AJ, Steneck RS, Greenfield P, Gomez E, Harvell CD, Sale PF, Edwards AJ, Caldeira K, Knowlton N, Eakin CM, Iglesias-Prieto R, Muthiga N, Bradbury RH, Dubi A, Hatziolos. 2007. ME Science. 2007. Dec 14; 318(5857):1737-42.

Kohler, K.E. and S.M. Gill. 2006. Coral Point Count with Excel extensions (CPCe): A Visual Basic program for the determination of coral and substrate coverage using random point count methodology. Computers and Geosciences, Vol. 32, No. 9, pp. 1259-1269, DOI:10.1016/j.cageo.2005.11.009

Knutson TR, McBride JL, Chan J, Emanuel K, Holland G, et al 2010. Tropical cyclones and climate change. Nature Geosci 3: 157–163. [Google Scholar]

Quinn NJ, Kojis BL. 2008. Variation in coral recruitment on Fijian reefs. Proceedings of the 11th International Coral Reef Symposium, Ft. Lauderdale, Florida, 7-11 July 2008. Session number 14

Miranda, Ricardo & Tagliafico, A & Kelaher, BP & Mariano-Neto, Eduardo & Barros, Francisco. 2018. Can invasive corals (Tubastraea spp.) impact native coral recruitment?. Marine Ecology Progress Series. 605. 10.3354/meps12731.

Muko S, Arakaki S, Tamai R, Sakai K. An individual-based model for population viability analysis of the brooding coral Seriatopora hystrix. Ecol Model. 2014;277:68–76.

Mohd HMF, Shahbudin S, Yukinori M and Zuhairi A., 2017. Relationship between adult abundance and successive coral recruitment density in the Tioman Island Marine Park, Malaysia. Zoology and Ecology, 2017 VOL . 27, NO S. 3–4, 328–334 https://doi.org/10.1080/21658005.2017.1396793

Moulding A.L. 2005. Coral Recruitment Pattern in Florida Keys. Rev. Biol. Trop. (Int. J. Trop. Biol. ISSN-0034-7744) Vol. 53 (Suppl. 1): 75-82, May 2005 (www.tropiweb.com)

Pizarro V, Herrón P, Thomason J. An improved technique for rearing *Montastraea faveolata* embryos and larvae, *Coral Reefs* 2006; 25 (3): 360-360.

Ritson-Williams R, Suzanne N. Arnold, Nicole D. Fogarty, Robert S. Steneck, Mark J. A. Vermeij, and Valerie J. Paul. 2009. New Perspectives on Ecological Mechanisms Affecting Coral Recruitment on Reefs

Riegl BM, Purkis SJ. Model of coral population response to accelerated bleaching and mass mortality in a changing climate. Ecol Model. 2009;220(2):192–208.

Ruiz-Zárate, M. A. & Arias-González, J. E. 2004. Spatial study of juvenile corals in the Northern region of the Mesoamerican Barrier Reef System (MBRS). Coral Reefs, 23, 584–594.

Smith D.J. 2006. Wakatobi, Indonesia field report. Technical Report. Unpublished.

Wilson, J. & Harisson, P. 2005. Coral Reef: Post-settlement mortality and growth of newly settled reef corals in a subtropical environment. 24:418. https://doi.org/10.1007/s00338-005-0033-1

Underwood JN, Smith LD, van Oppen MJH, Gilmour JP (2007) Multiple scales of genetic connectivity in a brooding coral on isolated reefs following catastrophic bleaching. Mol Ecol 16:771-784

5 REEF FISH INVENTORY

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5.1 Overview

In 2018, Dr. Kent Carpenter of the Old Dominion University and Dr. Jeffrey Williams of the Smithsonian Institution, conducted an initial inventory of reef fish species at the Tubbataha Reefs. Using the roving diver method, a total of 332 species are recorded from eight (8) sites in the park. Sixty (60) of these species were previously unrecorded from Tubbataha.

The source of the fish species list for Tubbataha is the annual fish visual census which provides information on the actual density and biomass values using belt transect method. However, as these surveys are restricted to fixed depth range transect survey and are focused on measuring density and biomass, the method is not as sensitive to fish biodiversity levels as the roving census method. Further, in-house expertise is insufficient to embark on a dedicated fish species inventory. Nevertheless, using two complementary methods helps provide a more comprehensive fish species inventory (Schmitt *et al* 2002). This year, Drs. Carpenter and Williams returned to Tubbataha to conduct further surveys. This is a brief report of their findings from the 2019 survey.

5.2 Methods

The roving diver survey (RDS) method (Schmitt and Sullivan 1996) is a rapid species assessment method where divers rove or swim around the reefs recording all species encountered. The roving method used by Carpenter and Williams starts at the depth of around 65 ft (approximately 20 meters), gradually swimming toward the shallowest part of the reef while identifying and recording all the species and their relative throughout the dive. Each census is done with a standard duration of 60 minutes. The goal is to find and record as many species as possible. Thus, divers also look for fishes under ledges (e.g., corals, rocks), in caverns, and crevices.

This year, Drs Carpenter and Williams were on the dive boat, Discovery Adventure, and surveyed sites were determined according to the schedule of the dive boat. Ten (10) dive sites were surveyed this year by two researchers, Drs. Carpenter and Williams. RDS data provided species list, frequency of distribution/sighting frequency and relative abundance data.

Table 6. Dive sites surveyed.

Dive No.	Description of dive sites
1	Dive site 'Staghorn Point', south of lighthouse island; drop off, high coral cover: South Atoll
2	Dive Site 'Delsan Wreck; South Atoll
3	Dive Site Ko-ok, the northern part of South Atoll
4	Dive Site T-Wreck, the northern part of South Atoll
5	Dive Site Black Rock, the northern part of South Atoll
6	Dive Site Malayan Wreck, the southern part of North Atoll, right in front of wreck, starting and ending at submerged part of the wreck in 3 m.
7	Dive Site Seafan Alley (at first buoy), the northern part of North Atoll.
8	Dive Site Shark Airport, over long sand flat and drop off, the northern part of North Atoll
9	Dive Site Jessie Beazley, directly in front of Island
10	Dive Site Jessie Beazley, the opposite side of reef from the island

While recording the species, the divers also took note of the relative abundance by using the following $\log_{10}$ categories (Schmitt and Sullivan 1996):

Single = 1 individual
Few = 2-10 individuals
Many = 11-100 individuals
Abundant = >100 individuals

Microsoft© Excel was used in collating the data. The descriptive analysis for this report was patterned after Schmitt *et al* (2002) and Schmitt and Sullivan (1996).

1. **Percent Sighting Frequency (%SF)** indicates the percentage of all dives in which the species was recorded or observed. Observed values ranged from 0-100% and were calculated as:

$$\%SF = 100 * \frac{S + F + M + A \text{ (for each species)}}{\text{(Number of surveys)}}$$

   Species were classified into three frequency categories based on the percentage of dives where each species was observed: frequent (≥70%), common (>20% x >70%), and uncommon (≤20%).

2. **Abundance Index** is a weighted average index, which is calculated to measure the abundance of each species using the abundance categories. This is calculated as:

$$\text{Abundance Index} = \frac{(S * 1) + (F * 2) + (M * 3) + (A * 4)}{\text{(Number of surveys/dives)}}$$

   where **S, F, M,** and **A** were the frequency categories of single, few, many, and abundant observations for each species and ***n*** was the total number of dives. This produced an abundance index per species, which was then scaled from 0 to 4, where Single = 1, Few = 2, Many = 3, Abundant = 4, and Not Observed = 0.

   These numbers indicate which abundance category each species was most often recorded. For example, if the abundance index of a species was 2.2, this means that in most of the dives the species occurred in 'few' numbers (2 to 10 individuals) but was also observed to be 'many' or 'abundant' in other dives.

   Abundance Index is organized in ranges for easy groupings of species: (0.1-1.0); (1.1 – 2.0); (2.1 -3.0); and (3.1-4.0). Species recorded under the abundance index range of 0.1 – 2.0 means that these species were observed in less abundance. Species that fell under the range of 2.0 – 3.0 were those generally recorded in few numbers but were occasionally observed in high abundance in other sites, while those that fell under range of 3.0-4.0 were observed to be abundant in most, if not in all sites.

To further estimate the overall biodiversity in Tubbataha Reefs, Estimate S (Colwell 2013) is used. This is a free software application that statistically computes biodiversity based on accumulation curves for rare faction and extrapolation (nonparametric) reference samples.

5.3 Results and Discussion

Number of species. A total of 338 species, including sharks and rays, were recorded this year. The highest number of species were identified under family Labridae (wrasses) with forty-nine (49) species recorded, followed by Pomacentridae (damselfish) (38 sp.), and Chaetodontidae (butterflyfish) (29 sp.).

Sixty-seven (67) of the total species were not identified in the previous year's survey of the same method. This year, twenty-six (26) species not previously listed in the Tubbataha fish list of species were recorded.

Species richness varied from 125 to 172 species per site (Figure 27). Site T8 (Shark Airport) had the highest count of fish species recorded. In the previous year, Shark Airport had also the highest number of species identified. Site T5 (Black Rock), Site T6 (Malayan Wreck), and Site T1 (Staghorn Point), had the highest number of species identified following Site T8. T10 (Jessie Beazley B) had the lowest species identified.

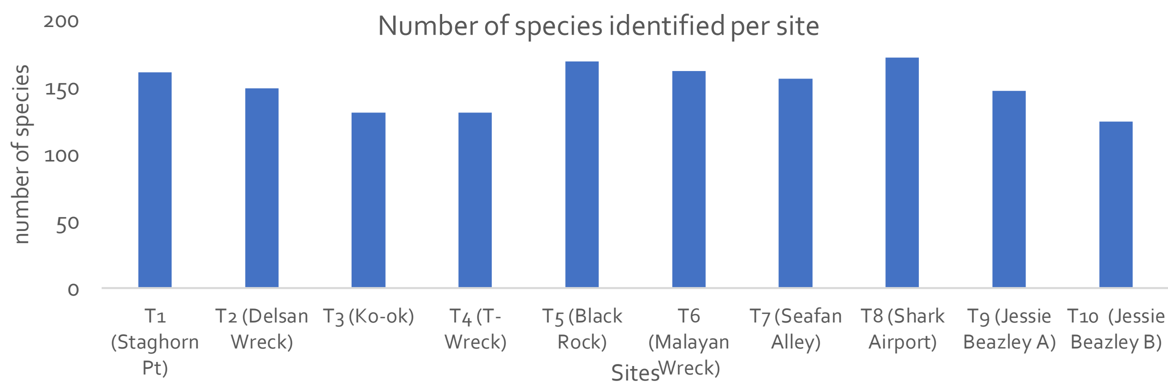


Figure 27. Number of species identified at each survey site.

Sighting Frequency and Abundance Index

Twenty-three species were frequently observed at all sites surveyed (Figure 28). These include six (6) species of Pomacentridae, three (3) of Labridae (wrasses), three (3) of Chaetodontidae (butterflyfish), one (1) each of Acanthuridae (surgeonfish), Carangidae (jacks and trevallies), Balistidae (triggerfish), Holocentridae (squirrelfish), and Zanclidae (Moorish idol). Of these groups, four species belonged to target species or those with high commercial value as food or ornamentals (FAO2003a). These were the Chocolate surgeonfish (*Acanthurus pyroferus*), Oranged-lined triggerfish *(Balistapus undulatus)*, Bluefin trevally *(Caranx melampygus)*, and

Silverspot squirrelfish *(Sargocentron caudimaculatum).* Least common (uncommon) species, or those recorded only once out of all dives/sites, comprised the bulk (46%) of the total number of species identified this year.

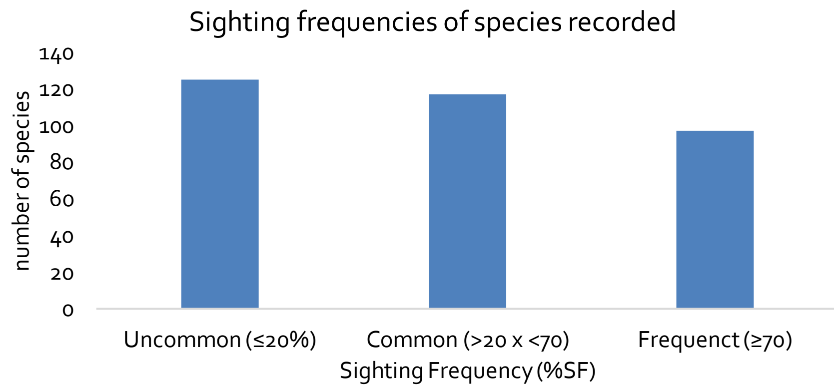


Figure 28. The number of species in each sighting frequency at the Tubbataha

Figure 29 graphs the number of species and according to their relative abundance at the Tubbataha Reefs. Most of the species found to be abundant are in the families Pomacentridae (damselfish) and Serranidae: Anthiinae (fairy basslets), dominated by Goldbelly damsel (*Pomacentrus auriventris),* Blue-axil chromis *(Chromis caudalis),* Golden damselfish (*Amblyglyphidodon aureus)* and Princess anthias *(Pseudanthias smithvanizi)*. These three species occurred in the most abundant category (4.0) and were observed at all sites. In the previous year's RDS, Threadfin anthias (*Pseudanthias huchtii)* and Yellowstriped fairy basslet (*Pseudanthias tuka)* were the most abundant species. In the fish survey conducted in May (Chapter 2), however, the most abundant species recorded were the Threadfin anthias (*Pseudanthias huchtii)*, Bicolor chromis (*Chromis margaritifer)*, and Dispar anthias (*Pseudanthias dispar).*

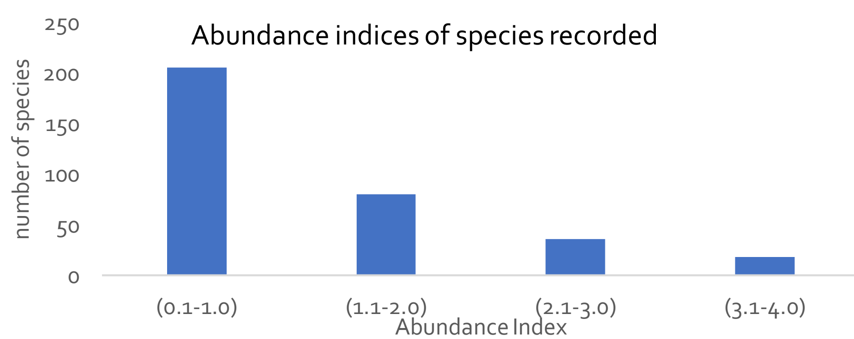


Figure 29. Number of species in each abundance index range.

About 15% of the frequently observed species fell under the upper ranges of the abundance index (2.1-4.0), which means that these species occur in high numbers in at least half of the dives (Table 7). Commercially important species such as the Dark-banded fusilier (*Pterocaesio tile)* and Thompson's surgeonfish (*Acanthurus thompsoni)* were also found to occur in high abundance. Other commercially important species which occurred in high abundance were the Peacock hind (*Cephalopholis argus)*, Blue-fin trevally *(Caranx melampygus)*, Two-spot red snapper *(Lutjanus bohar)*, Redfin emperor *(Monotaxis heterodon)*, Midnight snapper (*Macolor macularis)*, Bleeker's parrotfish (*Chlorurus bleekeri)*, Steephead parrot *(Chlorurus microrhinos)*, Bignose unicornfish *(Naso vlamingii)*, Chocolate surgeonfish (*Acanthurus pyroferus)*, and Pacific bullethead parrotfish (*Chlorurus spilurus)*.

Even if there is a strong relationship between the relative abundance and sighting frequency, the latter alone could not be an absolute assurance that the species also occur in high numbers (Schmitt and Sullivan 1996). Some fishes tend to occur in large concentrations, e.g., Pomacentridae (damselfish), while some were either solitary, in pairs, or in relatively small groups. For example, some species of Chaetodontidae (butterflyfish) were recorded in most dives (≥70), however, as Chaetodontidae rarely occur in large groups, they were observed to be less abundant.

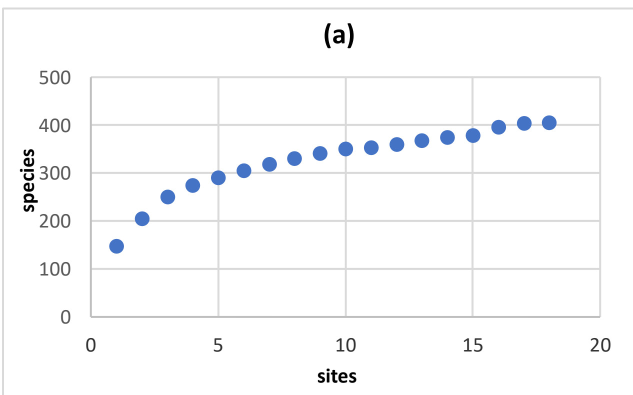
A list of the frequently observed species with their corresponding abundance at the Tubbataha Reefs is provided in Appendix 9. There were more uncommon species in low abundance identified this year compared with the previous year.

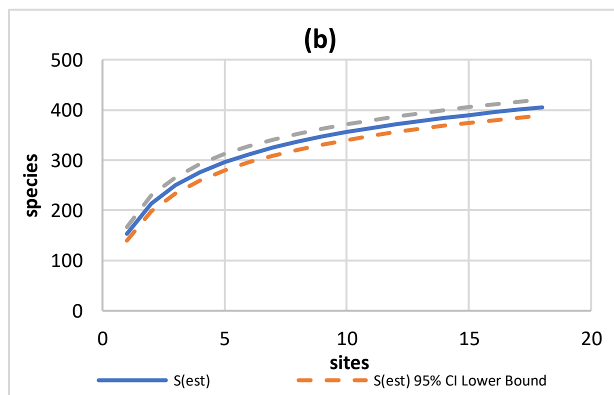
Table 7. Number of species on each sighting frequency and their abundance indices.

	Sighting Frequency			
Abundance Index	**Frequent (≥70%)**	**Common (>20% x <70%)**	**Uncommon (≤20%)**	**Total**
(0.1-1.0)	2	77	125	**204**
(1.1-2.0)	42	38	0	**80**
(2.1-3.0)	34	2	0	**36**
(3.1-4.0)	18			**18**
Total	**96**	**117**	**125**	**338**

Species accumulation curves

To predict the number of species that could be identified at the Tubbataha Reefs, species accumulation curves using the rarefaction and extrapolation from sample references were used (Figure 30). The raw species accumulation curve at 18 collections shows more than 400 species identified during the last two years (a and b). In the accumulation curve with extrapolation (c), the number of species is assumed to increase to 441 species (95% CI Lower Bound) or up to more than 500 species (95% CI Upper Bound) with up to 68 collection sites added. This means that new species should still be added until 68 collections are made before the accumulation curve starts to plateau, when fewer, or no additional, species will be identified. The expected accumulation of species should increase if surveys in the lagoons of both atolls are conducted since many fish species commonly inhabit lagoons that are not found on outer reefs (Komyakova et al 2018).





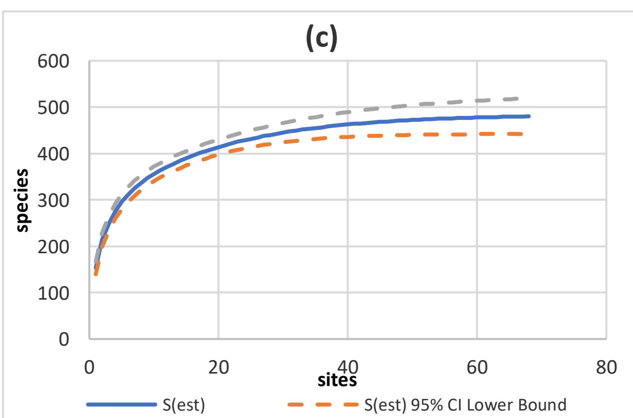


Figure 30. Results of the species abundance analysis for Tubbataha Reefs (2018-2019) using EstimateS software: (a) species accumulation curve collected from 18 sites; (b) sample based rarefaction using data collected from 18 sites with 95% Confidence Intervals (Upper and Lower Bound); and (c) species accumulation in 18 sites with extrapolation up to 68 sites with 95% confidence intervals (Upper and Lower Bound).

5.4 Conclusion and Recommendation

After only two years of survey, 401 fish species were recorded using this method. Ninety-six (96) species, not initially listed in the existing fish species list of the Tubbataha Management Office, were identified indicating the value of supplementing belt transect surveys with this roving census surveys. Continuing the survey is expected to increase the number of species identified in the park. Furthermore, conducting surveys in the lagoons of both atolls is expected to increase the species list significantly. Currently, around 790 species of fish were recorded at the Tubbataha Reefs Natural Park to date.

5.5 References

Carpenter, K. E. (2019, May 23). Updated Tubbataha Fish Roving Census spreadsheet. [e-mail].

Colwell, R.K. 2013. Estimate S: Statistical estimation of species richness and shared species from samples. Version 9 and earlier. User's Guide and application. http://purl.oclc.org/estimates

Komyakova, V., Jones, G. P., & Munday, P. L. (2018). Strong effects of coral species on the diversity and structure of reef fish communities: A multi-scale analysis. *PloS one*, *13*(8), e0202206.

Schmitt EF, Sullivan KM (1996) *Analysis of a volunteer method for collecting fish presence and abundance data in the Florida Keys.* Bull Mar Sci 59(2):404–416

Schmitt, E. F., Sluka, R. D., & Sullivan-Sealey, K. M. (2002). *Evaluating the use of roving diver and transect surveys to assess the coral reef fish assemblage off southeastern Hispaniola*. Coral Reefs, *21*(2), 216–223. https://doi.org/10.1007/s00338-002-0216-y

APPENDICES

Appendix 1. Monitoring Team

Fish and Benthos Monitoring (25 April to 2 May)

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Wilfredo Licuanan, De La Salle University
Sandra Bahinting, De La Salle University
Kristine Domingo, De La Salle University
Mary Joan Pecson, WWF-Philippines
Anton Cornel, WWF-Philippines
Ace Acebuque, WWF-Philippines
Kimry Delijero, WWF-Philippines

Reef Fish Inventory (17 to 23 April)

Dr. Kent Carpenter
Dr. Jeffrey Williams

Appendix 2. TMO Fish and Benthos Monitoring Sites

Sites	Stations	Latitude (N)	Longitude (E)
Site 1	Station 1A	8.93532 °	120.01302 °
	Station 1B	8.93781 °	120.00851 °
Site 2	Station 2A	8.89236 °	119.90627 °
	Station 2B	8.89128 °	119.90453 °
Site 3	Station 3A	8.75591 °	119.82881 °
	Station 3B	8.75186 °	119.82784 °
Site 4	Station 4A	8.80850 °	119.81907 °
	Station 4B	8.80656 °	119.82169 °
Jessie Beazley	Station JBA	9.04393 °	119.81599 °
	Station JBB	9.04557 °	119.81348 °
Grounding sites	USSG	8 49.297°	119 48.187°
	MPY	8 51.183°	119 56.188°

Appendix 3. Categories for evaluating ecological health of coral reef fish communities according to Hilomen *et al* (2000) and Nañola *et al* (2004).

Parameter	Measure	Category
Species Richness	Number of species per 500m^2)	
	<16	Very poor
	13.5-23.5	Poor
	24-37	Moderate
	37.5-50	High
	>50	Very High
Density	Number of fish per 500m^2)	
	< 100.5 fish	Very Poor
	101-338	Low
	338.5-1,133.5	Moderate
	1134-3,796	High
	> 3,796	Very High
Biomass	g/m^2	
	0-10	Very Low to Low
	11-20	Moderate
	21-40	High
	>40	Very High

Appendix 4. Relative density and biomass for all regular monitoring sites.

Families	Common Name	Density (ind/500m²)	Biomass (g/m²)
Acanthuridae	Surgeonfish	81.65	24.67
Apogonidae	Cardinalfish	3.40	0.01
Balistidae	Triggerfish	44.83	14.50
Blenniidae	Blenny	0.25	0.00
Caesionidae	Fusiliers	15.28	1.66
Carangidae	Jacks, trevallies	3.72	7.88
Chaetodontidae	Butterflyfish	21.73	2.30
Cirrhitidae	Hawkfish	1.80	0.03
Diodontidae	Porcupinefish	0.03	0.00
Ephippidae	Spadefish	0.10	0.37
Fistulariidae	Cornetfish	0.05	0.01
Gobiidae	Goby	0.02	0.00
Haemulidae	Sweetlips	1.15	2.62
Holocentridae	Squirrelfish	14.42	2.42
Kyphosidae	Sea Chub	1.07	0.97
Labridae	Wrasses	68.77	3.72
Lethrinidae	Emperor Fish	9.55	3.12
Lutjanidae	Snappers	8.02	4.29
Monacanthidae	Filefish	0.38	0.04
Mullidae	Goatfish	1.37	0.22
Muraenidae	Moray eel	0.02	0.04
Nemipteridae	Breams	0.02	0.00
Ostraciidae	Boxfish	0.20	0.02
Pempheridae	Sweeper	0.05	0.00
Pomacanthidae	Angelfish	14.33	0.80
Pomacentridae	Damselfish	643.28	7.26
Priacanthidae	Bigeyes	0.02	0.02
Pseudochromidae	Dottyback	0.02	0.00
Ptereleotridae	Dartfish	1.97	0.01
Scaridae	Parrotfish	16.15	15.52
Scombridae	Tunas, mackerel	0.03	0.20
Scorpaenidae	Scorpionfish	0.05	0.00
Serranidae	Groupers	15.33	4.45
Serranidae: Anthiinae	Fairy basslet	704.65	2.53
Siganidae	Rabbitfish	0.53	0.20
Tetraodontidae	Pufferfish	0.48	0.40
Zanclidae	Moorish Idol	3.45	0.69
Grand Total		**1678.27**	**102.79**

Appendix 5. Relative mean density and mean biomass of fish community in USS Guardian grounding site.

Families	Common Name	Density (individuals/500m^2)	Biomass (grams per m^2)
Acanthuridae	Surgeonfish	63.50	14.58
Balistidae	Triggerfish	105.00	21.79
Blenniidae	Blennies	0.17	0.00
Carangidae	Jacks and trevallies	4.00	12.98
Carcharhinidae	Sharks	0.50	9.49
Chaetodontidae	Butterflyfish	15.33	1.50
Cirrhitidae	Hawkfish	1.17	0.02
Haemulidae	Sweetlips	1.17	2.07
Holocentridae	Squirrelfish	7.83	4.06
Kyphosidae	Sea chubs	0.50	0.62
Labridae	Wrasses	61.50	2.74
Lethrinidae	Emperor fish	15.00	5.77
Lutjanidae	Snappers	2.67	3.27
Monacanthidae	Filefish	0.17	0.02
Mullidae	Goatfish	0.17	0.03
Muraenidae	Moray eel	0.17	0.03
Ostraciidae	Boxfish	0.33	0.07
Pomacanthidae	Angelfish	17.83	1.68
Pomacentridae	Damselfish	311.17	4.08
Ptereleotridae	Dartfish	0.33	0.00
Scaridae	Parrotfish	12.50	17.49
Serranidae	Groupers	15.00	4.11
Serranidae: Anthiinae	Fairy basslets	590.50	2.94
Siganidae	Rabbitfish	0.67	0.52
Tetraodontidae	Pufferfish	0.67	1.02
Zanclidae	Moorish idol	3.67	0.65
Grand Total		**1231.50**	**111.56**

Appendix 6. Relative mean density and mean biomass of fish community in Min Ping Yu grounding site.

Families	Common Name	Density (individuals/500m²)	Biomass (grams per m²)
Acanthuridae	Surgeonfish	64.33	11.92
Balistidae	Triggerfish	7.83	4.72
Caesionidae	Fusiliers	44.33	7.11
Carangidae	Jacks and trevallies	1.67	4.93
Chaetodontidae	Butterflyfish	20.50	1.71
Cirrhitidae	Hawkfish	1.83	0.02
Haemulidae	Sweetlips	1.00	1.54
Holocentridae	Squirrelfish	14.17	2.22
Labridae	Wrasses	72.33	7.66
Lethrinidae	Emperor fish	23.67	3.80
Lutjanidae	Snapper	3.50	1.67
Malacanthidae	Tilefish	0.17	0.03
Monacanthidae	Filefish	1.50	0.11
Mullidae	Goatfish	3.33	0.46
Nemipteridae	Breams	0.33	0.04
Ostraciidae	Boxfish	0.50	0.14
Pomacanthidae	Angelfish	8.17	0.18
Pomacentridae	Damselfish	623.00	5.94
Ptereleotridae	Dartfish	0.50	0.00
Scaridae	Parrotfish	17.50	12.61
Serranidae	Groupers	6.33	2.34
Serranidae: Anthiinae	Fairy basslets	121.33	0.46
Siganidae	Rabbitfish	1.33	0.44
Tetraodontidae	Pufferfish	0.17	0.02
Zanclidae	Moorish idol	1.17	0.22
Grand Total		**1040.50**	**70.28**

Appendix 7. Taxonomic amalgamation units (TAUs)

CORAL (HC)

Acanthastrea (ACAN)
Acropora branching (ACB)
Acropora corymbose (ACC)
Acropora digitate (ACD)
Acropora hispidose (ACH)
Acropora plate (ACT)
Acropora robusta group (ACR)
Astreopora (AST)
Attached fungiids (AF)
Caulastrea (CAU)
Coeloseris (COE)
Coscinarea (COS)
Cyphastrea (CYP)
Diploastrea heliopora (DIP)
Echinophyllia (ECHY)
Echinopora (ECHI)
Euphyllia (EUP)
Favia (FAV)
Favites (FVI)
Fungia (CMR)
Galaxea (GAL)
Goniastrea (GONIA)
Goniopora (GONIO)
Heliopora branching (HELB)
Heliopora encrusting (HELE)
Heliopora submassive (HELS)
Hydnophora branching (HYDB)
Hydnophora encrusting (HYDE)
Isopora (ISO)
Leptoria (LEPA)
Leptoseris (LEPS)
Lobophyllia (LOB)
Merulina (MER)
Millepora (MILL)
Montastrea (MON)
Montipora branching (MONTB)
Montipora encrusting (MONTE)
Montipora foliose (MONTF)
Mycedium (MYC)
Other branching corals (CB)
Other bubble corals (BUB)
Other encrusting corals (CE)
Other foliose corals (CF)
Other free living fungiids (FOT)
Other massive corals (CM)
Oulastrea (OULA)
Oulophyllia (OULO)
Oxypora (OXY)
Pachyseris encrusting (PACE)
Pachyseris foliose (PACF)
Pavona (PAV)
Pectinia (PEC)
Platygyra (PLAT)
Pocillopora (POC)
Porites branching (PORB)
Porites encrusting (PORE)
Porites massive (PORM)
Seriatopora (SER)
Stylophora (STY)
Symphyllia (SYM)
Tubipora musica (TUBI)
Turbinaria (TURB)

SOFT CORAL (SC)

Soft coral (SC)

ALGAE (AA)

Algal assemblage (AAA)
Crustose Coralline algae (CA)
Halimeda (HA)
Turf (TU)

MORTALITIES (MOR)

Dead coral (DC)
Dead coral with algae (DCA)

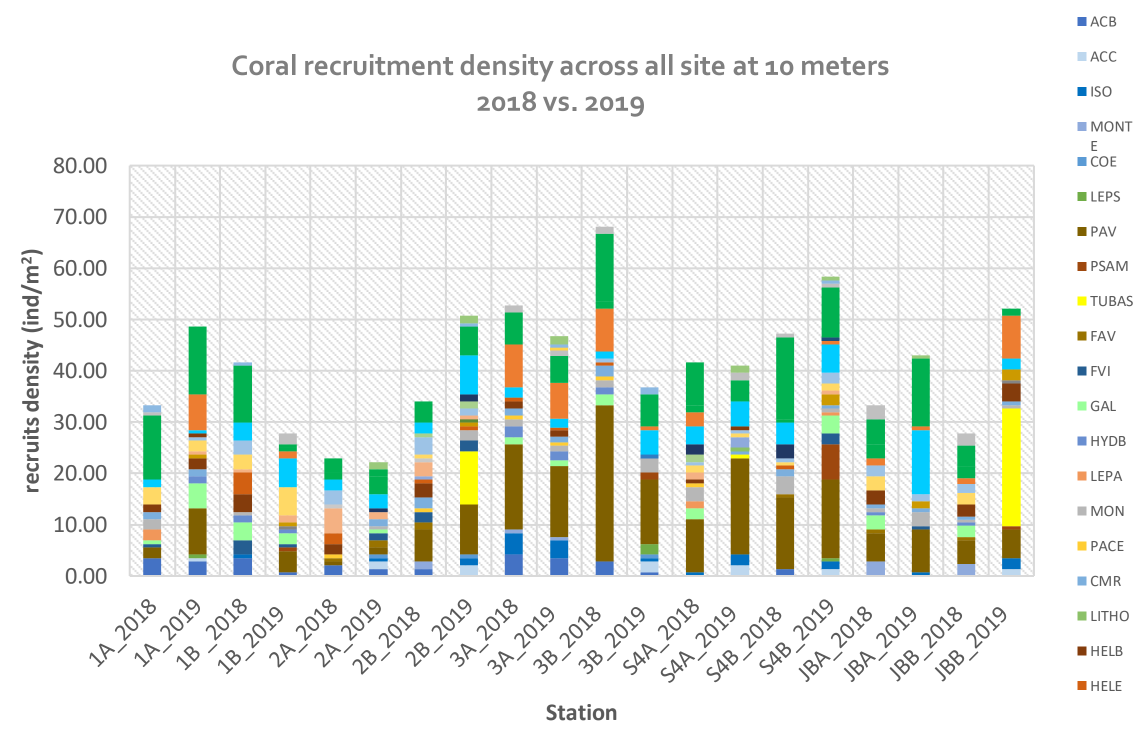
ABIOTIC (AB)

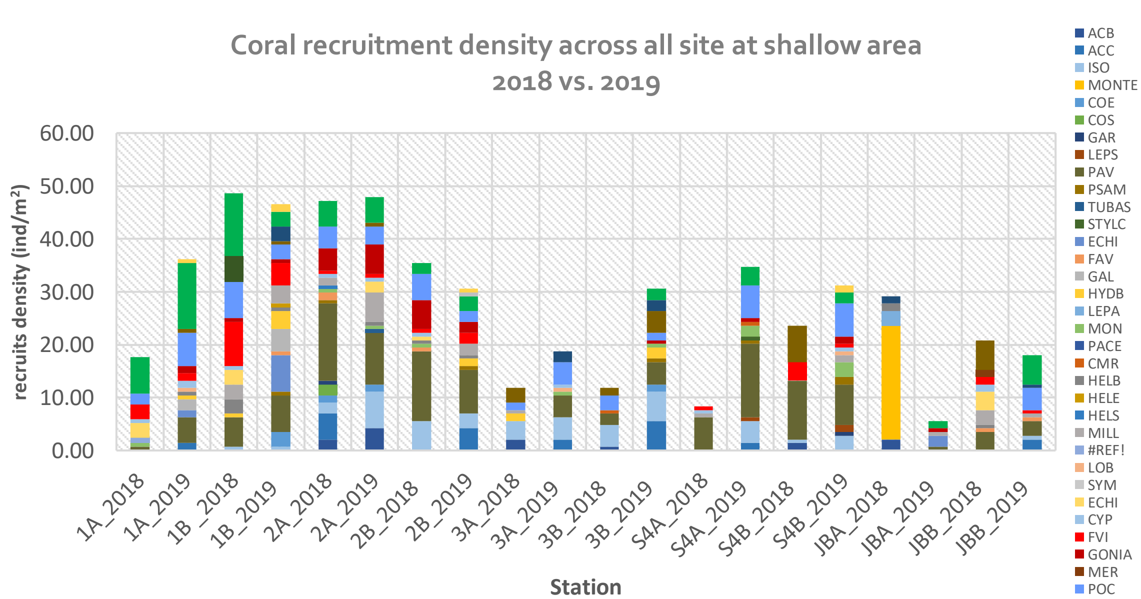
Rubble (R)
Sand (S)
Silt (SI)
Rock (RCK)

OTHER INVERTEBRATES (OT)

Corallimorpharian (COR)
Sponge (SP)
Zoanthid (ZO)
Ascidian (ASC)
Gorgonian (GORG)
Invertebrates (INV)

Appendix 8. Coral recruitment density in 2018-2019.





Appendix 9. List of most abundant fish species in Tubbataha Reefs Natural Park

Species	Families	Abundance Index (AI)
Amblyglyphidodon aureus	Pomacentridae	4
Chromis caudalis	Pomacentridae	4
Pomacentrus auriventris	Pomacentridae	4
Pseudanthias smithvanizi	Serranidae: Anthiinae	4
Pseudanthias hutchi	Serranidae: Anthiinae	3.8
Pomacentrus brachialis	Pomacentridae	3.7
Chromis xanthura	Pomacentridae	3.6
Pseudanthias tuka	Serranidae: Anthiinae	3.6
Chromis atripes	Pomacentridae	3.5
Chromis margaritifer	Pomacentridae	3.5
Chromis weberi	Pomacentridae	3.4
Pseudanthias dispar	Serranidae: Anthiinae	3.4
Chromis retrofasciata	Pomacentridae	3.2
Pseudanthias squamipinnis	Serranidae: Anthiinae	3.2
Pterocaesio tile	Caesionidae	3.2
Acanthurus thompsoni	Acanthuridae	3.1
Chromis amboinensis	Pomacentridae	3.1
Dascllus reticulatus	Pomacentridae	3.1