Ecosystems Research and Monitoring Report 2018

TRNP Ecosystem Research and Monitoring Report 2018

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Executive Summary

The Tubbataha Reefs Natural Park is the largest marine protected area in the country and is one of very few managed under a 'no-take' policy. Research and monitoring, being one of its conservation programs, is designed to determine ecosystem health; measure biophysical indicators of management effectiveness; and provide the scientific basis for formulation of proactive strategies and responses to emerging issues.

The TMO annual ecosystem research and monitoring report includes the results of monitoring of fish, reef benthos and seabirds. This report also includes other studies conducted this year: coral recruitment, fish inventory and reef benthos assessment.

Three hundred four (304) species belonging to 35 families and subfamilies were recorded during the regular monitoring in Tubbataha Reefs this year. This is slightly fewer than the number of species observed last year (316 species). The estimated species richness across all sites was 189 species per 500 m^2 which is very high (>50 species per 500 m^2) according to the established categories for a healthy reef fish community (Hilomen *et al.* 2000). The mean reef fish density of the deep areas is significantly higher at 1,466 ind/500 m^2 than the shallow stations with 1,095 ind/500 m^2. Overall mean reef fish density is 1,298 individuals/500 m^2 which falls under high category Hilomen *et al.* (2000).

Deep areas contributed significantly higher yields than the shallow stations in terms of overall biomass. The total mean biomass of 134 g/m^2 in deep areas is mainly represented by Carangidae (jacks and trevallies), Acanthuridae: Nasinae (unicornfish), and Scaridae (parrotfish). In the shallow stations, the biomass estimates of 62.25 g/m^2 is represented by Balistidae (triggerfish), Scaridae (parrotfish), and Acanthuridae: Nasinae (unicornfish).

The density of target fish this year is comparable with the previous year, while the biomass is comparable with that of 2014. Compared to last year, encounters with large-bodied schooling fishes are less frequent this year, contributing to lower target biomass. The mean biomass of indicator species this year is 1.75 g/m², an improvement from last year's 1.45 g/m². Major species' density is represented by fairy basslets/anthias (889.5 ind/500m²) and damselfish (825 ind/500m²).

Some species of special interest were also sighted during this year' survey. These include Grey reef shark (*Carcharinus amblyrhincos*), Black tip reef shark (*Carcharinus melapterus*), and Whitetip reef shark (*Triaenodon obesus*), Humphead wrasse (*Cheilinus undulatus)*, Camouflage grouper (*Epinephelus polyphekadion*), Bumphead parrotfish *(Bulbometopon muricatum)* and Saddleback Grouper (*Plectropomus laevis*).

The average hard coral cover in the deep areas (10 meters) this year is 29.9%, almost similar to the 29% last year. Most of the corals recorded in these stations comprise of the Genus *Echinopora* (encrusting), *Porites* (encrusting), *Lobophyllia* and *Diploastrea heliopora*. Coral formations in the deep areas are mostly encrusting and massive. In general, soft coral cover is relatively low in the deep areas of most sites, except for Station JBA. Algae, in the case of TRNP, is mostly coralline algae, which are important contributors to reef calcium carbonate and can facilitate coral recruitment.

The average hard coral cover at five meters is 36.75%, which is classified under 'good' condition according to Licuanan *et al.* (2017). The occurrence of soft corals is minimal in the shallow areas except in Station JBB. Algal assemblage in the shallow areas are relatively high in Site 3 and is consistent with the deep areas of the same site. This coincides with the relatively high percentage of mortalities, mostly dead corals with algae, in Site 3. This occurrence might be influenced by the effect of strong current and wave actions.

A total of 39 coral Genera belonging to 16 Families were recorded in all the sites in TRNP during this survey; 32 coral genera were observed in the shallow and 36 in the deep sites. The deep areas were dominated by Genus *Echinopora*, *Porites*, *Diploastrea*, *Goniopora* and *Montipora*. In the shallow areas, Genus *Porites*, *Isopora*, *Montipora*, *Acropora* and *Echinopora* were the most common.

A very few invertebrate species were noted in the transects, which includes Giant clam (mostly *Tridacna crocea*), sea cucumbers, nanded coral shrimp, lobster, and long spined urchin.

A total of 23 species of birds were identified during the inventory. The total number of avifauna species recorded in TRNP is 115 species. A total 41,794 adult individuals of six breeding and one former breeding seabird species were recorded; 37,663 individuals on Bird Islet and 4,134 individuals on South Islet. The population on Bird Islet has increased by17% since 2016 when it hosted 73% of the total population. On South Islet, due to habitat loss, the population has decreased from 27% to 10% since 2016. The total result of the May count in 2018 is about 12% higher than in 2017 and represents the highest documented count of breeding seabirds in the history of TRNP.

A decrease of 30% in the population of Red-footed booby was observed this year, while the Brown booby population remained stable. Brown noddy population recorded the second highest breeding population since 1981. A continued decrease in the population and occurrence of nesting of Black noddy corresponds to the decline in the number and condition of the vegetation. On South Islet the decline in the number of adult birds is 54%. Nesting is lower by 57% compared to May 2017. On Bird Islet the pilot establishment of artificial breeding areas increased the presence of adult birds, from around 800 in 2017 to more than 2,500 in 2018. The increase in the breeding population of Great Crested Tern continued in 2018 but at lower pace compared to 2017. Overall, the population is at its highest number ever recorded. The breeding season of Sooty Tern started end of February/ beginning of March. Hence, the inventory was able

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document what can be perceived as the entire adult population represented by the highest count ever.

Coral recruitment baseline study was conducted during the annual monitoring this year. This survey recorded twenty-nine (29) coral genera belonging to nine families. The average estimated coral recruit density across all sites was 45.56 ind/m^2 at 10 meters, with values ranging from 0.83 ind/m^2 (±0.26 SE) to 20 ind/m^2. In the shallow areas of TRNP (five meters), the average density is 30.50 ind/m^2 and values ranged from 0.10 ind/m^2 to 6.87 ind/m^2.

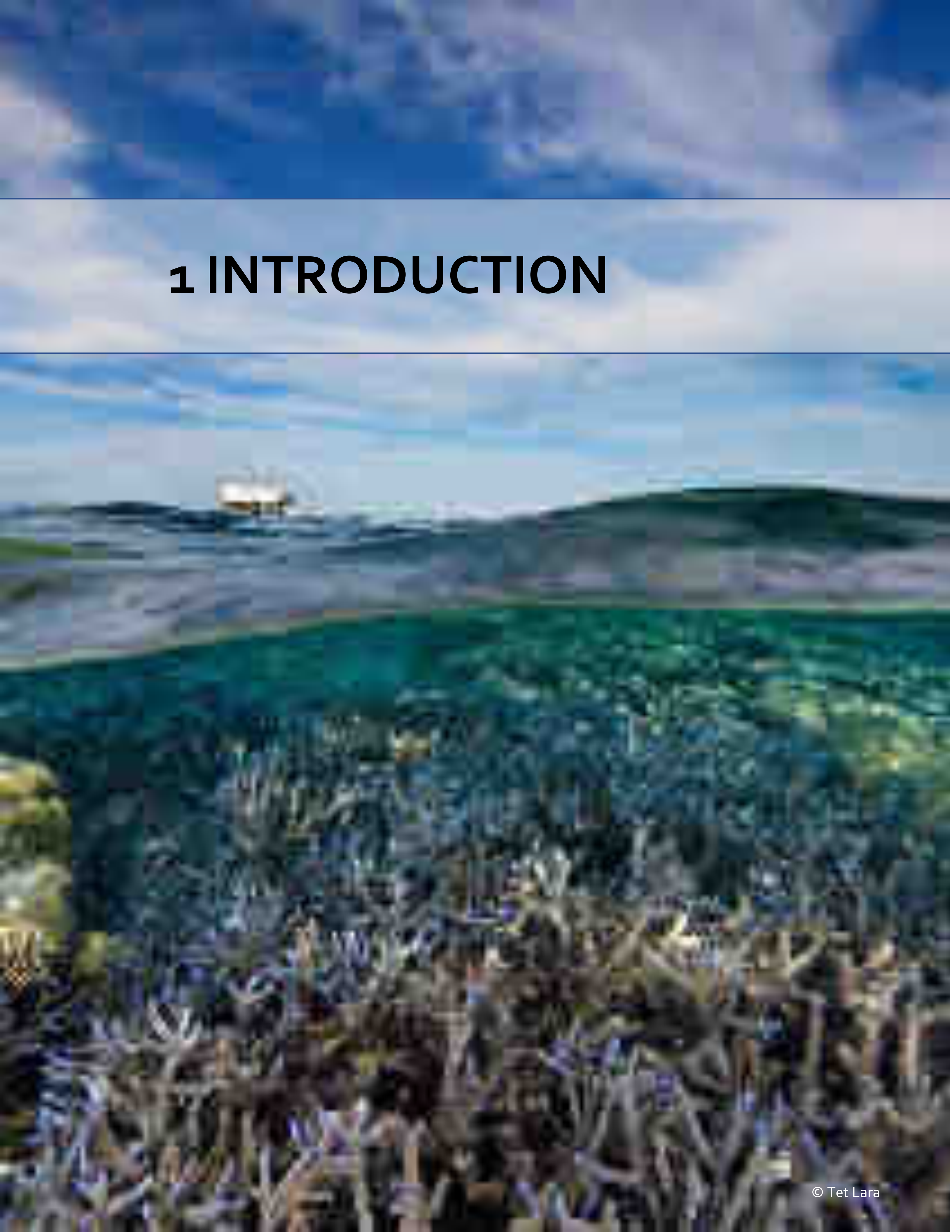
Deep sites were dominated by coral recruits belonging to Families *Poritidae*, *Faviidae* and *Agariciidae.* Families *Agariciidae*, *Acroporidae*, *Faviidae* and *Pocillporidae* mostly comprised the coral recruits in the shallow areas (five meters). Coral recruit density in the deep areas was observed to be higher compared to that in shallow areas. Most of the coral recruits at both depths were between >1cm to ≤4 cm, which for most coral families are considered to be the juvenile stage.

Using roving diver survey method, fish species inventory was conducted this year with the help of external experts. A total of 332 species under 37 families were identified in the Tubbataha Reefs during this survey. Most species (46 species) belong to Family Labridae (wrasse). Forty species (40) were identified under family Pomacentridae (damselfish), 31 species for family Chaetodontidae (butterflyfish), 22 species were identified for both family Gobiidae (gobies) and family Serranidae (groupers and fairy basslets), and 21 species of Scaridae (parrotfishes). Sixty (60) species not initially listed in the Tubbataha fish species list were identified in this survey. Thirty-six (36) out of the 98 species categorized as frequently observed were recorded in all sites. There are 146 species that are common and were recorded between 2 to 5 surveys/dives. In terms of abundance, 17 species were observed in very high abundance, while 273 species were recorded under the less abundant category.

Tubbataha Reefs has the highest average count of species compared to other sites in the Philippines. It also has the highest minimum species count and has the highest maximum count among all sites in the country. Dr. Carpenter (personal communication) also stated that Tubbataha has higher average counts than other sites in Indonesia and Malaysia where they employed the same census method.

A team from De La Salle University also joined this year's monitoring trip to conduct reef assessment in the shallow areas of TRNP. The average hard coral cover of all regular monitoring stations this year is 30.0% ± 2.0%. Since 2012, there was no significant change in the hard coral cover of the shallow areas being monitored by the DLSU. The average number of TAUs for all stations in Tubbataha in 2018 is 19 ± 1, and it did not change significantly over time.

1 INTRODUCTION



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1.1 Overview

In 2017, the UNESCO World Heritage Centre released its first global scientific assessment on the 'Impacts of climate change on World Heritage Coral Reefs' (Heron *et al.* 2017). The report produced coral bleaching projections based on climate scenarios of the Intergovernmental Panel on Climate Change (IPCC). Their projections suggest that TRNP will most likely experience severe stress (DHW ≥8°C-weeks) twice per decade from year 2030 (Heron *et al.* 2017). In 2017, TRNP was recognized as one of the only three Global Ocean Refuge awardees. This is based on the scientific assessments done in no-take marine protected areas. Being regarded as such, TRNP is now considered as one of the refugia for marine ecosystems. Thus, strengthening its management, including research and monitoring, is very crucial.

Aside from prolonged above-average sea surface temperatures, other stressors to coral reefs include increased frequency and intensity of storms, ocean acidification, land-based pollution and unsustainable fishing and tourism practices (Hughes *et al.* 2007). Coral reefs are one of the most vulnerable marine ecosystems and more than half of the world's reefs are under medium or high risk of degradation (IPCC 2014).

As a response, managers and scientists have designed tools to monitor changes in the health of corals and reef-associated species, and be able to design management strategies to better conserve these resources. The Tubbataha Reefs Natural Park is the largest marine protected area in the country and is one of very few managed under a 'no-take' policy. Research and monitoring, being one of its conservation programs, is designed to:

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

The TMO annual ecosystem research and monitoring report includes the results of monitoring of fish, reef benthos and seabirds. 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. On the other hand, the method employed for seabird population monitoring is modified from the DENR Biodiversity Monitoring System.

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).

Seabird populations were monitored in Bird Islet, South Islet and Jessie Beazley Reef. Emerging sand cays were also visited to take into account resting seabirds.

Field Surveys

The fish and benthos surveys were conducted on 2 to 9 May while the seabirds survey was conducted on 11 to 16 May. In-house researchers and marine park rangers were assisted by volunteer researchers from the UP-Mindanao, Jose Rizal Memorial State University, De La Salle University, Philippine Biodiversity Conservation Foundation, Inc., and UP-Los Baňos. The members of the monitoring team are listed in Annex 1.

1.3 Other researches

TMO also conducted a coral recruitment study this year to establish baseline data at both depths of the monitoring stations. Researchers from the De La Salle University – Br. Alfred Shields Marine Station also monitor the spatial and temporal changes of reef benthos in the shallow portions of the reef (3 to 5 meters) using the photo-transect method. They also monitor the changes in benthic structure of the two grounding sites using photo-quadrats.

A team of researchers from the Fish-I Project of the UP-Diliman also joined this year's survey. Fish-I technology is a semi-automated reef fish counting and biomass estimation system. It uses a camera-software system that performs fish species identification and estimates fish density and biomass. The goal of the team was to calibrate the software to areas with high fish abundance, such as TRNP. TRNP has also drawn interest from other research institutions, both local and international. This year, the following institutions conducted research trips in the park:

- University of Queensland – Global Change Institute
- University of San Agustin
- University of the Philippines – Marine Science Institute
- Large Marine Vertebrates Research Institute Philippines
- Coastal Conservation and Education Foundation, Inc.

1.4 References

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2 REEF FISH COMMUNITY

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2.1 Overview

Marine Protected Areas (MPAs) have proven to be effective management tools for achieving marine sustainability (Valdés and Hatcher 2009). MPAs are established to improve and conserve marine biodiversity. Specifically, they maintain and seed fish stocks and other species to neighboring areas through dispersal (Russ *et al.* 1992, Russ and Alcala 1996) and preserve the population of threatened species (Wilkenson *et al.* 2003).

Tubbataha is one of the largest and best managed marine protected areas in the Philippines (ADB 2014). It is believed to disperse fish and coral larvae to the surrounding reefs carried by ocean currents (Dygico 2006), hence, securing the food source of the Filipino people. Annual surveys are conducted to examination the status of the reef fish community. These assessments could reflect the overall condition of the reef, as well as damages from natural and anthropogenic disturbances (Wilkenson *et al.* 2003). The results of this survey would also gauge the effectivity of management and be could be used for the formulation of science-based policies.

This year, the fish survey was conducted simultaneous with benthos survey on 2- 9 May, with reef fish experts from Jose Rizal Memorial State University and University of the Philippines - Mindanao.

2.2 Methodologies

Data Collection

Seven (7) monitoring sites, including the USS Guardian and Min Ping Yu grounding sites, were re-surveyed. Except for these adjacent sites of grounding areas, all monitoring sites have two stations (A and B) each, which are approximately 500 meters apart. Fish Visual Census (FVC) patterned from English *et al*. (1997) was employed to determine the components of fish community such as biomass, density, and species richness.

The established monitoring sites were first located using the Global Positioning System (GPS) device. Three (3) 50-meter replicate transects, separated by 10-meter buffer, were laid in deep (~10m) and shallow (~5m) areas of each station. Each transect has an imaginary 5-meter coverage on both sides, 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. The scientific name, actual count, and estimated length/size of the fish encountered inside the established corridor were recorded. Highly mobile species were recorded first before the slower ones (i.e., transient and cryptic species). Three (3) divers completed the survey this year, assessing the deep transects first and the shallow afterwards. This year, 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. The 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 (inds/500m^2). The biomass was simplified in grams per square meter (g/m^2) and was calculated with the existing length and weight model (Pauly 1984), using the formula:

$$\mathbf{W = aL^b}$$

where ***W*** is derived weight (g), **L** is the estimated total length (cm), and **a** and **b** are 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. Whereas, two-factor analysis of variance (ANOVA) in the Microsoft Excel 2016 is used to detect if there were significant differences in the overall biomass between sites and between years (2013-2018).

2.3 Results and Discussions

Present conditions

Species richness and density

Three hundred four (304) species belonging to 35 families and subfamilies were recorded in the Tubbataha Reefs this year. This is slightly fewer than the number of species observed last year (316 species). Family richness ranged from 21, recorded in the shallow transects of Station 1B (Malayan Wreck), to 26 families in deep area in Station 3A (Delsan Wreck). That same station in Delsan Wreck also had the highest number of species at 124, while its shallow transects in Station 3B recorded the lowest with 89 species. Overall, the estimated species richness across all sites was 63 species per 500 m^2 which is very high (>50 species per 500 m^2) according to the established categories for a healthy reef fish community (Hilomen, *et al.* 2000) (Appendix 3).

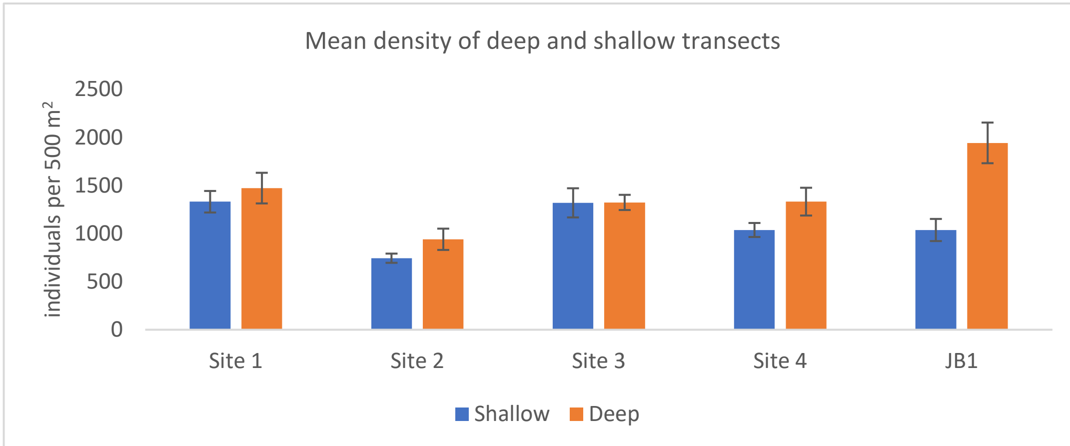


Figure 3. Mean fish density (individuals per 500 m²) at depths per site. Error bar represents the standard error of the mean.

The mean reef fish density of the deep areas is significantly higher (t-test; p=0.02) at 1,466 ind/500 m² than the shallow stations with 1,095 ind/500 m². Comparing the density in each site with that of the previous year's, Site 1 and Site 4 have increased in abundance while the other sites decreased. In terms of overall mean density, Pomacentridae (damselfish), followed by Serranidae: Anthiinae (basslets/anthias) dominated the North Atoll sites (Site 1 and 2) and JB1. South Atoll (Site 3 and 4) is dominated by Serranidae:Anthiinae (basslets/anthias), followed by Pomacentridae (damselfish). Appendix 2 lists the families and their mean density per depth. Overall mean reef fish density is 1,298 individuals/500 m², slightly lower than the previous year's, but not significantly different (t-test; p=0.17). This fell under the high category (1,134 – 3,798 ind./500m²) established for a healthy coral reef by Hilomen *et al.* (2000) (Appendix 3).

Biomass

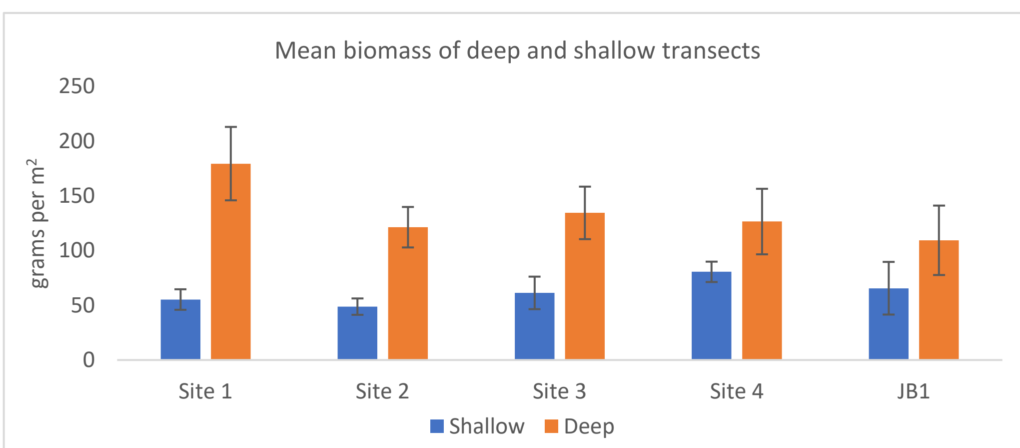


Figure 4. Distribution of mean biomass (gram per m²) per depth in Tubbataha Reefs. Error bar represents the standard error of the mean.

Deep areas (t-test; p=0.01) contributed significantly higher yields than the shallow stations in terms of overall biomass. The total mean biomass of 134 g/m^2 in deep areas is mainly represented by Carangidae (jacks and trevallies), Acanthuridae: Nasinae (unicornfish), and Scaridae (parrotfish). In the shallow stations, the biomass estimates of 62.25 g/m^2 is represented by Balistidae (triggerfish), Scaridae (parrotfish), and Acanthuridae: Nasinae (unicornfish). Appendix 3 lists the families with their mean biomass contribution for each depth. Both estimates for deep and shallow areas exceed the minimum established biomass yield for a healthy reef fish community (Nañola *et al*. 2004).

Fish groups: Target, indicator, and major

Fishes were clustered into three functional groups – target, indicator, and major species. Targets are species that are commercially important as food or as ornaments (Sabater 2002, unpub). They usually form schools and are highly mobile. Indicators refer to the species that closely rely on live corals for food and shelter (Cole *et al.* 2008), thus their presence can approximate the 'health' condition of a reef (Crosby and Reese 1996; Ohman *et al*. 1998; Hourigan *et al.* 1998), as the high species richness or abundance is related to the high coral cover (Pereira and Videira 2005; Cole *et al.* 2008). Lastly, the major group are species that occur in high numbers and concentrations and are targeted as ornaments but not mainly as food (Sabater 2002, unpub).

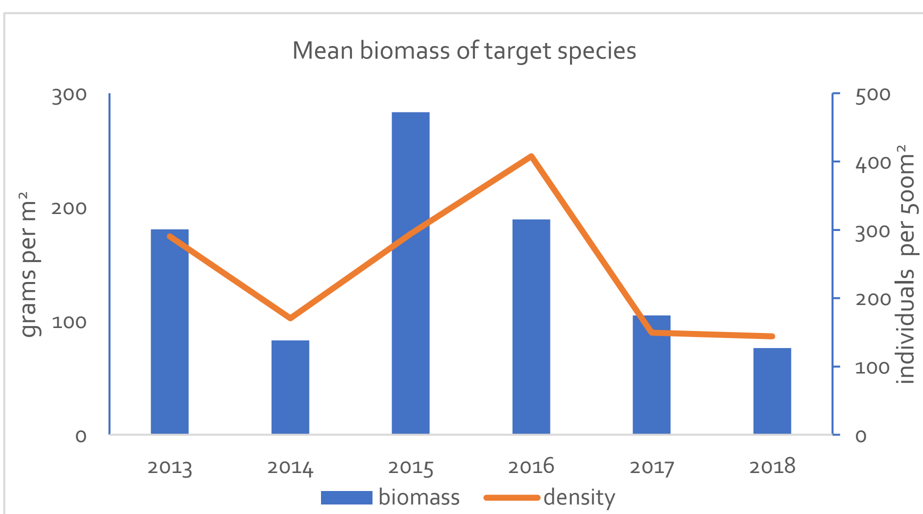


Figure 5. Temporal patterns of density (inds./500 m^2) and biomass (g/m^2) of fishery targeted species since 2013.

The density of target fish this year is comparable with the previous year, while the biomass is comparable with that of 2014 (Figure 5). Compared to last year, encounters with large-bodied schooling fishes are less frequent this year, contributing to lower target biomass. Despite of this, paired t-test verified that the differences between 2017 and 2018 density ($p=0.8$) and biomass ($p=0.2$) are not significant. The most prominent species this year are the Genus *Caranx*, Genus *Naso*, and family Scaridae.

In the case of indicator species, all sites, except Site 3, were characterized by high mean density of angelfish (Pomacanthidae) ranging from 8 ind/500m^2 (Site 3) to 18 ind/500m^2 (Site 1). On the other hand, the biomass of the butterflyfish (Chaetodontidae) was consistently higher than that of the angelfish (Pomacanthidae) across all the survey sites. Overall, the mean biomass of indicator species this year is 1.75 g/m^2, an improvement from last year's 1.45 g/m^2. Their increased presence can indicate that the coral community or their preferred prey is adequate to support their diet. It is still unclear how the abundance of corallivores can affect and limit the recovery of their prey coral species, and further stress the corals especially after a site experiences extrinsic disturbance (Cole *et al*. 1998; Glynn 1996; Bellwood *et al.* 2006).

Major species' density is represented by fairy basslets/anthias (889.5 ind/500m^2) and damselfish (825 ind/500m^2). Although they have the highest contribution in the density, the triggerfish (Balistidae) is the highest contributor of biomass in all sites, except in deep areas of Site 4 (Ko-ok) and JB4 (Jessie Beazley Reef).

Patterns of Fish Biomass

Large-bodied fishes, e.g., jacks, unicorn fish, snappers, considerably influenced the biomass estimates for the previous years' causing the data to fluctuate. Sharks and large-bodied schooling fishes of more than 100 individuals were excluded from the computation from 1999 to 2016. This is because it is believed to be unlikely that more than 100 individuals would fit in the corridor being monitored. Therefore, only a snapshot (Halford and Thompson 1994) of the fish observed within the corridor being monitored was considered. Following the standard, only the sharks and rays were removed in the 2017 and 2018 estimates.

The polynomial trend is stable although there are some years with abrupt decrease such as in 2003, 2008, and 2014. This may be due to compensation of the increase in biomass estimates in subsequent years (Figure 6). Meanwhile, 2016 – 2018 exhibited a downward trend. This decline in the biomass from the last three (3) years were driven by the significant decrease in the presence of Scaridae (parrotfish) recorded in 2015. Two-factor analysis of variance (ANOVA) (Appendix 6), used to examine the biomass estimates from 2013 to the present, suggests that variation between values are influenced by temporal (p=0.0002) rather than spatial factors (p=0.05). Being a no-take zone and considering the application of vigilant enforcement in the area, it is safe to assume that fishing pressure is not the main reason for this decline. One factor that may have attributed to this fluctuation is the presence or absence of large-bodied fishes within the transects. These chance encounters can be linked to the movement of fishes that are influenced by demands correlated with feeding and predator avoidance (Dahlgren and Egglestone 2000; Helfman *et al.* 2009), and mortality risk, and habitat shifting (Dahlgren and Egglestone 2000). In other conditions, a much larger horizontal migration may occur driven by spawning, feeding, and ontogenetic shifts in habitat requirements (Bone and Moore 2008; Sale 2002). Furthermore, variations in observers and lack of opportunity to standardize methods might also play a role in these fluctuations.

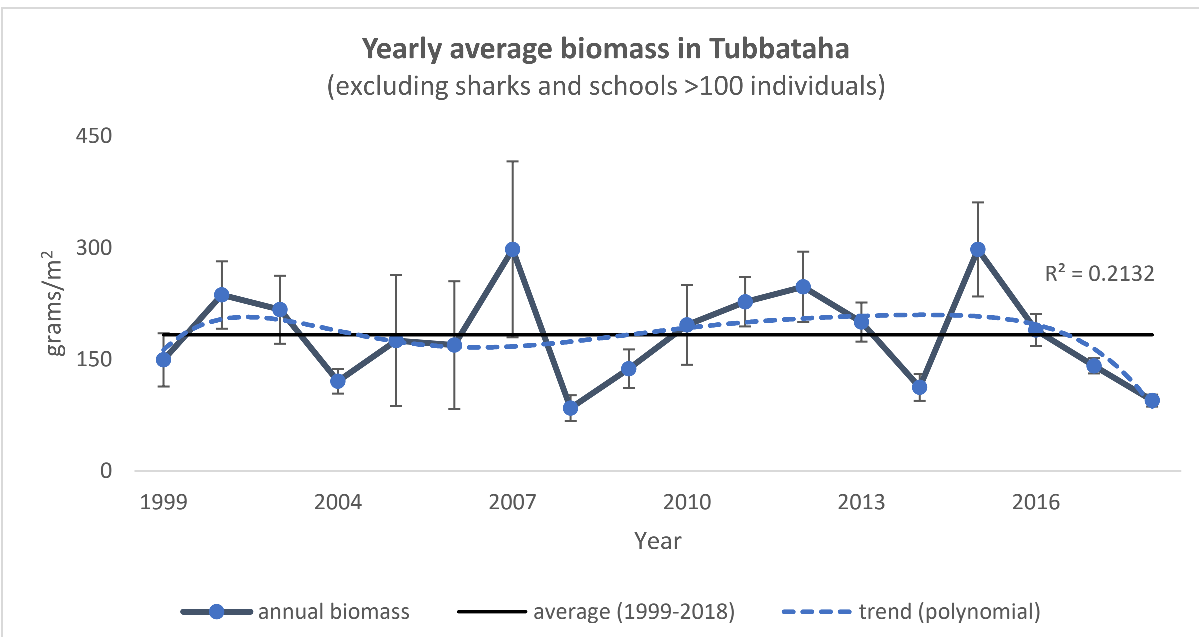


Figure 6. Temporal patterns of mean biomass (g/m2) (excluding sharks and big schools) in TRNP. Error bar represents the standard error of the mean.

The annual biomass estimates in shallow areas are much closer to average than in its deep counterpart (Figure 7). Moreover, it appears more stable. An oscillating pattern exhibited by polynomial trend in deep areas resembled the form in Figure 6. The polynomial trend in shallow transects exhibited a downward trend in the earlier years of surveys and plateauing until 2015 but showing downward trend again from 2017. Yet again, the seasonality and other ecological factors affecting the movements of fishes as mentioned above were attributed to the fluctuations and decline in the biomass yields of Tubbataha Reefs. Families that contributed to the decrease in the biomass from 2015 – 2018 in the deep stations were the Caesionidae (fusiliers), Lutjanidae (snappers), and Scaridae (parrotfish), while the decrease in Nemipteridae (breams) and Carangidae (jacks and trevallies) contributed in the shallow part. Less sightings of Acanthuridae (surgeonfish) for both depths also contributed to these declines.

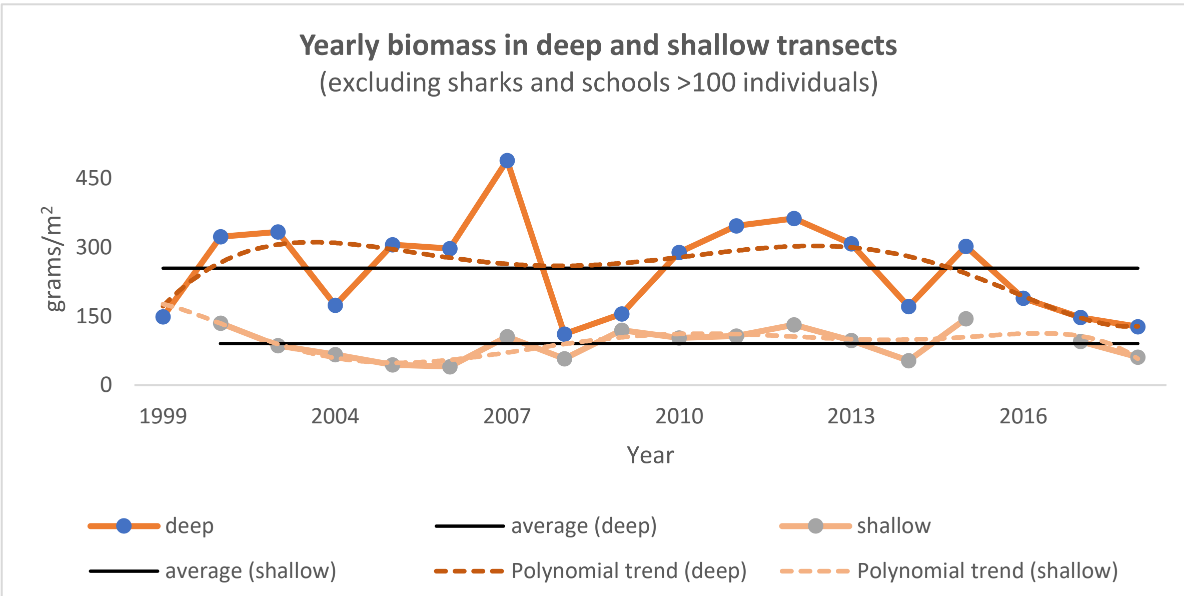


Figure 7. Temporal patterns of mean biomass (g/m²) of deep and shallow areas (excluding sharks and schools with >100 individuals). No data for shallow areas in 2016.

Pelagic and Demersal

Pelagics/outliers are species with large sizes, occasionally in schools, highly mobile, erratic in nature (Kaunda-Arara and Rose 2004), and more often traverse the deeper part of the reef. Encountering these species crossing the transect line are rare and more a function of chance. Demersal species, on the other hand, are smaller, highly-territorial, and live and feed on or at the bottom of coral reefs. Being reef-associated, demersal species is more reliable in determining the 'true' biomass yield of a site, as there is a higher chance of encountering the same individuals/species in the same area.

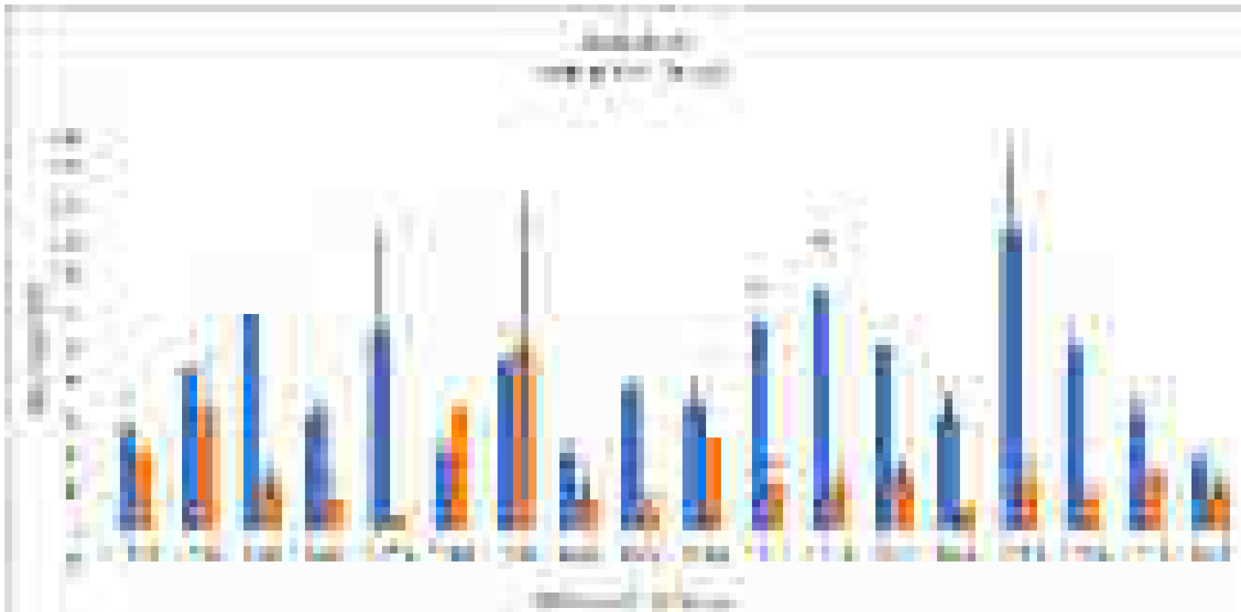


Figure 8. Temporal patterns of mean biomass (grams per m2) distribution of pelagic and demersal species per depths in regular monitoring sites of Tubbataha Reefs.

Demersal species are still more dominant than the pelagics. There seems to have a cyclical pattern in the trend observed in the biomass of the demersal fishes. An increasing trend were observed in 1999-2003, 2008-2012, and in 2014 -2016, while a decreasing trend were noted on 2003 -2006, 2012 – 2014, and from 2016 to 2018. The highest estimate of demersal fishes was in 2015, largely attributed to very high biomass of Scaridae (parrotfish) observed in Station2A (Malayan Wreck) and in Station4A (T-Wreck), which were not observed in succeeding years. The lowest biomass was recorded in 2008 and in 2018. No distinct trends could be established for the pelagic fishes. The highest biomass estimate for pelagic fishes was in 2007, mainly attributed to Carangidae (jacks and trevallies). This year's estimate for both groups is comparable with 2008 and 2014. Although the density of the reef fishes is almost the same as in 2017, the fishes encountered were of smaller sizes, thus contributing to lower biomass.

It is worth noting that the biomass estimates for demersal fishes in Tubbataha still exceed the country's minimum standard for a reef fish community to be considered very healthy (Nañola *et al.* 2004). The pattern of dominance between pelagic and demersal has not changed through the years. Furthermore, being deep zone inhabitants, and rarely visiting shallow areas, it is observed that pelagics have higher biomass contributions and presence in the deep transects across all sites. This is in contrast with the demersal fishes that has higher biomass yield in shallow areas.

Trophic Groups

The concept of the 'feeding guild' (Bone and Moore 2008) or the trophic group was created based on the fishes sharing the same diet specializations. The structure of these trophic categories could imply the availability and abundance of food source in a site. Below are the categories used in this report (Helfman *et al.* 2009):

Benthic Invertivore:	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

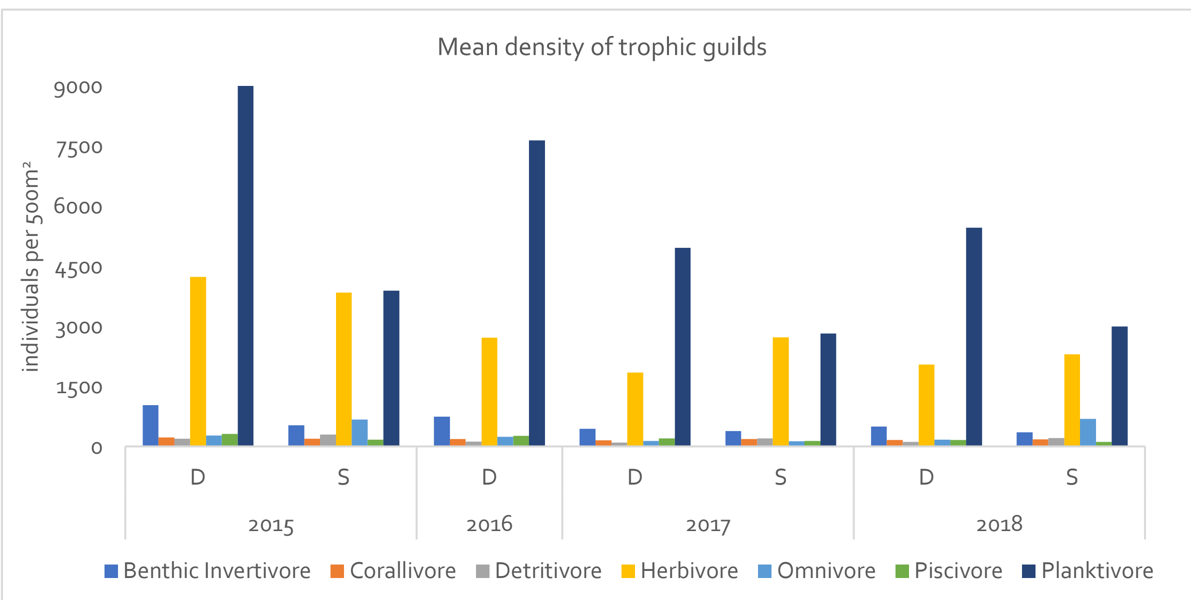


Figure 9. Density (g/m^2) of trophic groups (based on the species' diet) at shallow and deep areas from 2015 to 2018. No data for shallow areas of 2016 due to lack of manpower.

Herbivores, omnivores, benthic invertivores, detritivores, and planktivores, all exhibited downward abundance in deep and shallow areas until 2017, with reference to 2015 estimates (Figure 9). In 2018, an increase was observed in these trophic groups. Only the piscivorous fishes showed a slight decrease in density, possibly due to lesser encounters with larger sized, schooling fishes.

Planktivores, followed by herbivores and benthic invertivores, are the top three most abundant groups in deep areas across all years. There is an observed interchange in hierarchy among piscivores, omnivores, and corallivores per year. Detritivore remained the least abundant. In shallow stations, planktivores and herbivores are still the most abundant groups. Shifts in hierarchy in other trophic groups is observed year after year.

In the Eltonian pyramid, also called 'pyramid of numbers', conceptualized by Charles Elton (Hickman *et al.* 1993; Lindman 1942), animals at the base of the food chain are relatively abundant, and the number decreases higher up the food chain. This is reflected in the abundance of trophic guilds in the Tubbataha Reefs where planktivores and herbivores have the highest number, respectively, and piscivores (top predator) have the lowest. A typical food chain starts with the phytoplankton (primary producers) which will be eaten by herbivorous zooplankton (primary consumers). These two will be consumed by planktivorous fishes, which in turn will be fed upon by omnivores or piscivores (secondary/tertiary consumers). Omnivores can also consume the primary producers, making them partly herbivores, therefore, they can also be primary consumers. This abundance of fishes in each trophic level also mirror the typical characteristics of an unfished or lightly fished area with a healthy coral cover (Helfman *et al.* 2009).

Furthermore, in the 'fishing down the web' concept popularized by Pauly *et al.* (1998), fishing decreases the number/biomass of top trophic group, in this case the piscivores, thus herbivorous species will be fished out in turn until only smaller fishes remain. Hence, marine protected areas are established partly to improve and restore the population of large predators given the time of effective protection (Russ and Alcala, 1996; Helfman *et al.* 2009). The presence of piscivores in the Tubbataha Reefs clearly reflects continued effective protection of the park. Although this year has the lowest recorded density of piscivores since 2015, it does not necessarily imply the presence of fishing pressure. The presence or absence piscivores may be influenced by the vertical and horizontal migrations of fishes.

Threatened Species

Several species of interest were also observed during the survey. These are the species listed under the International Union for Conservation of Nature (IUCN) Red List of Threatened Species. Their presence serves as an indication of recovery from disturbances, such as from overfishing, and of stringent protection.

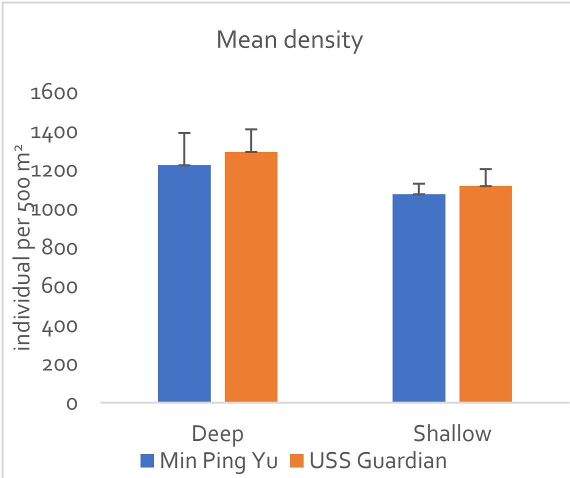
As mentioned in the previous sections, the monitoring stations are often visited by large-bodied schooling fishes and sharks including, but not limited to, Grey reef shark (*Carcharinus amblyrhincos*), Black tip reef shark (*Carcharinus melapterus*), and Whitetip reef shark (*Triaenodon obesus*). Rays were also observed around the survey areas. The presence of these rare and endangered species clearly reflects the effective protection of the park.

This year, the Endangered (EN) Humphead wrasse (*Cheilinus undulatus)* was again observed in all sites, including in the grounding sites. Two (2) individuals of the Near Threatened (NT) Camouflage grouper (*Epinephelus polyphekadion*), and two (2) individuals of Bumphead parrotfish *(Bulbometopon muricatum)* were encountered in Ko-ok and USS Guardian grounding site. Ten individuals of the Near Threatened Whitetip reef shark (*Trianodon obesus*) were also recorded during this survey.

Other threatened species observed outside the transects were the Saddleback Grouper (*Plectropomus laevis*), which was also recorded last year. Green sea *(Chelonia mydas*) and Hawksbill turtles(*Eretmochelys imbricata*) were also observed during the conduct of the survey.

Grounding Sites

A total of 163 species under 29 families and subfamilies were identified in the Min Ping Yu grounding site, while 137 species under 24 families were recorded in the USS Guardian site. This is an improvement from last year's 131 (Min Ping Yu) and 110 (USS Guardian) species. The Min Ping Yu site has a family richness of 25.5, while the USS Guardian site has 21 families recorded. The Min Ping Yu grounding site has a species richness of 72.5 sp./ 500m^2 and USS Guardian has 53 sp./ 500m^2. Both fall under the very high level of established categories for a healthy reef fish community (Hilomen *et al.* 2000).



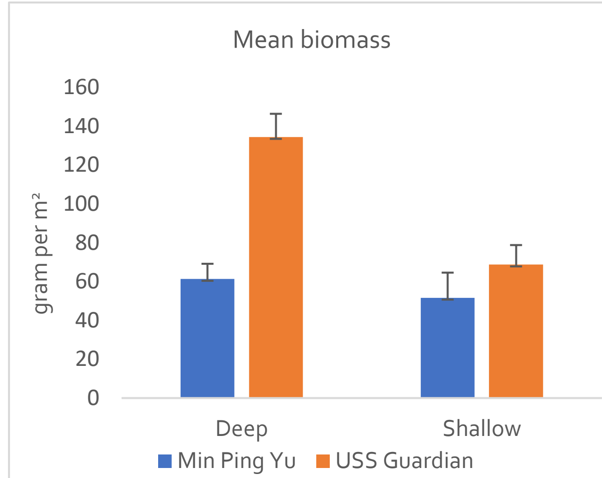


Figure 10. Relative distribution of mean density (individuals per 500 m²) and biomass (g/m²) in shallow and deep areas of Min Ping Yu and USS Guardian grounding sites. Error bar represents standard error of the mean.

Only the transects laid in the shallow area of USS Guardian is the actual grounding impact site. The mean density in this portion is slightly lower than the adjacent area (deep areas) (Figure 10), but paired t-test suggests that the difference is not significant ($p=0.9$). No significant variations were also found in the mean density of the deep area and shallow area ($p=0.9$ of Min Ping Yu (Figure 10). The total mean density for both Min Ping Yu (1202 ind./ 500 m²) and USS Guardian (1,261 ind./ 500 m²) grounding sites is higher than the previous year's output but the difference is not significant (t-test; $p=0.2$ and $p=0.1$, respectively).

Both grounding sites' mean density falls under the very high category of a healthy reef fish community (Hilomen *et al.* 2000). Similar to the dominance observed in regular monitoring sites in the North Atoll, Pomacentridae (damselfish) and Serranidae: Anthiinae (basslets/anthias), constituted three-fourths of the total mean density of the Min Ping Yu (Figure 10). Acanthuridae (surgeonfish), Labridae (wrasses), and Chaetodontidae (butterflyfish) were also among the top contributors. Demersal fishes made up the 97% of the total density in this area.

In the case of the USS Guardian, the distribution was primarily attributed to Anthias, followed by Damselfish; a pattern of dominance similar with regular sites in the South Atoll. These two families alone covered 75% of the total density in the area. Labridae (wrasses), Balistidae (triggerfish), and Acanthuridae (surgeonfish), respectively, are also among the top contributors in this area. Appendix 7 and Appendix 8 list the families with their respective mean density per depth in both grounding sites. Demersal fishes constitute 98% of the USS Guardian site density. Planktivores and herbivores, respectively, were the most abundant trophic guilds in both sites.

Despite the increase in density, the mean biomass output of both grounding sites has decreased compared to last year, although the difference is not significant: Min Ping Yu (t-test; p=0.2) and USS Guardian (t-test; p=0.1). This might be explained by the dependence of fish biomass on species variety and size estimates, and not on abundance alone. The mean biomass of the USS Guardian shallow area, as an impacted area, still exceeds the minimum requirement for reef fish community to be considered very healthy (Nañola *et al.* 2004). It is also the same for all depths in these two sites.

Min Ping Yu's total mean biomass of 56.6 g/m^2 is primarily attributed to Scaridae (parrotfish), Balistidae (triggerfish), and Pomacentridae (damselfish). Demersal fishes constitute 80% of the total mean biomass in this site. On the other hand, Balistidae (triggerfish), Scaridae (parrotfish) and Acanthuridae: Nasinae (unicornfish) primarily represent 101 g/m^2 mean biomass of USS Guardian grounding site. Demersal fishes also constitute 80% of this mean biomass. Appendix 7 and 8 list the families with their mean biomass per depth for both sites.

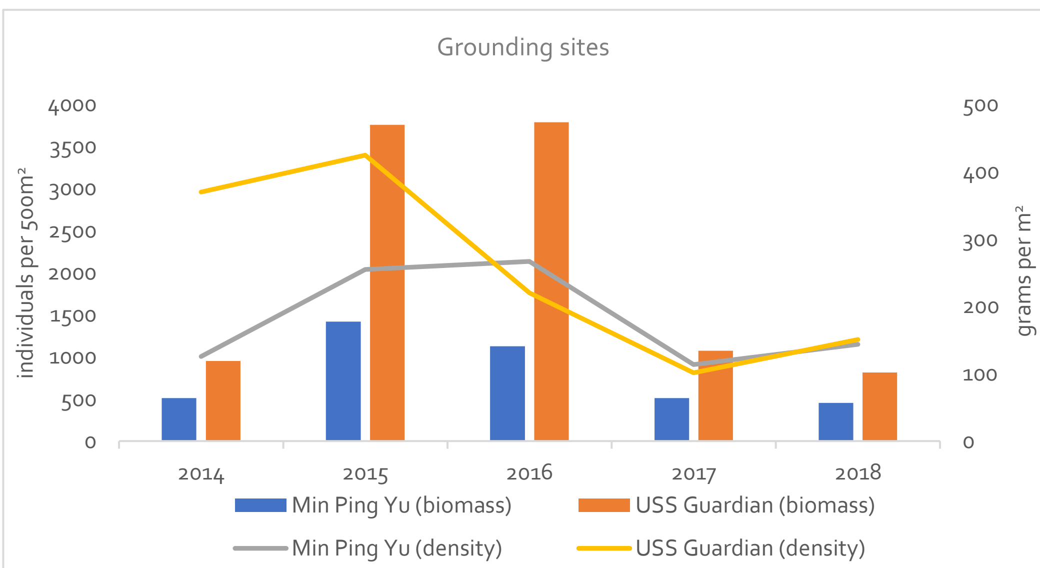


Figure 11. Temporal patterns of mean biomass (g/m2) and mean density (ind./500 m2) of Min Ping Yu and USS Guardian grounding sites.

As with the previous years of monitoring, the mean density and mean biomass of sites adjacent to USS Guardian is relatively higher compared to Min Ping Yu (Figure 11). The mean biomass of both sites shows an increasing trend until 2016, which is mainly attributed to encounters with large-bodied, schooling fishes. However, these groups were not prominent in 2018, thus resulting in lower biomass yields. Again, these chance encounters can be attributed to the horizontal and vertical migration pattern of fish influenced by feeding and spawning, diver presence, and ontogenetic shifts in habitat requirements (Bone and More 2008; Sale 2002). Furthermore, observer bias due to different readers through years may also be a key factor in the huge difference between 2015-2016 and 2017-2018 biomass estimates. Moreover, it is worth noting that in spite of the disturbances that affected these sites, the fish community has remained healthy, evident in high density and high biomass outputs (Hilomen *et al*. 2000; Nañola *et al.* 2004) since 2014.

2.4 Conclusions

The Tubbataha Reefs consistently displayed very high biomass estimates of fishes over the years, exceeding the minimum yield (>40 g/m^2) for a marine protected area. It has one of the highest biomass outputs for marine protected areas in the Philippines, given the fact that this year's biomass is lower compared to the previous years. The substantial decline in biomass estimates might be caused by temporal variations and movements of fishes driven by factors such as vertical and horizontal migration. Inconsistent observers and lack of opportunity to standardize are other factors that were considered to have effect in the overall results. Abundance of several trophic guilds, in addition to the presence of top predators and threatened species, such as sharks, Napoleon wrasse (*Cheilinus undulatus*), and Bumphead parrotfish (*Bolbometopon muricatum*), among others, show that Tubbataha Reefs is in good condition.

Areas adjacent to the USS Guardian and Min Ping Yu grounding sites showed an increased in density from last year, but biomass decreased. Despite having the lowest biomass yield for the past five years of monitoring, it is worth noting that this year's mean biomass at both adjacent sites is still considered among the highest in the Philippines. The impacted area in the USS Guardian site is also in good condition. This suggests that the presence of healthy surrounding reefs and protection play key roles in the replenishment and recovery of fishes in these disturb areas.

The high biomass yields, and the abundance and richness of the species found in Tubbataha clearly indicates a healthy fish population. This reflects the effectiveness of consistent and continued protection of the park, thereby indicating the efficacy and success of a well-protected marine protected area. The natural characteristics of the reefs – its degree of accessibility and the diverse reef types, also influenced this healthy fish community (Dantis et al 1999).

2.5 Recommendations

1. It is recommended that at least one dive be dedicated to the standardization of size and count estimates among the observers prior to the actual surveys to ensure uniformity among all observers.

2. The same observers need to be employed every year as much as possible.

3. Further, it is also recommended that the practice of having dedicated personnel to lay and retrieve the transect lines be continued to increase efficiency.

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3 REEF BENTHOS

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3.1 Overview

Coral reefs are vital ecosystems, providing benefits and services such as source of income, food and coastal protection for millions of people, among others. With the decline in fisheries production each year, the call to conserve marine habitats such corals reefs must not be unheeded. Unfortunately, coral reefs are also among the most vulnerable ecosystems in the world. Disturbances such as bleaching, fishing, pollution, waste disposal, coastal development, sedimentation, tourism, anchor damage, predator outbreaks, invasive species and epidemic diseases have all acted synergistically to degrade coral reef health and resilience. Today, an estimated 20% of coral reefs worldwide have been destroyed, while 24% are in imminent danger. A further 26% are under longer term danger of collapse (Grimsditch and Salm 2005; Wilkinson 2004).

Monitoring of marine protected areas is a very important management tool in ensuring the health of coral reefs and their associated communities. This chapter reports the status of the reef benthos in TRNP, describing scleractenian coral composition with additional notes on other invertebrates.

3.2 Methods

Data collection

In recent years, reef benthos monitoring in TRNP followed the benthos point intercept method, characterizing the substrate according to the 31 lifeforms described by English *et al.* (1997). In 2018, we employed the photo-transect method (following DENR Technical Bulletin 2017-05: Guidelines on the Coastal and Marine Ecosystem), 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 1600 photos from all the monitoring sites.

In the same transect, invertebrate species were also noted following the Reef Check method. Inverts were recorded every five meters within a five-meter imaginary corridor of 2.5 meters on both sides of the transect.

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. Percentage cover per TAUs and diversity indices – Simpson's (1-D) and Shannon Index (H) – were produced per transect and these were summarized and analyzed using Excel. Comparisons with the previous years were made using paired t-test 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
Excellent	>44%
Good	>33 – 44%
Fair	>22 – 33%
Poor	0 – 22%

3.3 Results and Discussions

Present conditions

The average hard coral cover in the deep areas (10 meters) this year is 29.9% (±2.2 SE), almost similar to the 29% last year (TMO 2017, *unpub.*). This value is higher compared to the regional mean hard coral cover in the Indo-Pacific which is 22.1% (Bruno & Selig 2007). The highest hard coral cover was recorded in Station 1B (42.75%), followed by Station 1A (38.50%). Most of the corals recorded in these stations comprise of the Genus *Echinopora* (encrusting), *Porites* (encrusting), *Lobophyllia* and *Diploastrea heliopora*. Coral formations in this site are mostly encrusting and massive. Coral formations such as these are very common in the deep monitoring areas of TRNP located in the reef walls/drop-offs.

In general, soft coral cover is relatively low in the deep areas of most sites, except for Station JBA, where almost half (46.13%) of the monitoring transects is covered in soft corals. Algae, in the case of TRNP, is mostly coralline algae, which are important contributors to reef calcium carbonate and can facilitate coral recruitment (Dean *et al.* 2015). Mortalities occurred in very low numbers, suggesting that there were no recent disturbances in the deep areas across all monitoring sites. The percentage of abiotic components (mainly rocks) has significantly increased in both stations of Site 2 (t-test; p=.02). This increase may be attributed to strong wave action brought about by the southwest monsoon. Rocky substrate with patches of corals in between and the presence of sand was observed in this area. The cause of these changes appear to be gradual (e.g., storm surges and wave action) rather than abrupt (e.g., blast fishing), which suggests that the increase in abiotic components was brought about by natural causes.

The percentage cover of abiotic components is also high in Station 3B, although the difference from last year is not significant (t-test; p=.48). The increase in rubble in Station 3B was noted last year and was attributed to the possible effects of strong waves exacerbated by the northeast monsoon. Site 3 is primarily composed of branching *Isopora bruggemanni*, which is susceptible to breakage and bleaching (Marshall and Baird 2000; Floros *et al*. 2004). Other invertebrates in the deep sites are mostly composed of sponges that are encrusting in form.

Table 1. Characterization of reef benthos of the deep areas in 2018 using the photo-transect method.

DEEP	Site 1	Site 2	Site 3	Site 4	JB	AVE
Hard Corals	40.63	25.94	24.75	30.21	27.75	29.9
Soft Corals	16.19	16.25	6.94	14.07	27.25	16.1
Algal assemblage	22.50	28.75	30.56	23.81	18.31	24.8
Mortalities	0.13	0.00	0.88	0.38	0.44	0.4
Abiotic components	11.50	21.57	20.56	2.49	4.06	12.0
Other invertebrates	9.06	7.50	16.31	29.04	22.19	16.8

The average hard coral cover at five meters is 36.75% (±3.8 SE), which is classified under 'good' condition according to Licuanan *et al.* (2017). This value is comparable to the results of DLSU's reef monitoring (See Annex 1) this year where the average hard coral cover was at 30.0% ± 2.0%. Recent assessments conducted by Licuanan *et al.* (2017) reveals that the average hard coral cover in their monitoring sites in the Philippines is 22%, which falls under the 'poor' category. This finding is almost identical to the average hard coral cover of 22.1% in the Indo-Pacific region (Bruno & Selig 2007). The occurrence of soft corals is minimal in the shallow areas except in Station JBB, where it covered 30% of the transect.

Algal assemblage in the shallow areas are relatively high in Site 3 and is consistent with the deep areas of the same site. We observed that some portions of the previously healthy beds of *I.*

bruggemanni are eroding. This also coincides with the relatively high percentage of mortalities, mostly dead corals with algae, in Site 3. This occurrence might still be influenced by the effect of strong current and wave actions. Site 3 is facing the western side of the atoll and is greatly affected by the northeast monsoon. We discount the possibility of blasting, in this case, because only the upper layers of the *I. bruggemanni* beds have eroded, contrary to what we can expect from blasting.

Abiotic components, mainly rocks, is high in Sites 1 and 2; however, the difference from last year is not significant (t-test; p=0.31 and p=0.06, respectively).

Table 2. Characterization of reef benthos of the shallow areas in 2018 using the photo-transect method.

SHALLOW	Site 1	Site 2	Site 3	Site 4	JB	AVE
Hard Corals	38.56	35.71	25.88	39.27	44.31	36.7
Soft Corals	8.69	8.68	1.31	4.00	16.38	7.8
Algal assemblage	16.88	9.16	52.31	26.27	22.38	25.4
Mortalities	0.00	0.00	3.88	0.81	1.75	1.3
Abiotic components	30.82	42.55	9.44	15.88	2.38	20.2
Other invertebrates	5.06	3.91	7.19	13.75	12.81	8.5

Temporal patterns

The graphs below present the long-term monitoring data of the reef benthos in the deep (10 meters) and shallow (5 meters) areas in TRNP. The broken vertical line (Figure 12 and Figure 13) demarcates the recent change in methods; therefore, comparison to earlier data is inconclusive.

This year's hard coral cover in the deep areas is the lowest recorded since 1997. However, the change in methods used precludes the assumption that coral cover has declined compared to the previous years. Nevertheless, the hard coral cover this year is still better compared to most reefs in the country and in the Indo-Pacific region (Licuanan *et al.* 2017; Bruno & Selig 2007).

Algal assemblage in Tubbataha is mostly crustose coralline algae, which plays an important role in reef building and coral recruitment. Encrusting sponges constitute most of the other invertebrates in the deep areas in TRNP. 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).

Hard coral cover in the shallow areas of TRNP (36.75% ± 3.8 SE) is also low. This may be attributed to the shift in methods this year. Despite this, TRNP is still better than most sites in the Philippines and the Indo-Pacific region.

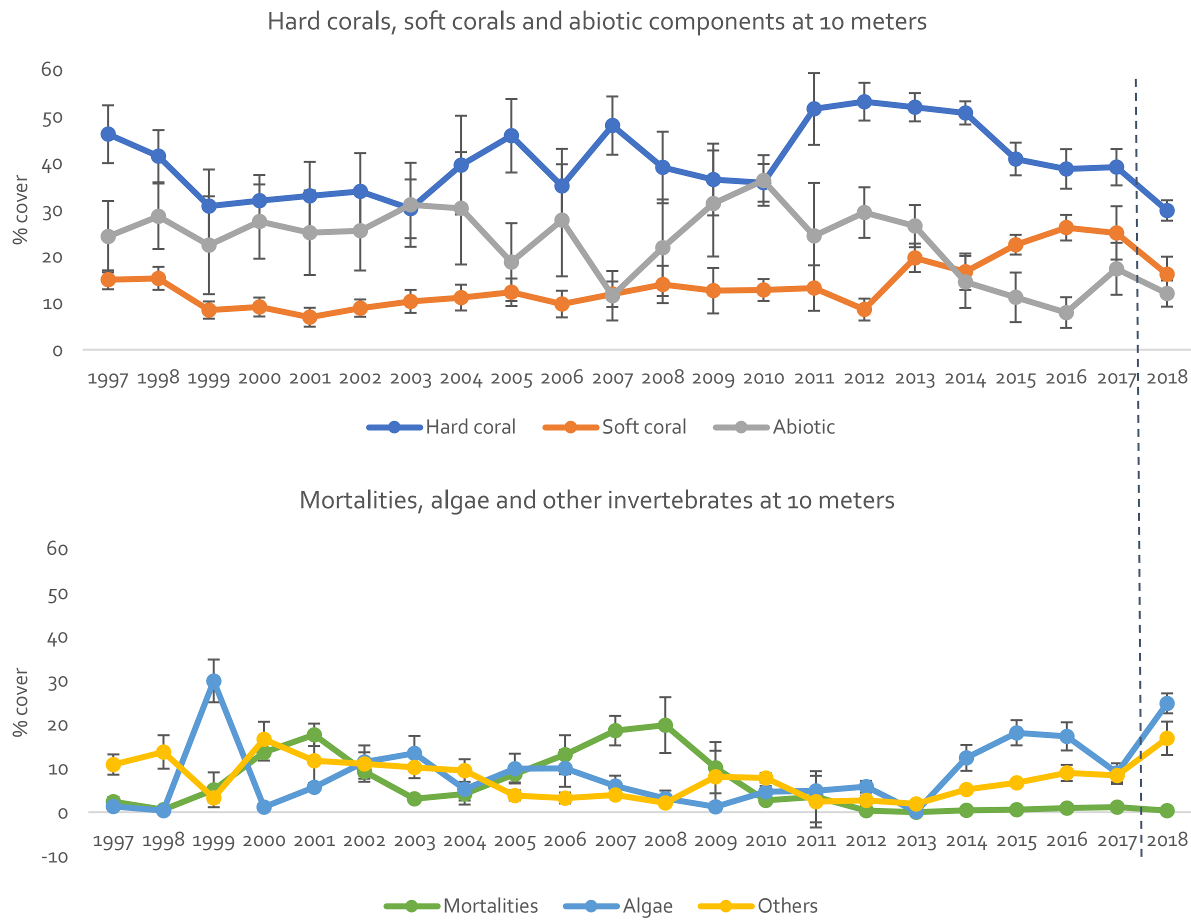

Figure 12. Characterization of reef benthos at the deep monitoring areas of TRNP. Error bars represent the standard error of the mean.

Although we monitored the same stations with the same number of transects, the change in method from benthos-point intercept to photo-transect resulted to major changes in the results. Therefore, comparison with the other years is not encouraged. On the other hand, photo-transect method allowed for a more randomized sampling of the area since the identification of points to be scored is run by a software. Biases identified in the benthos point-intercept method, such as small area being covered due to the proximity of the sampling points to the transect, was addressed by the photo-transect method. This also allows for the comparison of our data with the rest of the sites in the country and in the region. Although there is a 6.5% difference in the hard coral cover between this report and that of DLSU, the difference is still small compared to previous years (28% in 2017 and 29.8% in 2016) when the benthos-point intercept method was used.

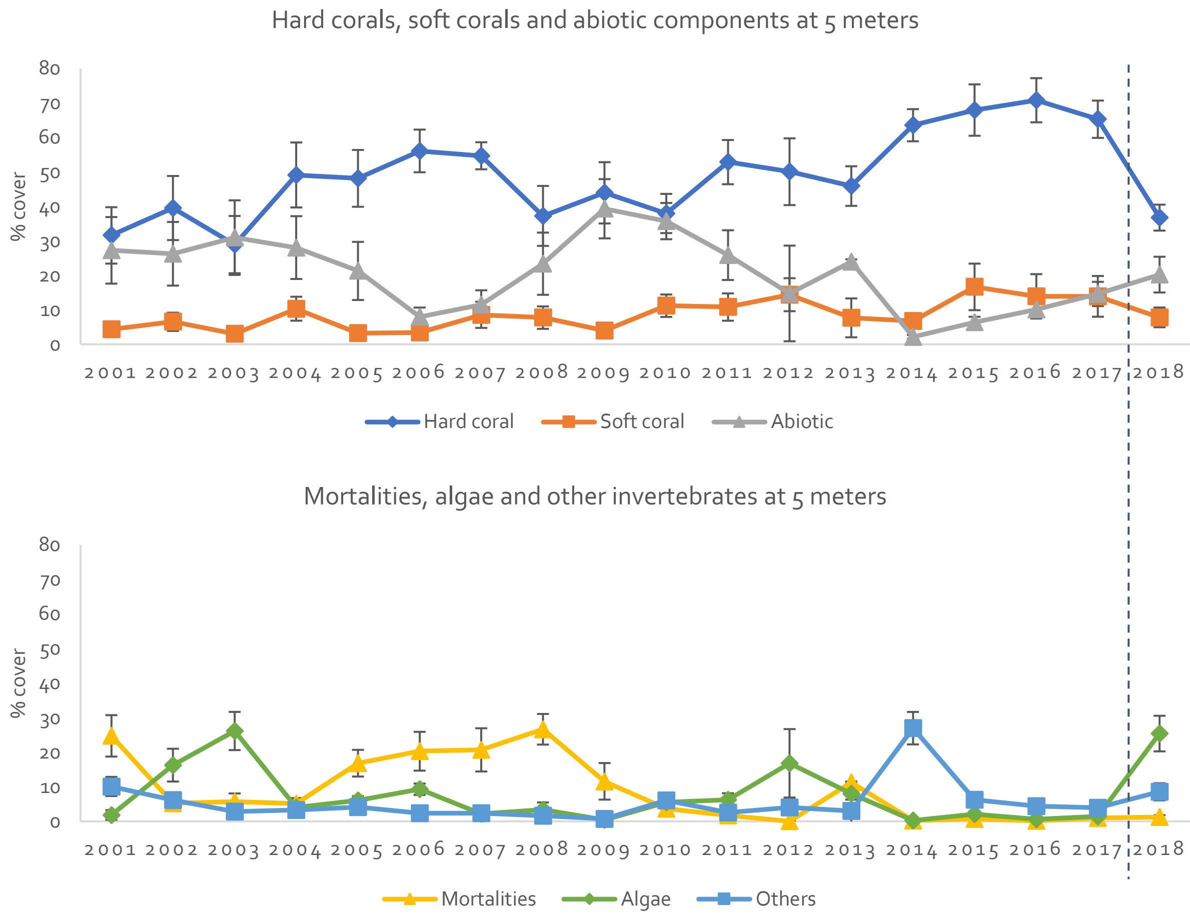

Figure 13. Characterization of reef benthos at the shallow monitoring areas of TRNP. Error bars represent the standard error of the mean.

Scleractinian Coral composition

A total of 39 coral Genera belonging to 16 Families were recorded in all the sites in TRNP during this survey; 32 coral genera were observed in the shallow and 36 in the deep sites. Shannon and Simpson's Diversity Indices for hard corals per station were generated through the CPCe software. The deep areas were dominated by Genus *Echinopora*, *Porites*, *Diploastrea*, *Goniopora* and *Montipora*. In the shallow areas, Genus *Porites*, *Isopora*, *Montipora*, *Acropora* and *Echinopora* were the most common.

The hard coral cover in Site 1 is mostly composed of Genus *Echinopora* (encrusting) and *Porites* (encrusting and massive), for both stations at both depths. Other genera mostly recorded in this site include *Leptoria*, branching *Acropora* and *Lobophyllia* (massive). The number of Genus recorded in Station 1A is relatively high compared to other sites in TRNP (See Table 3). Both depths of Station 1A also have relatively high results for the two diversity indices indicating that the distribution of abundances amongst the Genus recorded in the station is fairly equal. The deep area of Station 1B has the highest hard coral cover among the deep areas and it is one of the stations with the highest number of coral genera recorded. The most dominant Genus is *Echinopora* (encrusting) which covers 16% of the area. The coral cover in the shallow area of Station 1B can be classified as 'excellent' (Licuanan *et al.* 2017) due to the dominance of Genus *Echinopora* (encrusting) which covers 24% of the surveyed area. However, is has a low diversity index (H=1.868).

Massive *Porites* corals compose most of the hard corals in Site 2. Other Genus recorded in this site includes branching *Acropora* and *Pocillopora*. The coral cover in the shallow areas of Site 2 can be classified as 'good'. The diversity indices for both depths at Station 2A suggest that the abundance of coral genera is relatively equal. The deep areas of Station 2B has the lowest hard coral cover among all stations in the park. However, there is a relatively equal distribution of coral genera as denoted by the diversity indices (H=2.529 and 1-D=0.871). More dominant corals in this area are *Diploastrea heliopora* (6.5%) and Genus *Porites* (5.26%).

Site 3 is mostly covered in beds of branching *Isopora brueggemanni* corals. The deep areas of the two stations in Site 3 have almost similar percentage of hard coral cover. The diversity indices for both depths also suggest that coral genera in the area have relatively the same percent cover. The hard coral cover in the shallow areas of both stations in Site 3 are classified as 'fair'. The shallow areas of Site 3 have the lowest diversity indices amongst all stations, which indicates that there are only a few coral genera recorded in the area, with the *I. bruguemanni* highly dominant.

The deep areas of Site 4 are composed mostly of *Echinopora* (foliose) and *D. heliopora* (massive) while the shallow areas are mainly composed of massive *Porites* and *Platygyra* corals. The deep areas of Site 4 have a relatively high number of coral genera and diversity indices. The coral cover in the shallow areas of Site 4 can be classified as 'good'. Furthermore, both deep and shallow areas of Station 4B have the highest number of Genus recorded among all the monitoring stations.

The hard coral cover in Jessie Beazley station A is mostly composed of *Montipora* (foliose), other encrusting corals, and branching *Acropora* and *Pocillopora.* A total of 11 Genus were recorded in the deep area of Station JBA, which is relatively low compared to other stations. On the other hand, the shallow area of this station has an 'excellent' coral condition. However, its diversity index is relatively low (H=1.763) due to the dominance of *Montipora* (foliose), which covered 33% of the surveyed area. Jessie Beazley Station B is mostly composed of *Goniopora* (massive), *Millepora* and *Echinopora* (encrusting).

Table 3. Percent hard coral cover, number of coral genera and hard coral diversity indices per station.

HARD CORALS		Deep				Shallow		
Station	Hard coral cover (%)	No. of Genus	Shannon Index (H)	Simpson's Index (1-D)	Hard coral cover (%)	No. of Genus	Shannon Index (H)	Simpson's Index (1-D)
1A	38.5	24	2.830	0.922	31.875	20	2.637	0.892
1B	42.75	23	2.498	0.826	45.25	18	1.868	0.682
2A	29.625	24	2.823	0.909	36	17	2.406	0.872
2B	22.25	18	2.529	0.871	35.42	19	2.424	0.878
3A	25.375	19	2.872	0.917	24.875	7	0.688	0.281
3B	24.125	19	2.659	0.883	26.875	10	1.318	0.612
4A	26.5	23	2.888	0.930	37.674	26	2.948	0.932
4B	33.917	25	2.961	0.928	40.875	25	2.967	0.930
JBA	23	11	2.013	0.766	64.375	11	1.763	0.698
JBB	32.5	20	1.973	0.706	24.25	19	2.683	0.893

The sites monitored in TRNP presents relatively different coral reef formations and diversity. Sites 1, 2, 4 and Jessie Beazley Station B are generally dominated by massive and encrusting corals; Site 3 is composed mostly of branching corals; while foliose coral formations dominate Jessie Beazley A. These differences in coral formations also denote varying levels of resilience to environmental phenomenon such as climate change. Considering morphology, fast-growing branching species (e.g. *Acropora*, *Seriatopora*, *Stylophora*, *Millepora* and *Pocillopora*) were often observed to suffer higher bleaching mortality than slow-growing massive species (e.g. *Favites, Favia*, *Goniastrea*, *Astreopora* and *Turbinaria*) (Marshall and Baird 2000; Floros *et al.* 2004; McClanahan *et al.* 2004). Thus, it is possible that among all the sites, Site 3 is most vulnerable to bleaching because it is covered in monospecific beds of branching *I. bruguemanni.* Other sites have relatively higher coral diversity indices and growth forms and therefore different degrees of susceptibility and resilience to bleaching.

When it comes to more localized conditions, massive and encrusting corals, which are slow growing, can better withstand wave action, contrary to the *Acropora*-branching type which are fast growing but more prone to breakage. The latter may be the case in Site 3 where we have recorded breakage that were most likely caused by strong wave actions brought by the monsoons. Furthermore, studies have shown that in bleaching events, branching *Acropora* species seems to be the first to be affected. As branching coral populations are reduced by bleaching a long-term global shift from branching to massive corals and consequent loss of coral diversity is widely predicted (Loya *et al.* 2001).

Notes on Invertebrates

Table 4 presents the frequency counts of invertebrate species in each site. There are very few species encountered in both depths, especially in the deep areas. Giant clam, mostly *Tridacna crocea*, is the most abundant species in the shallow areas, while sea cucumbers had the highest occurrence in the deep areas.

Table 4. Frequency count of invertebrate species in TRNP following the Reef Check method.

Deep	1	2	3	4	JB
Banded coral shrimp	-	-	1	-	-
Collector urchin	-	-	-	-	-
Crown-of-thorns	-	-	-	-	-
Giant clam	-	-	3	-	-
Lobster/crayfish	-	-	-	-	-
Long spined urchin	-	-	-	-	-
Pencil urchin	-	-	-	-	-
Sea cucumber	1	-	-	3	-
Trumpet triton	-	-	-	-	-
Shallow					
Banded coral shrimp	-	-	-	-	-
Collector urchin	-	-	-	-	-
Crown-of-thorns	-	-	-	-	-
Giant clam	2	11	-	10	7
Lobster/crayfish	2	-	-	1	-
Long spined urchin	2	-	-	1	-
Pencil urchin	-	-	-	-	-
Sea cucumber	1	6	-	-	-
Trumpet triton	-	-	-	-	-

Other observations

We did not record any crown-of-thorns starfish *Acanthaster plancii* in the monitoring stations, but divers reported their presence in the west side of the South Islet. The monitoring team went to the site to assess the condition of the reefs, while the marine park rangers collected the crown-of-thorns starfish. A brief report on their occurrence is presented in Annex 1 (DLSU Reef Benthos Report).

We also did not observe coral bleaching in the park during the annual assessment, however we continue to monitor for its occurrence throughout the year. In 2017, UNESCO World Heritage Centre released its first global coral reef assessment across Marine World Heritage Sites (Heron *et al.* 2017). In this report, they projected the occurrence of coral bleaching among the marine WHS based on climate models and scenarios from reports of the IPCC. From historical records of bleaching levels based on degree heating weeks (DHW), Tubbataha Reefs Natural Park has experienced three bleaching stresses (DHW ≥4°C-weeks) within 28 years, from 1995 to 2013. They have also recorded recent stresses between mid-2014 to mid-2017 when TRNP experienced two bleaching stresses (DHW ≥4°C-weeks) and one severe stress (DHW ≥8°C-weeks) in a span of three years. Projections suggest that TRNP will most likely experience severe stress (DHW ≥8°C-weeks) twice per decade from year 2030 (Heron *et al.* 2017).

3.4 Conclusion

The establishment of transects in the deep and shallow areas is advantageous for monitoring corals in Tubbataha to better observe the difference in the characteristics of corals in the two depths and in their response to changes in the environment. The results of our long-term monitoring exhibited differences in coral community in the reef flat and walls/drop-offs, which is important in understanding the reef ecology of TRNP. In general, shallow areas have higher hard coral cover than their deep counterparts. However, the deep areas tend to have higher biodiversity indices, which means more variability in coral genera and growth formations. Studies show that locations supporting high diversity of corals may also support populations with individuals that can withstand and adapt to different environmental stressors. On the other hand, the presence of crustose coralline algae, may be a positive response and adaptation by the reef system to environmental stressors. Encrusting crustose coralline algae aid settlement and growth of coral recruits thereby contributing to strong recruitment.

Both deep and shallow areas in TRNP have hard coral cover percentages that exceeds most of the reefs in the Philippines and in the Indo-Pacific region. While it is hard to compare this year's data to those of the previous years' because of the change in method, contributing to a major drop in the record of hard coral cover, we can now better characterize the corals of Tubbataha because monitoring is done to the level of genus, as opposed to lifeforms as previously used.

3.5 Recommendations

Based on this year's reef benthos assessment results, we recommend the following:

1. Monitoring method. Shifting to photo-transect method limited the comparison of this year's data to our long-term monitoring data. The photo-transect method is recommended by the DENR through Technical Bulletin 2017-05 and is now most widely used in the country as well as worldwide. With this method, we are now able to produce more robust results, such as characterizing reef composition with coral genera rather than lifeforms. Long-term coral composition data like this can be used to better describe resilience or vulnerability of the reefs to climate change impacts. Thus, we recommend the continued employment of the photo-transect method.
2. Study on sponges. This year, we observed the high percentage of encrusting sponges in the deep areas. A thorough characterization of these encrusting sponges and its interaction with corals might be essential in understanding reef ecology in the park.
3. Capacity building. It is important that the TMO researchers/rangers consistently practice the use of the CPCe software as it takes skills and familiarity to be able to process the photos efficiently. TMO researchers/rangers must also undergo a coral taxonomy training to be able to score the photos better, and improve identification of coral genera as coral formations previously being identified are no longer used.
4. Equipment. We also recommend the procurement of a back-up set of camera with underwater casing to be used for the photo-transect to respond to potential technical problems and malfunctions in the field.

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4 SEABIRD POPULATION

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4.1 Overview

The objectives of the monitoring and inventory are:

- Review of avifauna field data produced by the Tubbataha Management Office (TMO) Marine Park Rangers (MPRs) since May 1017;
- Assessment of survey methods used by the TMO research team guided by the Consultant;
- On-the-job skills enhancement of the TMO MPRs, staff and partners in seabird monitoring and conduct of inventories;
- Preparation of a monitoring and inventory report on the seabirds and their breeding areas in the Tubbataha Reefs Natural Park (TRNP).

Period: Updates on the inventory methods used in the past years and assignment of tasks for the field work were carried out at the TMO in Puerto Princesa on 11 May. The MPR monitoring and inventory reports since May 2017 were also evaluated. Actions taken in response to the 2017 recommendations of the Consultant were discussed the same day. Field work was conducted from 12 May to 15 May: at Jessie Beazley Reef and South Islet on 12 May, Bird Islet on 13 to 15 May, and the Ranger Station on 15 May.

Weather: Throughout the inventory period, the weather was dominated by daily thunderstorms with heavy rainfall and strong wind gusts. Wind speed ranged from 0 meter/second to 3 meter/second with the very limited wind coming from a northeasterly direction. Daily cloud cover ranged from 2/8 to 5/8. Daytime temperatures peaked at about 35° Celsius.

4.2 Methods

The field work followed methods for distance count monitoring and for inventories of breeding seabirds established and used since 2004 (Jensen 2004). For methodologies, see Appendix 12 and Appendix 13. The team camped overnight at Bird Islet from 13 to 15 May in order to carry out optimal field work. South Islet was only visited in the morning of 12 May, from 8:30am to 11:30am, due to limitations imposed by the tides. However, three inventory teams surveyed sequentially in South Islet.

The counts of the breeding bird populations represent a combination of different count methods. These includes direct day-time inventories of adults, immatures, juveniles, pulli, eggs and nests. To determine the total seabird population numbers, an afternoon count of birds flying in to roost was conducted from 4:30pm to 6:30pm on 12 May at South Islet (Appendix 19) and on 13 May at Bird Islet (Appendix 20). A count of dead birds and autopsies on sample individuals were also carried out. The field team also removed debris from the islets.

Major equipment used were handheld binoculars (10 x 50), spotting scopes (20-60 x), GPS and cameras. Taxonomic treatment and sequencing follows Gill F & D Donsker (Eds) 2017. IOC World Bird List (v 7.2).

Calculation of breeding populations

The methods used to calculate the seabird populations followed the previous years' approach:

- day time direct counts of birds, nests and eggs;
- in-flight data of Red-footed Booby *Sula sula*, Brown Booby *Sula leucogaster*, and on South Islet Brown Noddy *Anous stolidus*, and Black Noddy Noddy *Anous minutus* ;
- early morning (5 am) count of Brown Boobies at the 'Plaza';
- count of Great Crested Tern *Thalasseus bergii* and Brown Noddy along the shoreline at high tide

The result of the fieldwork is compared with data sets from the second quarter of the previous years carried out by WWF Philippines from 1998 to 2004 and the annual inventory teams from 2004 to 2017 and also data sets gathered by MPRs. The data sets until 2013 were analyzed in detail by Jensen and Songco (2016) and published in the Journal of Asian Ornithology (FORKTAIL 32 (2016): 72–85). Other analyses are found in the 28-year seabird population development report released in 2009 and in the 2004 to 2006 and the 2010 to 2017 seabird field reports (see Jensen 2004 to 2006 and 2009 to 2016, and Jensen *et al.* 2017).

Calculation of land area and vegetative cover

Photos of permanent photo documentation sites in Bird Islet and South Islet were taken (Appendix 23). These sites were established in 2004 in order to measure changes in land area and in vegetation. GPS readings were taken measuring the land area at high tide of both Bird Islet and South Islet.

Vegetative cover was monitored by conducting a census of the condition of trees on the islets. Trees, mostly *Argusia argentia and Pisonia alba (grandis)*, were classified as either in optimal (good), moderately deteriorating (fair) or severely deteriorating (bad) condition and lastly, as dead. The inventory of 2018 was carried out using the same methodology as all other years, except in 2013, the trend over time is, therefore, comparable.

4.3 Results and conclusion

Monitoring of Changes in Land Area

Independent sets of measurements were taken using two separate GPS units. The measurements were taken at high tide along the shoreline as the vegetation line previously used as reference has disappeared. Due to this shift in methodology, data sets from 2016 onwards may not be comparable to the previous years.

Bird Islet: Overall, the land area has decreased by 18.4%; from 18,760 m^2 in 1981(Kennedy 1982) to about 15,373 m^2 in 2018 (Table 5).

The circumference of the islet measured along the high tide line is 568 meters compared to 586 meters in 2017, or about the same (variation = 3%). The land area was measured to be 15,373 m^2 (lowest measurement dataset) compared to 15,307 m^2 or about the same as in 2017 (variation = 66 m^2 or 2.2%).

The 'Plaza' defined as the central area of the islet dominated by barren soil with no or little vegetation was measured to only to be 2,572 m^2, or historically the smallest area ever recorded. Compared to 2016 it is a reduction by 1,941 m^2 or 43% caused by tussock grass expansion into 'Plaza', especially in the northern part. Erosion in May 2018 did not impact the size of 'Plaza'. Only a minor section of the northeastern coastline, first noted in 2012, has continued to erode although in a much smaller scale since 2016.

Hydrology studies have not been previously been conducted around the islets within TRNP. Thereby there was little understanding of currents influence on the erosion of Bird Islet. In 2018 TMO consulted the University of the Philippines-Marine Science Institute for advice on halting the erosion of the islet (Appendix 14). Scientists at the Institute gave two recommendations:

1. Minimizing sand loss by installing structures that can attenuate wave energy coming from the west/southwest (e.g. reef balls or submerged breakers) but must be done carefully such that longshore currents in the other parts of the island are not affected significantly;
2. Active beach sand nourishment which is to physically pump sand deposited away from the shore back closer to the shore where it can eventually be incorporated into the seasonal sand migration. This will require identifying where these deposition

areas are and using sand pumps to transfer the sand closer to shore. However, this may also affect the bird populations if the sand pump engines will disturb bird behavior.

Table 5. Approximate changes in the land area of Bird Islet from 1911 to 2018. Source: Worcester 1911, Kennedy 1982, Heegaard and Jensen 1992, Manamtam 1996, WWF Philippines 2004 and Tubbataha Management Office 2004 to 2018

Year	Land area (length x width)/circumference (m)	Land area (high tide) (m²)	Open area ("Plaza") (m²)	Major sandbars position and condition	Erosion area
1911	400 x 150	60,000	No data	>40,000 m² (?)	No data
1981	268 x 70	18,760	18,000	NW, SE	South coast
1991	>220 x 60	> 13,200	>8,000 (est.)	NW, SE	South coast
1995	265 x 82	21,730	8,000 (est.)	NW, SE	South coast
2004	219 x 73	17,000	>1,100 (est.)	NW: Stable SE : Decrease	South coast
2005	No data	15,987	>4,000 (est.)	NW, SE: Stable	South coast
2006	No data	14,694	7,900 (est.)	NW, SE: Stable	South coast
2007	No data	13,341	8,000 (est.)	NW, SE: Stable	South coast
2008	No data	12,211	< 8,000	NW: Decreasing SE : Stable	South coast
2009	No data	10,557	< 7,000	NW: Eroded SE : Decreasing	West coast
2010	No data	11,038	4,367	NW: Eroded SE : Stable	South coast
2011	No data	12,968	4,000 (est.)	NW: Stable SE : Stable	Northeast coast
2012	590	12,494	3,892	NW: Stable SE : Stable	Northeast coast
2013	548	10,955	4,840	NW: Decreasing SE : Stable	Northeast coast
2014	503	>10,220	4,124	NW: Decreasing SE : Stable	Northeast coast

2015 [1]	<561	<13,408	3,279	NW: Stable SE : Stable	Northeast coast
2016 [2]	590	15,649	4,513	NW: Disappeared SE : Decreasing	Northeast coast
2017 [3]	588	15,307	6,704	NW: Disappeared SE : Decreasing	Northeast coast
2018	568	15,373	2,572	NW: Two small sandbars off the coast SE : As above	Northeast coast

Note 1: In 2015, new GPS equipment were used. Detailed comparison with previous year's data is therefore not possible.

Note 2: Measurement approach changed from measurement along shore vegetation line to measurement along the high tide line. Data can therefore not be compared.

Note 3: Expansion in area of Plaza is due to inclusion of former forested areas

South Islet: South Islet was originally part of a large sandbar until a circumferential concrete seawall was constructed in the 1980s (Kennedy 1982) to accommodate a lighthouse. Based on photographic evidence, the land area remained the same at least until 1981 (Kennedy 1982). In 1991about 1/3 of the seawall had collapsed and was partly submerged (Heegaard and Jensen 1992). In May 2018 new cracks in the wall were noted in additional sections of the seawall segments.

The circumference of the islet was measured to be 230 meters compared to 240 meters in 2017 and 247 meters in 2016. The land areas was measured to 2,884 m² compared to 2,980 m² in 2017 and 2016. The variation, about 3.2%, represents an eroded area now effectively part of the sea caused by a crack in the seawall.

Monitoring of Changes in Habitats

Overall, the combined baseline data from Bird islet and from South Islet shows a baseline around 2009 to 2006 of around 355 trees, generally in a very good condition (229 trees on Bird Islet and 125 trees on South Islet). In 2018 a total of only 39 trees (2017: 50 trees) or about 11% of the original beach forest remained (Figure 14 and Appendix 15).

In response to recommendations presented in the 2017 report, 24 cloned beach forest seedlings of the species *Pisonia alba (grandis)* and *Argusia argentia* were planted in Bird Islet in 2017.

Bird Islet: The baseline was 229 trees recorded in 2006. In 2018 only bush-height vegetation were found. It represented 13 trees (2017: 39 trees) compared to 110 trees in 2016 (Figure 14). No seedlings were found and none of the new seedlings planted from June to October survived.

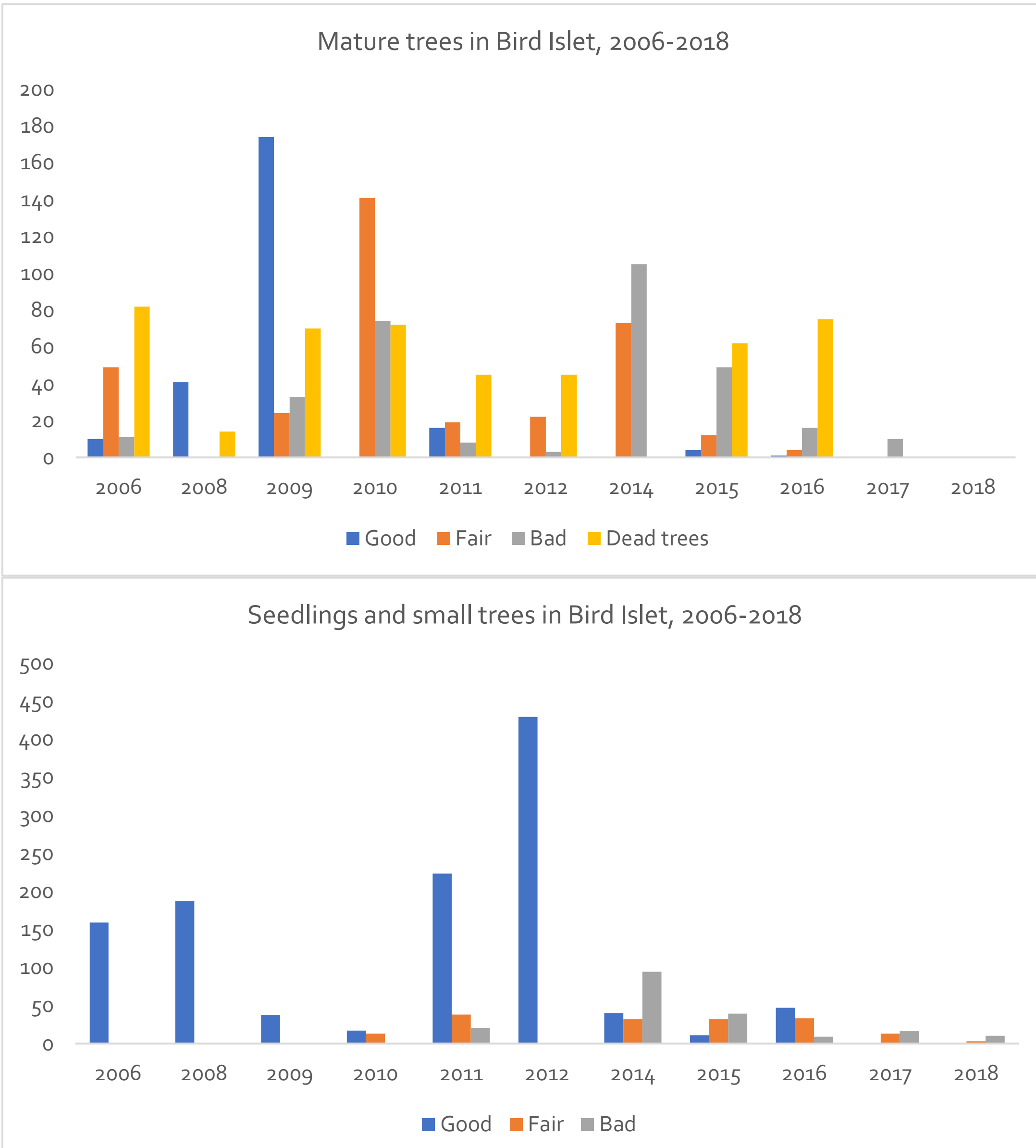

Figure 14. Status of vegetation in Bird Islet from 2006 to 2018.

Of the 13 trees found in May 2018, only 3 trees were in a fairly good condition. Without more successful assisted restoration the forest may be unable to recover on its own.

South Islet: Until 2009, the beach forest comprising of about 125 trees was in an optimal condition, with several trees as high as about 30 feet.

In 2018, a total of 20 trees excluding seedlings or 44% fewer than in 2017 were recorded (Figure 15, Appendix 15). No trees were found to be in good condition, and just six seedlings were found. The number of trees in a severe deteriorating condition represented 65% of all vegetation surveyed. Without assisted restoration the forest may be unable to recover.

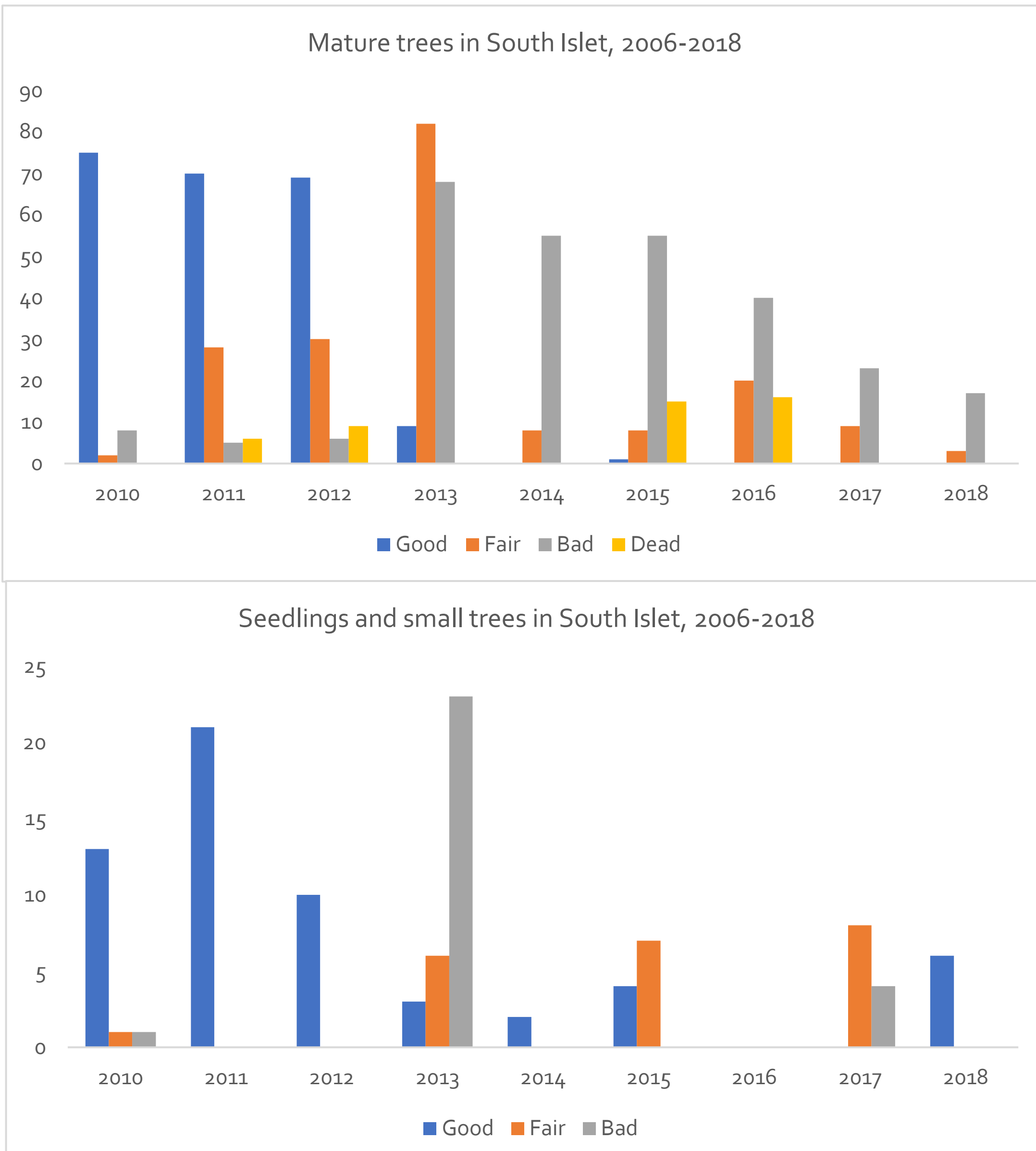

Figure 15. Status of vegetation in South Islet from 2010 to 2018.

Avifauna

Review of MPR Monitoring Data

Since the avifauna inventory in May 2018, MPRs made three full avifauna inventories on both Bird Islet and South Islet (Appendix 16). The inventory in November 2017 included in-flight counts. The data gathered revealed some important observations (see Table 6).

The MPRs also conducted 11 distance counts, or one count every month on Bird Islet and on South Islet. No distance counts were carried out at Jessie Beazley Reef.

Table 6. Selected results of MPR distance and direct counts from June 2017 to April 2018

Species	Bird Islet	South Islet
Masked Booby	Presence at least in November 2017 and in February 2018.	
Brown Booby	On 17 November 2017 the highest nest and egg count ever (1,074 nests and 1,388 eggs) and with almost 2,500 adults present. Relative high estimates of adults in March 2018 (1,345)	No breeding population
Brown Noddy	For the first ever an overwintering population of up to 950 birds present	Absent from November to February as is the normal pattern for this species
Black Noddy	An unusual presence throughout the winter months (December – February)	Normally absent from October to March
Great Crested Tern	Absence from October 2017 – February 2018	No breeding population
Sooty Tern	A 2nd breeding population from September to November 2017. And uniquely, an overwintering population of up to 860 adult individuals from December to March.	No breeding population

Avifauna Inventory Results

A total of 23 species of birds were identified during the inventory (Appendix 21). The total number of avifauna species recorded in TRNP is 115 species.

Twelve of the species can be classified as pelagic or coastal-living seabirds. Of these, seven species breed or attempt to breed in TRNP: Masked Booby *Sula dactylatra*, Red-footed Booby *Sula sula*, Brown Booby *Sula leucogaster*, Brown Noddy *Anous stolidus*, Black Noddy *Anous minutus*, *Great* Crested Tern *Thalasseus bergii*, and Sooty Tern *Onychoprion fuscata.* Other breeding species are the Pacific Reef Heron *Egretta sacra*, *Barred Rail Gallirallus torquatus* and Eurasian Tree Sparrow *Passer montanus*.

Among the seabird species, the migrant Christmas Frigatebird *Fregata andrewsii* is listed as Critically Endangered (IUCN 2017). Among the breeding species, the Brown Booby and Black Noddy are proposed for listing as Endangered species, and Brown Noddy, Great Crested Tern and Sooty Tern as Vulnerable (Gonzales *et al* 2018). Further, the Black Noddy has been included in Appendix II of the Convention of Migratory Species since October 2017 (Appendix 22). Appendix II species are those species that will benefit from international protection and management agreements.

Overall, the booby species of TRNP breed throughout the year and tern species around nine months annually (Heegaard and Jensen 1992, Manamtam 1996, Kennedy *et al.* 2000, Jensen 2009, Jensen and Songco 2016). The inventory result therefore represents only the breeding population present during the time of the inventory.

A total 41,794 adult individuals of six breeding and one former breeding seabird species were recorded; 37,663 individuals on Bird Islet and 4,134 individuals on South Islet (Table 7). Bird Islet hosted 90% of the breeding population and South Islet 10% of the population. The population on Bird Islet has increased by17% since 2016 when it hosted 73% of the total population. On South Islet, due to habitat loss, the population has decreased from 27% to 10% since 2016.

The total result of the May count in 2018 is about 12% higher than in 2017 and represents the highest documented count of breeding seabirds in the history of TRNP (Appendix 17). The combined population of all breeding seabirds in 2018 was 208% higher than the first inventory conducted in 1981 (Kennedy 1982). The high count result on May 2018 is mainly due to increase in the numbers of Great Crested Tern and of Sooty Tern.

In summary, the count results for May 2018 showed:

- <u>Red-footed Booby</u>: Compared to 2017, a population decrease of more than 30%. The population is now 40% lower than in 2004 when the species started to breed in large numbers in TRNP.

- Brown Booby: A stable population, about 11% lower than in the baseline year of 1981 (3,768 adults). The result in May 2018 falls within the margin of inaccuracy of the data produced and may not express a decline.

- Brown Noddy: Second highest breeding population and more than 60% higher than in 1981 when the population was counted for the first time. The species surprisingly overwintered in relatively large numbers (> 700 individuals) at Bird Islet but not at South Islet. Presence of around 1,500 adults with more than 500 nests, of which most contained eggs, in early February 2018. This is the first ever recorded extremely early start of the breeding season. The season extended at least until May 2018.

- Black Noddy: A continued decrease in the population and occurrence of nesting corresponds to the decline in the number and condition of the vegetation. On South Islet the decline in the number of adult birds is 54%. Nesting is lower by 57% compared to May 2017. On Bird Islet the pilot establishment of artificial breeding areas increased the presence of adult birds, from around 800 in 2017 to more than 2,500 in 2018. A corresponding increase in nests from around 150 nests in 2017 to about 680 in 2018 was also recorded. Nearly all nests were established on artificial breeding structures erected since 2017. Despite the very positive result the input is insufficient: 57% of the breeding population or about 6,100 adult birds are now absent from TNRP due to continued lack of nesting sites and, importantly, also nesting materials.

- Great Crested Tern: The increase in the breeding population of Great Crested Tern continued in 2018 but at lower pace compared to 2017. Overall, the population is at its highest number ever recorded.

- Sooty Tern: The breeding season of Sooty Tern started end of February/ beginning of March. Hence, the inventory was able document what can be perceived as the entire adult population represented by the highest count ever.

Table 7. Total count numbers of adult resident seabirds present on Bird Islet and South Islet 12 – 15 May 2018.

Species/ Number	Bird Islet	South Islet	Total
Masked Booby *Sula dactylatra*	1	0	1
Red-footed Booby *Sula sula*	826	617	1,443
Brown Booby *Sula leucogaster*	3,367	(304)	3,367
Brown Noddy *Anous stolidus*	1,984	1,486	3,470

Black Noddy *Anous minutus*	2,445	2,028	4,473
Great Crested Tern *Thalasseus bergii*	17,752	(7)	17,752
Sooty Tern *Onychoprion fuscata*	11,288	(4)	11,288
Total	**37,663**	**4,131**	**41,794**

Species Account of Breeding Birds

The combined results of the adult populations and their development over time at Bird Islet and South Islet are shown in Appendix 17. Data on the number of immature, juvenile, and pulli populations and on the number of eggs and nests recorded since 2004 on the two islets are presented in Appendix 18. Percentages of in-flight populations of Red-footed Booby, Brown Booby, Brown Noddy and Black Noddy are shown in Appendix 19 (South Islet) and Appendix 20 (Bird Islet). A complete list of avifauna records in May 2018 including all breeding species is found in Appendix 21.

Masked Booby (Conservation Status - Proposed Philippine Red List: Other Threat Status): The individual presumed to be an adult male, was again found in the main colony of Brown Booby at the 'Plaza" on May 2018. It is assumed to be the same bird that was recorded during the inventories in May 2016 and May 2017. Since 2016, the individual has occupied at least one patch within the territory of a Brown Booby, where it first incubated a Brown Booby egg alternately with a female Brown Booby. MPR records show the species presence in November 2017 and February 2018. For further details, see Conales and Pagliawan (2017).

Red-footed Booby: The total population in May 2018 was 1,443 adult individuals, down by 32% compared with the 2017 adult populations of 2,087 individuals (Figure 16 and Appendix 17). Compared to the baseline year for this species (2004: 2,435 adult individuals), the population is lower by 41%. The declining population is a reflection of the decline in the breeding habitat. Correspondingly, the number of nests, 223 nests, were as low as in 2006 but 25% higher compared to the results in May 2017(117 nests). The number of pulli and of juveniles recorded were the lowest since the 2004 baseline year (Figure 17 and Appendix 8).

Of the adult population found in May 2018, about 57% were located on Bird Islet. On South Islet 43% of the adult were found compared to 42% in 2017 (70% in 2016). However, compared to the 70% population found in South Islet in 2016, a reduction is evident, which mirrors the continued decrease in vegetation used for breeding and roosting.

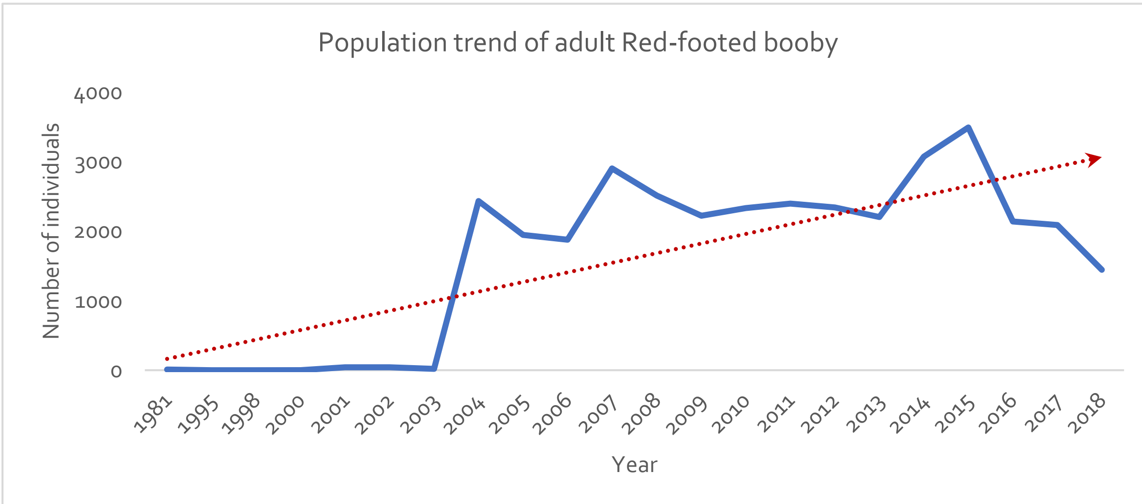

Figure 16. Population trend of adult Red-footed Booby from 1981 to 2018

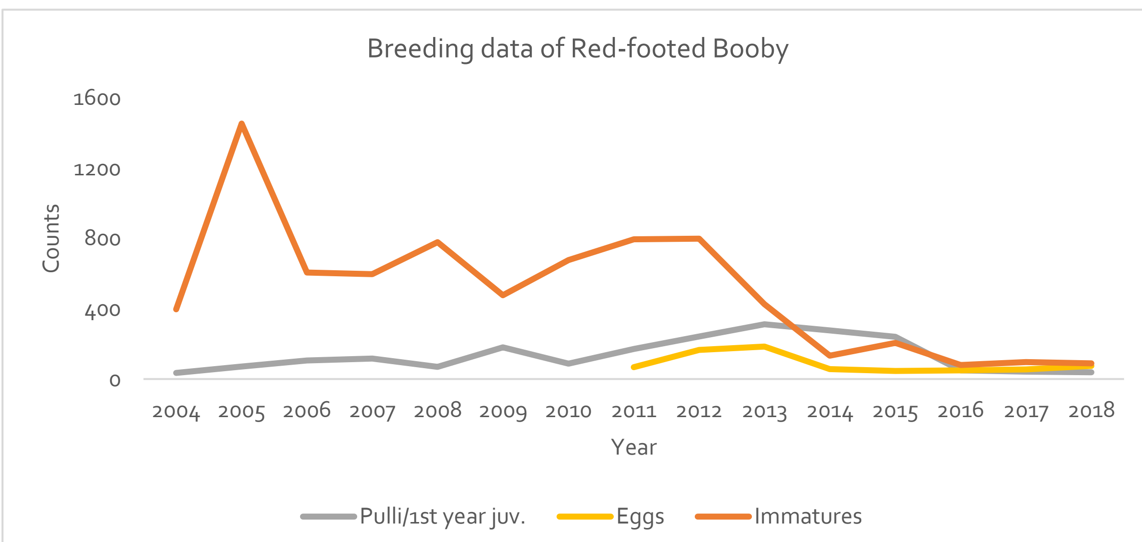

Figure 17. Breeding data of Red-footed Booby from 2004 to 2018

Brown Booby (Conservation Status - Proposed Philippine Red List: Endangered): The inventory resulted in a total count of about 3,367 adults on Bird Islet. The species is not breeding on South

Islet. Although about 5% lower than in 2017, the variance is within the margin of inaccuracy in counts and estimates used to calculate the adult population present during the inventory period.

The result in May 2018 continues to be among the highest numbers counted since the baseline year of 1981 (Figure 18 and Appendix 17); about 11% lower than the baseline count (Kennedy 1982). A very high number of adults (2,500 adults) was also observed by MPRs in November 2017.

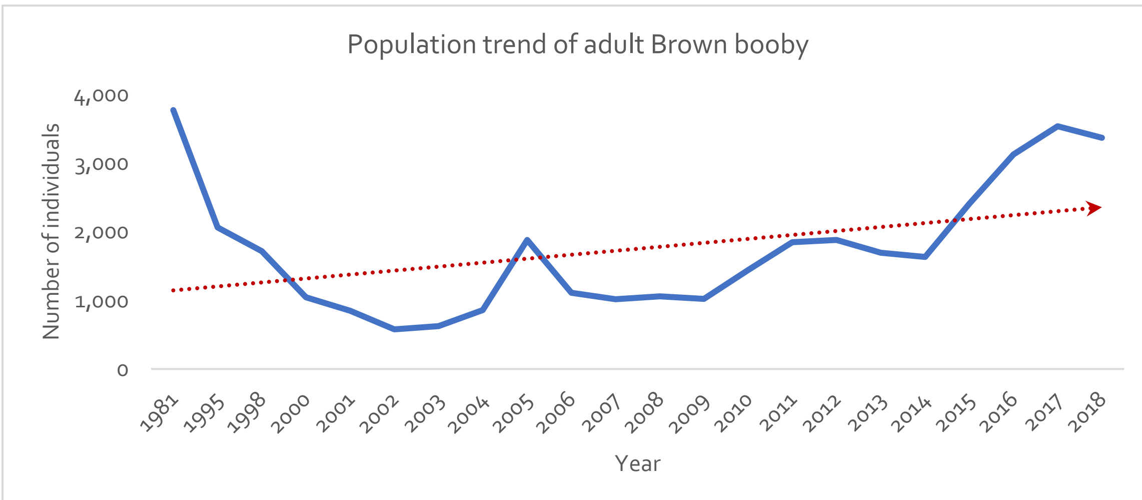

Figure 18. Population trend of adult Brown Booby from 1981 to 2018.

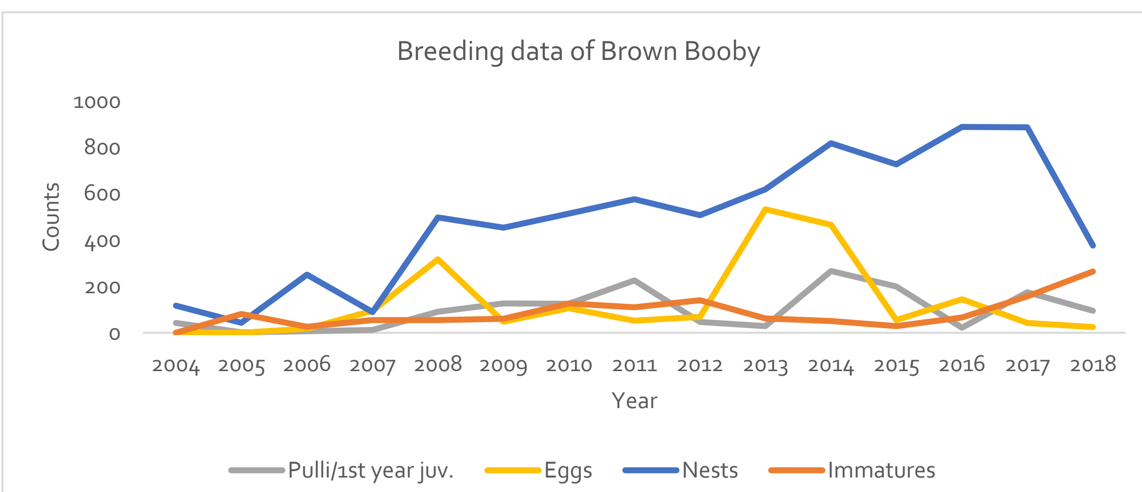

Figure 19. Breeding data of Brown Booby from 2004 to 2018.

Prior to the May 2018 inventory, MRPs in November 2017documented the highest number of nests and eggs ever counted (1,074 nests and 1,388 eggs) suggesting a continued very high reproductivity. The presence of the highest number of counted immature birds (264 individuals) in May 2018 also suggests that species recovery is continuing. However, in May 2018 the number of nests where unusually low, with 376 nests compared to around 886 nests both in 2017 and 2016. Lower counts of nests compared to the 2018 May count only occurred from 2004 to 2007 (Figure 6 and Annex 8). A major contributing factor may be a substantial reduction in the species' main breeding area in 'Plaza'; a reduction by 2,120 m² or 45% compared to the average size of 'Plaza', 4,692 m² the previous five years (Figure 14). Management actions restoring 'Plaza' back to its original size should be an urgent consideration.

Also, the number of pulli were very low in May 2018; only 95 pulli were recorded compared to 175 in 2017. Combined, the number of eggs, pulli and first year juveniles (120 individuals) is lower by 45 % compared to 2017 (Appendix 18).

In July and August 2017 and in May 2018 a total of 67 colorbands and steelrings used to band Brown Boobies from 2006 to 2009 were read on Bird Islet. Of these birds, 34 were banded as adults and 33 individuals as pulli, Table 8. The birds banded as pulli are now from nine to twelve years old or less than half of the lifespan of the species which can reach an age of 25 years (Hennicke et al. 2012).

Table 8. Results of ring readings of Brown Booby on Bird Islet from July and August 2017 and May 2018

Year	Adult	Pulli	Total
2006	4	4	8
2007	16	15	31
2008	7	13	20
2009	7	1	8
Total	34	33	67

Brown Noddy (Conservation Status - Proposed Philippine Red List: Vulnerable).

The 1,984 adults recorded in May 2018 on Bird Islet and 1,486 individuals on South Islet, or a total of 3,470 adult noddies, were lower by 18% or 739 adults compared to the inventory in 2017 (Figure 20 and Appendix 17). A population decrease of 1,020 individuals or 34% occurred on Bird Islet while the population on South Islet continued to increase by 23 % compared to the 2017 records.

The species is normally absent from TRNP from November to February, but on Bird Islet, for the first time ever, at least 700 birds overwintered and around 1,500 adults with 534 nests containing 433 eggs were found breeding as early as 10 February 2018. It is very likely that some of the birds that had finalized their early breeding cycle prior the May 2018 inventory had left Bird Islet at the time of the inventory. Therefore, the population decline noted in May may not express a decline in the breeding population but rather a spaced breeding season. If the adult February population representing 433 nests with eggs and 20 juveniles were added to the May 2018 count, the total population would be 4,376 adults compared to 4,209 adults in 2017, or a slight population increase of 4%.

The May 2018 count result of nests, 1,644 nests and correspondingly 1,074 eggs and pulli, is the second highest result since annual inventories were established in 1997. In fact, if the MRPs data from 10 February 2018 is added (433 nests with eggs and 20 juvenile birds), this year's result would break the record and become the highest counts of nest, eggs and offsprings (Figure 21, Appendix 18). Likewise, 2018 is the fourth consecutive year when the start of the breeding season was early, this year starting in Bird Islet on January and the three previous years in March.

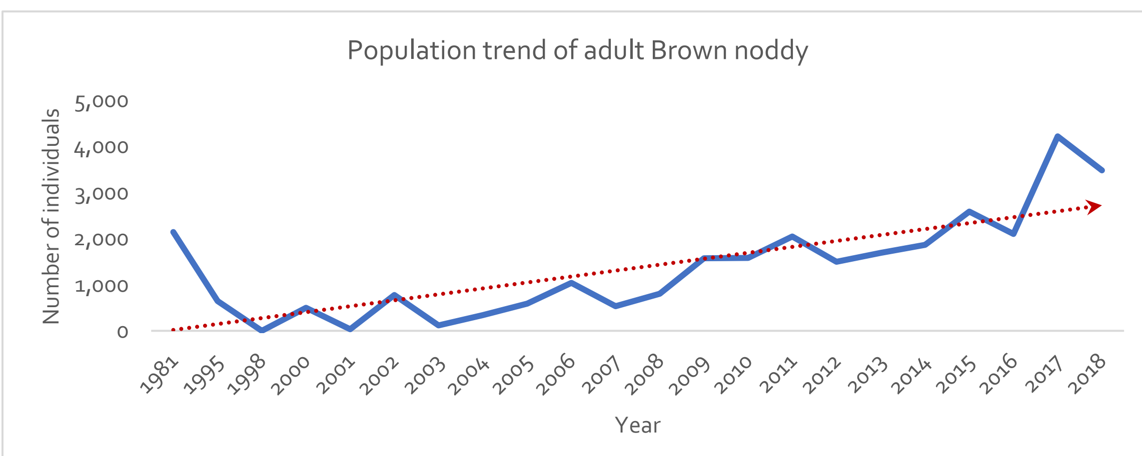

Figure 20. Population trend of adult Brown Noddy from 1981 to 2018.

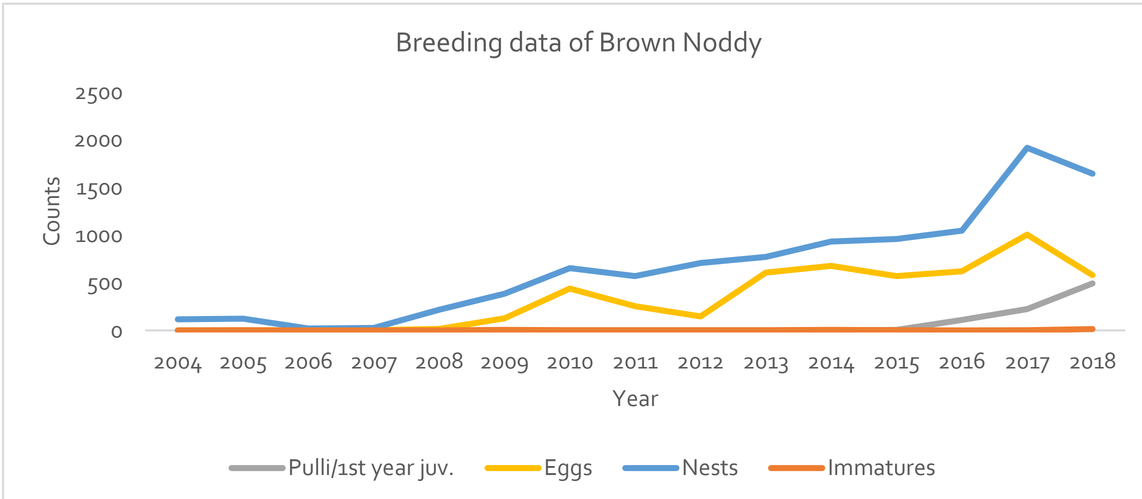

Figure 21. Breeding data of Brown Noddy from 2004 to 2018.

Black Noddy (Conservation Status – Proposed Philippine Red List: Endangered):

A total of 4,473 adult birds were counted compared to 5,191 adult individuals in 2017, representing a 16% decline in the adult population. Compared to the peak count of 10,656 adults in 2013, less than 58 % of the breeding population was present in May 2018 (Figure 22, Appendix 17). The populations were distributed between the South Islet (2,028 individuals) where 45% of the population were found and Bird Islet where 2,445 individuals or 55% were counted.

The population on South Islet has declined from 91% in 2016 and the ratio of nesting to adult birds is very low. The decline in the number of adult birds, from 4,382 individuals in 2017 to 2,028 individuals in May 2018, represents a decline 54% of the South Islet population. Overall, it appears that the majority of the adult population were inactive due to lack of breeding materials to construct nests. Active nesting was observed only in 44% of the adult population present. Of the 449 nests found, only 36% or 162 nests contained eggs (Figure 23).

On Bird Islet six artificial nesting structures made of bamboo were built in 2017. As a result, 196 nests were observed in August 2017 and 300 nests in September 2017 were made by the Black Noddy. Supplementary nesting materials were brought to the Islet on March 2018.

The pilot establishment of artificial breeding structures increased the presence of adult birds, from around 800 in 2017 to 2,445 in 2018. It also corresponded with an increase in nests from around 150 in May 2017 to about 680 in May 2018. However, more than 1,000 adult birds remained inactive and without nests due to lack of breeding materials.

The decline in the Black Noddy population on both islets corresponds to the decline of the vegetative cover (Figure 9, Appendix 15). Nearly all nests observed were established on artificial breeding structures constructed in 2017. Despite the initial improved nesting situation in 2018 as a result of the construction of breeding platforms for the Black Noddy, the input proved insufficient. Majority of the adult birds had no breeding materials due to near-absence of trees. Fifty-eight percent (58%) of the breeding population or about 6,200 adult birds, were absent from TNRP due to the lack of nesting sites and materials needed to sustain the overall population.

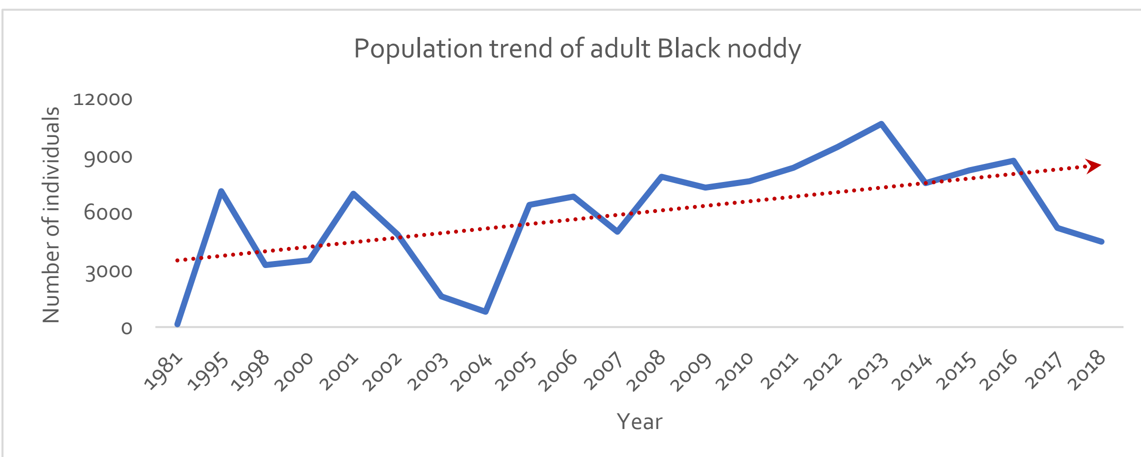

Figure 22. Population trend of adult Black Noddy from 1981 to 2018.

Similar to the population of Brown Noddy, a part of the Black Noddy population overwintered in TRNP (230 bird present in January 2018). Early breeding was noted by the MRPs when they counted 976 adult birds with 141 nests containing 80 eggs and one pullus on 10 February 2018. The very early presence of the species was also noted in February 2017 (2,300 adults present on 17 February).

Since May 2015 the species was observed breeding in small numbers on the ground at South Islet. In May 2018 nests of Black Noddy were again recorded on the ground around and inside the

Lighthouse on South Islet. However, the numbers of nests appeared to be substantially lower than in 2017 when 287 nests were found.

Without substantial improvement in breeding success, the continued breeding failure could lead to a 75% decline in population over the next 10-year period. Nationally and internationally, the Department of Environment and Natural Resources (DENR) and the 12th Conference of the Parties of the Convention on Migratory Species (CMS) have responded to the critical situation for the Black Noddy given that the Philippine population is a subspecies confined only to TRNP. The DENR now recognizes the Tubbataha subspecies as Endangered. The CMS has placed it on the Convention's Appendix II list of migratory species which have an unfavorable conservation status and which require and can benefit from international agreements for their conservation and management.

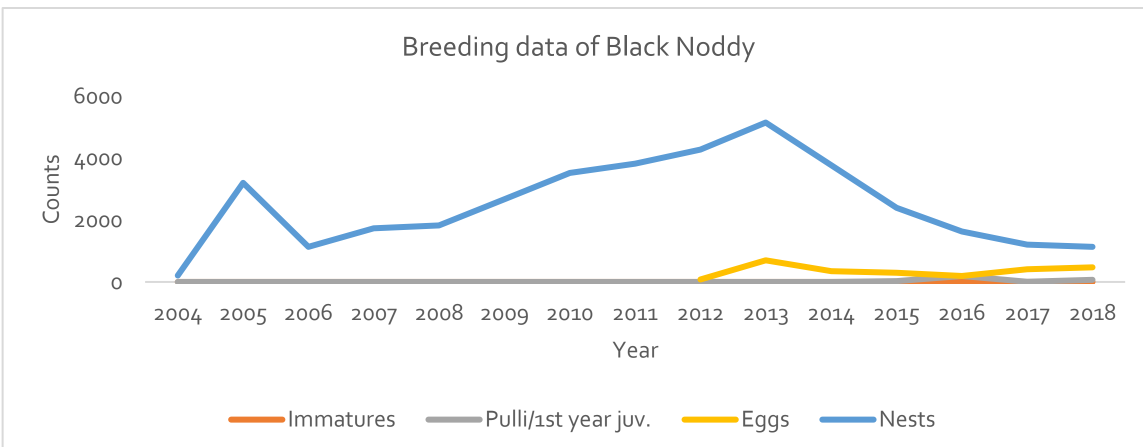

Figure 23. Breeding data of Black Noddy from 2004 to 2018.

Great Crested Tern (Conservation Status - Proposed Philippine Red List: Vulnerable):

The breeding population on Bird Islet reached at around 17,752 adult individuals, or an increase by 4% compared to the record-breaking number of 2017 (Figure 25, Appendix 17). However, the increase is within the anticipated error margin of the manual counts. Because of the large size of the population, a detailed and structured photo documentation should be added as a method in counting number of individuals in the colonies.

The arrival of 1,250 breeding individuals , was first noted on 18 March 2018 by the MRPs. In May 2018 the majority of the population was in an active egg-laying stage while about 10% of the population already had pulli offsprings. More than 7,460 eggs were counted but it was noted that more birds laid eggs from day to day (Figure 24, Appendix 18). The continuous population growth has resulted in a breeding population that is now more than three times larger than in the baseline year of 1981 (Kennedy 1982). As in the previous years, there was no breeding population found on South Islet.

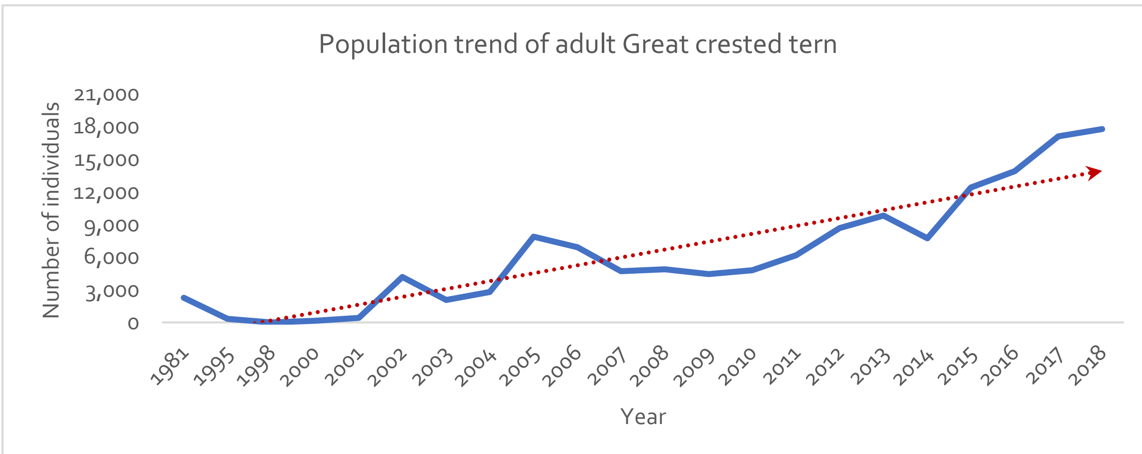

Figure 25. Population trend of adult Great Crested Tern from 1981 to 2018.

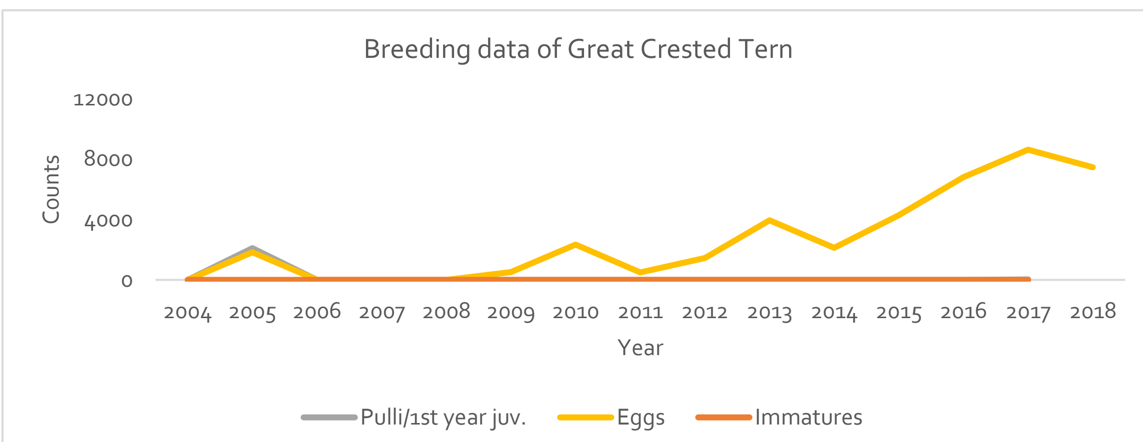

Figure 24. Breeding data of Great Crested Tern from 2004 to 2018.

Sooty Tern (Conservation Status – Proposed Philippine Red List: Vulnerable):

At least 11,288 adult birds, representing what may be the entire population breeding in TRNP, were present during the May 2018 inventory (Figure 26, Appendix 17). This is the highest count since regular annual counts were initiated in 1997. Surprisingly, 130 adult birds overwintered between 2017 and 2018. Overwintering by this species has not been noted at Bird Islet in previous years.

At least 860 birds were present at Bird Islet from February 2018. These early birds may be the parents to the 832 pulli or 12% of the population with pulli found in May 2018 (Figure 27, Appendix 18). The remaining population representing over 9,900 breeding adults, including some birds banded in 2006 or 2007, were in an active egg-laying stage. A second breeding population in 2017 was found by the MRPs 17 November 2017 where at least 2,124 adults were found with 198 eggs and 864 pulli and juveniles. No birds were found breeding on South Islet.

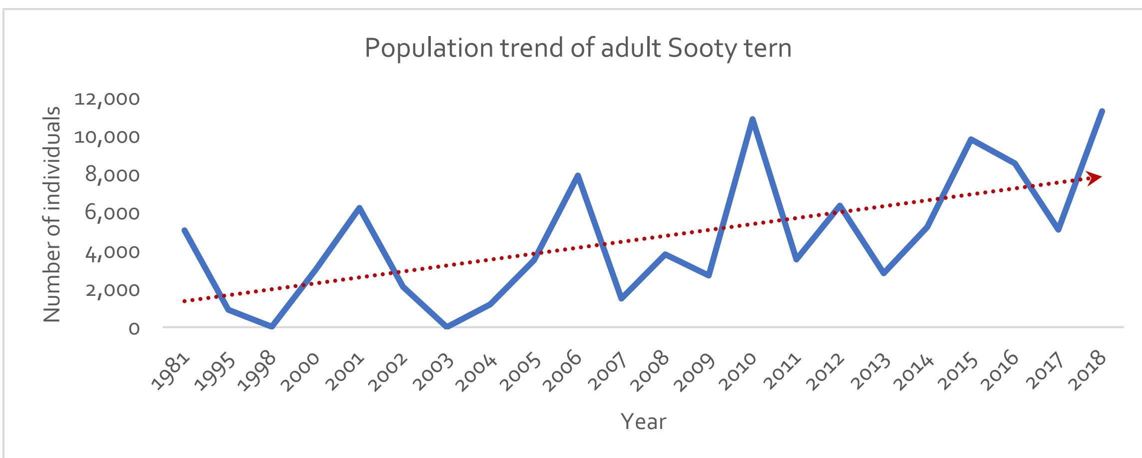

Figure 27. Population trend of adult Sooty Tern from 1981 to 2018.

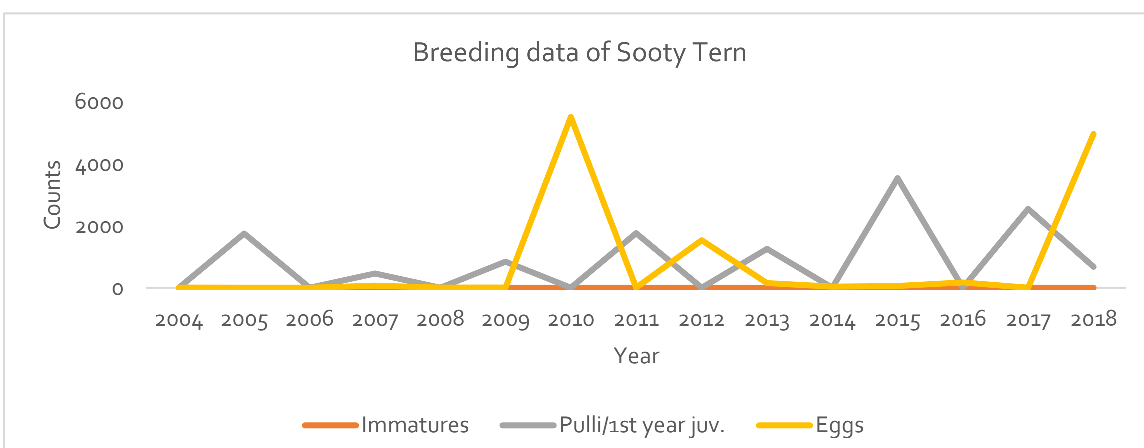

Figure 26. Breeding data of Sooty Tern from 2004 to 2018.

Pacific Reef Heron: The total adult population in May 2018 was only 9 adult individuals compared to16 individuals 2017 and 19 individuals in 2016. Four birds were recorded on South Islet together with one nest containing 3 eggs and two empty nests. On Bird Islet four adult birds but no nests were found. All birds recorded in May 2018 were of the dark phase.

Barred Rail: For the first time since 2016 the species was again observed on Bird Islet where at least one individual was observed several times. It used to occur on South Islet as well, although none was observed this year.

Eurasian Tree Sparrow: Six individuals were recorded in South Islet and seven individuals in Bird Islet.

Results of examination of dead birds in Bird Islet

Only two dead noddies, an immature Brown Noddy and one adult male Black Noddy, were collected to determine the cause and manner of death. Possible cause of death of the Brown Noddy was severe gastric impaction and the Black Noddy seemed to have died of pneumonia accompanied by starvation. Other mummified birds, which was very low in number, were neither counted nor identified to the species level.

4.4 Management recommendations for 2018 and beyond

Habitat

1. Restoration of Beach Forest: Considering the Philippines proposal to include the Philippine subspecies of Black Noddy under the Convention on Migratory Species and its call for an urgent action plan to restore its population, substantial effort needs to be applied to find ways to restore the beach forest in TRNP. Hence, the 2017 recommendation remains valid, namely to establish a nursery to produce a large number of seedlings of drought-resilient beach forest species and plant these on the islets of TRNP. However, additional protocols on when best to plant, how to increase survival rates and monitoring of the survival of the out planted seedlings needs to be established.

2. Restoration of 'Plaza': The main breeding area for Brown Booby is now reduced by close to half due to a substantial expansion of bunch *grasses.* Management actions restoring 'Plaza' back its original size should be an urgent consideration. However, ensure that the area is restored as a flat area after grass removal. Holes in the surface may during rainfall act as water retention traps that could endanger eggs and pulli.

Species

3. Black Noddy: As a top priority, replenish lost breeding habitats for the breeding population by increasing construction of artificial nesting structures, also in South Islet, before the start of the breeding season in 2019. Assist further the population by providing substantial quantities of nesting materials. Best is dried beach forest leaves brought from Puerto Princesa.

4. Satellite-tracking to gain management knowledge: Include in the annual budgeting and fund-raising, a budget for satellite-transmitter tacking and tracking of up to 8 adult and juvenile Black Noddy and Sooty Tern to gain necessary management knowledge. Applicable tracking advices such as 5g solar PTT are available for 3,750 USD per piece, e.g. from Microwave Telemetry, Inc. (MTI)

Methodology

5. Bird counts. Continue monthly distance counts, and conduct three direct counts in January/February, August/September and October/November. Include counts of other species such as Pacific Reef Heron, Barred Rail, and of the migratory Ruddy Turnstone and Grey-tailed Tattler.

6. Great Crested Tern and Sooty Tern. Because of the size of the population, a detailed and structured photo documentation should be added to the methods currently used.

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OTHER STUDIES

5 CORAL RECRUITMENT

Rowell Alarcon, Maria Retchie Pagliawan, Noel Bundal and Jeffrey David

5.1 Overview

Monitoring of coral health and its trends provides managers with a context for assessing both natural and human impacts and serves as basis for making management decisions. In TRNP, this is mostly limited to assessing the abundance and distribution of adult coral colonies and other biota. For a deeper understanding of the resilience of the reefs, however, there is a need to investigate the underlying mechanisms of change that affect the overall reef conditions. Coral recruitment patterns need to be further understood as these play an important role in the recovery of the reef from disturbances (Moulding *et al.* 2016). Coral recruitment is the process by which young individuals (coral larvae) undergo larval settlement and survive to become part of the adult population (Kegler *et al.* 2016). It reflects patterns of larval settlement, larval substrate selection, and post-settlement mortality rate until the time of census (Smith 2006).

Although there is extensive knowledge on juvenile coral populations in other reefs (Van Morseel 1988), there is a need to understand its complexity in Tubbataha. The rate, scale, and spatial structure of larval settlement have significant implications for population dynamics and resilience of the reef (Golbuu *et al.* 2012). This study intends to quantify juvenile coral abundance, recruitment density, and distribution in TRNP for analysis as well as for establishing a baseline for future reference. 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 whole coral population.

5.2 Materials and Methods

Monitoring Site

As discussed in Chapter 1, the coral recruitment survey was conducted together with the annual monitoring of fish and benthos in TRNP. Modified from the method described by Burges *et al.* (2009), data was collected from the first 50 meters of the transect in both the shallow (five meters) and the deep (10 meters) areas of each of the two stations per monitoring site. With five regular monitoring sites covered, a total of 10 50-meter transects were surveyed for this study.

Sampling Design

Figure 28. 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.

At each transect, a diver randomly placed a 34 x 34 cm (0.12 m^2) quadrat, with scale bars attached (2 and 5 cm) on both sides, on the substrate along the transect to get representative samples of the station (Figure 28.a-b). 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 randomly 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.

Sampling of coral recruits required random placement of quadrats, color correction, checking for clarity of images, and recording other observations for proper processing.

Data from a total of 20 quadrats (10 from the shallow depth and 10 from the deep) were processed per station. 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) (Appendix 11). 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 were deemed remnants of adult corals were excluded.

Estimates of coral recruit density was then calculated for each quadrat as the number of recruits per 0.12 m^2. Differences in densities of recruits across stations and depths were tested using block One-way ANOVA. Post hoc pair-wise comparisons were performed using the Tukey test when significant differences were found. Densities and mean percentage covers were plotted in Microsoft Excel across depths and stations.

Bray-Curtis similarity index was also used to further test the similarity in generic composition of recruits among depths and stations. Generic abundance data were pooled for all quadrats within a site and the data were square-root transformed (PRIMER v6). The results were also used to construct a non-metric, multi-dimensional scaling (MDS) plot.

5.3 Results and Discussion

A total of 945 coral recruits from 605 photographs were processed, covering a total of 24 m^2 for the whole park. This survey recorded twenty-nine (29) coral genera belonging to nine families. The average estimated coral recruit density (pooled taxa) across all sites were 45.56 ind/m^2 (±4.56 SE) at 10 meters, with values ranging from 0.83 ind/m^2 (±0.26 SE) to 20 ind/m^2 (±11.59 SE). It is six times higher than in Great Barrier Reef (Keppel and Lizard Island) with 6.92 ind/m^2 (±0.25 SE) at 10 meters (Trapon *et al.* 2013). In the shallow areas of TRNP (five meters), the average density is 30.50 ind/m² (±5.54 SE) and values ranged from 0.10 ind/m² (±0.09 SE) to 6.87 ind/m² (±1.95 SE). Generally, a lower density of coral recruits was observed in the shallow areas.

Coral recruitment at 10 meters

Three major families dominated most of the sites at this depth. Family *Poritidae* (23%) had the highest percentage cover, followed by *Faviidae* (21%) and *Agariciidae* (18%) (Figure 29). These families are known to be slow growing, but are more tolerant and resilient to strong currents and disturbances with its thick walls (Nyström 2006; Huang 2008). The deep areas (10 meters) in TRNP are usually characterized by drop-offs with small pockets for corals to grow. *Poccilloporidae* and *Acroporidae*, mostly composed of branching species, accounted for 11% and 7%, respectively (Figure 29). Belonging to this families are fast-growing species that are prone to breakage (Nakamura and van Woesik 2001). Other families observed are solitary corals belonging to *Fungiidae* and *Euphylliidae*.

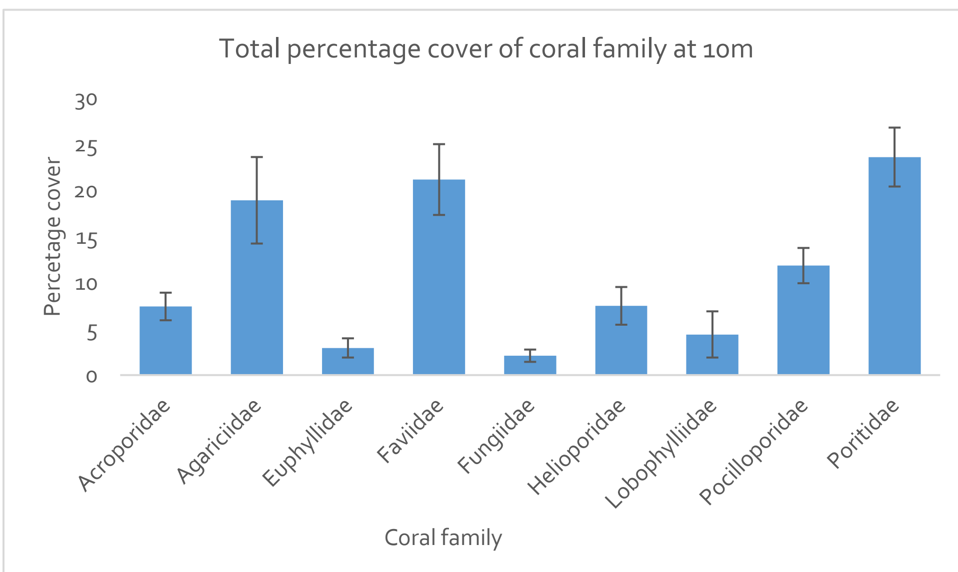

Figure 29. Mean percentage cover of coral families at 10 meters. Error bars represent standard error of the mean.

Coral recruit density at 10 meters was observed to be higher compared to that in shallow areas. The highest juvenile densities were observed at Stations 3B (68.05 ind/m²) and 3A (63.33 ind/m²).

These stations are mainly composed of corals belonging to genus *Acropora*, *Pavona* and *Porites*. Stations 4B and 4A recorded 56.66 ind/m^2 and 50 ind/m^2, respectively, and were dominated by encrusting *Porites* (Figure 30). The lowest density was observed in Station JBA covering only 27.5 ind/m^2. Station JBB is the only station which recorded a high density of the genus *Caulastrea,* which is not common in all the other stations. Variability of coral recruit density at this depth showed no significant difference among the sites (block ANOVA p=0.616).

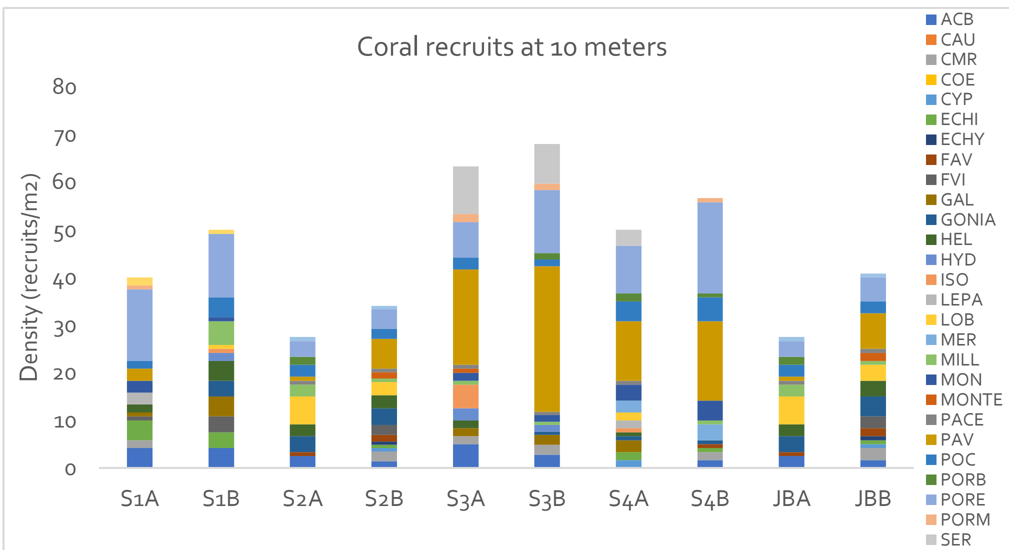

Figure 30. Average density of coral recruits in m² for 10 stations at 10 meters.

Figure 31 presents the size frequency distribution of the coral recruits. Assuming a one to three (1 – 3) mm diameter monthly growth rate (Bak and Engel 1979; Van Moorsel 1988), corals that are less than five (<5) cm in size are approximately one to four years old. To further classify coral recruits, we divided these according to size. Those that were less than one centimeter (<1cm) were described as newly settled larvae (Wilson and Harrison 2005; Acosta *et al.* 2011). Those between one to four centimeters (>1 and <4 cm) were considered juveniles (Acosta *et al.* 2011). The juvenile stage of a coral is considered an important phase because of the high incidence of mortality during this stage. Purportedly, survival is assured when coral recruits reach a size of more than four centimeters, when they are likely to become new coral colonies (Ritzon-Williams *et al.* 2009).

The size frequency distribution of coral recruits seems to vary among sites, although a Chi-square test for size-frequency distribution did not show significant difference among sites. Recruits <1cm and ≥4cm were observed in low numbers, across all stations (Figure 31).

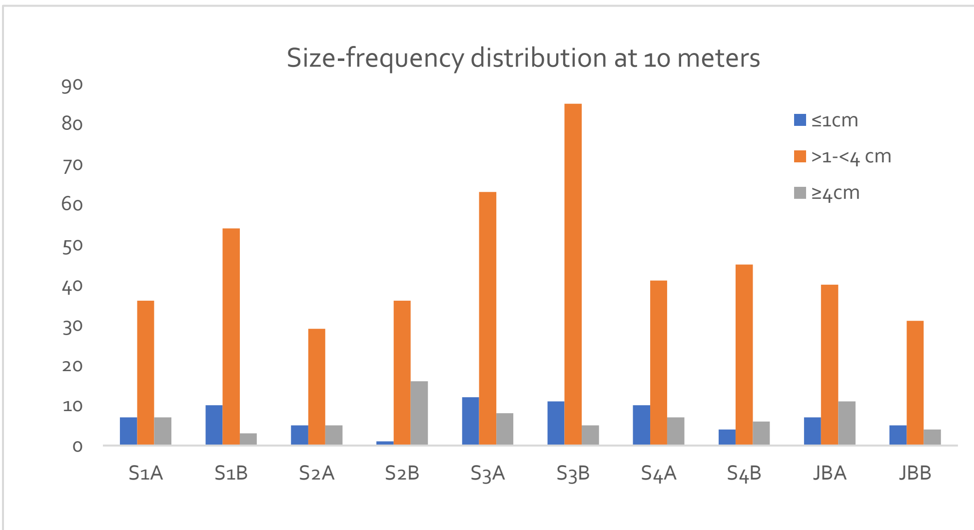

Figure 31. Size-frequency distribution of coral recruits per Station. Bars represent the number of recruits in each size class.

Coral recruits greater than 1 cm to less than 4 cm predominated (Figure 31), suggesting that these sites are conducive to coral survival. However, more in-depth study on the time of coral spawning and the proportion of mature colonies that brood or spawn in TRNP needs to be done to validate this observation.

Coral recruitment at 5 meters

Agariciidae (23.4%), *Acroporidae* (22%), *Faviidae* (20%) and *Pocillporidae* (18%) mostly comprised the coral recruits at five meters (See Figure 32). High densities of the genus *Pavona* (Family *Agariicidae*) dominated most of the stations at this depth (Figure 33). Coral genera belonging to *Acroporidae* mainly composed of *Acropora* branching type recorded high densities at the Stations 2A, 1B, 4B, while both *Acropora* branching and *Montipora* dominated Station JBA (Figure 33).

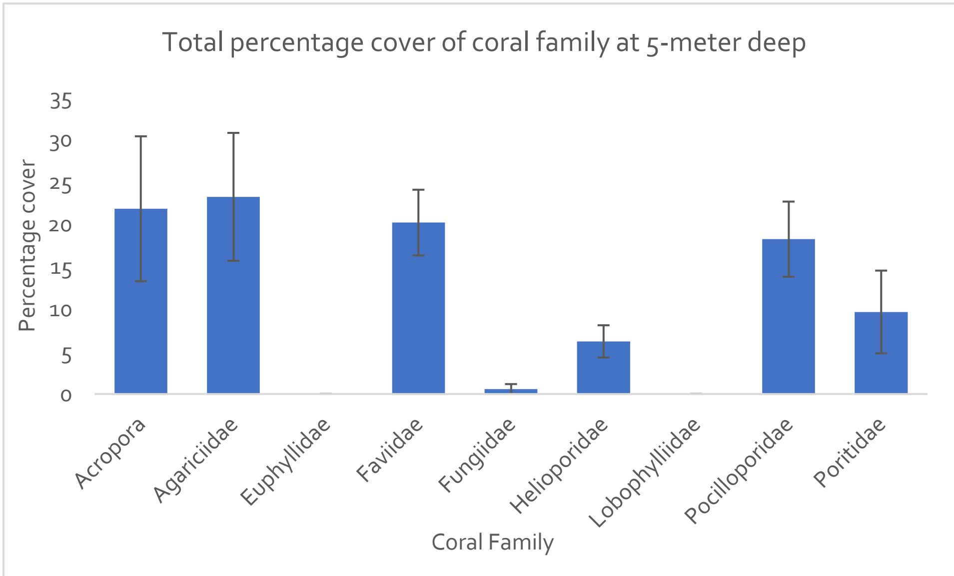

Figure 32. Mean percentage cover of coral families at five meters. Error bars represent standard error of the mean.

At this depth, reef building colonies such as *Acroporidae* and massive colonies of corals such as *Faviidae*, were almost of the same proportion. Coral genera belonging to the Family *Faviidae*, which varied from massive with thick walls (*e.g.*, *Monstarea*, *Favia* and *Favites)* to encrusting type (*e.g.*, *Echinopora)* were not very common in most of the sites at this depth. Coral mushrooms belonging to *Fungiidae* were the lowest at this depth.

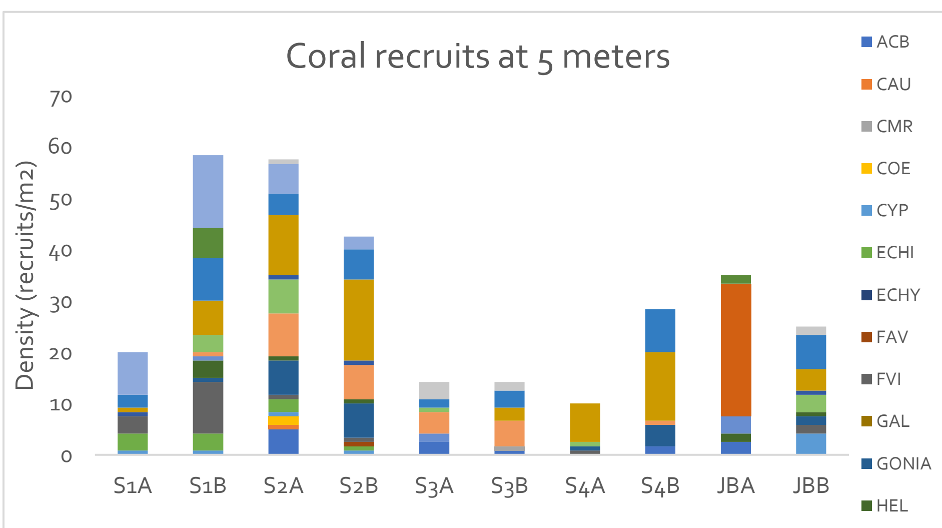

Figure 33. Average density of coral recruits per m² for 10 stations at five meters .

The highest coral density at this depth was recorded at Stations 1A (58.33 ind/m²) and 1B (57.5 ind/m²) and the lowest at Station 4A which only had 10 ind/m² (Figure 33). However, variations of the density per site did not show significant difference (block ANOVA p=0.194). The shallow areas of Stations 3A and 3B had low coral recruit densities (14.16 ind/m²) compared to the deep areas of the same stations (63.33 ind/m² in 3A and 68.05 ind/m² in 3B). This was probably due to the fact that Stations 3A and 3B were dominated by beds of branching *Isopora brugemmanni*, leaving almost no space for the coral larvae to settle.

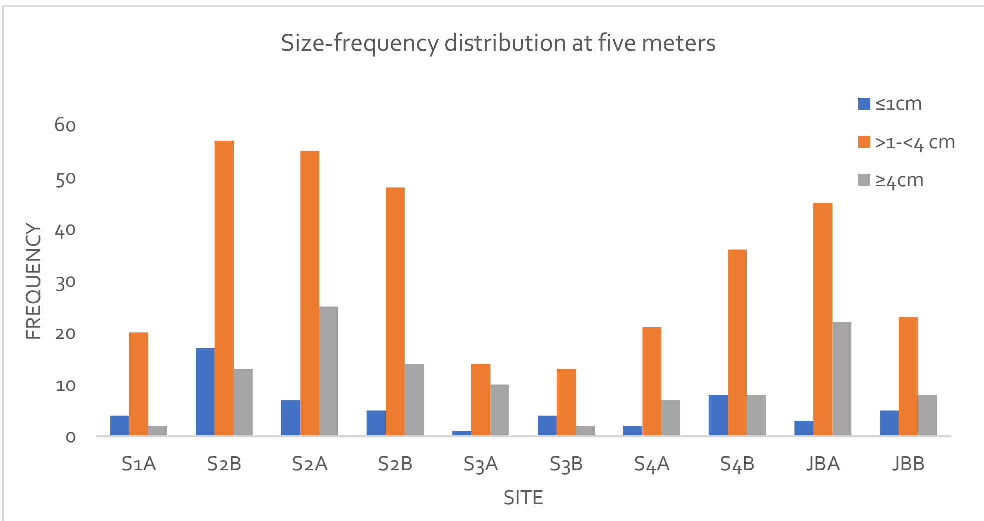

Figure 34. Size frequency distribution of coral recruits by station. Bars represent the number of recruits in each size class.

The size frequency distribution at this depth closely mimicked the pattern observed at 10 meters. Recruits with sizes less than or equal to one centimeter were the least encountered across all stations at this depth. Again, the juvenile stage (>1 to ≤4cm) of coral recruits predominated at this depth. Chi-square test for size frequency distribution across the stations at this depth failed to show significant differences.

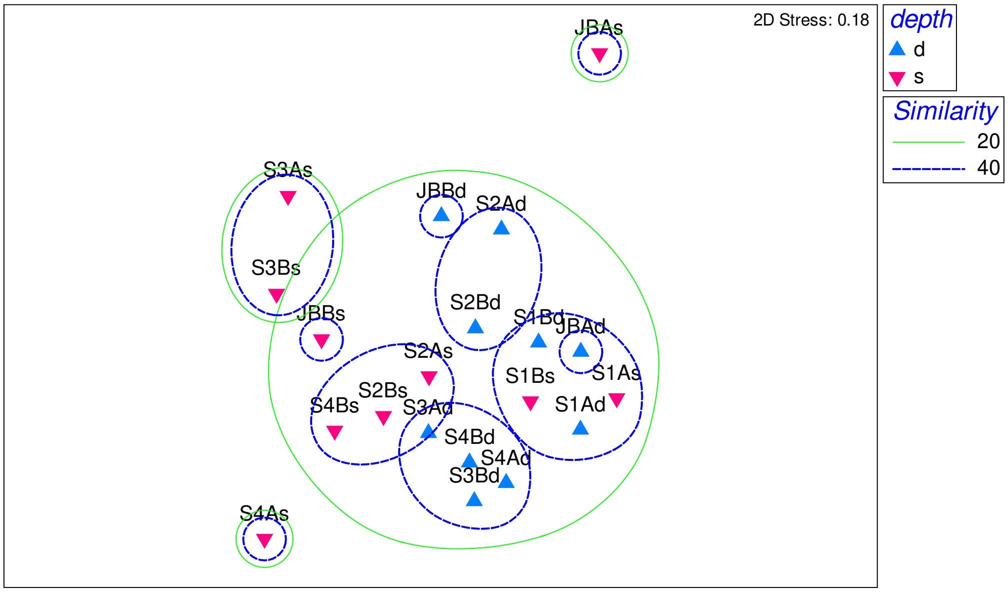

Figure 35. Non-metric multi-dimensional scaling (MDS) plot of Bray-Curtis similarity index of recruit species composition across the sites at both depths. Green dotted line implies 20% similarity of the stations; blue dotted line implies 40% similarity.

A non-metric multi-dimensional scaling (MDS) plot was used to visualize the Bray-Curtis similarity of sites based on the generic abundance at each station and depth (Figure 35). As expressed in the MDS plot, stations that shared almost the same generic composition formed a cluster. Four major clusters with 40% similarity were formed: (1) Stations 3A, 3B, 4A and 4B at 10 meters; (2) Stations 2A, 2B and 4B at 5 meters; (3) Stations 2A and 2B; and (4) combination of all stations at both depths of Site 1 and Station JBA. ANOSIM revealed a significant difference among depths indicating that depth is a factor affecting coral recruit structure in TRNP (r=02, *p*=0.007). However, it failed to show the differences among stations due to too many small values generated even after the computation of the log-transformation (square root) of the data. Presumably, the coral juveniles found were mostly seeded by the mature colonies at each depth. The shallow areas of Stations 3A, 3B, 4A and JBA seem to be separate from the group, which might have been influenced by the low number of coral genera and densities found in those areas.

5.4 Conclusion

The mean estimated juvenile coral density in TRNP recorded at 46.16/m^2 (±5.17 SE) and 30.50/m^2 (±5.54 SE) may be considered high. It is six times higher than that recorded in a study in the Great Barrier Reef (Keppel and Lizard Island) with 6.92 ind/m^2 (±0.25 SE) at 10 meters (Trapon *et al.* 2013). The results of this study contradicted the previous findings of Garcia and Aliño (2008) in TRNP, which recorded low coral recruit densities at 10 meters. Coral recruits in TRNP were mainly composed of *Poritidae*, *Agariciidae* and *Faviidae* at 10 meters, while *Acroporidae* and *Pocillporidae* dominated at five meters. These groups of corals seemed to influence the coral composition in TRNP. These thriving coral families could be related to its ecosystem functionality.

We recorded high coral recruit densities of *Poritidae*, which is known to be a stress-tolerant group and to be reef-builders, as they spawn several times in a year (Szmant 1986; Darling *et al.* 2013). It appears that *Poritidae* is the major competitor among other coral families specially at the deep sites, which are characterized by occasionally strong currents. These current flows may influence the transport and removal of the other less competing coral recruits from the site (Elmer *et al*. 2016) to the advantage of the *Poritidae*. While our data could not conclusively address the issue, the high densities of *Poritidae* may relate to the proportion that the mature colonies within the sites in Tubbataha.

Often found at 10 meters are *Agariciidae* and *Faviidae.* These are stress-tolerant corals characterized by thick walls. They are slow growing but can withstand disturbances such as strong currents and temperature increases (Nyström 2006; Darling *et al.* 2013). The presence of these massive coral growth forms makes the deeper sites more resilient than the shallow sites. The shallow areas of TRNP are dominated by *Acroporidae* and *Pocilloporiidae*, which are mostly the branching type and are rapid colonizers, therefore, key players in reef building (Hughes and Connell 1999). The shallow sites at the reef crests experience less currents and disturbance than the deep sites, thereby these areas are favorable to *Acropidae* and *Pocilloporidae*.

Presumably, the dominance of coral recruitment in TRNP is influenced by several processes such as depth, competition, and current flows that influence the structure of coral communities. Further studies may validate this claim.

Most of the coral recruits at both depths were between >1cm to ≤4 cm, which for most coral families are considered to be the juvenile stage. Family Poritidae was observed to be the most abundant coral recruit in the deep sites, while family Acroporidae dominated the shallow sites. This result coincides with the studies conducted in Fiji and other Pacific Islands by Quinn and Kojis (2008).

In this study, coral recruits >4 cm in size were observed in low densities for both depths. The factors that might have influenced this result is unknown. Succeeding studies may focus on the most dominant genera and species, e.g., *Acropora* and *Porites* massive (*Porites asteroides)*, to be able to derive more conclusive results.

In this study, we only included coral recruits measuring less than 5 cm, which might have limited the results of the study. Thus, for the next monitoring survey, we suggest that sampling be focused on the most dominant species (e.g., *Acropora* and *Porites* massive (*Porites astreoides)*, and to include all sizes of coral recruits. This will provide a better understating of the different life stage strategies, selection of substrate settlement, and interaction with reef organisms, which leads to the survival of the species.

5.5 Recommendations

This study is an initial attempt to improve knowledge on reef complexity and function. Since this is the first time for TMO to conduct a coral recruitment study, these results may be considered as the baseline. This study could provide a more in-depth understanding of how corals can recover from stressors. It is recommended that this study be continued and incorporated in the annual monitoring activity of TMO. A high-resolution camera with underwater casing dedicated for this study will be required. The main issue this year was the low quality of the photos due to unavailability of a high-resolution camera, which is very important considering the size of the corals being analyzed.

However, more in-depth study on the time of coral spawning and the proportion of mature colonies that brood or spawn in TRNP needs to be done to validate this observation. While, narrow down the study to the most dominant coral recruit species found in TRNP, Acropora and Porites massive (e.g., *Porites asteroides*), for a more conclusive result.

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6 REEF FISH INVENTORY

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6.1 Overview

The Coral Triangle is the region with the highest concentration of marine species in the world (Veron 1995; Allen and Werner 2002). This includes the Philippine archipelago that is geographically located at its apex (ADB 2014) and that harbors one of the Philippines' oldest marine protected areas, the Tubbataha Reefs Natural Park (Dizon *et al.* 2013). Tubbataha Reefs is known to host at least 600 species of reef fishes. The fish species list was obtained from observations during the annual fish and benthos monitoring of the Tubbataha Management Office (TMO) and WWF-Philippines from 1999 to the present. An estimate of the species richness, density, and biomass within the park is based on Fish Visual Censusing methodology developed by English *et al*. (1997).

However, our fish monitoring is limited to depths of up to 33 feet (10 meters). Hence, species that may be found beyond this depth are not recorded. There is a need to conduct an inventory to come up with a more comprehensive fish species list for the park. Dr. Kent Carpenter of Old Dominion University and Dr. Jeffrey Williams of Smithsonian Institution, both experts on fish taxonomy, joined the fish larval study trip organized by the BFAR-NFRDI on 24-30 April 2018 to conduct a dedicated inventory of the fish species at the Tubbataha Reefs.

6.2 Methods

The team revisited Station A of all five TMO monitoring sites as described in Chapter 1 and surveyed three additional sites - south of Ranger Station, Shark Airport, and south of South Atoll (See Table 9). The roving diver survey (RDS) method (Schmitt and Sullivan 1996; Hill and

Wilkenson 2004), was used to conduct the survey. Two divers rove or swim around the reefs starting at around 65 ft deep (approximately 20 meters), gradually swimming towards the shallowest part of the reef, while identifying all the species observed. In Tubbataha, the direction of underwater current determines the course researchers take as they swim around the reef. Each census was standardized at exactly 60 minutes of dive time. The goal is to find and record as many species as possible, thus divers also look for fishes under the ledges (e.g., corals, rocks), in caverns, and crevices.

*Table 9. Survey sites with corresponding coordinates. Note: * Corresponds to TMO monitoring stations*

Site Code	Site Description	Coordinates
T1	Station 2A*	08.89236 N, 119.90627 E
T2	South of Ranger Station	08.84462 N, 119.91200 E
T3	Shark Airport	08.92560 N, 120.00948 E
T4	Station 1A*	08.93532 N, 120.01302 E
T5	Southernmost tip of South Atoll	08.73973 N, 119.81822 E
T6	Station 3A*	08.75591 N, 119.82882 E
T7	Station 4A	08.80850 N, 119.81907 E
T8	Station Jessie Beazley A*	09.04393 N, 119.81599 E

The method being employed by TMO in its monitoring follows specific protocols on transect length and width, and species count and total length, to produce results such as fish biomass, density and species richness. The roving diver survey, on the other hand, is a rapid assessment tool, which was introduced as a participatory monitoring method to determine the presence, abundance and occurrence frequency of reef fishes.

The roving diver survey method is more useful for comprehensive species listing as it covers a wider spatial range than a fish visual census (which is limited to the transect) and can record large fish that are wary of divers, cryptic species, and roving pelagic fishes that require an intensive search of the reef (Hill and Wilkenson 2004). Additionally, this does not require the divers to make an actual count of the fishes, unlike the fish visual census which needs an estimated value. Instead, the divers take note of the species abundance by using the following logarithmic-based categories (Schmitt and Sullivan 1996):

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

Data were collated in Microsoft Excel 2016. Descriptive analysis of data for this report was patterned after Schmitt *et al.* (2002) and Schmitt and Sullivan (1996). **Percent Sighting Frequency (%SF)** was calculated to measure how often the species was observed. It indicates the percentage of times the species was recorded divided by the total number of surveys. Observed values ranged from 0-100% and are 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 (<70% x > 20%), and uncommon (≤20%).

The **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** are the frequency categories of single, few, many, and abundant observations for each species and ***n*** is the total number of dives. This produces an abundance index per species, which is 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 in which each species was most often recorded. For example, if the abundance index of a species is 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.

6.3 Results and Discussion

Number of species identified. A total of 332 species under 37 families were identified in the Tubbataha Reefs during this survey. Most species (46 species) belong to Family Labridae (wrasse). Forty species (40) were identified under family Pomacentridae (damselfish), 31 species for family Chaetodontidae (butterflyfish), 22 species were identified for both family Gobiidae (gobies) and family Serranidae (groupers and fairy basslets), and 21 species of Scaridae (parrotfishes).

Site T3 (Shark Airport) has the highest count of fish species across all sites, while both Sites T1 (Malayan Wreck) and T2 (South of Ranger Station) have the lowest counts. Sixty (60) species not initially listed in the Tubbataha fish species list were identified in this survey.

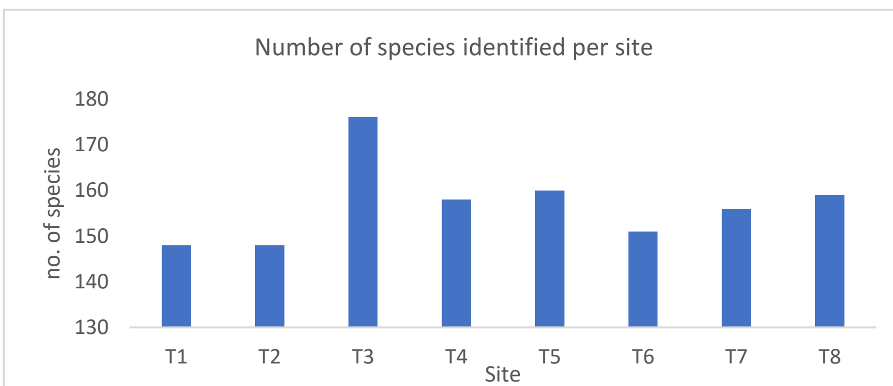

Figure 36. Total number of species identified in each site, including cryptic species.

Sighting frequency. Thirty-six (36) out of the 98 species categorized as frequently observed were recorded in all sites. There are 146 species that are common and were recorded between 2 to 5 surveys/dives. This category also has the highest number of species identified. Eighty-six (86) species were categorized as uncommon. Uncommon species are those recorded only once out of all dives or sites.

It could not be generally assumed that each species recorded under the uncommon category are only present in the specific site where it was observed or can only be observed in lower sighting frequency. For instance, in this survey, the Slender grouper (*Anyperodon leucogrammicus*) and Twospot surgeonfish (*Ctenochaetus binotatus*) were only recorded in T1 (Station2A) and T4 (Station1A), respectively. Meanwhile, in the fish visual census (FVC) survey conducted by TMO (Chapter 2), the Slender grouper (*Anyperodon leucogrammicus*) was recorded in Station3A and Station4A but not in Station2A. The Twospot surgeonfish *Ctenochaetus binotatus*) was recorded in all regular monitoring sites (for sites, refer to Table 9). Fishes move from place to place. This movement could be influenced by several factors such as the availability of food, avoidance of predators (Helfman *et al.* 2009), or it may be due to a larger seasonal migration occurring related to spawning and feeding (Bone and Moore 2008).

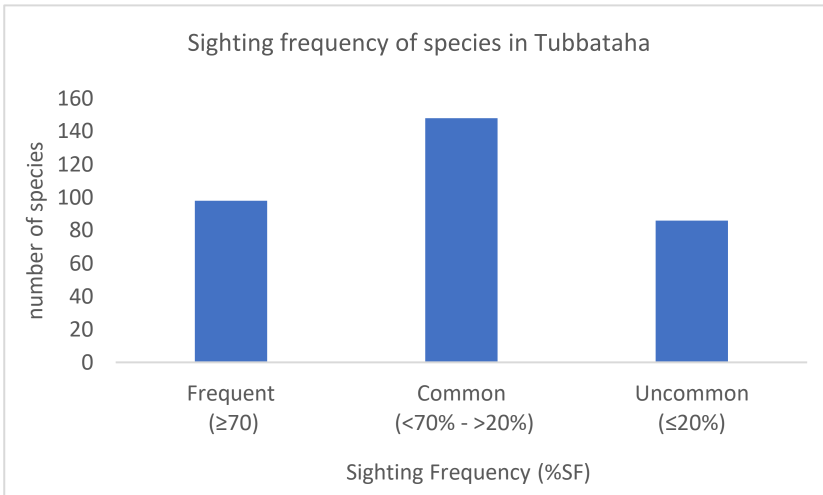

Figure 37. The number of species in each sighting frequency in the Tubbataha Reefs.

Abundance. Figure 38 shows the number of species observed in each abundance index. Abundance Index was organized in range for easy groupings of species: 0.1-1.0; 1.1 – 2.0; 2.1 -3.0; and 3.1-4.0. Two hundred seventy-three (273) species were recorded under the abundance index range of 0.1 – 2.0, which means that these species are less abundant. 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. Seventeen (17) species were observed in very high abundance (3.1 – 4.0). Yellowstriped fairy basslet (*Pseudanthias tuka*) and Red-cheeked fairy basslet (*Pseudanthias huchtii*) were abundant in all sites. Both species were also among the top five most abundant species in the Fish Visual Census survey conducted by the TMO (Chapter 2).

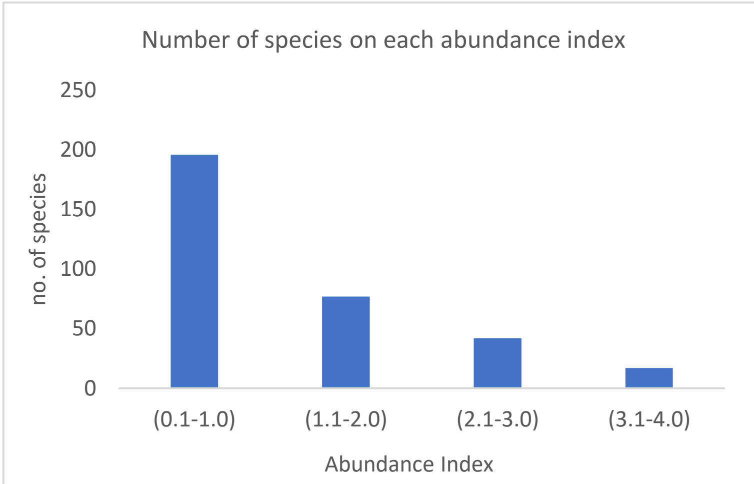

Figure 38. Number of species on each abundance index range.

Abundance and Sighting Frequency. Table 10 provides the list of the number of species under different sighting frequency categories and their corresponding abundance index ranges. It was observed that the most frequently recorded species also occurred in high abundance, while most of the common and all the uncommon species tend to have low abundances (Table 10). Schmitt and Sullivan (1996) argued that although the sighting frequency and abundance are strongly related, sighting frequency could not be an absolute indicator for the abundance of a species. For example, in this survey, Yellowface angelfish (*Pomacanthus xanthometopon*) was frequently observed but in low abundance (01.1-1.0). Thus, each species can be described independently by either its sighting frequency or its abundance in the area (Schmitt and Sullivan 1996).

It is worth noting however that some target species such as Bignose tang (*Naso unicornis*), Dark-banded fusiliers (*Pterocaesio tile*), and Thompson's surgeonfish (*Acanthurus thompsoni*), are frequently sighted (≥75) in high abundance (3.0-4.0) across all sites. Other target species such as various fusiliers (*Caesio caerularea, Caesio teres, Caesio lunaris, Pterocaesio randalli*), Red snapper (*Lutjanus gibbus*) and Bluefin trevally (*Caranx melampygus*) may not be frequently seen but when they were present, they were observed in either abundance category 3 (Many) or 4 (Abundant). These target species, being the focus of fishing effort (FAO 2003a), are first to disappear in an area (Pauly *et al.* 1998), thus their presence can indicate a positive impact of reef protection. A list of the frequently observed species with their corresponding abundance in the Tubbataha Reefs is provided in Appendix 24.

Table 10. The number of species on each sighting frequency and their abundance index ranges.

	Sighting Frequency			
Abundance Index	**Frequent (≥70%)**	**Common (70% <x> 20%)**	**Uncommon (≤20%)**	**Total**
(3.1-4.0)	17 sp			17 sp
(2.1-3.0)	38 sp	4 sp		42 sp
(1.1-2.0)	42 sp	35 sp		77 sp
(0.1-1.0)	1 sp	109 sp	86 sp	196 sp
Total	**98 sp**	**148 sp**	**86 sp**	**332 sp**

Tubbataha vs. other sites (excluding cryptic species)

Figure 39 shows that Tubbataha Reefs has the highest average count of species compared to other sites in the Philippines. It also has the highest minimum species count and has the highest maximum count among all sites in the country. Dr. Carpenter (personal communication, 5 May 2018) also stated that Tubbataha has higher average counts than other sites in Indonesia and Malaysia where they employed the same census method.

There are evidences which suggest that the primary predictors of reef fish species richness are coral reef areas (Parravicini *et al*. 2013; Holbrook *et al.* 2015) and biogeographic region (Parravicini 2013). Hence, the Coral Triangle, having the highest species richness of corals in the world, also has the highest diversity of fish species (Allen 2007). Consequently, the loss of coral habitat in an area may also lead to the loss of the fish species diversity in a local scale (Holbrook *et al*. 2015). For this reason, marine protected areas (MPAs), such as the Tubbataha Reefs, are established to protect and conserve the species diversity for both fish and corals (Rashid *et al.* 1994).

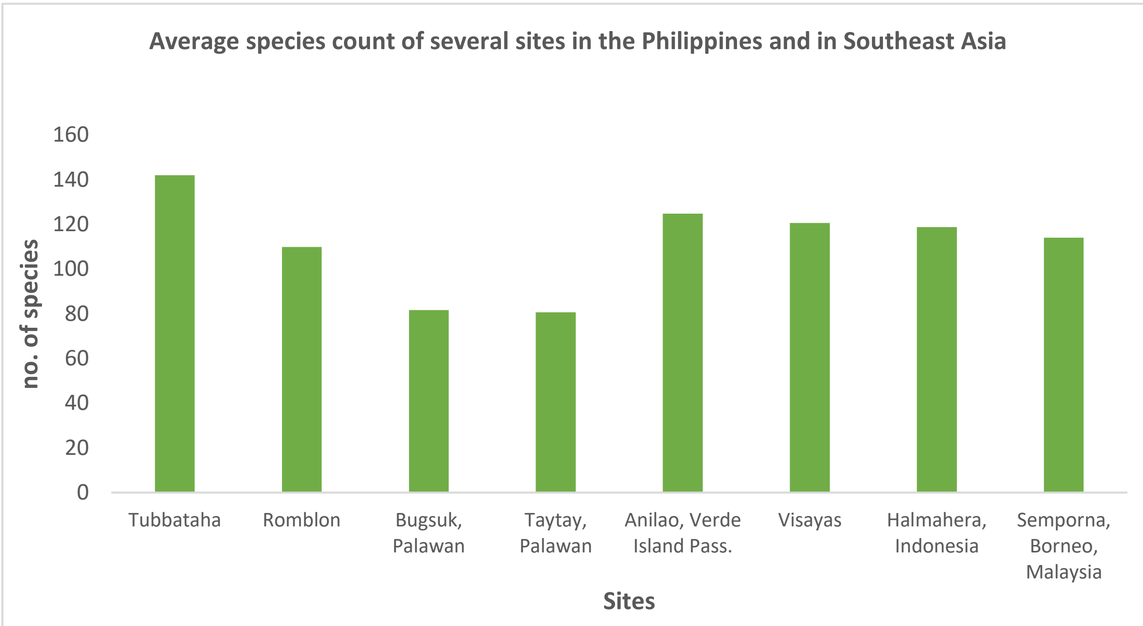

Figure 39. Comparison of averages for species identified in different sites in the Philippines and in Southeast Asia, employing the Roving Visual Census method. Cryptic species were not included in the count. (Data obtained from Dr. Kent E. Carpenter)

6.4 Conclusion and Recommendation

The Roving Diver Method is a good complement to TMO's Fish Visual Census. RDM gives us a more comprehensive list of species, while FVC produces data on biomass and density. RDM is not restricted within the transect, thus divers can freely swim and search at varying depths and can cover a larger area within the park.

Tubbataha Reefs has one of the most diverse fish communities in the Philippines and in Southeast Asia. Maintaining and protecting the diversity of these fishes means ensuring the health and diversity of coral reefs as well. Dr. Carpenter and Dr. Williams recommended they conduct more species inventory trips in TRNP to come up with a more comprehensive fish species list for the park.

6.5 References

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7 REEF BENTHIC SURVEY

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7.1 Overview

The Tubbataha Reefs Natural Park is located in the Philippines, which lies at the apex of Coral Triangle. Tubbataha has been a protected area since 1988 by virtue of a presidential decree declaring it as a no-take zone, banning collection of any marine organisms. The beauty of the natural park became more evident to the international community when it was declared as a UNESCO World Heritage Site, and in 1999, Tubbataha became a part of the Ramsar list of Wetlands of International Importance. In 2010, Tubbataha was included in the Philippine National Integrated Protected Area System (NIPAS), which further intensified its protection against unauthorized and unlawful activities.

The Tubbataha Reef Natural Park is an undisturbed reef system in the Sulu Sea that serves as a refuge for organisms on land and on sea. It provides direct ecosystem services to people, serving as a food source and a venue for tourism, research and education (Subade, 2007). Indirect environmental services of Tubbataha include provision of habitat to the marine organisms and protection against strong waves (Subade, 2007). The Park is home to around 600 species of fish, 360 species of corals, 11 species of sharks, and 100 species of birds (Biodiversity, n.d.). This diversity thrives due to the sustained implementation of various legal protections.

7.2 Methods

Resurvey activities were carried out in May 3 to 8, 2018 by staff of the Br. Alfred Shields FSC Ocean Research (ShORe) Center of De La Salle University, in coordination with personnel of the Tubbataha Management Office. Five (5) regular monitoring sites were visited in the 2018 resurvey: Site 1, Site 2, Site 3, Site 4, and Jessie Beazley (Figure 1). These sites have two (2) stations each, and they have been monitored since 2012. However, Jessie Beazley has insufficient data from 2012 and 2013; thus, the report for this site will only cover the years 2015 to 2018. In addition, two (2) ship grounding sites (i.e., those of the USS Guardian and Min Ping Yu) were also resurveyed (Figure 1). These two (2) stations have been monitored since 2014. Lastly, a new station was assessed this year, Southwest Wall (Figure 1), because there were reports of a crown-of-thorns outbreak in the reef.

The regular monitoring sites (i.e., Site 1, Site 2, Site 3, Site 4, and Jessie Beazley) follow the hierarchical sampling scheme stipulated in the Coral Reef Targeted Research and Capacity Building for Management (CRTR) protocol (van Woesik et al. 2009). However, because of their sizes, the ship grounding sites of Min Ping Yu and the USS Guardian do not have replicate stations; instead, three permanent 4 × 4m quadrats are monitored in each station (Figure 40). The Southwest Wall also consists of one 25 × 75m reef assessment station (Figure 40).

Figure 40 Sampling scheme of sites and stations in the Tubbataha Reefs Natural Park.

The photo-transect method indicated in the CRTR protocol was used describe the state of benthic communities in Tubbataha (van Woesik et al. 2009). A 75-m base transect was deployed at the deepest end of each monitoring station (5-7 m depth) to demarcate the sampling area. Four 50-m belt transects were then deployed parallel to the base transect at randomly determined starting points (x,y-meter coordinates) within the monitoring station (Figure 41).

Figure 41. Five belt transects were deployed to describe the benthic communities in each monitoring station.

Photographs were taken every meter on the shallower side of each transect using a Sony RX 100 Mark II camera enclosed in an Ikelite underwater housing with an attached Inon UWL-100 wide-angle lens. This camera set-up was fixed on a 1-m long aluminum monopod with a 1-m base. In each monitoring station, a total of 250 transect photographs covering five 50-m intervals (beginning with a randomly determined point in transect 1) were taken and analyzed.

Benthic cover and diversity were measured in transect photographs using Coral Point Count with Excel extensions (CPCe; Kohler and Gill 2006). Ten random points were generated in each photograph, and each point was scored according to its benthic category. The six major benthic categories used for scoring were: hard coral (HC), algal assemblage (AA), abiotic material (AB), macroalgae (MA), *Halimeda* (HA) and other biota (OB). HC was further identified into 60 TAUs (Taxonomic Amalgamation Units; Appendix 25).

Hard coral cover from five sites i.e., site 1,2,3,4, and Jessie Beazley was categorized according to the hard coral cover categories: excellent, good, fair, poor (Licuanan AM, Reyes, Luzon, Chan, & Licuanan, 2017). To avoid confusion with the widely-used but arbitrary scale of Gomez et al. (1981), the categories will be called HCC Category A, B, C, or D in this report (Table 11). On the other hand, the coral diversity or the number of TAUs present in the reef sites was identified according to diversity categories (Licuanan W, Reyes, & Robles, in prep; Table 11).

Table 11 Hard Coral Cover and TAU diversity scale categories used in this report (AM Licuanan et al. 2017; WY Licuanan et al. in prep).

Category		Hard Coral Cover	TAUs Diversity
Excellent	Category A	>44%	>26
Good	Category B	>33-44%	>22-26
Fair	Category C	>22-33%	>18-22
Poor	Category D	0-22%	0-18

The changes in HCC and diversity were examined using linear regression, which can provide information on the relationship of the independent variable (i.e., monitoring period) and the dependent variables (i.e., HCC and diversity). Linear regression can determine if there are statistically significant changes in terms of HC and diversity happening in the Tubbataha monitoring sites. Linear regression was applied at the location, site, and station level as described in Licuanan *et al.* (2017). The p-values, rate of change, coefficient of determination (r^2), and Pearson's coefficient (r) are provided in Tables 2 and 3. JMP Pro 11 (SAS Institute Inc. 2013) was used for all statistical analyses. Confidence intervals were set at 95% for all runs.

7.3 Results and Discussion

HCC Categories

The average HCC of all regular monitoring stations in 2018 is 30.0% ± 2.0%. Of the ten stations, only Jessie Beazley A had HCC belonging to HCC Category A (61.5% ± 4.1%; Plate 1). Two stations, 1B and 3A had HCC classified as HCC Category B, with HCC of 42.7% ± 1.3% and 33.5% ± 1.8%, respectively (Plates 2 & 3). Four stations belong to HCC Category C, namely stations 2B (25.5% ± 1.2%), 3B (26.9% ± 3.6%), 4B (29.1% ± 2.7%) and Jessie Beazley B (30.8% ± 2.1%; Plates 4 to 7). Stations 1A, 2A, and 4A fell under HCC Category D, with average HCC of 18.6% ± 0.9%, 13.9% ± 1.8%, and 17.6% ± 2.8%, respectively (Plates 8 to 10; Figure 42). From 2012 to 2018, Sites 1,2,3 and 4 had an average HCC of 26.0% ± 3.3%.

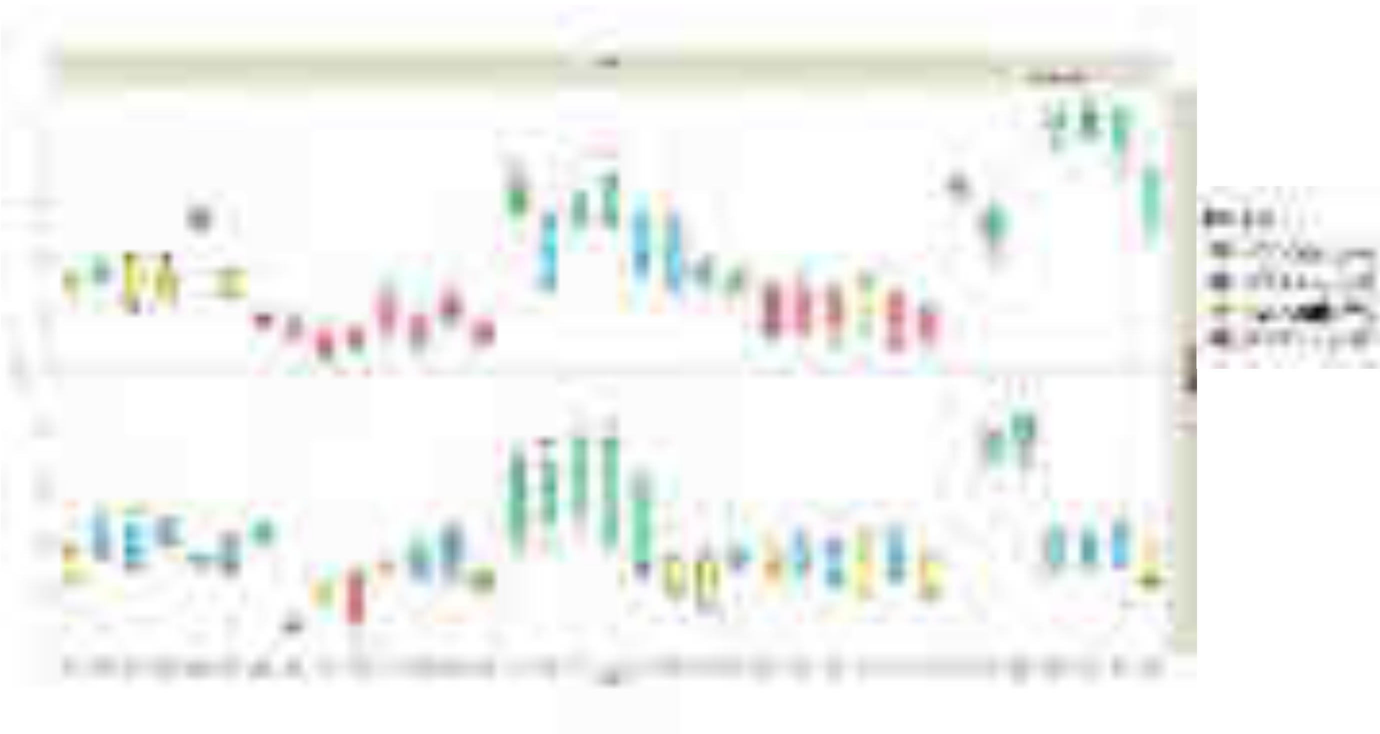

Figure 42 Box and whiskers plot of coral cover for Tubbataha stations from 2012 to 2018. Error bars indicate +/- 1 standard error.

7.4 Change in Hard Coral Cover

At the location level, linear regression was used to determine if there were any statistically significant changes in all of the sites revisited in Tubbataha. Overall, there was no significant change over time ($p=0.9212^{ns}$; Table 2). The same analysis was done at the site level, and Sites 2, 3, and 4 show significant changes while Site 1 and Jessie Beazley showed no significant differences (Table 12). To determine further which stations contribute to these changes, linear regression was done at the station level. This reveals that half (five out of the ten) of the stations show statistically significant changes over time (Table 12). The relationship of hard coral with time in Stations 3A and 4A is considered moderately strong based on their Pearson's correlation coefficients (r=0.5, r=0.4, respectively, Table 2) while Stations 2B, 3B, and Jessie Beazely A reveal strong relationships between HCC and time (r=0.7, r=0.6, r=0.7, respectively, Table 2). Station 2B shows a positive trend based on its rate of change; this means that hard coral cover in this station increased by 3.1% from 2012-2018 (Table 12). This is in contrast to the pattern for Stations 3A, 3B, 4A, and Jessie Beazley A whose hard coral covers decreased by 3.5%, 5.5%, 1.6%, and 8.0%, respectively.

*Table 12 Linear regression of HC at different levels i.e. location, site, and station level wherein ns=P>0.05; * = p≤0.05; ** =p≤0.01; *** =p≤0.001.*

	p-values	Coefficient of Determination (r^2)	Pearson's Correlation (r)	Rate of change (b)
WHOLE LOCATION	0.9212^{ns}	0.003%	0.01	0.1
SITE LEVEL:				
SITE 1	0.8469^{ns}	0.1%	0.02	-0.1
SITE 2	0.0003***	17.8%	0.4	1.9
SITE 3	<0.0001***	33.3%	0.6	-4.5
SITE 4	0.0413*	6.0%	0.2	-1.1
JESSIE BEAZLEY	0.1701^{ns}	4.9%	0.2	-4.9
STATION LEVEL:				
STATION 1A	0.4413^{ns}	1.8%	0.1	-0.7
STATION 1B	0.3099^{ns}	3.1%	0.2	0.5
STATION 2A	0.0809^{ns}	8.9%	0.3	0.8
STATION 2B	**<0.0001*** **	**42.7%**	**0.7**	**3.1**
STATION 3A	**0.0006*** **	**30.1%**	**0.5**	**-3.5**
STATION 3B	**<0.0001*** **	**37.4%**	**0.6**	**-5.5%**
STATION 4A	**0.0178***	**15.9%**	**0.4**	**-1.6**
STATION 4B	0.3095^{ns}	3.1%	0.2	-0.6
JESSIE BEAZLEY A	**0.001*** **	**46.2%**	**0.7**	**-8.0%**
JESSIE BEAZLEY B	0.2223^{ns}	8.2%	0.3	-1.74

TAUs Diversity

The average number of TAUs for all stations in Tubbataha in 2018 is 19 ± 1. Three monitoring stations are classified under Diversity Category B, namely stations 1B (23 ± 1 TAUs), 2B (24 ± 0 TAUs) and 4B (23 ± 1 TAUs). Jessie Beazley B is the only station with Diversity Category C, with an average of 20 ± 2 TAUs. The rest of the monitoring stations fall under Diversity Category D, each having up to 18 TAUs.

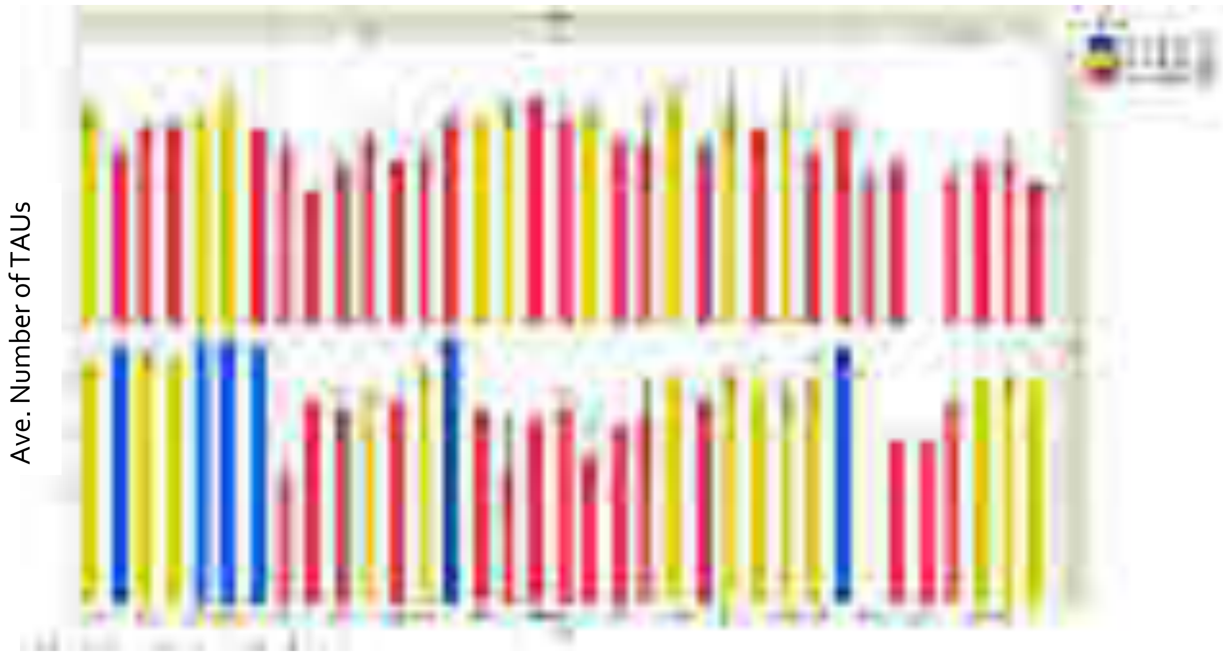

Figure 43 Bar graphs of TAU diversity per year for all sites/stations. Error bars indicate +/- 1 standard error.

7.5 Change in TAUs diversity

TAU diversity in Tubbataha did not show any significant change at the location level (p=0.1003 ^{ns}; Table 13) from 2012 to 2018. Sites 1, 3, 4, and Jessie Beazley also did not show any statistically significant changes at the site and station levels (Table 13). Site 2, on the other hand, showed a statistically significant change at the site (p<0.0001; Table 3) and station level (2A p=0.0299*; 2B p<0.0001***; Table 13). The relationship between the number of TAUs and year for Stations 2A and 2B can be described as a moderate and a strong relationship, respectively, using the Pearson's coefficient (r=0.4 and r=0.8, Table 3) as basis. The rate of change is below two TAUs for both stations. This means that every year from 2012 to 2018, Stations 2A and 2B increased in diversity by one and two TAUs. It is worth noting that the TAUs diversity in Station 2B has been steadily improving since 2016 (Figure 43).

*Table 13 Linear regression of TAUs at different levels i.e. location, site, and station level wherein ns=P>0.05; * = p≤0.05; ** =p≤0.01; *** =p≤0.001.*

	p-value	Coefficient of Determination (r^2)	Pearson's Coefficient (r)	Rate of change
LOCATION LEVEL	0.1003^{ns}	0.8%	0.1	0.2
SITE LEVEL:				
SITE 1	0.2971^{ns}	1.6%	0.1	0.2
SITE 2	<0.0001***	29.8%	0.5	1.1
SITE 3	0.5125^{ns}	0.6%	0.1	-0.2
SITE 4	0.6700^{ns}	0.3%	0.1	0.1
JESSIE BEAZLEY	0.7305^{ns}	0.3%	0.1	0.2
STATION LEVEL:				
STATION 1A	0.4395 ^{ns}	1.8%	0.1	0.2
STATION 1B	0.2055 ^{ns}	4.8%	0.2	0.3
STATION 2A	0.0299*	13.5%	0.4	0.6
STATION 2B	<0.0001***	59.4%	0.8	1.6
STATION 3A	0.1372 ^{ns}	6.6%	0.3	-0.5
STATION 3B	0.8602 ^{ns}	0.1%	0.0	0.1
STATION 4A	0.5419 ^{ns}	1.1%	0.1	-0.2
STATION 4B	0.1752 ^{ns}	5.5%	0.2	0.4
JESSIE BEAZLEY A	0.7798 ^{ns}	0.4%	0.1	-0.2
JESSIE BEAZLEY B	0.2487 ^{ns}	7.3%	0.3	0.6

Discussion

The stations that have a decreasing trend in hard coral cover (HCC) i.e., Stations 3A, 3B, 4A, and Jessie Beazley A have moderate to moderately strong Pearson's correlation coefficients. This indicates that these stations should be carefully observed for any more changes in the succeeding resurveys. The changes in HCC in Stations 3A and 3B could be related to large fields of *Isopora brueggemanni* rubble in the deeper portions of the stations (Plate 11), which may have been created by logs and payao floats that hit the reef (Eneria and Licuanan, 2017). Rubble moving around due to strong water movement could further destabilize the substrate and damage more coral. A similar situation may exist in Jessie Beazley A where foliose growth forms of *Montipora* dominate the reef. Foliose colonies of *Montipora* are considered 'competitive' corals (Darling, Alvarez-Filip, Oliver, Mcclanahan, & Cote, 2012). These types of corals are more competitive for space against other corals. They have faster growth rate, they can dominate a reef rapidly and they create canopies to get more sunlight. However these types of corals are more vulnerable to disturbances such physical breakage (Darling et al., 2012).

Results from Station 4A reveal decreasing hard coral cover. It is possible that the presence of thick tufts of turf algae (Plate 13) here may have limited the growth and settlement of new coral recruits. These stations should be carefully tracked in the future.

Station 2B is dominated by colonies of *Isopora*, massive *Porites* and *Favites*. These are 'stress-tolerant' corals that can withstand disturbances such as warming temperatures and breakage (Darling et al., 2012). This trait may have allowed the corals in this station to endure, but it does not explain its increasing HCC, especially since these same corals are also slow-growing.

However, it is of note that all rates of change are less than 5%, which is lower than the 9% minimum detectable change of the methods used at the station level (WY Licuanan *et al.* 2017). This suggests that these values are statistically significant but may not be ecologically significant, as these may be attributed to the spatial variability that accompanies re-randomization of transects within the sampling area during each monitoring survey (WY Licuanan *et al.* 2017).

A simple linear regression revealed that station 2A and 2B have statistically significant changes in coral TAU diversity over time. The change in the number of TAUs in 2B shows a stronger relationship than in Station 2A. Five TAUs were recorded in 2018 that were not recorded in the previous two years, namely ACAN, AF, COS, MON and PAV (Appendix 25). These may also be due to re-randomization of transects within the monitoring station during each survey.

These results indicate that hard coral cover and diversity have not significantly changed in the Tubbataha Reefs Marine Natural Park since reef monitoring activities in 2012, despite two ship groundings, typhoons, and two thermal events that affected the reefs within the monitoring period (see also WY Licuanan *et al.* 2017). However, changes at the site and station level will need to be examined again in the future. These, along with minor impacts, like discarded fishing lines in Jessie Beazley (Plate 12), may foreshadow future problems. "Blooms" of turf algae was also observed in stations 4A and 4B (Plate 13), and these may be caused by nutrient-rich run-off from the lagoon. The occurrence of this algae is notable, as Tubbataha substrate would usually be characterized by "clean" carbonate rock (WY Licuanan, personal communication).

The protection of Tubbataha has proven effective, as indicated by the stable coral cover and diversity at the location level. Other indicators of a healthy reef ecosystem include the large sizes, high density and diversity of reef fishes, the presence of apex predators such as various species of sharks, numerous individuals of endangered species such as hawksbill and green turtles and giant clams, as well as large, highly-prized fish species such as the bumphead parrotfish and humphead wrasse. All these were spotted in at least one reef monitoring station during the survey. Tubbataha remains a benchmark of a healthy reef ecosystem and remains one of the most well-protected reefs locally and globally (Nañola *et al.* 2011, AM Licuanan *et al.* 2017, WY Licuanan *et al.* 2017).

Plates

Plate 1 Reef shot of Jessie Beazley A, with divers for scale. The reef is dominated by foliose Montipora colonies.

Plate 2 Reef shot of Station 1B, with a diver for scale. The reef is dominated by corals with branching and massive life forms.

Plate 3 Reef shot of Station 3A, with a diver for scale. Deeper parts of the monitoring station are dominated by Isopora brueggemanni, while the shallower parts are dominated by a more several genera of massive corals.

Plate 4 Reef shot of Station 2B. A 75-m base transect is used to demarcate the deepest part of the monitoring station.

Plate 5 Reef shot of Station 3B, with a diver for scale. Station 3B shares similar coral distribution patterns as its replicate station, 3A.


Plate 6 Reef shot of Station 4B, with a diver for scale.


Plate 7 Reef shot of Jessie Beazley B, showing a diver taking photographs of the benthos using an aluminum monopod. Deeper parts of the reef are dominated by soft corals.

Plate 8 Reef shot of Station 1A.

Plate 9 Reef shot of Station 2A. Green turtles (Chelonia mydas) were observed in the reef during the time of survey.

Plate 10 Reef shot of Station 4A, with a diver for scale.

Plate 11 Large stands of Isopora brueggemanni in Station 3B are interspersed with vast fields of coral rubble (divers for scale).

Plate 12 Discarded fishing lines observed in Jessie Beazley A.

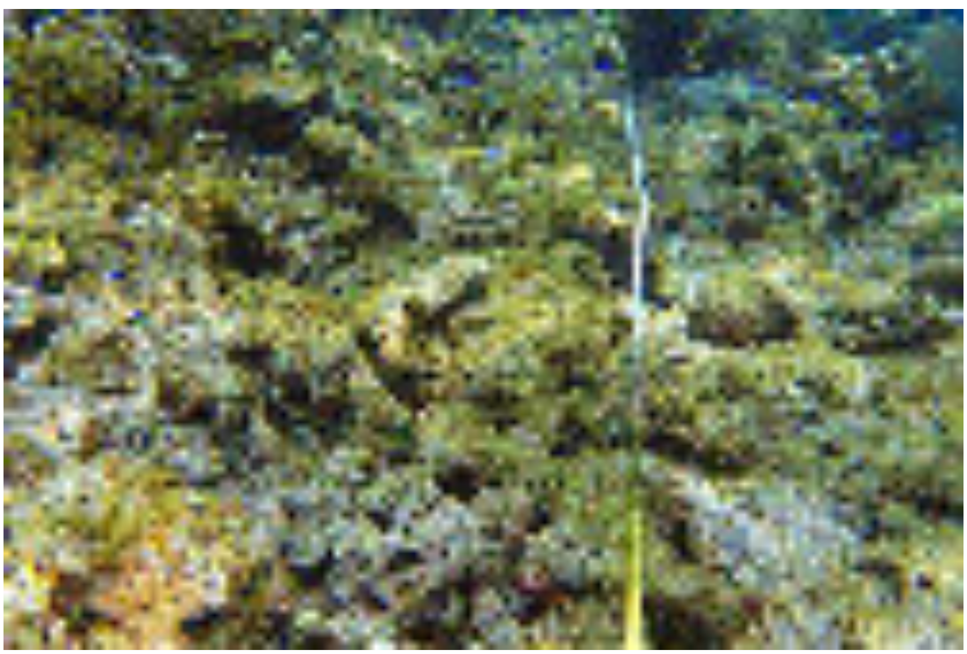

Plate 13 A layer of turf algae on the carbonate substrate observed in Station 4A.

7.6 Ship Grounding Sites

Method

Tubbataha is a highly protected coral reef ecosystem, but it is not free from human impacts. Such impacts include the two ship groundings, i.e., those of the USS Guardian and Min Ping Yu, in Tubbataha. The Avenger-class minehunter USS Guardian ship hit the northwest side of the South Atoll in January 2013, and then three (3) months later a Chinese fishing vessel, F/V Min Ping Yu, hit the southeast side of the North atoll. Estimated cost of the damage from the ship grounding was around Php 60M and Php 7M, respectively ("What Went Before: Damage wrought by USS Guardian", 2014; "Province Takes Custody of the Chinese Vessel, Min Ping Yu", 2014).

The two (2) ship grounding sites were surveyed using three 4m x 4m quadrat plots each (Figure 40). 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, one quadrat in a buffer zone, and another quadrat in a control zone. Simple linear regression was used to identify the rate of changes in the different zones of the grounding sites. Confidence interval was set at 95%.

Results

'Ground Zero' in Figure 6 refers to the area in USS Guardian site that was the most damaged, while the 'impact border' refers to the area that was moderately damaged. The 'adjacent control' refers to the area of the site where no damage from the grounding was observed. 'Small fragments' in Figure 45 refers to the area in Min Ping Yu site that was the most damaged while the 'large fragments' refers to the area that was moderately damaged. The 'adjacent control' refers to the area of the site where no damage from the grounding was observed.

The 'ground zero' quadrat in USS Guardian shows a statistically significant rate of change of 1.4% (p-value = 0.0010) in hard coral cover from 2014-2018 using a simple linear regression analysis. There was also a statistically significant decrease in algal assemblage cover by 2.7% (p-value <0.0001) for the same period. On the other hand, 'adjacent control' shows a significantly increasing trend of 2.5% (p-value 0.0217) in algal assemblage cover.

The quadrats in Min Ping Yu were established in similar situations as those at the USS Guardian site. The 'small fragments' quadrat represent the most damaged area in the reef. This is because the ship repeatedly hit the reef and the corals there were reduced to small fragments. These fragments were then subsequently scraped together by the ship to one side. Adjacent areas from the immediate grounding consisted of larger fragments created when ship's rudder hit massive corals. These areas are represented by the 'large fragments' quadrat. 'Adjacent control' quadrat represents part of the same reef that was not directly damaged by the grounding. None of the quadrats in Min Ping Yu show statistically significant changes in HCC, but the 'small fragments' quadrat shows a significant increase in algal assemblage cover of 8.1% (p-value < 0.0001) based on a simple linear regression analysis.

Figure 44. Hard coral cover (HCC) at and around the grounding site of the USS Guardian at the South Atoll of the Tubbataha Reefs. Error bars indicate +/- 1 standard error.

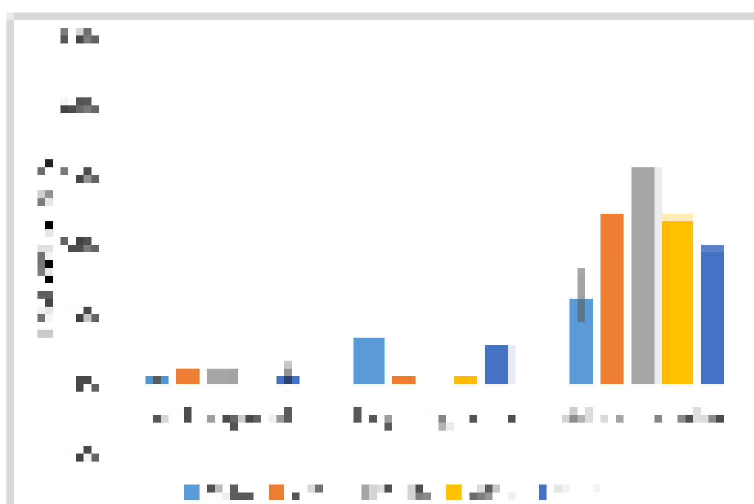

Figure 45. Hard coral cover (HCC) in fixed plots at and around the Ming Ping Yu grounding site at the North Atoll of the Tubbataha Reefs. Error bars indicate +/- 1 standard error.

Discussion

'Ground zero' in USS Guardian shows a significant increase in hard coral cover at a rate of 1.4%, and small corals (<5cm, Figure 46) are becoming common in the site. Although small, this rate of change is an indication that USS Guardian site is gradually recovering from the damage the ship has caused in 2013. This recovery is also evident in the decrease in algal assemblage cover by 2.7% (p-value <0.0001). As hard corals are slowly growing over the reef, the amount of available space is decreasing.

Figure 46. Small corals found in USS Guardian with a ruler for scale.

It is possible that the reason why the quadrats in Min Ping Yu did not show any signs of coral recovery is the rubble in the grounding site. This may have prevented the growth of new coral recruits because rubble does not serve as a stable substrate needed for the growth of corals (Flower et al., 2017; Figure 47).

Figure 47. Rubble was observed scattered all over the Min Ping Yu grounding site.

7.7 Southwest Wall

Method

A second method, the C-30 sampling method (Licuanan et al., in prep.), was used along with the photo-transect method to survey the benthos within the Southwest Wall station, with the main objective of detecting the presence and impact of a reported crown-of-thorns starfish outbreak. Using a sampling station with the same 25 × 75m dimensions, 1 × 1m photographs of the substrate were taken at randomly-determined positions. Two sets of random numbers were used to determine where photographs would be taken in the survey area – one set corresponding to the number of fin kicks from the previous imaging point and another set corresponding to one of the eight cardinal directions (i.e., N, S, E, W, NE, NW, SE, SW) which the diver will swim towards. A total of 50 photographs were taken using this methodology. A subset of 30 randomly selected photographs were then scored using modified TAUs that correspond to the TAU major categories (Appendix 25). This method was found to be more sensitive for detecting small impacts such as those created by crown-of-thorns outbreaks because of the higher number of replicates (30) compared to the five replicates of the photo-transect method (Licuanan et al. in prep.).

Results

Using the photo-transect method outlined in Part 1 of this report, it was found that the Southwest Wall's HCC is 15.6 ± 3.4% with an average diversity of 20 ± 2 hard coral TAUs. Thus, the Southwest Wall belongs to HCC Category D and Diversity Category C (AM Licuanan et al. 2017; Licuanan et al. in prep). The substrate is mostly comprised of algal assemblages, amounting to 72.4% ± 8.3% of the benthic composition. While the station was assessed because of a reported crown-of-thorns outbreak, crown-of-thorns sea stars were not encountered in the photo-transects.

Using the C-30 method, HCC in Southwest Wall was reported at 18.3% ± 2.7%, which does not differ significantly from the HCC values obtained using the photo-transect method (WY Licuanan et al. 2017). Like the photo-transect method, the C-30 method was also not able to detect the presence of crown of thorns starfish in the station.

Discussion

Based on observations, there were less than ten (10) COTS within the 25 × 75m sampling area. Most crown-of-thorns sea stars were located under crevices in the deeper areas of the station, which is why they were not encountered along the photo-transect and C30 images during the assessment. COTS along the base transect and near the drop-off were extracted by members of the Tubbataha Management Office staff. There were *Stylophora* colonies that were seen eaten by COTS, as denoted by the clean white skeleton with no live tissue and covered by a thin layer of turf algae (Figure 49).

Figure 48 Crown-of-thorns observed in Southwest Wall site with a hand as a scale.

Figure 49 Stylophora sp. colony that seems like it was freshly eaten by crown-of-thorns sea star.

Conclusion and Recommendation

Reefs that are protected from anthropogenic disturbance such as destructive and irresponsible fishing have a better chance of recovering from disturbances such as ship groundings, crown-of-thorns outbreaks, and warming due to climate change. In terms of hard coral cover, Tubbataha reefs have not changed significantly in the last few years, which indicates that their management and protection have been effective, and the natural processes in a coral reef are kept intact. Tubbataha is arguably the best protected reef system in the country and the results in this report shows that its protection should be continued for the years to come.

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APPENDICES

Appendix 1. Monitoring Team

REEF FISH

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Giannina Feliciano, De La Salle University

SEABIRDS

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Segundo Conales Jr, TMO PR
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Darius Cayanan, WWF-Philippines
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SGT Rudy N Tani PN
Angelito Y. Favila
Teri Aquino, Marine Wildlife Watch of the Philippines
Bonifaco Ganotice Jr., Field Assistant
Juan Carlos Gonzales, Professor and Curator, University of the Philippines, Los Baños
Philip Godfrey Jakosalem, Ornithologist, Philippines Biodiversity Conservation Foundation, Inc.
Lisa Paguntalan, Director, Philippines Biodiversity Conservation Foundation, Inc.

Appendix 2. Fish and Benthos Monitoring Sites

Sites	Stations	Latitude (N)	Longitude (E)
Site 2	Station 1A	8.93532 °	120.01302 °
	Station 1B	8.93781 °	120.00851 °
Site 4	Station 2A	8.89236 °	119.90627 °
	Station 2B	8.89128 °	119.90453 °
Site 6	Station 3A	8.75591 °	119.82881 °
	Station 3B	8.75186 °	119.82784 °
Site 7	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 1000m^2)	
	<26	Very poor
	27-47	Poor
	48-74	Moderate
	75-100	High
	>100	Very High
Density	Number of fish per 1000m^2)	
	< 201 fish	Very Poor
	202-676	Low
	677-2267	Moderate
	2268-7592	High
	> 7592	Very High
Biomass	mt/km^2	
	0-10	Very Low to Low
	11-20	Moderate
	21-40	High
	>40	Very High

Appendix 4. Mean density of fish families in deep (n=30) and shallow (n=30) areas in the regular monitoring sites.

Family	Common Names	Deep	Shallow
Acanthuridae	Surgeonfish	48.2	51.1
Acanthuridae:Nasinae	Unicornfish	16.2	7.8
Apogonidae	Cardinalfish	0.1	0.0
Balistidae	Triggerfish	18.5	32.6
Blenniidae	Bleniies	0.2	0.1
Caesionidae	Fusiliers	44.6	0.8
Carangidae	Jacks and Trevallies	4.3	2.0
Carcharhinidae	Sharks	0.3	0.0
Chaetodontidae	Butterflyfish	27.0	17.5
Cirrhitidae	Hawkfish	1.0	2.3
Dasyatidae	Stingrays	0.0	0.0
Ephippidae	Spadefish	0.1	0.0
Fistulariidae	Cornetfish	0.0	0.1
Haemulidae	Sweetlips	1.6	1.2
Holocentridae	Squirrelfish	26.5	1.1
Kyphosidae	Sea chubs	0.6	1.9
Labridae	Wrasses	34.9	85.5
Lethrinidae	Emperor fish	14.2	1.6
Lutjanidae	Snappers	10.5	2.0
Monacanthidae	Filefish	0.2	0.7
Mullidae	Goatfish	1.5	1.6
Muraenidae	Moray eels	0.2	0.1
Ostraciidae	Boxfish	0.1	0.2
Pinguipedidae	Sandperches	0.0	0.0
Pomacanthidae	Angelfish	17.9	15.4
Pomacentridae	Damselfish	547.7	531.2
Ptereleotridae	Gudgeonfish	0.7	4.5
Scaridae	Parrotfish	16.2	15.1
Scombridae	Tuna and Mackerel	0.1	0.0
Serranidae	Groupers	12.4	12.8
Serranidae: Anthiinae	Fairy basslets/Anthias	613.8	335.8
Siganidae	Rabbitfish	1.2	0.6
Tetraodontidae	Pufferfish	1.1	1.2
Zanclidae	Moorish Idol	4.2	3.1
Grand Total		**1466.5**	**1130.8**

Appendix 5. Mean biomass of fish families in deep (n=30) and shallow (n=30) areas in the regular monitoring sites.

Family	Common Names	Deep	Shallow
Acanthuridae	Surgeonfish	7.31	4.07
Acanthuridae:Nasinae	Unicornfish	22.17	8.29
Apogonidae	Cardinalfish	0.01	0.00
Balistidae	Triggerfish	7.91	12.04
Blenniidae	Bleniies	0.00	0.00
Caesionidae	Fusiliers	5.71	0.08
Carangidae	Jacks and Trevallies	26.70	4.87
Carcharhinidae	Sharks	6.69	1.75
Chaetodontidae	Butterflyfish	2.47	1.36
Cirrhitidae	Hawkfish	0.02	0.02
Dasyatidae	Stingrays	0.00	0.09
Ephippidae	Spadefish	0.12	0.16
Fistulariidae	Cornetfish	0.00	0.22
Haemulidae	Sweetlips	3.57	2.88
Holocentridae	Squirrelfish	6.71	1.48
Kyphosidae	Sea chubs	0.74	1.43
Labridae	Wrasses	2.07	1.62
Lethrinidae	Emperor fish	4.09	0.47
Lutjanidae	Snappers	6.69	1.69
Monacanthidae	Filefish	0.05	0.06
Mullidae	Goatfish	0.33	0.27
Muraenidae	Moray eels	0.22	0.06
Ostraciidae	Boxfish	0.02	0.03
Pinguipedidae	Sandperches	0.00	0.00
Pomacanthidae	Angelfish	0.76	0.39
Pomacentridae	Damselfish	5.39	3.28
Ptereleotridae	Gudgeonfish	0.00	0.02
Scaridae	Parrotfish	14.89	11.23
Scombridae	Tuna and Mackerel	0.39	0.00
Serranidae	Groupers	5.21	3.74
Serranidae: Anthiinae	Fairy basslets/Anthias	1.90	1.00
Siganidae	Rabbitfish	0.50	0.24
Tetraodontidae	Pufferfish	0.54	0.18
Zanclidae	Moorish Idol	0.92	0.58
Grand Total		**134.11**	**63.62**

Appendix 6. Results of the analysis of variance (ANOVA) between spatial and temporal means of fish biomass in in TRNP.

Anova: Two-Factor Without Replication

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
2013	5	1157.179289	231.4359	2678.9917
2014	5	581.0266174	116.2053	1002.6167
2015	5	1672.349578	334.4699	28489.861
2016	5	1094.286253	218.8573	3390.5731
2017	5	755.3677886	151.0736	1221.3391
2018	5	490.9218382	98.18437	170.3532
Seafan Alley	6	1122.363401	187.0606	3825.8432
Malayan Wreck	6	1124.025953	187.3377	15476.602
Delsan Wreck	6	988.456782	164.7428	5170.4934
Ko-ok	6	1623.837386	270.6396	30499.898
Jessie Beazley	6	892.4478423	148.7413	2772.0029

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
between years (2013-2018)	193974.1541	5	38794.83	8.1888786	0.000242	2.71089
between sites	53064.89498	4	13266.22	2.800257	0.053755	2.866081
Error	94750.04529	20	4737.502			
Total	341789.0944	29				

Appendix 7. Mean density of fish families in deep (n=6) and shallow (n=3) of Min Ping Yu grounding site.

Families	Common name	Deep	Shallow
Acanthuridae	Surgeonfish	61.33	79.67
Acanthuridae:Nasinae	Unicornfish	13.33	2.67
Apogonidae	Cardinalfish	0.33	0.00
Balistidae	Triggerfish	7.67	11.67
Blenniidae	Bleniies	1.67	0.33
Caesionidae	Fusiliers	21.33	18.67
Carangidae	Jacks and Trevallies	1.67	2.67
Chaetodontidae	Butterflyfish	23.67	20.33
Cirrhitidae	Hawkfish	0.00	1.67
Fistulariidae	Neddlefish	3.33	0.00
Haemulidae	Sweetlips	2.00	0.33
Holocentridae	Squirrelfish	24.67	12.33
Labridae	Wrasses	65.00	50.67
Lethrinidae	Emperorfish	6.00	13.67
Lutjanidae	Snappers	4.67	3.33
Monacanthidae	Filefish	3.00	0.67
Mullidae	Goatfish	2.00	5.67
Nemipteridae	Breams	0.00	0.67
Pempheridae	Sweepers	1.00	0.00
Pinguipedidae	Sandperches	0.00	0.67
Pomacanthidae	Angelfish	16.00	10.00
Pomacentridae	Damselfish	680.00	755.00
Ptereleotridae	Gudgeonfish	0.67	3.33
Scaridae	Parrotfish	16.00	24.00
Serranidae	Groupers	4.33	10.67
Serranidae: Anthiinae	Basslets/Anthias	260.67	149.33
Siganidae	Rabbitfish	2.00	0.00
Tetraodontidae	Pufferfish	1.00	0.33
Zanclidae	Moorish Idol	1.33	0.67
Grand Total		**1224.67**	**1179.00**

Appendix 8. Mean density of fish families in deep (n=6) and shallow (n=3) of USS Guardian grounding site.

Families	Common names	Deep	Shallow
Acanthuridae	Surgeonfish	32.00	95.67
Acanthuridae:Nasinae	Unicornfish	9.33	4.67
Balistidae	Triggerfish	91.67	67.33
Blenniidae	Blennies	0.33	0.00
Carangidae	Jacks and Trevally	0.33	3.67
Chaetodontidae	Butterflyfish	14.67	9.00
Cirrhitidae	Hawkfish	0.67	2.33
Ephippidae	Batfish	0.00	0.33
Haemulidae	Sweetlips	1.00	0.33
Holocentridae	Squirrelfish	23.67	0.67
Kyphosidae	Sea chubs	0.33	0.00
Labridae	Wrasse	49.67	175.00
Lethrinidae	Emperorfish	4.33	0.00
Lutjanidae	Snappers	3.33	1.67
Mullidae	Goatfish	0.00	3.33
Muraenidae	Moray Eel	0.00	0.33
Pomacanthidae	Angelfish	22.00	17.67
Pomacentridae	Damselfish	263.67	462.00
Ptereleotridae	Gudgeonfish	0.67	1.33
Scaridae	Parrotfish	28.33	12.67
Serranidae	Groupers	15.00	17.33
Serranidae: Anthiinae	Fairy basslets/Anthias	775.00	305.67
Tetraodontidae	Pufferfish	1.33	2.00
Zanclidae	Moorish idol	1.33	0.67
Grand Total		**1338.67**	**1183.67**

Appendix 9. Mean biomass of fish families in deep (n=6) and shallow (n=3) of Min Ping Yu grounding site.

Families	Common name	Deep	Shallow
Acanthuridae	Surgeonfish	3.90	5.18
Acanthuridae:Nasinae	Unicornfish	7.57	1.70
Apogonidae	Cardinalfish	0.03	0.00
Balistidae	Triggerfish	3.72	8.81
Blenniidae	Bleniies	0.01	0.00
Caesionidae	Fusiliers	2.72	0.66
Carangidae	Jacks and Trevallies	2.38	7.52
Chaetodontidae	Butterflyfish	2.35	1.07
Cirrhitidae	Hawkfish	0.00	0.01
Fistulariidae	Neddlefish	1.18	0.00
Haemulidae	Sweetlips	5.28	0.57
Holocentridae	Squirrelfish	4.34	1.61
Labridae	Wrasses	0.96	2.14
Lethrinidae	Emperorfish	2.52	1.41
Lutjanidae	Snappers	2.56	1.71
Monacanthidae	Filefish	0.17	0.06
Mullidae	Goatfish	0.35	0.57
Nemipteridae	Breams	0.00	0.07
Pempheridae	Sweepers	0.13	0.00
Pinguipedidae	Sandperches	0.00	0.02
Pomacanthidae	Angelfish	0.29	0.14
Pomacentridae	Damselfish	6.02	5.23
Ptereleotridae	Gudgeonfish	0.00	0.01
Scaridae	Parrotfish	10.41	9.06
Serranidae	Groupers	2.05	3.64
Serranidae: Anthiinae	Basslets/Anthias	0.82	0.46
Siganidae	Rabbitfish	1.53	0.00
Tetraodontidae	Pufferfish	0.02	0.04
Zanclidae	Moorish Idol	0.18	0.08
Grand Total		**61.50**	**51.77**

Appendix 10. Mean biomass of fish families in deep (n=6) and shallow (n=3) of USS Guardian grounding site.

Families	Common Names	Deep	Shallow
Acanthuridae	Surgeonfish	11.73	8.62
Acanthuridae:Nasinae	Unicornfish	26.30	4.52
Balistidae	Triggerfish	21.62	19.11
Blenniidae	Blennies	0.00	0.00
Carangidae	Jacks and Trevally	4.89	5.19
Chaetodontidae	Butterflyfish	2.26	0.63
Cirrhitidae	Hawkfish	0.05	0.05
Ephippidae	Batfish	0.00	0.94
Haemulidae	Sweetlips	5.68	0.52
Holocentridae	Squirrelfish	12.52	0.91
Kyphosidae	Sea chubs	0.60	0.00
Labridae	Wrasse	4.04	2.43
Lethrinidae	Emperorfish	0.95	0.00
Lutjanidae	Snappers	3.70	3.03
Mullidae	Goatfish	0.00	0.25
Muraenidae	Moray Eel	0.00	0.64
Pomacanthidae	Angelfish	2.07	1.20
Pomacentridae	Damselfish	3.58	2.29
Ptereleotridae	Gudgeonfish	0.00	0.00
Scaridae	Parrotfish	25.15	11.45
Serranidae	Groupers	6.83	6.08
Serranidae: Anthiinae	Fairy basslets/Anthias	2.28	0.77
Tetraodontidae	Pufferfish	0.13	0.10
Zanclidae	Moorish idol	0.19	0.14
Grand Total		**134.56**	**68.86**

Appendix 11. 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 12. Distance count estimate: objectives and methods

Objective	Documentation of: a) presence or absence of seabird species, and, b) the relative population trend variation throughout the year.
Method	Distance counts include all species of boobies, frigatebirds and terns including noddies.
	Distance counts are carried out as a monthly patrol routine at both Bird Islet and South Islet.
	It is carried out from a patrol boat while cruising at very low speed, e.g. 5 knots,interrupted by frequent stops every 80-100 meters parallel to the shoreline. If the birds show signs of being disturbed or start to fly, it may indicate the distance is too close and needs to be adjusted.
	The count is an estimation of the population numbers carried out by using a binocular with magnification 8 x 50 or 10 x 50. The method does not allow for exact count of population numbers.
	Two Park Rangers conducts the count: One counts/estimates the bird population numbers, the other serves as the recorder. At least two independent counts must be made.
Analysis	The average estimated figures are used to determine the population variation trend of the different species throughout the year.
Data storage	The results are reported on a quarterly basis to the TMO in Puerto Princesa. The TMO is responsible for storing and safeguarding the data.

Appendix 13. Inventory and population calculation methods per breeding species

Species	Calculation methods
Red-footed Booby	The active adult breeding population size is expressed as the number of nests multiplied by two = the minimum number of active adult breeding birds. This result is compared to the day-time number of adult birds counted. Whichever number is higher represents the daytime population. The in-flight counts of adult birds are added to the day-time results to determine the total minimum population present. Although more adult birds arrive during the night, there is currently no method used to capture this part of the population given that night counts with flashlight is unfeasible and highly disturbing to the birds.
	Reproduction rate is expressed as the number of nests, eggs and/or pulli, juvenile and immature birds recorded. For the immature population the result of the in-flight count is added.
Brown Booby	The active adult breeding population size is expressed as the number of nests multiplied by two = the minimum number of active adult breeding birds. This result is compared to the day-time number of adult birds. Whichever count is higher is used to represent the daytime population. The in-flight result of adult birds is added to the day-time result in order to express the minimum adult population present. Since more adult birds arrive during the night, two to three distance counts of adults present at dawn at 'Plaza' is carried out and the average result is compared with the combined results of the day-count and the inflight-count. Whichever of these two counts is the highest is used to express the maximum adult population present.
	The species only irregularly breeds at South Islet, the count result of adults from this islet is not included in the calculation of the total population of the species.
	Reproduction rate is expressed as the number of nests, eggs and/or pulli, juvenile and immature birds recorded. For the immature population the result of the in-flight count is added.
Pacific Reef Heron	The number of adult birds counted at high tide represents the breeding population. The result from South Islet is added to the result for North Islet in order to express the total population of the species present at TRNP.
	Reproduction rate is expressed as the number of nests, eggs and/or pulli and juveniles found during the inventory of other breeding species.

Barred Rail	The number of adult birds noted during counts of other breeding species represents the breeding population. Nests are difficult to find. If nest is found, one nest represents 2 adult birds
Brown Noddy	The population size is expressed as the number of nests found multiplied by two = minimum number of adult birds. This result is compared to the day-time number of adult birds counted next to the nests, the number of birds roosting along the shoreline and the results of the in-flight count. The total of these three counts is used to express the maximum adult population present.
	At South Islet in-flight counts are normally not carried out and only two data sets are used to determine the population at this islet: the number of nests found compared to the number of adult birds counted next to the nests, and the birds roosting along the shoreline and on the wreck. The results from South Islet are added to the result for North Islet in order to express the total population of TRNP.
	Reproduction rate is expressed as the number of nests, eggs and/or pulli and juveniles found during the inventory.
Black Noddy	The population size is expressed as the average number of nests found during two to three separate counts multiplied by two = the total active breeding population. This result is compared to the average result of two to three daytime counts of birds carried out during nest counts plus the results of the in-flight count. Whichever of the two count results is the highest is used. At South Islet in-flight counts are normally not carried out and only two data sets are used to determine the population at this islet: number of nests and number of adult birds counter. This result from South Islet is added to the result for North Islet in order to express the total population.
	Reproduction rate is expressed as the number of nests, eggs and/or pulli and juveniles found during the inventory. Because the nests mostly are placed at high elevation in the vegetation, total counts of eggs and pulli is only possible at Bird Islet. Identification of immature birds is not possible as they look similar to adults.

Great Crested Tern	Population size is expressed as the number of eggs and/or pulli and juvenile found multiplied by two = the minimum number of active breeding birds. This result is compared to the day-time number of adult birds counted next to the eggs/pulli/juveniles plus the average result of two to three high tide counts along the shoreline. Whichever of these two results is the highest is used to express the maximum breeding population. In years with very high population density, adult birds should be photo-ducmented using structured picture-taking of clearly demarcated and numbered sub-sections of the breeding areas. At South Islet where breeding only occurs irregularly, the number of territorial adult birds are counted and added to the figure for North Islet in order to express the total population of species present at TRNP.
	Since the species is not breeding at either Black Rock, Amos Rock or Ranger Station, the count result from these localities are not included in the population calculation.
	Reproduction rate is expressed as the number of eggs and/or pulli and juveniles found.
Sooty Tern	Population size is expressed as the number of eggs and/or pulli and juveniles recorded multiplied by two = minimum number of active breeding birds. This result is compared to the day-time number of adult birds counted next to the eggs/pulli/juveniles and to the average results of two to three late afternoon/evening estimates of the total adult population present at that time. Whichever of these three results is the highest is used to express the breeding population.. In years with very high population density, adult birds should be photo-ducmented using structured picture-taking of clearly demarcated and numbered sub-sections of the breeding areas.
	Since the species is not breeding at South Islet, the count result from this islet is not included in the calculation of the total population.
	Reproduction rate is expressed as the number of eggs and/or pulli and juveniles found during the inventory.
Eurasian Tree Sparrow	Population size is expressed as presence of adult birds since nests have not yet been found.

Appendix 14. Bird Islet Beach Erosion Assessment

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Introduction

Ocular observations in recent years have suggested that the Bird Islet is being eroded. This is alarming because the Bird Islet is basically just a small sand cay with a very low and flat topography. It is entirely covered in sand and is exposed to the open sea monsoon winds and occasional typhoons that visits the area. Fortunately, the Bird Islet is located within the North Atoll so it is well protected from strong offshore waves. Waves do reach the shores of Bird Islet but is significantly attenuated due to the shallow depths of the reef. The islet is located on the back reef so it may be exposed to stronger wave energy during the southwest monsoon due to a slight fetch within the lagoon. This report attempts to gain insights on sediment transport and potential erosion patterns in the Bird Islet, Tubbataha Reefs.

Methods

The beach sediment transport patterns were inferred from 2 aerial photographs taken by drones. The photographs were taken in May 2017 (Figure 1) and October 2017 (Figure 2), representing the end of the Northeast Monsoon and Southwest Monsoon, respectively. The two photographs were overlain using a GIS software to ensure that both have the same scale as close as possible. Beach sediment seasonal transport patterns were then inferred from these photographs.

Figure 1. Aerial photograph of Bird Islet take by a drone in May 2017

Figure 2. Aerial photograph of Bird Islet taken by a drone in October 2017

Results

The photo taken in May 2017 (Figure 1) represents the beach sediment distribution after the northeast monsoon. A spit is formed on the southwest end of the island resulting from the southward alongshore transport driven by waves reaching the island from the northeast. A spit is a protrusion into the water of the shoreline due to deposition of sediment. It is during the end of the northeast monsoon that the northern side of the island appears eroded, leaving rocks exposed.

Figure 2, which was taken in October 2017, shows the shape of the island representing beach sediment distribution after the southwest monsoon. Several spits are formed, including one on the north and one each on the eastern and western tips of the island. The orientation of the spits indicates the direction of sand transport and suggests that the direction of incident waves is from the west-southwest. The spits have a much more defined distal (end protruding into the water) and proximal (end attached to the island) ends perhaps suggesting more intense longshore transport of sand and longshore currents during the southwest monsoon. The southwest spit is of particular interest because this is the same spit formed during the northeast monsoon from sand transported from the northern part of the island. During the southwest monsoon, it swings to the east and probably loses some of that sand off the island, unable to return to the pool of sand that drifts around the island.

This seasonal cycle of sand transport repeats annually. If sand is removed from the island every southwest monsoon, erosion effects will eventually appear after a few seasonal cycles. Deposition areas of sand from the shore of the island which appear as light colored areas are very distinct in the May 2017 picture (Figure 1). The stronger longshore drift during the southwest monsoon is a function of the longer fetch in the southwest direction

The pathway of sand loss appears to be as follows (see Figure 3). During the northeast monsoon, sand is transported via longshore drift from the northern end of the island to the southwest tip to form the southern spit seen in Figure 1. However during the southwest monsoon, this sand is not transported back to the north shore but is instead pushed towards the east, some of which are deposited some distance from the shore. The inability of some of the sand to return to the north shore during the southwest monsoon results in a net loss of the sand budget of the island and, over time, leads to erosion.

Figure 3. Schematic of longshore transport/drift of beach sand during the Northeast Monsoon (top) and Southwest Monsoon (bottom).

Recommendations

The strength and characteristics of the monsoons slightly vary from year to year so it is important to continue taking aerial pictures of the island at the end of each monsoon season. This photographic database will be very important in trying to understand the beach sand dynamics in Bird Islet.

The observed erosion is clearly due to a net loss in the island's sand budget. Most of the sand loss occurs during the southwest monsoon when the Bird Islet is more exposed to stronger wave energies. Minimizing sand loss by installing structures that can attenuate wave energy coming from the west/southwest (e.g. reef balls or submerged breakers) is a possible option but must be done carefully such that longshore currents in the other parts of the island are not affected significantly.

The other option is to do active beach sand nourishment which is to physically pump sand deposited away from the shore back closer to the shore where it can eventually be incorporated into the seasonal sand migration. This will require identifying where these deposition areas are and using sand pumps to transfer the sand closer to shore. However, this may also affect the bird populations if the sand pump engines will disturb bird behavior.

Appendix 15. Condition of vegetation on Bird Islet and South Islet

Condition of vegetation on Bird Islet, May 2006 (baseline year) and 2016 to 2018

Trees/ Condition	Good (optimal)				Fair (moderately deteriorating)				Bad (severely deteriorating)				Total (live trees)				Dead trees			
	2006	2016	2017	2018	2006	2016	2017	2018	2006	2016	2017	2018	2006	2016	2017	2018	2006	2016	2017	2018
Dead trees																	82	75	ND	
Mature,live trees (> 3 feet)	10	1	0	**0**	49	4	0	**0**	11	16	10	**0**	70	21	10	**0**				
Small, live trees (2- 3 feet)	109	33	0	**0**	0	24	4	**3**	0	7	9	**10**	109	64	13	**13**				
Seedlings (< 1 feet)	50	14	0	**0**	0	9	9	**0**	0	2	7	**0**	50	25	16	**0?**				
Total	**169**	**48**	**0**	**0**	**49**	**37**	**13**	**3**	**11**	**25**	**26**	**10**	**229**	**110**	**39**	**13**	**82**	**75**	ND	ND
Note	Coco Palms 2018: 3																			

Condition of vegetation on South Islet May 2011 (baseline year) and 2015 to 2018

Trees/ Condition	**Good (optimal)**				**Fair (moderately deteriorating)**				**Bad (severely deteriorating)**				**Total (live trees)**				**Dead**			
	2011	**2016**	**2017**	**2018**	**2011**	**2016**	**2017**	**2018**	**2011**	**2016**	**2017**	**2018**	**2011**	**2016**	**2017**	**2018**	**2011**	**2016**	**2017**	**2018**
Dead trees																	6	16	ND	**ND**
Mature, live trees (> 3 feet)	70	0	0	**0**	28	20	9	**3**	5	40	23	**17**	103	60	32	**20**				
Small, live trees (2- 3 feet)	2	0	0	**0**	0	0	0	**0**	0	0	4	**0**	2	0	4	**0**				
Seedlings (< 1 feet)	19	0	0	**6**	0	0	8	**0**	0	0	0	**0**	19	0	8	**6**				
Total	**91**	**0**	**0**	**6**	**28**	**20**	**17**	**3**	**5**	**40**	**27**	**17**	**124**	**60**	**44**	**26**	**6**	**16**	**ND**	**ND**
Notes:	Coco Palms 2011: 13, 2016: 6, 2017:6, 2018:10																			

Appendix 16. Results of Park Rangers' inventory counts, August and November 2017 and February 2018 at Bird Islet and South Islet

Bird Islet	**2017**				**2018**
Species/Date	17 August	17 November			10 February
Red-footed Booby	Day Count	Day Count	Inflight	Total	Day Count
Adult	274	371	331	702	576
Sub-adult	5	7	21	28	18
Pullus/ juvenile	1	20		20	16
Eggs	3	36		36	12
Nests	63	139		139	106
Brown Booby					
Adult	78	1201	1292	2493	1047
Sub-adult	3	0	33	36	24
Pullus/ juvenile	6	215		215	452
Eggs	6	1388		1388	74
Nests	196	1074		1074	637
Masked Booby					
Adult		1		1	1
Great Crested Tern					
Adult	20	0		0	30
Sub-adult	2	0		0	0
Pullus/ juvenile	0	0		0	0
Eggs	10	0		0	0
Nests	0	0		0	0

Sooty Tern					
Adult	87	1077	0	1077	970
Sub-adult	5	697	0	697	17
Pullus/juvenile	0	167	0	167	0
Eggs	36	198	-	198	0
Nests	0	0	-	0	0
Brown Noddy					
Adult	642	378	-	378	1500
Sub-adult	20	0	-	0	20
Pullus/juvenile	131	0	-	0	0
Eggs	58	3	-	3	433
Nests	159	13	-	13	534
Black Noddy					
Adult	240	289	-	289	976
Sub-adult	6	0	-	0	0
Pullus/juvenile	17	0	-	0	1
Eggs	32	2	-	2	80
Nests	24	5	-	5	141

South Islet	**2017**		**2018**
Species/Date	17 August	17 November	10 February
	Day Count	Day Count	Day Count
Red-footed Booby			
Adult	322	175	458
Sub-adult	6	2	29
Pullus/ juvenile	5	16	20
Eggs	2	25	0
Nests	95	53	207
Brown Booby			
Adult	20	2	24
Sub-adult	0	0	0
Pullus/ juvenile	0	0	0
Eggs	0	0	0
Nests	0	0	0
Great Crested Tern			
Adult	0	0	0
Sub-adult	0	0	0
Pullus/juvenile	1	0	0
Eggs	0	0	0
Nests	0	0	0
Sooty Tern			
Adult	0	0	0
Sub-adult	0	0	0
Pullus/ juvenile	0	0	0

Eggs	0	0	0
Nests	0	0	0
Brown Noddy			
Adult	366	1	0
Sub-adult	17	0	0
Pullus/ juvenile	0	0	0
Eggs	25	0	0
Nests	119	36	0
Black Noddy			
Adult	137	1	0
Sub-adult	4	0	0
Pullus/juvenile	0	0	0
Eggs	16	0	0
Nests	226	0	0

Appendix 17. Population results and population trend of breeding seabirds in TRNP April to June 1981 – 2018.

Source: Kennedy 1982, Manamtam 1996, WWF Philippines 1998-2004 and TMO 2004-2018. Baseline years are underlined .

Species/ Numbers	1981	1995	1998	2000	2001	2002	2003	2004	2005	2006	2007	2008
Ground-breeders Sub-total	**13,388**	**3,949**	**1,744**	**4,695**	**7,529**	**7,635**	**2,804**	**5,200**	**13,825**	**16,957**	**7,746**	**10,534**
Masked Booby	150	1	0	0	0	0	0	0	0	0	0	0
Brown Booby	3,768	**1)** 2,060	1,716	1,045	850	577	623	856	1,877	1,108	1,016	1,059
Brown Noddy	2,136	643	0	500	37	775	115	336	590	1,035	530	800
Great Crested Tern	2,264	335	0	150	414	4,160	2,064	2,808	7,858	6,894	4,700	4,875
Sooty Tern	5,070	**1)** 910	28	3,000	6,228	2,123	2	1,200	3,500	7,920	>1,500	3,800
Tree-breeders Sub-total	**156**	**7,128**	**3,250**	**3,502**	**7,042**	**5,003**	**1,630**	**3,240**	**8,353**	**8,727**	**7,902**	**10,403**
Red-Footed Booby	9	0	0	2	44	43	20	2,435	1,947	1,877	2,902	2,513
Black Noddy	147	7,128	3,250	3,500	6,998	4,860	1,610	805	6,406	6,850	> 5,000	7,890
TOTAL	**13,544**	**11,077**	**4,994**	**8,197**	**14,571**	**12,638**	**4,434**	**8,440**	**22,178**	**25,684**	**15,648**	**20,937**

Notes: 1) End of March data. 2) Based on Park Rangers distance count 1 June 2014. 3) Based on Park Rangers count 9 August 2014. 4) Based on Park Rangers egg count 14 Feb 2015

Species/ Numbers	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Trend (%)
Ground-breeders Sub-total	**9,721**	**18,669**	**13,592**	**18,383**	**15,988**	**16,448**	**27,193**	**27,654**	**29,940**	**35,878**	**+ 168**
Masked Booby	0	0	0	0	0	0	0	1	1	1	**- 99**
Brown Booby	1,018	1,438	1,846	1,879	1,690	1,632	2,403	3,122	3,535	3,367	**- 11**
Brown Noddy	1,570	1,575	2,042	1,492	1,688	1,862	2,583	2,096	4,209	3,470	**+ 62**
Great Crested Tern	4,433	4,790	6,160	8,653	9,794	**2)** 7,730	<12,387	3,880	17,097	17,752	**+ 684**
Sooty Tern	2,700	10,866	3,544	6,359	2,816	**3)** 5,224	**4)** 9,820	8,555	>5,098	11,288	**+ 123**
Tree-breeders Sub-total	**9,525**	**9,975**	**10,746**	**11,776**	**12,858**	**10,630**	**11,718**	**11,101**	**7,278**	**5,916**	**+ 3,695**
Red-Footed Booby	2,220	2,331	2,395	2,340	2,202	3,074	3,492	2,141	2,087	1,443	**- 41**
Black Noddy	> 7,305	7,644	8,351	9,436	10,656	7,556	8,226	8,716	5,191	4,473	**- 37**
TOTAL	**19,246**	**28,644**	**24,338**	**30,159**	**28,846**	**27,078**	**38,911**	**38,549**	**37,218**	**41,794**	**+ 208**

Appendix 18. Seabird breeding data from Bird Islet and from South Islet, April to June 2004-2018

Source: WWF Philippines 2004 and TMO 2004 to 2018

Species/Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Red-footed Booby															
Immatures	398	1,455	606	597	780	477	677	795	799	426	134	206	80	97	89
Pulli/1st year juv.	> 35	71	105	116	69	180	88	171	243	312	277	240	49	43	39
Eggs	+	+	+	+	+	+	+	68	>166	>185	>57	>46	> 49	55	74
Nests	279	217	225	404	361	367	451	369	739	848	431	379	315	177	223
Brown Booby															
Immatures	0	81	26	55	55	61	126	110	140	62	51	28	66	157	264
Pulli/1st year juv.	43	2	7	12	91	126	125	225	46	28	266	200	22	175	95
Eggs	1	0	18	95	317	48	106	52	69	532	466	55	144	43	25
Nests	117	43	250	89	497	453	513	575	507	618	816	726	887	886	376
Brown Noddy															
Immatures	0	2	0	0	0	4	1	1	2	3	5	2	0	2	14
Pulli/1st year juv.	0	0	0	0	0	0	0	0	0	0	0	6	109	223	493

Eggs	0	0	0	3	17	126	438	253	>147	>607	679	571	620	1,005	581
Nests	115	124	20+	25+	218	384	653	571	709	771	931	960	1,048	1,917	1,644
Black Noddy															
Immatures	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pulli/1st year juv.	0	0	0	0	0	0	0	0	0	0	0	30	193	8	74
Eggs	ND	+	0	+	+	430	+	+	>80	>700	>351	>299	>191	406	468
Nests	208	3,203	1,131	1,734	1,824	2,680	3,525	3,827	4,282	5,156	3,778	2,397	1,634	1,205	1131
Great Crested Tern															
Immatures	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Pulli/1st year juv.	0	2,100	0	0	0	0	0	0	0	0	0	0	0	29	832
Eggs	0	1,829	0	0	0	515	2,341	498	1,456	3,939	2,120	4,280	6,800	8,620	7,461
Sooty Tern															
Immatures	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Pulli/1st year juv.	0	1,750	0	458	0	846	0	1,764	0	1,258	0	3,538	0	2,549	680
Eggs	9	0	0	63	2	3	5,515	2	1,534	146	37	52	166	0	4,964

Appendix 19. In-flight to roost statistics of boobies and noddies on South Islet May 2014 to 2018

Species/ Numbers	2014	2015	2016	2017	2018	2014	2015	2016	2017	2018	2015	2016	2017	2018
Red-footed Booby						**Brown Booby**					**Black & Brown Noddy** (Note 1)	(Note2)	(Note 3)	
	May 8: 16.30 - 17.30	May 8: 16.30 - 18.30	May 13: 16.30 - 18.30	May 9: 16.30 - 18.30	May 12: 16.30 - 18.30	May 8: 16.30 - 17.30	May 8: 16.30 - 18.30	May 13: 16.30 - 18.30	May 9: 16.30 - 18.30	May 12: 16.30 - 18.30	May 8: 16.30 - 18.30	May 13: 16.30 - 18.30	May 9: 16.30 - 18.30	May 12; 16.30 - 18.30
Adult: Daytime	401	366	508	584	262	7	22	40	31	160	6,856	> 4,421	4,126	2,179
In-flight	910	1,020	1,018	633	355	2	28	24	11	144	4,678	> 3,500	< 2,066	1,335
Adjusted to 2-hour period	1,820	-	-	-	-	4	-	-	-	-	4,678	-	-	-
Total	2,221	1,386	1,526	1,217	617	11	50	64	42	304	11,534	7,921	6,192	3,514
% in-flight population	82.0%	73.6%	66.7%	52.0%	57.5%	18.2%	56.0%	37.5%	26.2%	47.4%	40.6%	44.2%	33.4%	38.0%
											Black Noddy			
Immature: Daytime	68	58	32	27	22	0	2	0	4	32	**Adult:** Daytime		2,921	1,347
In-flight	1	Not counted	21	1	23	0	No count	Not counted	1	0	In-flight	(Note 4)	1,461	681

Adjusted to 2-hour period	2	-	-	-	-	0	-	-	-	-	Adjusted to 2-hour period	-	-	-
Total	70	> 58	63	28	45	0	>2	0	5	32	**Total**		4,382	2,028
% in-flight population	2.9%	-	33.3%	3.6%	51.1%	0%	-	-	20.0%	0%	% in-flight population		33.3%	33.6%
											Brown Noddy			
											Adult: Daytime		1,205	832
											In-flight	(Note 4)	605	654
											Adjusted 2-hour period		-	
											Total		1,810	1,486
											% in-flight population		33.4%	44.0%

Note 1: Predominantly Black Noddy

Note 2: From 16.30 to 17.30 more birds left the islet compared to the number of birds arriving. From 17.30 to 18.00 more birds arrived than left the islet

Note 3: 578 individuals left the islet while 2,644 flew in = 2,066

Note 4: Number extrapolated based on ratio between the numbers of the two species present during daytime

Appendix 20. In-flight to roost statistics of boobies and noddies on Bird Islet May 2005 to May 2018

Species/ Numbers	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
	May 10: 17.00-18.15	Apr 28: 16.30-18.25	May 8: 16.30-18.20	May 7: 16.00-18.00	May 7: 16.30-18.30	May 13: 16.30-18.30	May 9: 16.30-18.30	May 10: 16.30-18.30	May 10: 16.30-18.30	May 9: 16.30-18.30	May 9: 16.30-18.30	May 11: 16:30 – 18.30	May 10: 16.30 – 18.00	May 14: 16.30 – 18.00
	Red-footed Booby													
Adult: Daytime	823	655	631	1,241	686	982	1,011	382	830	950	1,499	248	343	470
In-flight	960	1,171	2,082	1,272	1,534	1,259	1,259	1,680	779	813	602	367	527	356
Adjusted to 2-hour period	1,012	1,222	2,271	-	-	-	-	-	-	-	-	-	-	-
Total	1,835	1,877	2,902	2,513	2,220	2,241	2,270	2,062	1,609	1,763	2,101	615	870	826
%-in-flight population	55%	65%	78%	51%	69%	56%	55%	81%	48%	46%	29%	25%	25%	43.1%
Average In-flight (%)	**51.9%**													
Immature: Daytime	514	>205	275	239	179	194	106	174	125	61	111	8	29	24
In-flight	588	401	295	541	298	483	483	249	149	5	37	17	40	20
Adjusted to 2-hour period	941	419	322	-	-	-	-	-	-	-	-	-	-	-
Total	1,455	>606	597	780	477	677	589	423	274	66	148	25	69	44
%-in-flight population	65%	69%	54%	69%	63%	71%	82%	59%	54%	8%	25%	25%	25%	45%
Average In-flight (%)	**51.0%**													
	Brown Booby													
Adult: Daytime	629	405	660	691	650	930	1,338	1,060	968	834	1,505	1,920	2,257	1,295
In-flight	360	225	326	368	368	508	508	819	722	798	848	1,202	1,278	2,072
Adjusted to 2-hour period	576	235	356	-	-	-	-	-	-	-	-	-	-	-
Total	1,205	640	1,016	1,059	1,018	1,438	1,846	1,879	1,690	1,632	2,353	3,122	3,535	3,367

%-in-flight population	48%	37%	35%	35%	36%	35%	28%	44%	43%	49%	36%	25%	25%	62%
Average In-flight (%)							**38.4%**							
Immature: Daytime	22	20	21	20+?	22	30+	96	81	30	13	1	25	74	127
In-flight	37	6	31	34	39	96	14	59	32	39	25	41	78	105
Adjusted to 2-hour period	59	6	34	-	-	-	-	-	-	-	-	-	-	-
Total	81	26	55	54	61	126	110	140	64	51	26	66	152	232
%-in-flight population	73%	23%	62%	63%	64%	76%	13%	42%	50%	76%	96%	62%	51%	45%
Average In-flight (%)							**56.9%**							
	Brown Noddy													
Adult: Daytime							618	607	1,004	1,045	1,031	992	2,953	1,984
In-flight							1,124	525	142	239	378	358	51	
Total							1,742	1,132	1,146	1,284	1,409	1,350	3,004	
%-in-flight population							65%	46%	12%	19%	27%	27%	2%	
Average In-flight (%)							**28.3%**							
	Black Noddy													
Adult: Daytime							421	1,098	2,243	1,506	2,412	711	800	2,445
In-flight							1,334	1,124	272	318	132	84	9	
Total							1,755	2,222	2,515	1,824	2,544	795	809	
%-in-flight population							76%	51%	11%	17%	5%	11%	1%	
Average In-flight (%)							**24.6%**							

Appendix 21. Systematic list of avifaunal records from Jessie Beazley Reef, South Islet, Bird Islet, and Ranger Station from 12 to 15 May 2018.

Breeding species are indicated in bold letters. Taxonomic treatment and sequence follows IOC/Wild Bird Club of the Philippines 2017. Threat status follows Gonzales, J.C.T. *et al* 2018. Scientific review and update of the National List of Threatened Terrestrial Fauna of the Philippines.

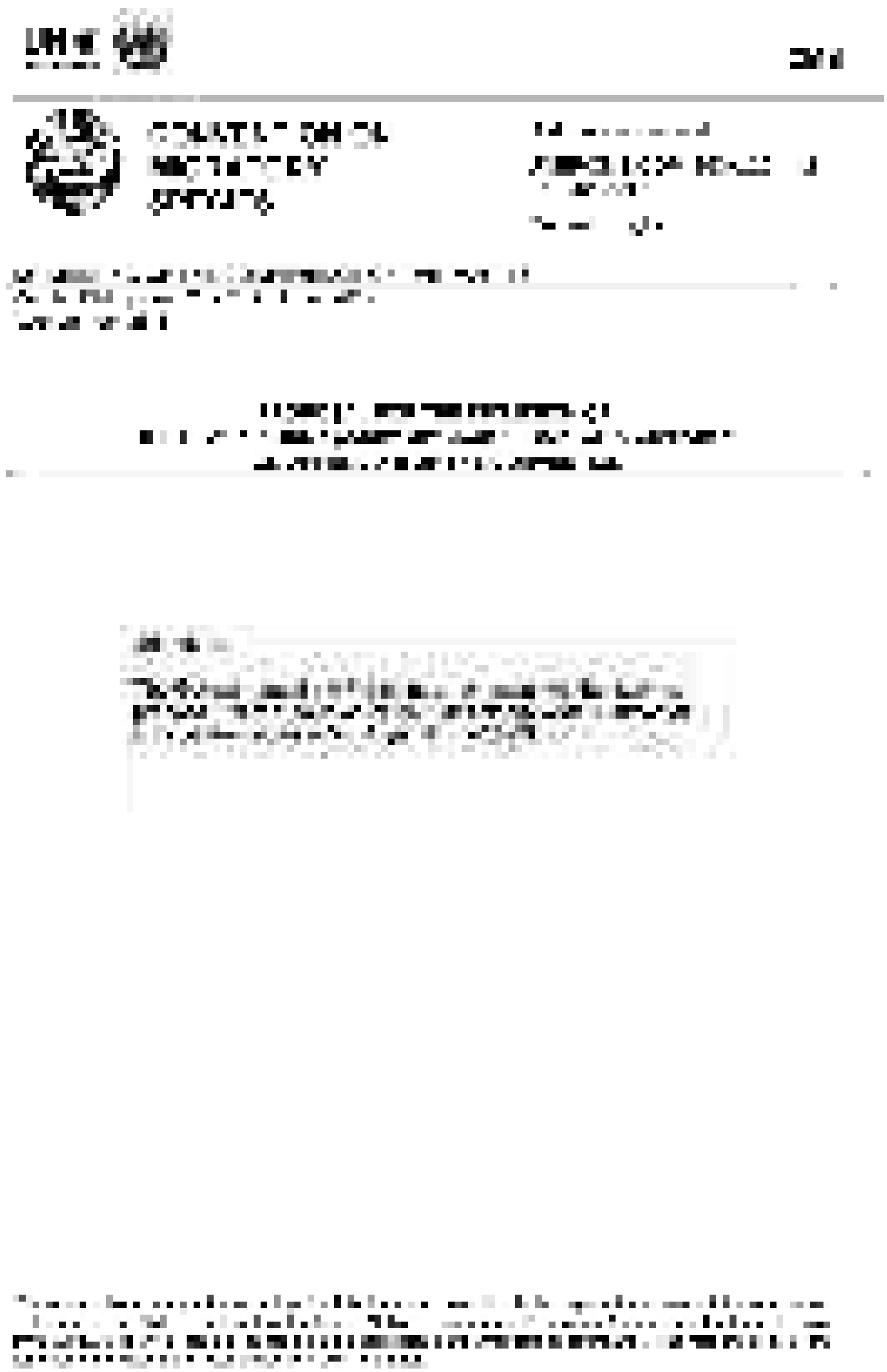
CR – Critically Endangered, EN – Endangered, VU – Vulnerable, OTS – Other Threatened Species, Near Threatened, LC – Least Concern

Abundance (within Sulu Sea) Threat Status (IUCN and National Red List)	Species name	Number of individuals	Locality	Notes
Resident Uncommon LC	**Pacific Reef Heron** *Egretta sacra*	Adults: 4 Nests: 0	Bird Islet	Dark phase
		Adults: 1	Ranger Station	Dark phase
		Adults: 4 Nests: 3	South Islet	Dark phase. 3 eggs in one nest
Migrant Rare CR	Christmas Frigatebird *Fregata andrewsii*	Juv: 1	Bird Islet	
Migrant Locally uncommon LC	Great Frigatebird *Fregata minor*	Adults: 1	Bird Islet	Adult female 1
		Adults: 8	South Islet	Adult female 3, male 5
		Immature: 1	Jessie Beazley Reef	
Migrant Locally uncommon LC	Lesser Frigatebird *Fregata ariel*	3	Bird Islet	Immatures
	Unidentified Frigatebird *Fregata sp.*	9	South Islet	Distance too far for identification
Extirpated Rare OTS	**Masked Booby** *Sula dactylatra*	Adult: 1	Bird Islet	Male. Same bird as first found in May 2016.
Resident Locally uncommon LC	**Red-footed Booby** *Sula sula*	Adults: 826 Immatures: 44 Pulli/juv.: 19 Nests: 122 Eggs: 42	Bird Islet	More than 10 pairs breeding on the structures for Black Noddy
		Adults: 617	South Islet	

		Immatures: 45 Pulli/juv.: 20 Nests: 101 Eggs: 32		
Resident Rare EN	**Brown Booby** *Sula leucogaster*	Adults: 3,367 Immatures:232 Pulli/juv.: 95 Nests: 376 Eggs: 25	Bird Islet	
		Adults: 304 Immature: 32	South Islet	Not breeding
		Adult: 1	Jessie Beazley Reef	
Resident Uncommon LC	**Barred Rail** *Gallirallus torquatus*	1	Bird Islet	
Resident Fairly Common LC	Watercock *Gallicrex cinerea*	1	Bird Islet	Male. Died 15 May
		1	South Islet	Male
Migratory Common NT	Grey-tailed Tattler *Heteroscelus brevipes*	1	Bird Islet	
Migrant Fairly common LC	Ruddy Turnstone *Arenaria interpres*	7	Bird Islet	Breeding plumage
		1	Ranger Station	Breeding plumage
Resident Locally Rare VU	**Brown Noddy** *Anous stolidus*	Adults: 1,984 Pullus: 353 Nests: 992 Eggs: 357	Bird Islet	High Number of juveniles, suggest early breeding start
		Adults: 1,486 Immatures: 14 Pullus: 140 Nests: 652 Eggs: 224	South Islet	
Resident Locally Rare EN	**Black Noddy** *Anous minutus*	Adults: 2,445 Pullus: 74 Nests: 682 Eggs: 306	Bird Islet	4th time with pulli in May. Nearly adult birds were found on the artificial breeding structures
		Adults: 2,028 Pullus: 0 Nests: 449 Eggs: 162	South Islet	Massive decline due to lack of breeding trees
Resident Fairly Common VU	**Great Crested Tern** *Thalasseus bergii*	Adults: 17,752 Pullus: 832 Eggs: 7,461	Bird Islet	Highest number ever recorded; one count suggested a population even higher. High number of pulli suggest

				early breeding start for small part of population
		Adults: 7	South Islet	Not breeding
		Adults: 173	Ranger Station	Not breeding
		Adults: 80	Jessie Beazley Reef	Not Breeding
Resident Locally Rare VU	**Sooty Tern** *Onychoprion fuscata*	Adults: 11,288 Pulli: 680 Juv: 12 Eggs: 4,964	Bird Islet	Highest number ever recorded. Number of pulli suggest early breeding start for small part of population
		Adults: 4	South Islet	Not breeding
		Adults: 90	Jessie Beazley Reef	Not breeding
Migrant? Rare LC	Roseate Tern *Sterna dougallii*	6	Ranger Station	Roosting, then flew north
Resident Uncommon LC	Black-naped Tern *Sterna sumatrana*	11	Bird Islet	Passing by
		2	Ranger Station	
Resident Common LC	Collared Kingfisher *Todiramphus chloris*	1	Bird Islet	Left islet and passed research vessel first day
Migrant Common LC	Barn Swallow *Hirundo rustica*	1	Bird Islet	
Migrant Uncommon LC	Lanceolated Warbler *Locustella lanceolata*	1	Bird Islet	
Migrant Uncommon LC	Chestnut-cheeked Starling *Agropsar philippensis*	1	Bird Islet	
Resident Common LC	**Eurasian Tree Sparrow** *Passer montanus*	7	Bird Islet	
		6	South Islet	
Migrant Common LC	Eastern Yellow Wagtail *Motacilla tschutschensis*	3	Bird Islet	
		2	South Islet	

Appendix 22. Inclusion of the Black Noddy (*Anous minutus*) subspecies *worcesteri* on Appendix II of the Convention on Migratory Species



PROPOSAL FOR THE INCLUSION OF THE BLACK NODDY (*Anous minutus*) SUBSPECIES *worcesteri* ON APPENDIX II OF THE CONVENTION ON THE CONSERVATION OF MIGRATORY SPECIES OF WILD ANIMALS

A. PROPOSAL

This proposal is for the inclusion of Black Noddy (*Anous minutus*) subspecies *worcesteri* in Appendix II. The species is classified as Endangered on account of a very small population which breeds within a tiny area of occupancy on just two islets, and is projected to decline by more than 70 per cent over the next 10 to 11 years.

B. PROPONENT: Government of the Republic of the Philippines

C. SUPPORTING STATEMENT

1. Taxonomy

1.1 Class: Aves
1.2 Order: Charadriiformes
1.3 Family: Laridae
1.4 Genus, species or subspecies, including author and year:
Anous minutus worcesteri (McGregor, 1911)
1.5 Scientific synonym(s): No known synonyms
1.6 Common name(s), in all applicable languages used by the Convention:
English - Black Noddy
French - Noddi noir
Spanish - Tiñosa menuda

2. Overview

Anous minutus subspecies *worcesteri* breeds only on two islets totaling 1.6 hectares in the Tubbataha Reefs Natural Park, the Philippines where a small population has been in continuous decline since 2013 due to massive loss in breeding habitat. When not breeding, it covers a relative small oceanic area which mainly included Indonesia and Malaysia. The species would benefit from enhanced protection and concerted management actions plans.

3. Migrations

3.1 Kinds of movement, distance, the cyclical and predictable nature of the migration

The Black Noddy subspecies *worcesteri* leaves its breeding ground at the Central Sulu Sea (Tubbataha Reefs Natural Park, the Philippines) in November and returns mainly in March (Jensen and Songco 2016). [illegible]. A juvenile bird banded on Bird Islet, Tubbataha Reef Natural Park was documented from Lankayan Island, Sabah, Malaysia three years after it was banded. There is only one recent record of the subspecies from within the Philippines outside of the Sulu Sea suggesting that migration takes place to nearby Indonesian and Malaysian waters and occasionally west to Sri Lanka (Dickinson 1991).

3.2 Proportion of the population migrating, and why that is a significant proportion

The entire adult population of the subspecies is migratory and is absent from the breeding grounds and the Philippines for about four months annually.

Appendix 23. Comparison of the landscape and habitats seen from the Permanent Photo Documentation Sites on Bird Islet and South Islet, May 2004 and May 2018

Bird Islet

Viewing angle for photo: facing NW 180º   Comments: panoramic view   Photo name code: BI 01   **Photo Doc Site NI No. 01 - 2004**

Film no: 33, 34, 35, 36   Date: May 7, 2004   Photo no (camera): 4 shots

Photo name code: B1 01   Comments: 7 shots (Stitched by Microsoft ICE)   Date: May 15, 2018   **Photo Doc Site NI No. 01 - 2018**

Photo nos.: DSC 7926 – 32   Photo credit: Teri Aquino

Viewing angle for photo: facing NE 038º

Film no: 27, 28

Photo name code: BI 02

Comments: 2 shots good angle

Photo no (camera):

Photo no (negative):

Date: May 7, 2004

Photo name code: BI 02

Photo nos.: DSC_7876 - 83

Comments: 7 shots

Date: May 15, 2018

Photo Doc Site NI No. 02 - 2018

Viewing angle for photo: facing S 165º

Comments: 3 shots panoramic view

Photo name code: BI 03

Film no: 22, 23, 24

Date: May 7, 2004

Photo no (camera):

Photo name code: BI 03

Comments: 10 shots stitched (Microsoft ICE)

Photo credit: Teri Aquino

Date: May 15, 2018

Photo no (camera): DSC_7900 - 10

Photo Doc Site NI No. 04 - 2004

Viewing angle for photo: facing E 067º

Film no: 14

Photo no (negative):

Photo name code: BI 04

Photo no (camera):

Comments: 1 shot plaza

Date: May 7, 2004

Photo name code: BI 04

Comments: 1 shot plaza

Date: May 15, 2018

Photo nos.: DSC_7851

South Islet:

Viewing angle for photo: facing S 060º

Comments: shot includes view of parola at the background

Photo name code: SI 01

Photo name code: SI 01

Date: May 15, 2018

Comments: single shot including parola at the background

Photo no (camera): DSC_7851

Appendix 24. Species which were seen frequently (≥70%) in the Tubbataha Reefs. Species are listed in order of decreasing frequency. The frequency score is listed before each name. After each species name, the abundance index is given in parentheses.

100%	Pseudanthias hutchi (4)
100%	Pseudanthias tuka (4)
100%	Pseudanthias smithvanizi (3.875)
100%	Macolor macularis (3.25)
100%	Chaetodon kleinii (3)
100%	Cephalopholis argus (2.875)
100%	Caranx melampygus (2.875)
100%	Lutjanus bohar (2.875)
100%	Myripristis kuntee (2.125)
100%	Chaetodon lunulatus (2.125)
100%	Chaetodon vagabundus (2.125)
100%	Pygloplites diacanthus (2.125)
100%	Chaetodon auriga (2)
100%	Chaetodon baronessa (2)
100%	Chaetodon ornatissumus (2)
100%	Heniochus chrystostomus (2)
100%	Heniochus singularis (2)
100%	Aethaloperca rogaa (1.75)
100%	Nemateleotris magnifica (2.125)
100%	Chromis analis (3.875)
100%	Chromis retrofasciata (4)
100%	Dascllus reticulatus (3.875)
100%	Pomacentrus auriventris (4)
100%	Pomacentrus brachialis (3.875)
100%	Bodianus diana (dictynna) (2.5)
100%	Pseudocheilinus evanides (2.25)
100%	Pseudocheilinus hexataenia (2)
100%	Thalassoma lunare (3)
100%	Acanthurus pyroferus (2.75)
100%	Naso vlamingii (3.5)
100%	Balistapus undulatus (2.375)
100%	Balistoides viridescens (2.125)
100%	Melichthys niger (2.875)
100%	Melichthys vidua (3)
100%	Arothron nigropunctatus (2.25)
87.5%	Cephalopholis urodeta (2.375)
87.5%	Centropyge vroliki (2.375)
87.5%	Sargocentron spiniferum (2)
87.5%	Psecuochromis bitaeniata (1.875)
87.5%	Chaetodon melanotus (1.875)
87.5%	Heniochus varius (1.875)
87.5%	Trimma erdmanni (1.875)
87.5%	Chaetodon ulietensis (1.75)
87.5%	Triaenodon obesus (1.5)
87.5%	Meiacanthus atrodorsalis (1.625)
87.5%	Plagiotremus rhinorhynchus (1.75)
87.5%	Amblyglyphidodon aureus (3.375)
87.5%	Chromis amboinensis (3.375)
87.5%	Chromis margaritifer (3.5)
87.5%	Chromis ternatensis (3.5)
87.5%	Chromis weberi (3.375)
87.5%	Chromis xanthura (3.375)
87.5%	Pomacentrus bankanensis (2.5)
87.5%	Pomacentrus lepidogenys (2.875)
87.5%	Bodiaus mesothorax (1.75)
87.5%	Cheilinus undulatus (1.875)
87.5%	Gomphosus varius (2.125)
87.5%	Halichoeres hortulanus (2.125)
87.5%	Labroides dimidiatus (2.625)
87.5%	Thalassoma hardwickii (2.25)
87.5%	Chlorurus microrhinos (1.75)
87.5%	Scarus dimidiatus (2.125)
87.5%	Zanclus cornutus (2.5)
87.5%	Acanthurus thompsoni (3.5)
87.5%	Naso lituratus (1.75)
87.5%	Zebrasoma scopas (2.375)
75%	Pterocaesio tile (3)
75%	Lutjanus gibbus (2.25)
75%	Lutjanus decussatus (1.75)
75%	Sargocentron caudimaculatum (1.625)
75%	Chaetodon ephippium (1.5)
75%	Chaetodon lunula (1.5)
75%	Chaetodon ocellicaudus (1.5)
75%	Chaetodon punctofasciatus (1.5)
75%	Gracilia albomarginata (1.375)
75%	Aphaerus furca (1.375)
75%	Parupeneus cyclostomus (1.375)
75%	Cephalopholis cyanostigma (1.25)
75%	Pomacanthus xanthometopon (1)
75%	Ecsenius dilemma (1.875)
75%	Chromis atripectoralis (2.5)
75%	Chromis atripes (2.625)
75%	Chromis viridis (3)
75%	Dascyllus trimaculatus (2.5)
75%	Plectroglyphidodon dickii (2)
75%	Epibulus brevis (1.125)
75%	Halichoeres chrysus (2.125)

75%	Labroides bicolor (1.5)
75%	Thalassoma amblycephalum (2.625)
75%	Thalassoma jansenii (1.5)
75%	Thalassoma purpureum (1.5)
75%	Cetoscarus bicolor (now ocellatus) (1.5)
75%	Siganus vulpinus (1.5)
75%	Acanthurus japonicus (1.75)
75%	Acanthurus nigrofuscus (2)
75%	Naso brevirostris (1.875)
75%	Naso hexacanthus (2.25)
75%	Arothron meleagris (1.375)

Appendix 25. Taxonomic Amalgamation Units (TAUs) (van Woesik et al. 2009; Licuanan et al. 2017)

Hard 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)
Bleached coral (BLEC)
Caulastrea (CAU)
Coeloseris (COE)
Coscinaraea (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 (HEL)
Hydnophora (HYD)
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 (CMR)
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)
Algal Assemblage (AA)
Algal assemblage (AA)
Crustose/coralline algae (CA)
Dead coral (DC)
Dead coral with algae (DCA)
Disease (DIS)
Abiotic (AB)
Gravel (GRV)
Rubble (R)
Sand (S)
Sedimentary rock (RCK)
Silt (SI)
Macroalgae (MA)
Codium (COD)
Kappaphycus (KAPP)
Macroalgae (MA)
Sargassum (SARG)
***Halimeda* (HA)**
Halimeda (HA)
Other biota (OT)
Acanthaster (COTS)
Corallimorpharian (COR)
Diadema (DIA)
Gorgonian (GORG)
Isis (ISIS)
Other invertebrates (OT)
Seagrass (SG)
Soft coral (SC)
Sponge (SP)
Zoanthid (ZO)

Appendix 26. Top ten hard coral TAUs of Tubbataha reef stations

Station 1A	Station 1B	Station 2A	Station 2B
Porites (encrusting)	*Echinopora*	*Isopora*	*Isopora*
Echinopora	*Millepora*	*Porites* (massive)	*Porites* (massive)
Porites (branching)	*Platygyra*	*Millepora*	*Favites*
Porites (massive)	*Favites*	*Montipora* (encrusting)	*Cyphastrea*
Platygyra	*Favia*	*Acropora* (corymbose)	*Pocillopora*
Favia	*Porites* (encrusting)	*Pocillopora*	*Acropora* (branching)
Favites	*Porites* (branching)	*Acropora* (plate)	*Goniastrea*
Pocillopora	*Porites* (massive)	*Goniastrea*	*Platygyra*
Montipora (encrusting)	*Acropora* (branching)	*Favia*	*Millepora*
Millepora	*Heliopora*	*Favites*	*Montipora* (encrusting)
Station 3A	**Station 3B**	**Station 4A**	**Station 4B**
Isopora	*Isopora*	*Favites*	*Favites*
Favites	*Favites*	*Porites* (massive)	*Millepora*
Porites (massive)	*Favia*	*Platygyra*	*Porites* (massive)
Favia	*Porites* (massive)	*Goniastrea*	*Platygyra*
Platygyra	*Goniastrea*	*Pocillopora*	*Cyphastrea*
Acropora (corymbose)	*Platygyra*	*Millepora*	*Porites* (encrusting)
Millepora	*Symphyllia*	*Montipora* (encrusting)	*Goniastrea*
Goniastrea	*Millepora*	*Favia*	*Isopora*
Cyphastrea	*Porites* (branching)	*Porites* (encrusting)	*Porites* (branching)
Pocillopora	*Montipora* (encrusting)	*Symphyllia*	*Echinopora*
Jessie Beazley A	**Jessie Beazley B**	**Southwest Wall**	
Montipora (foliose)	*Millepora*	*Millepora*	
Montipora (encrusting)	*Acropora* (branching)	*Pocillopora*	
Acropora (plate)	*Isopora*	*Favites*	
Acropora (branching)	*Pocillopora*	*Porites* (massive)	
Isopora	*Heliopora*	*Platygyra*	
Montipora (branching)	*Platygyra*	*Favia*	
Porites (massive)	*Porites* (encrusting)	*Cyphastrea*	
Acropora (corymbose)	*Porites* (encrusting)	*Montipora* (encrusting)	
Porites (encrusting)	*Porites* (massive)	*Goniastrea*	
Heliopora	*Favites*	*Porites* (encrusting)	