TUBBATAHA REEFS NATURAL PARK
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Contributors:

Maria Retchie Pagliawan, Rowell Alarcon, Gerlie Gedoria, Sandra Enn Bahinting, Jennifer Deauna–Mendoza, Wilfredo Licuanan, Eznairah-Jeung Narida, Arne Jensen, Angelique Songco, Segundo Conales Jr., Jeffrey David, Cresencio Caranay Jr., Noel Bundal, Rodulf Anthony Balisco

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Executive Summary

The Near Threatened Leopard Coral Grouper (Plectropomus leopardus) swims by the wall of the reef. Photo by: Yvette Lee

This report summarizes the findings from the monitoring of reef benthos, coral recruitment, reef fish, and seabird populations, which are important indicators of reef health. A special assessment on coral bleaching was also conducted to monitor the effects of the recent rise in sea surface temperature in Tubbataha. These results will serve as input to the management effectiveness evaluation of the park and will be used in the formulation of policies.

A total of two hundred ninety-six (296) species of fish were identified in this survey. The deep areas had higher mean species richness at 63 species per 500 m^2 (sp/500m^2), than its shallow counterpart with only 47 sp/500m^2. These values fell under the 'very high' and 'high' categories, respectively, according to the modified categories of healthy reef fish communities. Overall, the reefs' mean species richness remained under the category "very high" with a value of 55 sp/500m^2.

The average biomass was estimated at 117 grams per m^2 (g/m^2), higher than the previous year's value of 102 grams per m^2. The prominent families of Acanthuridae: Nasinae (unicornfish) and Scaridae (parrotfish) were the major contributors to the 30% increase in biomass. The mean fish biomass in TRNP is considered "very high" based on Philippine standards. The biomass in the deep areas was relatively higher (149 g/m^2) than its shallow counterpart (85 g/m^2). The annual variations in biomass values were mainly influenced by the presence or absence of species from families of unicornfish, jacks, trevallies, and triggerfish that were commonly observed in groups and had large sizes; hence significantly affecting the overall biomass outputs.

The mean density estimate was 1,680 individuals per 500 m^2 (ind/500m^2), not far from last year's 1,678 ind/500m^2. Fish density in deep areas was relatively higher (2,045 ind/500m^2), than the shallow areas (1,315 ind/500m^2). The mean fish density of the reef was considered 'high' according to Philippine standards.

Several species of interest that were recorded include Whitetip and Grey Reef Sharks, Tiger Shark, and Leopard Coral Grouper, listed as Near Threatened in the IUCN Red List. Furthermore, Vulnerable species such as Blacksaddle coral grouper, a school of Bumphead parrotfish, and Whale Shark were also observed. Humphead wrasse, classified as Endangered, was recorded in most of the sites.

The species richness inside and outside the impact area of the Min Ping Yu (MPY) grounding site fell under the 'very high' category. The biomass and density outputs outside the impact area were four and five times higher, respectively, compared to the impact area. The species richness inside and outside the impact area of the USS Guardian (USSG) grounding site was classified as 'high' and 'very high', respectively. Meanwhile, the total mean biomass and density outside the impact area were significantly higher than inside the impact area. Over the years, both grounding sites remained at the best category in terms of fish biomass and density based on the Philippine standard.

Blunt-head parrotfish (Chlorurus microrhinos) functions as small excavators/bioeroders, by feeding on benthic algae and removing dead corals. Photo by: TMO/Giga Songco

The hard coral cover (HCC) in the shallow area was classified under Category B (33.3%), with an average of 19 coral TAUs generic diversity. The HCC of TRNP was higher than the average for the Sulu Sea Bioregion (28.4%). The average HCC in the four monitoring sites (Sites 1, 2, 3, and 4) in the Tubbataha atolls showed a significant annual decline of 1% from 2012-2020. This significant decrease in the trend of HCC was evident in Sites 3 and 4 in the South Atoll, coinciding with the 1.8% annual increase of algal assemblages (turf algae) for the same period in all four sites. Moreover, sponges were also observed in all sites but the cover in 2020 was highest in Site 2 (13.5 %) followed by Site 4 (7.2%). Outbreaks of sponges and increases in algal assemblages pose a variety of negative effects on the reef e.g., algal assemblages hinder the growth of small corals, while sponges can actively outgrow and kill benthic organisms.

The mean HCC in the deep area was 25.8%, with an average of 22 coral TAUs generic diversity. The highest HCC was recorded in Site 1 (31%) while the lowest was in Site 2 (24.7%). Algal assemblages, mostly turf algae, covered 36.7%, higher than the average HCC this year. The high percentage cover of algal assemblages in the deep areas was consistent with the findings in the shallow areas. Since 2012, a downward trend in HCC and an increase in algal assemblages were observed at both depths.

In the MPY grounding site, the HCC of the adjacent control (14.3%) was higher than the large fragment plot (10.8%) and eight times higher than the small fragment plot (1.7%). A steady increase in HCC was observed in the large fragments plot at an annual rate of 1.5% since 2014, while the small fragments plot showed a decrease of 1.4% from last year. Meanwhile, in the USSG grounding site, the impact border showed the highest HCC (11.2%) compared to ground zero (9.1%) and twice that of the adjacent control (5.4%). The HCC in ground zero continues to increase at an annual rate of 1.2% since 2014, while the impact border, with relatively stable cover for the past two years, regained its 2017 coral cover. However, the adjacent control or undamaged zone has not yet recovered from the drastic drop in HCC in 2017 and is still decreasing by 2.8% annually.

Coral recruits, with diameter of 1cm to <4cm, were also assessed in the monitoring sites. The average coral recruitment density in the shallow areas was 53.75 ind/m^2, which was higher than the previous year's. In the deep areas, the mean coral recruitment density was 61.67 ind/m^2, which was higher compared to 2019 (42.28 ind/m^2), and two times higher compared to the other reefs in Indo-Pacific region. Meanwhile, a lower density of coral recruits was observed in the shallow compared to deep areas, similar to last year's results.

The average coral recruit density in the MPY grounding site (23.37 ind/m^2) was higher than in the USSG grounding site (17.59 ind/m^2). The highest density in the MPY grounding site was recorded at the small fragments plot (30.55 ind/m^2), while the large fragment plot and adjacent control had 27.77 ind/m^2 and 11.80 ind/m^2, respectively. Meanwhile, the mean densities recorded at the USS Guardian grounding site were 22.91 ind/m^2 in the buffer zone, 17.36 ind/m^2 in the control zone, and 12.5 ind/m^2 in the impact zone. The control and buffer zones recorded an increase, while the impact zone declined compared to 2019.

Coral recruits thrive on stable substrates. The colored markings in the quadrat serves as guide for measuring the size of the recruit. Photo by: TMO/Rowell Alarcon

An increase in the incidence of coral bleaching was observed between May and June. This prompted the conduct of an additional trip to Tubbataha to re-assess the regular monitoring sites and quantify coral bleaching in July, which was the peak of sea surface temperature in the Sulu Sea. In the shallow areas, bleached hard corals ranged from 3.4% to 19.7%, while in the deep areas, bleaching ranged from 3.4% to 16.3%. Most of the hard corals that bleached included those that are branching in form, e.g., *Pocillopora, Acropora, Isopora, Seriatopora*, and *Montipora*. Bleaching was also recorded in some massive corals such as *Goniastrea, Porites,* and *Favites,* as well as in soft corals. The result of the reef benthos monitoring next year will be compared to the results of the May and July 2020 assessments, to describe the extent and severity of this bleaching episode in TRNP. Compared to other sites in the Philippines, the percentage of corals that bleached in Tubbataha was relatively lower. Up to 45% bleaching was recorded in Busuanga, Palawan, while up to 75% of the corals in Calatagan, Batangas bleached.

A total of 17 species of birds were identified during this year's inventory, bringing the total avifauna recorded in TRNP to 118 species. Among the bird species recorded were the Short-tailed Shearwater *Ardenna tenuirostris* (a first record) and the White-tailed Tropicbird *Phaethon leptura* (fourth sighting in Tubbataha). A total of 32,633 adult individuals of seven breeding seabird species were recorded. This was 17.76% higher than the previous year's count, mainly due to the increase in the numbers of Brown Booby, Great Crested Tern, and Sooty Tern. The Brown Noddy population showed a moderate decline in numbers while the adult population of the Red-footed booby decreased by 35% compared to 2019 and was 73% lower compared to the baseline inventory in 2004. The decrease reflected the loss of trees in the islets. This year, an adult male and female Masked Booby established their territory in Bird Islet.

White-tailed Tropicbird (Phaethon leptura) seen in Bird Islet. Photo by: Teri Aquino

The Black Noddy population has declined since 2013. Of the 10,650 adult birds recorded in 2013, only about 25% remained this year. The population decline mirrored the loss of breeding habitat in both islets. To address this loss of habitat in the islets, artificial structures made out of bamboo were constructed and nesting materials (cut grass, leaves, seaweeds) were provided in June and August 2019 and in May 2020. A 10% increase in the number of nests was recorded this year. The species now only breed on nine artificial nesting structures made out of bamboo on Bird Islet and on five structures on South Islet. In September 2020, six additional experimental nesting structures made of steel and PVC were installed in both islets in the hope of increasing the breeding population of Black Noddy in Tubbataha.

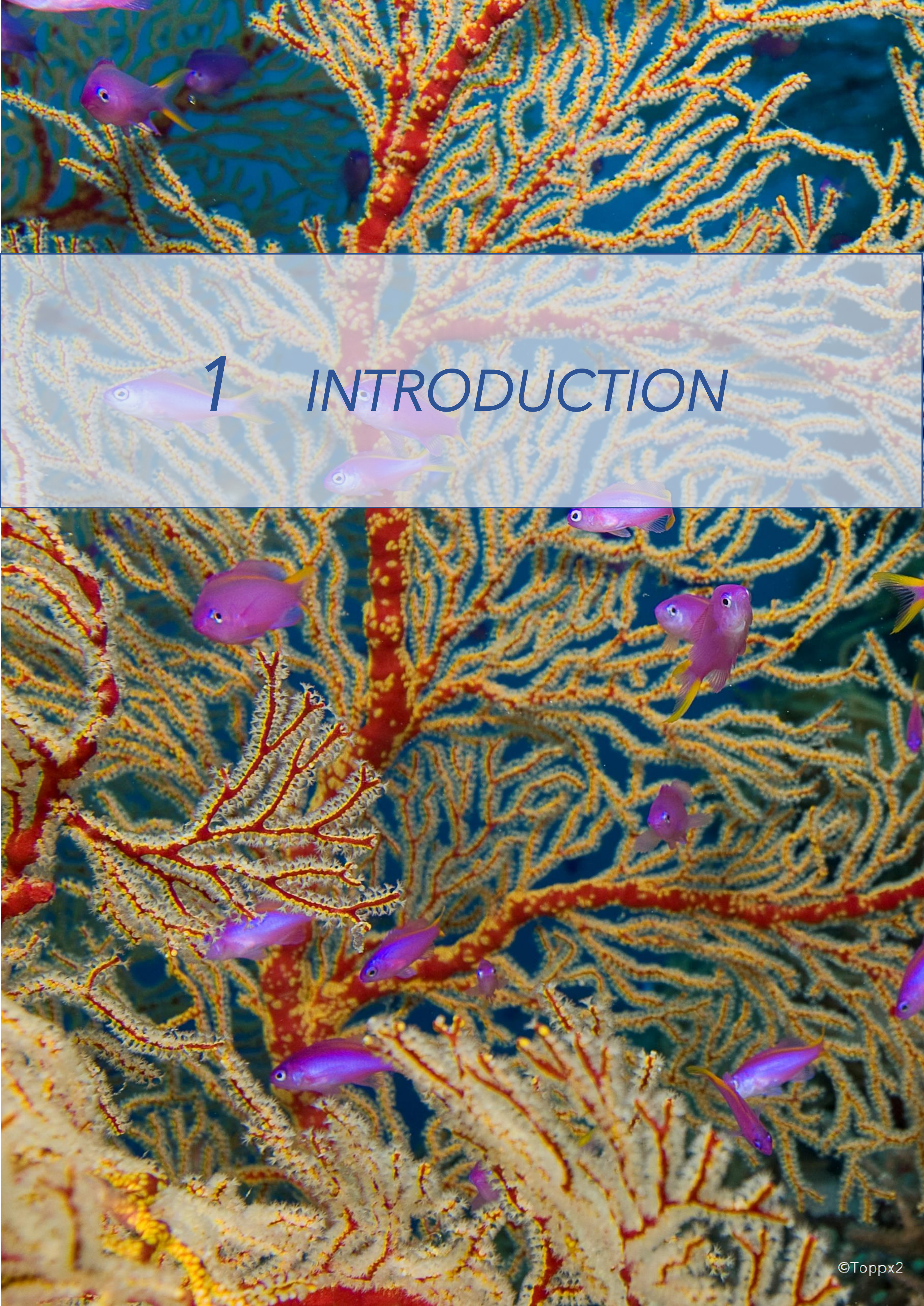
To restore the beach forest in both islets, TMO planted saplings of Anuling and a few Tree Heliotrope. A total of 430 saplings were planted – 329 in Bird Islet and 101 in South Islet, with an estimated survival rate of 75% to 90% recorded in August 2020.

Great Crested Tern rebuilds a colony in South Islet. Photo by: Teri Aquino

The land area of Bird Islet appears to have increased by 2.9%, from 18,760 m^2 in 1981 to about 19,297 m^2 in 2020. Meanwhile, the land area of South Islet increased by 81%, from 2,884 m^2 in 2018 to 5,222 m^2 in 2020. This increase was attributed to the expansion of the new sea wall when the Philippine Coast Guard commissioned the repair of the lighthouse for navigational reasons in 2019.

Lastly, the quality of Tubbataha waters remains excellent in terms of color and total suspended solids. Four of the 10 parameters measured slightly exceeded the maximum guideline set for Class SA under DAO 2016-08. These include oil and grease and fecal coliform. Slightly elevated values for oil and grease may have influenced by the construction of the new ranger station. Meanwhile, the slightly elevated value for fecal coliform is believed to have been caused by seabird guano in the waters around the islets. The mean values show that Tubbataha waters are within the highest level of water quality for marine areas.

Research and monitoring activities this year were made possible through the joint support of the Pilipinas Shell Foundation, Inc., and the Department of Environment and Natural Resources.



1 INTRODUCTION

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1.1 Overview

Coral reefs, being the most productive and biodiverse ecosystem in the world, provide essential services and goods to populations in coastal areas that value in the billions of dollars annually (Spalding and Grenfell 1997; Spalding *et al*. 2001; Costanza *et al*. 2014). However, since the pre-industrial period, the continuous emission of anthropogenic greenhouse gases contributed to the increasing global temperature, leading to climate change, and correlated with the increasing incidence of thermal anomalies across the tropics in recent decades (Heron *et al*. 2016; Lough *et al*. 2018). Thermal anomalies are critical disturbances recognized as a primary global challenge to the persistence of coral reefs (Darling and Cote 2018). These resulted in mass coral bleaching events across the tropics with increasing frequency, leading to global degradation of coral reef ecosystems (Hughes *et al*. 2018). Prominent examples of these events are the 1997-1999 and the recent 2014-2017 thermal anomalies, which prompted massive bleaching globally, including in the Philippines. The thermal anomaly in 1997-1999 triggered one of the most intense and massive bleaching events, causing a decrease of 46% in live coral cover in the Philippines (Arceo *et al*. 2001). In Tubbataha, 19% of hard corals were lost during the 1997-1999 bleaching event. Meanwhile, the 2014-2017 event did not cause as much damage despite the bleaching in other areas across the world (Licuanan *et al*. 2019).

Even coral reefs that are isolated from the pressures of anthropogenic activities are not entirely resistant to the impacts of prolonged elevated sea surface temperature (Cerutti *et al*. 2019). Although the lack of local disturbances could increase the probability of the reef to recover rapidly than those exposed to local stressors, the shorter return time between thermal anomalies could compromise and test this ability (Licuanan *et al*. 2016; Heron *et al*. 2017; Head *et al*. 2019). The establishment of fully protected marine areas was seen as the most cost-effective and practical strategy to create resilience against climate change, while the world is pursuing efforts to lessen carbon emissions to reduce global warming (Simard *et al*. 2016; Heron *et al*. 2017; Roberts *et al*. 2017).

Tubbataha Reef Natural Park (TRNP) is the largest no-take marine protected area in the Philippines (Dygico *et al*. 2013). It is situated in the Sulu Sea, one of the most diverse regions in the Coral Triangle (Veron *et al*. 2009; Sanciangco *et al*. 2013). The strict protection afforded to TRNP and its remoteness, are some reasons why it has maintained its ecological integrity and outstanding universal value as a UNESCO World Heritage Site.

Research and monitoring could reflect the overall condition of the reef, as well as the damages it has sustained from natural (e.g., coral bleaching) and anthropogenic (e.g., grounding) disturbances (Wilkenson *et al*. 2003). The results of this survey would also gauge the effectiveness of management strategies and interventions, and could be used in the formulation of science-based policies, as well as climate change adaptation strategies. Research and monitoring, being one of TMO's conservation programs, is designed to:

1. determine ecosystem health;
2. measure biophysical indicators of management effectiveness, and;
3. inform decision-making.

This year's report includes a discussion of the present condition of the reefs and an analysis of the temporal and spatial trends of fish and reef benthos. The methods recommended through DENR Technical Bulletin 2017-05 in conducting fish and reef benthos monitoring were applied since 2018. In response to the ongoing coral bleaching event in the country, a special assessment of coral bleaching was undertaken, applying the methodologies used in reef benthos monitoring. Seabird populations were surveyed in Bird and South Islets.

1.2 Monitoring design

Study Sites

TMO established five regular monitoring 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 station is provided in Annex 2. In each station, shallow (~5meters) and deep (~10meters) areas were assessed to acquire a better understanding of the condition of the reefs at varying depths. The two ship grounding sites, USS Guardian (USSG) and Min Ping Yu (MPY) have been monitored since 2013 to assess changes through time. This hierarchical sampling design is presented in Figure 1. Coral bleaching assessment was also conducted in the five regular monitoring sites. Meanwhile, seabird monitoring was conducted in the Bird and South islets.

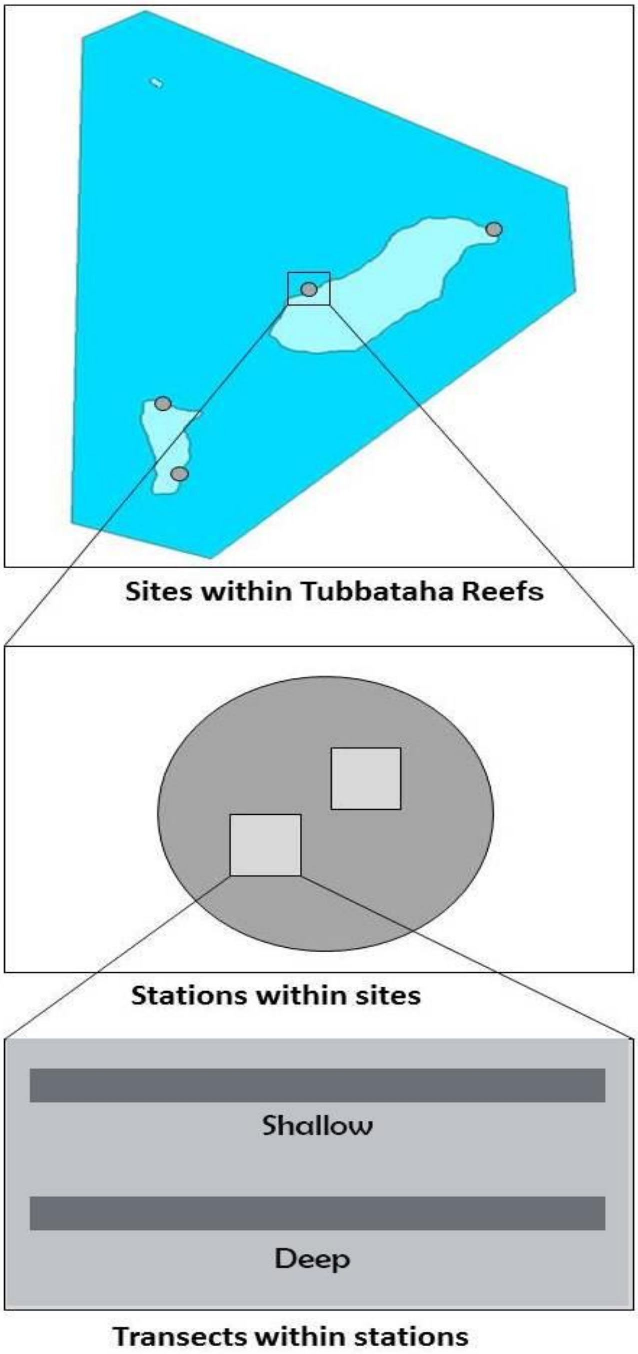

Figure 1. Hierarchical sampling design (Modified from Licuanan et al. 2016).

Field Surveys

The seabird survey was conducted on May 16 to 22, while fish and benthos were conducted on May 25 to June 02. Coral bleaching assessment was conducted on July 15 to 21. TMO researchers and marine park rangers were assisted by volunteers and consultants based in Puerto Princesa City. The members of the monitoring team are listed in Annex 1.

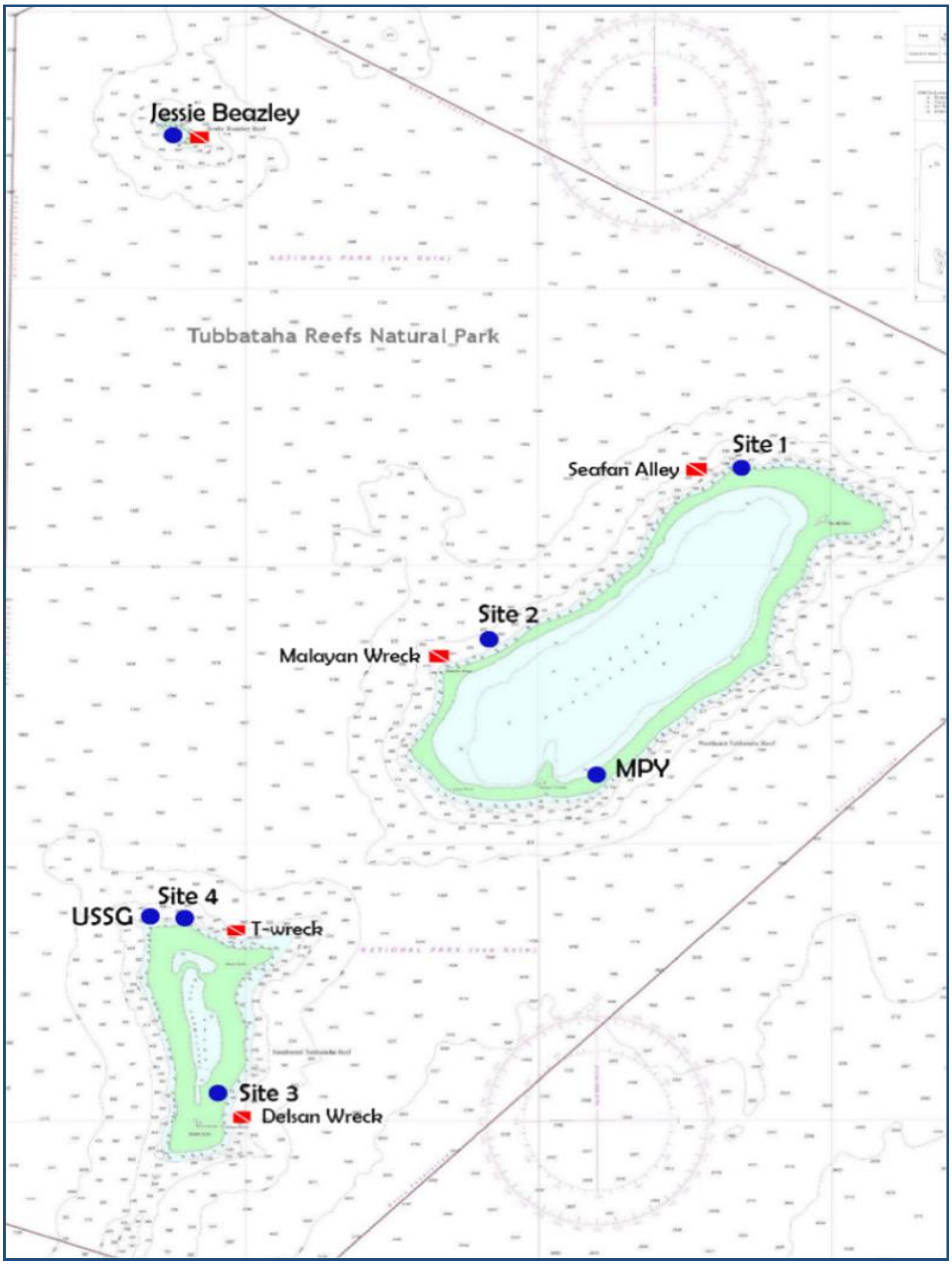

Figure 2. Location map of the regular monitoring sites (blue dot).

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2 REEF FISH COMMUNITY

Gerlie Gedoria[1], Segundo Conales Jr[1], Rodulfo Anthony Balisco[2], Cresencio Caranay Jr[1]

[1]Tubbataha Management Office, Puerto Princesa City
[2]Western Philippines University, Puerto Princesa City

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2.1 Overview

Fish biomass, abundance, and species richness are some of the parameters used to determine the condition of the reef ecosystem. Since 1999, annual fish monitoring has been conducted in the Tubbataha Reefs to examine the status of the reef fish community. The results of this assessment would also gauge the effectiveness of management and will be used for the formulation of science-based policies.

This section discusses the result of this year's fish assessment, along with the temporal trends in the two decades' worth of fish data collected. The fish community status of the two grounding sites, Min Ping Yu and USS Guardian, were also reviewed. This year's monitoring was conducted simultaneously with the reef benthos survey. Mr. Rodulfo Anthony Balisco of Western Philippines University and Nathan Songco assisted in the conduct of this year's fish community assessment.

2.2 Methods

Data Collection

The five regular monitoring sites, plus the USS Guardian and Min Ping Yu grounding sites, were re-visited. A total of 12 stations were resurveyed. Except for the grounding areas, all monitoring sites have two stations each (A and B), which are approximately 200 meters apart. Temporary markers were established, using a buoy, to mark the location of the first transect. Three 50-meter replicate transects, separated by a 10-meter buffer, were laid in deep (~10m) and shallow (~5m) areas of each station. Each transect had 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. Daytime Fish Visual Census (FVC) described by English *et al.* (1997) was employed to determine the attributes of the fish community such as biomass, density, and species richness.

In the previous years, depth was considered in selecting the location of the transects in the grounding sites. This year, the team opted to move the transects to the impact area and the adjacent area. In the MPY grounding site, the shallow transect was transferred in the impact area from the previous five-meter depth location. This is referred to as 'inside' the grounding site. Another transect was placed in the adjacent area, at least 30 meters away from the impact area, to serve as a proxy for the pre-disturbed state of the site. This is referred to as 'outside' in this report. Only one transect was able to fit in the impact area of the MPY grounding site, thus we opted to also put one outside of the impact area as the proxy. In the case of USS Guardian, three transects were laid 'inside' and 'outside' of the impact site, as the damaged area was able to cover 2.3 meters of the transects.

Researchers recorded the scientific name, actual count, and estimated length/size of the fish encountered within the established corridor. Highly mobile species were recorded first before the slower ones (i.e., transient and cryptic species). Three (3) divers completed this year's survey, assessing the deep transects first and the shallow afterward.

Data Analysis

Data were collated and organized using the format adapted from Coral Reef Visualization and Assessment (CoRVA) system introduced by the DENR in 2014. Species richness was determined using the actual number of species identified during the survey, while the fish density was expressed by the number of individuals per given area (individuals per $500m^2$). The biomass was simplified in grams per square meter (grams per m^2) and was calculated with the existing length and weight model (Kulbicki *et al*. 1993), using the formula:

$$W = aL^b$$

> 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, and between this year and the previous year's estimates, at $p=0.05$. Two-factor analysis of variance (ANOVA) in Microsoft Excel was used to detect if there were significant differences in the overall biomass between sites and between years, from 2013-2020. The same statistical analysis was applied to the density and biomass outputs between depths of each grounding site.

The fish species were further classified into various groups – according to nature (pelagic or demersal) and category (target, major, and indicator) - to generate a clearer picture of their contribution to total biomass and density.

2.3 Results and Discussion

Present status of the permanent monitoring sites

Species richness

Two hundred ninety-six (296) species of fish were identified during this survey. These belong to 35 families and subfamilies, with the majority under the families Labridae (wrasses) (47 species), Pomacentridae (damsel) (42 species), and Acanthuridae (surgeonfish) (32 species). Station 3A had the highest number of species recorded with 169, while the lowest number was in Station 4A, with 128 species recorded. Overall, Site 3 had the highest number of species recorded with 204.

The deep transects had higher mean species richness at 63 species per 500 m^2 than its shallow counterpart with only 47 species per 500 m^2. These values fell under "very high" (>50 species per 500 m^2) and 'high' (37-50 species per 500 m^2) levels, respectively, according to the modified categories of healthy reef fish communities from Hilomen *et al.* in 2000 (Annex 3).

Overall, the reefs' mean species richness remained at a "very high" level (>50 species per 500 m^2) with a value of 55 species per 500 m^2.

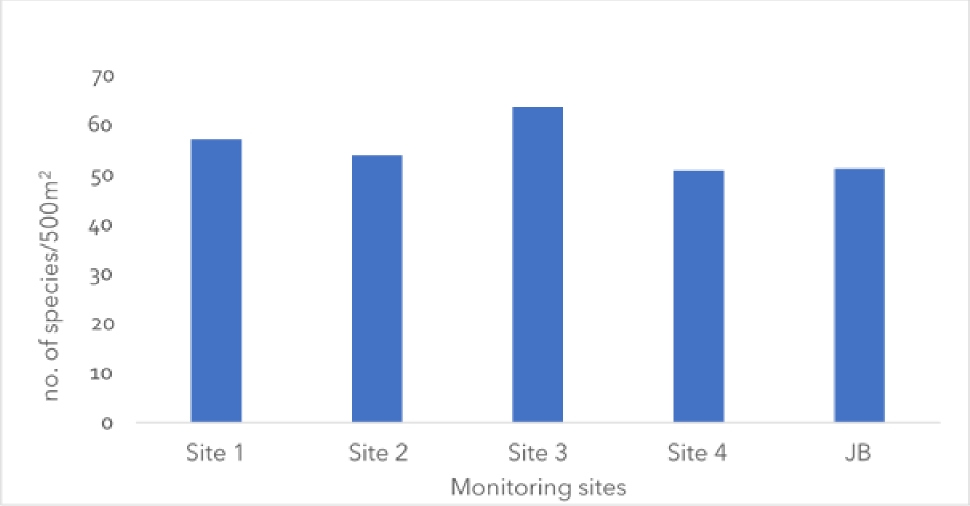

Figure 3. Species richness (number of species per 500m^2) in each monitoring site.

Biomass

Station 3A recorded the highest biomass output (Figure 4). Acanthuridae: Nasinae (unicornfish) and Serranidae: Anthiinae (fairy basslets) were the major families that attributed to this high biomass in the said station. Station 4B (152 g/m^2) and Station JBB (128 g/m^2) also exhibited high biomass outputs. Overall, Site 3 had the highest biomass output among all sites. All sites in the present survey exhibited an increase in biomass estimates compared to 2019.

The mean biomass value this year was at 117 g/m^2, higher than the previous year's value of 102 g/m^2. However, no significant difference was found between these two years' biomass estimates (t-test; p=0.08). Acanthuridae: Nasinae (unicornfish) and Scaridae (parrotfish) were the most prominent contributors to the mean biomass this year. Thirty percent (30%) of the overall biomass estimate was attributed to these two families alone. Acanthuridae (surgeonfish) and Carangidae (jacks and trevallies) were major contributors to the increase in

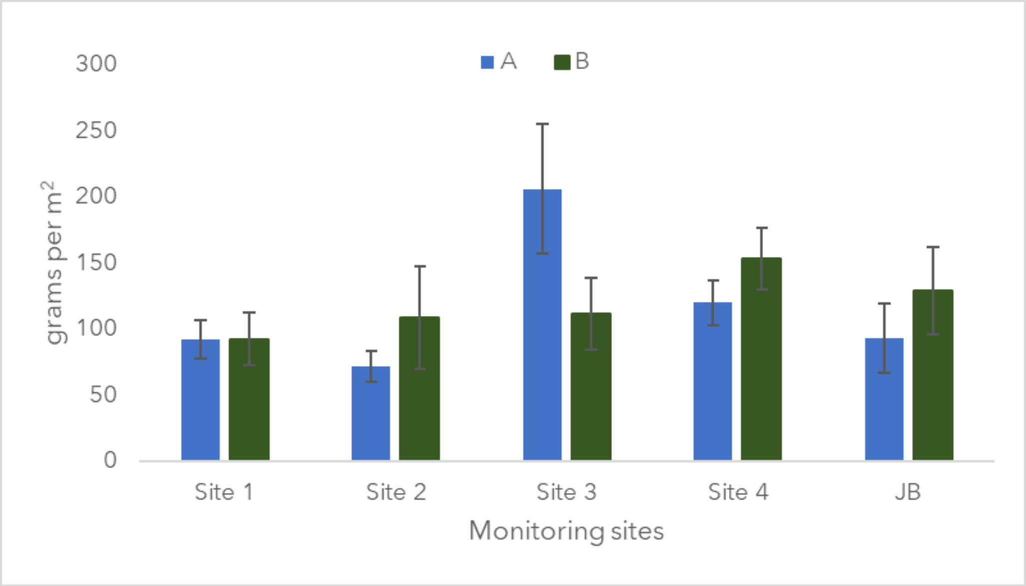

Figure 4. Mean biomass (grams per m^2) of fish per station. Vertical bar denotes standard error of the mean.

biomass from the previous year. Mean fish biomass in TRNP can be considered at a "very high" level (i.e.,>40 g/m^2) based on the categories established by Nañola *et al.* in 2004 (see Annex 3).

Biomass: deep vs. shallow

The mean biomass output in deep areas was relatively higher at 149 g/m^2 than its shallow counterpart with 85 g/m^2. Despite the difference, there was no statistical variation found between the two depths (t-test; p=0.08). The highest biomass output was recorded in the deep areas of Site 3, while the lowest output was in the shallow area of JB (Figure 5). Acanthuridae: Nasinae (unicornfish) was the main contributor (32 g/m^2) in biomass output in the deep transects. Shallow transects mainly attributed its biomass output to Balistidae (triggerfish) (15 g/m^2) and Pomacentridae (damselfish) (13 g/m^2). The comprehensive biomass estimates of each family in both depths are listed in Annex 3.

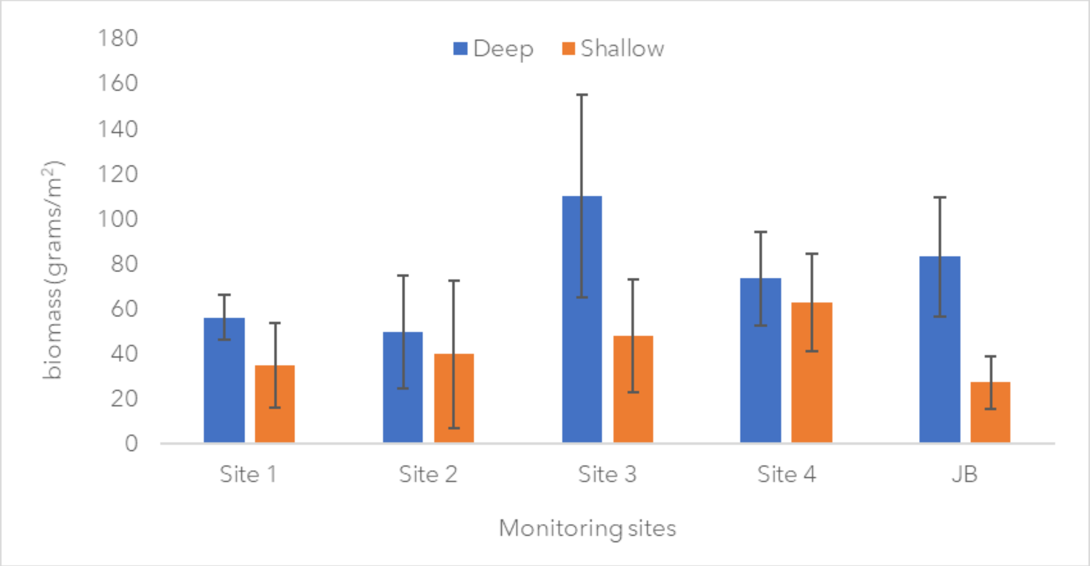

Figure 5. Mean biomass (grams per m^2) of reef fish at deep (~10m) and shallow (~5m) areas. Vertical bar denotes standard error of the mean.

Biomass: fish groups

To further picture the sources influencing the biomass estimates, the reef fishes were classified according to their category (target, indicator, and major) and nature (demersal and pelagic). The commercially targeted fishes constituted around 66% (78 g/m^2) of the total biomass this year. This group is highly valued as food (FAO 2003a). Hence, their presence or absence serves as an indicator of fishing pressure in an area. Species from Acanthuridae: Nasinae (unicornfish) was the most prominent target fish observed in all sites except for Site 4, where Scaridae (parrotfish) were more abundant. Along with Carangidae (jacks and trevallies), these three families constituted 51% of the total biomass of commercially important fishes observed in the park.

Indicator fishes, or those species that are highly dependent on corals for food and shelter, comprised the lowest proportion (1.6%) of the total biomass. This was mostly made up of species from Chaetodontidae (butterflyfish) and Pomacanthidae (angelfish) families. The remaining percentage (32% or 37 g/m^2) in the total biomass constituted the major species or those fishes that are often found in high concentrations, significantly dominated by Pomacentridae (damselfish) and Balistidae (triggerfish).

Biomass: demersal vs. pelagic

Demersal fishes were responsible for one-third (83 g/m^2) of the biomass output this year. This group of fishes is highly associated with coral reefs, hence, are more reliable in determining reef health than its pelagic counterpart. Pelagic fishes are those species that commonly inhabit and feed in the open water column of coastal and oceanic waters (Lal and Fortune 2000) and seldom visit the reef. The demersal fishes were mainly comprised of Balistidae (triggerfish), Scaridae (parrotfish), and Pomacentridae (damselfish), with each family contributing around 13 g/m^2 to the total biomass output. In contrast, pelagic fishes were dominated by species from family Acanthuridae: Nasinae (unicornfish) and Carangidae (jacks and trevallies), with biomass estimates of 18 g/m^2 and 10 g/m^2, respectively.

Biomass: trophic groups

The fishes were further classified based on the similarity of diet specializations, irrespective of their taxonomic affinities (Bellwood and Green 2009). The structure of these trophic categories could imply the availability and abundance of food sources in a site. In this report, the following classification of feeding guild by Helfman *et al.* (2009) was used:

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)

Herbivores and piscivores had the highest biomass relative to other trophic groups. These two groups are mostly comprised of large-bodied species (e.g., unicornfish, groupers, jacks). Most of the herbivorous species recorded were from families Acanthuridae: Nasinae (unicornfish) and Scaridae (parrotfish). Meanwhile, piscivores were dominated by species from the families Carangidae (jacks and trevallies), Serranidae (groupers), Lutjanidae (snappers), and Haemulidae (sweetlips). Piscivorous species are highly valued as commercially targeted fish; hence, they are usually the first ones to disappear from a heavily fished area (FAO2003a).

The presence of corallivorous fishes was also noted as a critical component of a healthy coral reef. This group can approximate the reef's health condition (Crosby and Reese 1996;

Ohman *et al.* 1998; Hourigan *et al.* 1998). Pomacanthidae (angelfish) and Chaetodontidae (butterflyfish) mainly represented this group. Planktivores accounted for 12% of the total mean biomass in Tubbataha, primarily represented by Pomacentridae (damselfish), Serranidae: Anthiinae (fairy basslets), and Caesionidae (fusiliers). This group thrives in areas where reefs are far from the coast (Floeter *et al.* 2007). They proliferate in less turbid water since they rely more on their vision and light intensity in feeding than other species in different trophic groups (De Robertis *et al.* 2003).

Benthic invertivore predators, mainly represented by Holocentridae (soldierfish), Labridae (wrasses), and Lethrinidae (emperor fish), are also an essential component of the reef as they have a variety of feeding habits and prey, such as crustaceans and mollusks. Thus, they can also indicate the abundance of invertebrates in coral reefs (Ferreira *et al.* 2004).

The omnivores, mainly represented by Balistidae (triggerfish) and Acanthuridae (surgeonfish), can feed on different food types (plant or animals) depending on availability. Hence, they have an essential role in maintaining the balance between animal and plant (i.e., algae) growth (Agren *et al.* 2012).

Detritivores have an important role in the turnover of detritus for the reuse of nutrients by primary producers such as phytoplankton (Engelman 1961); hence they prevent the accumulation of decaying matter in the coral reefs. This year, the group was mainly represented by species from Acanthuridae (surgeonfish) and Scaridae (parrotfish). The presence of species in each trophic group, which differ in the rates and pathways they process resources, keeps the balance of different ecosystem processes, such as herbivory and competition (Chapin 1997). Furthermore, fishes are situated at the top of food webs in many habitats and their feeding activities trigger trophic cascades, affecting other organisms down the food web (Helfman *et al.* 2009).

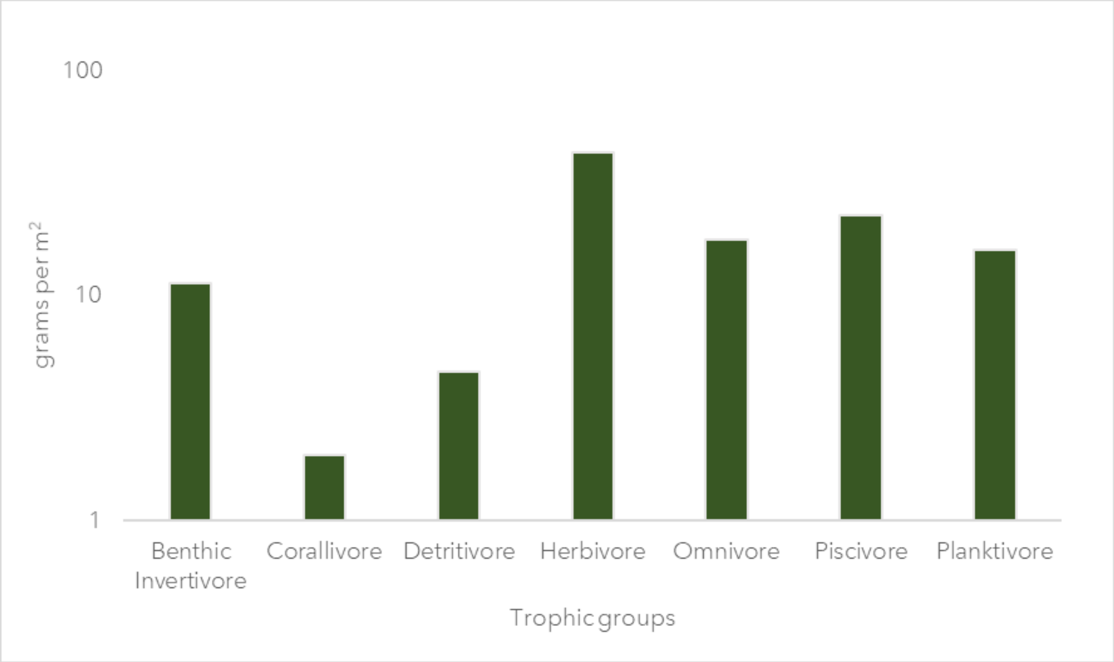

Figure 6. Mean biomass (grams per m^2) of each trophic group.

Density

Both stations of Site JB had the highest number of fishes recorded. This is despite the observed coral damage in the monitoring stations, suspected to be caused by dynamite fishing. Species from the family Acanthuridae (surgeonfish), Caesionidae (fusiliers), and Labridae (wrasse) showed an increase in number in the said monitoring site. In general, only Sites 1 (-12%) and 2 (-5%) exhibited a decrease in fish density from the previous year's assessment.

The mean density estimate was 1,680 individuals per 500 m^2, not far from last year's 1,678 individuals per 500 m^2. The species which significantly contributed to this year's fish density were from the family Pomacentridae (damselfish), which comprised 44% of the overall estimate at an average of 747 individuals per 500 m^2. This was followed by Serannidae: Anthiinae (fairy basslets) with a density value of about 440 individuals per 500 m^2. Annex 3 lists all the fish families and their corresponding mean density values this year. The mean fish density of the reef was considered 'high' (1,134-3,796 individuals per 500 m^2) according to the categories set by Hilomen *et al.* (2000) for fish density.

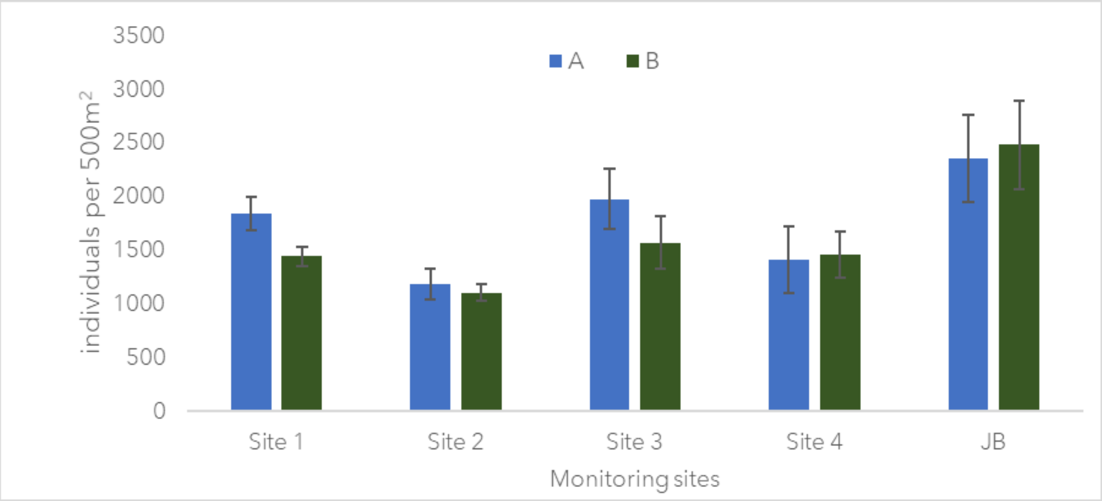

Figure 7. Mean fish density (individuals per 500 m^2) per station (A and B). Vertical bar denotes standard of error.

Density: deep vs. shallow

Fishes in deep areas contributed relatively more to the total mean density, with 2,045 individuals per 500 m^2, than the shallow areas with only 1,315 individuals per 500 m^2. However, this difference was not statistically significant (t-test; p=0.2). The deep area of Site JB had the highest mean density recorded, while the lowest was in the shallow area of Site 4 (Figure 8). Both depths were dominated by Pomacentridae (damselfish) and Serranidae: Anthiinae (fairy basslets). These two families alone attributed 70% to the total mean density.

Deep areas were dominated by Dispar anthias (*Pseudanthias dispar)* and Princess anthias (*Pseudanthias smithvanizi*), while shallow areas were dominated by Bicolor Chromis (*Chromis margaritifer)* and Ternate chromis (*Chromis ternatensis).*

Density: fish groups

Target fishes comprised 11% of the total density output this year, with an estimated number of 185 individuals/500m^2. Majority were contributed by species from families Acanthuridae (surgeonfish) and Caesionidae (fusiliers), with 54 individuals/500m^2 and 40 individuals/500m^2, respectively. In four sites (Sites 1 to 4), Acanthuridae (surgeonfish) was the most abundant target group, while in JB, Caesionidae (fusiliers) was the most recorded.

Meanwhile, indicator fishes comprised 2% of the total fish density, with an estimated 32 individuals/500m^2. Pomacanthidae (angelfish) and Chaetodontidae (butterflyfish) had the most number encountered with mean values of 13 individuals/500m^2 and ten individuals/500m^2, respectively.

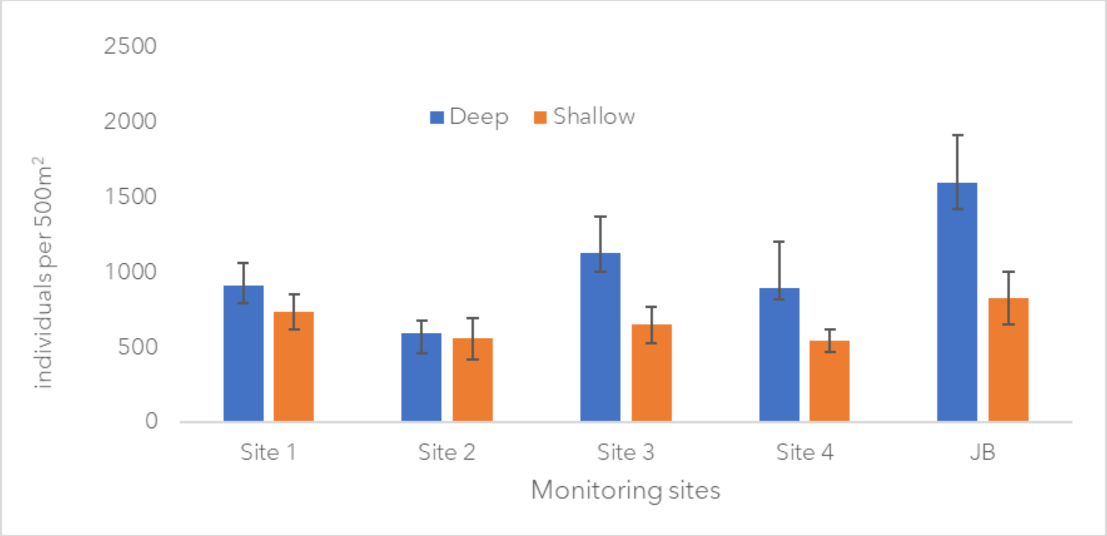

Figure 8. Mean density (individuals per 500 m^2) of reef fish at deep (~10m) and shallow (~5m) areas. Vertical bar denotes standard error of the mean.

Major species comprised the bulk (87%) of the density output this year with estimates of 1,468 individuals/500m^2. This was greatly attributed to Pomacentridae (damselfish), with a density estimate of 745 individuals/500m^{2,} and Serranidae: Anthiinae (fairy basslets) with 441 individuals/500m^2. These two families alone comprised 81% of the total number of major species observed during the survey.

Density: demersal vs. pelagic

Demersal fishes accounted for 96% of the total density output this year. This was equivalent to 1,619 individuals/500m^2. The majority (73%) of these were under families Pomacentridae (damselfish) and Serranidae: Anthiinae (fairy basslets). These two families were the most abundant groups recorded in all sites.

Meanwhile, pelagic species comprised four percent of the total mean density. Caesionidae (fusiliers) were the most abundant pelagic group recorded with estimates of 41 individuals/500m^2. This was followed by Acanthuridae: Nasinae (unicornfish) with an estimated count of 12 individuals/500m^2.

Density: trophic groups

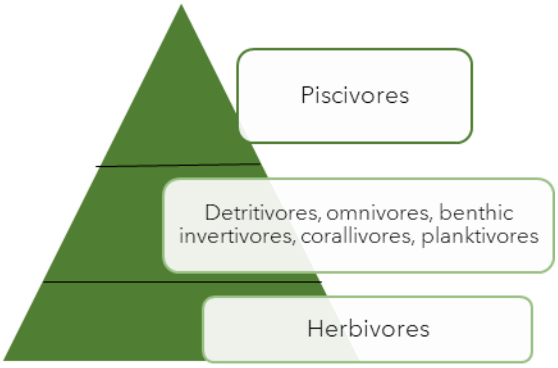

Figure 9. Modified Eltonian pyramid of numbers for aquatic habitat (Helfman et al. 2007, 2009; Hickman et al. 1993).

Figure 10 illustrates the relative distribution of the mean density of each trophic group during this year's survey. Planktivores, having the highest number of individuals relative to the other groups, were mainly represented by species from Serranidae: Anthiinae (fairy basslets) with 26,510 individuals recorded, followed by species from Pomacentridae (damselfish) with 18,657 individuals recorded. Some species of Pomacentridae are herbivores, thus contributing to the high mean density of the group, second to planktivores. This is consistent with the Eltonian concept on the pyramid of numbers which states that the species at the base of the food chain are relatively abundant (Hickman *et al.* 1993; Lindman 1942). Generally, herbivores are located at the bottom of the pyramid, while piscivores (top predators) are at the top. Piscivore group has the lowest number of individuals in the pyramid. An unfished or lightly fished coral reef can support several trophic guilds along with abundant coral cover (Helfman *et al.* 2009). The general pyramid of numbers for fish adapted and modified from Helfman *et al.* 2007 and 2009, and Hickman *et al.* (1993), is illustrated in Figure 9. Take note that the pyramid illustrated is only for abundance. Other trophic groups, e.g., omnivores, may also be at a similar level with herbivores within the pyramid without necessarily being the most abundant. In general, ecological pyramids are far more complex in the lower trophic level; however, piscivorous species will always be at the top of this pyramid of numbers (Helfman *et al.* 2009; Helfman 2007).

Corallivorous species, represented by Pomacanthidae (angelfish) and Chaetodontidae (butterflyfish), which are obligate feeders of coral polyps (Cole *et al.* 2008) we observed. On the other hand, the presence of a high number of herbivore species is also crucial because they play a pivotal role in controlling algal growth, providing space for coral recruits to grow (Lirman 2001; Mumby *et al.* 2006; Hughes *et al.* 2007). Therefore, they are also an indicator of reef resilience (Green *et al.* 2009). This group was mainly represented by species from Pomacentridae (damselfish) and Acanthuridae (surgeonfish). Benthic invertivores were mainly represented by species from Labridae (wrasses) and Holocentridae (surgeonfish). Omnivores were dominated by Pomacentridae (damselfish).

Temporal patterns of fish community

Figure 11 shows that the temporal patterns in mean biomass of reef fishes were variable, with the 2020 mean biomass lower than the established average biomass for TRNP from 1999-2019. These variabilities were prominent in the years 2003-2006, 2013-2014, and 2016 to the present. To test the sources of fluctuations of annual mean biomass, analysis of variance (ANOVA) in temporal (years) and spatial (sites) factors were used. However, this analysis can only be applied to data from 2013 due to the reduction in the number of monitoring sites seven (1999-2012) to five (2013-present). The ANOVA results revealed that both temporal (p= 0.000008) and spatial (p=0.04) factors significantly influence the biomass values of the Tubbataha Reefs.

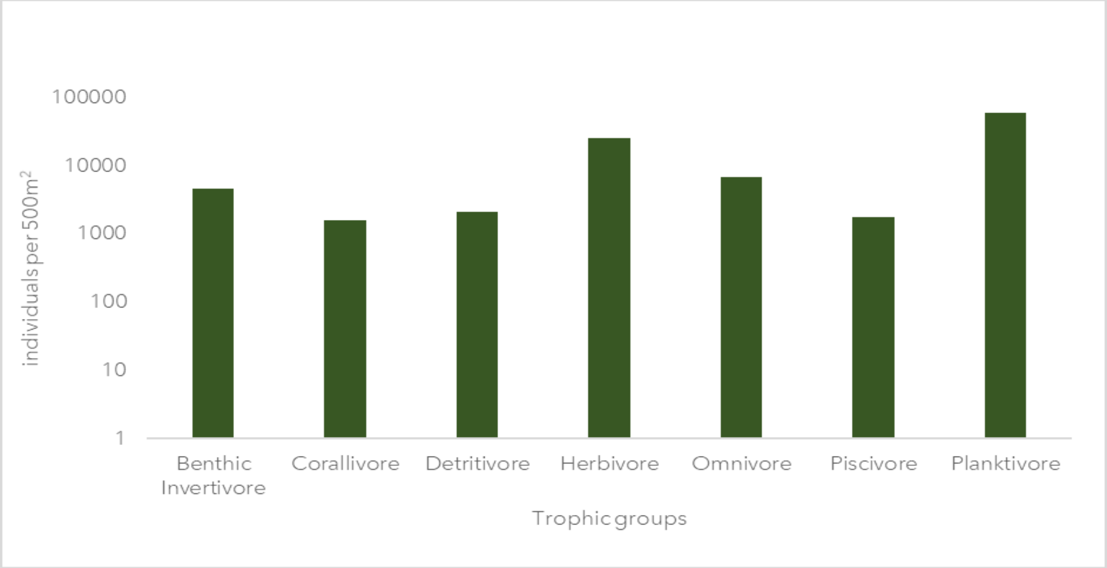

Figure 10. Mean density (individuals per 500 m²) of each trophic group.

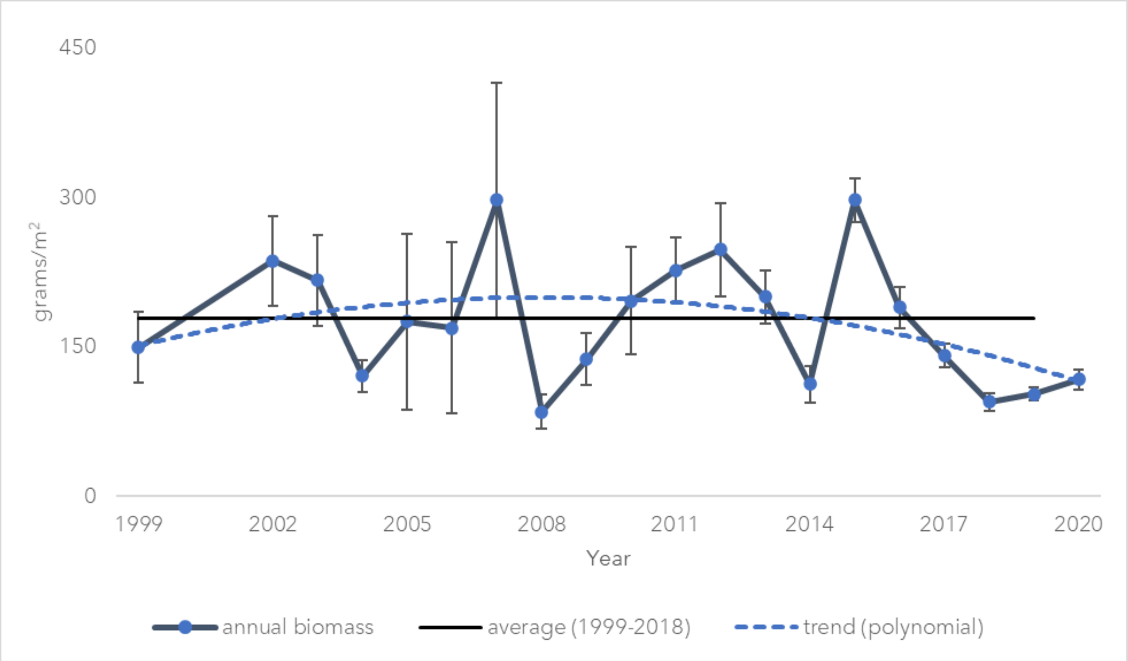

Figure 11. Temporal average biomass values in the Tubbataha Reefs. Vertical bar denotes the standard error of the mean.

It was noted that an abrupt increase in biomass was observed in 2015 (Figure 11). This was mainly attributed to the high number of individuals of Scaridae (parrotfish) encountered. The same group was not encountered in the succeeding years. Variations in biomass values year after year were mainly influenced by the presence or absence of species from families of Nasinae (unicornfish), Carangidae (jacks and trevallies), and Balistidae (triggerfish). These families are commonly observed in groups and had large sizes, hence significantly affecting the overall biomass outputs. The families Acanthuridae (surgeonfish) and Scaridae (parrotfish) were seldom recorded in groups, but they also influenced the overall biomasses values with their presence or absence.

The biomass output this year (Figure 11) was higher than the values in 2014, 2017, and 2018. However, it was still not the same as the estimate in 2013. Since 2013, only the biomass output of family Acanthuridae (unicornfish) exhibited an increase of around 40%. The biomass of other families mentioned above was still 30-50% lower compared to the 2013 estimates.

Furthermore, differing biomass yields in each site was also the source of variations. Figure 12 shows the biomass estimates in regular monitoring sites from 2013. Among all the sites, Site 4 exhibited the highest biomass output, while Site JB had the lowest average biomass output during the last seven years. Moreover, the increasing and decreasing trends in biomass outputs of each site were consistent with the annual biomass trend (2013-2020) (see Figure 12).

Over the years, the pattern of the fish families that influenced each site could be observed. Biomass output in Site 1 was influenced by the presence and absence of Carangidae (jacks and trevallies) and Acanthridae: Nasinae (unicornfish). Sites 2, 3, and 4 were mainly dominated by Scaridae (parrotfish), Balistidae (triggerfish), and Acanthuridae: Nasinae (unicornfish). Meanwhile, Site JB biomass was greatly influenced by Acanthuridae: Nasinae (unicornfish), Balistidae (triggerfish), and Pomacentridae (damselfish).

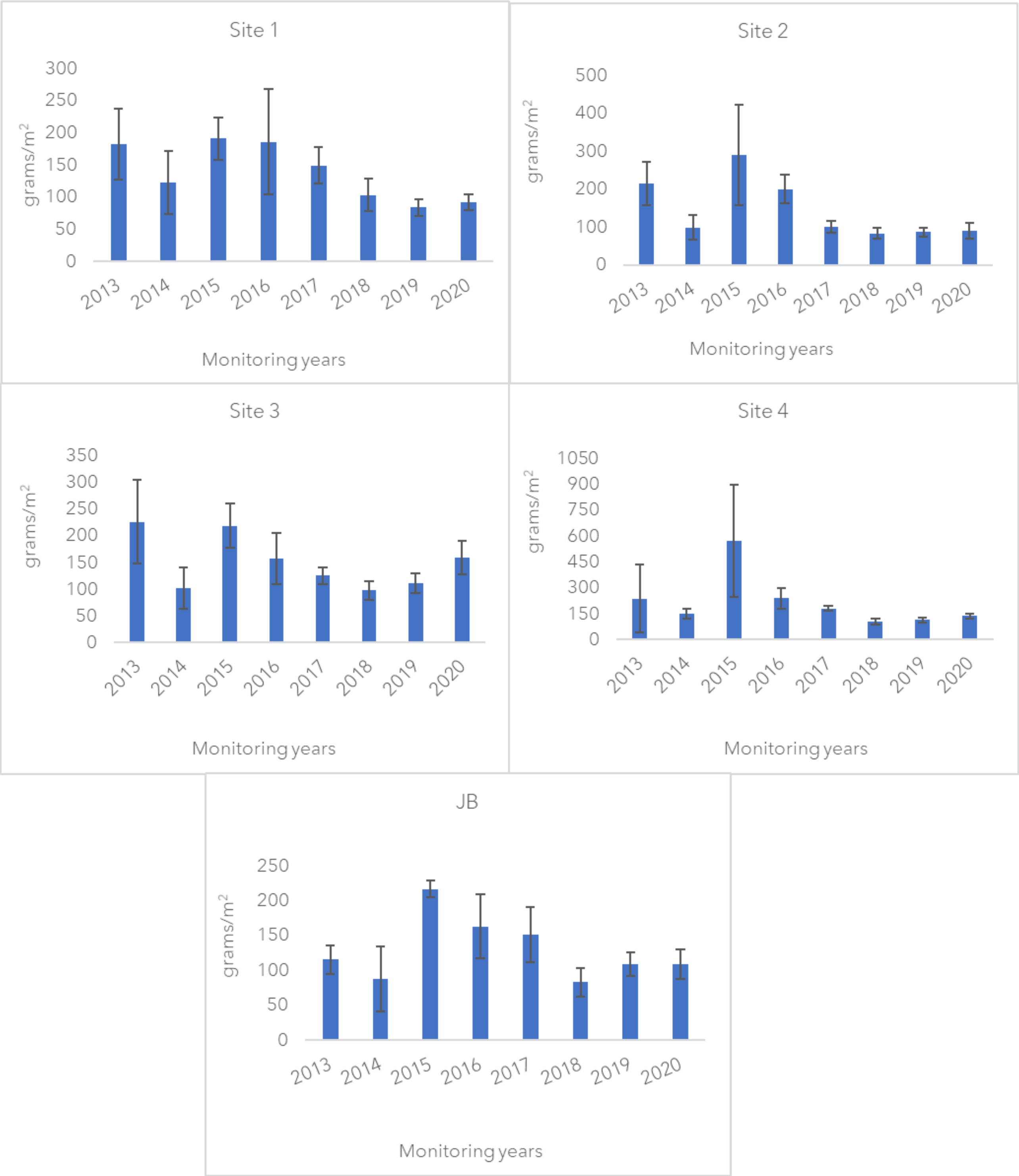

Figure 12. Biomass in regular monitoring sites from 2013-2020. Vertical bar denotes standard error of the mean.

Deep vs. shallow

The variability and oscillating pattern of annual biomass output were more prominent in deep areas than in their shallow counterparts (Figure 13). It was noted that fishes in the deep areas contributed more to the overall biomass as opposed to the shallow. Biomass in the deep areas was predominantly influenced by pelagic species. In Tubbataha, these pelagic species were the Acanthuridae: Nasinae (unicornfish), Caesionidae (fusiliers), and Carangidae (jacks and trevallies). These three families were also among the most abundant large-bodied fishes in the park. Hence, their presence or absence could lead to variability in the biomass output per year. This year's biomass output in the deep was higher compared to the 2019 value (Figure 13) mainly due to the encounters with higher numbers of Caesionidae and Acanthuridae: Nasinae.

The trend in the shallow area was more stable and closer to the average (Figure 13) than the deep area. In the shallow part, species from the families Balistidae (triggerfish), Scaridae (parrotfish), and Acanthuridae (surgeonfish) were the major influencers of the overall biomass. Carangidae (jacks and trevallies) and other large-bodied fishes that often traverse the deeper parts of the reef seldom visit the shallows, which could significantly influence the biomass yield in these areas. The most prominent example of this was in 2015, when many individuals from the family Carangidae (jacks and trevallies) were recorded, causing the highest biomass output recorded in the shallow. This year's biomass output in the shallow part was slightly lower than the previous year, mainly due to fewer encounters with Balistidae (triggerfish) and Acanthuridae: Nasinae (unicornfish). However, it was worth noting that encounters with species of large-bodied demersal fishes, such as from family Acanthuridae (unicornfish), Scaridae (parrotfish), and Serranidae (groupers), were showing a stable and increasing trend over the years.

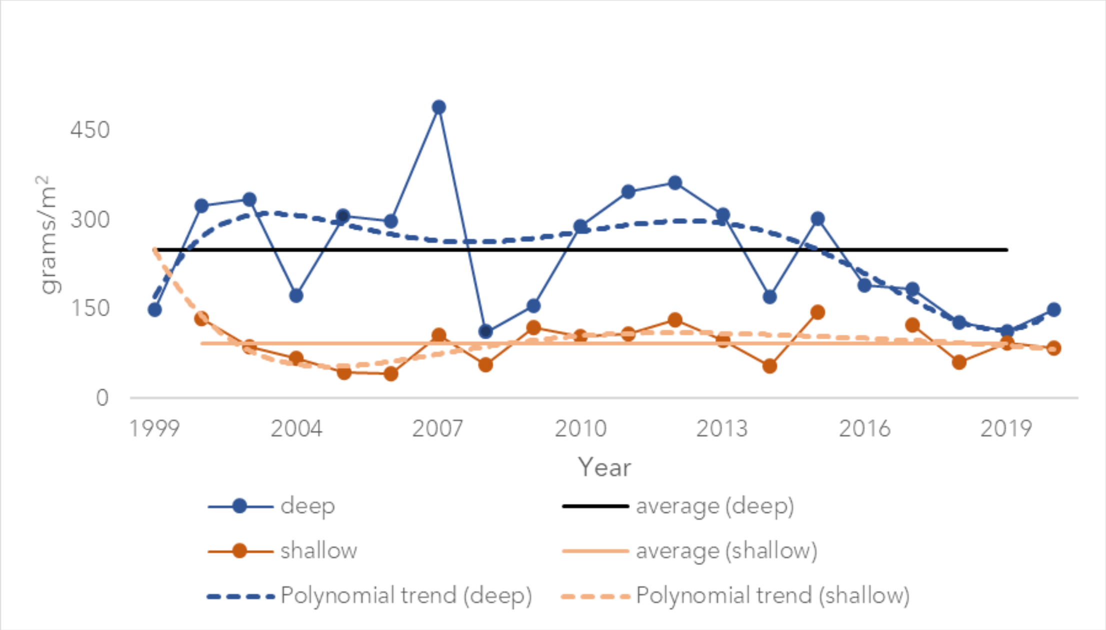

Figure 13. Temporal biomass output in deep and shallow areas of the Tubbataha Reefs.

Fish Groups

The presence of fishery targeted fish species, or those in the top trophic level, in an area, would serve as an indication of the positive impacts of reef protection. Hence, marine protected areas are established partly to improve and restore the population of these fishes, given the time of adequate protection (Russ and Alcala 1996; Helfman *et al.* 2009). Figure 14 shows the fluctuating temporal trend of the potential harvestable biomass of fishery targeted species in TRNP. The relative proportion of target fishes in the total biomass over the years range from 55-90%. This group was represented mainly by Scaridae (parrotfish), Nasinae (unicornfish), and Carangidae (jacks and trevallies). These three families alone constituted 30-60% of the total biomass output in the park annually.

Moreover, the annual biomass output ranged from 65 g/m^2 to 250 g/m^2, which was very high according to the categories set for reef fish biomass in the Philippines (Nañola *et al.* 2004).

Also, indicator species constituted 2-4% of the total biomass and were represented mainly by Chaetodontidae (butterflyfish) and Pomacanthidae (angelfish). The major group contributed 20-30% to the total biomass annually. The group was represented by Balistidae (triggerfish), Pomacentridae (damselfish), and Serranidae: Anthiinae (fairy basslets). Furthermore, both indicators and major groups exhibited an increasing trend during the two-decade monitoring.

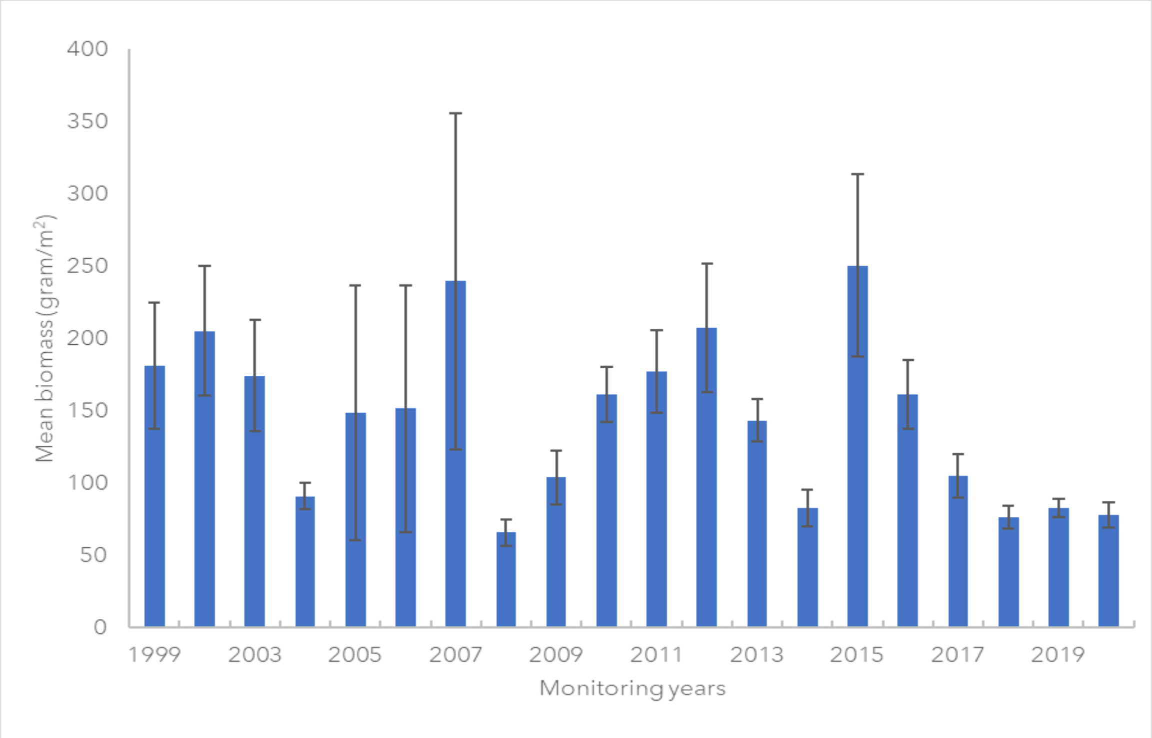

Figure 14. Temporal mean biomass of target fishes. Vertical bar denotes the standard error of the mean.

Pelagic vs. Demersal

Figure 15 shows the annual patterns of the relative proportion of pelagic and demersal fishes in TRNP since 1999. Both groups show an oscillating pattern with the highest estimate in 2007 for pelagic, and 2015 for demersal. In this report, fish families that were considered pelagic were Acanthuridae: Nasinae (unicornfish), Caesionidae (fusiliers), Carangidae (jacks and trevallies), Scombridae (tuna and mackerel), and Sphyraenidae (barracudas). Over the years, pelagic species accounted for 25% to 60% of the total biomass output in the park. Acanthuridae: Nasinae (surgeonfish) and Carangidae (jacks and trevallies) were the most encountered pelagic groups year after year. In the present assessment, pelagic fish biomass accounted for 27% of the total estimate. It was relatively higher in comparison to estimates in 2003-2004, 2008-2009, 2014, and 2019.

Generally, the biomass of demersal fishes had a more prominent contribution to the overall biomass, with exceptions of 2006-2007. Demersal fishes are highly associated with coral reefs. Hence, they are better indicators of reef health than the pelagics, which in contrast, inhabit and feed in the open water column (Lal and Fortune 2000). Top families from the demersal group that significantly contributed to the total biomass over the years were Scaridae (parrotfish), Balistidae (triggerfish), Pomacentridae (damselfish), and Acanthuridae (surgeonfish). This year's biomass estimate was relatively higher in comparison to the 2018-2019 assessments.

Furthermore, being deep zone inhabitants, pelagic fishes have higher biomass contributions and presence in the deep transects across all years. Demersal fishes had higher biomass output in the shallow transects.

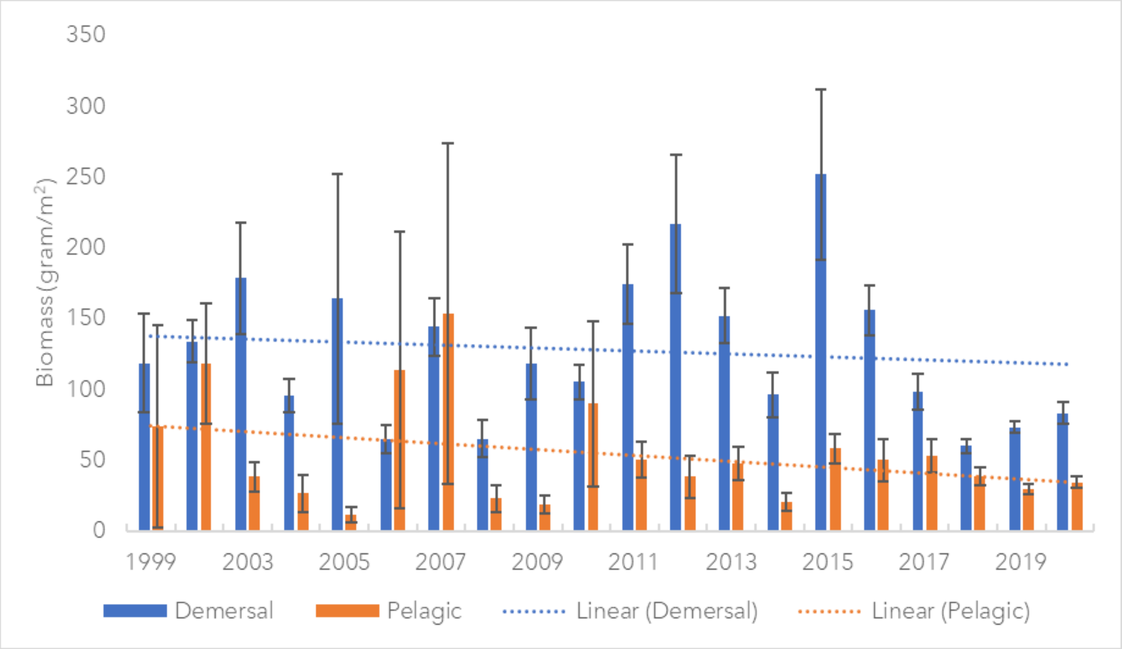

Figure 15. Temporal pattern of biomass estimates for pelagic and demersal fishes.

Since 2016, the decline was greatly attributed to the fewer encounters of pelagic species, mainly from families Acanthuridae: Nasinae, Caesionidae, and Carangidae. Furthermore, the large individuals (>30cm) of Red snapper *Lutjanus bohar* contributed to the increase in the biomass in 2016 but only occurred in fewer numbers from 2017-2020. Other large-bodied fishes, such as from families of Serranidae (groupers), Lethrinidae (emperor fish), and Scaridae (parrotfish), among others, were also exhibiting a generally declining trend. However, since stringent protection in the park is in place, it is assumed that it was not due to illegal fishing pressure. The presence or absence of large-bodied fishes within the transect may be influenced by the movements of fish species from one place to another, rather than illegal fishing. These movements are driven by various factors that affect and influence survival demands correlated with feeding and predator avoidance (Dahlgren and Egglestone 2000; Helfman *et al*. 2009), mortality risk, and habitat shifting (Dahlgren and Egglestone 2000). More extensive horizontal migration may also occur in other conditions driven by spawning, feeding, and ontogenetic shifts in habitat requirements (Sale 2002). This is depicted in the form of oscillatory movement (Bone and Moore 2008; Sale 2002). Furthermore, although some of the species that also exhibited decline were strongly associated with corals and had small home ranges, e.g., Red snapper *Lutjanus bohar*, the factors mentioned above could also drive more extended distance movements (Kaunda-Arara and Rose 2004). It was also cited above that one of the factors that could have influenced these variations was observer bias since different observers collected the data thru time.

Threatened Species

During this assessment, several species of interest that are listed in the International Union for Conservation of Nature (IUCN) Red List of Threatened Species were recorded. These species were noted outside of the transects. Among them were species listed as Near Threatened (NT) such as the Whitetip Reef Sharks (*Triaenodon obesus*), observed in almost all sites except in the MPY grounding site. Several individuals of Grey Reef Shark (*Carcharhinos amblyrhinchos*) were spotted in Site 2, and Tiger Shark (*Galeocerdo cuvier*) was noted in Sites 1 and 3. Another species under this category was the Leopard Coral Grouper (*Plectropomus leopardus)* spotted in Site 4. Furthermore, Vulnerable (VU) species were also observed such as Blacksaddled Coral Grouper (*Plectropomus laevis*) in Site 3 and 4; a school (40 individuals) of Green Bumphead Parrotfish (*Bolbometopon muricatum*) noted in Site 1; a Whale shark (*Rhincodon typus*) spotted during a dive in Delsan Wreck. Napoleon Wrasse (*Cheilinus undulatus)*, classified as Endangered (EN), was recorded in all sites except in the MPY grounding site.

The presence and abundance of these species listed in the IUCN Red List are some of the benefits of reef protection. By protecting the reef from extractive anthropogenic activities, ideal reef conditions for both benthic and fish communities could be restored.

Grounding Sites

Min Ping Yu

A total of 54 species, belonging to 17 families, were identified inside the MPY grounding site. This is also the estimated species richness of the area, which falls under the very high-level category (>50 sp/500m^2) established for the reef fish community by Hilomen *et al.* (2000). Ninety-four species were recorded outside of the impact area, which is also 'very high.' A total of 22 families were encountered. Overall, a total of 115 species were chanced upon within the monitoring site. Most of the species identified inside the area were under the family Labridae (9 species), Pomacentridae (8 species), and Chaetodontidae (8 species).

In the area outside of the impact site, the same families were also recorded. Labridae had 17 species recorded, Pomacentridae had 14 species, and Chaetodontidae with 12 species.

Biomass

The total mean biomass inside the MPY site was at 49 g/m^2 (Figure 16). Acanthuridae (surgeonfish) (11 g/m^2), Serranidae (groupers) (9 g/m^2), and Pomacentridae (8 g/m^2) primarily contributed to this value. The biomass output outside of the MPY impact site was at 185 g/m^2, four times higher than the values inside. This was mainly attributed to Chaetodontidae (butterflyfish) (88 g/m^2), Acanthuridae: Nasinae (unicornfish) (11 g/m^2), Zanclidae (Moorish idol) (11 g/m^2), and Acanthuridae (surgeonfish) (10 g/m^2). Despite the difference, there was no significant variation found between inside and outside of the impact site (t-test; $p>0.5$). Based on the categories established by Nañola *et al.* (2004) (Annex 3), the mean biomass of both sites fell under the 'very high' category (>40 g/m^2).

Target fishes constituted 74% of the fish biomass inside the grounding site. This was mainly attributed to species from families Scaridae (parrotfish) and Acanthuridae (surgeonfish). Major fishes were responsible for 23% of the total fish biomass in the area, which was significantly attributed to the presence of Balistidae (triggerfish) and Acanthuridae (surgeonfish). Meanwhile, only two families were recorded for indicator species, the Chaetodontidae and Pomacanthidae.

In contrast, the biomass outside of the impact area was dominated by major species (53%), mainly represented by Pomacentridae (damselfish) and Zanclidae (Moorish idol). Target fishes constituted around 23%, attributed mostly to Acanthuridae: Nasinae (unicornfish) and Acanthuridae (surgeonfish). Indicator fishes recorded were from families Chaetodontidae (butterflyfish), Pomacanthidae (angelfish), and Labridae (wrasses).

All the biomass of fishes identified inside the MPY grounding site were demersal, mainly attributed to the three families mentioned above. The biomass output outside the impact site constituted 88% of demersal fishes, with significant contributions from Pomacentridae and Acanthuridae. Pelagic fishes represented 12% of the total biomass, primarily attributed to three families: Acanthuridae: Nasinae (unicornfish), Caesionidae (fusiliers), and Carangidae (jacks and trevallies).

Density

Overall, the mean density inside the MPY impact site was at 773 individuals/500m^2, mainly influenced by the presence of Pomacentridae (damselfish) with 630 individuals/500m^2, and Acanthuridae (surgeonfish) at 52 individuals/500m^2. The mean density outside of the impact area was at 4,314 individuals/500m^2. This was also mainly attributed to Pomacentridae (3,058 individuals/500m^2) and Acanthuridae (180 individuals/500m^2). This difference, however, is not statistically significant. According to the categories established by Hilomen *et al.* in 2000, the mean density value inside the grounding site was at a 'moderate' level (338-1134 individuals/500m^2) while the output outside was at a 'very high' level (>3,796 individuals/500m^2).

Target species composed 10% of the total mean density inside the grounding site (81 individuals/500m^2), mainly represented by Acanthuridae (surgeonfish) and Scaridae (parrotfish). Species from major groups influenced 88% of the total mean density, primarily represented by individuals from family Pomacentridae (damselfish). Indicator groups accounted for only 2% of the total density, with 15 individuals/500m^2 recorded.

Similarly, the majority (93%) of the fishes outside the impact area was also constituted by major species. These were mainly Pomacentridae (damselfish) and Serranidae (Anthiinae). Target species, mostly Acanthuridae (surgeonfish) and Scaridae (parrotfish) comprised 6% of the total mean density in the area. Indicator species represent 2% of the overall mean density (54 individuals/500m^2).

All 774 individuals of fish identified inside the MPY grounding site were demersal fishes. The pelagic group recorded outside constituted only 1% of the total mean density.

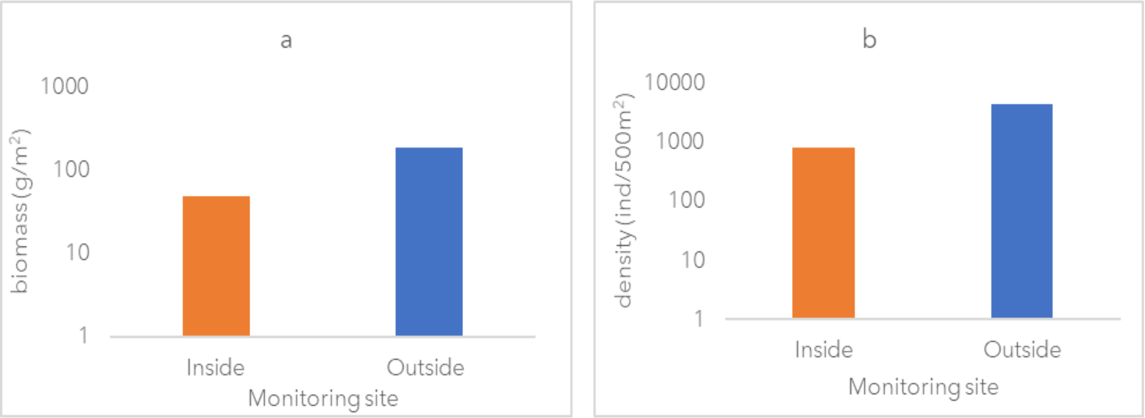

Figure 16. Mean biomass (a) and mean density (b) inside and outside of the Min Ping Yu grounding site.

USS Guardian

Eighty-five species, belonging to 23 families, were identified inside the grounding site of USS Guardian, while 121 species, under 18 families, were recorded outside of the impact site. The estimated species richness inside the impact site was at 43.6 species/500m^2, while the estimate outside was at 66 species/500m^2. Estimated species richness was categorized as 'high' level (37.5-50 sp/500m^2) inside the impact area, while it is 'very high' (>50 sp/500m^2)

outside. In total, 150 fish species were recorded in the area. Labridae (20 species), Pomacentridae (14 species), Chaetodontidae (8 species), Acanthuridae (8 species), and Scaridae (8 species) were the families with the most species identified. Outside of the impact area, Pomacentridae (20 species), Labridae (17 species), and Chaetodontidae (16 species) families represented most of the species identified.

Biomass

The overall mean biomass inside the impact area of the USS Guardian grounding site was 40 g/m^2, mainly represented by Acanthuridae: Nasinae (unicornfish) and Acanthuridae (surgeonfish), each accounted for 9 g/m^2 of mean biomass. Meanwhile, the total mean biomass outside of the impact area (341 g/m^2) was statistically higher than the biomass value inside the impact area (t-test; $p=0.03$). This was due to the encounters with large-sized individuals of Scaridae (parrotfish), which accounted for 154 g/m^2 of biomass, Acanthuridae: Nasinae (unicornfish) with 61 g/m^2, and Acanthuridae (surgeonfish) with 30 g/m^2. The biomass estimates of the two sites were considered 'very high' according to the category established for the reef fish community (Nañola *et al.* 2004).

Target species constituted about 66% of the total biomass inside the impact area. Most of these were species from Acanthuridae: Nasinae (unicornfish) and Acanthuridae (surgeonfish). Major species represented by Pomacentridae (damselfish) and Balistidae (triggerfish) comprised 29% of the total mean biomass. Four (4) percent were attributed to indicator species.

Meanwhile, target species represented 48% of the total mean biomass outside of the grounding site. The target group was primarily composed of Acanthuridae: Nasinae and Acanthuridae. Indicator species comprised 40% of the biomass, which was mainly due to the presence of more than 60 individuals of large sizes (~50cm) of Bumphead parrotfish *Bolbometopon muricatum,* contributing 135 g/m^2 in the biomass. Major species, primarily Balistidae (triggerfish), comprised 11% of the biomass.

Density

The total mean density inside the USS Guardian grounding site was at 1,009 individuals/500m^2. Pomacentridae (damselfish) (530 individuals/500m^2), Labridae (wrasses) (227 individuals/500m^2), and Serranidae: Anthiinae (fairy basslets) (111 individuals/500m^2) were the main contributors to this density. Meanwhile, the density output outside of the USS Guardian grounding site was averaged at 2,096 individuals/500m^2. This was represented mainly by Serranidae: Anthiinae (fairy basslets) with 851 individuals/500m^2, Pomacentridae (damselfish) with 741 individuals/500m^2, and Balistidae (triggerfish) with 140 individuals/500m^2. The difference between these two values was not statistically significant (t-test; $p=0.8$).

Most (89%) of the fishes recorded inside the area belong to the major groups, mainly represented by Pomacentridae (damselfish) (1,566 individuals/500m^2) and Labridae (wrasses) (680 individuals/500m^2). Target fishes constituted about 10% in this area, mainly due to the presence of Acanthuridae (surgeonfish) and Serranidae (grouper). Indicator species recorded in the area were under the family of Pomacanthidae (angelfish), Chaetodontidae (butterflyfish), Tetraodontidae (pufferfish), and Pomacentridae (damselfish).

Similarly, major species dominated (85%) the area outside the impact site. This was primarily attributed to Serranidae: Anthiinae (fairy basslets) and Pomacentridae (damselfish). These two families were the most abundant in the area. Target species were responsible for 13% of the total mean density, mainly due to high encounters with Acanthuridae (surgeonfish). Scaridae (parrotfish), Pomacanthidae (angelfish), and Chaetodontidae (butterflyfish) were the indicator groups recorded and constituted 2% of the mean density.

Demersal fishes constituted 99% of the total density inside the USS Guardian grounding site. This is mainly represented by Pomacentridae (damselfish) (1,571 individuals/500m^2), Labridae (wrasse) (682 individuals/500m^2), and Serranidae: Anthiinae (fairy basslets) (333 individuals/500m^2). Only 14 individuals of pelagic species, from the family Acanthuridae: Nasinae (unicornfish) and Carangidae (jacks and trevallies), were recorded inside the impact site.

Meanwhile, the majority (95%) of the fishes recorded outside were also demersal. Most of these were species from Serranidae: Anthiinae (fairy basslets) and Pomacentridae (damselfish), each with more than 2,000 individuals per 500m^2 recorded. Pelagic species recorded in the area were from Acanthuridae: Nasinae (unicornfish), Caesionidae (fusiliers), and Carangidae (jacks and trevallies).

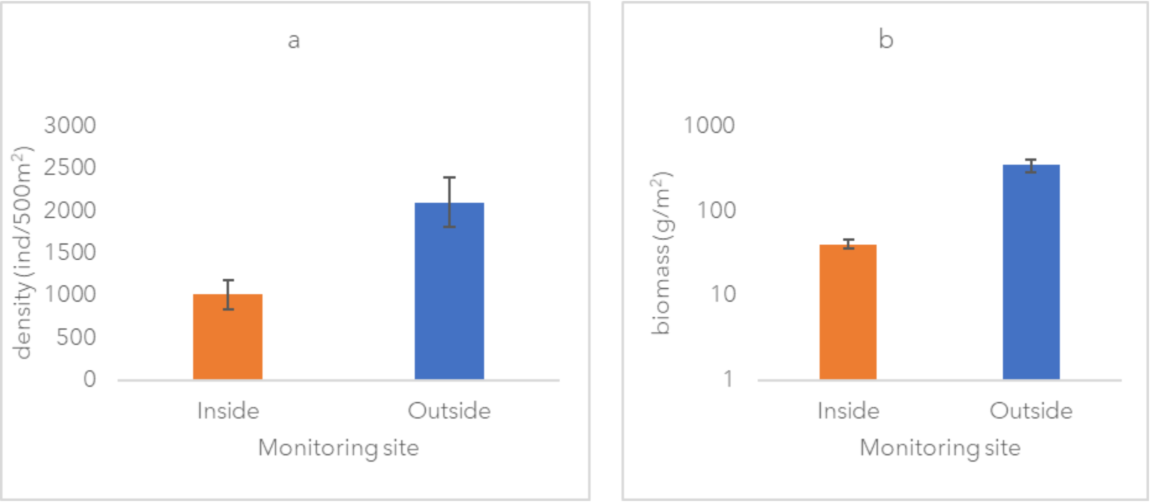

Figure 17. Mean biomass (a) and mean density (b) inside and outside of the USS Guardian grounding site.

Trophic Group: Min Ping Yu and USS Guardian grounding sites

Figure 18 shows the abundance of trophic groups inside and outside the Min Ping Yu and USS Guardian grounding sites. Piscivorous species are mostly large-sized predators such as jacks and trevallies, groupers, snappers, and emperor fishes. Species at the top or near the top of the ecological food web, often the piscivores and benthic carnivores, are of particular concern to conservation because their presence or severe loss/reduction could influence changes in environmental processes and diversity of an ecosystem (Steneck 1998). Their presence in an area could imply the presence of smaller fishes and that food is abundant. It is essential to note the 'completeness' of the trophic guilds in both areas, especially in the impact area, where the environment was disturbed. The presence of each trophic group could imply a healthy and balanced ecosystem in the area.

It is also important to note the presence and role of herbivorous species in these sites, especially inside the impact areas. Disturbances in coral reefs, e.g., grounding incidents that crushed the corals, could trigger phase shifts. The widely recognized and reported of these phase shifts are the algal-dominated system, where algae overtake a disturbed coral reef (Hughes 1992). Coral reefs shifting into an algal-dominated system provide lesser benefits and severe consequences on ecological, environmental, and economic aspects (McCook 1992; Bellwood *et al*. 2004). Macroalgae impact the restoration of disturbed reefs by inhibiting the establishment of coral recruits and survivorship. They compete with corals for space and light (Carpenter 1990) and may also kill them through physical scratching caused by its movement through current or waves (Green and Bellwood 2009). Factors that control the establishment and growth of macroalgal communities is critical in coral reef recovery and resilience (Bellwood and Green 2009). Herbivorous species play a vital role in this situation. They physically control algal growth through feeding, and they could influence the competitive interactions between macroalgal and corals (Williams and Polunin 2001; Bellwood *et al*. 2004). Often, they are the primary drivers in controlling the establishment of macroalgae (Lirman 2001; Mumby *et al*. 2006; Hughes *et al*. 2007).

This year, 218 individuals of herbivores under different functional groups (i.e., browsers, grazers, bioeroders, and scrapers) were recorded both inside and outside the impact area of the Min Ping Yu grounding site. An average of 386 individuals of herbivores was recorded both inside and outside of the impact area in the USS Guardian site, which includes a school of large-sized bioeroders - the Bumphead parrotfish (*Bolbometopon muricatum*). Since herbivore fishes feed and consume algae, and prevent them from ultimately establishing, spaces are provided for the coral recruits to attach and establish themselves. In the case of Tubbataha, the presence of herbivorous fishes, with different functional groups, inside and outside of the grounding areas, could indicate that the reef itself is resilient to algal phase shifts. The presence of these fishes could be one of the main contributing factors to the gradual yet consistent recovery of the grounding areas over the years.

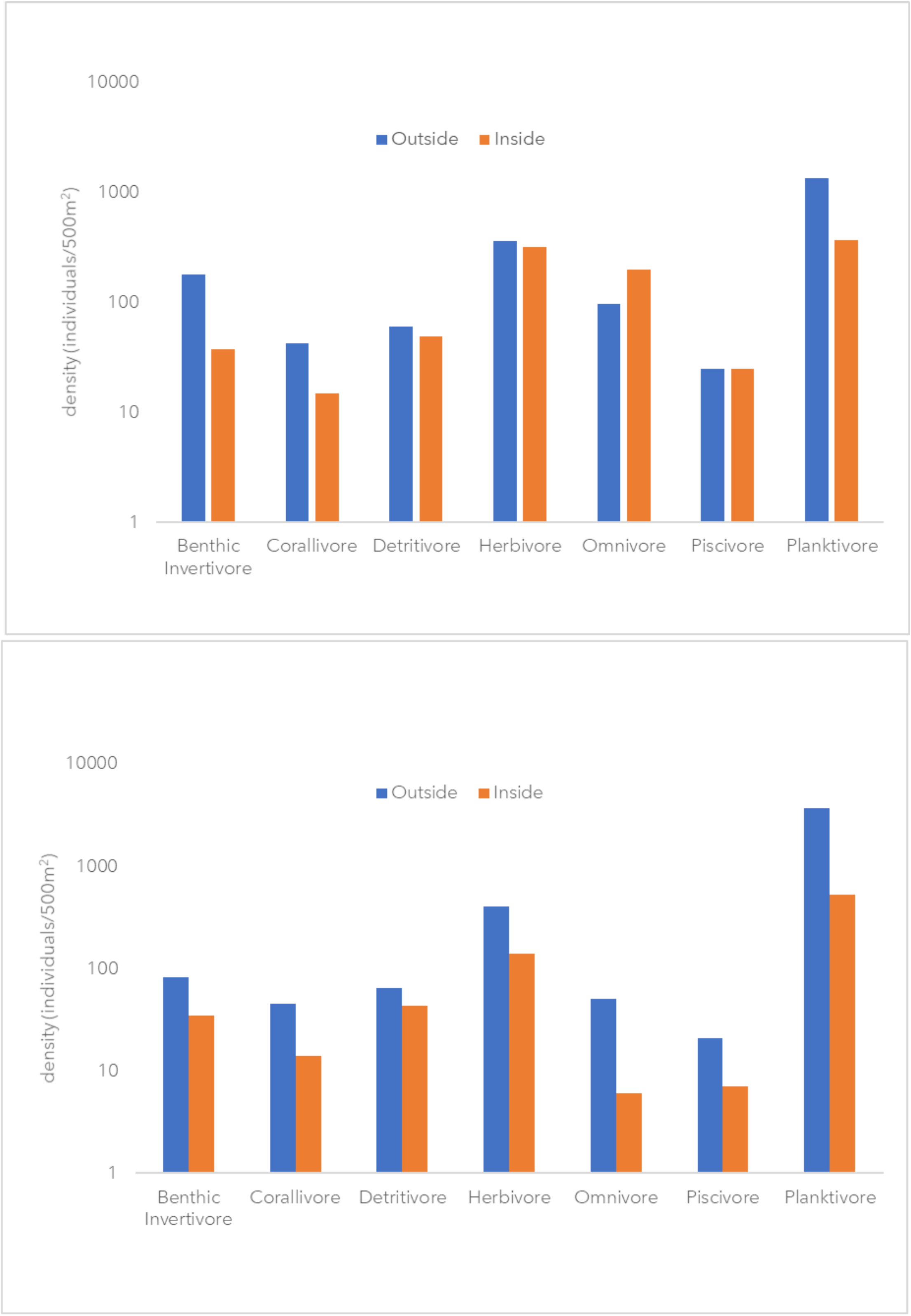

Figure 18. Mean biomass of each tropic group inside and outside of the impact site of USS Guardian and Min Ping Yu grounding sites.

Patterns of fish community

Although the temporal trend in these grounding sites exhibited the same pattern as the regular monitoring sites, fish biomass was relatively lower and varied significantly across the five regular monitoring sites in Tubbataha. However, over the years, the two sites remained within the 'best' category in terms of fish biomass and density based on the Philippine national standard established by Nañola *et al.* in 2006 (see temporal patterns in Figure 19). Since these two grounding sites were monitored in 2014, the biomass and density outputs exceeded the minimum value for a very healthy reef fish community based on the Philippine standards. Since no retrospective data is available during their pre-grounding states, it could not be concluded whether these values are the same as the pre-disturbed conditions. It is worth noting, however, that both sites exhibited high fish community values since 2014.

Figure 19. Temporal pattern of mean biomass and density of the Min Ping Yu (topmost) and USS Guardian grounding sites.

2.4 Conclusion and Recommendation

The fish community this year remains to be one of the healthiest in the Philippines. The diversity, abundance, and sizes improved from the previous year. Commercially important fishes continue to be abundant in the reefs. The presence of species of utmost interest, such as whale sharks, and top trophic species, like tiger sharks, groupers, and trevally, is an indication of ecological balance in the reef ecosystem. Over the years, Tubbataha Reefs has proven that stringent protection is a vital factor in securing mature fish populations, evident in the consistent display of high biomass outputs and the presence of top predators (e.g., sharks). Furthermore, its isolation and remoteness from anthropogenic disturbances and its size appear to be crucial factors in structuring the healthy fish community of the park.

The grounding sites and areas outside them both teem with fish. This shows that healthy surrounding reefs play a pivotal role in seeding disturbed areas with the fish population (Jones *et al.* 2009). Without further direct impact from anthropogenic activities, the reef itself allows natural processes to take place, as its recovery from grounding incidents both for fish and coral communities.

For the succeeding surveys, it is recommended that observers maintain the practice of standardizing the size and count estimates before the actual survey to diminish huge variations in the data collected.

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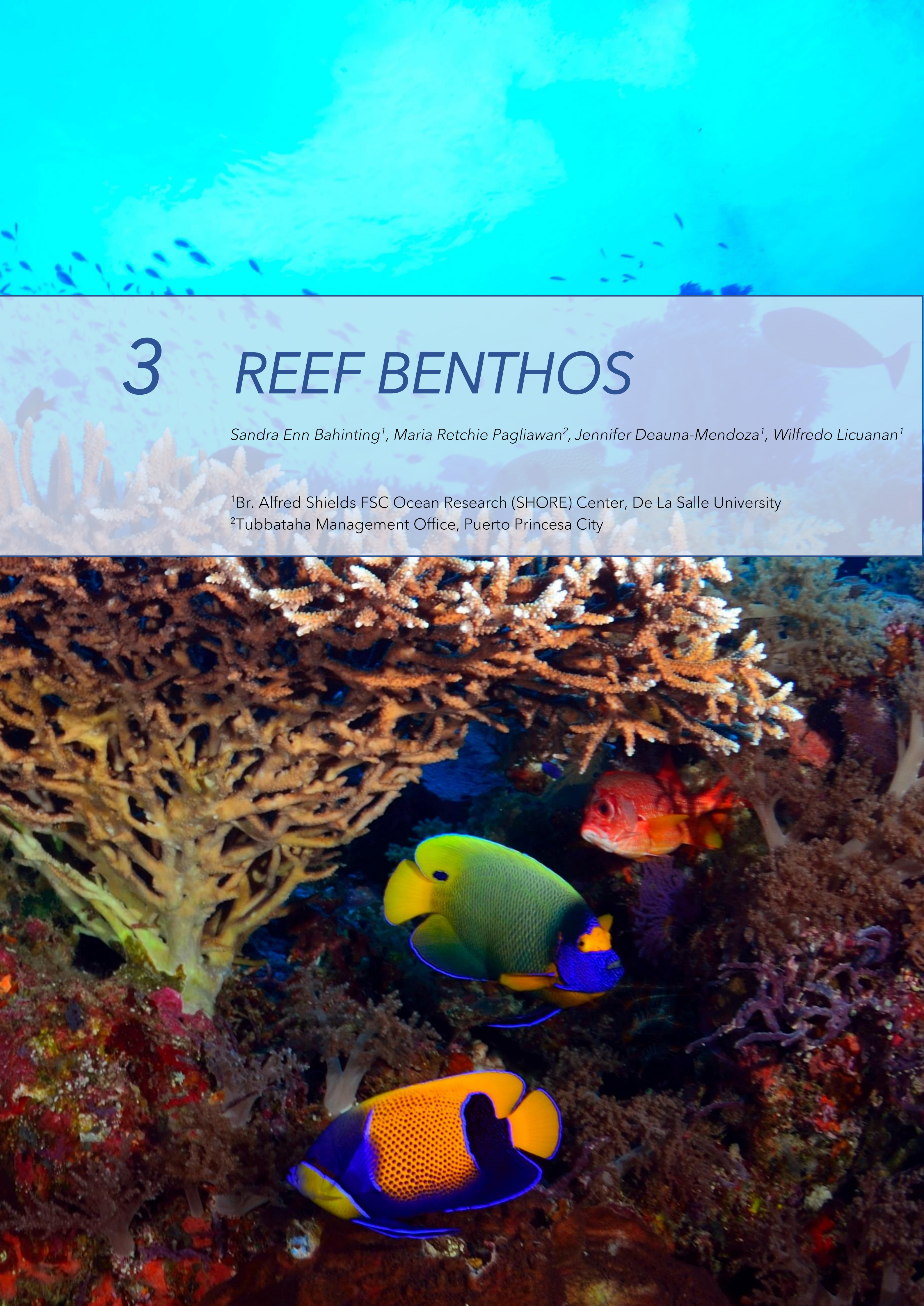

3

REEF BENTHOS

Sandra Enn Bahinting[1], Maria Retchie Pagliawan[2], Jennifer Deauna-Mendoza[1], Wilfredo Licuanan[1]

[1]Br. Alfred Shields FSC Ocean Research (SHORE) Center, De La Salle University
[2]Tubbataha Management Office, Puerto Princesa City

3.1 Overview

Reef benthos monitoring is an integral part of the conservation of TRNP. The data collected through time contributes immensely to the study of coral reefs in a relatively pristine state. The results of the annual monitoring generate information on changes and trends in the benthic cover and composition through time. The information generated helps in improving the efficacy and efficiency of current management and conservation efforts and guides the development of policy.

An overall and statistically significant decline in the hard coral cover in Tubbataha was documented in the benthos reports produced by TMO and DLSU in the past two years. In contrast, algal assemblage and sponges increased significantly over the same time frame. These changes might have serious implications on the health of the atoll ecosystems. An update of the status of the benthic community of the five (5) monitoring sites and the two (2) ship grounding sites in the Tubbataha Reefs in 2020 is presented in this chapter.

3.2 Methods

Data collection

To monitor the reef benthos in the shallow areas, the sampling stations, with an area of 75m x25m, were delineated at the reef slope with a depth of 2-6 m described on the Luzon et al. (2019) protocol. One 100-meter and four 50-meter transects were deployed randomly in parallel to each other from the deep edge going to the shallow part of the reef. On the shallow side of each of the transects, images of the underneath benthos were captured at 1-m intervals using a Sony RX 100 camera attached to an INON Wide Conversion Lens. The camera is equipped with Ikelite camera housing and mounted together to an aluminum monopod. This resulted in a minimum of 250 images, covering all the five transects for each station.

A fixed 4m x 4m quadrat was placed strategically within the sampling station. Images were captured, covering a 1m x 1m area with 50% overlapped between adjacent images corresponding to a minimum of 90 images. However, only 30 randomly chosen photos were used for processing.

In the deep areas (10 m), four (4) 20-meter transects laid five meters apart, were placed on the substrate. Photos were taken every one (1) meter distance on the shallow side of the transect. This resulted in a minimum of 80 images for each station.

The images were scored using the Coral Point Count with Excel extensions (CPCe; Kohler and Gill 2006) for the benthic cover and generic diversity. The software generated ten random points per image and the benthic organisms in each point were identified to the genus level and growth forms based on the 60 Taxonomic Amalgamation Units (TAUs). The TAUs were grouped into six major benthic categories, i.e., hard coral (HC), algal assemblage (AA), abiotic material (AB), macroalgae (MA), *Halimeda* (HA), and other biota (OB).

Data Analysis

Hard coral cover (HCC) and generic diversity categories presented by Licuanan et al. (2019; Table 1) was used to assign the average hard coral cover and generic diversity determined for all the monitoring stations from 2012 to the present.

Table 1. Hard coral cover and coral generic diversity values per category (Licuanan et al. 2019).

HCC or Diversity Category	Hard Coral Cover	Coral Generic Diversity
Category A	> 44%	> 26
Category B	> 33%-44%	> 22-26
Category C	> 22%-33%	> 18-22
Category D	0-22%	0-18

Linear regression and two-way analysis using repeated measures (ANOVAR) were used to determine the changes in the percentage of benthic cover and generic diversity over time at different levels i.e. location and site and across time and sites, respectively. These were computed for p-values, F-value, and degrees of freedom that were used for all statistical analyses. JMP Pro 11 and Program R (R, Core Team 2020), version 3.6.3 was used to perform all the statistical analysis mentioned.

3.3 Results and Discussion

Present conditions

Shallow areas

The present coral reef monitoring in Tubbataha revealed a 33.3% ± 2.1 SE hard coral cover and 19 coral TAUs ± 0.7 SE generic diversity. The average HCC reported was higher than that of the Sulu Sea Bioregion of 28.4% ± 2.4 SE but slightly lower in the number of genera (Sulu Sea: 20.8 ± 0.9 SE). Of the five monitoring sites, Jessie Beazley had the highest coral cover of 48.1± 9.4 SE but had the lowest number of genera (16 TAUs ± 5.1 SE). A monospecific stand of foliose *Montipora* that dominated Station A is the reason for the latter result. Site 2 had the lowest hard coral cover of 20.3 ± 2.4 SE, whereas Site 1 supported the highest number of genera with 23 TAUs ± 2.5 SE. Site 1 is dominated by *Goniastrea, Leptoria,* and *Favites*.

Among the 10 monitoring stations, only Station B of Sites 1, 3, and 4 moved one step higher in their HCC Category from 2019 to 2020, i.e. Category B to A (Site 1: 40.5 ± 10.1 SE), and Category C to B (Site 3: 33.9 ± 0.5 SE, Site 4: 23.6 ± 9.5 SE). The rest of the stations had the same HCC category as last year (Figure 20a). Furthermore, coral generic diversity in Figure 1b showed that only Stations 3A, 2B, 4B, and Jessie Beazley B changed from one TAU category to the other: Category C to D (Station 3A: 14 ± 3.3 SE), Category B to C (Station 2B: 20 ± 2.0 SE, JBB: 21 ± 1.0 SE) and Category C to B (Station 4B: 22 ± 2.0 SE). The remaining stations had the same category as last year.

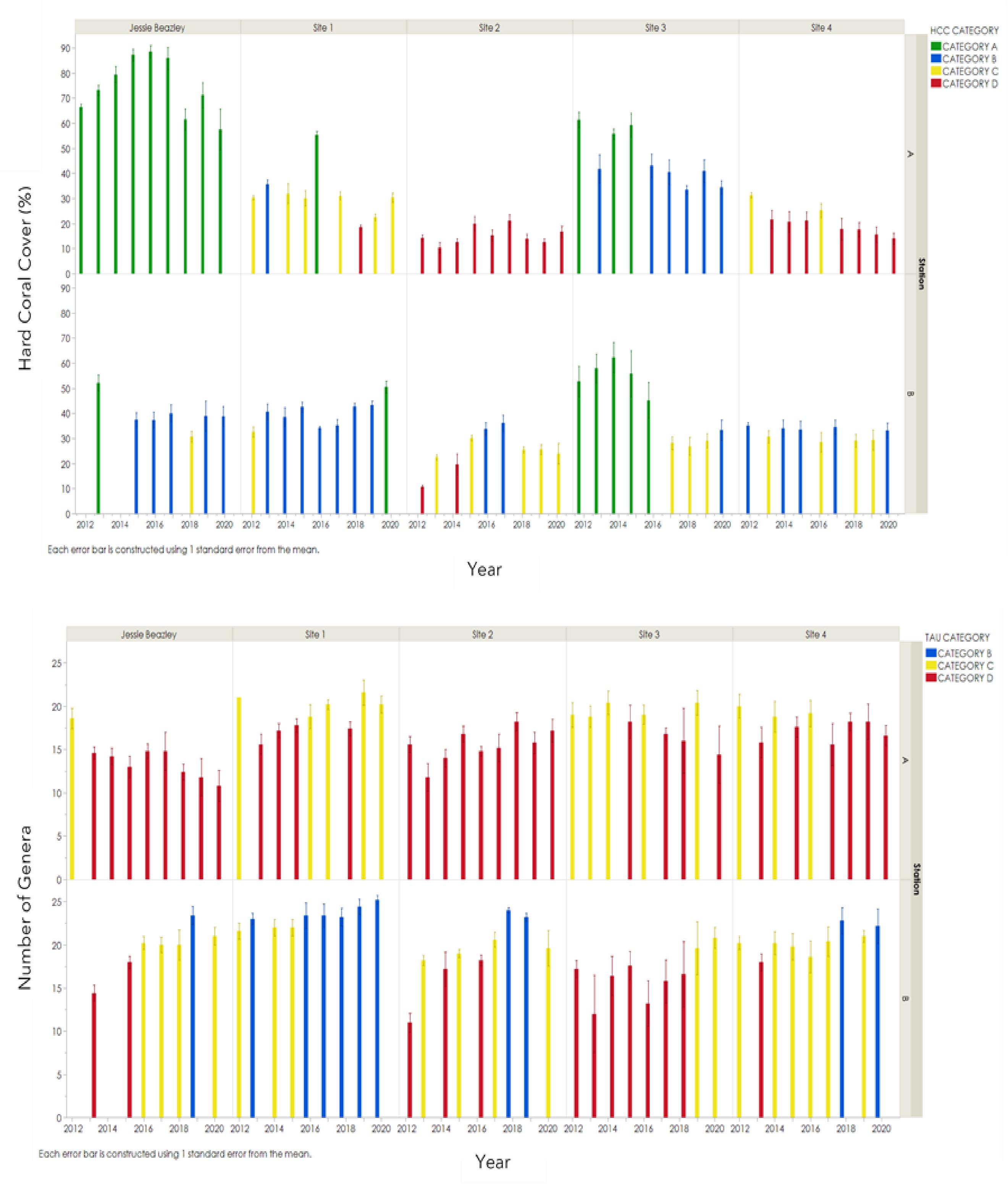

Figure 20. A column plot of the monitoring stations in the shallow areas from 2012-2020 according to (a) hard coral cover category and (b) generic diversity category. Results are color-coded based on the two assessment scale (Licuanan et al. 2019).

Like the previous year, the high cover of the algal assemblage was documented in Tubbataha (39.8 ± 2.3 SE), with Site 4 having the highest cover (63.5 ± 13.8 SE, Figure 22). As revealed in last year's report, thick algal turf mostly covered the reef slope of the site. Sponges were also observed in all sites but the cover in 2020 is highest in Site 2 (13.5 ± 0.5 SE) followed by Site 4 (7.2 ± 3.9 SE, Figure 20). Outbreaks of sponges and increases in algal assemblages pose a variety of negative effects on the reef community. Algal turf reduces available space hindering the settlement and recruitment of coral larvae (Roth *et al.* 2018) while sponges, another competitor for space, can actively outgrow and kill other benthic organisms (Pawlik *et al.* 2007). The abundance of these sessile organisms may account for the decline in coral cover. Their abundance may be caused by factors such as nutrient enrichment (Adam *et al.* 2020) and a decline in the population of grazers/detritivores (Cheal *et al.* 2012).

Deep areas

The mean HCC in the deep areas was 25.8% (± 1.7 SE), with an average of 22 (± 1.7 SE) coral TAUs generic diversity. Site 1 had the highest HCC of 31.2% (± 7.8 SE), as well as the highest number of coral TAUs of 32.2 (± 0.5 SE). Site 1 was composed mainly of encrusting *Porites, Echinopora, Pachyseris, and* massive *Diploastrea*. The lowest HCC was recorded in Site 2 (± 1.1 SE), while the lowest generic diversity was recorded in Jessie Beazley with 16 (± 1 SE) coral TAUs. Site 2 was composed of *Porites, Diploastrea, Isopora*, and *Millepora*, while Jessie Beazley was composed of *Pocillopora, Goniopora, Porites,* and *Millepora*.

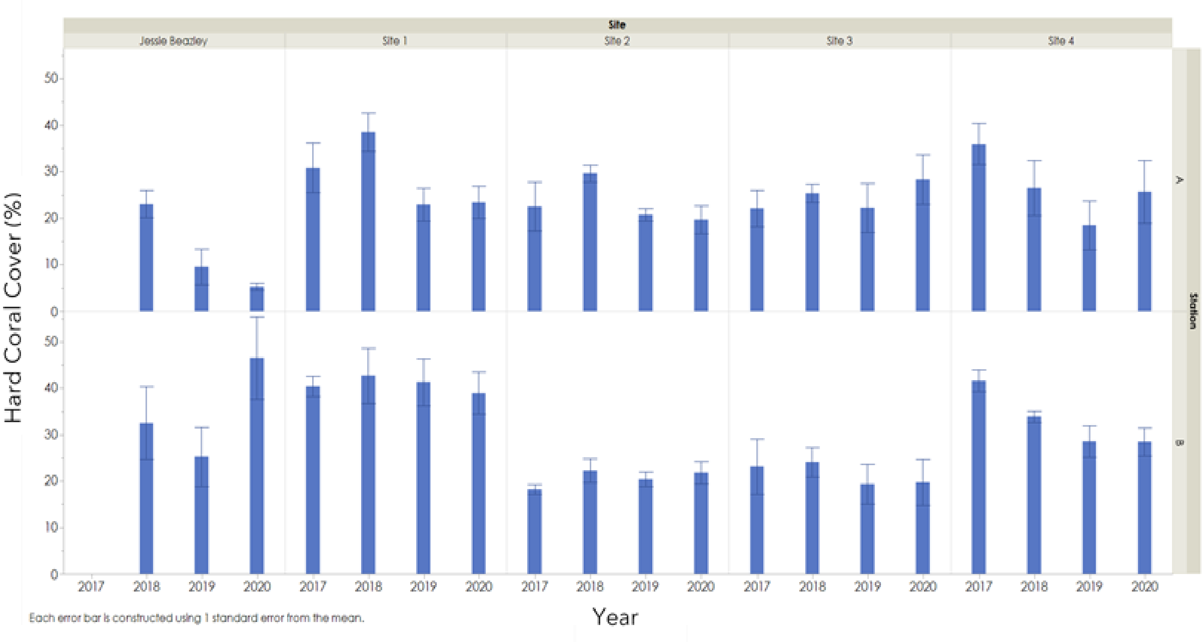

Figure 21. HCC in the deep areas of the monitoring stations from 2017 to 2020.

At the station level, the highest HCC was recorded in JBB (46.5%), which was dominated by *Goniopora*, *Millepora,* and *Goniastrea*. The lowest HCC was recorded in JBA (5.3%), which was mostly composed of *Pocillopora, Porites,* and *Acropora*. Soft corals covered 64.7% of the benthic community in JBA.

Algal assemblages, mostly algal turf, covered 36.7% (± 5.1 SE) of the benthic cover in the deep areas. This value is higher compared to the average HCC this year. Among all the stations, only Stations 1B and JBB recorded lower algal cover compared to HCC. The high percentage cover of algal assemblages in the deep areas was consistent with the findings in the shallow areas.

Temporal patterns

Shallow areas

The average hard coral cover in the four monitoring sites of the North and South Atolls showed a significant annual decline of 1% from 2012-2020 (Figure 22; ANOVAR Year: F_8= 2.44, $p< 0.05$; site x year, F_{24}= 2.18, $p< 0.05$). This significant decrease in the trend of HCC was evident in Sites 3 and 4 with an annual loss of 3.9% (F_{89}=52.4; $p<0.0001$*) and 1% (F_{89}= 6.9; $p<0.01$), respectively. In contrast to the decrease in HCC, algal assemblages (turf algae) showed the highest increase among the benthic groups of 1.8% annually for the same period in all four sites (ANOVAR Year: F_8= 46.97, $p< 0.0001$; site x year, F_{24}= 3.53, $p< 0.001$). This inverse relationship between coral and turf algae is a general pattern that can be observed across sites over time. This, however, is most apparent in Sites 3 and 4 of the South Atoll.

Site 3 showed a decline in HCC by 26% and an increase in algal assemblages from 2015 to 2017. The decline was attributed to the logs and payao floats that struck a large area of the reef in 2016, generating fields of *Isopora brueggemanni* rubble. These unconsolidated fragments were then overgrown by mostly algal turf and an encrusting type of sponge called *Terpios hoshinota*. Furthermore, the strong wave action driven by the five tropical storms that traversed the Sulu Sea from November 2017 to February 2018 may have exacerbated the damage to the reef. Strong typhoons cause strong wave action and water movement which causes fragile coral colonies to break contributing to rubble in the reef, thus slowing reef recovery (Wilkinson & Scouter 2008).

Similar changes were observed in Site 4 for HCC and algal assemblage, where cover of the latter was consistently highest among all the sites (Figure 22). This inverse relationship between the cover of these two benthic groups in the transect data paralleled the condition in the fixed plot established in Station 4B (Figure 24). HCC showed a decline of 1% (F_5=0.3344; $p>0.5$) annually, but an equivalent increase in algal assemblage was observed from 2015-2020. There was also an abundance of sponge and cyanobacteria with an annual increase of 1.2% (F_5=3.47; $p>0.05$) and 0.3% (F_5=0.1353; $p>0.5$), respectively, over the same period.

Villanoy *et al.* (2003, unpublished) reported that the outflow of nutrients from the lagoon, the residence time, and the flushing of water may have an effect on the reef communities in the atoll. Licuanan and Bahinting (in press) theorize that the accumulation of seabird guano in the South Islet lagoon is likely to contribute to the enrichment of nutrients in the seawater. This enrichment allows for the proliferation of many opportunistic organisms including crown-of-thorns starfish (Bell 1992), sponges (Holmes 2000), macro-algae (De'ath and Fabricius 2010), benthic cyanobacterial mats (Brocke *et al.* 2015), and turf algae (Vermiej *et al.* 2010). Therefore, the increased nutrient concentration in the south lagoon is suspected to trigger a shift in the composition of the benthic sessile communities.

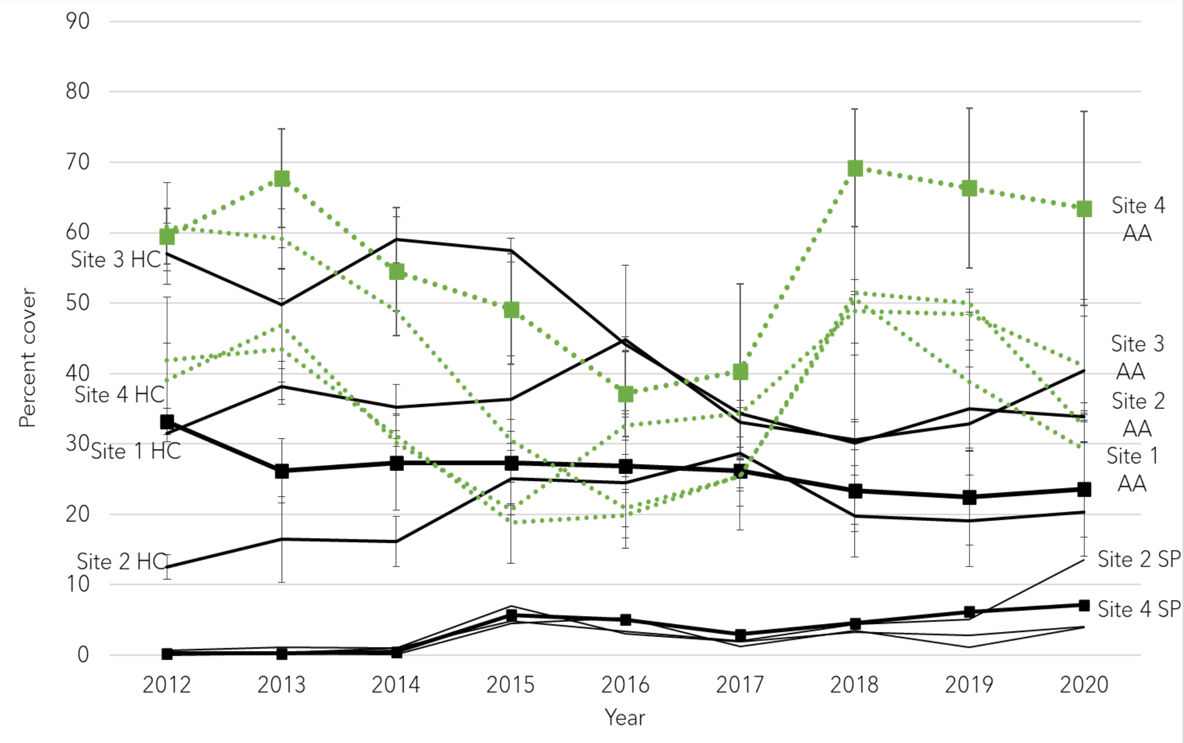

Figure 23. Percentage cover of hard coral, algal assemblage, and sponge in all the monitoring sites from 2012-2020.

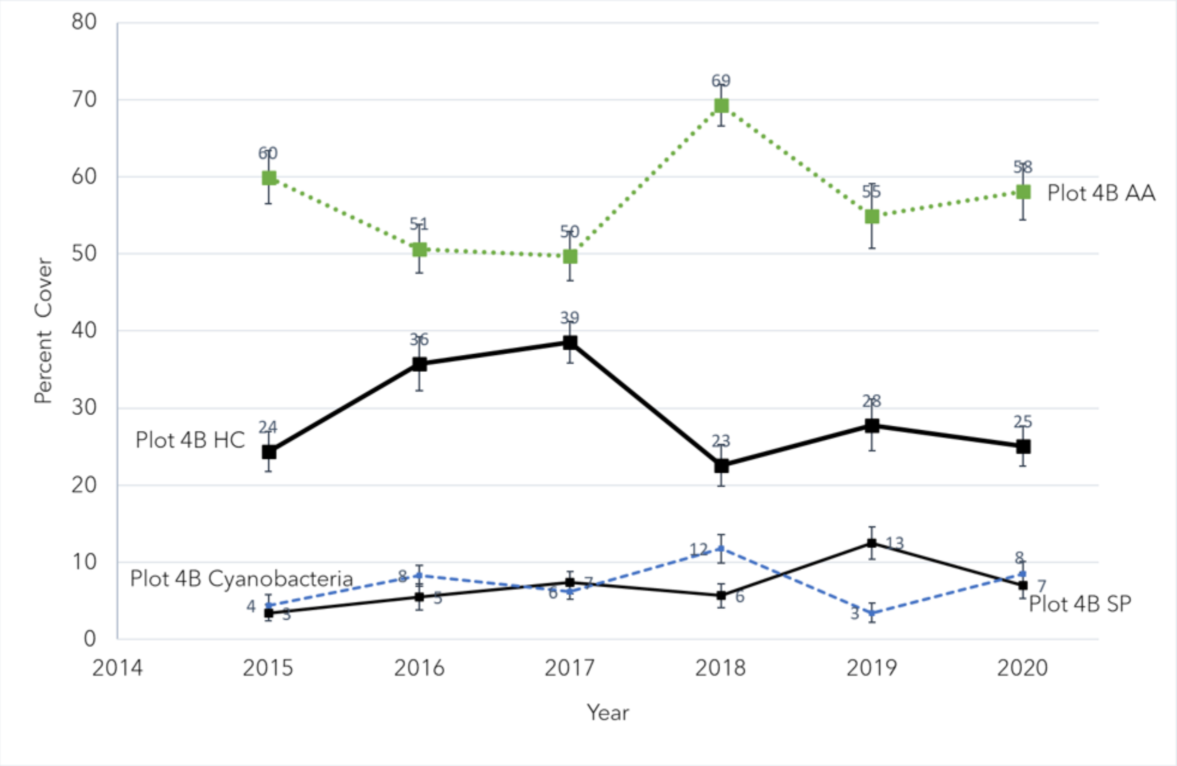

Figure 22. Percentage cover of hard coral, algal assemblage, cyanobacteria, and sponge in the fixed plot of Station 4B from 2015-2020.

Deep areas

Figure 24 presents the percentage cover of hard corals, soft corals, and algal assemblages since 1997. Comparison of values, however, was not statistically possible due to the changes in sampling methods employed.

Despite these limitations, a downward trend in HCC was observed in the deep areas beginning in 2013, similar to what was recorded in the shallow areas. This coincided with the increase in algal cover beginning in 2014. Bruno *et al.* (2009) and Adam *et al.* (2020) have documented shifts in coral-dominated to predominantly algae encrusted reefs.

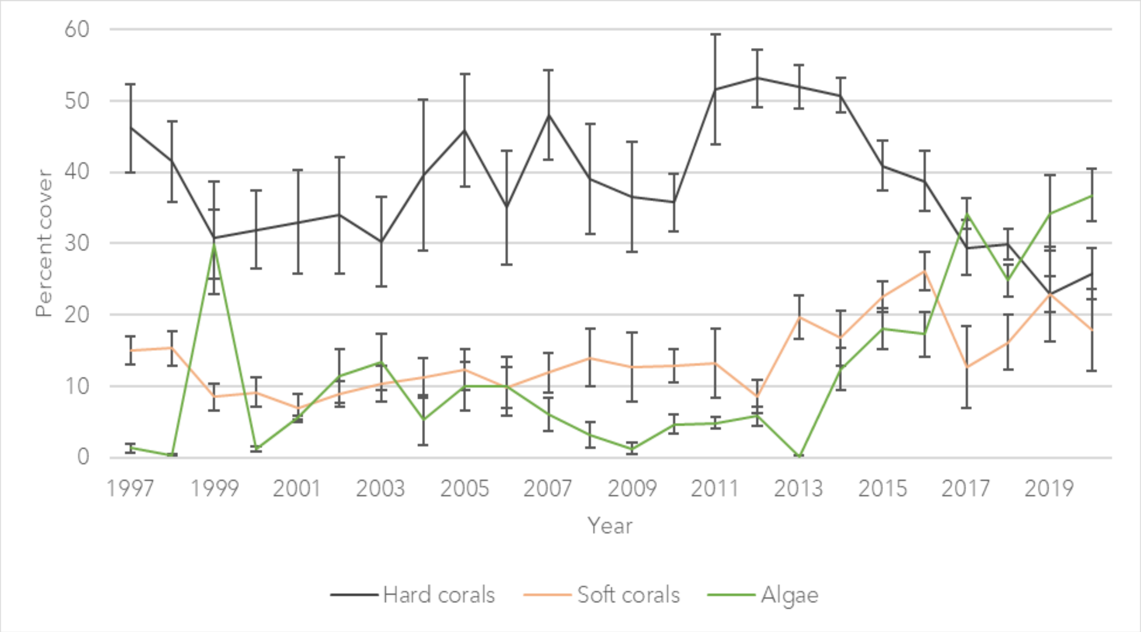

Figure 24. Hard coral, soft coral, and algal cover in the deep areas of TRNP from 1997 to 2020.

Ship Grounding Sites

Min Ping Yu

Three (3) fixed 4m x 4m plots were established to monitor the recovery process of the site damaged by the grounding event. A small fragment plot represents the area composed of a mass of small coral fragments and rubble left by the ship as it repeatedly hit the reef in 2013. Debris of large fragments of coral due to the pounding of the ship's rudder makes up the large fragment plot, while the nearby undamaged area is the adjacent control.

The HCC of the adjacent control (14.3 ± 3.6 SE) is much higher than the large fragment plot (10.8 ± 2.03 SE) and eight times that of the small fragment plot (1.7 ± 0.7 SE) (Figure 25). The HCC of large fragments has steadily increased with an annual rate of 1.5% since 2014 ($p>0.05$). The increase may be due to fragments providing stable space for recruits to settle allowing for the continuous growth of the remaining corals. Furthermore, the coral community in the plot was dominated by massive and encrusting *Porites* (6.8% and 1%), *Isopora,* and *Pocillopora* (both 1.1%). In contrast, HCC of the small fragments plot showed a decrease of 1.4% from last year. The instability of these unconsolidated fragments lowers the survival rate of recruits and small colonies, thus, hampering coral recovery (Flower *et al.* 2017). The sand that makes up the bottom of the adjacent control plot is the likely reason for the high variability of HCC here.

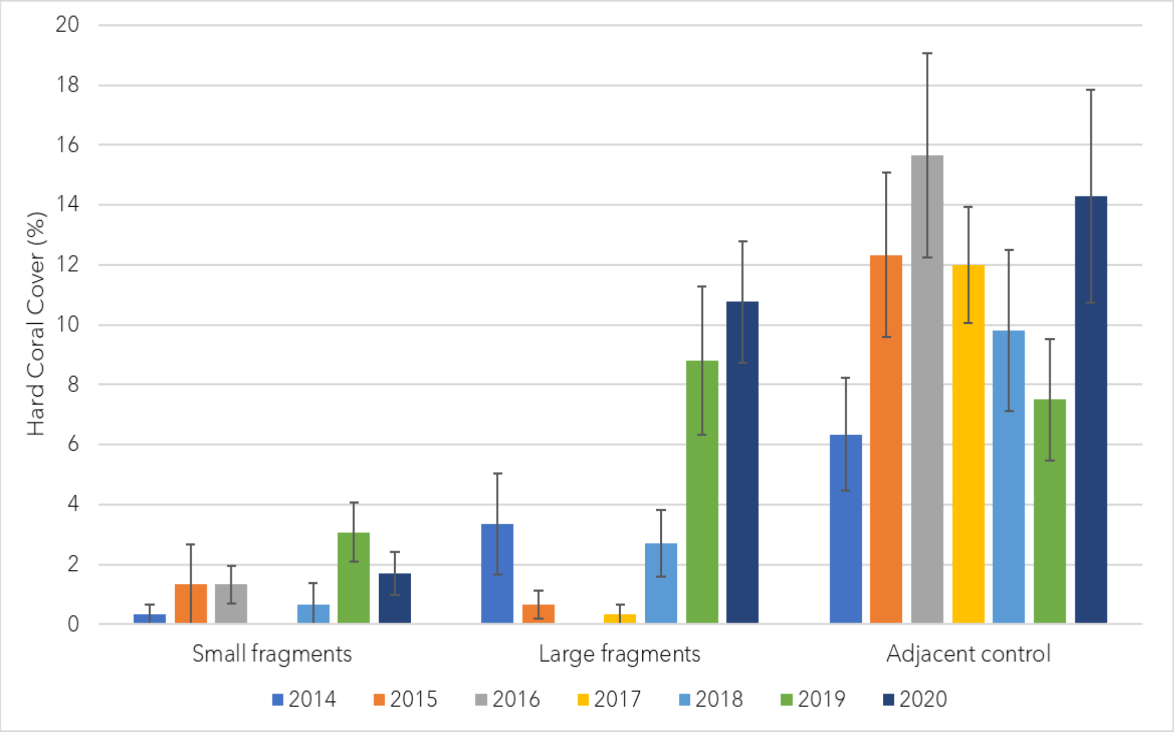

Figure 25. Hard coral cover in Min Ping Yu Site from 2014-2020. Error bars indicate+/- 1 standard error.

USS Guardian

Similar to MPY, three fixed 4m x 4m quadrats were placed strategically to monitor the changes in the reef community within the grounding site. Ground zero refers to the area that was the most damaged, while the 'impact border' refers to the area that was moderately damaged. The 'adjacent control' refers to the area where no damage from the grounding was observed.

The impact border showed the highest HCC (11.2 ± 2.1 SE) compared to ground zero (9.1 ± 2.0 SE) and twice that of the adjacent control (5.4 ± 1.5 SE). The HCC in ground zero continues to increase at an annual rate of 1.2% since 2014 ($p<0.05$) while the impact border, with relatively stable cover for the past two years, regained its 2017 coral cover. However, the adjacent control or undamaged zone has not yet recovered from the drastic drop in HCC in 2017 and is still decreasing annually (2.8%; $p<0.05$) (Figure 26). Deposition of the rubble from the impact of the ship may have been moved by waves or current into the adjacent control area hindering the growth of new corals. Site 4 is located near the northeast corner of South Atoll, where currents can be strong, especially during the shifting of tides. The coral genus, *Pocillopora*, which was one of the coral recruits most observed during the past surveys, still dominates the coral community in all plots.

Algal assemblages were consistently the most abundant benthic cover in all three zones. The highest cover was recorded in adjacent control (86.6 ± 2.1 SE), followed by ground zero

(82.07 ± 2.1 SE) and lastly, impact border (78.8 ± 2.9 SE). The occurrence of sponges was also observed with 3.5% (±1.1 SE) cover in ground zero, the highest among the three zones.

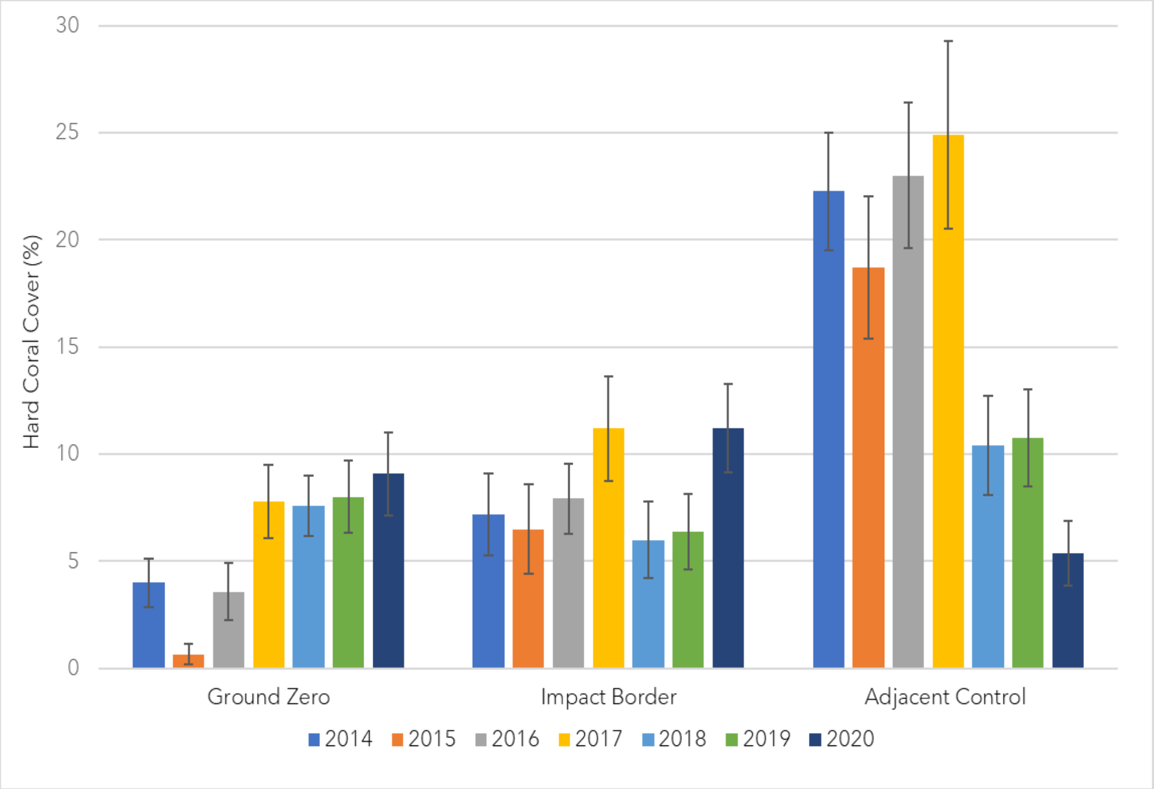

Figure 26. Hard coral cover in USS Guardian Site from 2014-2020. Error bars indicate +/- 1 standard error.

3.4 Conclusions

The small but incremental decrease in HCC in Tubbataha since 2012 has resulted in a significant downward trend. This is most evident in the South Atoll. The decline in coral cover coincided with the increase in cover of algal assemblage (mainly turf algae) which has become the dominant benthic category in all the sites, particularly in Site 4. Furthermore, an increase in the abundance of other competing benthic organisms, including sponges and cyanobacteria, was also observed. The changes in the cover of the aforementioned benthic groups were detected in both the transect and fixed plot data. These changes are attributed to the likely increase in nutrient levels in the lagoon of the South Atoll that is driven by the seabird droppings, increasing the competitive ability of algal turf among the benthic components. These changes, superimposed with those of ocean warming and climate change, threaten the corals in the study sites and might trigger a phase shift in the benthic species composition from a coral-dominated state.

3.5 Recommendations

The general trend in HCC is decreasing gradually coincident with an increase in algal assemblage through time. The present abundance of sponge and cyanobacteria is a concern in the management of the Park. Continued monitoring of the current sites and the conduct of a rapid assessment of the other areas of the atolls not surveyed recently is recommended. These should follow the methods used in this report. The assessment could provide a better understanding and evidence of this shift i.e., the underlying conditions and mechanisms that occur during the shift from one state to the other. The rapid assessment can provide a baseline for these areas while subsequent monitoring may be done intermittently. In the past years, no major disturbances (e.g., massive coral bleaching and crown-of-thorns infestations), which could explain the decline in HCC, were recorded. Thus, monitoring of other parameters such as water quality and other benthic sessile organisms should be considered to evaluate the possible eutrophication of lagoon waters. Current management strategies need to be reviewed to address and assess possible triggers of coral decline in the future.

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4 CORAL RECRUITMENT

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

Tubbataha Management Office, Puerto Princesa City

4.1 Overview

Tropical coral reefs are subject to a wide variety of disturbances of natural and anthropogenic origin, but one of the most immediate threats is the warming ocean, which can drive high coral mortality through bleaching (Hughes *et al.* 2017). Recently, it has become clear that coral communities on many reefs have lost the capacity to recover following mass mortality events (Hughes *et al.* 2018). For the reefs to recover from major disturbances, a critical factor is the capacity for a high coral recruitment rate.

Thus, understanding the processes which maintain coral populations should not be limited to studying adult coral colonies. Smaller colonies, such as coral recruits, provide insight to better evaluate the resilience of reef ecosystems (Doropoulos *et al.* 2015). This study intends to continue quantifying coral recruitment density and distribution in TRNP. Furthermore, it aims to identify and understand factors, such as the variability of juvenile corals among sites and depths, that may have implications on the overall coral population.

4.2 Methods

Sampling Design

At each transect, a diver randomly placed a 34 x 34 cm (0.12 m^2) quadrat on the substrate to obtain representative samples of each station. The quadrat was marked with scale bars (2 and 5 cm) on both sides for size reference (Figure 27).

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 27-c). This process was repeated 20 times along the transects at both depths, in each of the stations. images were taken using a 20-megapixel camera with an underwater casing. A total of 40 quadrats per station were processed – 20 in the shallow and 20 in the deep areas.

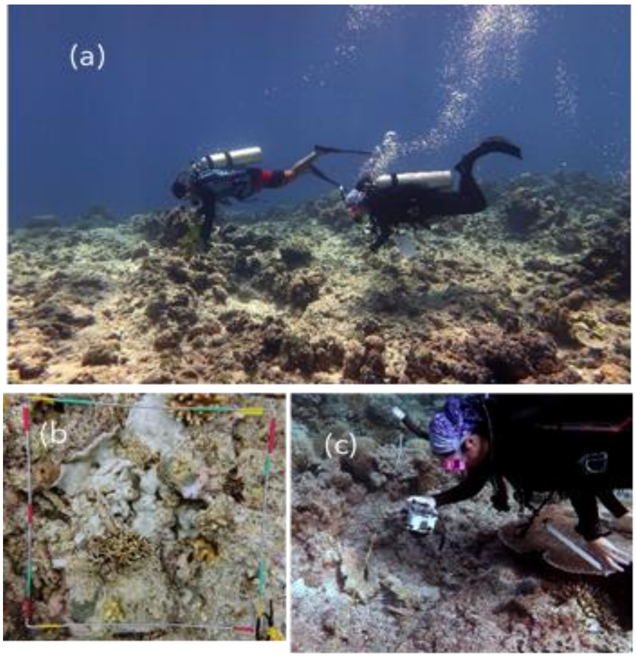

Figure 27. Coral recruitment sampling: (a) quadrat placed randomly within the transect; (b) close-up shot of the quadrat with scale bars, and; (c) multiple photos taken using underwater camera.

For the grounding sites, quadrats were laid inside the three (3) 4m x 4m fixed monitoring plots (Figure 28). They were strategically positioned to capture the impact of the ship grounding. In each of the grounding sites, one quadrat was positioned in the impact zone (Quadrat 1), one in the buffer zone (Quadrat 2), and another in the control zone (Quadrat 3).

Figure 28. Permanent quadrats of the two grounding sites established in 2014 (Licuanan et al. 2014).

Following the recommendations from last year, the number of quadrats sampled in each plot was increased from five to 10, to obtain more robust data. In each plot, the 34 x 34 cm quadrat was placed in 10 locations – in the middle of the plot, four corners, and five haphazardly. A total of 30 quadrats were sampled at each grounding site.

All photos were scored using the Coral Point Count with Excel Extension® (CPCe) software. Only coral colonies measuring <5cm were considered recruits (Burgess *et al.* 2009).

Data Analysis

In the CPCe software, each photo was calibrated using the 5cm 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 Units (TAUs). The Indo-Pacific Coral Finder version 3.0 and the Guide to the Corals of Bolinao-Anda Reef Complex served as references for coral identification. Small coral fragments that were deemed remnants of adult corals were excluded. The percentage of each hard coral (TAUs) was computed for every station and were plotted using Microsoft Excel. Paired t-test (assuming equal variance) was used to determine a significant difference.

Estimates of coral recruit density were calculated for each quadrat as the number of recruits per 0.12m^2. Differences in the densities of recruits across stations, depths, and years were tested using one-way Analysis of Variance (ANOVA). In addition, a paired t-test (assuming equal variance) was performed when significant differences were found. While the Chi-square test was the probability of the size-frequency distribution of recruits, juvenile and mature colonies of corals.

4.3 Results and Discussion

Coral recruitment patterns

This year marked the third year of coral recruitment monitoring in the park. A total of 1,860 coral recruits from 2,100 photographs were processed, covering a total of 48m^2 in the regular monitoring sites and 7.3m^2 in the grounding sites. This year 40 genera belonging to 14 families were recorded, higher than the previous year's record. The average coral recruitment density (all genera) at 10 meters, across all the regular monitoring sites, was 61.67 ind/m^2 (±6.18 SE), with density ranging from 0.68 individuals/m^2 to 38.19 ind/m^2. This was higher compared to 2019 (42.28 ind/m^2), and two times higher compared to Code Hole Reef in Australia at 36.67/m^2 (Burgess *et al.* 2010); Malapascua, the Philippines at 23.55 ind/m^2 (Dalongeville *et al.* 2018); and Tioman Island in Malaysia at 25.92 ind/m^2 (Muhhanmad *et al.* 2017). In the shallow areas, the average density was 53.75 ind/m^2 (±7.03 SE), which was higher than that of the previous year. Generally, a lower density of coral recruits was observed in the shallow compared to deep areas, similar to the previous year's results.

An increase in the coral recruit density was observed in both grounding sites. The highest recruitment density recorded in the USS Guardian (USSG) grounding site was 22.91 ind/m^2 in Quadrat 3 (adjacent control). Meanwhile, the highest density in the Min Ping Yu (MPY) grounding site was recorded at Quadrat 1 (small fragments) with 30.55 ind/m^2. The USSG recorded 12.50 ind/m^2 in Quadrat 1 (impact zone), which was 28% lower compared to 2019. MPY had a mean density of 30.55 ind/m^2 recorded in the small fragments (Quadrat 1), which was a 68% increase from last year.

Coral recruitment in the deep areas

In the deep area, 32 genera belonging to 14 families were recorded. This was higher compared to Tioman Island in Malaysia with 26 genera belonging to 12 families (Muhhanmad *et al.* 2017). The three major coral families with the highest percentage in the deep areas were Agariciidae, Poritidae, and Poccilloporidae. This was consistently observed for three years. Among all the coral families, Agariciidae which accounted for 25.28% of all coral recruits recorded this year, remained the most abundant, followed by Poritidae and Pocilloporidae at 20.99% and 15.81%, respectively (Figure 29). These dominant families were mostly composed of the brooder type of corals. Brooder corals tend to maintain their potential for high self-recruitment in shorter distances (Figueiredo 2013) and reproduce

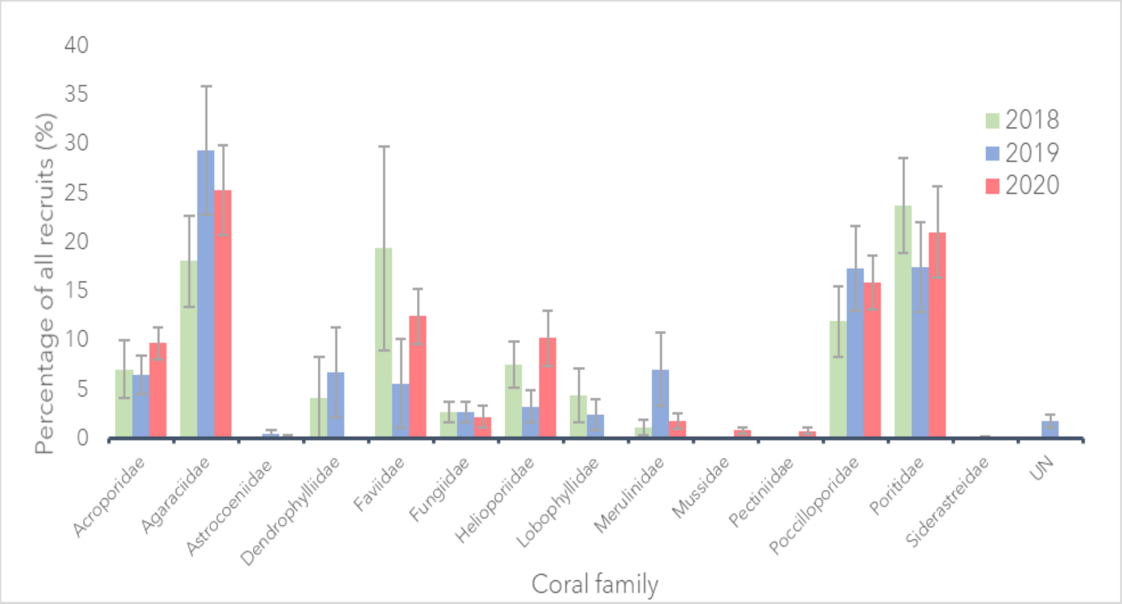

Figure 29. Mean percentage population of all coral recruits found at 10m deep. Error bar represent standard error of mean. Unidentified corals were group under the category UN.

multiple times in a year (Moulding 2005), as opposed to the annual reproduction of broadcast spawners (Acosta *et al.* 2001; Moulding 2005).

Coral recruits under the family Faviidae were observed to increase in cover from 5.58% in 2019 to 12.38% in 2020. Rare coral families, i.e., Pectinidae and Mussidae, were recorded this year. The difference in the percentage of all coral recruits found between last year and this year is not significant *(paired t-test=1, p=0.05).* Similar coral families were observed among the coral recruits and adult colonies across all stations.

A total of 32 genera were recorded across all stations, with the highest number of genera found in Stations 2A, 2B and 4A, ranging from 21 to 23 genera. Site JBA had the lowest number of coral genera (12 genera). In this year's survey, the mean coral recruitment density was 61.67 ind/m^2, which was significantly higher than in 2019 (41.57 ind/m^2, paired t-test=0.006, p=0.05) (Table 2).

Consistently, the deep areas of Tubbataha had higher coral recruit density compared to the shallow areas. These findings concur with the results of Pizarro *et al.* (2007), and Chiappone and Sullivan (1996), which suggest that as depth increases, juvenile density also increases.

Table 2. Mean coral recruit density at 10 meters.

	2018	*2019*	*2020*
1A	33.33 (±2.42 SE)	48.61 (±2.76 SE)	64.58 (±4.60 SE)
1B	41.66 (±2.36 SE)	27.78 (±1.41 SE)	56.25 (±2.61 SE)
2A	22.92 (±1.23 SE)	22.22 (±0.84 SE)	42.36 (±2.13 SE)
2B	34.03 (±1.53 SE)	50.69 (±2.57 SE)	31.25 (±1.55 SE)
3A	52.77 (±3.51 SE)	42.24 (±2.33 SE)	87.50 (±5.19 SE)
3B	68.05 (±6.11 SE)	36.80 (±2.33 SE)	85.42 (±6.93 SE)
4A	41.66 (±2.43 SE)	40.97 (±3.12 SE)	78.47 (±5.18 SE)
4B	47.22 (±3.85 SE)	58.33 (±3.06 SE)	65.22 (±4.40 SE)
JBA	33.33 (±1.59 SE)	43.05 (±3.10 SE)	38.19 (±3.28 SE)
JBB	27.78(±1.32 SE)	52.08 (±3.93 SE)	67.36 (±5.38 SE)
MEAN	**41.04 (±4.18 SE)**	**41.57 (±3.51 SE)**	**61.67 (±6.18 SE)**

The highest increase in density was observed in Site 3, where the values doubled in both stations - 87.50 ind/m^2 (Station A) and 85.42 ind/m^2 (Station B). Open spaces, rubbles, and small packets/crevices of stable substrates were observed in Site 3. These substrate compositions provide space for coral recruits to thrive. The dominance of brooder corals, such as genus *Pavona* and *Porites,* contributed most to the increase in coral recruitment densities in all stations in the deep areas. The lowest mean density was observed in Station 2B at 31.25 ind/m^2 (Table 2). However, the comparison of recruitment density at the station level did not show significant differences.

The size-frequency distribution of coral recruits seemed to consistently mirror the results of the previous surveys (Figure 30). The frequency of coral recruits of <1 cm in size was significantly lower in number (Chi-square test p=0.003, α=0.05) compared to the other size classes. Coral recruits that are less than 0.5 cm in size have a higher mortality rate compared to larger-sized juveniles (Pizzaro *et al.* 2006). Most of the coral recruits were juveniles ranging in size were between >1 to <4 cm.

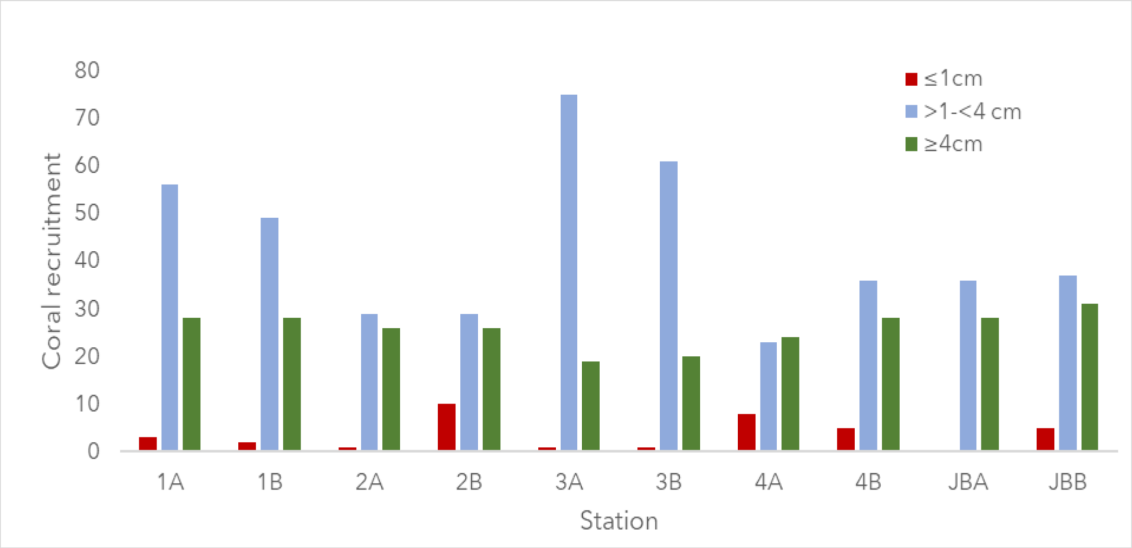

Figure 30. Size frequency distribution of coral recruits at 10 meters.

Coral recruitment in the shallow areas

The percentage of all coral recruits found in the shallow areas was dominated by families Acroporidae (26.59%), Poritidae (19.21%), and Faviidae (17.20%), a combination of broadcast (Acroporidae *and* Faviidae) and brooder type of corals (Poritidae). Like last year, the majority of the coral families that thrived in this area were encrusting to sub-massive. Family Acroporidae, mainly composed of encrusting *Isopora* and branching *Acropora* were recorded with the highest coral recruitment cover in Stations 3A and 3B. Foliose *Montipora* stands dominated Station JBA (Figure 31). Agariciidae dominated the shallow area in 2019 but seemed to be lower this year. These differences were not statistically significant (paired t-test=1, p=0.05). Furthermore, in all stations, coral genera belonging to the family Faviidae increased by 36% this year. These corals, usually described as the genera more tolerant to disturbances, *e.g., Goniastrea*, *Favia,* and *Favites,* were consistently present and observed to encrust some portions of the substrate in the shallow areas.

The relative abundance of Acroporidae, followed by Poritidae recruits found in the shallow areas in Tubbataha coincides with the findings in most Indo-Pacific reefs, *e.g.,* Kimberley Reef in Australia (Gilmour *et al.* 2016) and Gili Pandan Reef in Indonesia (Adrriyani and Nughara 2017). Most of Acroporidae form weedy branches which are also prone to breakage. However, Acroporidae is effective in producing a high number of fragments that have a higher chance of survival and reattachment. Massive Poritidae, on the other hand, use fission and fusion processes to maintain their local population in the reefs (Kayal *et al.* 2015). The dominance of these reef-building corals is important in reshaping the reefs. (Acosta *et al.* 2001), as they provide a foundation for the structural and biological components of the reefs (Putnam *et al.* 2017).

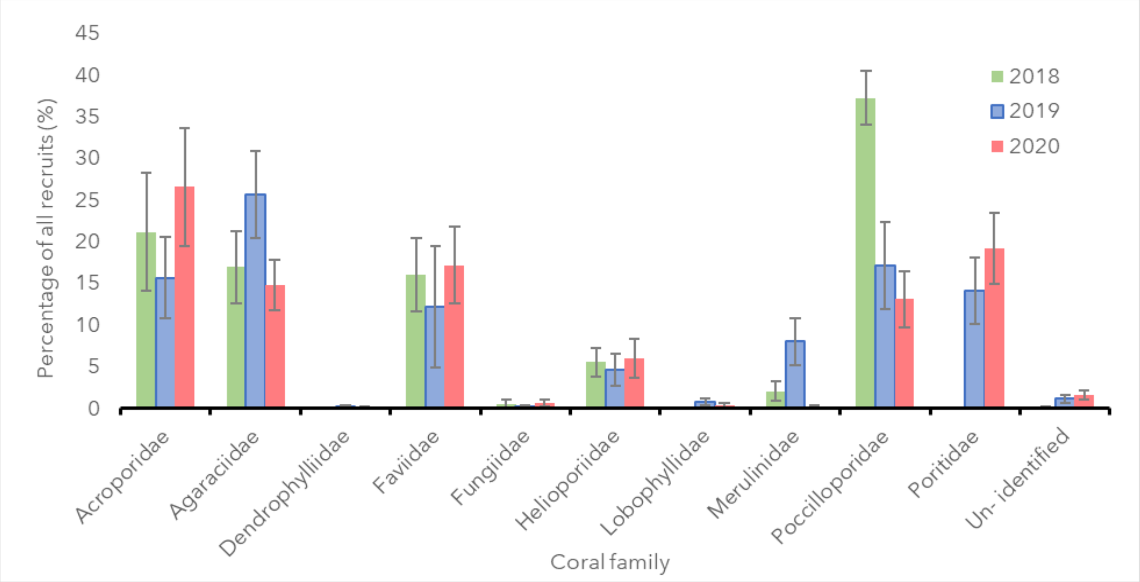

Figure 31. Mean percentage population of all coral recruits found at five meters. Error bar represent standard error of mean. Unidentified corals were group under the category UN.

Table 3. Mean recruitment density at five meters.

	2018	2019	2020
1A	14.47 (±1.58 SE)	30.09 (±2.57 SE)	65.28 (±7.89 SE)
1B	41.67 (±3.71 SE)	38.77 (±2.03 SE)	54.86 (±6.31 SE)
2A	41.67 (±2.72 SE)	39.35 (±2.89 SE)	40.28 (±4.16 SE)
2B	34.72 (±3.43 SE)	25.46 (±1.78 SE)	63.89 (±6.57 SE)
3A	11.00 (±1.04 SE)	15.63 (±1.32 SE)	68.75 (±10.50 SE)
3B	10.42 (±1.09 SE)	25.46 (±1.70 SE)	60.42 (±10.77 SE)
4A	14.47 (±1.62 SE)	28.94 (±2.82 SE)	37.50 (±3.52 SE)
4B	27.20 (±2.93 SE)	26.04 (±1.82 SE)	47.22 (±5.07 SE)
JBA	32.41 (±3.42 SE)	4.63 (±0.48 SE)	47.22 (±9.07 SE)
JBB	18.52 (±1.49 SE)	15.05 (±1.34 SE)	52.08 (±6.32 SE)
Mean	24.65 (±2.30 SE)	24.94 (±1.87 SE)	53.75 (±7.03 SE)

This year, the highest coral density at this depth was recorded in Stations 3A (68.75 ind/m^2) and 1A (65.28 ind/m^2), while the lowest density was documented in Station 4A with 37.50 ind/m^2 (Table 3). The variations of density at station level only showed significant increases in Stations 3A (paired t-test= 0.05) and JBA (paired t-test=0.04). These stations were observed to have low recruitment density in 2019.

In the previous years, Stations 3A and JBA were dominated by monospecific types of corals – branching *Isopora* and foliose *Montipora*. This may have contributed to the lower density of recruits in the past because of the limited space available in the substrate. However, an increase in coral recruit density was observed in these sites this year which may be attributed to the decrease in hard coral cover (adult colonies) observed in 2019 (TMO 2019, unpublished).

Pearson Correlation showed that coral recruits had a strong positive correlation with the adult colonies in the shallow areas (r=0.843) and a weak positive correlation in deeper areas (r=0.210). This supports the finding that coral recruits will most likely settle near established colonies of adult corals in shallow areas (Adjeruod *et al.* 2017).

The size-frequency distribution of coral recruits in the shallow areas varied across stations, mirroring the pattern observed in deeper areas. The frequency of newly settled corals <1 cm in size was consistently the lowest across all stations. The most frequently observed coral recruits were between >1 to <4 cm in size as observed since 2018 (Figure 32). An increase in the number of mature coral recruits (>4 cm) was observed in most of the stations this year. This may suggest a higher survival rate of coral recruits this year. During this phase, coral recruits have reached reproductive maturity to multiply itself effectively (Chiappone and Sulivan 1996). The Chi-square test for size-frequency distribution did not show a significant difference among the various sizes per station ($p=0.766$, $\alpha=0.05$). The higher density of recruits between >1 to <4 cm observed in Sites 1 and 3 may be due to some disturbances from the previous year, which gave the opportunity for coral recruits to thrive.

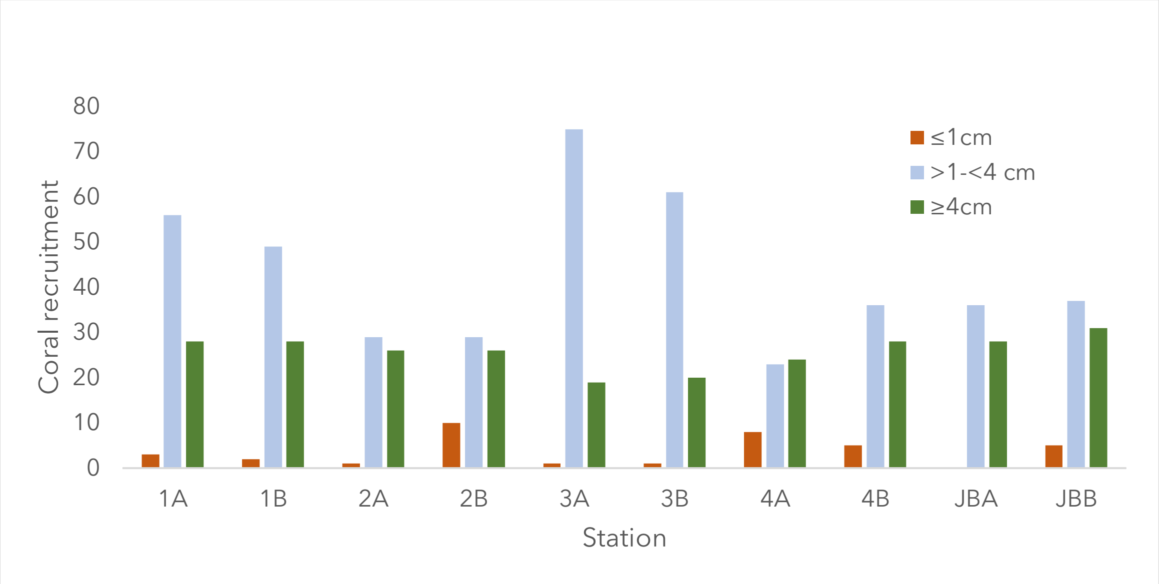

Figure 32. Size frequency distribution of coral recruits at 5 meters deep. Bars represent the number of recruits in each size.

Ship grounding sites

This year, the mean densities recorded at the USS Guardian grounding site were 12.5 ind/m^2 in the impact zone (Figure 33), 17.36 ind/m^2 in the control zone, and 22.91 ind/m^2 in the buffer zone (Figure 33). The coral recruitment density increased from last year. The buffer zone recorded an increase of 36%, while the impact zone declined to 28% from 2019. Brooder corals, e.g., encrusting *Porites*, *Pocillopora,* and *Pavona,* were observed in this site.

Meanwhile, the average density in the MPY grounding site (23.37 ind/m^2) was higher than in the USSG grounding site (17.59 ind/m^2). The increase in coral recruitment density in MPY may be due to the improved substrate composition in the site. Coral recruits were observed to encrust small packets/crevices and stable substrates. These provide the recruits with temporary shelter from dislodged rubble, specifically in the small fragment quadrat.

In MPY, coral recruitment densities were recorded at 30.55 ind/m^2 in the small fragments, 11.80 ind/m^2 in the large fragment, and 27.77 ind/m^2 in the adjacent control (Figure 34). MPY site was dominated by encrusting *Porites*, *Isopora* and *Goniastrea*, which contributed to the overall increase in all quadrats. Few colonies of genus *Montastrea* and *Astreopora* were also observed in the buffer zone. These were often observed in stable substrates and small crevices.

Both of the grounding sites showed an increase in recruitment densities suggesting that the condition in the grounding sites is gradually improving since the disturbance in 2013. Continued monitoring of coral recruitment may reveal a deeper understanding of the factors that contribute to the capacity of the reefs to recover.

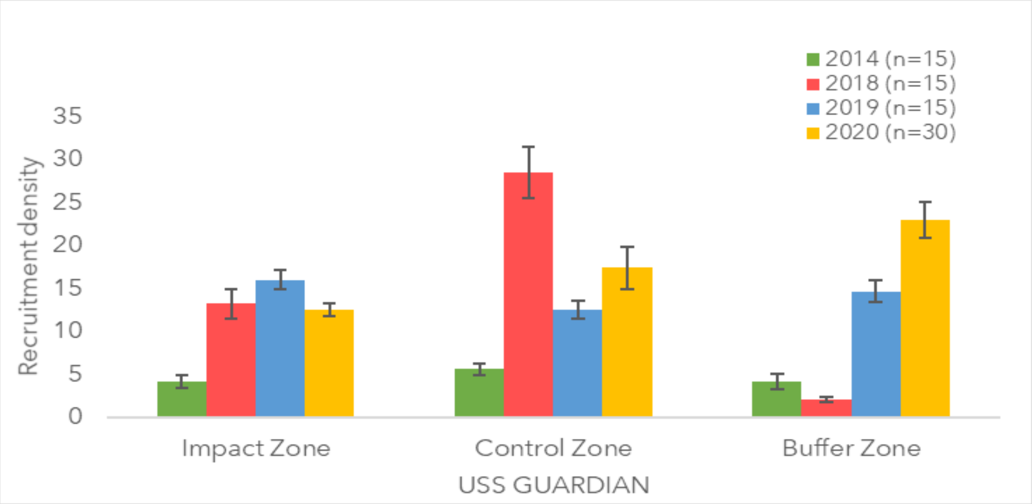

Figure 33. Mean coral recruitment densities at USSG grounding site. Error bar represent standard error of the mean.

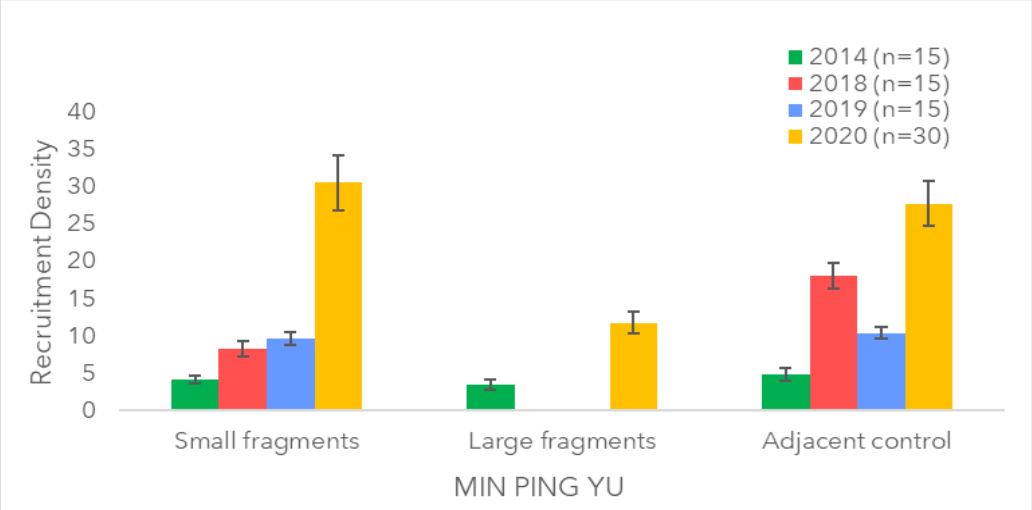

Figure 34. Mean Recruitment density of coral family at Min Ping Yu grounding site. Error bar represent standard error of the mean.

4.4 Conclusion

The high generic diversity (40 genera from 14 families) coupled with high recruitment densities observed may suggest that the Tubbataha reef system may be resilient when faced with disturbances such as climate change. The higher recruitment densities observed in the deep areas may be due to the higher number of brooder type of corals which reproduce frequently. Conversely, the positive link between adult colonies and recruit abundance may be viewed as an indication of strong stock-recruitment relationships in the shallow areas.

4.5 Recommendations

Streamlining of data collection for future studies may be necessary to increase the accuracy and precision of sampling. This can be done by randomly selecting 30 sample plots in a 50-meter transect. Random numbers will be generated per station using Microsoft Excel to minimize bias in data collection. In the shallow area, the quadrats will be placed at six randomly generated points per transect. In the deep area, 30 random samples will be collected along the first 50-meter transect. Continuous recruitment study in the monitoring sites is important to determine the trends in the future.

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5

CORAL BLEACHING

Maria Retchie Pagliawan[1], Eznairah Jeung-Narida[2], Rowell Alarcon[1]

[1]Tubbataha Management Office, Puerto Princesa City

[2]University of the Philippines – Marine Science Institute, Quezon City

5.1 Overview

Scientists warned of an El Niňo event as early as October 2019. This meant prolonged warming of ocean water. When corals are stressed by changes in conditions such as temperature, light, or nutrients, they expel the symbiotic algae living in their tissues, causing them to turn completely white, hence, the term 'bleaching'. Meanwhile as early as May 2020, marine protected area (MPA) practitioners, scientists, naturalists, scuba divers, and ordinary citizens raised the alarm as coral bleaching was observed in almost all coral reef ecosystems in the country.

TMO staff observed that a few corals were starting to bleach in May, but these were outside of the monitoring sites, hence, the phenomenon was not recorded. During the subsequent trips to Tubbataha in June, TMO staff and the rangers observed that bleaching had worsened. In July, TMO revisited the permanent monitoring sites to assess the severity of bleaching. It was believed that during this time, bleaching occurrence was at its peak, therefore, making the assessment very timely. Thus, the July data set provides a point of reference for a post-bleaching assessment to be conducted in 2021. This report presents the preliminary results of the coral bleaching assessment in TRNP during a bleaching episode.

5.2 Methods

The five permanent monitoring sites were assessed for coral bleaching from 14 to 20 July 2020. The team followed the photo-transect method used in the May 2020 reef benthos monitoring during the annual assessment. The photos taken in the monitoring sites were processed using the CPCe software. To determine whether there were already significant changes between the hard coral cover (HCC) in May and July, a paired t-test (p=0.05) was applied to the results per station.

5.3 Results and Discussion

Shallow areas

Bleaching of hard corals was observed in all monitoring stations. The bleached hard coral cover (HCC) per station ranged from 3.4% to 19.7% (Table 4). Among the 10 shallow stations, Station Jessie Beazley B (JBB) had the highest percentage of bleached HCC (19.7%) while Station 1A had a record of 3.4% bleached HCC. Figure 35 shows the HCC in May and July per station in the shallow areas. Declines in HCC were noted in six (6) of the 10 stations, but significant differences were only recorded in Stations 1B and 3B (Table 4).

Figure 35. Bleached Pocillopora sp. in the shallow area of Station 1. Photo by: Rowell Alarcon

Bleaching was also recorded among soft corals in some of the monitoring stations. The highest percentage of bleached soft corals were recorded in Stations JBB (9.8%) and 1B (8.4%) (See Figure 36). Comparisons between May and July data showed declines in soft coral cover in all the stations except in Stations 1A and 3B. However, these declines were not statistically significant.

Table 4. Comparison of hard coral cover in the shallow stations between the May and July.

Station	May HCC (%)	July HCC (%)	July Bleached HCC (%)	Paired t-test (May vs July HCC)
Station 1A	30.4	23.0	3.4	0.141745952
Station 1B	50.5	30.3	6.2	0.036998824*
Station 2A	16.7	20.2	8.1	0.047744336
Station 2B	23.9	29.4	11.1	0.090093837
Station 3B	33.3	19.0	5.2	0.022993407*
Station 4A	14.1	18.3	4.8	0.044877965
Station 4B	33.1	31.5	11.3	0.134856789
JBA	57.5	54.9	12.2	0.355362526
JBB	38.8	34.8	19.7	0.076580159

Note: * indicates significant decrease in cover

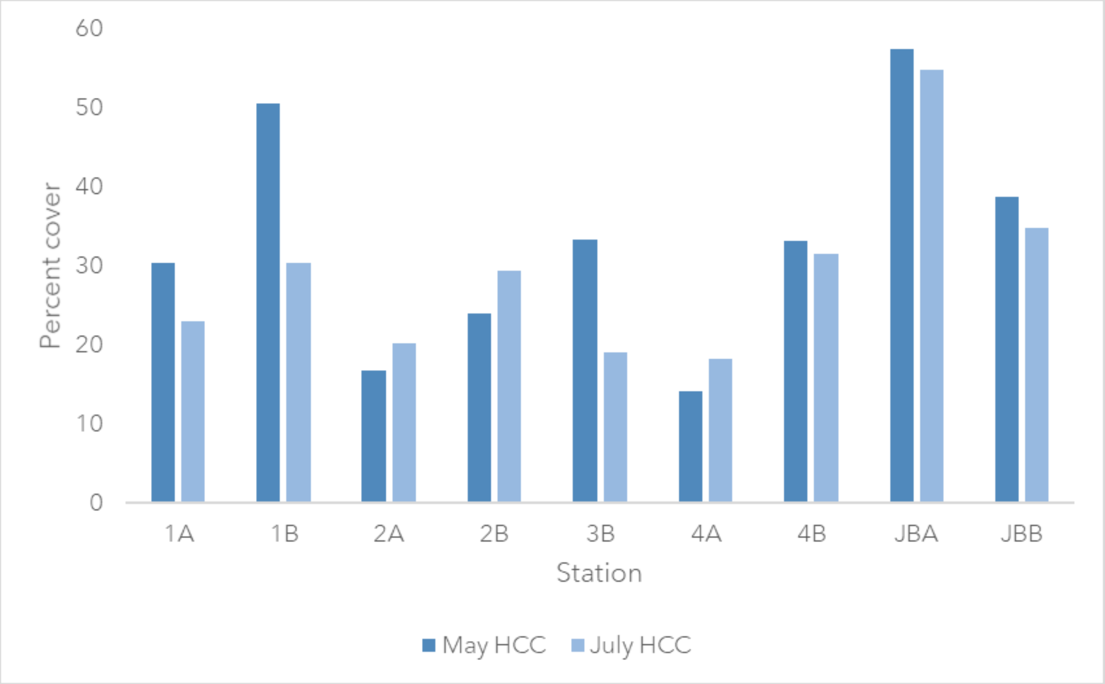

Figure 36. Percentage of HCC in the shallow areas in May and July 2020.

Table 5. Comparison of soft coral cover between May and July monitoring in the shallow stations.

Station	May SCC (%)	July SCC (%)	July Bleached SCC (%)	Paired t-test (May vs July SCC)
Station 1A	3.5	4.7	2.4	0.336703685
Station 1B	16.8	12.0	8.4	0.142892690
Station 2A	8.9	4.9	3.8	0.191552592
Station 2B	3.0	2.3	1.3	0.150288543
Station 3B	0.2	0.2	0.0	0.380339720
Station 4A	1.2	1.2	0.9	0.436478976
Station 4B	2.0	1.8	1.4	0.372680663
JBA	1.8	1.8	0.04	0.452433557
JBB	12.6	10.4	9.8	0.180517962

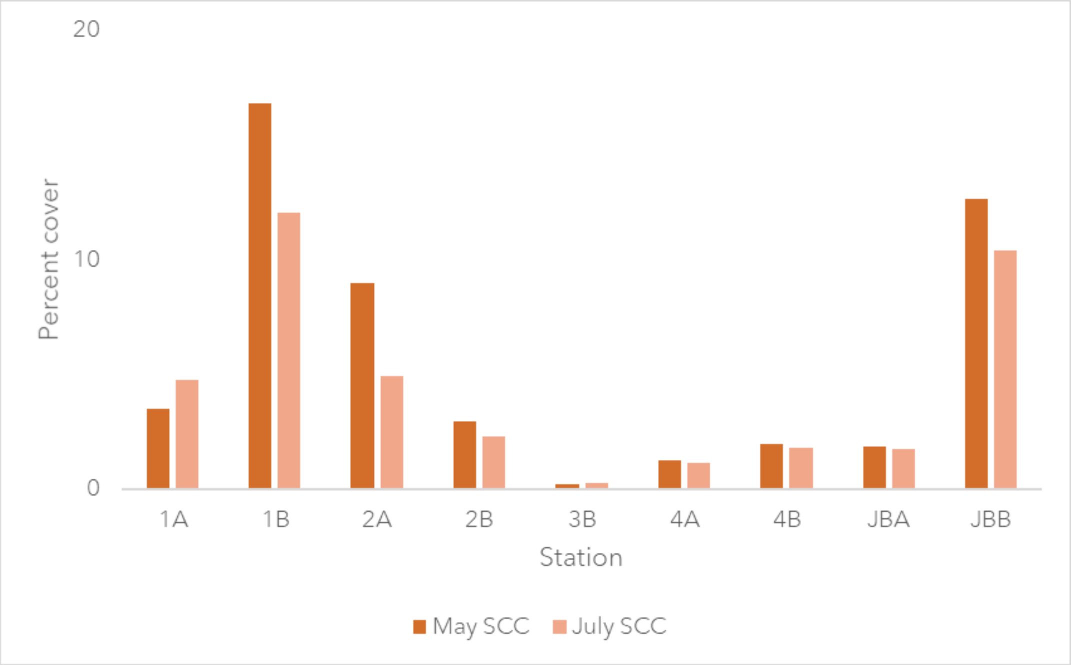

Figure 37. Percentage of soft coral cover in the shallow areas in May and July.

Deep areas

The bleached HCC per station ranged from 3.4% to 16.3% in the deep areas (Table 6). The highest percentage of bleaching was observed in Station 1B (16.3%), while the lowest was recorded in Station 4A (3.4%). Figure 38 shows the HCC in May and July. Six (6) of the 10 stations in the deep areas recorded declines in HCC, however, significant differences were only recorded in Stations 2B, 4A, and JBB.

Soft corals were also observed to bleach in the deep areas of the monitoring stations. The highest percentage of bleached soft corals was recorded in Station JBA (45%). More than half of the benthic composition in this monitoring station was composed of soft corals.

Declines in soft coral cover were noted in five (5) of the 10 stations, but a significant difference was only recorded in Station 2B (Table 6).

Table 6. Comparison of hard coral cover between May and July monitoring in the deep stations.

Station	May HCC (%)	July HCC (%)	July Bleached HCC (%)	Paired t-test (May HCC vs July HCC)
Station 1A	23.4	25.5	6.9	0.308630908
Station 1B	39.0	37.8	16.3	0.254734505
Station 2A	19.7	20.3	9.0	0.357357948
Station 2B	21.8	17.8	8.1	0.039868418*
Station 3A	28.3	25.9	16.0	0.324677051
Station 3B	19.7	18.8	7.8	0.314892407
Station 4A	25.7	12.8	3.4	0.046725406*
Station 4B	28.5	31.5	9.1	0.302434464
JBA	5.3	11.6	3.9	0.023272240
JBB	46.5	18.3	4.8	0.012535487*

Note: * indicates significant decrease in cover

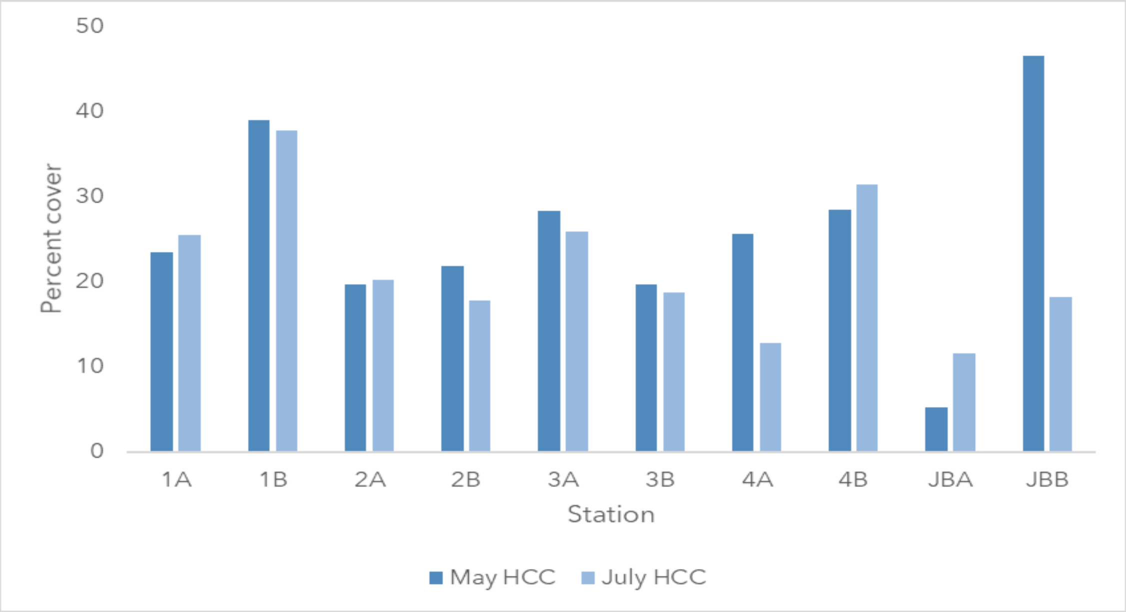

Figure 38. Percentage of HCC in the deep areas in May and July 2020.

Table 7. Comparison of soft coral cover between May and July monitoring in the deep areas.

Station	May SCC (%)	July SCC (%)	July Bleached SCC (%)	Paired t-test (May vs July SCC)
Station 1A	31.1	28.4	20.6	0.323589649
Station 1B	14.6	20.3	15.6	0.214049752
Station 2A	11.6	7.6	5.9	0.115684281
Station 2B	11.5	8.3	6.4	0.026004570*
Station 3A	7.9	8.5	7.3	0.466018136
Station 3B	1.1	1.8	0.0	0.123571474
Station 4A	13.6	26.0	14.0	0.025725075
Station 4B	12.9	12.6	12.1	0.477995862
JBA	64.7	56.5	45.0	0.147705517
JBB	9.3	18.6	17.5	0.045882042

Note: * indicates a significant decrease in cover

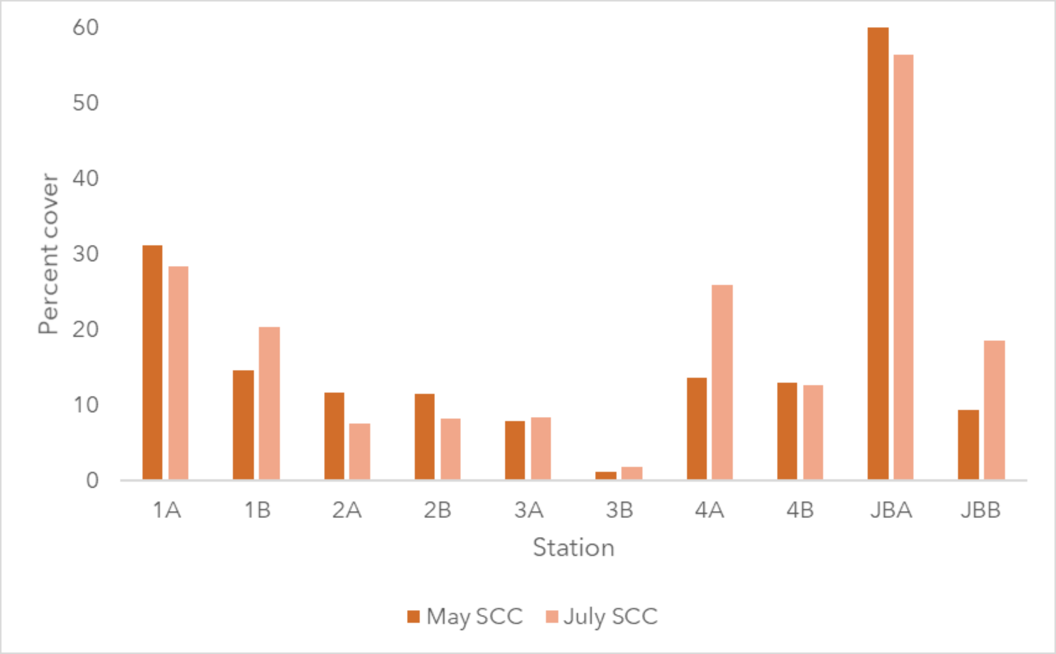

Figure 39. Percentage of soft coral cover in the deep areas in May and July.

In the shallow areas, the most common hard corals that bleached include *Pocillopora, Acropora, Isopora,* and *Seriatopora*, which have branching growth forms. A few massive corals such as *Favites, Porites,* and *Montipora* also bleached. In the deep areas, bleaching was mostly observed in branching *Pocillopora, Heliopora, Millepora, Acropora,* as well as in massive *Goniastrea* and *Favites*. One of the factors that influence the resistance of corals to bleaching is their growth forms. Fast-growing corals, which are normally fine-structured and with thinner polyps, tend to be more susceptible to bleaching (Marshall and Schuttenberg 2006). This includes *Seriatopora, Stylophora, Pocillopora,* and branching *Acropora* and *Montipora*. Massive corals with thicker walls and have slower growth rates, e.g., *Favia, Favites, Leptoria,* and *Porites*, tend to be more resilient to bleaching. Like hard corals, soft corals also react to thermal stress, through bleaching. According to Slattery *et al.* (2019), the susceptibility of soft corals to bleaching also varies between different species.

Figure 40. Bleached Acropora sp. at five meters. Photo by: Rowell Alarcon

5.3 Conclusion

Coral bleaching has affected all the monitoring sites in Tubbataha with different severity. Most of the corals that bleached were branching in form, which was expected based on scientific literature. Branching corals mostly have thinner tissues compared to the massive forms, making them more susceptible to bleaching.

Ideally, site assessments are conducted three times – before, during, and after bleaching events – so that the results can be compared. With these spatial data, the effects of bleaching in an area can be quantified. Since the data were collected before and during a bleaching event, the true extent and effects of bleaching in the regular monitoring sites cannot yet be fully determined. A post-bleaching assessment, preferably done a few months later, is ideal to determine how the corals respond to such stressors. Bleached corals are still living and, if the temperature subsides soon enough, are capable of surviving and repopulating their tissues with zooxanthellae. However, those that cannot survive the thermal stress will be overgrown by algae. This data will be an important input to the benthos monitoring next year when the effects of the bleaching event may be fully processed and quantified.

Although Tubbataha suffered from coral bleaching this year, the percentage of bleaching is comparatively lower compared to other sites in the Philippines. In Calatagan, Batangas, up to 75% of corals bleached, while in Busuanga, Palawan, up to 45% of the HCC bleached, according to reports submitted to the Philippine Coral Bleaching Watch.

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6 SEABIRD POPULATION

Arne Jensen[1], Angelique Songco[2], Maria Retchie Pagliawan[2],Ma. Theresa Aquino[3]

[1]Wetlands International, Wildbird Club of the Philippines
[2]Tubbataha Management Office, Puerto Princesa City
[3]Marine Wildlife Watch of the Philippines

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6.1 Overview

The objectives of the avifauna monitoring and inventories at Tubbataha Reefs Natural Park (TRNP) are:

- Review of avifauna field data produced by the Tubbataha Management Office (TMO) Marine Park Rangers (MPR) since May 2019;
- Enhance survey methods used by the TMO research team guided by the Consultant;
- Virtual skills enhancement of the TMO MPR, 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 TRNP;
- Discuss and advice on possible solutions to management issues related to the avifauna of TRNP.

Fieldwork

Period: Field work was conducted from 18 May to 20 May at Bird Islet and on 21 May at South Islet. The review of the inventory methods used in the past years and assignment of tasks for the fieldwork was carried out by the TMO on 17 May. The Marine Park Rangers (MPR) monitoring and inventory reports since May 2019 were also evaluated. Actions taken in response to the 2019 recommendations of the Consultant were discussed via the internet.

Weather: The weather was dominated by the limited wind coming from a southwesterly direction with wind speed ranging from 0 to 3 meters/second. Daily cloud cover ranged from 2/8 to 5/8. Daytime temperatures peaked at about 32° Celsius.

Seabird Inventory Team

A total of 20 TMO staff and MPRs headed by the Park Superintendent (PASu) of TRNP and three local volunteers participated in the seabird inventory (Annex 1). The team included seven researchers and MPRs from the TMO, four MPRs from the Philippine Coast Guard, one from the Philippine Navy, and two from LGU Cagayancillo. Due to the travel restriction brought about by the COVID 19 pandemic, the avifauna consultant and regular volunteers were unable to join the survey. M/Y Zamerdius was used to transport the team to TRNP.

6.2 Methods

The field work followed methods for distance count monitoring and inventories of breeding seabirds established and used since 2004 (Jensen 2004). For methodologies, see Annex 12 and Annex 13. The team camped overnight at Bird Islet from 18 to 20 May to carry out optimal field work. South Islet was only visited in the morning of 21 May, from 8:30am to 11:30am, due to limitations imposed by the tides.

The counts of the breeding bird populations represent a combination of different count methods. These include direct day-time inventories of adults, immatures, juveniles, pulli, eggs, and nests. To determine the total seabird population numbers, an afternoon count of boobies flying in to roost was conducted from 4:30pm to 6:30pm on 18 May at Bird Islet (Annex 17) and on 21 May at South Islet (Annex 18). Establishment and upgrades of artificial breeding structures for Black Noddy were conducted on both Bird islet and South Islet. Standardized assessments of the landscape and vegetation development were also carried as well as a clinical assessment of dead seabirds. The field team also conducted tree planting and 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 follow the IOC World Bird List Version 10.1 (25 January 2020 and Wild Bird Club of the Philippines Checklist of Bird of the Philippines 2020.

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 *Anous minutus*;
- Dawn count (5 am) of Brown Booby population 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 2019 and also data sets gathered by MPRs from June 2019 to August 2020. The data 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 published in 2009 and 2004 to 2006 and the 2010 to 2019 seabird field reports (see Jensen 2004 to 2006 and 2009 to 2016 and Jensen *et al* 2017-2019).

Calculation of land area and vegetative cover

Photos of permanent photo documentation sites in Bird Islet and South Islet were taken (Annex 21). These sites were established in 2004 to measure changes in land area and vegetation. GPS readings were taken measuring the land area at a high tide of both Bird Islet and South Islet.

Vegetative cover was monitored by conducting a census of the condition of trees and other vegetation on the islets. Trees, formerly comprising of *Scaevola taccada* (Beach Cabbage/

Sea Lettuce/ Beach Naupaka) *Heliotropium foertherianum* (Tree Heliotrope), and *Pisonia grandis* (Anuling, Bird-catcher Tree/Lettuce Tree/Cabbage Tree) were located and classified as either in optimal (good), moderately deteriorating (fair) or severely deteriorating (bad) condition and lastly, as dead. For photos of beach forest species, see Jensen *et al*. (2019). The vegetation inventory of 2020 was carried out using the same methodology as all other years, but the scarcity of vegetation simplified the inventory. Except for 2013, the trend over time is comparable.

6.3 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 a reference has disappeared. Due to this shift in methodology, data sets from 2016 onwards will not be fully comparable to the previous years.

Bird Islet: From two separate GPS measurements, it appears the land area has slightly increased by 2.9%; from 18,760 m^2 in 1981 (Kennedy 1982) to about 19,297 m^2 in 2020 (Table 6).

The circumference of the islet measured along the high tide line is 610 meters compared to 574 meters in 2019, or an increase of 6.2%. A specific expansion area could not be identified as the measurement route is not physically demarcated.

The 'Plaza', defined as the central area of the islet dominated by compacted barren soil with very limited vegetation (Figure 41), was measured to be 5,826 m^2 representing an area decline of 6.1% (6,202 m^2 in 2019). However, the circumference of the 'Plaza' is not demarcated and the data variation compared to 2019 may be a result of a slightly different measurement route used in May 2020.

Table 8. Approximate changes in the land area of Bird Islet from 1911 to 2020. Source: Worcester 1911, Kennedy 1982, Heegaard and Jensen 1992, Manamtam 1996, WWF Philippines 2004 and Tubbataha Management Office 2004 to 2020.

Year	Land area (length x width)/circumference (m)	Land area (high tide) (m^2)	Open area ("Plaza") (m^2)	Major sandbars position and condition	Erosion area
1911	400 x 150	60,000	No data	>40,000 m^2 (?)	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 [4]	568	15,373	2,572	NW: Two small sandbars off the coast SE : As above	Northeast coast
2019 [5]	574	17,987	6,202	NW: Two small sandbars off the coast SE: Three sandbars off the coast	None compared to 2018
2020	610	19,297	5,826	NW: Two stable sandbars SE: One stable and one expanding sandbar	No erosion

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

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

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

Note 4: Reduction in the area of Plaza is due to expansion in grass areas

Note 5: Expansion in the area of Plaza is due to a reduction in grass areas. Change in the land area may have been caused by the variation in the route walked as this is not physically demarcated.

South Islet: In 2019 an embankment and construction of a new seawall changed the size of the islet, Figure 42. The circumference of the islet is now 307 meters (measured as 292.3 meters in 2019) compared to 230 meters in 2018, or an increase of 33.4%. The land area is 5,222 m² (measured as 5,585 m² in 2019) compared to 2,884 m² in 2018. The 81% variation represents the reclamation of additional marine areas.

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. The land area remained the same at least until 1981 (Kennedy 1982). In 1991 about a third of the seawall had collapsed and was partly submerged (Heegaard and Jensen 1992).

Figure 41. Landscape of 'Plaza', Bird islet, May 2020. Photo: Teri Aquino

Figure 42. Landscape of South Islet, May 2020. Photo: Teri Aquino

Monitoring of Changes in Habitats

The combined baseline of beach forest trees at Bird and South Islet from around 2009 to 2016 of around 354 trees were generally in a very good condition (229 trees on Bird Islet and 125 trees on South Islet). Since 2016 all tree vegetation has died.

Beach forest seedlings (saplings) of Beach Cabbage, Tree Heliotrope, and Lettuce Trees were planted in small numbers from 2017 to 2020 on Bird Islet. To restore the beach forest at the Bird Islet and South Islet, however, a nursery was established at TMO in Puerto Princesa in October 2019 to grow tree species formerly found in the islets. The saplings, mostly Anuling and a few Tree Heliotrope, came from Barangay Talaga in Cagayancillo. In June 2020, TMO planted within the location of the original beach forest a total of 430 saplings, 329 in Bird Islet and 101 in South Islet, Figure 43. By August 2020 the survival rate of the planted saplings was estimated by TMO to be from 75% to 90%.

Bird Islet: The baseline was 229 beach forest trees recorded in 2006. Since June 2019,12 saplings of the species Anuling *Pisonia grandis* were planted. In May 2020, only three saplings had survived and in general, the islet has become a treeless, barren habitat. Lower vegetation including grasses observed in May 2020 was negatively impacted by drought caused by the El Niño phenomena (Figure 41 and Figure 45, Annex 13 and 20).

Figure 43. Planted saplings of Anuling Pisonia grandis. Photo: Lyka Irang/TMO

Figure 44. Reforestation of Bird Islet. Photo: Lyka Irang/TMO

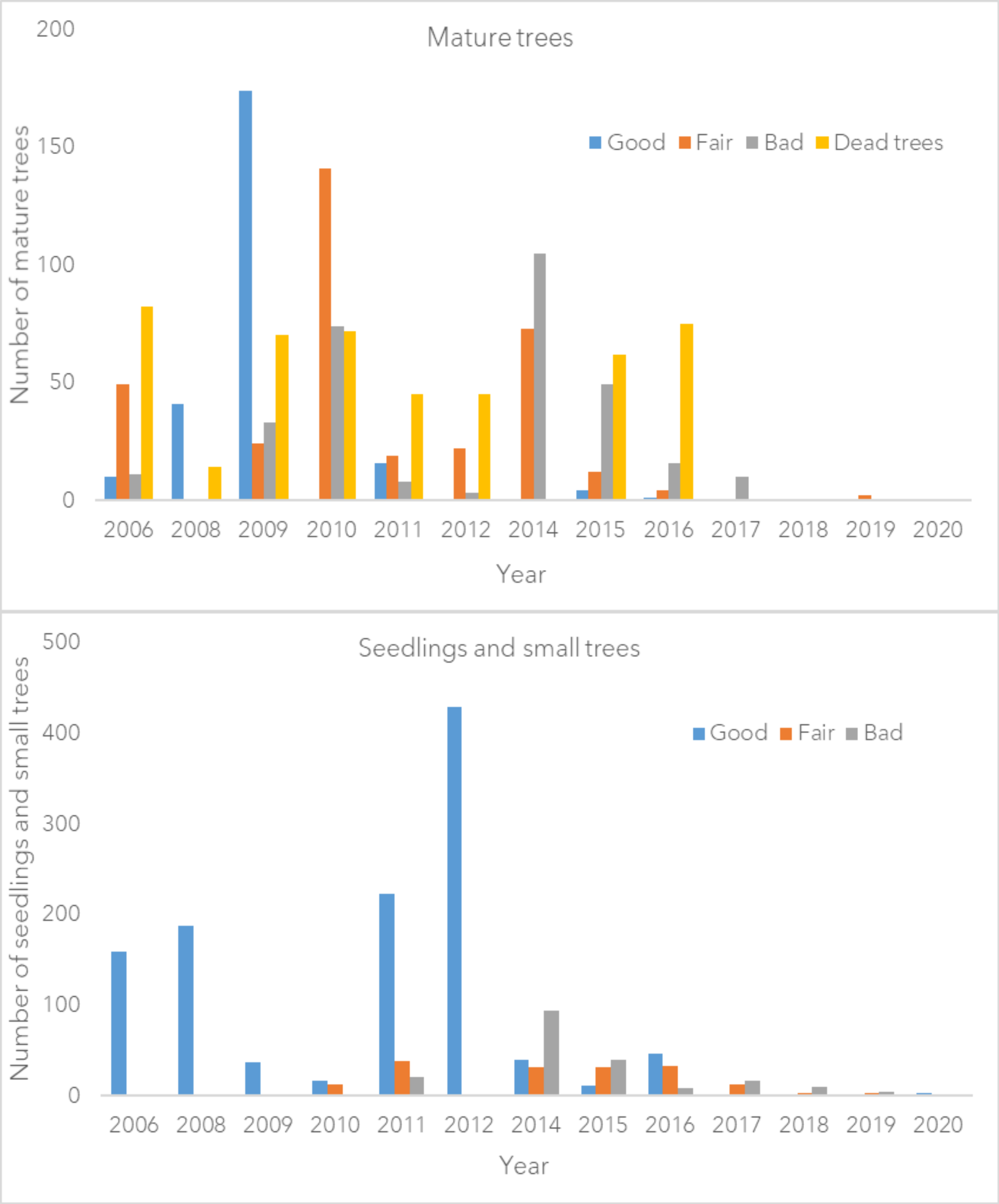

Figure 45. Status of vegetation in Bird Islet from 2006 to 2020.

South Islet: In 2020, the continued deterioration of the beach forest in combination with habitat conversion caused by the construction of a new seawall and a lighthouse in 2019, resulted in a generally barren sandy and treeless habitat except for a few stands of Coconut *Cocos nucifera* and patches of grass species (Figure 42, Annex 13 and 21).

Until 2009, the beach forest comprising of about 125 trees was in optimal condition, with several trees as high as about 30 feet. In 2013, the condition of the vegetation began to deteriorate so that by 2014, trees in bad condition dominated the vegetative cover of the Islet. In 2019, five remaining trees in a bad condition were removed during the reconstruction of the islet. In June 2020, 101 Anuling saplings were planted.

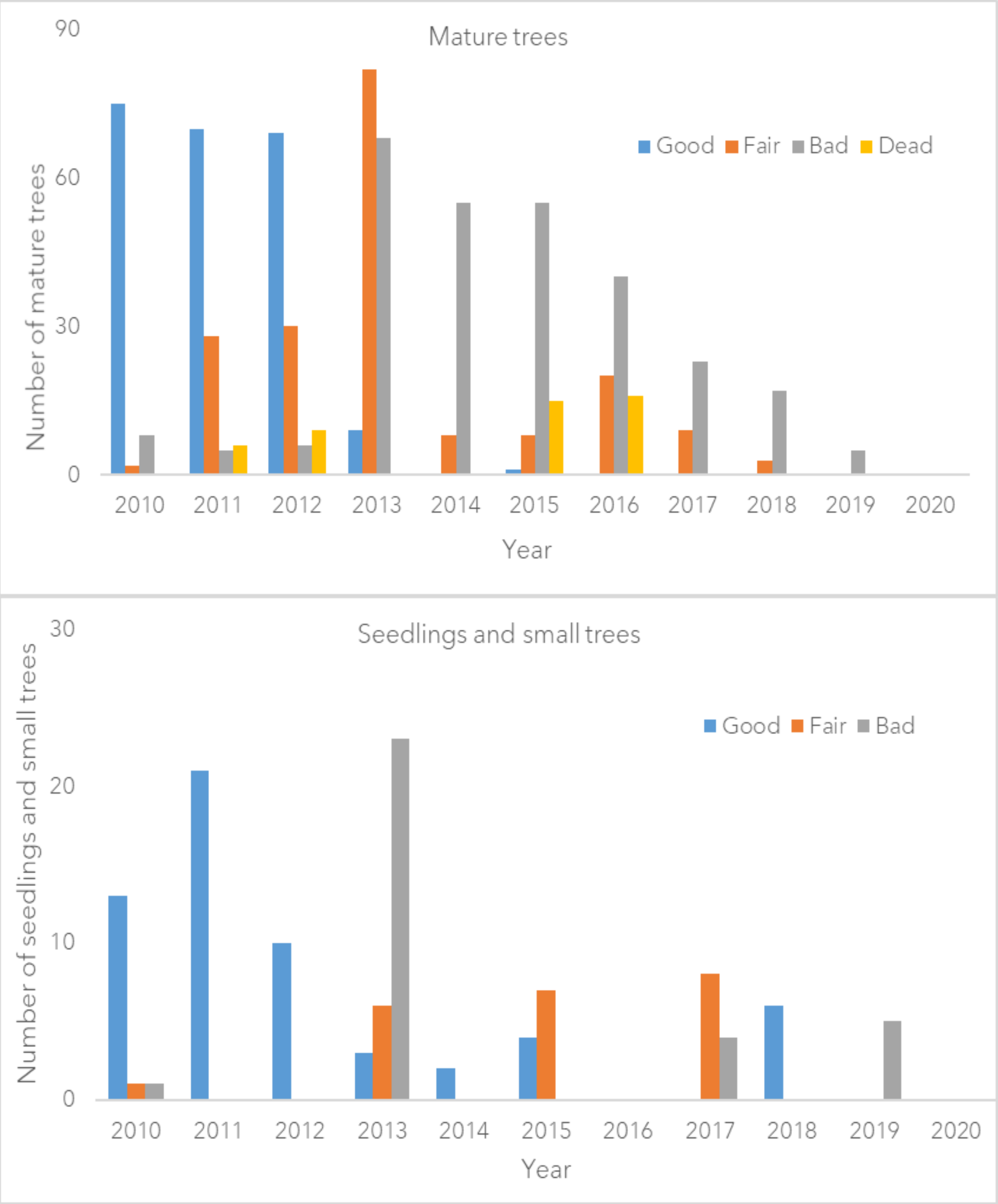

Figure 46. Status of vegetation in South Islet from 2010 to 2020.

Avifauna

Review of Marine Park Rangers Data

Since the previous avifauna inventory in May 2019, MPRs made three avifauna inventories on both Bird Islet and South Islet in August and November 2019, and in February 2020 (Annex 14). The inventory in November 2019 included in-flight counts. The data gathered revealed several important observations (see Table 9).

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

Table 9. Selected results of MPR distance and direct counts from June 2019 to April 2020

Species	Bird Islet	South Islet
Brown Noddy	Similar to 2017/2018 and 2018/2019 a new overwintering trend continued. High numbers, e.g. around 1,975 adults, on 10 January 2020. Early start of breeding season with more than 1,000 adults with 541 eggs and pulli already on 16 February 2020.	Absent from November 2019 to April 2020 which is the old normal pattern for this species.
Black Noddy	Following distance monitoring data, present throughout the year and overwintering similarly to 2017/2018 and 2018/2019, e.g. 1,460 adults on 10 January 2020. Early start of breeding season with 994 adults with 259 eggs and pulli already in February 2020.	Absent from October 2019 to mid-April 2020.
Great Crested Tern	Similar to previous season 2018/2019, absent from October (15th) to January. First single birds were observed on 10 January 2020 but in larger and increasing numbers from mid-February 2020.	No birds from June 2019 to March 2020. However, breeding in May 2020; for the first time in larger numbers since 2003.
Sooty Tern	Single birds from mid-December 2019 with main breeding population, > 7,250 adults w/ eggs, noted in mid-February 2020.	No breeding population.
Masked Booby	Presence from June 2019 to May 2020. Two adults in November and December 2019 and in May 2020. Laid eggs after the inventory period in May 2020.	
Red-footed Booby	Continued low numbers of adults and in nests from August 2019 to February 2020. In February only 35 active nests.	February 2020: 25 nests.
Brown Booby	In November 2019, similar to November 2017 and 2018, a high number of adults (2,280 individuals) with 1,247 nests. High number of 1,009 eggs in August 2019 and of pulli in November (1,103 individuals). Low numbers of adults in February 2020 (280 individuals).	No breeding.

Avifauna Inventory Results

A total of 17 species of birds were identified during the inventory (Annex 19). The total number of all avifauna species including migratory species recorded over time in TRNP is 118 species.

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

Among the seabird species recorded were the Short-tailed Shearwater *Ardenna tenuirostris, a first record,* and the White-tailed Tropicbird *Phaethon leptura,* the fourth *record* within TRNP. Both species occur only accidentally in the Philippines.

Of the breeding species, the Masked Booby is listed by the DENR as Critically Endangered, Brown Booby and Black Noddy as Endangered, and Brown Noddy, Great Crested Tern, and Sooty Tern as Vulnerable (DENR 2019). Further, the Black Noddy was included in Appendix II of the Convention of Migratory Species since October 2017. 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. The data analysis and conclusions, though, take into consideration MPR data prior to and after the May 2020 inventory.

In May 2020, a total of 32,633 adult individuals of seven breeding seabird species were recorded; 29,102 individuals on Bird Islet and 3,531 individuals on South Islet (Table 10). Bird Islet hosted 89.2% of the breeding population (97.4% in 2019) and South Islet 10,8% of the population (2.6% in 2019). Compared to 2019, the population on Bird Islet decreased by 8%. On South Islet, there has been a substantial recovery of the population of Brown Noddy, and the Great Crested Tern was again found breeding in relatively substantial numbers.

Compared to the 2019 inventory, the May 2020 count result is 17.7 6% higher (Annex 15). The total of adult seabirds in May 2020 is at the same level as the population in 2017 (30,159 adult individuals) but about 140% higher than in the baseline year of 1981 (Kennedy 1982). If the highest count estimate of Brown Booby and the breeding data of Sooty Tern in February 2020 is used, the total would be around adult individuals 36,340 individuals.

The difference in result for May 2020 compared to 2019 is mainly due to an increase in the numbers of Brown Noddy, Great Crested Tern, and Sooty Tern.

Table 10. Total count numbers of adult resident seabirds present on Bird Islet and South Islet from 18 to 21 May 2020.

Species/ Number	Bird Islet	South Islet	Total	% change 2019 - 2020
Masked Booby *Sula dactylatra*	2	0	**2**	
Red-footed Booby *Sula sula*	430	230	**660**	- 39.0
Brown Booby 1) *Sula leucogaster*	>2,528	449	**> 2,977**	- 5.1
Brown Noddy 2) *Anous stolidus*	2,134	1,128	**3,262**	+ 52.3
Black Noddy 3) *Anous minutus*	1,974	676	**2,650**	+ 27.9
Great Crested Tern *Thalasseus bergii*	16,762	1,048	**17,810**	+ 5.4
Sooty Tern 4) *Onychoprion fuscata*	>5,272	0	**> 5,272**	+ 21.4 (67.2)
Total	29,102	3,531	**32,633**	**+ 17.7**

Note 1: On Bird Islet 4,697 individuals, if average distance count data are used. This number is supported by similar high numbers counted in August 2020 (4,860 individuals)
Note 2: Increase, no birds breeding on South Islet in 2019
Note 3: Increase, no birds breeding on South Islet in 2019
Note 4: Or minimum 7,258 individuals, if inventory data 16 Feb 2020 is used.

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 Annex 16. 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 Annex 16. Percentages of in-flight populations of Brown Noddy, Black Noddy, Red-footed Booby, and Brown Booby are shown in Annex 17 (Bird Islet) and Annex 18 (South Islet). A complete list of avifauna records in May 2019 including all breeding species is found in Annex 19.

In summary, the count results for 2020 showed an overall increase of about 17.7% or a minimum of 32,633 adult individuals of resident seabirds:

- Brown Noddy: Moderately declining. The breeding population is 52.7% higher than in the baseline inventory year in 1981 but about 22% lower than the peak population counted in 2017 (4,209 adult individuals). The population on Bird Islet is stable; on South Islet it has not fully recovered from the man-made habitat changes in 2019.

  As in 2018/2019, the species overwintered at Bird Islet but not at South Islet. This is the third year with the early start of the breeding season: more than 1,000 breeding adults seen in February 2020 similar to 2018 and 2019.

- Black Noddy: Declining population. Of the original population of 10,656 adult birds (2013), about 25% or 2,650 individuals remain. The population decline mirrors the loss of breeding habitat. The species population now only breeds at artificial nesting structures installed by TMO.
- On Bird Islet there is a 5% population decline. At the time of the inventory 25% or 247 nests were found to have eggs or pulli. In February 2020 MPRs found that around 70% of nests contained either eggs, pulli, or juveniles. On South Islet, the population has declined by nearly 67% compared to data from before the construction of the new islet. The unique ground breeding sub-population is reduced to just one pair. Of the May 2020 breeding population,41% had nests but only about 22% of the nests have eggs.
- Great Crested Tern: Increasing population. The largest breeding number ever counted. Compared to May 2019, there is a population increase by 5.4% to 17,810 adult individuals. On South Islet, the species is again breeding in a relatively significant number. The habitat changes that have occurred on South Islet created an ideal sandy breeding habitat.
- Sooty Tern: Stable or Increasing population. MPR data shows that at least 7,258 adults were breeding from January 2020 (16 Feb: 3,629 eggs). At the time of the May inventory, many adults with juveniles had left their nesting territories and the adult was not all stationary during daytime at Bird Islet. Hence, the count result, about 27% lower than in February 2020 does not reflect the total adult population, which some years had two separate breeding seasons. The species is not breeding on South Islet.
- Masked Booby: Present at Bird Islet from June to December 2019 and from January to May 2020. In November and December 2019 and May 2020, a male and a female adult were recorded.
- Red-footed Booby: Compared to 2019, a population decrease of 37%. The population is now 73% lower than in 2004, the first year the species started to breed in large numbers in TRNP.
- Brown Booby: Increasing population. Although technically about 21% lower than in the baseline year of May 1981 (3,768 adults), early morning count and distance estimations of the adult population suggest a larger population ranging from around 4,600 to 5,300 adult individuals. After the May inventory, a population of around 5,000 adults was documented by MPRs in August 2020. The species was not found breeding on South Islet during the inventory but a pair with eggs were found by MPR in September 2020.

Black Noddy (Conservation Status – Philippine Red List: Endangered): Declining population. Total estimated population: 3,000 adult individuals.

Black Noddy is classified as Endangered by the Department of Environment and Natural Resources (DENR, DAO 2019-09) and is included as a conservation management-dependent species under the Convention for Migratory Species (Appendices II).

Of the original population of 10,656 adult birds (2013), only about 25% to 28% or 2,650 to 3,000 individuals remain (Figure 49, Annex 16). Its population decline mirrors the loss of its breeding habitat.

Figure 48. Nesting Black Noddy at Bird Islet, May 2020. Photo by Teri Aquino

A total of 2,650 adult birds were counted in May 2020 compared to 2,072 individuals in 2019, Table 11. Although the result suggests an increase of about 28%, compared to the inventory in 2018, the year before South Islet was reconstructed, it represents a de facto decline by 41% or by 1,823 individuals. The decline since 2018 on Bird islet is 19% and on South Islet 67%.

Figure 47. Artificial breeding structurers for Black Noddy in Bird Islet, September 2020. Photo: Jeffrey David/TMO

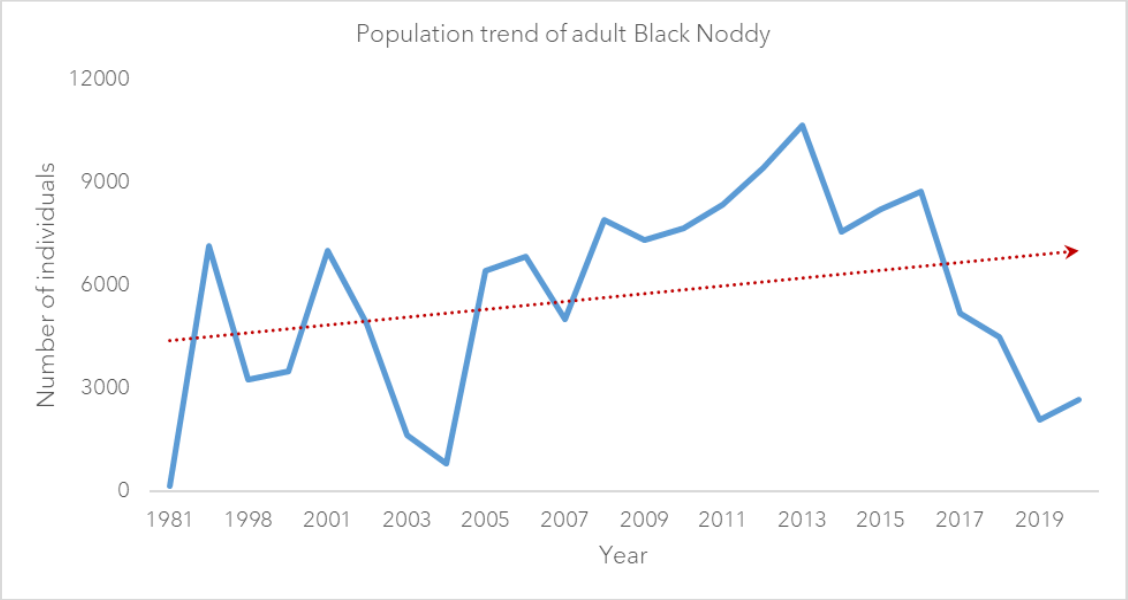

Figure 49. Population trend of adult Black Noddy from 1981 to 2020.

The species was present at Bird Islet every month since the May 2019 inventory. As such it has been overwintering (December 2019: about 500 individuals and January 2020: 1,460 individuals. At South Islet it was absent from October 2019 to April 2020.

Early breeding was noted on 16 February 2020 when 994 birds had 367 nests on Bird Islet. The early presence of the species was also noted in February 2017, 2018, and 2019. Black Noddy pairs stay together throughout the year or come together approximately 2 months before egg-laying. Their nests are normally re-used and reinforced every breeding season (Dewey 2009).

The species is now only breeding on nine artificial nesting structures made out of bamboo on Bird Islet and five structures on South Islet, Figure 47. Since May 2019, breeding materials (cut grass, leaves, seaweeds) were brought to the islets in June and August 2019, and in May 2020. The structures are currently fully exposed to wind and rainfall. The natural breeding habitat is made up of dense tree vegetation where their nest is better protected and not exposed to strong winds (Córdoba-Córdoba *et al.* 2010).

In September 2020, a total of six experimental nesting structures made of steel and PVC were installed in both islets (Figure 48). Four were established in Bird Islet and two in South Islet. Two designs were used (see photo), and one structure each was provided with a covering made of nipa as protection against the northeast monsoon.

Before the restoration of South Islet in 2019, nearly 600 Black Noddies had their nests placed directly on the ground (Jensen *et al.* 2017). In May 2020 only one nest was found on the ground.

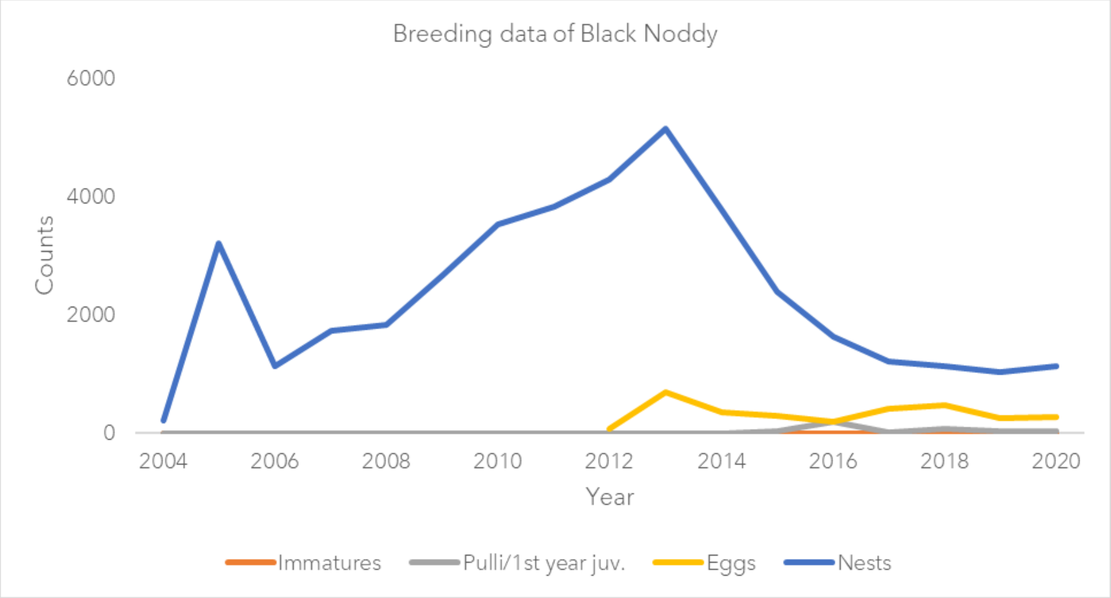

Figure 50. Breeding data of Black Noddy from 2004 to 2020.

Note: Egg data not collected in 2004 and 2007, 2009, 2010, and 2011 data are limited to the presence or absence of eggs.

Figure 51. Black Noddy nest mainly composed of grass, plastic debris, and seagrass. Photo by: Retch Pagliawan/TMO

The nests found in May 2020 were composed mainly of grass (60%), plastic debris (30%: plastic ropes, other plastic materials, and seagrass (10%), Figure 51. However, it was estimated that 90% of the nests have plastics in them. In some cases, it was noted that nests were mainly made up of plastic debris and guano, indicating a scarcity of available nesting materials.

Of 1,135 nests found in May 2020, 27% or 309 contained eggs or pulli (28% in 2019). It represents an increase in nest numbers by 10% compared to the May 2019 inventory. The number of active breeding birds, as indicated by the presence of eggs or pulli, increased by 5% compared to the inventory in May 2019 (Figure 50, Annex 16).

An additional 367 nests that contained 259 eggs, pulli, and juveniles were found in February 2020 by the MPRs (Annex 14). Together, the February and May 2020 inventory data represents about 3,000 adults with 1,502 nests of which 757 nests or 50% had eggs, pulli, or juveniles. In comparison, from 2017 to 2019 and the first three quarters of 2020, the species was found to have produced a very low number of eggs and offspring compared to the adult population present, Table 11. The percentage of eggs, pulli, and juveniles was higher from 2018 to 2020 compared to 2017. This may be the result of artificial breeding structures and imported nesting materials. Despite the relative success with the artificial breeding structures, the reproduction rate is too low to maintain the current number of the breeding population.

The population of 3,000 adults would need to be able to produce enough offsprings to replenish the population over time or one surviving juvenile per pair per year. With the current population number, this is equivalent to a minimum of 1,500 juveniles or an estimated 2,000 eggs, considering possible egg loss and pulli mortalities.

Table 11. Comparison of numbers of adults Black Noddy and numbers of eggs, pulli, and juveniles found in February, May, August, and November 2017 to 2019 and February, May, and August 2020 at Bird Islet and South Islet.

Year/Numbers	2017	2018	2019	2020
Adults	5,191	4,473	2,072	2,650
Eggs, pulli, and Juveniles	501	1064	575	720
Percentage of adult population	9.6	23.8	27.8	27.2

Brown Noddy (Conservation Status - Philippine Red List: Vulnerable): Moderately declining population. Total estimated population: 4,200 adult individuals. The breeding population in May, 3,262 individuals, is 52.7% higher than in the baseline inventory year in 1981 but about 22% lower than the peak population counted in 2017 (4,209 adult individuals). The population on Bird Islet is stable; on South Islet it has not fully recovered the man-made habitat changes made in 2019.

The May 2020 inventory resulted in a total count of 3,262 breeding adults (Table 10, Figure 53, Annex 15). At Bird Islet where 2,134 individuals were recorded, the population is stable.

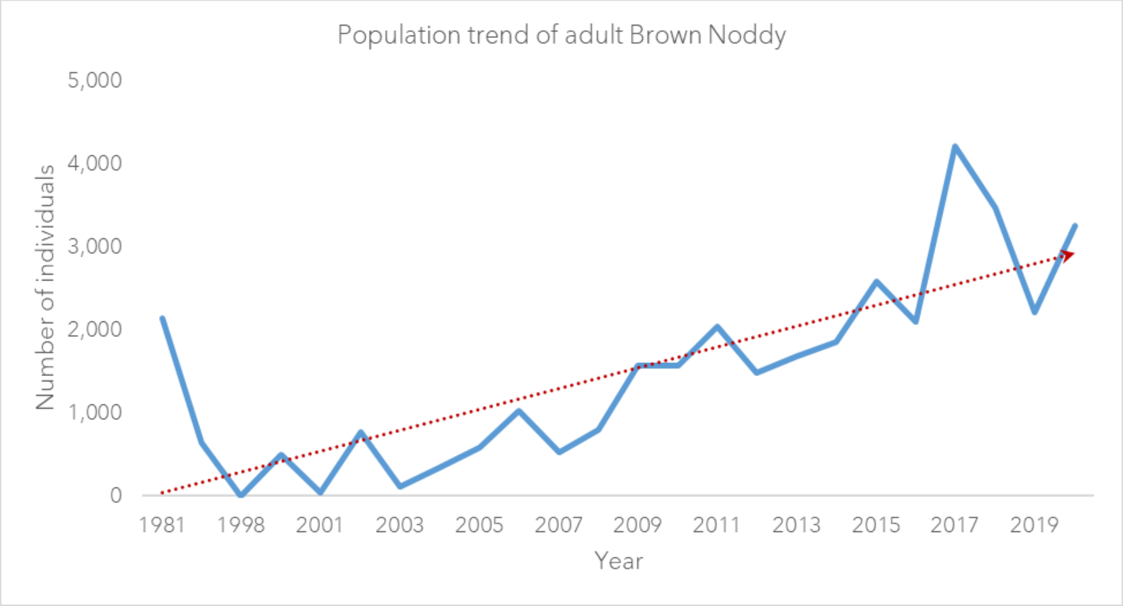

Figure 52. Population trend of adult Brown Noddy from 1981 to 2020.

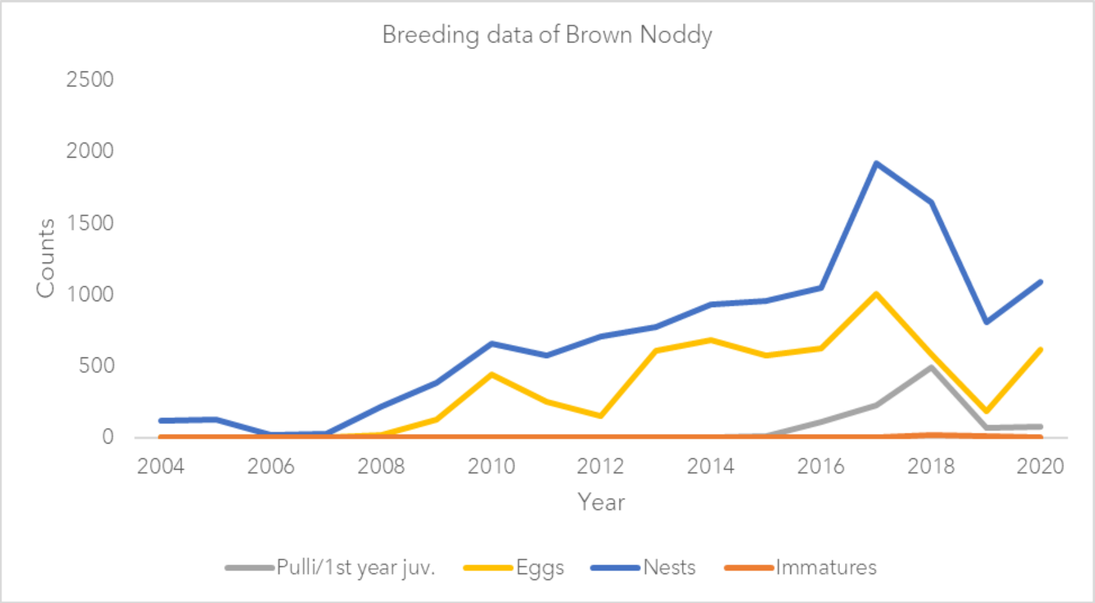

Figure 53. Breeding data of Brown Noddy from 2004 to 2020.

On South Islet where 1,128 individuals were counted, the population is still lower by 24% compared to 2018 (1,486 individuals); the year before the conversion of the species' breeding area due to the construction of a new lighthouse.

The species is normally absent from TRNP from November to February, but on Bird Islet the species is overwintered (1,430 individuals and 1,975 individuals December 2019/January 2020) like it did in 2018/2019. However, none were recorded in South Islet.

Similar to February 2018 and 2019, Brown Noddy was already breeding on Bird islet in February. On 16 February 2020, about 761 adults had 302 nests containing 239 eggs and pulli, Annex 14. In May 2020, a total of 1,065 nests, eggs, pulli, and juveniles were recorded at TRNP (Figure 53, Annex 16).

Great Crested Tern (Conservation Status - Philippine Red List: Vulnerable): Increasing population. Total estimated population: 18,000 adult individuals. Compared to May 2019, there is a population increase of 5.4% to 17,810 adult individuals in May 2020. This is the highest population number documented at TRNP (Figure 54, Annex 15). This record is almost eight times higher than in the baseline count of 2,264 individuals in 1981 (Kennedy 1982).

Adult birds were present at Bird islet in small numbers from mid-February 2020 and by mid-April in large numbers (4,175 individuals). In May 2020, 6,813 pulli and 1,568 eggs were counted (Figure 55, Annex 16).

On South Islet, the species was observed breeding for the first time since 2003, Table 5. Incubation took place later than on Bird Islet. The habitat changes that occurred on South Islet created an ideal sandy breeding habitat similar, although smaller in size than the habitat in 1981 when the species only bred at South Islet (Kennedy 1982).

Table 12. Breeding data from 1981 to 2020 of Great Crested Tern on South Islet.

Number/Year	1981	1985	2000	2002	2003	2020
Adults	2,264	135	50	560	64	1,026
Eggs	1,132	+	12	145	7	512
Pulli	0	0	0	25	19	2

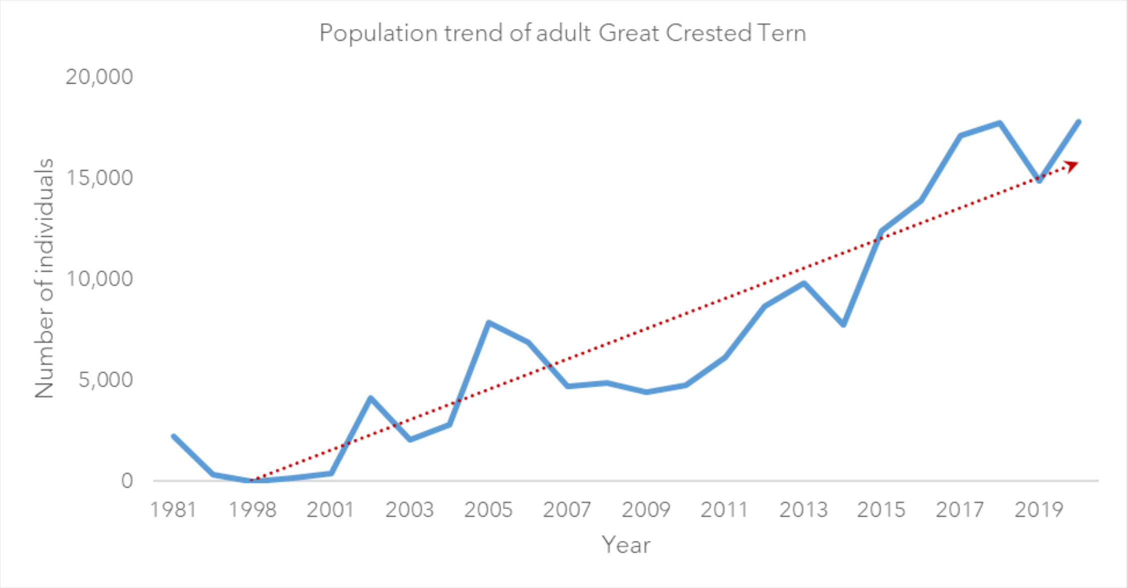

Figure 54. Population trend of adult Great Crested Tern from 1981 to 2020.

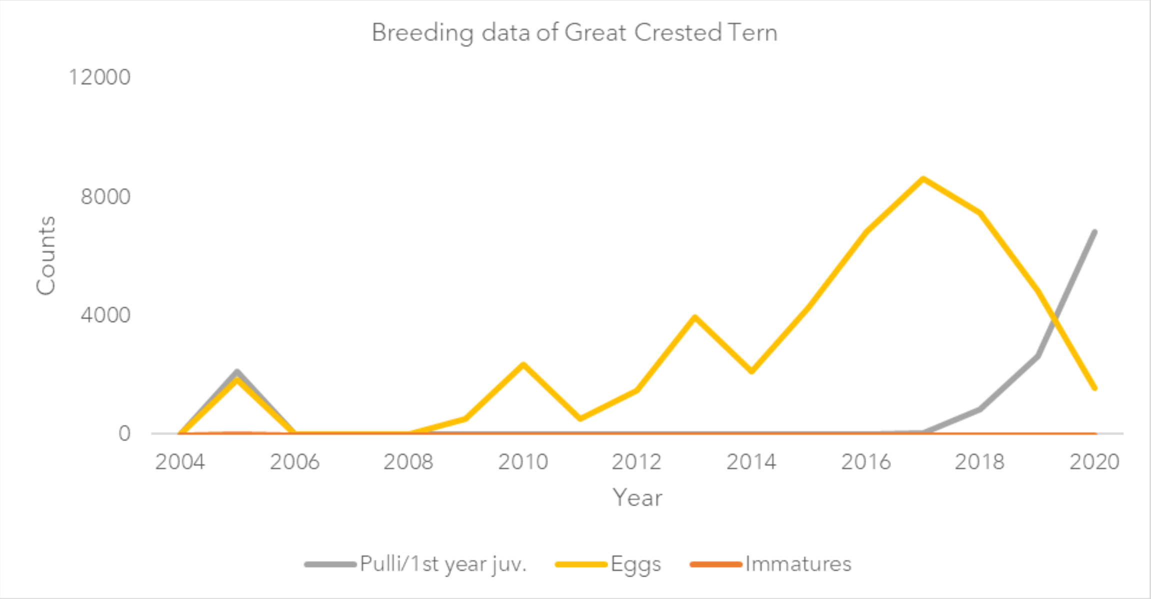

Figure 55. Breeding data of Great Crested Tern from 2004 to 2020.

Sooty Tern (Conservation Status – Philippine Red List: Vulnerable): Stable or Increasing population. Total estimated population: 12,000 to 14,000 adult individuals.

The breeding population of 5,272 individuals counted in Bird Islet in May is 4% higher than in the baseline inventory year of 1981 and higher by 21% compared to the May 2019 inventory of 4,342 individuals, Table 10, Figure 56 and Annex 15. The species does not breed on South Islet.

MPR data shows that at least 7,258 adults were breeding from January 2020 (16 Feb: 3,629 eggs). In comparison, the May inventory result is about 27% lower than in February 2020. However, in May 2020, many adults with juveniles were gone from their nesting territories and adults were flying in and out of the Bird Islet during the daytime. Hence, the total adult May population could not accurately be counted.

The Sooty Terns were present from December 2019 until July 2020. The breeding season, based on MPR data, may have started in mid-December 2019 with about two months of aerial swarming and ground-fall at night, courtship, and egg-laying. In mid-February, MPRs counted 3,629 eggs, equivalent to at least 7,258 adults. With an incubation time of 28-30 days, by mid-March, most eggs would have incubated and developed into pulli. With a fledgling period of about 60 days (57 to 63 days), by the time of the TMO inventory in May, the offspring were mainly juveniles able to fly with some pulli still in transition from downy to feathered plumages (Animalia.bio/sooty-tern). During the May 2002 inventory 2,622 juveniles or near juveniles and 14 eggs were counted (Figure 57, Annex 16).

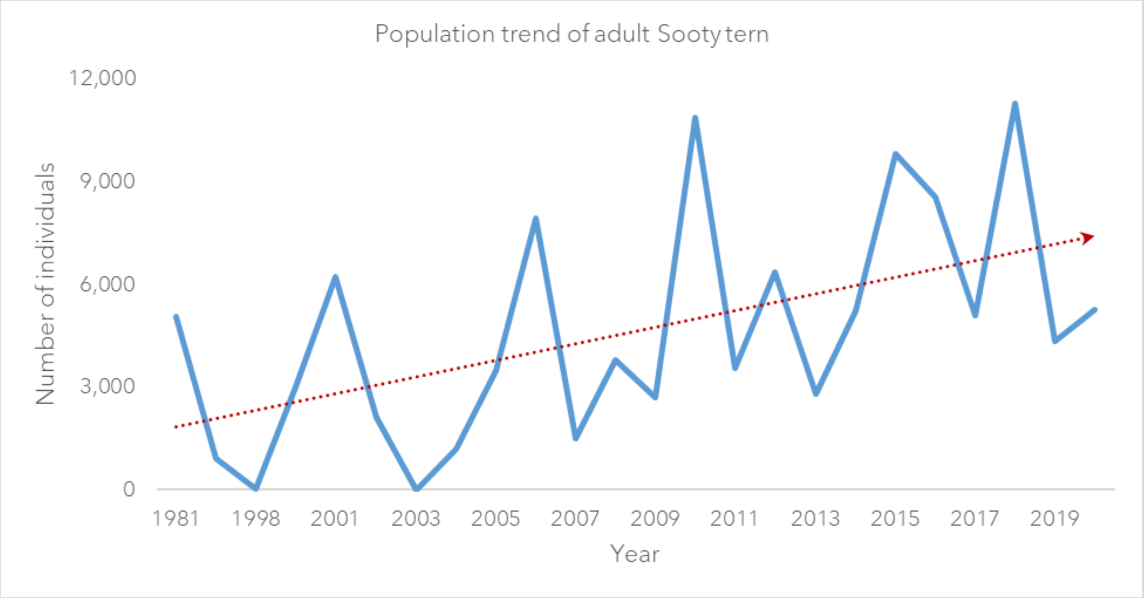

Figure 56. Population trend of adult Sooty Tern from 1981 to 2020.

The Sooty Tern breeds in two distinct sub-populations: either from May to August or February to April and from September to November. The species continue to have variations in breeding seasonality and the breeding cycle may not follow a calendar year as seen in 2018, when a breeding season started in September/October and ended in February 2019, Table 13.

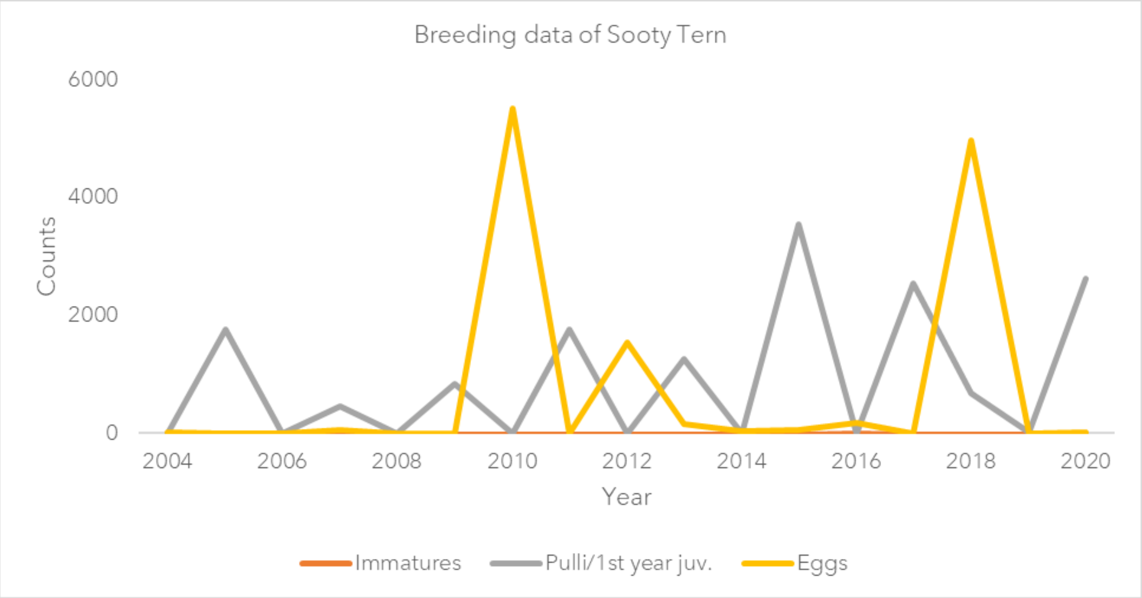

Figure 57. Breeding data of Sooty Tern from 2004 to 2020.

Table 13. Breeding months of Sooty Tern 2017 to 2020. Data presented in the table are based on May inventories and MPR data including inventories in February, August, and November.

Year/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2017	0	Pre	Pre	Pre	Pull	ND	0?	Egg/J	Pre	Pre	J(P)	Pre
2018	(Pre)	Pre	Pre	Pre	Egg	Pre	Pre	J(P) ?	(Pre)	(Pre)	Eggs	Pre
2019	Pre	J(P)	Pre	0	Pre	Pre	Pre	Egg	Pre	0	0	0
2020	Pre	Egg	Pre	Pre	J(P)	?	0	0	(Pre)	-	-	-

Legend: (Pre) – Present in low numbers, Pre – Present in breeding numbers (>500 adults), Egg – Eggs, or mainly eggs, Pull = Downy pulli, J(P) – Mainly juveniles with some pulli transitioning to juveniles, and J – Juveniles.

Masked Booby (Conservation Status - Philippine Red List: Critically Endangered): MPR records show the species was present at Bird Islet within the colony of Brown Booby at the 'Plaza" from June to December 2019, and from January to August 2020. In November and December 2019 there were two adults, identified by sound recordings to be a male and a female. Nearest likely recruitment areas are found in Indonesia and Australia (Banda Sea and islets of NW Australia). They established a breeding territory in May 2020 and two eggs were being incubated on 12 June. However, on 1 July only one egg was found and no eggs could be found when the MPRs visited Bird Islet on 13 July. On 13 August MPRs observed one egg and on 17 August two eggs were incubated (Figure 58). The status of this critically endangered species in the Philippines may now be changed from 'extirpated' to 'rare resident breeding' species.

Figure 58. Masked Booby breeding on Bird Islet in 2020. Photo: Retch Pagliawan/TMO

Red-footed Booby (Conservation Status - Philippine Red List: Least Concern): Declining population. Total estimated population: 700-800 adult individuals. The adult population in May 2020 was 660 individuals, down by 35% compared to the inventory in May 2019 (1,008 adult individuals) (Figure 59 and Annex 15). Compared to the baseline inventory year (2004: 2,435 adult individuals), the population is lower by 73%.

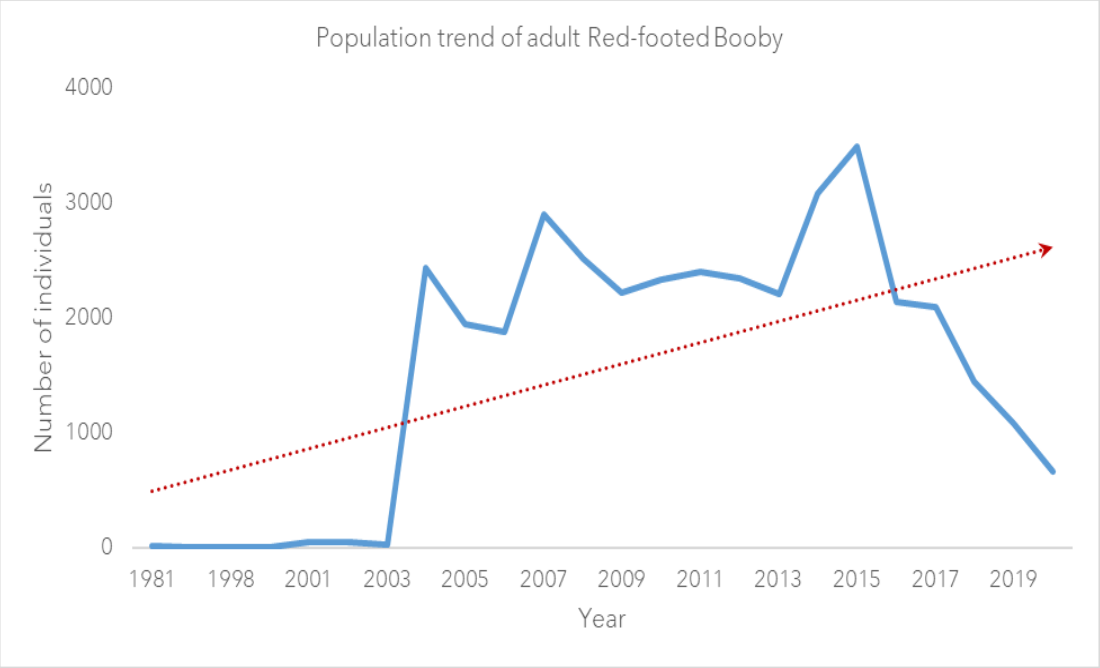

Figure 59. Population trend of adult Red-footed Booby from 1981 to 2020.

The declining population is a result of the reduced breeding habitat although 26 pairs were unsuccessfully using the noddy breeding structures for breeding (nests without eggs were removed). Correspondingly, the number of nests went down to 43, a reduction by around 40% compared to 2019 (Figure 60 and Annex 16). Low numbers of adults were also observed by the MPRs in February 2020.

Of the adult population recorded in May 2020, about 65% were found on Bird Islet. On South Islet, 40% of the population was recorded, the same percentage as recorded in 2019.

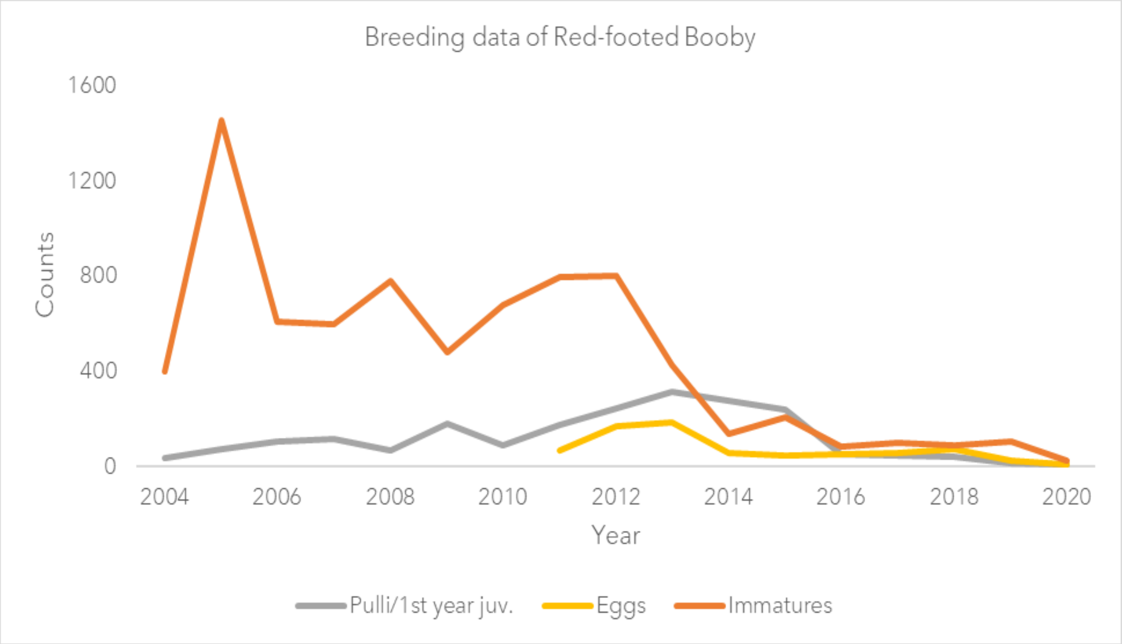

Figure 60. Breeding data of Red-footed Booby from 2004 to 2020.

Brown Booby (Conservation Status - Philippine Red List: Endangered): Increasing population. Total estimated population: 5,000 to 5,300 adult individuals. Based on direct counts, the population is about 21% lower than in the baseline inventory year of 1981 (3,768 adults), Annex 16. However, the average of early morning counts and distance estimations of the adult population on Bird Islet in May suggests a population ranging from 4,000 to 4,700 adult individuals of which at least 2,108 were breeding. A similarly high number of birds were observed by the MPRs during their inventory in August 2020. They recorded around 4,860 adults (including an extrapolated number of adults flying to roost) with 1,700 nests containing 663 pulli and juveniles, and 1,213 eggs. A high number of active breeding birds were also observed by the MPR's in November 2019 (2,494 individuals). The total minimum counted in May 2020, >2,977+ individuals, indicate a decline of around 5% in May 2020 compared to the 2019 count (Table 10, Figure 61, and Annex 15). The decline may not be real and may only reflect overlooked adults during day counts or birds that arrived after the end of the in-flight count period at 18.30pm.

The 1,054 nests found in May 2020 is only the fourth count in May since 2004 with more than 1,000 nests, Figure 62, Annex 16. The 294 eggs and pulli recorded at the time were also relatively high. However, in November 2019 the MPRs found 1,247 nests containing 1,103 pulli and juveniles, and 242 eggs, Annex 14. In August 2020, they found 1,694 nests with a correspondingly high number of 633 pulli and juveniles and 1,210 eggs. Despite the relatively high number of adults found on South Islet in May, no breeding pairs were observed at that time, Table 14.

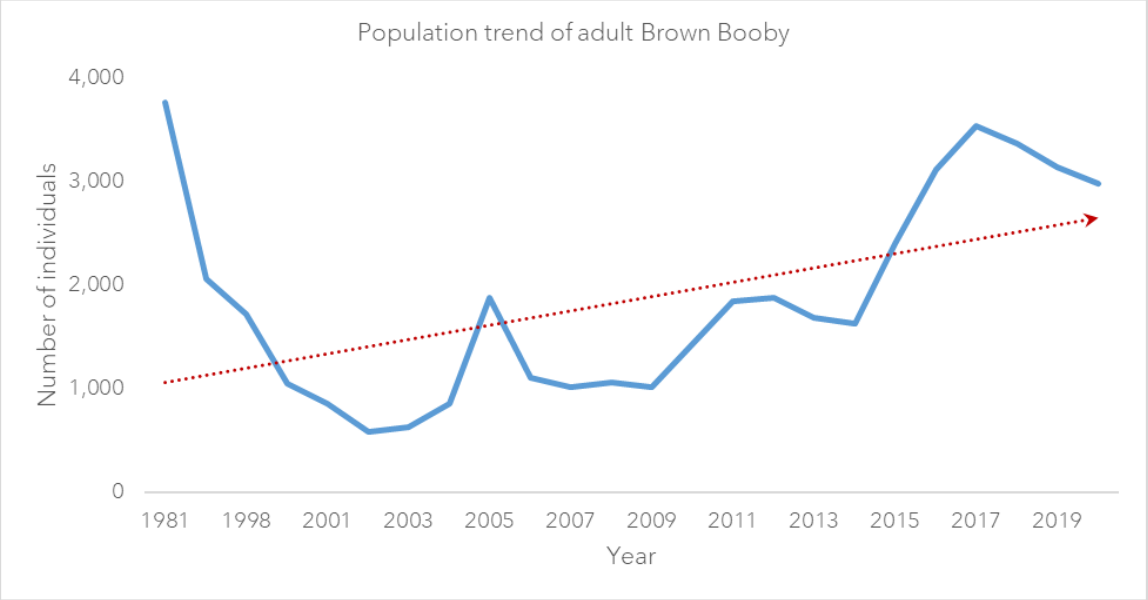

Figure 61. Population trend of adult Brown Booby from 1981 to 2020.

<u>Banded birds:</u> In November 2019 and in May 2020, a total of 94 Brown Boobies, color-banded and steel ringed between 2006 to 2009 on Bird Islet, had their bands and rings read. Of these birds, 48 were banded as adults and 56 individuals as pulli, Table 14. Adults banded in 2006 are at least 18 years old. The birds banded as pulli are now from 11 to 14 years old, or on average about half the lifespan of the species, which can reach the age of 25 years (Hennicke *et al.* 2012).

Table 14. Results of ring readings of Brown Booby on Bird Islet in November 2019 and May 2020

Total	*Pulli*	*Adult*	*Total*
2006	*2*	*7*	*9*
2007	*28*	*27*	*55*
2008	*21*	*8*	*29*
2009	*5*	*6*	*11*
Total	*56*	*48*	*94*

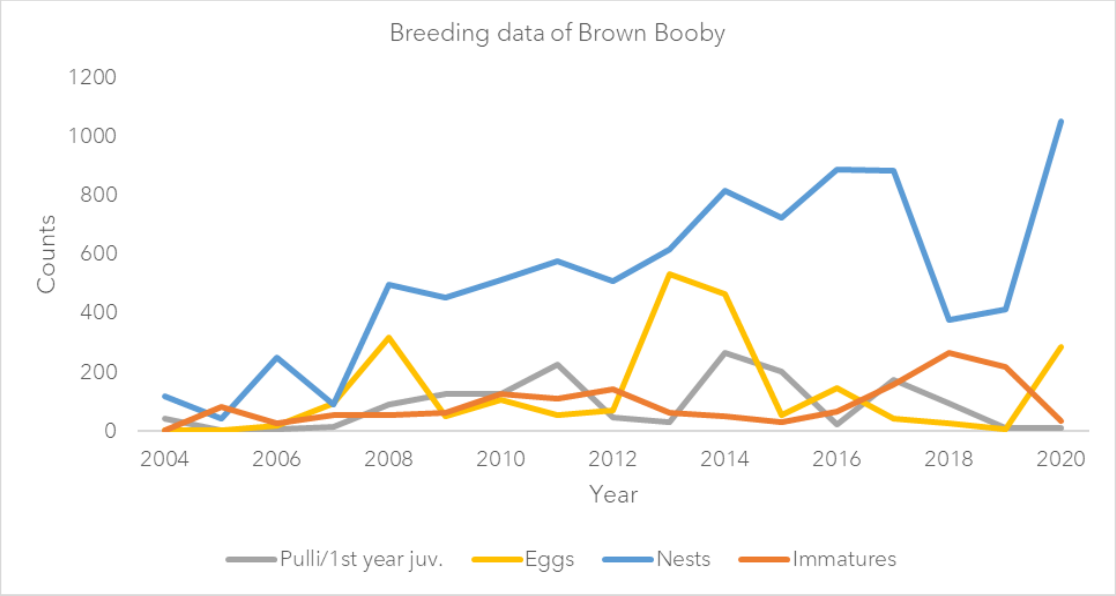

Figure 62. Breeding data of Brown Booby from 2004 to 2020.

Mortalities: Although the total number of carcasses were not recorded, several mortalities were observed. The condition of most specimens was in advanced decomposition or desiccation. Only one mortality was fresh and whole enough to warrant necropsy, Annex 20. This involved an adult male Brown Booby with a long, almost straight linear abrasion extending from the front of the left-wing cutting diagonally across the back down to just above the right hip. The wound appeared to be old and necrotic but only skin-deep. It appeared to have been caused by a thin object pressing or rubbing on skin, possibly a stick, a fine rope, or a fishing line. However, no such object was found on the bird. Internal examination did not reveal any notable lesion except an empty stomach. It is possible that the bird got entangled and was thus unable to feed, likely dying of hunger and exposure. The wound from the entanglement was not severe enough to have caused the death directly.

Barred Rail: Five birds were noted in Bird Islet in May 2020. The species was absent from South Islet. Absence of vegetation, which is preferred by rail species, may impact possible breeding.

Pacific Reef Heron: The total adult population in May 2020 may not have been counted since the TMO team only noted about four individuals. This is below the numbers normally counted (2019: 16 individuals, 2018: 9 individuals, 2017: 16 individuals, and 2016: 19 individuals). In August 2020 MPRs observed nine individuals. No nests were found in May 2020, but in August 2020 MPRs documented one nest with two pulli on Bird Islet.

Eurasian Tree Sparrow: For the first time since 1991, the species was not found on the islets. The only observation was of one individual in May 2020 at the Ranger Station.

6.4 Recommendations

Habitat

1. Restoration of Beach Forest: Following recommendations made in the 2019 Seabird Inventory Report, considerable efforts to reforest both Bird Islet and South Islet were made by the TMO. Success will be important for the long-term survival of the unique and threatened population of the subspecies *worcesteri* of Black Noddy. To possibly increase the survival rate of saplings planted and to be planted, it is recommended a) to seek further advice from experienced beach forest experts, and b) to make a written protocol guiding the MPRs on where to plant or not to plants, and how to monitor and document the survival rate of saplings per species planted. It is recommended that planting be limited to areas where the former beach forest was located in both islets.

2. Habitat restoration of South Islet

It is recommended to ensure a wide enough sandy beach habitat free of vegetation enabling Great Crested Tern and Brown Booby to breed on the islet.

As some of the islet's original grass vegetation seems to be recovering on its own, there may be no need to restore this habitat. However, a vegetation assessment should be carried out during the May 2021 inventory, and based on the result, if needed, a restoration be undertaken.

Species

3. Black Noddy: Continue to replenish lost breeding habitats by increasing the number of artificial nesting structures and bring in nesting materials regularly in both Bird Islet and South Islet. There is a need to establish about 10 structures per islet to provide at least 5,000 noddies with breeding opportunities.

4. As old designs and new experimental nesting designs do not protect the species from exposure to strong winds and rainfall, it is recommended that protective shields be installed around the structures. This may increase the reproduction rate which is very low at the moment.

5. Where Red-footed Booby nests are being constructed in the nesting structures, it is advised that these be removed by the MPRs regularly. Data on the number of nests removed should be made part of the seabird report of the MPRs.

6. There is substantial data on the readings of the color and steel bands applied on the Brown Booby from 2006 to 2009. It is recommended that these data collected by MPRs spanning an average of 13 years be analyzed.

7. It is further recommended that banded Black Noddy be recaptured and ring numbers be read for analysis.

8. Geo-locator tracking devices or geo-locators (lightweight electronic archival tracking devices) have become very light-weight and affordable. They can provide important information for the management of seabird species and their populations. Hence, it is recommended to include in fund-raising activities a budget for the purchase of geo-locators, including the cost of installation, data analysis, and results dissemination.

Methodology

9. Bird counts. Continue monthly distance counts, and conduct three direct counts in January/February, August/September, and October/November aside from the annual May census. Include counts of other breeding species such as Pacific Reef Heron, Barred Rail, and Eurasian Tree Sparrow, and of migratory species with declining or threatened populations such as Ruddy Turnstone and, if possible, Grey-tailed Tattler.

10. Recommended improvements on data collection and reporting includes the collection of data on:

a) data on empty nests to be separated from data on nests with eggs, pulli, and juveniles;

b) data on pulli to be separated from data on juveniles, which are birds living in their first calendar year;

c) immatures or birds on their second calendar year or more, of Sooty Tern, Great Crested Tern, and the two noddy species need not be aged and reported. Immatures of these species cannot be easily distinguished from adult birds, or at all.

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7 WATER QUALITY

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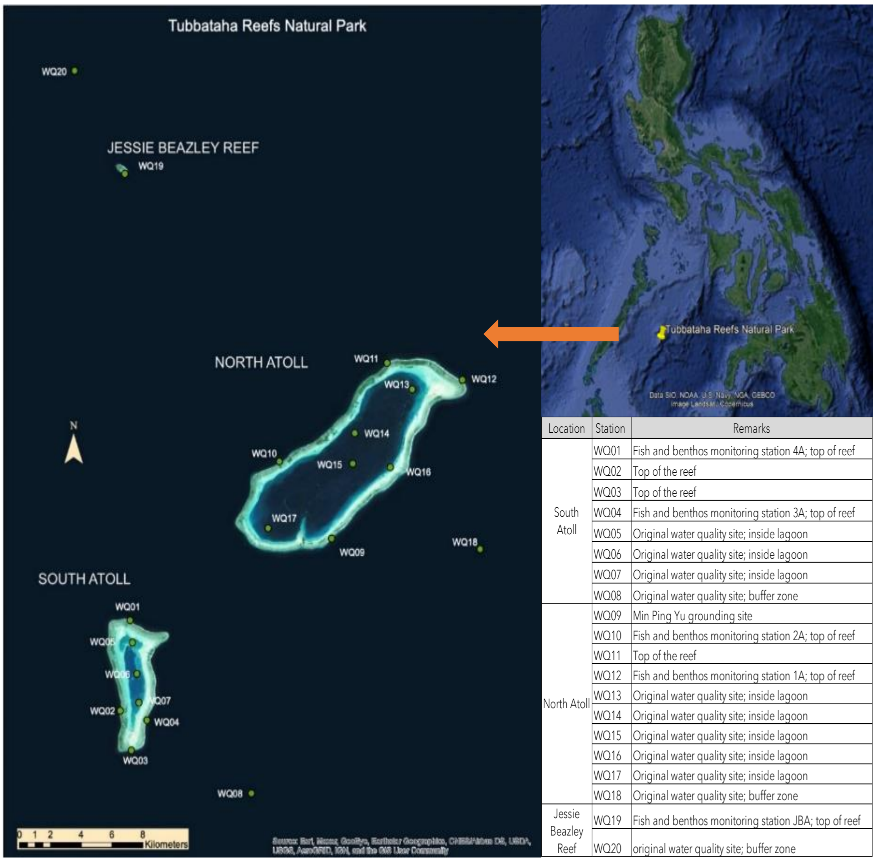
7. 1 Overview

The conduct of regular monitoring aims to determine the changes and trends of the general water quality of TRNP that may or may not be linked to human activities and climate change. The water quality monitoring started in April 2014, undertaken during the dive season, from March to May.

This year, the water quality monitoring was conducted in June 2020. This report shows the trends in water quality from 2014 to 2020, with a two-year gap in 2018 and 2019. It also discusses the factors influencing such trends, its implications, and possible mitigations.



Location	Station	Remarks
South Atoll	WQ01	Fish and benthos monitoring station 4A; top of reef
	WQ02	Top of the reef
	WQ03	Top of the reef
	WQ04	Fish and benthos monitoring station 3A; top of reef
	WQ05	Original water quality site; inside lagoon
	WQ06	Original water quality site; inside lagoon
	WQ07	Original water quality site; inside lagoon
	WQ08	Original water quality site; buffer zone
North Atoll	WQ09	Min Ping Yu grounding site
	WQ10	Fish and benthos monitoring station 2A; top of reef
	WQ11	Top of the reef
	WQ12	Fish and benthos monitoring station 1A; top of reef
	WQ13	Original water quality site; inside lagoon
	WQ14	Original water quality site; inside lagoon
	WQ15	Original water quality site; inside lagoon
	WQ16	Original water quality site; inside lagoon
	WQ17	Original water quality site; inside lagoon
	WQ18	Original water quality site; buffer zone
Jessie Beazley Reef	WQ19	Fish and benthos monitoring station JBA; top of reef
	WQ20	original water quality site; buffer zone

Figure 63. Water Quality Monitoring Stations in Tubbataha Reefs Natural Park.

7. 2 Methods

Water Quality Monitoring Stations

The annual water quality monitoring in TRNP started in April 2014 to 2017 and resumed in June 2020. Twenty (20) sampling stations were established for monitoring (Figure 63). These stations were chosen based on their location and proximity to North Atoll (WQ01 to WQ07), South Atoll (WQ09 to WQ17), and Jessie Beazley Reef (WQ19). Three stations outside the TRNP were established namely: WQ08 (outside South Atoll), WQ18 (outside North Atoll), and WQ20 (outside Jessie Beazley Reef). During the 2020 water quality monitoring activity, some of the monitoring stations were moved closer to the reef areas, where the dive sites and fish and benthos monitoring stations are located.

Collection of Water Samples

Grab water samples were taken from each station. Sample collection was done by holding the sample container near its base and plunging the neck downward, below the surface. The sample bottle was turned until its neck pointed slightly upward and its mouth directed toward the direction of the current. Water samples were collected from the upstream side of the patrol boat. Grab samples of surface water were collected for oil and grease analysis.

The container of water sample depends on the parameters to be analyzed. Samples for total and fecal coliform analyses were collected in a 150 ml sterilized glass bottle while samples for oil and grease analysis were collected using a 1-liter wide-mouthed glass bottle. For other physicochemical parameters, containers of 2.5-liter capacity-HDPE were used.

Figure 64. Collection of water samples in Tubbataha Reefs Natural Park in June 2020.

In situ measurements of water quality were conducted using a multi-probe meter to determine the dissolved oxygen, temperature, pH, salinity, and conductivity in each station. The prevailing weather conditions, activities nearby, and sea swell were also recorded.

All collected samples were sealed, packed properly, kept with ice in an ice chest. Preservative (1:1 Hydrochloric acid) was added for samples of oil and grease. The water samples were taken to the PCSD Environmental Laboratory for analysis immediately upon arrival in Puerto Princesa.

Water Quality Parameters

The criteria to assess water quality were based on the parameters prescribed in DENR Admin. Order No. 2016-08. The physico-chemical and microbiological methods of analysis were based on the prescribed and approved methods per DENR Admin Order No. 34-1990. Table 15 presents the water quality parameters, methods, and its relevance to water quality monitoring.

Table 15.General description and laboratory methods to analyze the water quality parameters.

Parameter	Description	Method of Analysis
A. Physico- chemical parameters		
pH*	A numerical measure of acidity (below 7) and alkalinity (above 7)	Glass Electrode Method
Temperature*	Degree of hotness or coldness of the water. It influences the physicochemical characteristics and the distribution and abundance of marine flora and fauna.	Multi-probe Meter
Dissolved Oxygen (DO)*	Refers to the amount of oxygen available in the water column. It is an important requirement for the maintenance of a balanced population of fish, shellfish, and other marine organisms.	Membrane Electrode Method (DO Meter)
Total Suspended Solids (TSS)	Particles that remain suspended in water, thereby causing turbidity or increase the color of the water. Higher TSS, the higher the turbidity.	Gravimetric dried at 103 - 105^{0}C
Total Dissolved Solids (TDS)**	A measure of the water's content of various dissolved materials	Gravimetric dried at 180^{0}C/ Multiparameter Meter
Salinity	A measurement of the mass of dissolved salts in a given amount of water.	Multiparameter Meter
Color	Caused by the presence of dissolved organic matter, metallic salts, or suspended	Visual Comparison Method (Platinum Cobalt Scale)
Nitrogen as Nitrates	Indicates the presence of nutrients in the water bodies. High concentration can cause severe illness to animals	Colorimetric using Hach Nitrate Powder Pillows
Phosphorus as Phosphates	Indicates the presence of one of the primary nutrients in the water bodies. High concentration fuels the growth of algae and other microorganisms	Colorimetric using Hach Phosphate Powder Pillows
Oil and Grease (O&G)	Fats, oils, waxes, and other related constituents found in water that is recovered in the solvent.	Gravimetric Method (Petroleum Ether Extraction)
Biochemical oxygen demand (BOD)	Measure of the oxygen consumed by microorganisms over time as they degrade organic matter in a water body.	Alkali Iodide Azide (5-day BOD Test)
Chromium hexavalent, Cr(IV)	Cr(VI) compounds may be used as pigments in dyes, paints, inks, and plastics. It also may be used as an anticorrosive agent added to paints, primers, and other surface coatings.	Diphenylcarbazide – colorimetric method
B. Microbiological Parameters		
Total Coliform (TC)	TC comprises all members of the coliform bacteria group, or the microorganisms from vegetation, soil, and water	Multiple Tube Fermentation Technique
Fecal Coliform (FC)	FC are members of the TC group that originate in the intestinal gut of warm-blooded animals.	Multiple Tube Fermentation Technique

Reference: Standard Methods for the Examination of Water & Wastewater, APHA-A4WWA 21st Ed, 2005.

*Measurement done on-site; ** Measured on-site and/or analyzed in the laboratory

Two parameters, the BOD and Chromium hexavalent (Cr(VI)) were not analyzed on water samples gathered this year because the standard method for BOD is not applicable to seawater samples due to its high chloride content (APHA AWWA 2005). The spectrophotometer of PCSD Environmental Laboratory broke down, thus Cr(VI) was not analyzed this year.

Water Quality Guidelines

The Water Quality Criteria set in DENR Admin. Order No. 34, Series of 1990 was superseded by DENR Admin Order No. 2016-08 or the Water Quality Guidelines and General Effluent Criteria of 2016.

The beneficial usage of the sea waters surrounding the TRNP falls under the classification Class SA, as "*Protected waters or waters designated as national or local marine parks, reserves, sanctuaries, and other areas established by law (Presidential Proclamation 1801 and other existing laws), and/or declared as such by appropriate government agency, LGUs, etc.*"

The results of the water quality monitoring from 2014 to 2020 were evaluated based on the water quality guidelines for primary parameters for Class SA (Table 16). Parameters such as BOD and total coliform were not given a guideline concentration for seawater.

Table 16. Water quality guidelines for primary parameters for Class SA (DAO 2016-08).

Parameters	Unit	DAO 2016-08
pH		7.0 – 8.5
Temperature	^{0}C	26-30
Color	PCU	5
Dissolved Oxygen, DO	mg/L	6
Total Suspended Solids, TSS	mg/L	25
Oil and Grease	mg/L	1
Fecal Coliform	MPN/100mL	<1.1
Phosphates	mg/L	0.1
Nitrate as NO_3-N	mg/L	10

7.3 Results and Discussion

General Water Quality

A total of 100 water samples were collected from 20 water quality monitoring stations from 2014 to 2017, and 2020. These samples were analyzed in the PCSD Environmental Laboratory for seven (7) parameters (nitrates, phosphates, total coliform, fecal coliform, color, total suspended solids, and oil and grease). Parameters such as pH, temperature, and dissolved oxygen were measured on-site.

Table 17 summarizes the mean values of the physico-chemical and microbiological parameters grouped per WQ monitoring station in TRNP vis-à-vis the water quality guideline for Class SA per DENR Administrative Order (AO) No. 2016-08. The mean values show that nitrates, color, TSS, and pH concentration is within WQ guidelines, while slightly elevated levels were observed for other parameters – temperature, dissolved oxygen, fecal coliform, and phosphates.

Table 17. Mean water quality parameters of TRNP by monitoring stations. June 2020.

Parameters	Unit	North Atoll	South Atoll	Jessie Beazley Reef	Outside TRNP Boundary	WQ Guidelines Class SA
pH	-	7.55	7.5	7.34	7.46	7.0 – 8.5
Temperature	^{0}C	30.45	30.28	30.3	30.62	26-30
Color	PCU	<5	<5	<5	<5	5
Dissolved Oxygen	mg/L	6.59	6.1	6.81	5.89	6
Total Suspended Solids, TSS	mg/L	6	5	1	5	25
Oil and Grease	mg/L	2.4	2.5	<1	1.2	1
Total Coliform	MPN/100 mL	13.2	10.7	14	16.6	-
Fecal Coliform	MPN/100 mL	2.4	2.6	2	5	<1.1
Phosphates	mg/L	0.2	0.59	0.28	0.22	0.1
Nitrates	mg/L	0.52	0.48	0.58	0.62	10

The descriptive statistics such as mean and standard deviation, and range of water quality parameters per station from 2014 to 2020 are summarized in Table 18.

Table 18. Mean values of water quality parameters at different water quality monitoring stations in TRNP (2014-2020).

Location	WQ Stations	pH	Temperature °C	TSS mg/L	Color PCU	Dissolved Oxygen mg/L	Nitrates mg/L	Phosphates mg/L	Oil and Grease mg/L	Total Coliform MPN/100 mL	Fecal Coliform MPN/100 mL
South Atoll	WQ01	8.26±0.33	28.45±3.63	4.58±3.63	5±0.4	7.04 ±0.84	1.12 ± 0.43	0.83±0.49	2.62±1.81	44.40 ± 26.56	13.90 ± 9.34
	WQ02	8.16±0.58	28.45±1.76	6.38 ± 4.06	6± 2.1	6.90 ± 1.24	1.12 ± 0.37	0.56 ± 0.23	2.83 ± 1.53	42.40 ± 12.61	21.58±19.52
	WQ03	8.33±0.33	28.85±1.44	4.36 ± 4.11	6± 2.1	7.04 ± 0.83	1.29 ± 0.49	0.61 ± 0.13	4.18 ± 2.90	31.10±16.24	19.27±13.01
	WQ04	8.21±0.34	30.16±1.48	7.38±4.79	5±0.4	7.17±0.75	1.04±0.45	0.27±0.13	2.19±1.86	41.36±40.14	29.95±38.02
	WQ05	8.15±0.32	29.70±0.64	8.60±6.15	6±2.1	6.34±0.60	1.08±0.40	0.46±0.40	2.00±1.12	67.10±56.81	31.75±24.93
	WQ06	8.10±0.45	29.81±1.04	9.20±5.38	6±2.1	7.04±0.65	1.08±0.35	0.52±0.50	1.92±0.59	70.10±58.36	47.00±39.82
	WQ07	8.14±0.46	30.39±1.17	8.80±5.60	5±0.4	6.76±0.55	1.18±0.50	0.68±0.36	2.59±0.73	130.96±130.15	66.75±53.80
Outside TRNP 1	WQ08	8.29±0.31	30.33±1.79	4.58±3.63	5±0.4	6.94±1.00	1.21±0.35	0.35±0.15	3.07±3.32	97.96±100.31	49.20±70.27
North Atoll	WQ09	8.3±0.30	30.60±2.07	12.40±3.72	5±0.4	7.06±0.90	1.21±0.40	0.79±0.46	1.75±0.49	70±49.73	34.60±32.57
	WQ10	8.35±0.47	31.44±2.53	8.60±6.68	5±0.4	7.11±1.00	1.36±0.66	0.41±0.28	2.92±1.11	20.80±10.17	14.73±13.74
	WQ11	8.11±0.50	29.93±0.51	11.20±4.79	5±0.4	6.95±1.05	1.06±0.51	0.56±0.33	2.55±1.36	42.10±25.83	20.70±20.32
	WQ12	8.26±0.35	28.77±1.54	8.20±4.17	7±2.6	6.89±1.11	1.38±0.64	0.30±0.16	1.73±0.40	42.90±33.50	20.95±20.09
	WQ13	8.20±0.34	30.10±0.71	5.58±3.41	5±0.4	7.34±0.92	1.16±0.47	0.34±0.32	3.04±1.66	47.40±37.58	27.65±26.77
	WQ14	8.11±0.45	29.73±1.40	7.36±6.32	5±0.4	6.93±0.87	1.10±0.49	0.21±0.11	2.48±1.14	55.40±23.34	18.08±16.54
	WQ15	8.20±0.40	30.39±0.68	4.38±3.57	5±0.4	7.06±0.74	1.20±0.53	0.50±0.44	1.79±1.20	33.20±18.29	19.70±18.64
	WQ16	8.14±0.48	29.55±1.36	4.80±1.17	6±2.1	7.56±0.44	1.39±0.94	0.47±0.49	2.29±1.77	65.56±58.15	57.75±50.57
	WQ17	8.10±0.56	30.50±0.86	4.96±5.36	7±4.1	7.13±0.98	1.25±0.53	0.41±0.29	3.18±1.96	65.40±64.30	35.25±35.09
Outside TRNP 2	WQ18	8.20±0.50	28.88±1.60	4.58±3.69	5±0.4	7.23±1.02	1.40±0.69	0.26±0.16	2.26±1.27	39±31.11	8.60±10.19
Jessie Beazley Reef	WQ19	8.19±0.50	29.87±0.42	3.56±2.97	6±2.1	7.43±0.51	1.30±0.67	0.30±0.14	2.54±1.43	51.20±45.66	30.20±37.83
Outside TRNP 3	WQ20	8.15±0.55	30.23±0.66	8.20±5.71	5±0.4	6.84±1.01	1.34±0.40	0.30±0.15	1.83±0.82	75.75±40.06	45.50±30.15
Range		8.10-8.35	28.45-30.60	3.56-12.40	5-7	6.34-7.56	1.04 - 1.40	0.21-0.83	1.73-3.18	20.80-130.96	8.60-66.75
WQ Standard Class SA		7.00-8.50	26-30	25	5	6	10	0.1	1	-	<1.1

The trends shown in this section are based on the results of water quality monitoring and sampling conducted in 2014, 2015, 2016, 2017, and 2020.

Physico-Chemical Parameters

Temperature

The measured temperature ranged from 25.4°C to 38.4°C with a mean value of 29.9°C. Both measured in 2014, the lowest temperature was measured in WQ02 (west, outside of South Atoll) while the highest temperature was measured in (inside North Atoll). Based on the latest monitoring in June 2020, the temperature in all stations ranged from 30.07 °C to 31.14 °C, with a mean value of 30.41 °C. These values were slightly higher than the maximum guideline set for Class SA at 30°C (DAO 2016-08), although still within the measured temperature in 1984, 1989, 1992, at 30°C to 32°C (Arquiza and White 1999). Variation of temperature is one of the important factors that influence the distribution and abundance of marine flora and fauna (Soundarapandian *et al.* 2009).

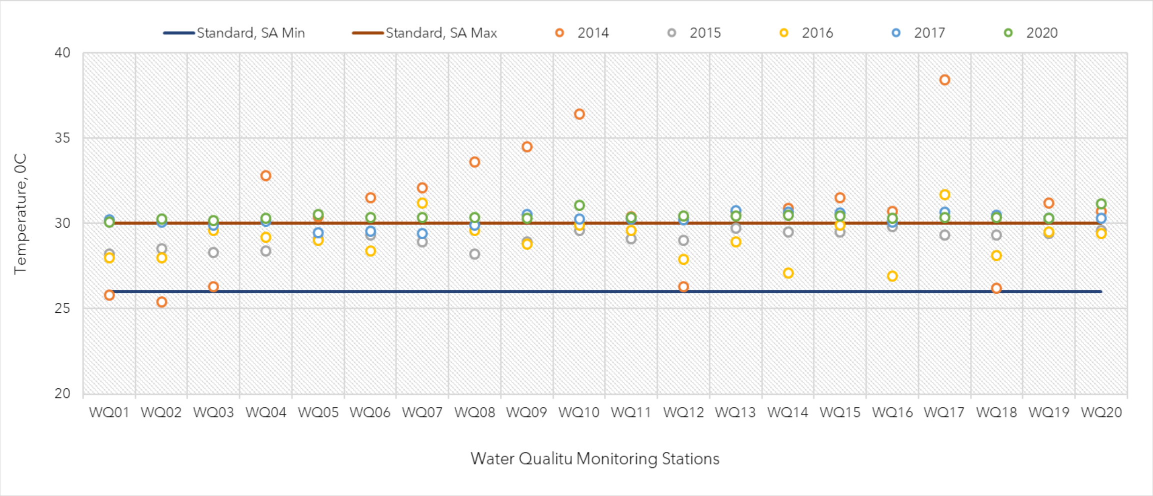


Figure 65. Trends of sea surface temperature measured in TRNP water quality monitoring stations from 2014 to 2020.

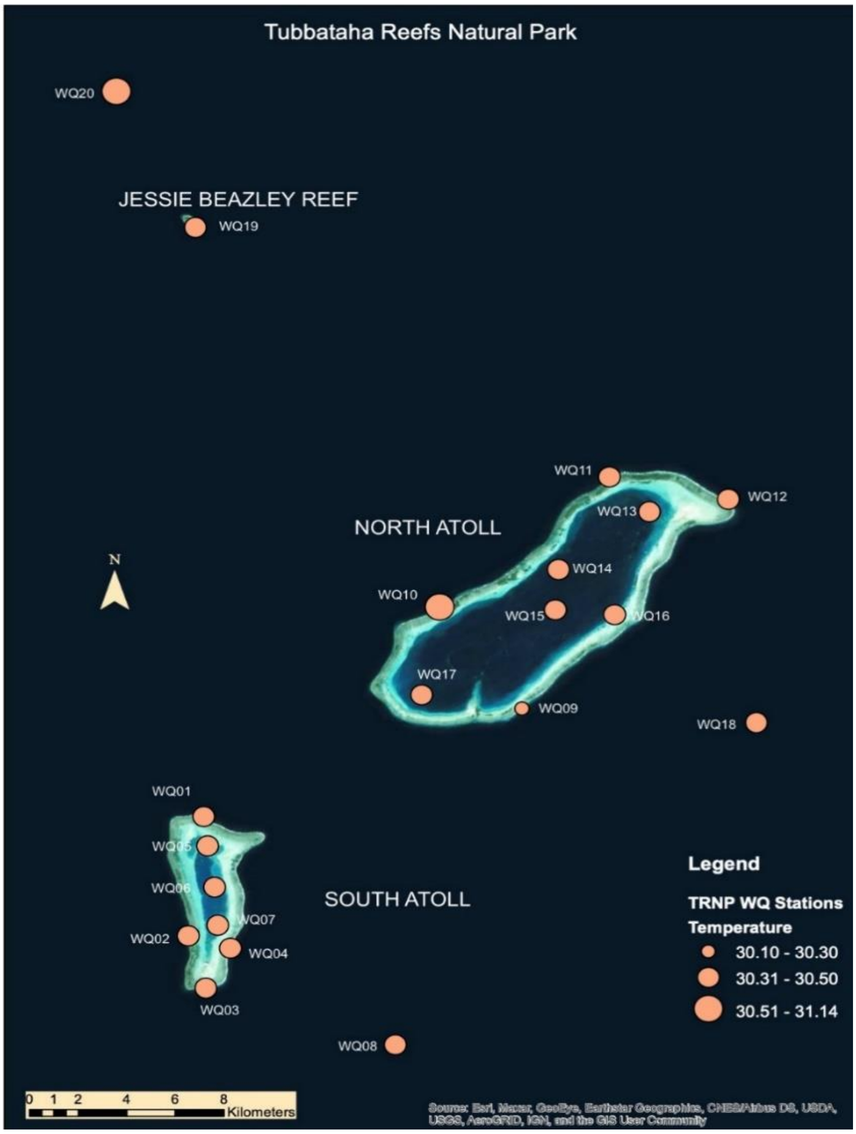


Figure 66. Temperature measured in TRNP water quality monitoring stations in June 2020.

pH

The water quality of TRNP in terms of potential hydrogen or how much hydrogen is mixed with water showed that the pH value per monitoring station is within the minimum pH of 7, but above the maximum pH guideline (pH 8.5) for seawater under Class SA as shown in Figure 67. The slight elevation or changes in the values in 2017 were not observed in 2020. It appears that TRNP maintains good pH values for coral reefs to thrive, which ranges from 6-9 (Tarigan 2003). The pH in Tubbataha is conducive for the respiration and other metabolic processes of fish, corals, and other aquatic organisms.

The increased acidity of the ocean and coastal waters is a growing concern. It reduces the saturation or availability of calcium carbonate minerals which are the building blocks for the skeletons and shells of many marine organisms. This increase in acidity was not observed in TRNP.

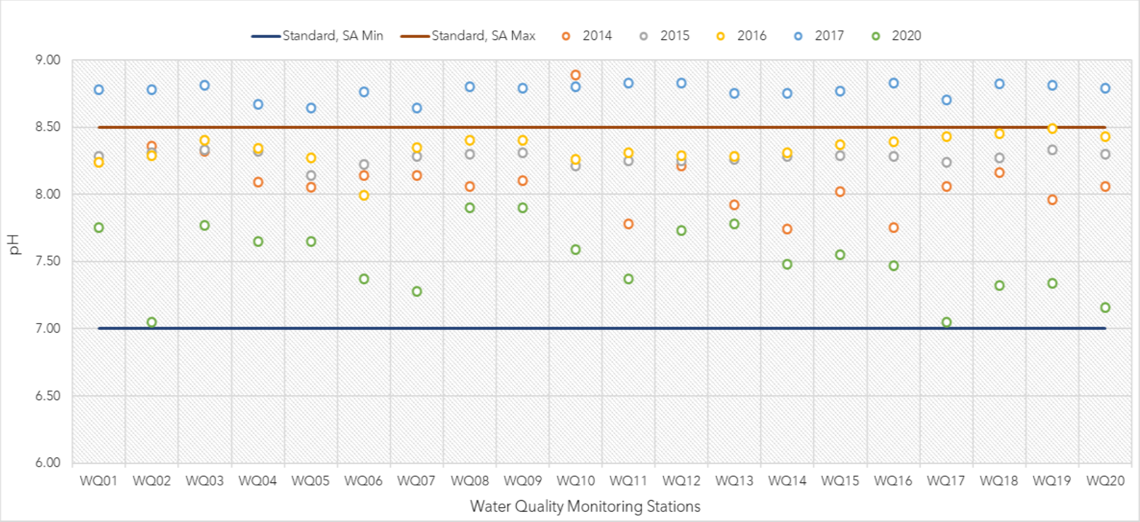


Figure 67. Trends of pH measured in TRNP water quality monitoring stations from 2014 to 2020.

Color

The color measures the clarity of the seawater, which is affected by the presence of dissolved organic matter, metallic salts, or suspended solids. The measured color of seawater surrounding TRNP ranged from <5 to 15 PCU (Figure 68).

While in exceedance in previous years, the color of samples measured from all water quality monitoring stations in 2020 were below the Class SA guideline of 5 PCU (DAO 2016-08).

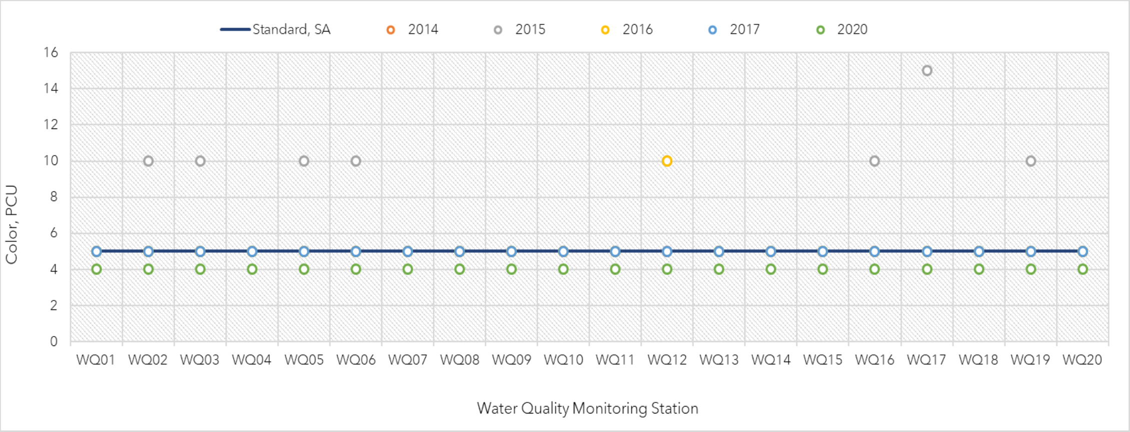


Figure 68. Trends of color measured in TRNP water quality monitoring stations from 2014 to 2020. Color unit: PCU - platinum cobalt unit.

Dissolved Oxygen

The dissolved oxygen (DO) ranged from 5.40 mg/L to 8.87 mg/L, with a mean value of 7.04 mg/L. It is important to note that the higher the value of DO, the better for the marine organisms. Therefore, DO values higher than the Class SA guideline of 6 mg/L is considered to be all within the prescribed water quality guidelines.

While DO below 6 mg/L was observed in some stations in the North and South Atolls in 2017 (Figure 69), such was not recorded during the 2020 monitoring, except in WQ12, located close to Bird Islet.

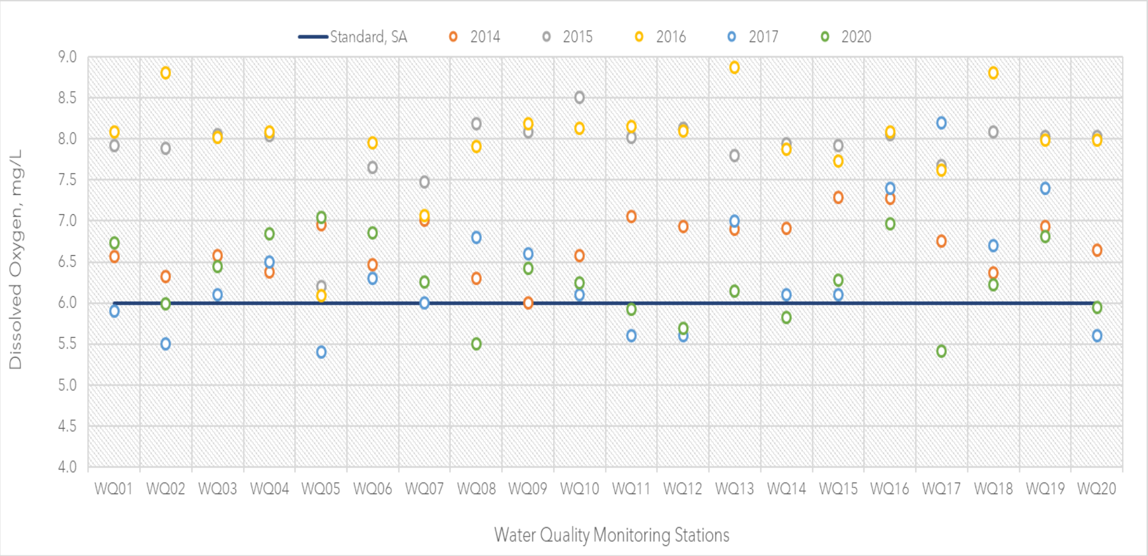


Figure 69. Trends of dissolved oxygen measured in TRNP water quality monitoring stations from 2014 to 2020.

Figure 70 shows the DO concentration recorded during the June 2020 water quality monitoring activity. A DO concentration higher than the Class SA WQ guideline is favorable to marine organisms. Prolonged exposure of low DO (less than 3) may cause asphyxiation leading to a fish kill. The major factor controlling dissolved oxygen concentration in the water is the biological activity where the oxygen is produced during photosynthesis while being consumed during respiration and nitrification (Best et al. 2007).

Figure 70. Dissolved oxygen measured in TRNP water quality monitoring stations in June 2020.

Oil and Grease

Concentrations of oil and grease range from <1 mg/L to 8.8 mg/L, with a mean value of 2.36 mg/L. Figure 71 shows the trends of oil and grease in the water quality monitoring stations. Two (2) sampling events for oil and grease were conducted in 2015; during the off-season (February 2015) and dive season (April 2015). This aimed to ascertain the possible effects of the increased number of boats entering the park during the dive season, on the levels of oil and grease. Higher levels of oil and grease were subsequently measured in April 2016 and June 2017, both conducted during the dive season.

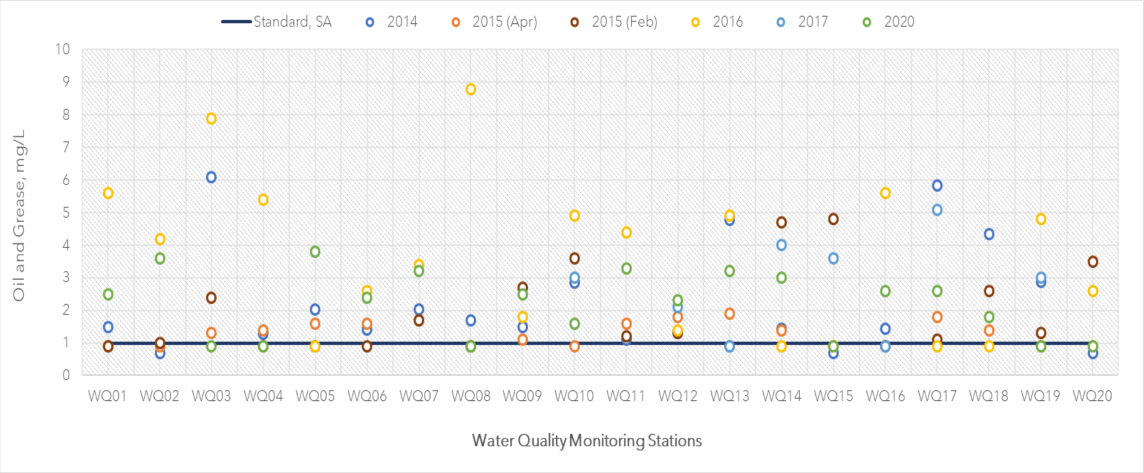


Figure 71. Trends of oil and grease measured in TRNP water quality monitoring stations from 2014 to 2020.

The high levels recorded from 2014 to 2017 could be attributed to shipping activities inside and outside the park. TRNP is next to the sea lanes used by different marine vessels such as cargo ships, fishing boats, and tankers. Based on the study conducted in 2014, a total of 4,451 cargo ships, tankers, and other types of watercraft were recorded to traverse within 50 NM from TRNP core zone from October 2012 and September 2013, and some were even within the 10 NM buffer zone (IMO 2017). Being vulnerable to damages due to international shipping, TRNP has been designated by IMO as a Particularly Sensitive Sea Area (PSSA) in 2017. As a protective measure, TRNP was declared as an area to be avoided (ATBA) by mariners. The PSSA status of TRNP entered into force on 01 January 2018.

In June 2020, when the park was closed due to the COVID 19 pandemic, oil and grease were at low concentrations (Figure 72). Despite the 96% decline in the number of dive trips to TRNP, the presence of oil and grease was recorded due to the entry of service boats and barge used for the on-going construction of the new ranger station in the North Atoll. Majority (47%) of non-tourism entry permits were issued to the vessels supporting the on-going construction of the ranger station in the North Atoll (TMO 2020a).

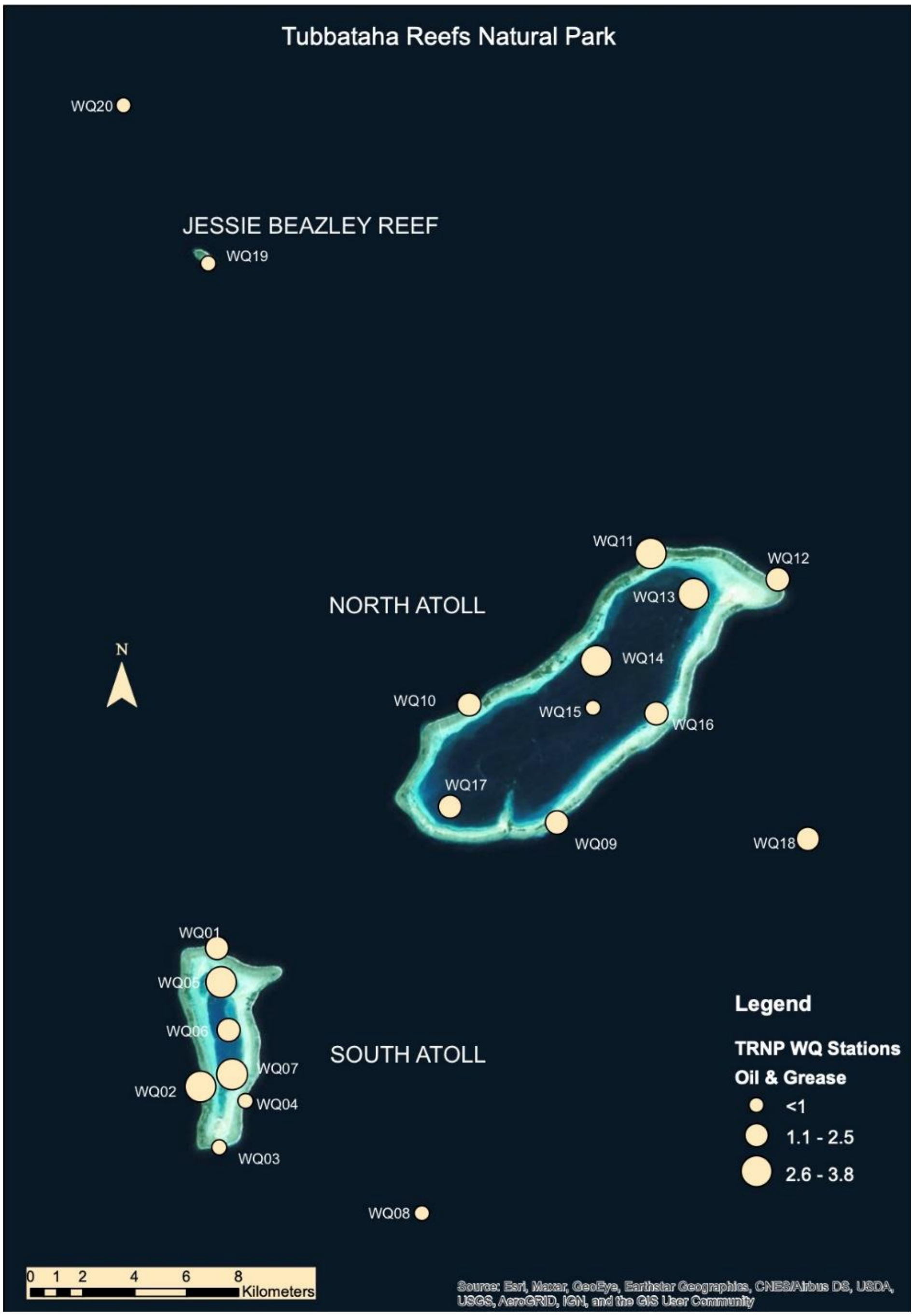


Figure 72. Oil and Grease measured in TRNP water quality monitoring stations in June 2020.

Nutrients – Phosphates and Nitrates

The average concentration of phosphate in TRNP from 2014 to 2020 is 0.46 mg/L. The highest concentration was recorded in Station 1 (South Atoll, outside) at 1.51 mg/L in June 2020, while the lowest concentration, 0.04 mg/L was measured in WQ13 and WQ14 (North Atoll, inside) during the 2016 WQ monitoring. It was noted that the levels of phosphates measured from all stations exceeded the water quality guidelines, with higher concentrations observed in the North Atoll. On the other hand, nitrate levels from all water quality monitoring stations were below the water quality guidelines (Figure 73).

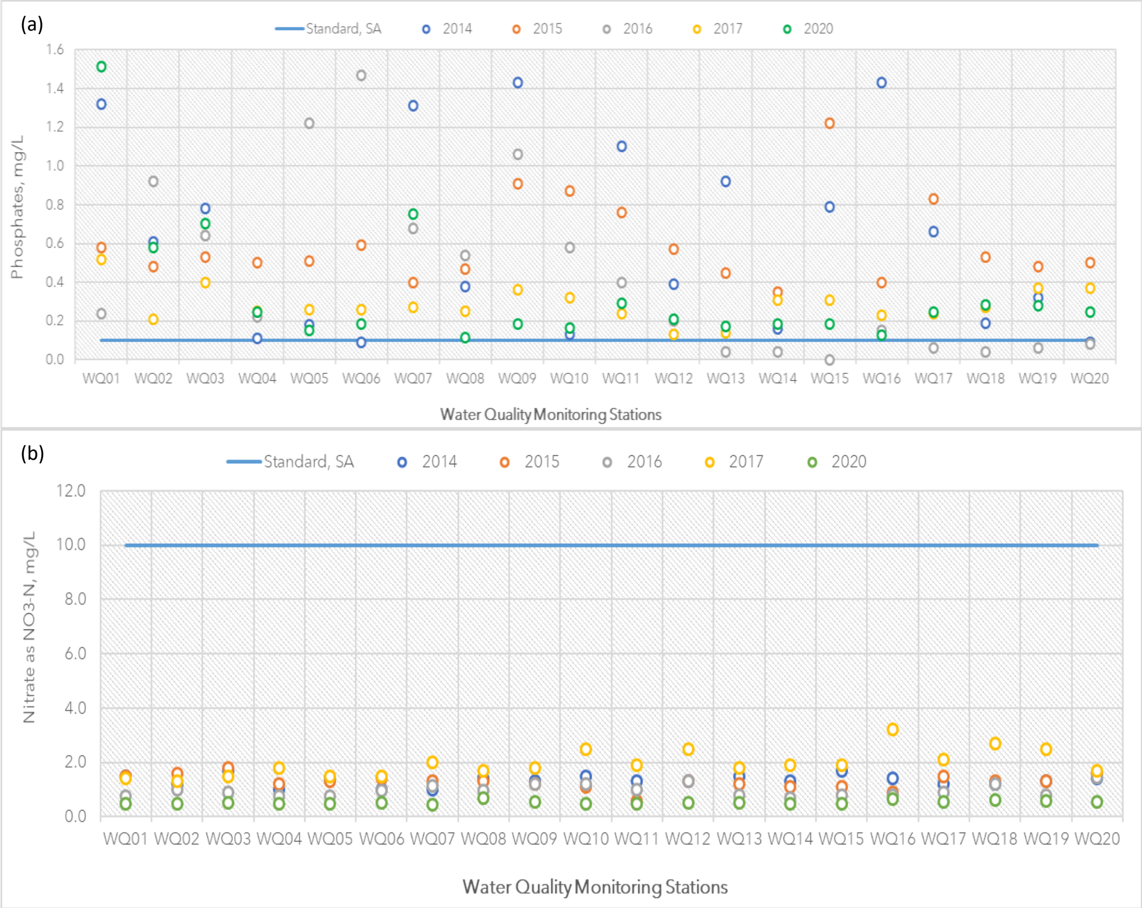


Figure 73. Trends of (a) phosphate and (b) nitrates measured in TRNP water quality monitoring stations from 2014 to 2020.

Phosphorus occurs naturally in the ocean at low concentrations. It is considered as the 'limiting nutrient in the aquatic ecosystem', or a controlling factor in the production of algae and aquatic animals. It also plays a central role in regulating the function of microbial communities. Phosphate is the most common form of phosphorus used by biological organisms. (Lomas *et al.* 2014). Cycling of phosphorus is the slowest of all biogeochemical cycles, thus, introduction through natural deposition from anthropogenic activities tends to stay longer in the natural system. In the form of orthophosphate, it plays a key role in ocean photosynthesis, thus, its availability in marine systems influence the carbon cycle and the sequestration of atmospheric carbon dioxide (Paytan and McLaughlin 2007).

Other analyzed water quality parameters from 2014 to 2017 such as chromium hexavalent and BOD are presented in Annex 24. The concentrations of chromium hexavalent were all way below the water quality guideline for Class SA (0.05 mg/L) of DAO 2016-08. The compound of chromium hexavalent are used as pigments in paints and plastics, and anticorrosive agent added to paints and surface coatings.

High levels of TDS (18,340 mg/L – 36,579 mg/L) and salinity (27.9 ppt to 36.80 ppt) are due to the high amount of dissolved salts in the ocean. Results of these parameters are shown in Appendix 24.

Microbiological Parameters

Total and fecal coliforms are a group of microorganisms used as indicators of bacteria. Their presence in the water indicates the likelihood of having disease-causing pathogens. Since there is a wide array of disease-causing microorganisms in the natural environment, the detection of every pathogenic organism in the water is difficult. It is important to note that indicator bacteria are generally not pathogenic, it only suggests the presence of disease-causing organisms.

Total Coliform

Total coliform consists of a large group of bacteria that may inhabit the intestinal tracts of both humans and animals. They may also be found in water as well as occurring naturally on leaves and in the soil. This group is generally not harmful to humans; thus, the DAO 2016-08 has not prescribed water quality guidelines for total coliform. However, its presence suggests the occurrence of pathogenic organisms, thus, further examination is required.

The highest total coliform concentration was measured at 350 MPN/100 mL in WQ07 (inside South Atoll) in 2015, and the lowest was <1.1 MPN/100 mL in WQ09 (North Atoll), WQ017 (North Atoll, outside), and WQ018 (Buffer zone, adjacent to South Atoll).

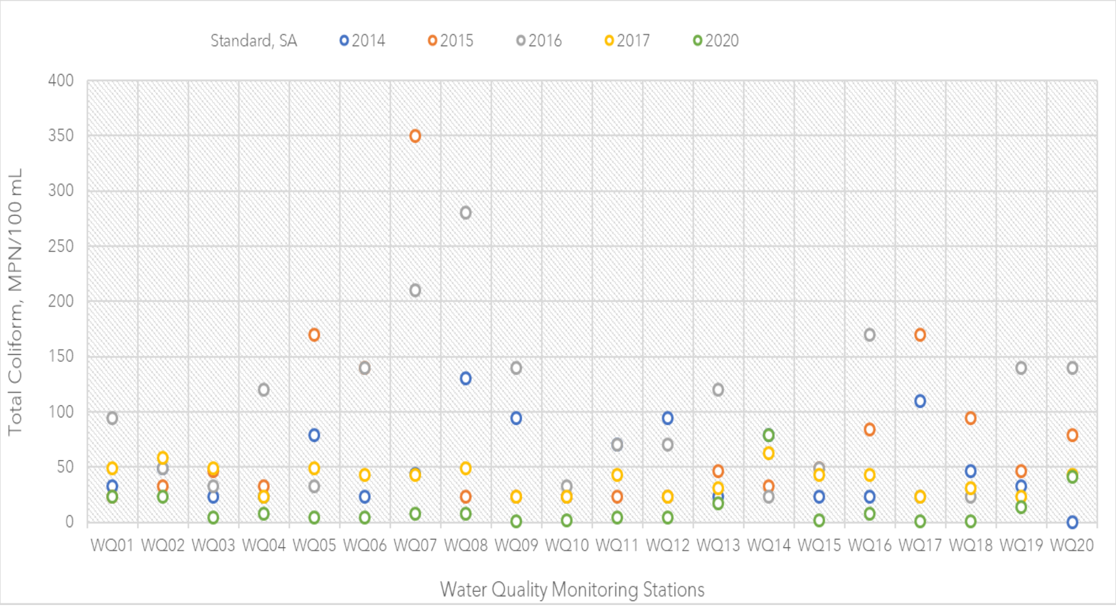


Figure 74. Trends of total coliform in TRNP water quality monitoring stations from 2014 to 2020.

Fecal Coliform

The DAO 2016-08 provides for the marine parks and protected areas (Class SA) to have the fecal coliform level of <1.1 MPN/100 mL (Figure 75). While measured fecal coliform concentration during the dive season in 2015 (20 MPN/100 mL), 2016 (66 MPN/100 mL) and 2017 (30 MPN/100mL) exceeded the Class SA, these concentrations are well below the water quality guideline of 100 MPN/100 mL for marine waters identified as tourist zones, wherein primary contact recreation such as bathing, swimming, skin diving are allowed (Class SB).

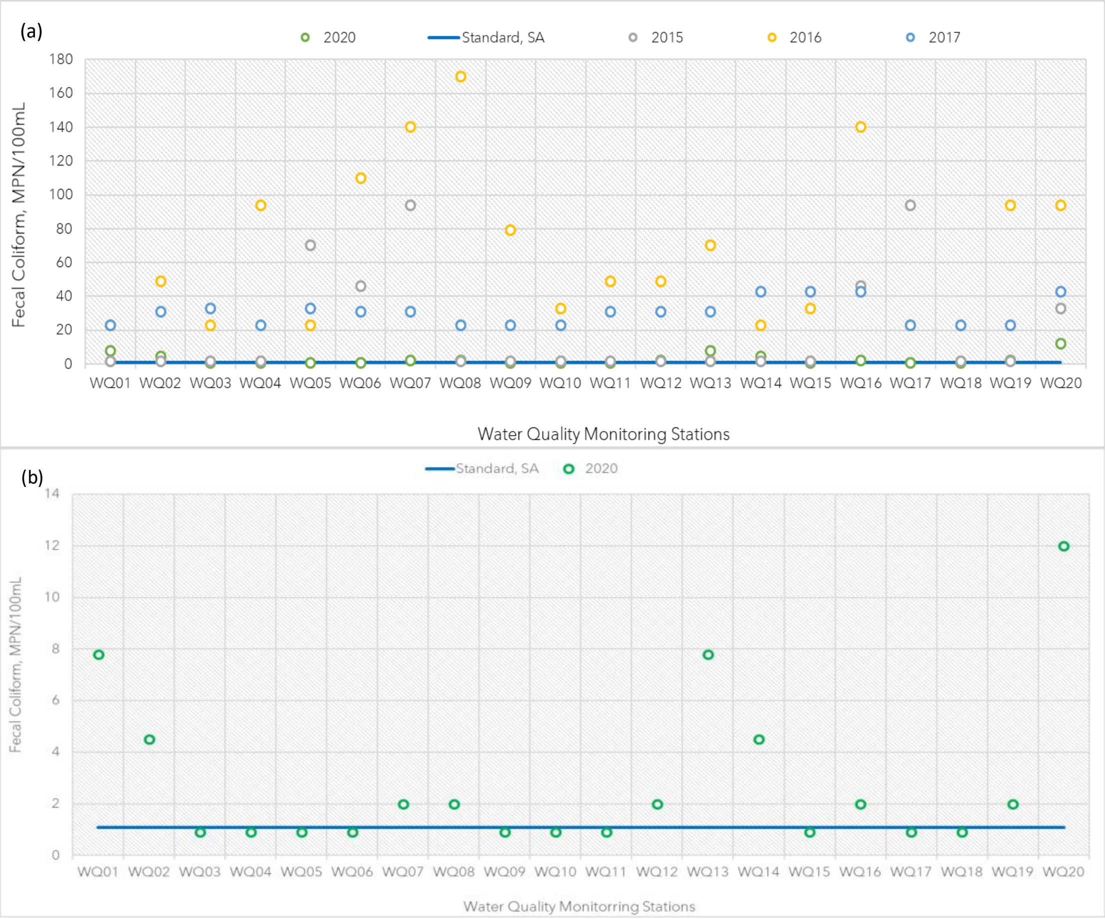


Figure 75. Trends of fecal coliform in TRNP water quality monitoring stations (a) from 2014 to 2020; and (b) results from June 2020 monitoring.

Fecal coliforms belong to a specific subgroup of total coliform, that are associated with the fecal material of warm-blooded animals. Although not pathogenic, fecal coliforms are used as indicator organisms to indicate the presence of other pathogenic bacteria in the water. Indicator organisms are used since it is impractical to monitor the pathogen which is typically present in small amounts.

For the first time since the TRNP opened for tourists and divers, diving and other recreational activities were limited in 2020 due to the pandemic. The fecal coliform levels in June 2020 showed concentrations <1.1 MPN/100 mL measured in 10 water quality stations in TRNP. The lowest average concentration was also measured at 3 MPN/100 mL during this period (Figure 75b and Figure 76).

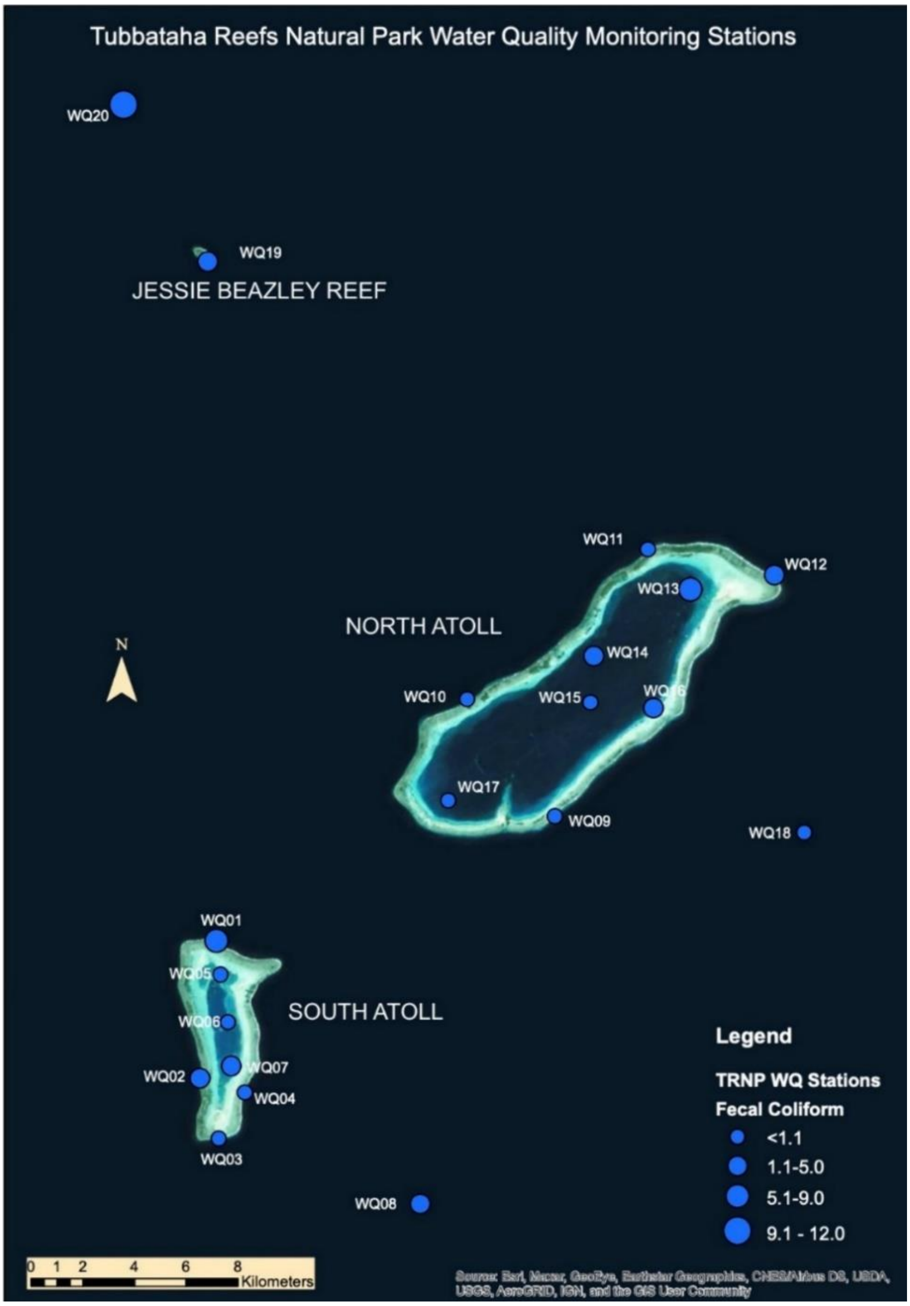


Figure 76. Fecal Coliform measured in TRNP water quality monitoring stations in June 2020.

Fecal coliform has two important fates in seawater, it can either multiply quickly under favorable conditions or die when conditions are not suitable. Cool temperature or long exposure to sunlight may cause a major die-off of fecal coliforms (Marino and Gannon 1991; Davies *et al.* 1995; Karbadeshi *et al.* 2017)

TRNP is a destination of choice for seasoned divers as shown in the increasing number of guests and trips every year, except for the year 2020 (Figure 77) when all outdoor activities were canceled due to the health threats of Covid-19.

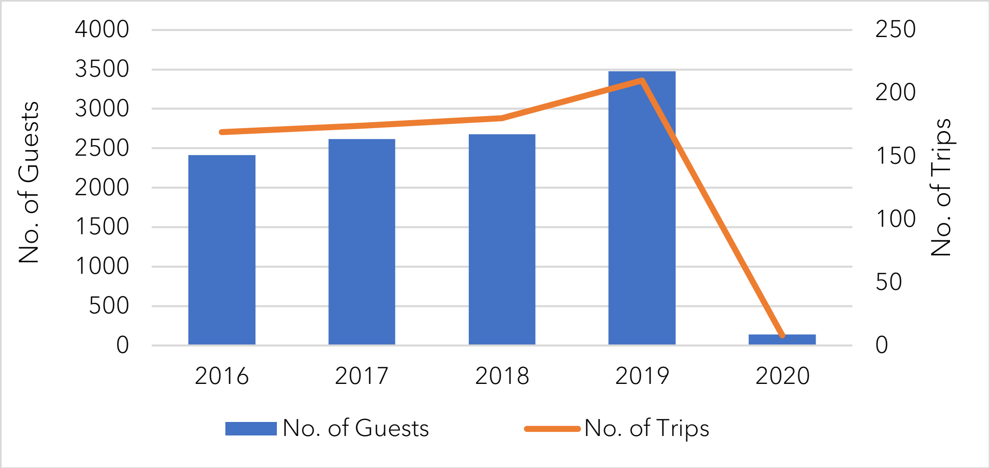


Figure 77. Number of guests and trips to Tubbataha Reefs Natural Park from 2016 to 2020.

With its designation as a PSSA by IMO in 2017, TRNP has been identified as an area to be avoided (ATBA) by mariners since January 2018. It reduces the possibility and risks of chemical and oil spills, as well as ships running aground in TRNP. Majority of the ships traveling along the North-South routes are cargo vessels as shown in Figure 78.

While it is prohibited for any person, entity, and vessel to throw wastes or clean and change the oil of any vessel within the park as stipulated in TRNP Act of 2009 (RA 10067, Sec. 23), solid wastes from outside park boundaries enter through wave action, currents, and prevailing wind speed and direction. Marine park rangers collected marine debris such as plastic containers and product packaging, which increased from 198 Kg in 2010 to 1,460 Kg in 2013 (IMO 2017). Furthermore, wastewater discharged from ships traveling along the North-South routes near TRNP could be brought towards the direction of the park by the strong westward currents (Villanoy *et al.* 2004; Han *et al.* 2009).

In the study conducted by Heij *et al.* (2013) on ship incident risk in TRNP, it was found out that the incident probabilities and monetary value at risk increased from 1997-2007. Similarly, the probability of pollution increased by 60% and the increase in pollution risk is even larger over the years.

Understanding the interaction between atmosphere and ocean is also essential in determining the water quality of TRNP. While pollutants may be carried towards TRNP through wave action, dust and particles are carried through the air.

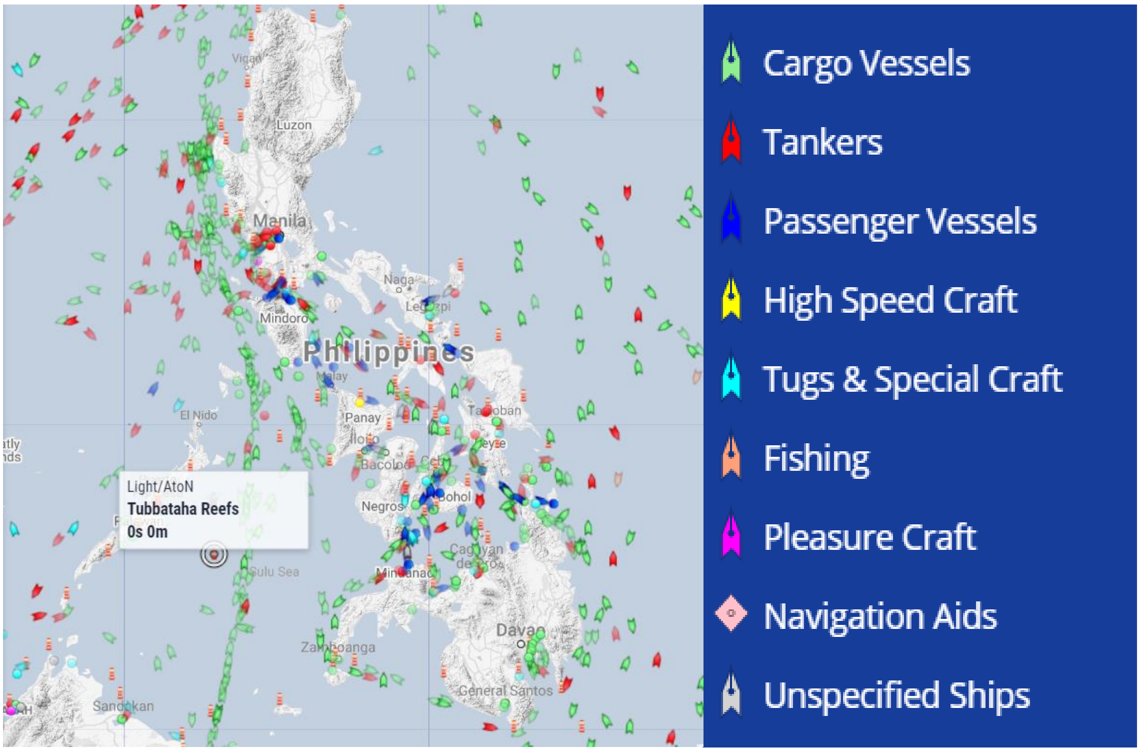


Figure 78. The ships traveling along the north-south routes near Tubbataha Reefs Natural Park on 17 November 2020. https://www.hellenicshippingnews.com/worldwidetraffic/

The atmosphere serves as a significant pathway for the transport of pollutants from natural and anthropogenic activities to the open ocean (Law *et al.* 2013). On a global scale, the atmospheric transport of chemicals to the ocean is a critical source of nutrients, toxins, and acids (Duce *et al.* 2009). Furthermore, the introduction of particles such as mineral aerosols, through atmospheric deposition, has been identified as the dominant source of phosphorus and iron to the open ocean (Baturin 2003; Jickells *et al.* 2005; Mahowald *et al.* 2008, 2009; Krishnamurthy *et al.* 2010; Liss and Johnson 2014), while nitrogen in the global ocean is introduced from the anthropogenic emissions in gaseous form (Duce *et al.* 2008).

Villanoy *et al.* (2014) monitored the wind direction in TRNP, finding that the wind blows from the northeast from November to March, and from the southeast from May to October, thus transporting pollutants via ocean and atmosphere from the Philippines and neighboring countries in the region.

Water bodies have the natural capacity to assimilate and disintegrate pollutants at low concentrations and low rates of addition. The presence of nitrogen and phosphorus in seawater is essential to support the exponential growth of bacteria that degrade crude oil. In the study conducted by Strynar *et al.* (1999), they found that the addition of nitrogen and phosphorus at appropriate concentrations supports the exponential growth of oil-degrading microorganisms in seawater, thus enhancing bioremediation. However, the indiscriminate adding of nutrients should be avoided as excessive nutrients influence the occurrence of algal bloom and disrupt the habitat.

The high temperature in TRNP in June 2020 (30.1 °C to 31.1 °C) was recorded by NOAA for the Coral Triangle. Figure 79 shows the increasing sea surface temperature from March to July 2020. This temperature range was recorded until July 2020.

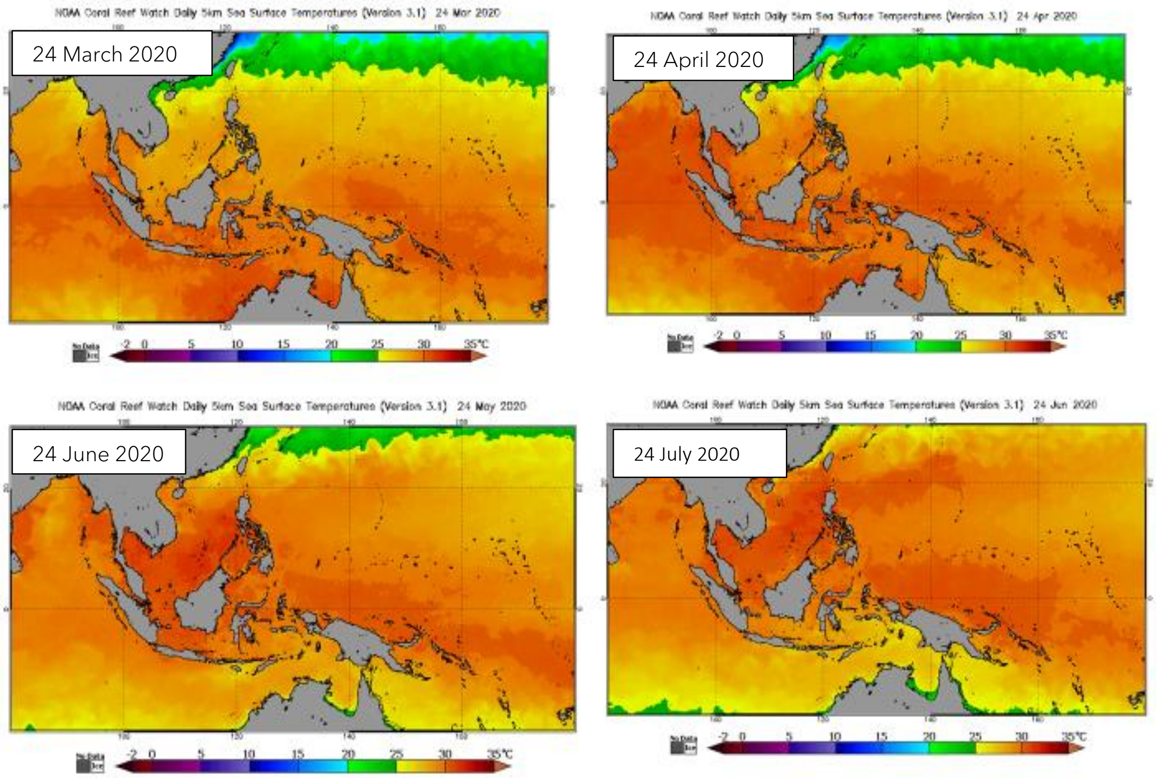


Figure 79. Monthly changes on sea surface temperatures in Coral Triangle and TRNP from 24 March 2020 to 24 July 2020. Field water quality monitoring was conducted on 24 June 2020. (Source: https://coralreefwatch.noaa.gov/index.php)

The increased temperature of seawater is detrimental to marine organisms. Within 10 weeks, the corals exposed to 30-32°C significantly weaken. In the experiment conducted on the corals from the Gulf of Panama, all corals subjected to 32°C died after five weeks, and after nine (9) weeks, the associated crustacean symbionts died (Glynn and D'Croz 1990).

Similarly, coral bleaching was observed and recorded in some areas of TRNP by TMO researchers during the annual monitoring from May to June 2020. Bleached species of fire corals (*Millepora*), massive corals (*Porites*), tabular (*Acropora*), solitary (*Fungia*) were observed in Kook, Delsan Wreck, and Jessie Beazley Reef (TMO 2020b).

The relatively high concentrations of fecal coliform near the Bird and South Islets may be influenced by the guano deposits produced by seabirds. In addition, bird guano may have contributed to the high phosphate and nitrate concentrations in the South Atoll, resulting in eutrophication in the waters inside the lagoon. As a result, high nutrient levels in the water could have an effect on the benthic composition (see Chapter 3). Licuanan and Bahinting (*In press*) suggested that the growth of sponges in the benthos monitoring sites in South Atoll may be related to eutrophication.

Furthermore, while the assimilation and cycling of phosphate in the ocean are influenced by microbial diversity (Lomas *et al.* 2014), the fecal coliform levels are also associated with the sediment particles, thus, it may grow and multiply when nutrients associated with sediments are present (Marino and Gannon 1991; Davies *et al.* 1995; Karbadeshi *et al.* 2017).

Generally, most of the water quality parameters were found to be at low levels in 2020 compared to the previous years (Figure 80), except for phosphate and temperature, which remained to be higher than the water quality guideline.

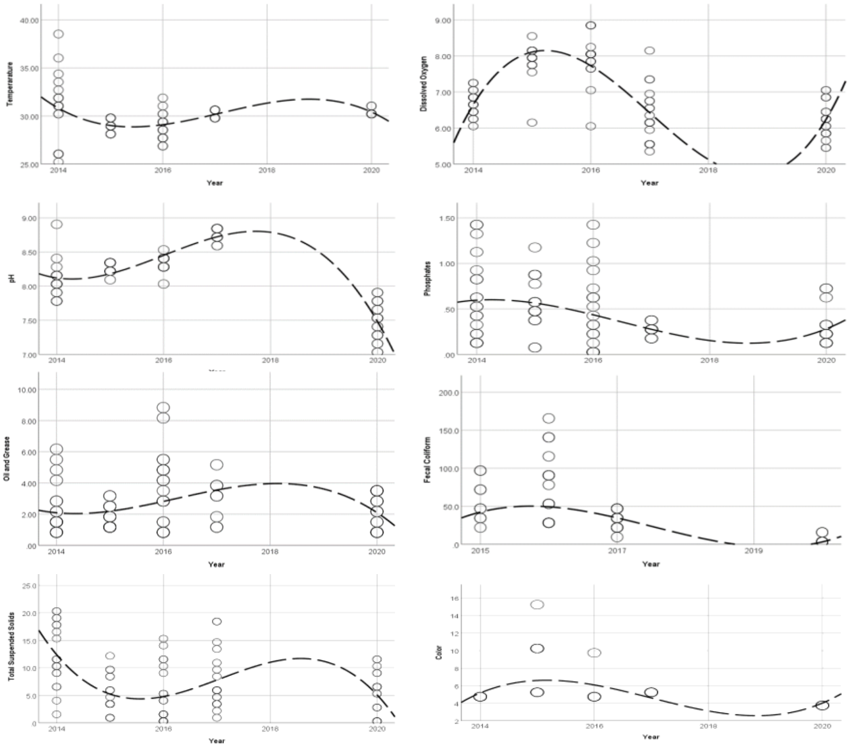


Figure 80. General trends of water quality parameters from 2014 to 2020. Note that water quality monitoring was not conducted in 2018 and 2019.

Most of the water quality parameters improved, compared to the previous years. However, it is too early to conclude that the improvement was influenced by tourism closure. Thus, it will be interesting to determine the water quality of TRNP next year, after a long period of closure from tourism activities.

The adjustments made on the water quality monitoring stations in June 2020, by moving some stations on top of the reefs, will give substantial input to the subsequent ecosystem research and monitoring.

7.4 Conclusion and Recommendations

The water quality of TRNP has been influenced by both anthropogenic and natural factors. While the aesthetic water quality remains excellent (color and total suspended solids), the levels of phosphates, oil, and grease were recorded above the Class SA guideline. Although the fecal coliform exceeded the maximum for Class SA, all concentrations are still below the guidelines for contact recreation such as bathing, swimming, skin diving (Class SB).

While the natural changes in water quality are beyond the control of TMO, there are measures that can be done to reduce, if not eliminate, the impact of anthropogenic activities. The following measures are recommended:

1. Water quality monitoring activity for 2021 should be conducted before the opening of TRNP to tourism and research activities. This will capture the WQ condition of the park after a long period of "closed season";

2. Continuous information dissemination to all visitors and dive boat operators to properly dispose all solid and liquid wastes while in the park;

3. All boats entering the park should have at least enough containment for sullage to ensure non-release of wastewater within the core and buffer zones of the park.

4. The TMO should purchase a multiparameter water quality meter, capable of on-site measurement of primary water quality parameters such as pH, dissolved oxygen, temperature, and salinity. The data that can be accumulated from the monitoring activities at regular intervals can generate relevant information on the trends and changes in water quality in TRNP.

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ANNEXES

Annex 1. Monitoring Teams

SEABIRDS
Angelique Songco, TMO
Noel Bundal, TMO
Jeffrey David, TMO
Segundo Conales Jr, TMO
Cresencio Caranay Jr., TMO
Maria Retchie Pagliawan, TMO
Rowell Alarcon, TMO
Gerlie Gedoria, TMO
Anthea Kristha Valenzuela, TMO
Lyka Mae Irang, TMO
Karl Joriel Amurao, TMO
Ma Theresa Aquiono, Marine Wildlife Watch of the Philippines
Joaquin Philippe Ortega, Volunteer
Nathan Songco, Volunteer
Dany E Lausing, LGU Cagayancillo
Bartolome C Atilano, LGU Cagayancillo
SN2 Bryan R Aldano PN, Naval Forces West
SN1 Zheel John F Oyando PN, Naval Forces West
SN2 Hilario F Olanga Jr PCG, Coast Guard District - Palawan
ASN Louis Jerome L Manga PCG, Coast Guard District - Palawan
ASN Jurace Reginald M Garcia PCG, Coast Guard District - Palawan

REEF FISH
Gerlie Gedoria, TMO
Segundo Conales Jr., TMO
Cresencio P. Caranay Jr., TMO
Rodulf Anthony Balisco, WPU
Nathan Songco, Volunteer

REEF BENTHOS
Maria Retchie Pagliawan, TMO
Rowell Alarcon, TMO
Noel Bundal, TMO
Jeffrey David, TMO
Ace Andrew Niño Acebuque, Volunteer
Ghislaine Songco, Volunteer
J-five Obak, Volunteer

CORAL BLEACHING
Maria Retchie Pagliawan, TMO
Rowell Alarcon, TMO
Noel Bundal, TMO
Jeffrey David, TMO
Gerlie Gedoria, TMO
Cresencio Caranay Jr.
Ace Andrew Niño Acebuque, Volunteer

Annex 2. Fish and Benthos Monitoring Sites

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

Annex 3. Categories for evaluating ecological health of coral reef fish communities according to Hilomen et al. (2000)) and Nañola et al. (2006)

Parameter	Measure	Category
Species Richness (Hilomen *et al.*)	Number of species per 500m²)	
	<16	Very poor
	13.5-23.5	Poor
	24-37	Moderate
	37.5-50	High
	>50	Very High
Density (Hiloment *et al.*)	Number of fish per 500m²)	
	< 100.5 fish	Very Poor
	101-338	Low
	338.5-1,133.5	Moderate
	1134-3,796	High
	> 3,796	Very High
Biomass (Nañola *et al.*.)	g/m²	
	0-10	Very Low to Low
	11-20	Moderate
	21-40	High
	>40	Very High

Annex 4. Mean biomass (grams per m^2) per family per depth in the regular monitoring sites in TRNP

Families	Depth	
	Deep (~10meters)	Shallow (~5 meters)
Acanthuridae	12.79	9.18
Acanthuridae:Nasinae	32.19	5.66
Apogonidae	0.05	0.00
Aulostomidae	0.01	0.01
Balistidae	12.18	15.06
Blenniidae	0.00	0.00
Caesionidae	3.83	0.00
Carangidae	12.67	8.20
Carcharhinidae	0.17	0.00
Chaetodontidae	3.51	1.13
Cirrhitidae	0.23	0.04
Ephippidae	0.00	0.14
Gobiidae	0.00	0.00
Haemulidae	4.63	2.45
Holocentridae	6.72	0.18
Kyphosidae	4.12	1.46
Labridae	3.38	2.61
Lethrinidae	4.43	0.87
Lutjanidae	6.28	1.44
Monacanthidae	0.01	0.01
Mullidae	0.31	0.09
Muraenidae	0.05	0.00
Nemipteridae	0.01	0.00
Ostraciidae	0.02	0.02
Pomacanthidae	1.57	0.79
Pomacentridae	12.13	13.88
Ptereleotridae	0.01	0.02
Scaridae	15.82	11.07
Scombridae	0.57	0.00
Serranidae	5.96	3.63
Serranidae: Anthiinae	3.60	6.61
Siganidae	0.54	0.17
Sphyraenidae	0.00	0.00
Tetraodontidae	0.80	0.11
Zanclidae	0.84	0.48
Grand Total	**149.42**	**85.32**

Annex 5. Mean density (individuals per 500m^2) per family per depth in the regular monitoring sites in TRNP

Families	Depth	
	Deep (~10 meters)	Shallow (~5 meters)
Acanthuridae	63.23	66.80
Acanthuridae:Nasinae	19.83	4.73
Apogonidae	16.80	0.00
Aulostomidae	0.10	0.07
Balistidae	40.97	54.00
Blenniidae	0.10	1.33
Caesionidae	81.13	0.00
Carangidae	6.10	3.90
Carcharhinidae	0.03	0.00
Chaetodontidae	27.13	12.90
Cirrhitidae	1.60	2.77
Ephippidae	0.00	0.07
Gobiidae	0.03	0.00
Haemulidae	1.27	0.67
Holocentridae	29.23	1.60
Kyphosidae	2.13	2.10
Labridae	59.47	152.40
Lethrinidae	13.47	1.13
Lutjanidae	8.77	1.27
Monacanthidae	0.07	0.13
Mullidae	2.73	0.80
Muraenidae	0.03	0.00
Nemipteridae	0.23	0.03
Ostraciidae	0.13	0.20
Pomacanthidae	17.83	11.27
Pomacentridae	728.47	766.13
Ptereleotridae	2.67	4.03
Scaridae	19.53	10.90
Scombridae	0.07	0.00
Serranidae	192.70	29.60
Serranidae: Anthiinae	703.57	180.10
Siganidae	1.07	0.33
Sphyraenidae	0.00	3.33
Tetraodontidae	0.23	0.40
Zanclidae	5.20	2.47
Grand Total	**2045.93**	**1315.47**

Annex 6. Mean biomass per families in the Min Ping Yu (MPY) and USS Guardian (USSG) grounding sites

Families	MPY	USSG
Acanthuridae	10.67	19.65
Acanthuridae:Nasinae	5.74	35.44
Apogonidae	0.00	0.00
Balistidae	2.29	10.76
Caesionidae	1.34	3.54
Carangidae	0.39	3.18
Chaetodontidae	1.85	1.50
Cirrhitidae	0.03	0.06
Ephippidae	0.00	1.10
Gobiidae	0.00	0.00
Haemulidae	0.00	4.04
Holocentridae	2.13	3.20
Labridae	1.78	9.41
Lethrinidae	0.15	1.02
Lutjanidae	0.29	3.03
Monacanthidae	0.35	0.03
Mullidae	0.33	0.01
Nemipteridae	0.03	0.06
Ostraciidae	0.12	0.08
Pomacanthidae	0.35	1.04
Pomacentridae	23.96	8.05
Ptereleotridae	0.02	0.00
Scaridae	7.23	78.36
Serranidae	4.46	4.57
Serranidae: Anthiinae	2.19	1.71
Siganidae	2.46	0.21
Synodontidae	0.03	0.00
Tetraodontidae	0.00	0.03
Zanclidae	5.72	0.24
Grand Total	73.90	190.31

Annex 7. Mean density per families in the Min Ping Yu (MPY) and USS Guardian (USSG) grounding sites

Families	MPY	USSG
Acanthuridae	116.00	77.50
Acanthuridae:Nasinae	2.00	34.00
Apogonidae	0.00	0.33
Balistidae	12.00	84.33
Caesionidae	8.50	18.33
Carangidae	0.50	2.00
Chaetodontidae	24.50	18.33
Cirrhitidae	1.50	1.17
Ephippidae	0.00	0.67
Gobiidae	1.00	0.00
Haemulidae	0.00	1.33
Holocentridae	8.00	7.33
Labridae	97.50	131.17
Lethrinidae	0.50	2.67
Lutjanidae	1.00	3.17
Monacanthidae	3.50	0.17
Mullidae	3.50	0.17
Nemipteridae	1.00	0.33
Ostraciidae	1.00	0.50
Pomacanthidae	14.00	10.17
Pomacentridae	1844.00	632.33
Ptereleotridae	2.00	1.33
Scaridae	22.00	24.00
Serranidae	12.00	18.33
Serranidae: Anthiinae	341.00	481.00
Siganidae	8.00	0.33
Synodontidae	1.00	0.00
Tetraodontidae	0.00	0.33
Zanclidae	17.50	1.50
Grand Total	**2543.50**	**1552.83**

Annex 8. 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)

Annex 9. Recruitment Density at 10 Meter Deep

TAUS CODE	1A	1B	2A	2B	3A	3B	4A	4B	JBA	JBB
ACAN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.83	0.00	0.00
ACB	1.39	1.39	3.47	2.78	3.47	3.47	1.67	8.33	1.67	0.83
ACC	2.08	2.08	1.39	1.39	3.47	0.00	0.83	0.83	0.00	1.67
ACR	0.00	0.00	0.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CAU	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	23.33
COS	1.39	1.39	0.69	3.47	2.78	4.17	4.17	0.83	1.67	0.83
ECHY	0.69	0.69	0.00	0.00	0.69	0.00	0.00	0.83	0.00	0.00
ECHI	1.39	2.78	0.00	0.00	2.78	0.00	1.67	1.67	0.83	0.00
FAV	1.39	0.69	0.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FVI	0.00	0.69	0.69	0.00	0.00	0.00	2.50	0.00	0.00	0.00
CMR	0.00	0.69	0.69	0.00	11.11	2.08	0.00	0.83	0.83	0.83
GAL	4.17	0.69	0.00	0.69	0.00	0.00	2.50	1.67	0.00	0.00
GONIA	1.39	2.08	2.78	0.69	0.00	0.69	11.67	5.83	1.67	0.00
HEL	2.78	6.94	2.78	0.00	0.00	0.00	5.00	0.83	2.50	19.17
HYD	0.69	0.00	0.00	0.00	7.64	1.39	0.83	0.00	0.83	0.00
ISO	0.00	0.00	0.69	0.69	2.08	1.39	5.00	1.67	0.00	0.83
LEPS	0.00	0.00	0.00	0.69	0.00	0.00	0.00	1.67	0.00	0.00
LOB	0.00	1.39	0.69	0.00	0.00	0.00	0.83	0.83	0.00	0.00
MER	0.69	1.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MILL	0.00	2.08	4.17	6.25	0.00	1.39	0.83	2.50	0.83	1.67
MON	0.00	0.69	0.00	1.39	0.00	0.00	2.50	0.00	1.67	0.83
MONTE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.83	0.00
MONTF	0.00	4.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MYC	0.00	0.00	0.00	0.69	0.00	0.00	0.00	0.00	0.00	0.00
OXY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.83	0.00	0.00
PACE	0.00	0.00	1.39	0.00	0.00	0.00	0.00	0.83	0.00	0.00
PACF	0.00	0.00	1.39	0.69	0.00	0.00	0.00	1.67	0.00	0.00
PAV	7.64	6.25	4.17	4.86	21.53	38.19	26.67	23.33	9.17	4.17
PLAT	0.69	0.00	0.00	0.00	0.69	0.00	0.00	0.00	0.00	0.00
POC	6.94	4.17	1.39	2.78	2.08	2.08	10.00	12.50	0.83	3.33
PORB	0.00	0.00	0.00	0.00	0.00	0.69	0.00	0.00	0.00	0.00
PORE	27.08	13.19	11.81	4.17	8.33	11.81	13.33	5.83	18.33	8.33
PORM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.33	0.00
SER	3.47	2.78	1.39	0.00	20.83	18.06	1.67	0.83	0.00	15.00
STY	0.00	0.00	0.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00
STYLO	0.69	0.00	0.69	0.00	0.00	0.00	1.67	3.33	0.83	0.00
SYM	0.00	0.00	0.00	0.00	0.00	0.00	0.83	0.00	0.00	0.00
Grand Total	**64.58**	**56.25**	**42.36**	**31.25**	**87.50**	**85.42**	**78.47**	**65.28**	**38.19**	**67.36**

Annex 10. Recruitment Density at 5 Meter Deep

TAUS CODE	1A	1B	2A	2B	3A	3B	4A	4B	JBA	JBB
MON	0.69	0.69	1.39	3.47	0.00	0.69	0.00	1.39	0.00	0.00
ACB	5.56	4.17	2.08	4.86	11.11	5.56	2.78	0.69	0.00	6.25
ACC	0.69	0.00	0.69	0.00	4.86	9.72	2.08	0.00	1.39	4.17
ACR	0.00	0.00	0.00	0.00	0.69	0.00	0.00	0.00	0.00	0.69
CB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.69
CE	0.69	2.08	0.69	1.39	0.69	0.00	0.00	0.69	0.00	0.00
CMR	0.00	1.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.08
COE	3.47	0.69	2.08	1.39	0.00	0.00	0.69	0.69	0.00	0.00
COS	0.00	0.00	0.00	0.00	1.39	2.08	3.47	1.39	0.00	0.00
CYP	0.00	4.17	0.00	0.00	0.00	0.00	0.69	1.39	0.00	0.69
ECHI	0.00	11.11	0.69	0.00	0.00	0.00	0.00	0.00	2.78	0.00
FAV	0.00	0.00	0.00	0.00	0.00	0.69	0.00	0.69	0.00	0.00
FVI	0.00	0.00	0.69	0.00	0.00	0.00	1.39	0.00	0.00	0.00
GAL	0.69	0.00	0.00	0.00	1.39	0.00	0.69	0.00	0.00	0.00
GONIA	4.17	0.00	2.78	4.17	0.00	1.39	2.08	3.47	0.00	0.69
HEL	0.69	4.86	0.00	2.78	0.00	0.00	0.69	0.00	0.69	2.08
HYD	1.39	4.17	0.00	0.00	31.94	0.69	0.00	0.69	2.08	0.00
ISO	0.00	0.00	7.64	8.33	3.47	22.92	1.39	0.00	1.39	1.39
LEPA	0.00	0.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.69
LEPS	1.39	0.69	2.08	1.39	0.69	0.00	0.69	2.08	0.00	0.00
LOB	0.00	0.00	1.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MER	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.69	0.00	0.00
MILL	6.25	8.33	0.00	2.08	0.69	0.00	0.00	1.39	0.69	2.78
MONTE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.86	0.00
MONTF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	24.31	0.00
OULO	0.00	0.00	0.00	0.69	0.00	0.00	0.00	0.00	0.00	0.00
PAV	8.33	2.78	3.47	11.11	3.47	6.25	4.17	10.42	0.69	0.69
POC	3.47	2.08	3.47	2.78	2.78	0.69	5.56	8.33	0.00	11.81
PORB	0.69	0.69	0.00	0.00	0.00	0.00	0.00	2.08	0.00	1.39
PORE	25.69	2.08	6.25	16.67	0.00	2.78	9.72	8.33	6.25	6.94
PORM	0.69	2.08	4.17	2.08	0.00	0.00	0.69	1.39	0.00	0.00
SER	0.00	0.00	0.00	0.00	4.86	6.94	0.69	1.39	0.69	7.64
STY	0.00	0.69	0.69	0.69	0.69	0.00	0.00	0.00	1.39	0.69
TURB	0.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
UN	0.00	1.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.69
Grand Total	**65.28**	**54.86**	**40.28**	**63.89**	**68.75**	**60.42**	**37.50**	**47.22**	**47.22**	**52.08**

Annex 11. 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 at least on a quarterly basis to the TMO in Puerto Princesa. The TMO is responsible for storing and safeguarding the data.

Annex 12. Inventory and population calculation methods per breeding species

(revised version 2020)

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 between 16.30 to 18.30 pm 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 the nocturnal part of the population. Night counts with flashlight is unfeasible and highly disturbing to the birds.
	Reproduction rate is expressed as the number of active but empty nests, and nest with eggs, pulli, and juvenile birds. For the immature population, the result of the in-flight count between 16.30 to 18.30pm is added to the number of immature birds counted during day time.
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 between 16.30 to 18.30 pm 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, if less than 100 birds, is not included in the calculation of the total population of the species. If the number is higher, it is included in the calculation.
	Reproduction rate is expressed as the number of active empty nests and nests with eggs, pulli, and juveniles. For the immature population, the result of the in-flight count between 16.30 to 18.30pm is added to the number of immature birds counted during day time.
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 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, indicates the possible breeding population. Nests are difficult to find. If a 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 three data sets are used to determine the population at this islet: a) the number of nests found compared to the number of adult birds counted next to the nests, b) the number of birds roosting along the shoreline and on the wreck and c) the in-flight result from between 16.30 to 18.30 pm. The in-flight result is the difference of birds flying in to the islet and the number of birds leaving the islet. 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 active empty nests, and nests with eggs, pulli and juveniles found during the inventory. Identification of immature birds (living in their second calendar year or more) is not possible as they look similar to adults.
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 three data sets are used to determine the population at this islet: a) the number of nests found compared to the number of adult birds counted next to the nests, b) the number of birds roosting along the shoreline and on the wreck and c) the in-flight results. The in-flight result from between 16.30 to 18.30 pm is the difference of birds flying in to the islet and the number of birds leaving the islet. 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 empty nests and the number of nests with eggs, pulli and juveniles found during the inventory. Identification of immature birds (living in their second calendar year or more) 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-documented 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, eggs and pulli and juveniles 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, pulli and juveniles found. Identification of immature birds (living in their second calendar year or more) is not possible as they look similar to adults.
Sooty Tern	Population size is expressed as the number of eggs, 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 estimates of birds termaling the sky and a quick evening estimate 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-documented 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, pulli and juveniles found during the inventory. Identification of immature birds (living in their second calendar year or more) is not possible as they look similar to adults.

Annex 13. Condition of vegetation on Bird Islet and South Islet.

Condition of vegetation on Bird Islet, May 2006 (baseline year), 2016 and 2019 to 2020

Trees/ Condition	Good (optimal)				Fair (moderately deteriorating)				Bad (severely deteriorating)				Total (live trees)				Dead trees			
	2006	2016	2019	2020	2006	2016	2019	2020	2006	2016	2019	2020	2006	2016	2019	2020	2006	2016	2018	2019
Dead trees																	82	75	ND	
Mature, live trees (> 3 feet)	10	1	0	0	49	4	2	0	11	16	0	0	70	21	2	0				
Small, live trees (2- 3 feet)	109	33	0	3	0	24	3	0	0	7	0	0	109	64	0	3				
Seedlings (< 1 feet)	50	14	12 *)	0	0	9	0	0	0	2	0	0	50	25	12	0				
Total	**169**	**48**	**12**	**3**	**49**	**37**	**3**	**0**	**11**	**25**	**20**	**0**	**229**	**110**	**14**	**3**	**82**	**75**	ND	ND
Note	*) Seedlings 2019 = planted saplings > 1 feet tall taken from Cagayancillo Municipality. In June 2020 329 Anuling saplings were planted. Coco Palms 2018: 3, 2019: 2, 2020: 0																			

Condition of vegetation on South Islet May 2011 (baseline year), 2016 and 2019 to 2020

Trees/ Condition	Good (optimal)				Fair (moderately deteriorating)				Bad (severely deteriorating)				Total (live trees)				Dead			
	2011	2016	2019	2020	2011	2016	2019	2020	2011	2016	2019	2020	2011	2016	2019	2020	2011	2016	2018	2019
Dead trees																	6	16	ND	ND
Mature, live trees (> 3 feet)	70	0	0	0	28	20	0	0	5	40	5	0	103	60	5	0				
Small, live trees (2- 3 feet)	2	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0				
Seedlings (< 1 feet)	19	0	0	0	0	0	0	0	0	0	0	0	19	0	0	0				
Total	91	0	0	0	28	20	0	0	5	40	5	0	124	60	5	0	6	16	ND	ND
Notes:	In June 2020 101 Anuling saplings > 1 feet tall were planted Coco Palms 2011: 13, 2016: 6, 2017:6, 2018:10, 2019:6, 2020:7																			

Annex 14. Results of Park Rangers' inventory counts, August and November 2019 and February 2020 at Bird Islet and South Islet

Bird Islet	2019				2020
Species/Date	15 August	13 November			16 February
Brown Noddy	Day Count	Day Count	In-flight	Total	Day Count
Adult	538	1732		1732	761
Juveniles	19	0		0	0
Pullus/juvenile	0	0		0	51
Eggs	6	174		174	188
Nests, empty	210	No data		No data	No data
Nests, Total	235	129		129	302
Black Noddy					
Adult	1329	1777		1777	994
Juveniles	2	0		0	17
Pullus/juvenile	21	0		0	46
Eggs	17	31		31	196
Nests, empty	204	133		133	108
Nests, Total	244	164		164	367
Great Crested Tern					
Adult	508	0		0	410
Juveniles	67	0		0	0
Pullus/ juvenile	0	0		0	0
Eggs	0	0		0	0
Sooty Tern					
Adult	2898	0		0	3760
Juveniles	0	65		65	0
Pullus/juvenile	622	0		0	0
Eggs	2175	0		0	3629
Masked Booby					
Adult	1	2		1	1
Red-footed Booby					
Adult	232	230	135	365	163
Sub-adult	6	4	21	25	0
Pullus/ juvenile	0	18		18	13
Eggs	27	15		15	22
Nests, empty	15	33		31	0
Nests, Total	42	64		64	35
Brown Booby					
Adult	1474	1206	1074	2280	280
Sub-adult	19	19	31	50	156
Pullus/ juvenile	58	1103		1103	40
Eggs	1009	242		242	17
Nests, empty	No data	No data		No data	200?
Nests, Total	880	1247		1247	257

South Islet	2019		2020
Species/Date	14 August	10 November	14 February
	Day Count	Day Count	Day Count
Brown Noddy			
Adult	450	0	0
Sub-adult	0	0	0
Pullus/ juvenile	0	6	0
Eggs	0	8	0
Nests	0	14	0
Nests, Total	0	14	0
Black Noddy			
Adult	272	1	0
Sub-adult	0	0	0
Pullus/juvenile	0	0	0
Eggs	0	0	0
Nests, empty	0	1	0
Nests, Total	0	1	0
Great Crested Tern			
Adult	0	0	0
Sub-adult	0	0	0
Pullus/juvenile	0	0	0
Eggs	0	0	0
Sooty Tern			
Adult	0	0	0
Sub-adult	0	0	0
Pullus/ juvenile	0	0	0
Eggs	0	0	0
Red-footed Booby			
Adult	14	180	50
Sub-adult	0	5	0
Pullus/ juvenile	0	0	0
Eggs	0	0	0
Nests, empty	0	0	0
Nests, Total	0	18	25
Brown Booby			
Adult	0	0	6
Sub-adult	0	0	0
Pullus/ juvenile	0	0	0
Eggs	0	0	0
Nests, empty			
Nests, Total	0	0	0

Annex 15. Population results and population trend of breeding seabirds in TRNP April to June 1981 – 2020

Inventory baseline years are underlined. Source: Kennedy 1982, Manamtam 1996, WWF Philippines 1998-2004 and TMO 2004-2020

Species/ Numbers	1981	1995	1998	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
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	9,721
Masked Booby	150	1	0	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	1,018
Brown Noddy	2,136	643	0	500	37	775	115	336	590	1,035	530	800	1,570
Great Crested Tern	2,264	335	0	150	414	4,160	2,064	2,808	7,858	6,894	4,700	4,875	4,433
Sooty Tern	5,070	1) 910	28	3,000	6,228	2,123	2	1,200	3,500	7,920	>1,500	3,800	2,700
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	9,525
Red-Footed Booby	9	0	0	2	44	43	20	2,435	1,947	1,877	2,902	2,513	2,220
Black Noddy	147	7,128	3,250	3,500	6,998	4,860	1,610	805	6,406	6,850	> 5,000	7,890	> 7,305
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	19,246

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.
5) 7,258 individuals based on Park Rangers egg count 16 Feb 2020

Species/ Numbers	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Trend (%)
Ground-breeders												
Sub-total	18,669	13,592	18,383	15,988	16,448	27,193	27,654	29,940	35,878	24,569	29,323	+ 119
Masked Booby	0	0	0	0	0	0	1	1	1	1	2	
Brown Booby	1,438	1,846	1,879	1,690	1,632	2,403	3,122	3,535	3,367	3,138	>2,977	- 21
Brown Noddy	1,575	2,042	1,492	1,688	1,862	2,583	2,096	4,209	3,470	2,208	3,262	+ 53
Great Crested Tern	4,790	6,160	8,653	9,794	2) 7,730	<12,387	3,880	17,097	17,752	14,880	17,810	+ 8250
Sooty Tern	10,866	3,544	6,359	2,816	3) 5,224	4) 9,820	8,555	>5,098	11,288	4,342	5)> 5,272	+ 4
Tree-breeders												
Sub-total	9,975	10,746	11,776	12,858	10,630	11,718	11,101	7,278	5,916	3,152	3,310	+ 2025
Red-Footed Booby	2,331	2,395	2,340	2,202	3,074	3,492	2,141	2,087	1,443	1,080	660	- 73
Black Noddy	7,644	8,351	9,436	10,656	7,556	8,226	8,716	5,191	4,473	2,072	2,650	- 63
TOTAL	28,644	24,338	30,159	28,846	27,078	38,911	38,549	37,218	41,794	27,721	32,633	+ 141

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.
5) 7,258 individuals based on Park Rangers egg count 16 Feb 2020.

Annex 16. Seabird breeding data from Bird Islet and from South Islet, 2nd Quarter (mainly May) 2004-2020

Species/Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Red-footed Booby																	
Immatures	398	1,455	606	597	780	477	677	795	799	426	134	206	80	97	89	104	24
Pulli/1st year juv.	> 35	71	105	116	69	180	88	171	243	312	277	240	49	43	39	14	8
Eggs	+	+	+	+	+	+	+	68	>166	>185	>57	>46	> 49	55	74	26	>7
Nests	279	217	225	404	361	367	451	369	739	848	431	379	315	177	223	72	43
Brown Booby																	Note 1
Immatures	0	81	26	55	55	61	126	110	140	62	51	28	66	157	264	218	35
Pulli/1st year juv.	43	2	7	12	91	126	125	225	46	28	266	200	22	175	95	8	8
Eggs	1	0	18	95	317	48	106	52	69	532	466	55	144	43	25	6	286
Nests	117	43	250	89	497	453	513	575	507	618	816	726	887	886	376	412	1,054
Brown Noddy																	Note 2
Immatures	0	2	0	0	0	4	1	1	2	3	5	2	0	2	14	9	0
Pulli/1st year juv.	0	0	0	0	0	0	0	0	0	0	0	6	109	223	493	68	79
Eggs	0	0	0	3	17	126	438	253	>147	>607	679	571	620	1,005	581	183	615
Nests	115	124	20+	25+	218	384	653	571	709	771	931	960	1,048	1,917	1,644	805	1092
Black Noddy																	Note 3
Immatures	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	o
Pulli/1st year juv.	0	0	0	0	0	0	0	0	0	0	0	30	193	8	74	39	40
Eggs	ND	+	0	+	+	430	+	+	>80	>700	>351	>299	>191	406	468	254	269
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	1036	1,135
Great Crested Tern																	Note 4
Immatures	0	1	0	0	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	2610	6,813
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	4830	1,568

Sooty Tern																	<u>Note 5</u>
Immatures	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	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	11	2,622
Eggs	9	0	0	63	2	3	5,515	2	1,534	146	37	52	166	0	4,964	3	14

Source: WWF Philippines 2004 and TMO 2004 to 2020

<u>Note 1:</u> MPRs counted 16 Feb 2020 40 pulli/juv, 17 eggs and 257 nests; on 13 Aug 3 juveniles, 630 pulli, 1,213 eggs and 1,1,700 nest
<u>Note 2:</u> MPRs counted 16 Feb 2020 51 pulli/juv, 188 eggs and 302 nests; on 13 Aug 254 pulli/juv, 70 eggs and 1020 nests
<u>Note 3:</u> MPRs counted 16 Feb 2020 46 pulli/juv, 196 eggs and 367 nests; on 13 Aug 60 pulli/juv, 82 eggs and 356 nests
<u>Note 4:</u> MPRs counted on 13 Aug 124 pulli/juv
<u>Note 5:</u> a) MPRs counted 16 Feb 2019 3,627 eggs; on 13 Aug 0 pulli/juv and 0 eggs
<u>Note 5:</u> b) 19 -20 May, juveniles and pulli with feathers, c). Many airborne juveniles could not be counted

Annex 17. In-flight to roost statistics of boobies and noddies on Bird Islet May 2005 to May 2020

Species/ Numbers	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
	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 – 18.30	May 14: 16.30 – 18.30	May15: 16.30 – 18.30	May 19: 16.30 – 18.30
	Red-footed Booby															
Adult: Daytime	823	655	631	1,241	686	982	1,011	382	830	950	1,499	248	343	470	362	131
In-flight	960	1,171	2,082	1,272	1,534	1,259	1,259	1,680	779	813	602	367	527	356	282	309
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	644	430
%-in-flight population	55%	65%	78%	51%	69%	56%	55%	81%	48%	46%	29%	25%	25%	43%	44%	72%
Average In-flight (%)	52.6%															
Immature: Daytime	514	>205	275	239	179	194	106	174	125	61	111	8	29	24	27	5
In-flight	588	401	295	541	298	483	483	249	149	5	37	17	40	20	34	16
Adjusted to 2-hour period	941	419	322	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	1,455	>606	597	780	477	677	589	423	274	66	148	25	69	44	61	21
%-in-flight population	65%	69%	54%	69%	63%	71%	82%	59%	54%	8%	25%	25%	25%	45%	56%	76%
Average In-flight (%)	52.9%															
	Brown Booby															
Adult: Daytime	629	405	660	691	650	930	1,338	1,060	968	834	1,505	1,920	2,257	1,295	2,212	888
In-flight	360	225	326	368	368	508	508	819	722	798	848	1,202	1,278	2,072	727	1,640
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	2,939	2,528

%-in-flight population	48%	37%	35%	35%	36%	35%	28%	44%	43%	49%	36%	25%	25%	62%	25%	65%
Average In-flight (%)	39.3%															
Immature: Daytime	22	20	21	20+?	22	30+	96	81	30	13	1	25	74	127	187	16
In-flight	37	6	31	34	39	96	14	59	32	39	25	41	78	105	30	19
Adjusted to 2-hour period	59	6	34	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	81	26	55	54	61	126	110	140	64	51	26	66	152	232	217	35
%-in-flight population	73%	23%	62%	63%	64%	76%	13%	42%	50%	76%	96%	62%	51%	45%	14%	26%
Average In-flight (%)	52.3%															
	Brown Noddy															
Adult: Daytime							618	607	1,004	1,045	1,031	992	2,953			
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			
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%															

Annex 18. In-flight to roost statistics of boobies and noddies on South Islet May 2014 to 2020

Species/ Numbers	2014	2015	2016	2017	2018	2019	2020	2014	2015	2016	2017	2018	2019	2020
	Red-footed Booby							Brown Booby						
	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 15: 16.30 - 18.30	May 21: 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 15: 16.30 - 18.30	May 21: 16.30 - 18.30
Adult: Daytime	401	366	508	584	262	154	32	7	22	40	31	160	41	73
In-flight	910	1,020	1,018	633	355	282	198	2	28	24	11	144	158	376
Adjusted to 2-hour period	1,820	-	-	-	-	-	-	4	-	-	-	-	-	-
Total	2,221	1,386	1,526	1,217	617	436	230	11	50	64	42	304	199	449
% in-flight population	82.0	73.6	66.7	52.0	57.5	64.7	86.1	18.2	56.0	37.5	26.2	47.4	79.4	83.7
Average	68.9							49.8						
Immature: Daytime	68	58	32	27	22	43	5	0	2	0	4	32	1	16
In-flight	1	No count	21	1	23	27	4	0	No count	No count	1	0	4	16
Adjusted to 2-hour period	2	-	-	-	-	-	-	0	-	-	-	-	-	-
Total	70	> 58	63	28	45	70	9	0	>2	0	5	32	5	32
% in-flight population	2.9%	-	33.3%	3.6%	51.1%	38.6	44.4	0	-	-	20.0	0	80.o	50.0
Average	29.0							30.0						

Year	2015	2016	2017	2018	2019	2020
Species	Black & Brown Noddy					
	(Note 1)	(Note2)	(Note 3)		(Note 4)	(Note 5)
	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 15: 16.30 - 18.30	May 21: 16.30 - 18.30
Adult: Daytime	6,856	> 4,421	4,126	2,179	0	-
In-flight	4,678	> 3,500	< 2,066	1,335	0	-
Adjusted to 2-hour period	4,678	-	-	-	-	-
Total	11,534	7,921	6,192	3,514	0	-
% in-flight population	40.6	44.2	33.4	38.0	-	-
Average	39.1					
	Black Noddy					
Adult: Daytime			2,921	1,347	0	427
In-flight			1,461	681	0	249
Adjusted to 2-hour period			-	-	-	-
Total			4,382	2,028	0	676
% in-flight population			33.3	33.6	0	36.8
Average	34.6					
	Brown Noddy					
Adult: Daytime			1,205	832	60	948
In-flight			605	654	19	171
Adjusted 2-hour period			-	-	-	-
Total			1,810	1,486	79	1,119
% in-flight population			33.4	44.0	24.0	15.3
Average	29.2					

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 in-flight

Note 4: 101 birds did not settle for landing as a results of ongoing construction and reclamation works

Note 5: Black Noddy: flying in to islet 421, flying out 172. Brown Noddy: flying in to islet 464, flying out 293

Annex 19. Systematic list of avifaunal records from South Islet, Bird Islet, and Ranger Station, Tubbataha Reefs Natural Park from 18 to 21 May 2020

Breeding species are indicated in bold letters. Taxonomic treatment and sequence follows IOC/Wild Bird Club of the Philippines 2020. Threat status follows DENR Administrative Order No 2019 – 09. Updated National List of Threatened Philippine Fauna and Their Categories

CR – Critically Endangered, EN – Endangered, VU – Vulnerable, NT -Near Threatened, LC – Least Concern

Status and Abundance (within Sulu Sea) Threat Status (IUCN and National Red List)	Species name	Number of individuals	Locality	Notes
Resident Common LC	Barred Rail *Gallirallus torquatus*	5	Bird Islet	No nests found
Migrant Fairly common LC	Ruddy Turnstone *Arenaria interpres*	7	Bird Islet	
Resident Locally Rare VU	**Brown Noddy** *Anous stolidus*	Adults: 2,134 Imm: - Pullus: 64 Nests: 528 Eggs: 107	Bird Islet	No data on sub-adults. Empty nests may be undercounted as they are difficult to identify
		Adults: 1,128 Immatures: - Pullus: 15 Nests: 564 Eggs: 508	South Islet	No data on sub-adults
Resident Locally Rare EN	**Black Noddy** *Anous minutus*	Adults: 1,128 Pullus: 40 Nests: 987 Eggs: 208	Bird Islet	Adults per nest count. All breeding birds were found on the artificial breeding structures
		Adults: 676 Pullus: 0 Nests: 148 Eggs: 61	South Islet	All nest except one placed in the breeding structurers. Number of nests placed on ground = 1
Resident Fairly Common VU	**Great Crested Tern** *Thalasseus bergii*	Adults: 17,762 Pullus: 6,863 Eggs: 1,568	Bird Islet	Number of adults based on eggs and pulli. Highest number ever recorded. 3,297 adults counted. High number of pulli indicate early breeding start

		Adults: 1,048 Pullus: 2 Eggs: 523	South Islet	Adult numbers based on nest count. Actually counted = 868 adults. First breeding since 2003. New larger sand habitat makes breeding more possible
Resident Locally Rare VU	**Sooty Tern** *Onychoprion fuscata*	Adults: 5,272 Pullus: 0 Juv: 2,622 Eggs: 14	Bird Islet	Started breeding in January 2020 (16 Feb 3,629 eggs = 7,258 adults). Many fledged juveniles were in the sky above or adjacent to the islet and could not be counted
		Adults: 0	South Islet	Not breeding
Migrant Rare Accidental	White-tailed Tropicbird *Phaethon leptura*	Adults: 1	Bird Islet	4th TRNP record
Migrant Rare Accidental	Short-tailed Shearwater *Ardenna tenuirostris*	Adults: 1	Caught SE of Ranger Station	New record for TRNP; 4th Philippine record. Caught on 9 May, died on 14 May
Migrant Locally uncommon LC	Great Frigatebird *Fregata minor*	Adults: 0 Juvenile: 1	Bird Islet	
		Adults: 0 Juvenile: 1-2	South Islet	
Migrant Locally uncommon LC	Lesser Frigatebird *Fregata ariel*	Adults: 0 Juvenile: 3	South Islet	
	Unidentified Frigatebirds *Fregata sp*	2	Bird Islet	
		0	South Islet	
Rare CE	**Masked Booby** *Sula dactylatra*	Adult: 2	Bird Islet	Male and female with a nest. Laid eggs after the inventory period; two eggs observed 12 June. Only one egg remained on 1 July and the second egg disappeared around 13 July. On 13 August a new egg was observed and 17 August two eggs.
Resident Locally uncommon	**Red-footed Booby** *Sula sula*	Adults: 430 Immatures: 21	Bird Islet	Minimum number of adults. Morning

LC		Pulli/juv.: 3 Nests: 40 Eggs: >6		counts + in-flights = Max. 583 Nests of 24 pairs breeding on the structures for Black Noddy were removed
		Adults: 230 Immatures: 4 Pulli/juv.: 5 Nests: 3 Eggs: 1	South Islet	Nests of 2 pairs breeding on the structures for Black Noddy were removed
Resident Rare EN	**Brown Booby** *Sula leucogaster*	Adults: 2,528 Immatures: 35 Pulli/juv.: 8 Nests: 1,054 Eggs: 286	Bird Islet	4,012 estimate of adults at dawn. Relative high number of nests and eggs
		Adults: 449 Immatures: 32	South Islet	No breeding despite very high number of adults and perfect breeding habitat
Migratory, Resident Fairly Common LC	**Striated Heron** *Butorides striata*	1	Ranger Station	
Migratory Rare VU	Chinese Egret *Egretta eulophotes*	1	Bird Islet	
Resident Uncommon LC	**Pacific Reef Heron** *Egretta sacra*	Adults: > 2 Nests: 0	Bird Islet	Dark phase. One nest with two pulli found after the inventory period (Sept. 2020)
		Adults: 2 Nests: 0	South Islet	Dark phase
Resident Common LC	**Eurasian Tree Sparrow** *Passer montanus*	0	Bird Islet	First time since 2015 without the species present
		0	South Islet	First time since 2016 without the species present
		1	Ranger Station	
Migrant Uncommon LC	Petchora Pipit *Anthus gustavi*	1	Bird Islet	

Annex 20. Necropsy report on dead boobies on Bird Islet

By: Ma. Theresa Aquino, DVM

Plate 1. Some of the seabird mortalities encountered during the 2020 seabird survey in Bird Islet.

Several mortalities were observed but the condition that most specimens were in, i.e., destroyed, in advanced decomposition or desiccated (Plate 1) negated the possibility of examination. Only one mortality was fresh and whole enough to warrant necropsy. This involved an adult male brown booby with a long, almost straight linear abrasion extending from the front of the left wing cutting diagonally across the back down to just above the right hip. The wound appeared to be old and necrotic but only skin-deep (Plate 2). It appeared to have been caused by a thin, dull object pressing or rubbing on skin, possibly a stick, a fine rope or a fishing line. However, no such object was found on the animal when the carcass was retrieved. A small number of arthropods (several lice and one tick) were found on the chest area which have been collected and submitted for proper identification. Internal examination did not reveal any notable lesion except an empty stomach. It is highly possible that the animal got entangled and was thus unable to feed, likely dying of hunger and exposure. The wound from the entanglement was not severe enough to have caused the death directly.

Plate 2. Long abrasion seen on the back of the animal extending from the top of the left wing to the right hip.

In another case involving a live brown booby, the animal was observed exhibiting an abnormal beak. The animal was first noticed sitting on a nest located at the fringes of the plaza (Plate 3). The animal was suspected to have been protecting an egg or a newly hatched pullus at the time since it did not leave when we approached the nest. However, about two months after the seabird survey, the rangers reported seeing the individual perched on a piece of driftwood and did not appear to be with a partner or an offspring.


Plate 3. Possible case of vitamin/mineral deficiency in a female brown booby.

As can be noted in the picture, the beak does not appear to be fully calcified, suggesting a mineral (possibly calcium or even selenium and zinc) or vitamin deficiency (vitamin D or E). The cause of the abnormality can only be speculated upon given limited information. If the animal had been breeding, the abnormality could have been triggered by the high calcium demand during egg shell production thus exacerbating the deficiency. The condition may also suggest that the animal may have suffered malnutrition at some stage of its life. Given that the animal spends part of its life away from Bird Islet, it would be difficult to say where it may have suffered from poor nutrition. Only one individual has been observed to exhibit this abnormality so far but it would behoove management to be on the lookout for other possible cases from here on.

Annex 21. Comparison of the landscape and habitats seen from the Permanent Photo Documentation Sites on Bird Islet and South Islet, May 2004 and May 2020

Bird Islet:

Viewing angle for photo: facing NW 180°
Date: May 7, 2004

Comments: panoramic view
Photo no (camera): 4 shots

Photo Doc Site NI No. 01 - 2004

Photo name code: B1 01
Photo nos.: DSC_2367-72

Comments: 6 shots (Stitched by Microsoft ICE)
Photo credit: Teri Aquino

Date: 20 May, 2020

Photo Doc Site NI No. 01 - 2020

Viewing angle for photo: facing NE 038°

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_2352-53

Comments: 2 shots
Date: 20 May, 2020

Photo Doc Site NI No. 02 - 2020

Viewing angle for photo: facing S 165° 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: 5 shots stitched (Microsoft ICE) Photo credit: Teri Aquino

Date: 20 May 2020 Photo no (camera): DSC 2358-62

Photo Doc Site NI No. 04 - 2004

Viewing angle for photo: facing E 067°

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: 20 May, 2020 Photo nos.: DSC_2347-51
Photo Doc Site NI No. 04 – 2020 Photo credit: Teri Aquino

South Islet:

Viewing angle for photo: facing S 060°

Comments: shot includes view of the old lighthouse at the background

;

Photo taken behind the old nipa hut

Photo name code: SI 01

Date: 21 May 2020

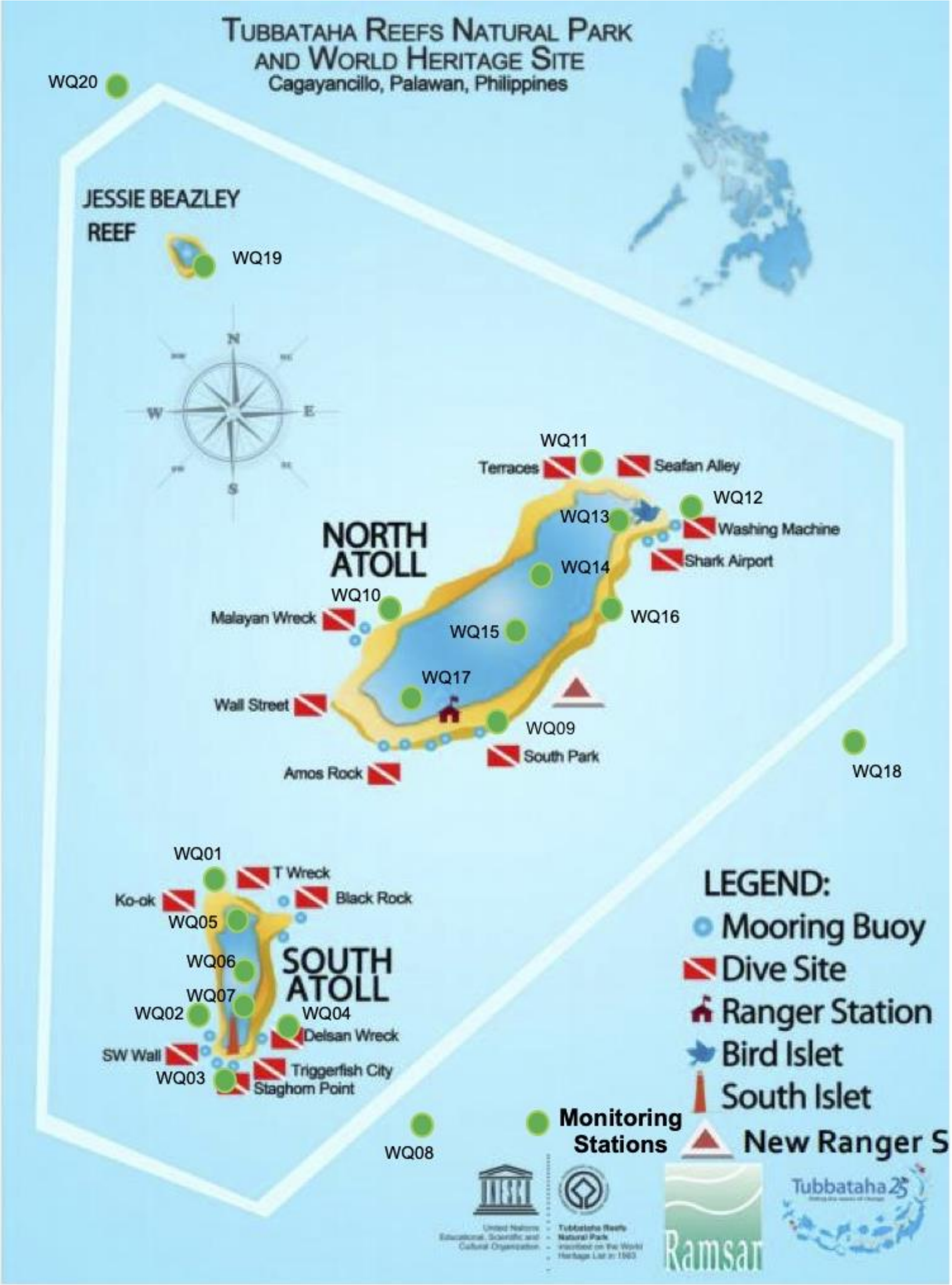
Comments: single shot including new lighthouse at the background;
Coordinates for new photocdoc site was taken in 2019

Photo no (camera): DSC_2669

Annex 22. TRNP Water Quality Monitoring Stations 2020

Site	Latitude	Longitude	Remarks	Additional details
WQ01_20	N8.80850	E119.81907	Fish and benthos monitoring station 4A; top of the reef; south atoll	dive site
WQ02_20	N8.76090	E119.81323	top of the reef; south atoll	not frequently visited by divers
WQ03_20	N8.74000	E119.81985	top of the reef; south atoll	near mooring buoy
WQ04_20	N8.75591	E119.82881	Fish and benthos monitoring station 3A; top of the reef; south atoll	dive site
WQ05_20	N8.79677	E119.82043	original water quality site; inside lagoon; south atoll	lagoon, off-limits to tourists
WQ06_20	N8.78020	E119.82298	original water quality site; inside lagoon; south atoll	lagoon, off-limits to tourists
WQ07_20	N8.76509	E119.82423	original water quality site; inside lagoon; south atoll	lagoon, off-limits to tourists
WQ08_20	N8.71731	E119.88983	original water quality site; buffer zone; south atoll	deep waters
WQ09_20	N8.85174	E119.93661	Min Ping Yu grounding site	shallow reef, not visited by divers
WQ10_20	N8.89222	E119.90623	Fish and benthos monitoring station 2A; top of the reef; north atoll	dive site
WQ11_20	N8.94423	E119.96908	top of the reef; north atoll	dive site
WQ12_20	N8.93532	E120.01302	Fish and benthos monitoring station 1A; top of the reef; north atoll	dive site; near bird islet
WQ13_20	N8.93041	E119.98394	original water quality site; inside lagoon; north atoll	lagoon, off-limits to tourists, near bird islet
WQ14_20	N8.90721	E119.95018	original water quality site; inside lagoon; north atoll	lagoon, off-limits to tourists
WQ15_20	N8.89108	E119.94903	original water quality site; inside lagoon; north atoll	lagoon, off-limits to tourists
WQ16_20	N8.88924	E119.97104	original water quality site; inside lagoon; north atoll	lagoon, off-limits to tourists
WQ17_20	N8.85709	E119.89962	original water quality site; inside lagoon; north atoll	lagoon, off-limits to tourists, near the ranger station
WQ18_20	N8.84606	E120.02347	original water quality site; buffer zone; north atoll	deep waters
WQ19_20	N9.04393	E119.81599	Fish and benthos monitoring station JBA; top of the reef; Jessie Beazley Reef	dive site
WQ20_20	N9.09828	E119.78667	original water quality site; buffer zone; Jessie Beazley Reef	deep waters

Annex 23. Map of Water Quality Monitoring Stations vis-à-vis Tourism Sites in TRNP



Annex 24. Water Quality Parameters Per WQ Monitoring Stations 2014-2020

WQ01	TSS, mg/L	Temp, °C	Color, PCU	pH	Dissolved Oxygen, mg/L	Nitrates, mg/L	Phosphates, mg/L	Oil and Grease, mg/L	Total Coliform, MPN/100 mL	Fecal Coliform, MPN/100 mL	TDS, mg/L	Chromium hexavalent, mg/L	BOD, mg/L	Salinity, ppt
2014	11	25.8	5	8.24	6.57	1.5	1.32	1.5	33	no data	25,060	-0.0022	2	35.8
2015	3	28.2	5	8.28	7.92	1.5	0.58	<1	23	1.8	25,078	0.0001	0.5	35.5
2016	2	28	5	8.24	8.09	0.75	0.24	5.6	94	23	18,768	0.0001	0.5	34.8
2017	6	30.19	5	8.78	5.9	1.4	0.52	no data	49	23	20,184	<0.003	<1	29.1
2020	<1	30.07	<5	7.75	6.73	0.46	1.51	2.5	23	7.8	30,240	no data	no data	30.07

WQ02	TSS, mg/L	Temp, °C	Color, PCU	pH	Dissolved Oxygen, mg/L	Nitrates, mg/L	Phosphates, mg/L	Oil and Grease, mg/L	Total Coliform, MPN/100 mL	Fecal Coliform, MPN/100 mL	TDS, mg/L	Chromium hexavalent, mg/L	BOD, mg/L	Salinity, ppt
2014	12	25.40	5	8.36	6.32	1.20	0.61	0.69	49	no data	27,640	-0.0028	2.6	35.8
2015	4	28.5	10	8.31	7.89	1.60	0.48	<1	33	1.8	24,720	0.0001	0.5	35.5
2016	<1	28	5	8.29	8.8	1.00	0.92	4.2	49	49	21,200	0.0001	1	34.8
2017	5	30.07	5	8.78	5.5	1.30	0.21	no data	58	31	23,506	<0.003	<1	29
2020	10	30.26	<5	7.05	5.99	0.49	0.58	3.6	23	4.5	30,080	no data	no data	29.88

WQ03	TSS, mg/L	Temp, °C	Color, PCU	pH	Dissolved Oxygen, mg/L	Nitrates, mg/L	Phosphates, mg/L	Oil and Grease, mg/L	Total Coliform, MPN/100 mL	Fecal Coliform, MPN/100 mL	TDS, mg/L	Chromium hexavalent , mg/L	BOD, mg/L	Salinity, ppt
2014	12	26.27	5	8.32	6.58	1.7	0.78	6.08	23	no data	25778	-0.0034	0.9	34.9
2015	<1	28.3	10	8.33	8.05	1.8	0.53	1.85	46	1.8	24875	0.0001	0.5	35.5
2016	<1	29.6	5	8.4	8.02	0.9	0.64	7.9	33	23	19099	0.0001	0.5	34.5
2017	3	29.91	5	8.81	6.1	1.5	0.4	no data	49	33	22084	<0.003	<1	28.4
2020	5	30.15	<5	7.77	6.44	0.53	0.70	<1	4.5	<1.1	29900	no data	no data	29.67

WQ04	TSS, mg/L	Temp, °C	Color, PCU	pH	Dissolved Oxygen, mg/L	Nitrates, mg/L	Phosphates, mg/L	Oil and Grease, mg/L	Total Coliform, MPN/100 mL	Fecal Coliform, MPN/100 mL	TDS, mg/L	Chromium hexavalent, mg/L	BOD, mg/L	Salinity, ppt
2014	15	32.8	5	8.09	6.38	1.00	0.11	1.29	23	no data	27,186	0.0008	2.9	35.9
2015	5	28.4	5	8.32	8.04	1.20	0.50	1.15	33	1.8	25,943	0.0001	0.5	35.2
2016	10	29.2	5	8.34	8.09	0.75	0.22	5.4	120	94	19,325	0.0001	0.5	33.4
2017	6	30.1	5	8.67	6.5	1.80	0.25	no data	23	23	23,352	<0.003	<1	29.1
2020	<1	30.29	<5	7.65	6.84	0.48	0.25	<1	7.8	<1.1	30,490	no data	no data	30.33

WQ05	TSS, mg/L	Temp, °C	Color, PCU	pH	Dissolved Oxygen, mg/L	Nitrates, mg/L	Phosphates, mg/L	Oil and Grease, mg/L	Total Coliform, MPN/100 mL	Fecal Coliform, MPN/100 mL	TDS, mg/L	Chromium hexavalent, mg/L	BOD, mg/L	Salinity, ppt
2014	19	30.4	5	8.05	6.95	1.4	0.18	2.03	79	no data	29,788	0.0005	0.9	36.1
2015	10	29.1	10	8.14	6.2	1.3	0.51	1.25	170	70	25,280	0.0001	0.5	35.6
2016	4	29	5	8.27	6.09	0.75	1.22	<1	33	23	19,215	0.0001	0.5	34.9
2017	1	29.46	5	8.64	5.4	1.5	0.26	no data	49	33	24,045	<0.003	<1	29
2020	9	30.52	<5	7.65	7.04	0.47	0.15	3.8	4.5	<1.1	30,390	no data	no data	30.22

WQ06	TSS, mg/L	Temp, °C	Color, PCU	pH	Dissolved Oxygen, mg/L	Nitrates, mg/L	Phosphates, mg/L	Oil and Grease, mg/L	Total Coliform, MPN/100 mL	Fecal Coliform, MPN/100 mL	TDS, mg/L	Chromium hexavalent, mg/L	BOD, mg/L	Salinity, ppt
2014	19	31.5	5	8.14	6.47	1	0.09	1.41	23	no data	29436	-0.0046	3.8	36.1
2015	9	29.3	10	8.22	7.65	1.4	0.59	1.25	140	46	26000	0.0001	0.5	35.6
2016	9	28.4	5	7.99	7.95	0.95	1.47	2.6	140	110	20080	0.005	1	34.8
2017	6	29.53	5	8.76	6.3	1.5	0.26	no data	43	31	22552	<0.003	<1	29.2
2020	3	30.34	<5	7.37	6.85	0.53	0.18	2.4	4.5	<1.1	30310	no data	no data	30.25

WQ07	TSS, mg/L	Temp, °C	Color, PCU	pH	Dissolved Oxygen, mg/L	Nitrates, mg/L	Phosphates, mg/L	Oil and Grease, mg/L	Total Coliform, MPN/100 mL	Fecal Coliform, MPN/100 mL	TDS, mg/L	Chromium hexavalent, mg/L	BOD, mg/L	Salinity, ppt
2014	18	32.1	5	8.14	7.01	1	1.31	2.04	44	no data	26096	-0.0034	1.1	35.5
2015	6	28.9	5	8.28	7.48	1.3	0.4	1.7	350	94	26225	0.0001	0.5	35.6
2016	12	31.2	5	8.35	7.07	1.15	0.68	3.4	210	140	24010	0.0001	0.5	34.4
2017	2	29.39	5	8.64	6	2	0.27	no data	43	31	23982	<0.003	<1	29
2020	6	30.36	<5	7.28	6.26	0.44	0.75	3.2	7.8	2	30340	no data	no data	30.17

WQ08	TSS, mg/L	Temp, °C	Color, PCU	pH	Dissolved Oxygen, mg/L	Nitrates, mg/L	Phosphates, mg/L	Oil and Grease, mg/L	Total Coliform, MPN/100 mL	Fecal Coliform, MPN/100 mL	TDS, mg/L	Chromium hexavalent, mg/L	BOD, mg/L	Salinity, ppt
2014	11	33.6	5	8.06	6.3	1.40	0.38	1.69	130	no data	26,533	-0.0022	2.5	34.9
2015	3	28.2	5	8.30	8.18	1.30	0.47	0.9	23	1.8	27,728	0.0001	0.5	35.4
2016	2	29.6	5	8.40	7.91	0.95	0.54	8.8	280	170	21,158	0.0001	0.5	34.3
2017	6	29.91	5	8.80	6.8	1.70	0.25	no data	49	23	18,340	<0.003	5	28.9
2020	1	30.36	<5	7.90	5.5	0.69	0.12	<1	7.8	2	28,310	no data	no data	27.9

WQ09	TSS, mg/L	Temp , °C	Color, PCU	pH	Dissolved Oxygen, mg/L	Nitrates, mg/L	Phosphates, mg/L	Oil and Grease, mg/L	Total Coliform, MPN/100 mL	Fecal Coliform, MPN/100 mL	TDS, mg/L	Chromium hexavalent, mg/L	BOD, mg/L	Salinity, ppt
2014	18	34.5	5	8.1	6	1.3	1.43	1.49	94		33265	-0.0037	1.4	35.1
2015	10	28.9	5	8.31	8.09	1.2	0.91	1.19	23	1.8	28270	0.0001	0.5	35.4
2016	14	28.8	5	8.4	8.18	1.2	1.06	1.8	140	79	22580	0.0001	2	35
2017	13	30.5	5	8.79	6.6	1.8	0.36	no data	23	23	22746	<0.003	5	28.8
2020	7	30.3	<5	7.9	6.42	0.55	0.18	2.5	<1.1	<1.1	30510	no data	no data	30.35

WQ10	TSS, mg/L	Temp, °C	Color, PCU	pH	Dissolved Oxygen, mg/L	Nitrates, mg/L	Phosphates, mg/L	Oil and Grease, mg/L	Total Coliform, MPN/100 mL	Fecal Coliform, MPN/100 mL	TDS, mg/L	Chromium hexavalent, mg/L	BOD, mg/L	Salinity, ppt
2014	20	36.4	5	8.89	6.58	1.5	0.13	2.86	23	no data	34643	-0.0028	0.9	36.4
2015	12	29.6	5	8.21	8.51	1.1	0.87	2.25	23	1.8	26100	0.0001	0.5	35.6
2016	2	29.9	5	8.26	8.13	1.2	0.58	4.9	33	33	23232	0.0001	2	35.2
2017	6	30.25	5	8.8	6.1	2.5	0.32	3	23	23	21688	<0.003	<1	29
2020	3	31.04	<5	7.59	6.25	0.49	0.17	1.6	2	1.1	30760	no data	no data	30.6

WQ11	TSS, mg/L	Temp, °C	Color, PCU	pH	Dissolved Oxygen, mg/L	Nitrates, mg/L	Phosphates, mg/L	Oil and Grease, mg/L	Total Coliform, MPN/100 mL	Fecal Coliform, MPN/100 mL	TDS, mg/L	Chromium hexavalent, mg/L	BOD, mg/L	Salinity, ppt
2014	20	30.4	5	7.78	7.05	1.3	1.1	1.1	70	no data	29535	-0.0028	1.3	36.6
2015	8	29.1	5	8.25	8.02	0.6	0.76	1.4	23	1.8	27270	0.003	0.5	35.5
2016	11	29.6	5	8.31	8.15	1	0.4	4.4	70	49	20520	0.0001	0.5	35.1
2017	6	30.24	5	8.83	5.6	1.9	0.24	no data	43	31	22091	<0.003	<1	29
2020	11	30.33	<5	7.37	5.92	0.50	0.29	3.3	4.5	<1.1	30640	no data	no data	30.51

WQ12	TSS, mg/L	Temp, °C	Color, PCU	pH	Dissolved Oxygen, mg/L	Nitrates, mg/L	Phosphates, mg/L	Oil and Grease, mg/L	Total Coliform, MPN/100 mL	Fecal Coliform, MPN/100 mL	TDS, mg/L	Chromium hexavalent, mg/L	BOD, mg/L	Salinity, ppt
2014	4	26.28	5	8.21	6.93	1.3	0.39	1.3	94	no data	36579	-0.001	0.9	32.1
2015	6	29	10	8.25	8.13	1.3	0.57	1.55	23	1.8	27151	0.0001	0.5	35.5
2016	15	27.9	10	8.29	8.1	1.3	0.2	1.4	70	49	23546	0.009	1	34.7
2017	11	30.23	5	8.83	5.6	2.5	0.13	2.1	23	31	23839	<0.003	<1	29
2020	5	30.44	<5	7.73	5.69	0.52	0.21	2.3	4.5	2	30750	no data	no data	30.62

WQ13	TSS, mg/L	Temp, °C	Color, PCU	pH	Dissolved Oxygen, mg/L	Nitrates, mg/L	Phosphates, mg/L	Oil and Grease, mg/L	Total Coliform, MPN/100 mL	Fecal Coliform, MPN/100 mL	TDS, mg/L	Chromium hexavalent, mg/L	BOD, mg/L	Salinity, ppt
2014	10	30.7	5	7.92	6.9	1.5	0.92	4.8	23	no data	23910	-0.0025	1.48	36.4
2015	4	29.7	5	8.26	7.8	1.2	0.45	1.4	46	1.8	25366	0.0001	0.5	35.5
2016	0.9	28.9	5	8.28	8.87	0.8	0.04	4.9	120	70	23050	0.0001	2	35.1
2017	4	30.74	5	8.75	7	1.8	0.14	<1	31	31	23091	<0.003	7	29.2
2020	9	30.45	<5	7.78	6.15	0.51	0.17	3.2	17	7.8	30700	no data	no data	30.56

WQ14	TSS, mg/L	Temp, °C	Color, PCU	pH	Dissolved Oxygen, mg/L	Nitrates, mg/L	Phosphates, mg/L	Oil and Grease, mg/L	Total Coliform, MPN/100 mL	Fecal Coliform, MPN/100 mL	TDS, mg/L	Chromium hexavalent, mg/L	BOD, mg/L	Salinity, ppt
2014	17	30.9	5	7.74	6.91	1.3	0.16	1.43	79	no data	35706	-0.0043	<1	30.9
2015	0.9	29.5	5	8.28	7.94	1.1	0.35	3.05	33	1.8	22051	0.0001	0.5	35.6
2016	0.9	27.1	5	8.31	7.87	0.7	0.04	<1	23	23	22428	0.0001	0.5	35.3
2017	6	30.67	5	8.75	6.1	1.9	0.31	4	63	43	23095	<0.003	5	28.7
2020	12	30.48	<5	7.48	5.83	0.48	0.18	3	79	4.5	30610	no data	no data	30.64

WQ15	TSS, mg/L	Temp, °C	Color, PCU	pH	Dissolved Oxygen, mg/L	Nitrates, mg/L	Phosphates, mg/L	Oil and Grease, mg/L	Total Coliform, MPN/100 mL	Fecal Coliform, MPN/100 mL	TDS, mg/L	Chromium hexavalent, mg/L	BOD, mg/L	Salinity, ppt
2014	7	31.5	5	8.02	7.29	1.7	0.79	0.7	23	no data	35846	-0.0028	0.9	36.5
2015	3	29.5	5	8.29	7.92	1.1	1.22	2.85	49	1.8	22880	0.0001	0.5	35.6
2016	1	29.9	5	8.37	7.73	0.8	0.02	<1	49	33	21128	0.0001	3	35.5
2017	10	30.61	5	8.77	6.1	1.9	0.31	3.6	43	43	18861	<0.003	<1	29
2020	<1	30.42	<5	7.55	6.28	0.49	0.18	<1	2	<1.1	30610	no data	no data	30.46

WQ16	TSS, mg/L	Temp, °C	Color, PCU	pH	Dissolved Oxygen, mg/L	Nitrates, mg/L	Phosphates, mg/L	Oil and Grease, mg/L	Total Coliform, MPN/100 mL	Fecal Coliform, MPN/100 mL	TDS, mg/L	Chromium hexavalent, mg/L	BOD, mg/L	Salinity, ppt
2014	6	30.7	5	7.75	7.28	1.40	1.43	1.45	23	no data	22,228	-0.0037	1.18	36.8
2015	6	29.8	10	8.28	8.05	0.90	0.4	0.90	84	46	23,000	0.0001	0.5	35.6
2016	4	26.9	5	8.39	8.09	0.80	0.15	5.6	170	140	21,906	0.0001	0.5	35.3
2017	5	30.07	5	8.83	7.4	3.20	0.23	0.9	43	43	22,181	<0.003	<1	28.8
2020	3	30.28	<5	7.47	6.97	0.64	0.13	2.6	7.8	2	30,520	no data	no data	30.37

WQ17	TSS, mg/L	Temp, °C	Color, PCU	pH	Dissolved Oxygen, mg/L	Nitrates, mg/L	Phosphates, mg/L	Oil and Grease, mg/L	Total Coliform, MPN/100 mL	Fecal Coliform, MPN/100 mL	TDS, mg/L	Chromium hexavalent, mg/L	BOD, mg/L	Salinity, ppt
2014	2	38.4	5	8.06	6.76	1.20	0.66	5.83	110	no data	25,408	-0.0028	1.38	35.9
2015	6	29.3	15	8.24	7.67	1.50	0.83	1.45	170	94	23,611	0.0001	0.5	35.7
2016	1	31.7	5	8.43	7.62	0.90	0.06	<1	23	23	20864	0.0001	0.5	35.1
2017	15	30.65	5	8.70	8.2	2.10	0.24	5.1	23	23	22,818	<0.003	<1	28.9
2020	1	30.36	<5	7.05	5.41	0.54	0.248	2.6	<1.1	<1.1	30340	no data	no data	30.17

WQ18	TSS, mg/L	Temp, °C	Color, PCU	pH	Dissolved Oxygen, mg/L	Nitrates, mg/L	Phosphates, mg/L	Oil and Grease, mg/L	Total Coliform, MPN/100 mL	Fecal Coliform, MPN/100 mL	TDS, mg/L	Chromium hexavalent, mg/L	BOD, mg/L	Salinity, ppt
2014	9	26.19	5	8.16	6.37	1.2	0.19	4.35	46	no data	22133	-0.0043	0.9	35.7
2015	3	29.3	5	8.27	8.08	1.3	0.53	2	94	1.8	24970	0.003	0.5	35.6
2016	1	28.1	5	8.45	8.8	1.2	0.04	<1	23	no data	21728	0.0001	0.5	34.9
2017	9	30.48	5	8.82	6.7	2.7	0.27	no data	31	23	19595	<0.003	<1	28.8
2020	<1	30.35	<5	7.32	6.22	0.62	0.28	1.8	<1.1	<1.1	30680	no data	no data	30.4

WQ19	TSS, mg/L	Temp, °C	Color, PCU	pH	Dissolved Oxygen, mg/L	Nitrates, mg/L	Phosphates, mg/L	Oil and Grease, mg/L	Total Coliform, MPN/100 mL	Fecal Coliform, MPN/100 mL	TDS, mg/L	Chromium hexavalent, mg/L	BOD, mg/L	Salinity, ppt
2014	9	31.2	5	7.96	6.93	1.3	0.32	2.88	33	no data	23470	-0.0016	0.9	36.6
2015	4	29.4	10	8.33	8.03	1.3	0.48	1.1	46	1.8	23081	0.005	0.5	35.6
2016	0.9	29.5	5	8.49	7.99	0.8	0.06	4.8	140	94	23229	0.0001	0.5	35.4
2017	3	30.28	5	8.81	7.4	2.5	0.37	3	23	23	19630	<0.003	<1	28.1
2020	<1	30.3	<5	7.34	6.81	0.58	0.28	<1	14	2	30990	no data	no data	30.89

WQ20	TSS, mg/L	Temp, °C	Color, PCU	pH	Dissolved Oxygen, mg/L	Nitrates, mg/L	Phosphates, mg/L	Oil and Grease, mg/L	Total Coliform, MPN/100 mL	Fecal Coliform, MPN/100 mL	TDS, mg/L	Chromium hexavalent, mg/L	BOD, mg/L	Salinity, ppt
2014	10	30.7	5	8.06	6.65	1.4	0.09	0.69	no data	no data	21901	-0.0004	2.67	36.6
2015	1	29.6	5	8.3	8.03	1.6	0.5	2.2	79	33	23701	0.003	0.5	35.6
2016	5	29.4	5	8.43	7.99	1.45	0.08	2.6	140	94	24952	0.0001	3	35.4
2017	18	30.32	5	8.79	5.6	1.7	0.37	no data	43	43	20532	<0.003	<1	29
2020	7	31.14	<5	7.16	5.95	0.56	0.25	<1	41	12	30930	no data	no data	30.81