


Ecosystems Research and Monitoring Report 2018



Tubbataha Reefs Natural Park
and World Heritage Site



TRNP Ecosystem Research and Monitoring Report 2018

Suggested Citation:

*Tubbataha Management Office. 2018. Ecosystem Research and Monitoring Report 2018.
Tubbataha Protected Area Management Board. Puerto Princesa City, Philippines*

Contributors:

Maria Retchie Pagliawan, Rowell Alarcon, Gerlie Gedoria, Arne Jensen, Denmark Recamara, Cleto Nañola, Jr., Wilfredo Licuanan, Segundo Conales, Jr., Noel Bundal, Jeffrey David, Cresencio Caranay, Jr., Jennifer Deauna, Giannina Feliciano, Angeli Songco, Ma. Theresa Aquino

Contents

| | |
|----------------------------------|------|
| List of Tables | iv |
| List of Figures | v |
| List of Appendices | viii |
| Executive Summary..... | x |
| 1 INTRODUCTION..... | 1 |
| 1.1 Overview..... | 2 |
| 1.2 Monitoring design..... | 3 |
| 1.3 Other researches..... | 4 |
| 1.4 References | 4 |
| 2 REEF FISH COMMUNITY | 6 |
| 2.1 Overview..... | 7 |
| 2.2 Methodologies..... | 7 |
| 2.3 Results and Discussions..... | 8 |
| 2.4 Conclusions..... | 19 |
| 2.5 Recommendations..... | 20 |
| 2.6 References | 21 |
| 3 REEF BENTHOS..... | 24 |
| 3.1 Overview..... | 25 |
| 3.2 Methods..... | 25 |
| 3.3 Results and Discussions..... | 26 |
| 3.4 Conclusion | 34 |
| 3.5 Recommendations..... | 35 |
| 3.6 References | 35 |
| 4 SEABIRD POPULATION | 37 |
| 4.1 Overview..... | 38 |

| | | |
|-----|--|-----|
| 4.2 | Methods..... | 38 |
| 4.3 | Results and conclusion | 40 |
| 4.4 | Management recommendations for 2018 and beyond | 58 |
| 4.5 | References | 59 |
| | OTHER STUDIES | 62 |
| 5 | CORAL RECRUITMENT | 63 |
| 5.1 | Overview..... | 63 |
| 5.2 | Materials and Methods..... | 64 |
| 5.3 | Results and Discussion | 65 |
| 5.4 | Conclusion | 72 |
| 5.5 | Recommendations | 73 |
| 5.6 | References | 73 |
| 6 | REEF FISH INVENTORY | 76 |
| 6.1 | Overview..... | 76 |
| 6.2 | Methods..... | 76 |
| 6.3 | Results and Discussion | 79 |
| 6.4 | Conclusion and Recommendation..... | 83 |
| 6.5 | References | 84 |
| 7 | REEF BENTHIC SURVEY | 86 |
| 7.1 | Overview..... | 86 |
| 7.2 | Methods..... | 86 |
| 7.3 | Results and Discussion | 89 |
| 7.4 | Change in Hard Coral Cover | 90 |
| 7.5 | Change in TAUs diversity | 92 |
| 7.6 | Ship Grounding Sites..... | 102 |
| 7.7 | Southwest Wall | 105 |
| | APPENDICES..... | 110 |

List of Tables

| | |
|--|----|
| Table 1. Characterization of reef benthos of the deep areas in 2018 using the photo-transect method. | 27 |
| Table 2. Characterization of reef benthos of the shallow areas in 2018 using the photo-transect method. | 28 |
| Table 3. Percent hard coral cover, number of coral genera and hard coral diversity indices per station. | 32 |
| Table 4. Frequency count of invertebrate species in TRNP following the Reef Check method. | 33 |
| Table 5. Approximate changes in the land area of Bird Islet from 1911 to 2018. Source: Worcester 1911, Kennedy 1982, Heegaard and Jensen 1992, Manamtam 1996, WWF Philippines 2004 and Tubbataha Management Office 2004 to 2018..... | 41 |
| Table 6. Selected results of MPR distance and direct counts from June 2017 to April 2018 | 45 |
| Table 7. Total count numbers of adult resident seabirds present on Bird Islet and South Islet 12 – 15 May 2018. | 47 |
| Table 8. Results of ring readings of Brown Booby on Bird Islet from July and August 2017 and May 2018 | 51 |
| Table 9. Survey sites with corresponding coordinates. Note: * Corresponds to TMO monitoring stations | 77 |
| Table 10. The number of species on each sighting frequency and their abundance index ranges. | 82 |
| Table 11 Hard Coral Cover and TAU diversity scale categories used in this report (AM Licuanan et al. 2017; WY Licuanan et al. in prep). | 89 |
| Table 12 Linear regression of HC at different levels i.e. location, site, and station level wherein ns= $P>0.05$; * = $p\leq 0.05$; ** = $p\leq 0.01$; *** = $p\leq 0.001$ | 91 |

| | |
|--|----|
| Table 13 Linear regression of TAUs at different levels i.e. location, site, and station level wherein ns= $P > 0.05$; * = $p \leq 0.05$; ** = $p \leq 0.01$; *** = $p \leq 0.001$ | 93 |
|--|----|

List of Figures

| | |
|---|----|
| Figure 1. Hierarchical sampling design (Modified from Licuanan et al. 2016). | 3 |
| Figure 2. Location map of the monitoring sites (blue dots). | 3 |
| Figure 3. Mean fish density (individuals per 500 m ²) at depths per site. Error bar represents the standard error of the mean. | 9 |
| Figure 4. Distribution of mean biomass (gram per m ²) per depth in Tubbataha Reefs. Error bar represents the standard error of the mean. | 9 |
| Figure 5. Temporal patterns of density (inds./500 m ²) and biomass (g/m ²) of fishery targeted species since 2013. | 10 |
| Figure 6. Temporal patterns of mean biomass (g/m ²) (excluding sharks and big schools) in TRNP. Error bar represents the standard error of the mean. | 12 |
| Figure 7. Temporal patterns of mean biomass (g/m ²) of deep and shallow areas (excluding sharks and schools with >100 individuals). No data for shallow areas in 2016. | 13 |
| Figure 8. Temporal patterns of mean biomass (grams per m ²) distribution of pelagic and demersal species per depths in regular monitoring sites of Tubbataha Reefs. | 14 |
| Figure 9. Density (g/m ²) of trophic groups (based on the species' diet) at shallow and deep areas from 2015 to 2018. No data for shallow areas of 2016 due to lack of manpower. | 15 |
| Figure 10. Relative distribution of mean density (individuals per 500 m ²) and biomass (g/m ²) in shallow and deep areas of Min Ping Yu and USS Guardian grounding sites. Error bar represents standard error of the mean. | 18 |

| | |
|---|----|
| Figure 11. Temporal patterns of mean biomass (g/m ²) and mean density (ind./ 500 m ²) of Min Ping Yu and USS Guardian grounding sites. | 19 |
| Figure 12. Characterization of reef benthos at the deep monitoring areas of TRNP. Error bars represent the standard error of the mean. | 29 |
| Figure 13. Characterization of reef benthos at the shallow monitoring areas of TRNP. Error bars represent the standard error of the mean. | 30 |
| Figure 14. Status of vegetation in Bird Islet from 2006 to 2018. | 43 |
| Figure 15. Status of vegetation in South Islet from 2010 to 2018. | 44 |
| Figure 16. Population trend of adult Red-footed Booby from 1981 to 2018. | 49 |
| Figure 17. Breeding data of Red-footed Booby from 2004 to 2018. | 49 |
| Figure 18. Population trend of adult Brown Booby from 1981 to 2018. | 50 |
| Figure 19. Breeding data of Brown Booby from 2004 to 2018. | 50 |
| Figure 20. Population trend of adult Brown Noddy from 1981 to 2018. | 52 |
| Figure 21. Breeding data of Brown Noddy from 2004 to 2018. | 53 |
| Figure 22. Population trend of adult Black Noddy from 1981 to 2018. | 54 |
| Figure 23. Breeding data of Black Noddy from 2004 to 2018. | 55 |
| Figure 24. Breeding data of Great Crested Tern from 2004 to 2018. | 56 |
| Figure 25. Population trend of adult Great Crested Tern from 1981 to 2018. | 56 |
| Figure 26. Breeding data of Sooty Tern from 2004 to 2018. | 57 |
| Figure 27. Population trend of adult Sooty Tern from 1981 to 2018. | 57 |
| Figure 28. Coral recruitment sampling. (a) randomized quadrat sampling within the transect. (b) close-up shot of the quadrat with scale bars (c) multiple photos were taken using underwater camera. | 64 |
| Figure 29. Mean percentage cover of coral families at 10 meters. Error bars represent standard error of the mean. | 66 |
| Figure 30. Average density of coral recruits in m ² for 10 stations at 10 meters. | 67 |
| Figure 31. Size-frequency distribution of coral recruits per Station. Bars represent the number of recruits in each size class. | 68 |
| Figure 32. Mean percentage cover of coral families at five meters. Error bars represent standard error of the mean. | 69 |
| Figure 33. Average density of coral recruits per m ² for 10 stations at five meters. | 69 |
| Figure 34. Size frequency distribution of coral recruits by station. Bars represent the number of recruits in each size class. | 70 |

| | |
|---|-----|
| Figure 35. Non-metric multi-dimensional scaling (MDS) plot of Bray-Curtis similarity index of recruit species composition across the sites at both depths. Green dotted line implies 20% similarity of the stations; blue dotted line implies 40% similarity..... | 71 |
| Figure 36. Total number of species identified in each site, including cryptic species. | 79 |
| Figure 37. The number of species in each sighting frequency in the Tubbataha Reefs. | 80 |
| Figure 38. Number of species on each abundance index range. | 81 |
| Figure 39. Comparison of averages for species identified in different sites in the Philippines and in Southeast Asia, employing the Roving Visual Census method. Cryptic species were not included in the count. (Data obtained from Dr. Kent E. Carpenter) | 83 |
| Figure 40 Sampling scheme of sites and stations in the Tubbataha Reefs Natural Park..... | 87 |
| Figure 41. Five belt transects were deployed to describe the benthic communities in each monitoring station. | 88 |
| Figure 42 Box and whiskers plot of coral cover for Tubbataha stations from 2012 to 2018. Error bars indicate +/- 1 standard error. | 90 |
| Figure 43 Bar graphs of TAU diversity per year for all sites/stations. Error bars indicate +/- 1 standard error. | 92 |
| Figure 44. Hard coral cover (HCC) at and around the grounding site of the USS Guardian at the South Atoll of the Tubbataha Reefs. Error bars indicate +/- 1 standard error. | 103 |
| Figure 45. Hard coral cover (HCC) in fixed plots at and around the Ming Ping Yu grounding site at the North Atoll of the Tubbataha Reefs. Error bars indicate +/- 1 standard error. | 103 |
| Figure 46. Small corals found in USS Guardian with a ruler for scale..... | 104 |
| Figure 47. Rubble was observed scattered all over the Min Ping Yu grounding site. | 105 |
| Figure 48 Crown-of-thorns observed in Southwest Wall site with a hand as a scale..... | 107 |
| Figure 49 Stylophora sp. colony that seems like it was freshly eaten by crown-of-thorns sea star. | 107 |

List of Appendices

| | |
|---|-----|
| Appendix 1. Monitoring Team | 111 |
| Appendix 2. Fish and Benthos Monitoring Sites..... | 112 |
| Appendix 3. Categories for evaluating ecological health of coral reef fish communities according to Hilomen et al. (2000) and Nañola et al. (2004)..... | 113 |
| Appendix 4. Mean density of fish families in deep (n=30) and shallow (n=30) areas in the regular monitoring sites..... | 114 |
| Appendix 5. Mean biomass of fish families in deep (n=30) and shallow (n=30) areas in the regular monitoring sites. | 115 |
| Appendix 6. Results of the analysis of variance (ANOVA) between spatial and temporal means of fish biomass in in TRNP. | 116 |
| Appendix 7. Mean density of fish families in deep (n=6) and shallow (n=3) of Min Ping Yu grounding site. | 117 |
| Appendix 8. Mean density of fish families in deep (n=6) and shallow (n=3) of USS Guardian grounding site. | 118 |
| Appendix 9. Mean biomass of fish families in deep (n=6) and shallow (n=3) of Min Ping Yu grounding site. | 119 |
| Appendix 10. Mean biomass of fish families in deep (n=6) and shallow (n=3) of USS Guardian grounding site. | 120 |
| Appendix 11. Taxonomic amalgamation units (TAUs) | 121 |
| Appendix 12. Distance count estimate: objectives and methods | 122 |
| Appendix 13. Inventory and population calculation methods per breeding species..... | 123 |
| Appendix 14. Bird Islet Beach Erosion Assessment | 126 |
| Appendix 15. Condition of vegetation on Bird Islet and South Islet..... | 131 |
| Appendix 16. Results of Park Rangers' inventory counts, August and November 2017 and February 2018 at Bird Islet and South Islet..... | 133 |

| | |
|--|-----|
| Appendix 17. Population results and population trend of breeding seabirds in TRNP April to June 1981 – 2018..... | 137 |
| Appendix 18. Seabird breeding data from Bird Islet and from South Islet, April to June 2004-2018 | 139 |
| Appendix 19. In-flight to roost statistics of boobies and noddies on South Islet May 2014 to 2018 | 141 |
| Appendix 20. In-flight to roost statistics of boobies and noddies on Bird Islet May 2005 to May 2018..... | 143 |
| Appendix 21. Systematic list of avifaunal records from Jessie Beazley Reef, South Islet, Bird Islet, and Ranger Station from 12 to 15 May 2018..... | 145 |
| Appendix 22. Inclusion of the Black Noddy (<i>Anous minutus</i>) subspecies <i>worcesteri</i> on Appendix II of the Convention on Migratory Species | 148 |
| Appendix 23. Comparison of the landscape and habitats seen from the Permanent Photo Documentation Sites on Bird Islet and South Islet, May 2004 and May 2018..... | 155 |
| Appendix 24. Species which were seen frequently ($\geq 70\%$) in the Tubbataha Reefs. Species are listed in order of decreasing frequency. The frequency score is listed before each name. After each species name, the abundance index is given in parentheses. | 160 |
| Appendix 25. Taxonomic Amalgamation Units (TAUs) (van Woesik et al. 2009; Licuanan et al. 2017)..... | 162 |
| Appendix 25. Top ten hard coral TAUs of Tubbataha reef stations | 163 |

Executive Summary

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

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

Three hundred four (304) species belonging to 35 families and subfamilies were recorded during the regular monitoring in Tubbataha Reefs this year. This is slightly fewer than the number of species observed last year (316 species). The estimated species richness across all sites was 189 species per 500 m² which is very high (>50 species per 500 m²) according to the established categories for a healthy reef fish community (Hilomen *et al.* 2000). The mean reef fish density of the deep areas is significantly higher at 1,466 ind/500 m² than the shallow stations with 1,095 ind/500 m². Overall mean reef fish density is 1,298 individuals/500 m² which falls under high category Hilomen *et al.* (2000).

Deep areas contributed significantly higher yields than the shallow stations in terms of overall biomass. The total mean biomass of 134 g/m² in deep areas is mainly represented by Carangidae (jacks and trevallies), Acanthuridae: Nasinae (unicornfish), and Scaridae (parrotfish). In the shallow stations, the biomass estimates of 62.25 g/m² is represented by Balistidae (triggerfish), Scaridae (parrotfish), and Acanthuridae: Nasinae (unicornfish).

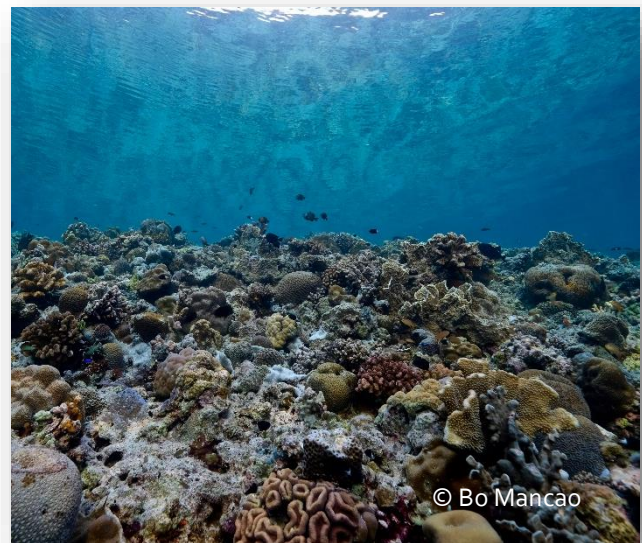


© Yvette Lee

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

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

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



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

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

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

A total of 23 species of birds were identified during the inventory. The total number of avifauna species recorded in TRNP is 115 species. A total 41,794 adult individuals of six breeding and one former breeding seabird species were recorded; 37,663 individuals on Bird Islet and 4,134 individuals on South Islet. The population on Bird Islet has increased by 17% since 2016 when it hosted 73% of the total population. On South Islet, due to habitat loss, the population has decreased from 27% to 10% since 2016. The total result of the May count in 2018 is about 12% higher than in 2017 and represents the highest documented count of breeding seabirds in the history of TRNP.

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




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

Coral recruitment baseline study was conducted during the annual monitoring this year. This survey recorded twenty-nine (29) coral genera belonging to nine families. The average estimated coral recruit density across all sites was 45.56 ind/m² at 10 meters, with values ranging from 0.83 ind/m² (± 0.26 SE) to 20 ind/m². In the shallow areas of TRNP (five meters), the average density is 30.50 ind/m² and values ranged from 0.10 ind/m² to 6.87 ind/m².



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

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



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

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

1 INTRODUCTION



1.1 Overview

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

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

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

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

The TMO annual ecosystem research and monitoring report includes the results of monitoring of fish, reef benthos and seabirds. While considering comparability to previous years' data, TMO have also adopted the new methods recommended by DENR through Technical Bulletin 2017-05 in conducting fish and reef benthos monitoring. On the other hand, the method employed for seabird population monitoring is modified from the DENR Biodiversity Monitoring System.

1.2 Monitoring design

Study Sites

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

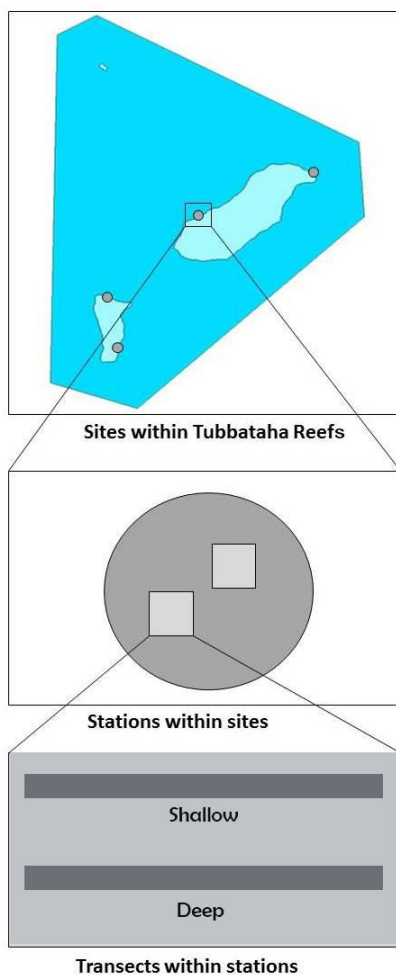


Figure 1. Hierarchical sampling design (Modified from Licuanan et al. 2016).

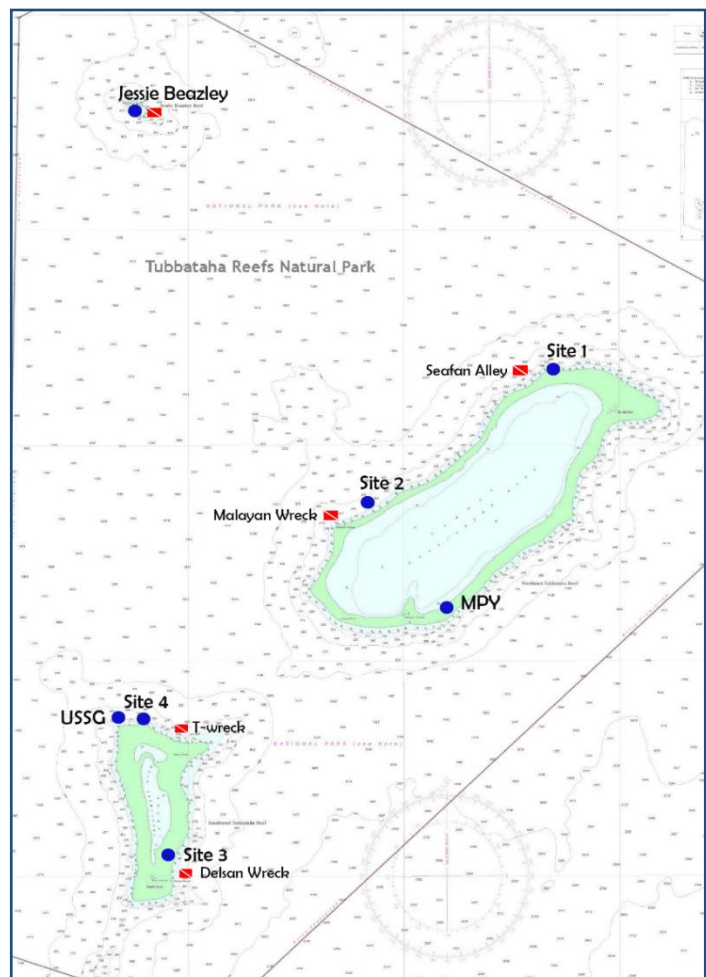



Figure 2. Location map of the monitoring sites (blue dots).



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

Field Surveys

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

1.3 Other researches


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

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

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

1.4 References

Heron, S., Eakin, C. and Douvère, F. 2017. Impacts of Climate Change on World Heritage Coral Reefs: A First Global Scientific Assessment. Paris, UNESCO World Heritage Centre.



Hughes, T., Rodrigues, M., Bellwood, D., Ceccarelli, D., Hoegh-Guldberg, O., McCook, L., Molschaniwskyj, N., Pratchett, M., Steneck, R. and Willis, B. 2007. Phase Shifts, Herbivory, and the Resilience of Coral Reefs to Climate Change. *Current Biology* 17, 360-365. DOI:10.1016/j.cub.2006.12.049

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

2 REEF FISH COMMUNITY

Gerlie T. Gedoria¹, Segundo F. Conales Jr.¹, Cleto L. Nañola, Jr.², and Denmark Recamara³

¹*Tubbataha Management Office, Puerto Princesa City,*

²*University of the Philippines- Mindanao, Davao City*

³*Jose P. Rizal Memorial State University, Dapitan City Campus*



2.1 Overview

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

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

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

2.2 Methodologies

Data Collection

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

The established monitoring sites were first located using the Global Positioning System (GPS) device. Three (3) 50-meter replicate transects, separated by 10-meter buffer, were laid in deep (~10m) and shallow (~5m) areas of each station. Each transect has an imaginary 5-meter coverage on both sides, establishing a 10 x 50-meter corridor. A transect was further segmented into 5-meter stops along its length and was surveyed one segment after another. The scientific name, actual count, and estimated length/size of the fish encountered inside the established corridor were recorded. Highly mobile species were recorded first before the slower ones (i.e., transient and cryptic species). Three (3) divers completed the survey this year, assessing the deep

transects first and the shallow afterwards. This year, the same sampling design was replicated in the grounding sites.

Data Analysis

Data was collated and organized using the format adapted from Coral Reef Visualization and Assessment (CoRVA) system introduced by the DENR in 2014. The species richness was determined using the actual number of species identified during the survey while the fish density was expressed by the number of individuals per given area (inds/500m²). The biomass was simplified in grams per square meter (g/m²) and was calculated with the existing length and weight model (Pauly 1984), 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, sites, and between this year and previous year's estimates at p=0.05. Whereas, two-factor analysis of variance (ANOVA) in the Microsoft Excel 2016 is used to detect if there were significant differences in the overall biomass between sites and between years (2013-2018).

2.3 Results and Discussions

Present conditions

Species richness and density

Three hundred four (304) species belonging to 35 families and subfamilies were recorded in the Tubbataha Reefs this year. This is slightly fewer than the number of species observed last year (316 species). Family richness ranged from 21, recorded in the shallow transects of Station 1B (Malayan Wreck), to 26 families in deep area in Station 3A (Delsan Wreck). That same station in Delsan Wreck also had the highest number of species at 124, while its shallow transects in Station 3B recorded the lowest with 89 species. Overall, the estimated species richness across all sites was 63 species per 500 m² which is very high (>50 species per 500 m²) according to the established categories for a healthy reef fish community (Hilomen, *et al.* 2000) (Appendix 3).

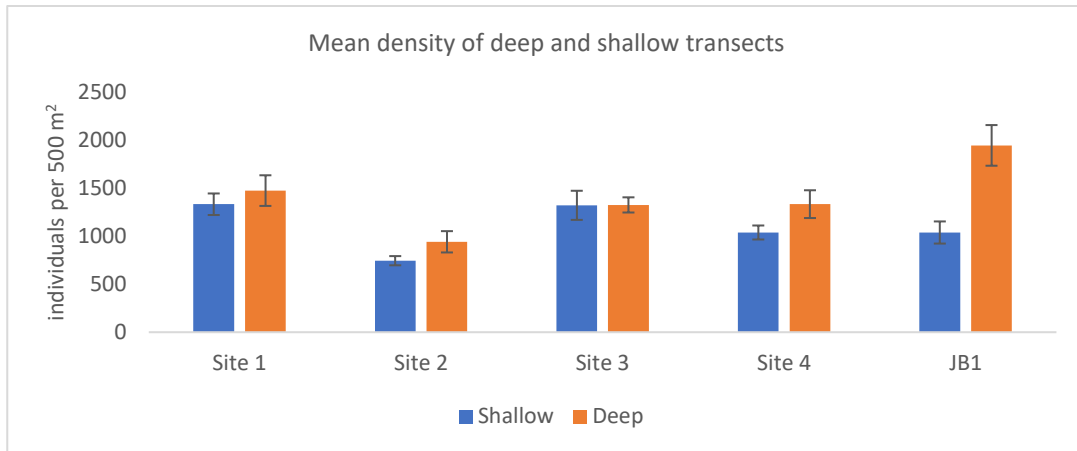


Figure 3. Mean fish density (individuals per 500 m²) at depths per site. Error bar represents the standard error of the mean.

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

Biomass

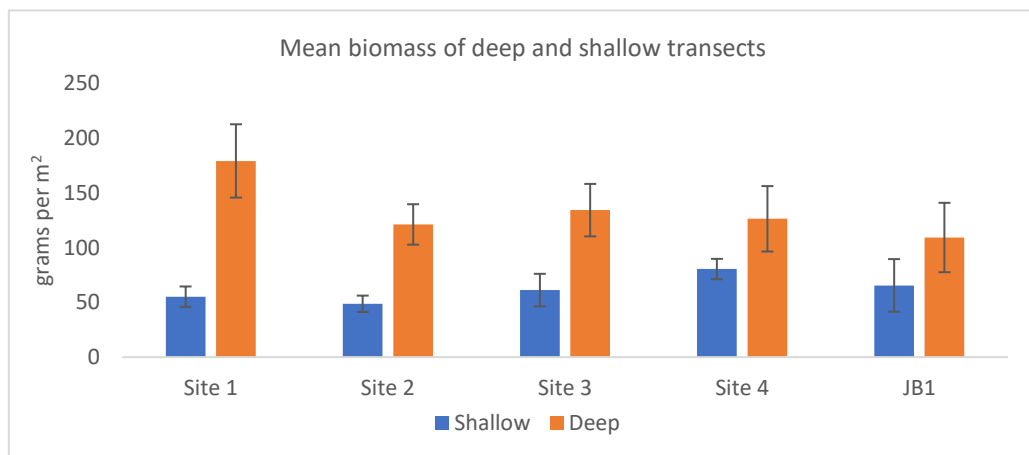


Figure 4. Distribution of mean biomass (gram per m²) per depth in Tubbataha Reefs. Error bar represents the standard error of the mean.

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

Fish groups: Target, indicator, and major

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

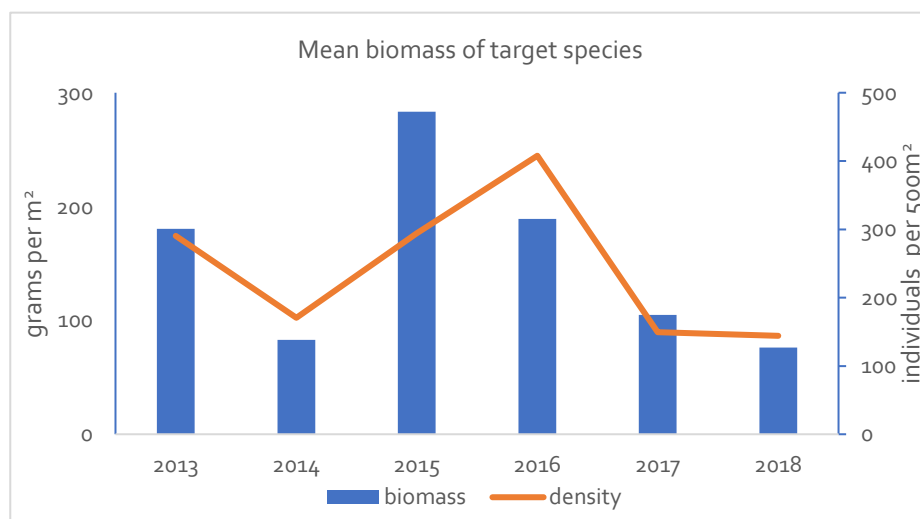


Figure 5. Temporal patterns of density (inds./500 m²) and biomass (g/m²) of fishery targeted species since 2013.

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

In the case of indicator species, all sites, except Site 3, were characterized by high mean density of angelfish (Pomacanthidae) ranging from 8 ind/500m² (Site 3) to 18 ind/500m² (Site 1). On the other hand, the biomass of the butterflyfish (Chaetodontidae) was consistently higher than that of the angelfish (Pomacanthidae) across all the survey sites. Overall, the mean biomass of indicator species this year is 1.75 g/m², an improvement from last year's 1.45 g/m². Their increased presence can indicate that the coral community or their preferred prey is adequate to support their diet. It is still unclear how the abundance of corallivores can affect and limit the recovery of their prey coral species, and further stress the corals especially after a site experiences extrinsic disturbance (Cole *et al.* 1998; Glynn 1996; Bellwood *et al.* 2006).

Major species' density is represented by fairy basslets/anthias (889.5 ind/500m²) and damselfish (825 ind/500m²). Although they have the highest contribution in the density, the triggerfish (Balistidae) is the highest contributor of biomass in all sites, except in deep areas of Site 4 (Kook) and JB4 (Jessie Beazley Reef).

Patterns of Fish Biomass

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

The polynomial trend is stable although there are some years with abrupt decrease such as in 2003, 2008, and 2014. This may be due to compensation of the increase in biomass estimates in subsequent years (Figure 6). Meanwhile, 2016 – 2018 exhibited a downward trend. This decline in the biomass from the last three (3) years were driven by the significant decrease in the

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

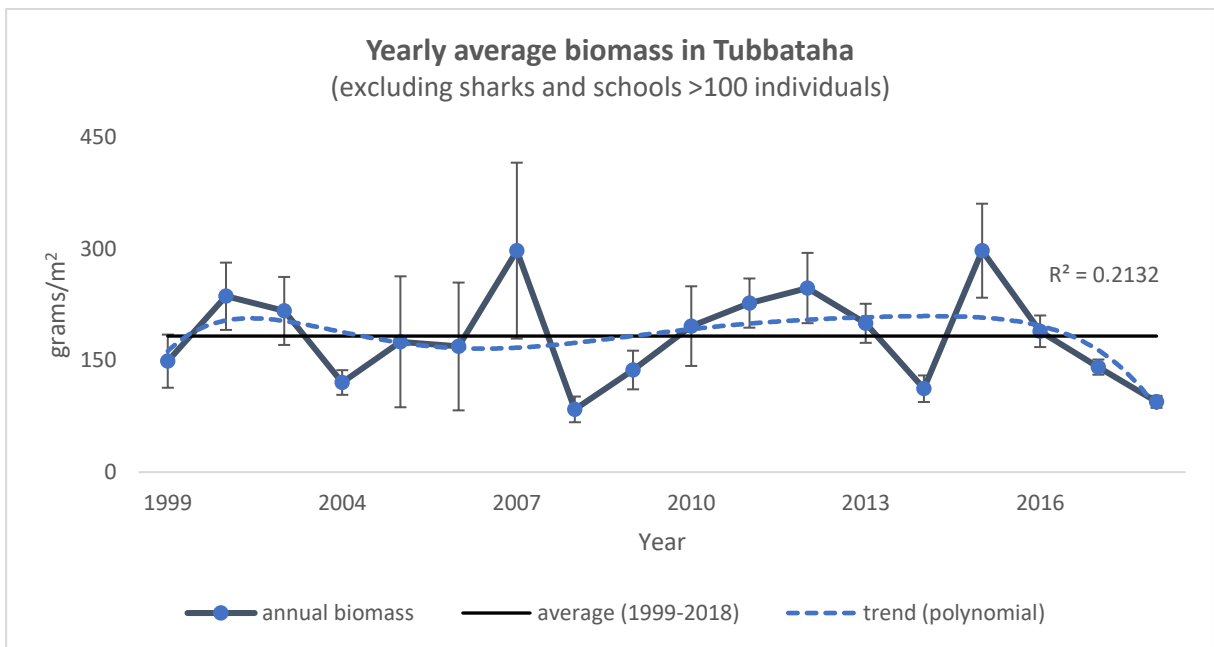


Figure 6. Temporal patterns of mean biomass (g/m²) (excluding sharks and big schools) in TRNP. Error bar represents the standard error of the mean.

The annual biomass estimates in shallow areas are much closer to average than in its deep counterpart (Figure 7). Moreover, it appears more stable. An oscillating pattern exhibited by polynomial trend in deep areas resembled the form in Figure 6. The polynomial trend in shallow transects exhibited a downward trend in the earlier years of surveys and plateauing until 2015 but showing downward trend again from 2017. Yet again, the seasonality and other ecological factors affecting the movements of fishes as mentioned above were attributed to the

fluctuations and decline in the biomass yields of Tubbataha Reefs. Families that contributed to the decrease in the biomass from 2015 – 2018 in the deep stations were the Caesionidae (fusiliers), Lutjanidae (snappers), and Scaridae (parrotfish), while the decrease in Nemipteridae (breams) and Carangidae (jacks and trevallies) contributed in the shallow part. Less sightings of Acanthuridae (surgeonfish) for both depths also contributed to these declines.

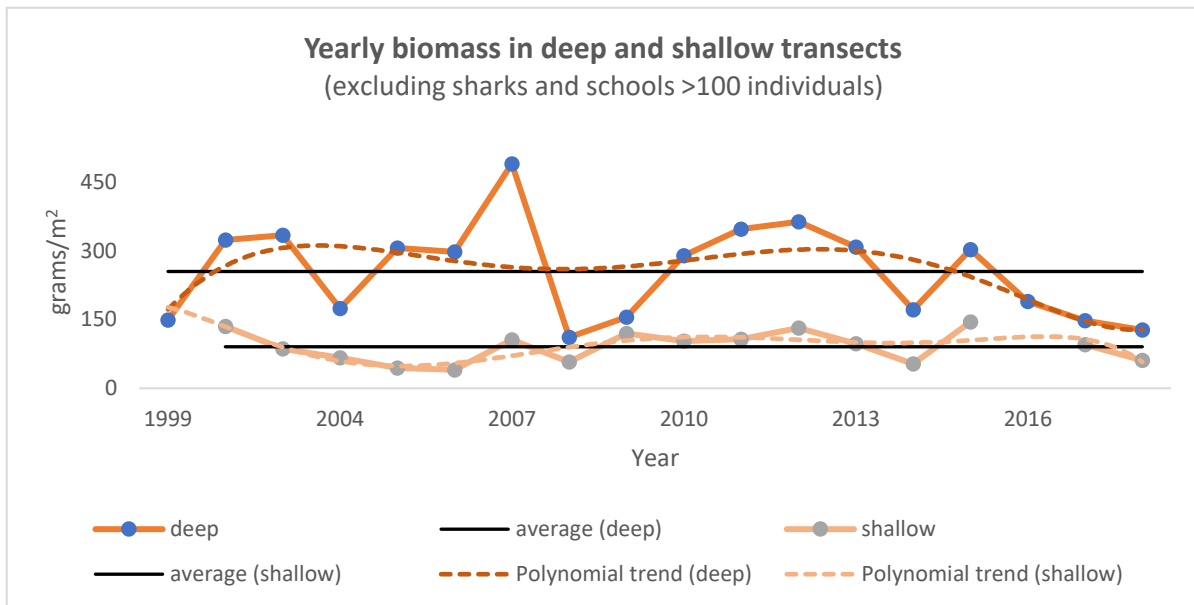


Figure 7. Temporal patterns of mean biomass (g/m²) of deep and shallow areas (excluding sharks and schools with >100 individuals). No data for shallow areas in 2016.

Pelagic and Demersal

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

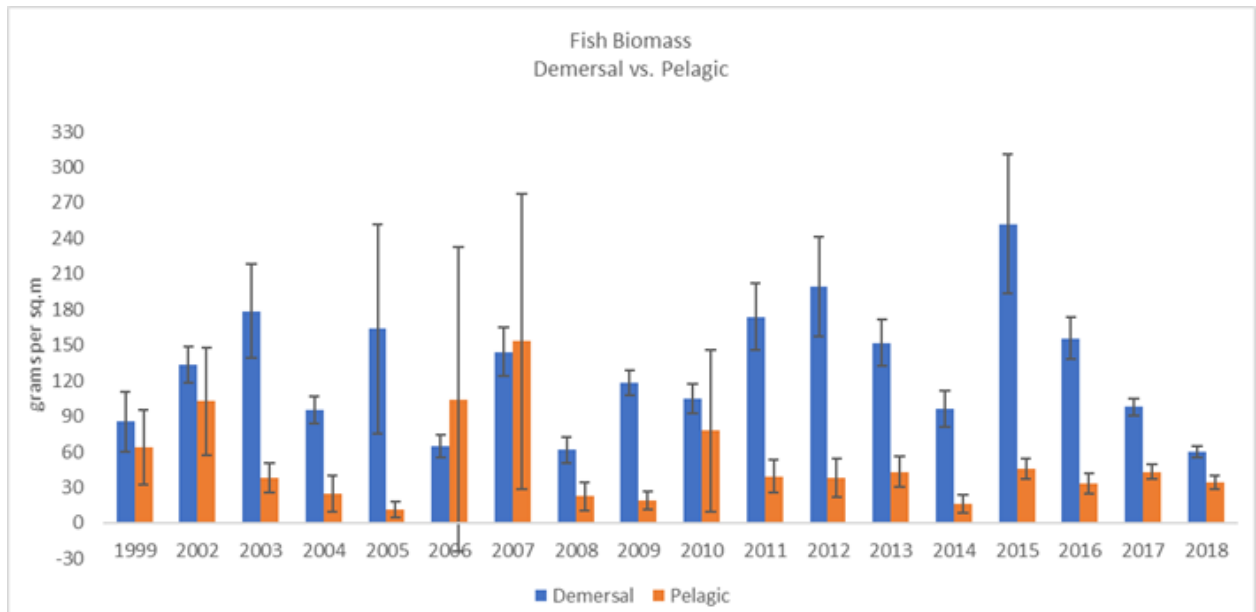


Figure 8. Temporal patterns of mean biomass (grams per m²) distribution of pelagic and demersal species per depths in regular monitoring sites of Tubbataha Reefs.

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

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

Trophic Groups

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

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

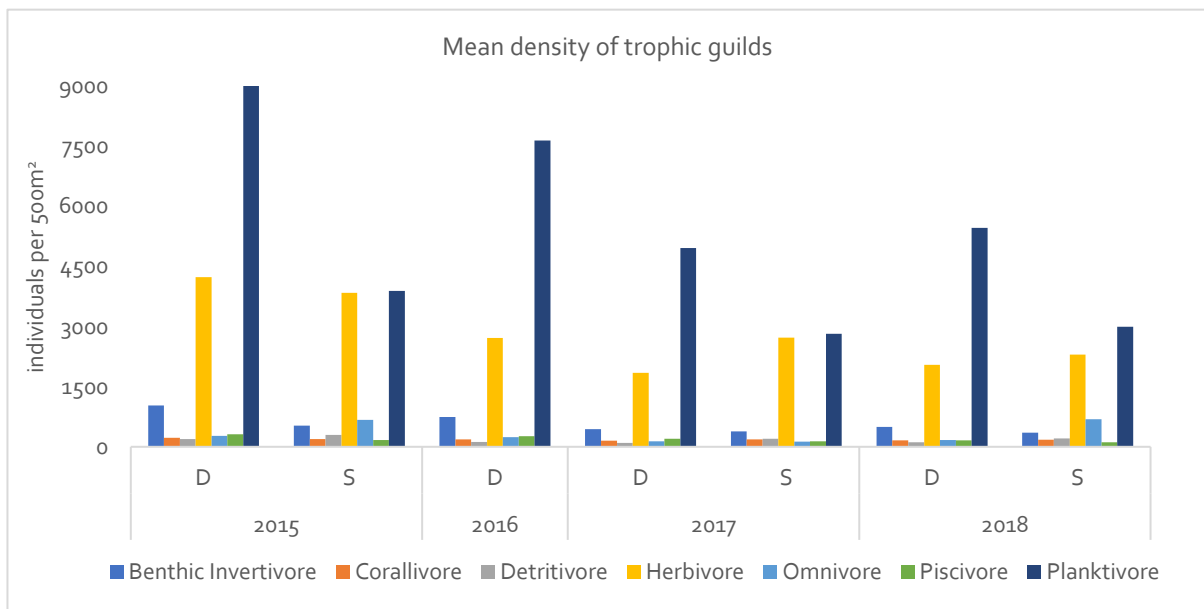


Figure 9. Density (g/m^2) of trophic groups (based on the species' diet) at shallow and deep areas from 2015 to 2018. No data for shallow areas of 2016 due to lack of manpower.

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

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

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

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

Threatened Species

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

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

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

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

Grounding Sites

A total of 163 species under 29 families and subfamilies were identified in the Min Ping Yu grounding site, while 137 species under 24 families were recorded in the USS Guardian site. This is an improvement from last year's 131 (Min Ping Yu) and 110 (USS Guardian) species. The Min Ping Yu site has a family richness of 25.5, while the USS Guardian site has 21 families recorded. The Min Ping Yu grounding site has a species richness of 72.5 sp./ 500m² and USS Guardian has 53 sp./ 500m². Both fall under the very high level of established categories for a healthy reef fish community (Hilomen *et al.* 2000).

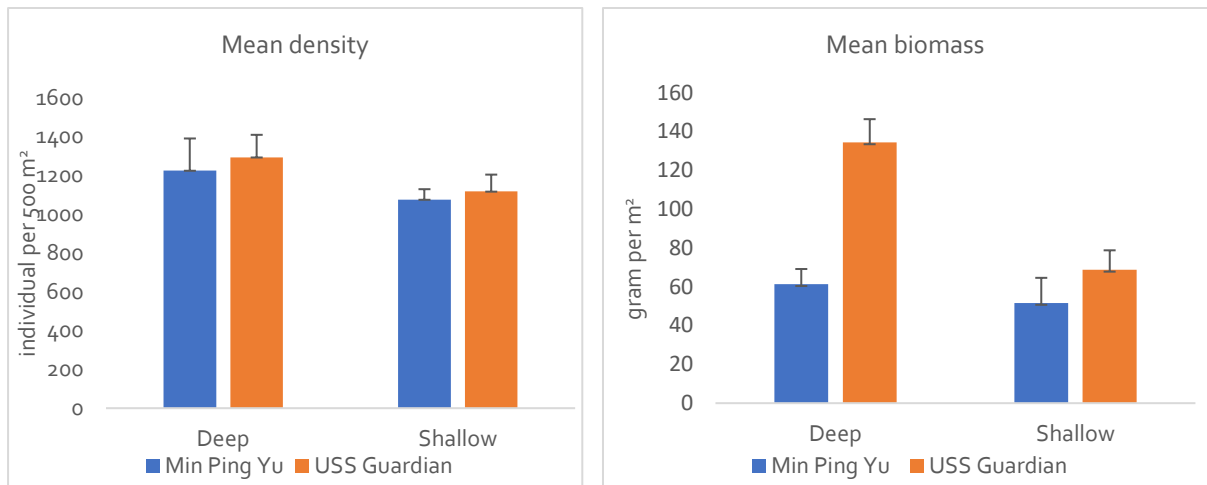


Figure 10. Relative distribution of mean density (individuals per 500 m²) and biomass (g/m²) in shallow and deep areas of Min Ping Yu and USS Guardian grounding sites. Error bar represents standard error of the mean.

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

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

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

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

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

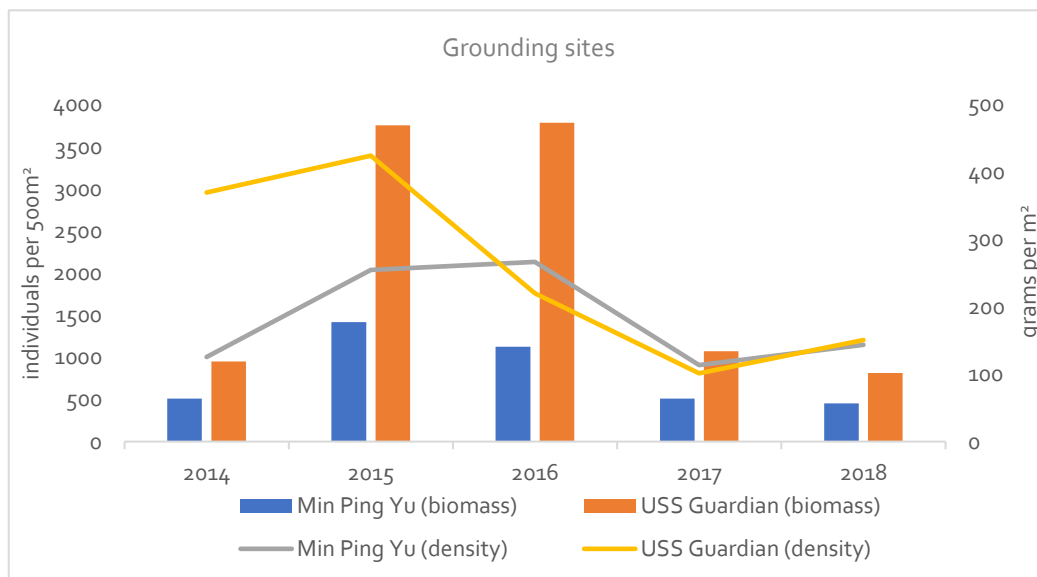


Figure 11. Temporal patterns of mean biomass (g/m^2) and mean density (ind./500 m^2) of Min Ping Yu and USS Guardian grounding sites.

As with the previous years of monitoring, the mean density and mean biomass of sites adjacent to USS Guardian is relatively higher compared to Min Ping Yu (Figure 11). The mean biomass of both sites shows an increasing trend until 2016, which is mainly attributed to encounters with large-bodied, schooling fishes. However, these groups were not prominent in 2018, thus resulting in lower biomass yields. Again, these chance encounters can be attributed to the

horizontal and vertical migration pattern of fish influenced by feeding and spawning, diver presence, and ontogenetic shifts in habitat requirements (Bone and More 2008; Sale 2002). Furthermore, observer bias due to different readers through years may also be a key factor in the huge difference between 2015-2016 and 2017-2018 biomass estimates. Moreover, it is worth noting that in spite of the disturbances that affected these sites, the fish community has remained healthy, evident in high density and high biomass outputs (Hilomen *et al.* 2000; Nañola *et al.* 2004) since 2014.

2.4 Conclusions

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

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

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

2.5 Recommendations

1. It is recommended that at least one dive be dedicated to the standardization of size and count estimates among the observers prior to the actual surveys to ensure uniformity among all observers.
2. The same observers need to be employed every year as much as possible.
3. Further, it is also recommended that the practice of having dedicated personnel to lay and retrieve the transect lines be continued to increase efficiency.

2.6 References

BONE, Q. AND MOORE, R. 2008. *Biology of Fishes*. Third Edition.

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

DYGICO, M. 2006. *Tubbataha Reefs: A marine protected area that works. A case study on the Philippines*. WWF-Philippines, Quezon City, Philippines


ENGLISH, S. S., WILKINSON, C. C. & BAKER, V. V. 1997. *Survey manual for tropical marine resources*. Australian Institute of Marine Science (AIMS).

FROESE, R. AND D. PAULY (eds.). Oct 2015. *FishBase*. www.fishbase.org.

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

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

- HOURIGAN TF, TC TRICAS, AND ES REESE. 1988. *Coral Reef Fishes as Indicators of Environmental Stress on Coral Reefs*. In DF Soule and GS Kleppel (Eds.). *Marine Organisms as Indicators* (pp. 107 – 136). New York, NY: Springer – Verlag.
- KAUNDA-ARARA B AND GA ROSE. 2004. *Long-distance movements of coral reef fishes*. *Coral Reefs*, 23 pp 410-412
- LEDESMA, M. 2005. *Technical Report. Monitoring changes in the benthic and fish community structure of Tubbataha Reef National Marine Park from 1997 to 2005*. Tubbataha Protected Area Management Board, Puerto Princesa City, Palawan. Unpublished report.
- LINDMAN, R. 1942. *The trophic-dynamic aspect of ecology*. *Ecology*. Vol. 23, No.4., pp. 399-417
- NAÑOLA, C.L., A.C. ALCALA, P.M. ALIÑO, H.O. ARCEO, W.L. CAMPOS, E.D. GOMEZ, W.Y. LICUANAN, M.C. QUIBILAN, A.J. UYCHIAOCO, AND A.T. WHITE. 2004. *Status of Philippines Reefs*. In Global Coral Reef Monitoring Network (GCRMN) report.
- OHMAN MC, RAJASURIYA A AND SVENSSON S. 1998. *The use of butterflyfishes (Chaetodontidae) as bio-indicators of habitat structure and human disturbance*. *Ambio* 27(8):708-716
- PAULY, D. 1984. *Fish population dynamics in tropical waters: a manual for use with programmable calculators*. ICLARM Studies and Reviews 8, 325p. International Center for Living Aquatic Resources Management, Manila, Philippines.
- PAULY, D., R. FROESE AND V. CHRISTENSEN. 1998. *How pervasive is "Fishing down marine food webs": response to Caddy et al*. *Science* 282: 183.
- PEREIRA, M.A. AND VIDEIRA, E. 2005. *Distribution and Community Structure of Butterflyfishes (Pisces: Chaetodontidae) in Southern Mozambique*. *Western Indian Ocean J. Mar. Sci.* Vol. 4, No. 1, pp. 39-46
- RUSS, G AND ALCALA, A. 1996. *Do marine reserves export adult fish biomass? Evidence from Apo Island, central Philippines*. *Marine Ecology Progress Series*. Vol. 132: pp. 1-9
- RUSS, G.R., ALCALA, A.C., AND CABANBAN, A.S. 1992. *Marine Reserves and fisheries management on coral reefs with preliminary modelling of the effects on yield per recruit*. pp. 978-985. In: *Proceedings of the Seventh International Coral Symposium, Guam*.

- 
- SABATER M. 2002. *Fish community structure in Tubbataha reefs and other sites along the Cagayan Ridge with emphasis on spatial and temporal variations and trophic relationships*. Annual research and monitoring report 2002. WWF-Phils. Unpublished report.
- TUBBATAHA MANAGEMENT OFFICE. 2017. *Ecosystem Research and Monitoring 2017*. Tubbataha Protected Area Management Board. Puerto Princea City, Palawan
- WILKENSON, C., GREEN, A., ALMANY, A. AND DIONNE, S. 2003. *Monitoring Coral Reef Marine Protected Areas. A practical guide on how monitoring can support effective management of MPAs*. Australian Institute of Marine Science and the IUCN Marine Program.

3 REEF BENTHOS

*Maria Retchie Pagliawan, Rowell Alarcon, Noel Bundal, and Jeffrey David
Tubbataha Management Office*



3.1 Overview

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

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

3.2 Methods

Data collection

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

As in the previous years, four 20-meter transects were laid on the substrate at each depth. Each transect was placed approximately five (5) meters away from each other to provide four independent transects and avoid pseudo-replication. Photographs were taken at every meter of the transect using a digital camera with an underwater casing mounted on an aluminum monopod. This produced 20 frames of photos per transect, or a total of 1600 photos from all the monitoring sites.

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

Data Analysis

The photos were then processed using Coral Point Count with Excel extensions (CPCe) (Kohler and Gill 2006). The software overlaid ten random scoring points per image (1x1 meter frame), and benthos under each point was identified based on modified taxonomic amalgamation units (TAUs), introduced by van Woesik *et al.* (2009) which corresponds roughly to the common genera in TRNP (See Appendix 1). A total of 200 data points was scored per transect. Percentage cover per TAUs and diversity indices – Simpson’s (1-D) and Shannon Index (H) – were produced per transect and these were summarized and analyzed using Excel. Comparisons with the previous years were made using paired t-test in Excel.

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

| Category | Hard Coral Cover |
|-----------|------------------|
| Excellent | >44% |
| Good | >33 – 44% |
| Fair | >22 – 33% |
| Poor | 0 – 22% |

3.3 Results and Discussions

Present conditions

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

In general, soft coral cover is relatively low in the deep areas of most sites, except for Station JBA, where almost half (46.13%) of the monitoring transects is covered in soft corals. Algae, in the case of TRNP, is mostly coralline algae, which are important contributors to reef calcium carbonate and can facilitate coral recruitment (Dean *et al.* 2015). Mortalities occurred in very low

numbers, suggesting that there were no recent disturbances in the deep areas across all monitoring sites. The percentage of abiotic components (mainly rocks) has significantly increased in both stations of Site 2 (t-test; $p=0.02$). This increase may be attributed to strong wave action brought about by the southwest monsoon. Rocky substrate with patches of corals in between and the presence of sand was observed in this area. The cause of these changes appear to be gradual (e.g., storm surges and wave action) rather than abrupt (e.g., blast fishing), which suggests that the increase in abiotic components was brought about by natural causes.

The percentage cover of abiotic components is also high in Station 3B, although the difference from last year is not significant (t-test; $p=0.48$). The increase in rubble in Station 3B was noted last year and was attributed to the possible effects of strong waves exacerbated by the northeast monsoon. Site 3 is primarily composed of branching *Isopora bruggemanni*, which is susceptible to breakage and bleaching (Marshall and Baird 2000; Floros *et al.* 2004). Other invertebrates in the deep sites are mostly composed of sponges that are encrusting in form.

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

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

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

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

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

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

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

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

Temporal patterns

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

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

Algal assemblage in Tubbataha is mostly crustose coralline algae, which plays an important role in reef building and coral recruitment. Encrusting sponges constitute most of the other invertebrates in the deep areas in TRNP. Encrusting sponges are known to compete with corals for space at different rates depending on the angle at which the sponge approaches the coral (López-Victoria *et al.* 2006).

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

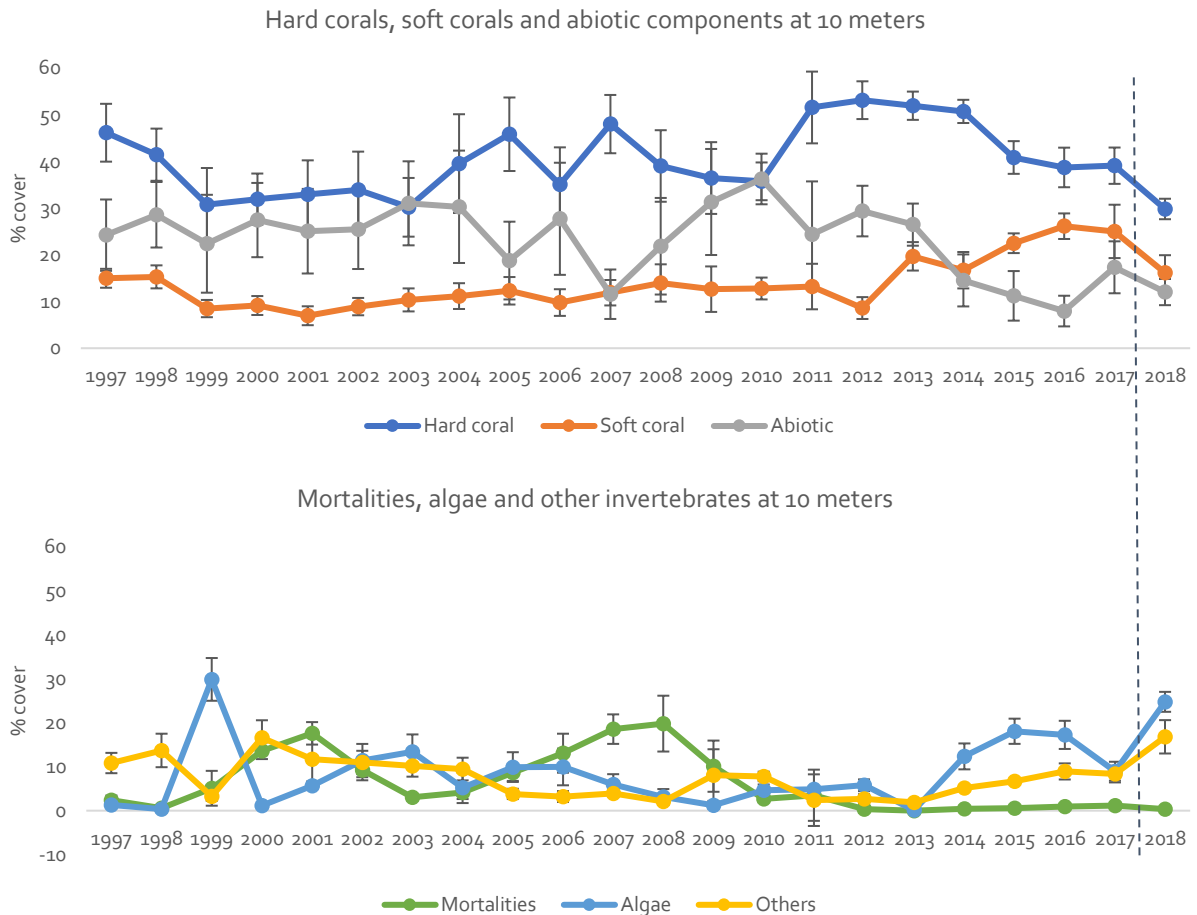


Figure 12. Characterization of reef benthos at the deep monitoring areas of TRNP. Error bars represent the standard error of the mean.

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

hard coral cover between this report and that of DLSU, the difference is still small compared to previous years (28% in 2017 and 29.8% in 2016) when the benthos-point intercept method was used.

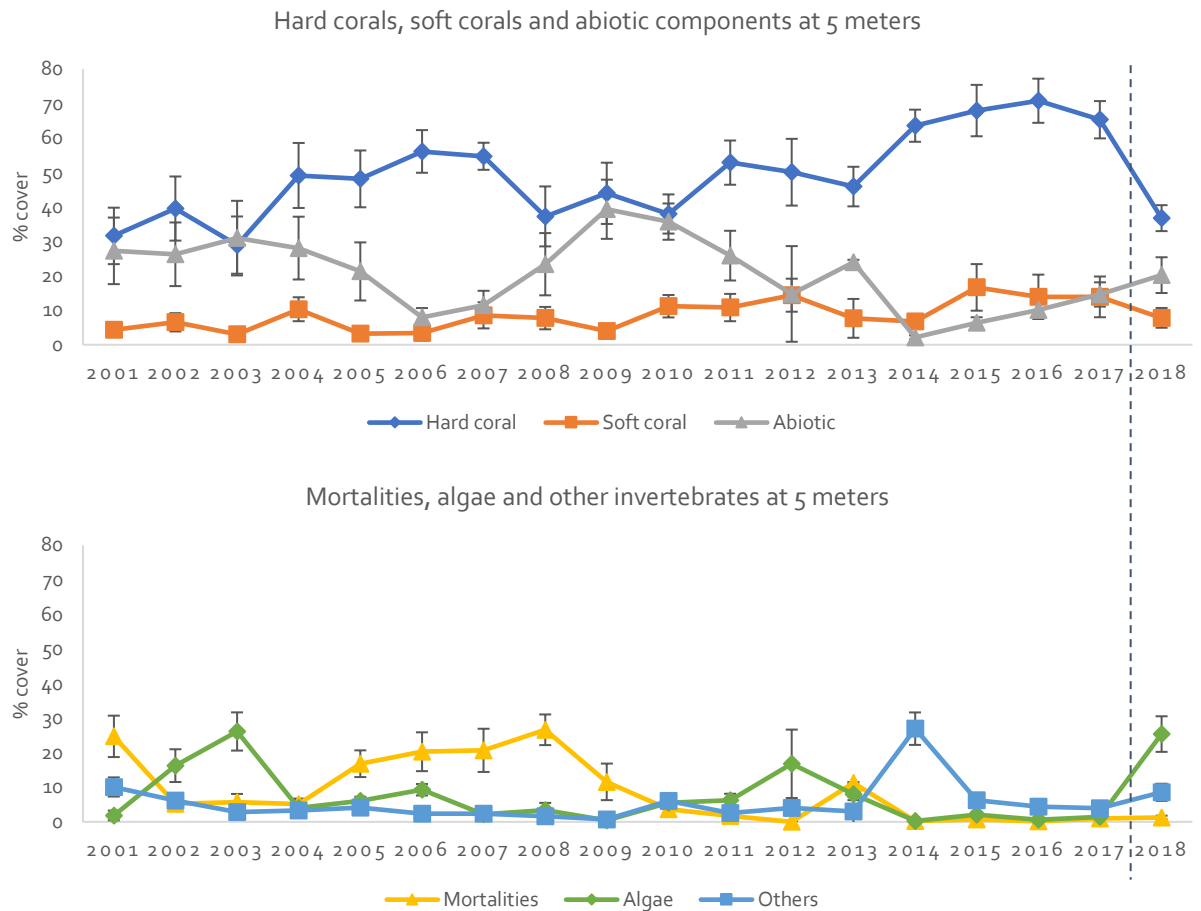


Figure 13. Characterization of reef benthos at the shallow monitoring areas of TRNP. Error bars represent the standard error of the mean.

Scleractinian Coral composition

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

and *Montipora*. In the shallow areas, Genus *Porites*, *Isopora*, *Montipora*, *Acropora* and *Echinopora* were the most common.

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

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

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

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

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

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

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

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

When it comes to more localized conditions, massive and encrusting corals, which are slow growing, can better withstand wave action, contrary to the *Acropora*-branching type which are

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

Notes on Invertebrates

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

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

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

Other observations

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

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

3.4 Conclusion

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

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

3.5 Recommendations

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

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

3.6 References

BRUNO JF and SELIG ER. 2007. Regional decline of coral cover in the Indo-Pacific: Timing, extent, and subregional comparisons. *PLoS ONE* 2(8): e711.

DEAN, A., STENECK, R., TAGER, D., and PANDOLFI, J. 2015. Distribution, abundance and diversity of crustose coralline algae on the Great Barrier Reef. *Coral Reefs* 34:581–594.

- FLOROS, CD, SAMWAYS, MJ and ARMSTRONG, B. 2004. Taxonomic patterns of bleaching within a South African coral assemblage. *Biodiversity and Conservation* 13, 1175-1194.
- GRIMSDITCH, G. and SALM, R. 2005. Coral Reef Resilience and Resistance to Bleaching. IUCN, Gland, Switzerland.
- KOHLER KE and GILL SM. 2006. Coral Point Count with Excel extensions (CPCe): a Visual Basic program for the determination of coral and substrate coverage using random point count methodology. *Computers & Geosciences* 32(9): 1259-1269.
- LICUANAN, A., REYES, M., LUZON, K., CHAN, M.A., and LICUANAN, W. 2017. Initial Findings of the National Assessment of Philippine Coral Reefs. *Philippine Journal of Science* 146(2):177-185
- LÓPEZ-VICTORIA, M., ZEA, S., and WEIL, E. 2006. Competition for space between encrusting excavating Caribbean sponges and other coral reef organisms. *Marine Ecology Progress Series*. Vol. 312: 113–121.
- LOYA, Y., K. SAKAI, K. YAMAZATO, Y. NAKANO, H. SAMBALI, and R. VAN WOESIK. 2001. Coral Bleaching: The Winners and the Losers. *Ecology Letters* 4: 122–131.
- MARSHALL PA and BAIRD AH. 2000. Bleaching of corals on the Great Barrier Reef: Differential susceptibilities among taxa. *Coral Reefs* 19, 155-163.
- MCCLANAHAN, T.R., BAIRD, A.H., MARSHALL, P.A., and TOSCANO, M.A. 2004. Comparing bleaching and mortality responses of hard corals between southern Kenya and the Great Barrier Reef, Australia. *Marine Pollution Bulletin* 48, 327-335.
- TUBBATAHA MANAGEMENT OFFICE. 2017. Ecosystem Research and Monitoring Report 2017. Tubbataha Protected Area Management Board. Puerto Princesa City, Philippines
- VAN WOESIK, R., GILNER, J. and HOOTEN, A. J. 2009. Standard Operating Procedures for Repeated Measures of Process and State Variables of Coral Reef Environments. Coral Reef Targeted Research and Capacity Building for Management Program. Queensland, St Lucia: The University of Queensland
- WILKINSON, C. (ed.). 2004. Status of coral reefs of the world. AIMS: Townsville, Australia 557 pp

4 SEABIRD POPULATION

Arne Erik Jensen¹, Angelique M. Songco², Maria Retchie C. Pagliawan² and Ma. Theresa R. Aquino³

¹ Wetlands International, Wild Bird Club of the Philippines

² Tubbataha Management Office

³ Marine Wildlife Watch of the Philippines



4.1 Overview

The objectives of the monitoring and inventory are:

- Review of avifauna field data produced by the Tubbataha Management Office (TMO) Marine Park Rangers (MPRs) since May 2017;
- Assessment of survey methods used by the TMO research team guided by the Consultant;
- On-the-job skills enhancement of the TMO MPRs, staff and partners in seabird monitoring and conduct of inventories;
- Preparation of a monitoring and inventory report on the seabirds and their breeding areas in the Tubbataha Reefs Natural Park (TRNP).

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

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

4.2 Methods

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

The counts of the breeding bird populations represent a combination of different count methods. These includes direct day-time inventories of adults, immatures, juveniles, pulli, eggs and nests. To determine the total seabird population numbers, an afternoon count of birds flying in to roost

was conducted from 4:30pm to 6:30pm on 12 May at South Islet (Appendix 19) and on 13 May at Bird Islet (Appendix 20). A count of dead birds and autopsies on sample individuals were also carried out. The field team also removed debris from the islets.

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

Calculation of breeding populations

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

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

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

Calculation of land area and vegetative cover

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

Vegetative cover was monitored by conducting a census of the condition of trees on the islets. Trees, mostly *Argusia argentia* and *Pisonia alba (grandis)*, were classified as either in optimal (good), moderately deteriorating (fair) or severely deteriorating (bad) condition and lastly, as dead. The

inventory of 2018 was carried out using the same methodology as all other years, except in 2013, the trend over time is, therefore, comparable.

4.3 Results and conclusion

Monitoring of Changes in Land Area

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

Bird Islet: Overall, the land area has decreased by 18.4%; from 18,760 m² in 1981(Kennedy 1982) to about 15,373 m² in 2018 (Table 5).

The circumference of the islet measured along the high tide line is 568 meters compared to 586 meters in 2017, or about the same (variation = 3%). The land area was measured to be 15,373 m² (lowest measurement dataset) compared to 15,307 m² or about the same as in 2017 (variation = 66 m² or 2.2%).

The 'Plaza' defined as the central area of the islet dominated by barren soil with no or little vegetation was measured to only to be 2,572 m², or historically the smallest area ever recorded. Compared to 2016 it is a reduction by 1,941 m² or 43% caused by tussock grass expansion into 'Plaza', especially in the northern part. Erosion in May 2018 did not impact the size of 'Plaza'. Only a minor section of the northeastern coastline, first noted in 2012, has continued to erode although in a much smaller scale since 2016.

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

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

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

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

| Year | Land area (length x width)/circumference (m) | Land area (high tide) (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 | 568 | 15,373 | 2,572 | NW: Two small sandbars off the coast SE : As above | Northeast coast |

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

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

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

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

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

Monitoring of Changes in Habitats

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

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

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

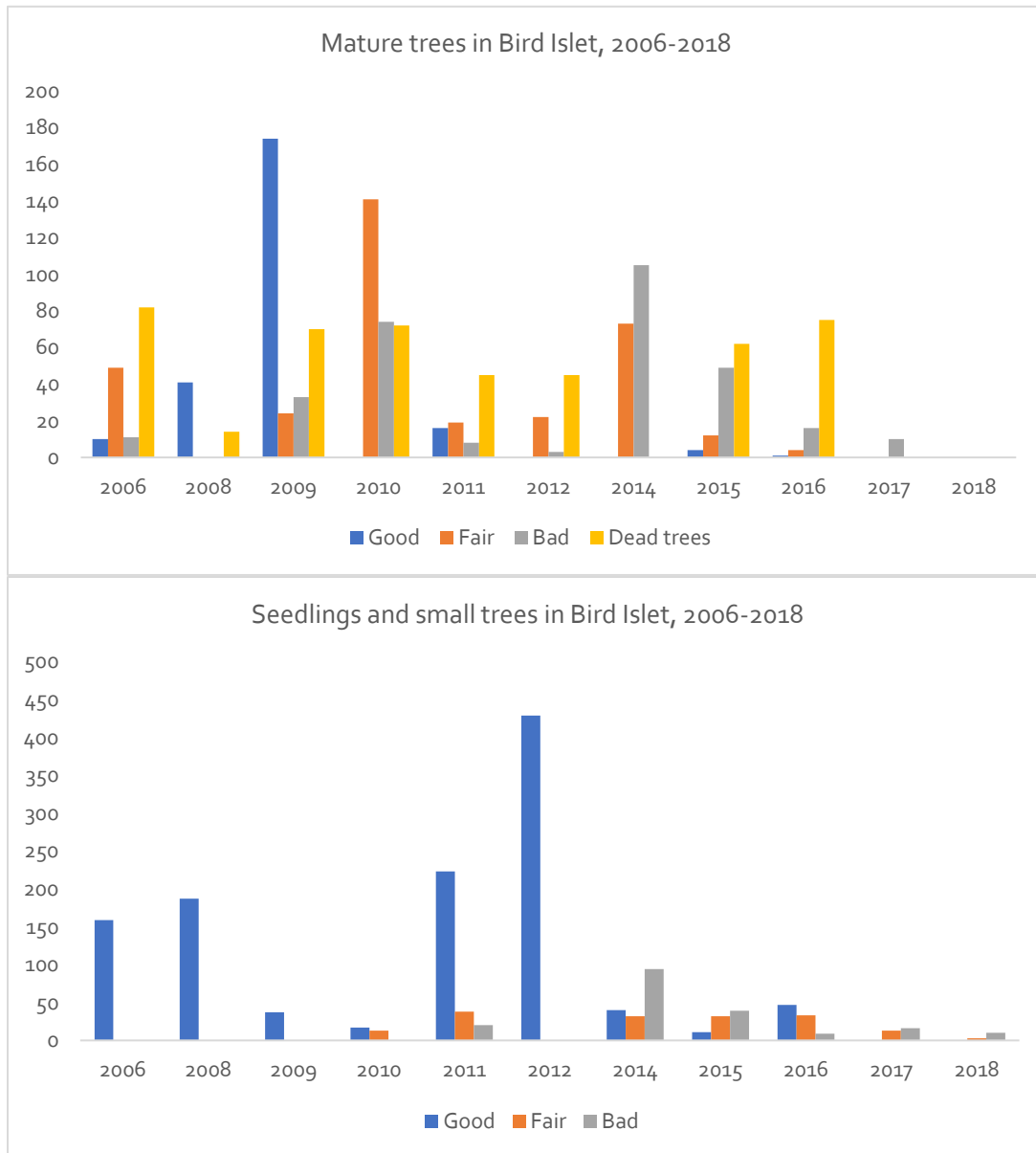


Figure 14. Status of vegetation in Bird Islet from 2006 to 2018.

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

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

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

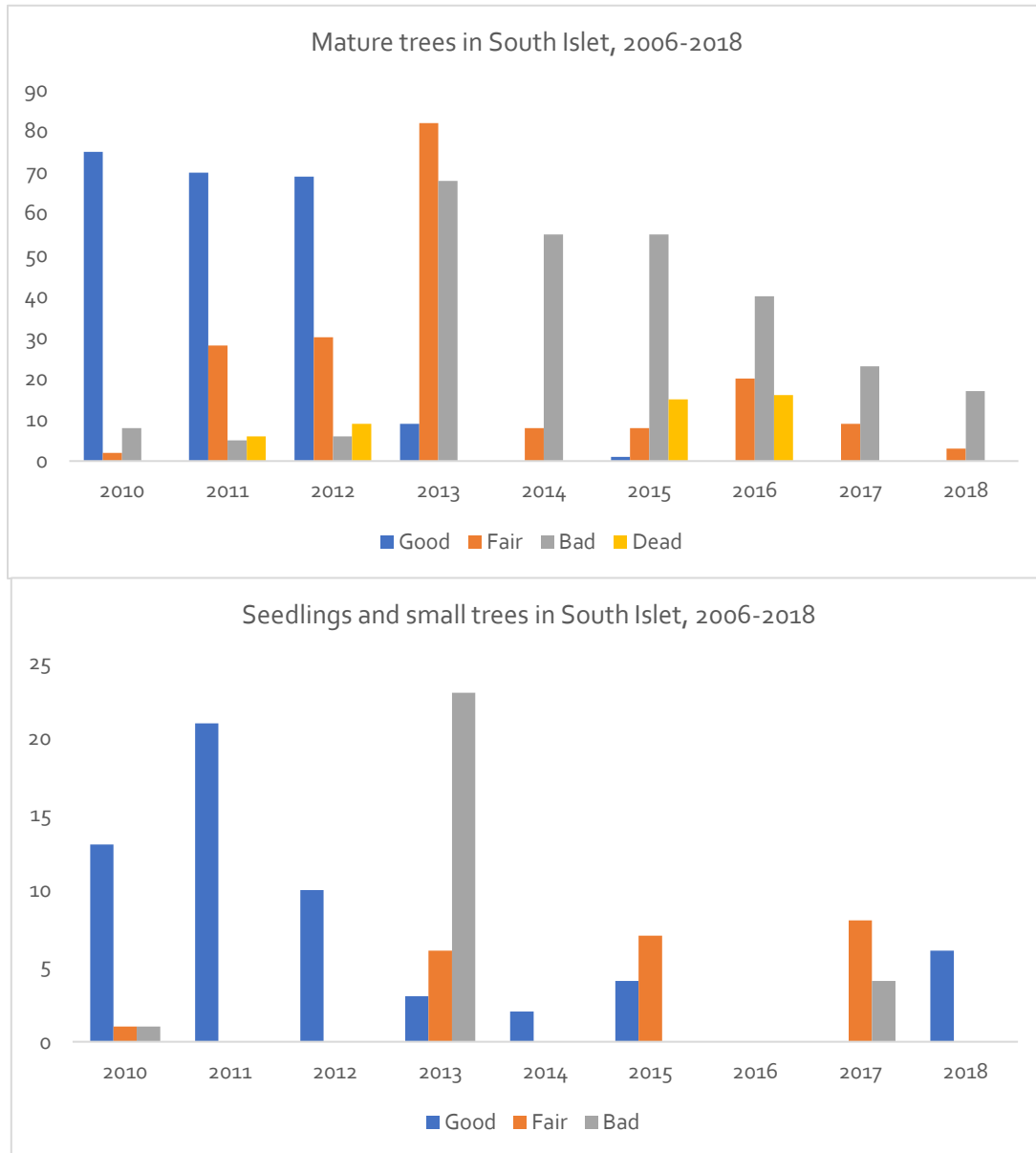


Figure 15. Status of vegetation in South Islet from 2010 to 2018.

Avifauna

Review of MPR Monitoring Data

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

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

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

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

Avifauna Inventory Results

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

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

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

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

A total 41,794 adult individuals of six breeding and one former breeding seabird species were recorded; 37,663 individuals on Bird Islet and 4,134 individuals on South Islet (Table 7). Bird Islet hosted 90% of the breeding population and South Islet 10% of the population. The population on Bird Islet has increased by 17% since 2016 when it hosted 73% of the total population. On South Islet, due to habitat loss, the population has decreased from 27% to 10% since 2016.

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

In summary, the count results for May 2018 showed:

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

- **Brown Booby:** A stable population, about 11% lower than in the baseline year of 1981 (3,768 adults). The result in May 2018 falls within the margin of inaccuracy of the data produced and may not express a decline.
- **Brown Noddy:** Second highest breeding population and more than 60% higher than in 1981 when the population was counted for the first time. The species surprisingly overwintered in relatively large numbers (> 700 individuals) at Bird Islet but not at South Islet. Presence of around 1,500 adults with more than 500 nests, of which most contained eggs, in early February 2018. This is the first ever recorded extremely early start of the breeding season. The season extended at least until May 2018.
- **Black Noddy:** A continued decrease in the population and occurrence of nesting corresponds to the decline in the number and condition of the vegetation. On South Islet the decline in the number of adult birds is 54%. Nesting is lower by 57% compared to May 2017. On Bird Islet the pilot establishment of artificial breeding areas increased the presence of adult birds, from around 800 in 2017 to more than 2,500 in 2018. A corresponding increase in nests from around 150 nests in 2017 to about 680 in 2018 was also recorded. Nearly all nests were established on artificial breeding structures erected since 2017. Despite the very positive result the input is insufficient: 57% of the breeding population or about 6,100 adult birds are now absent from TNRP due to continued lack of nesting sites and, importantly, also nesting materials.
- **Great Crested Tern:** The increase in the breeding population of Great Crested Tern continued in 2018 but at lower pace compared to 2017. Overall, the population is at its highest number ever recorded.
- **Sooty Tern:** The breeding season of Sooty Tern started end of February/ beginning of March. Hence, the inventory was able document what can be perceived as the entire adult population represented by the highest count ever.

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

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

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

Species Account of Breeding Birds

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

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

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

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

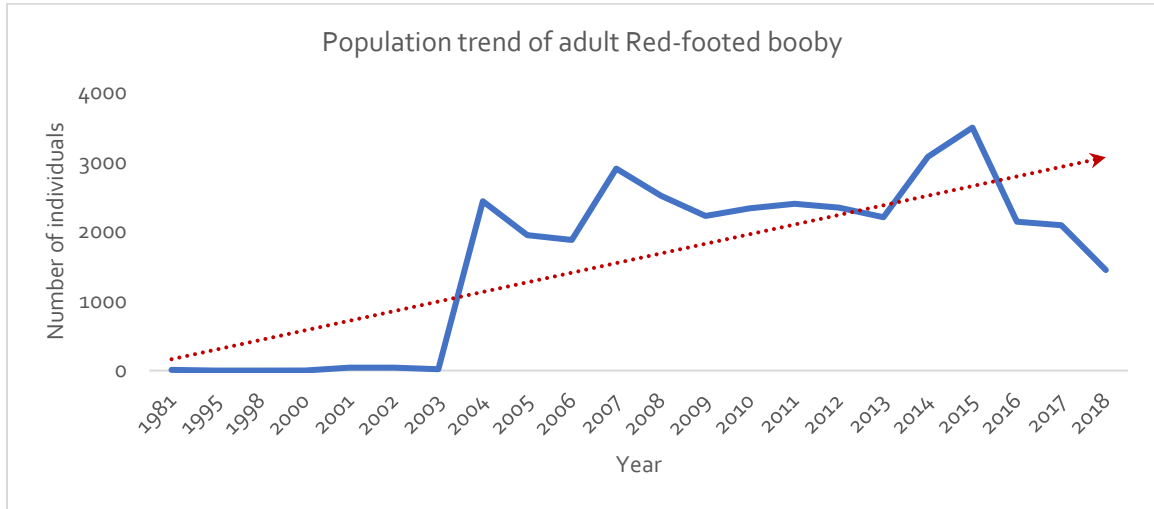


Figure 16. Population trend of adult Red-footed Booby from 1981 to 2018

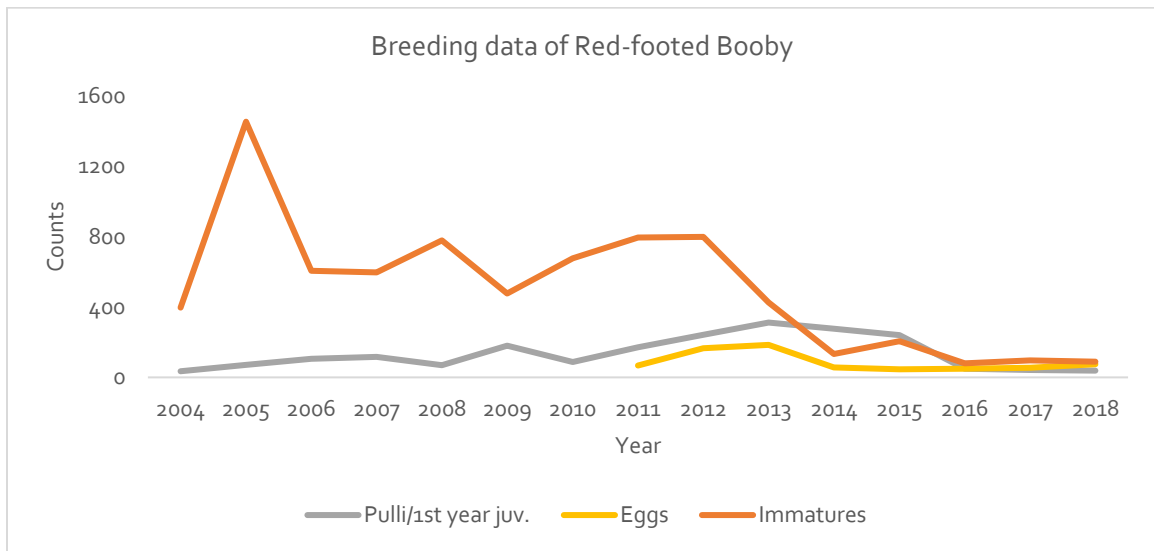


Figure 17. Breeding data of Red-footed Booby from 2004 to 2018

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

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

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

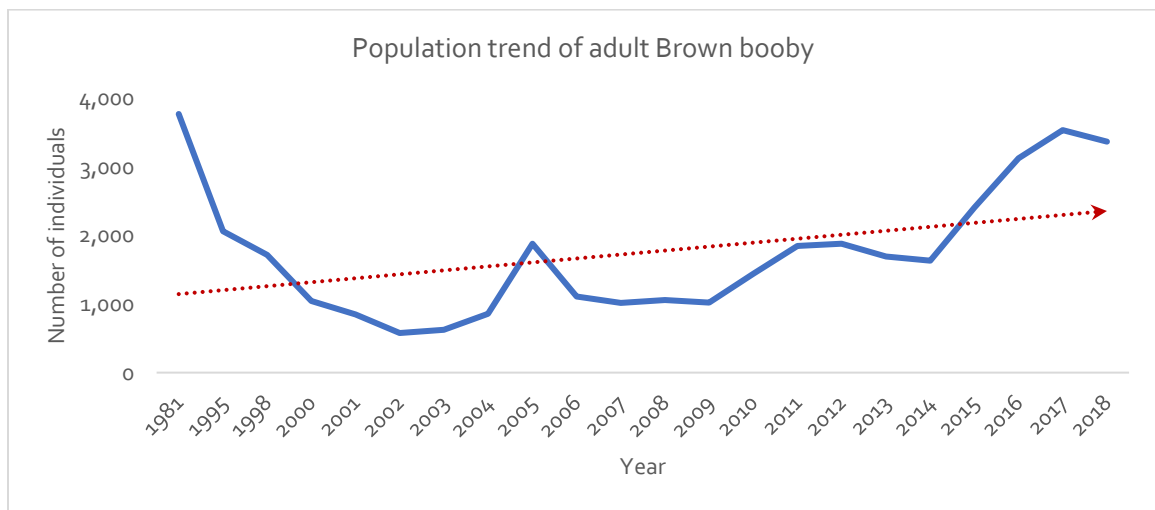


Figure 18. Population trend of adult Brown Booby from 1981 to 2018.

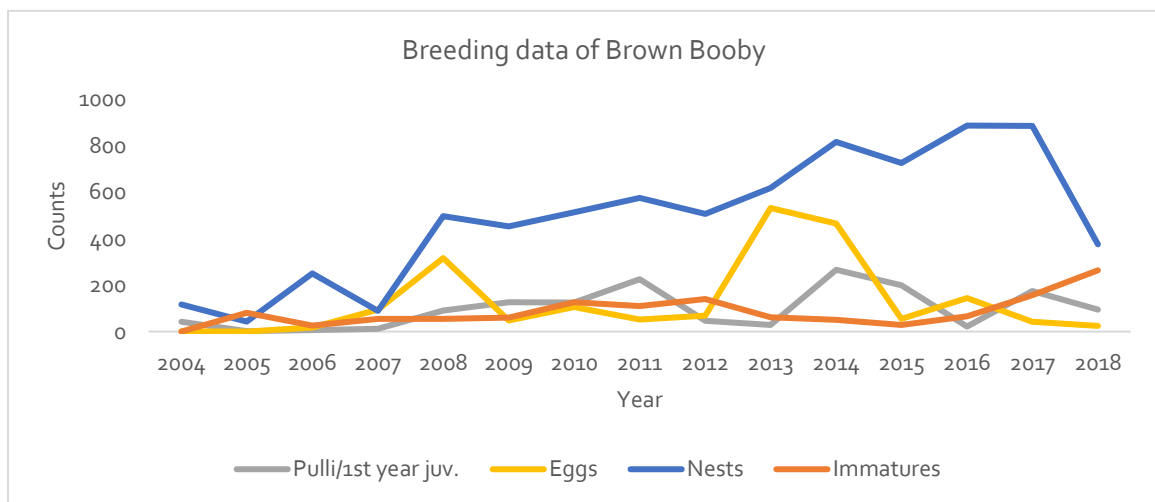


Figure 19. Breeding data of Brown Booby from 2004 to 2018.

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

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

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

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

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

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

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

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

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

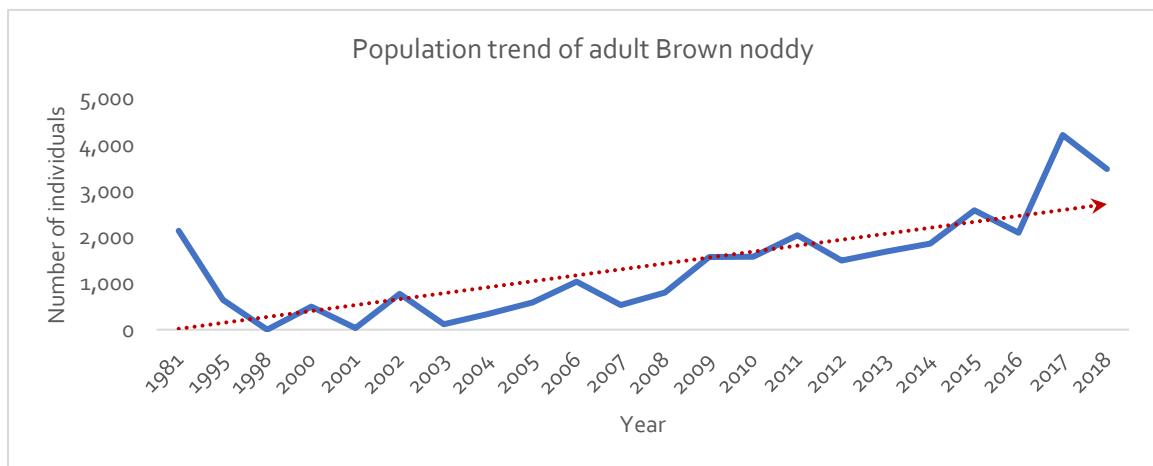


Figure 20. Population trend of adult Brown Noddy from 1981 to 2018.

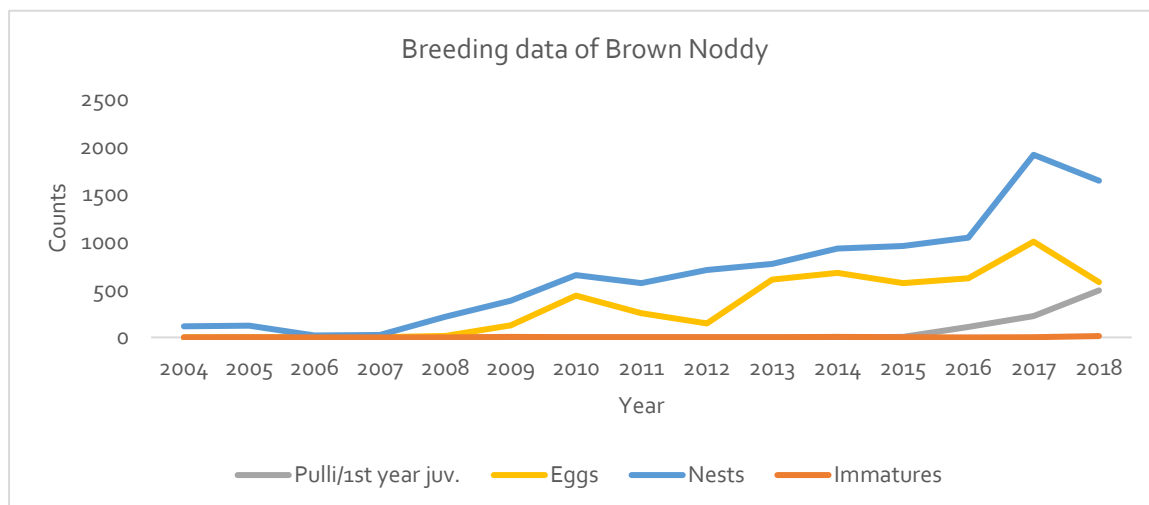


Figure 21. Breeding data of Brown Noddy from 2004 to 2018.

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

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

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

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

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

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

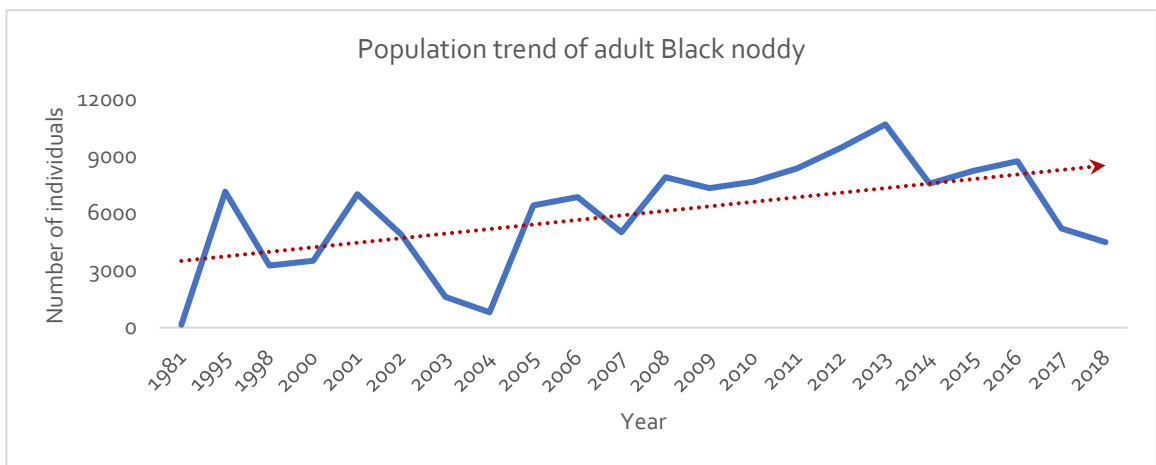


Figure 22. Population trend of adult Black Noddy from 1981 to 2018.

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

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

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

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

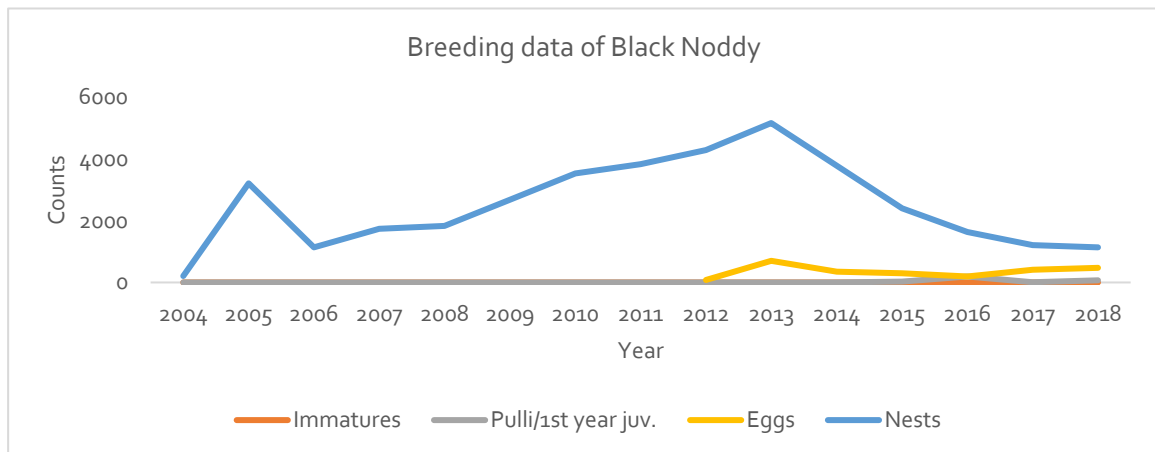


Figure 23. Breeding data of Black Noddy from 2004 to 2018.

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

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

The arrival of 1,250 breeding individuals, was first noted on 18 March 2018 by the MRPs. In May 2018 the majority of the population was in an active egg-laying stage while about 10% of the

population already had pulli offsprings. More than 7,460 eggs were counted but it was noted that more birds laid eggs from day to day (Figure 24, Appendix 18). The continuous population growth has resulted in a breeding population that is now more than three times larger than in the baseline year of 1981 (Kennedy 1982). As in the previous years, there was no breeding population found on South Islet.

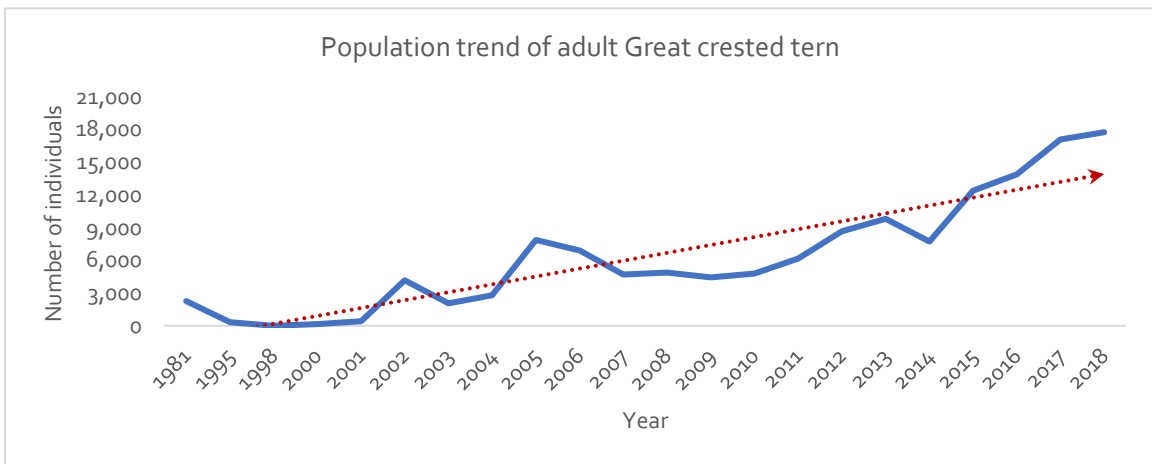


Figure 25. Population trend of adult Great Crested Tern from 1981 to 2018.

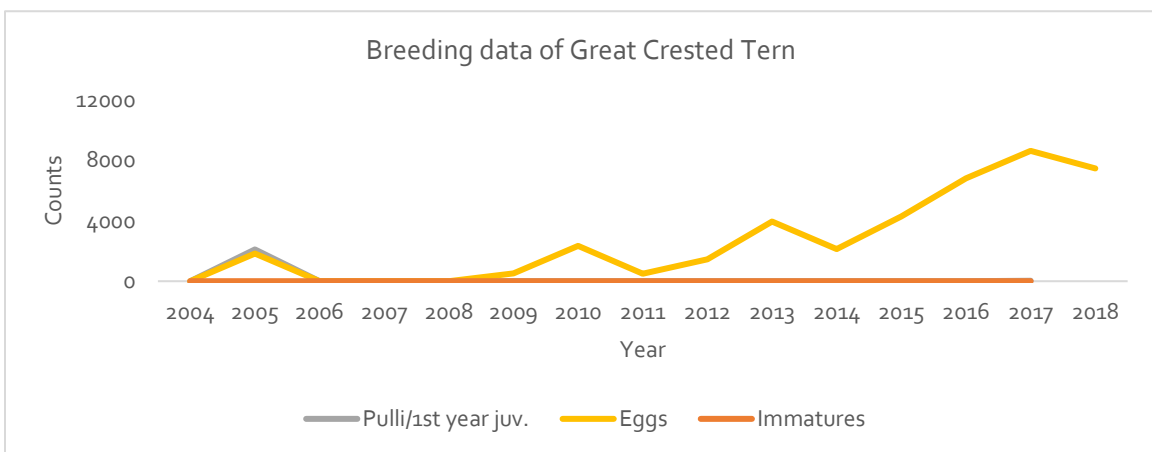


Figure 24. Breeding data of Great Crested Tern from 2004 to 2018.

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

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

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

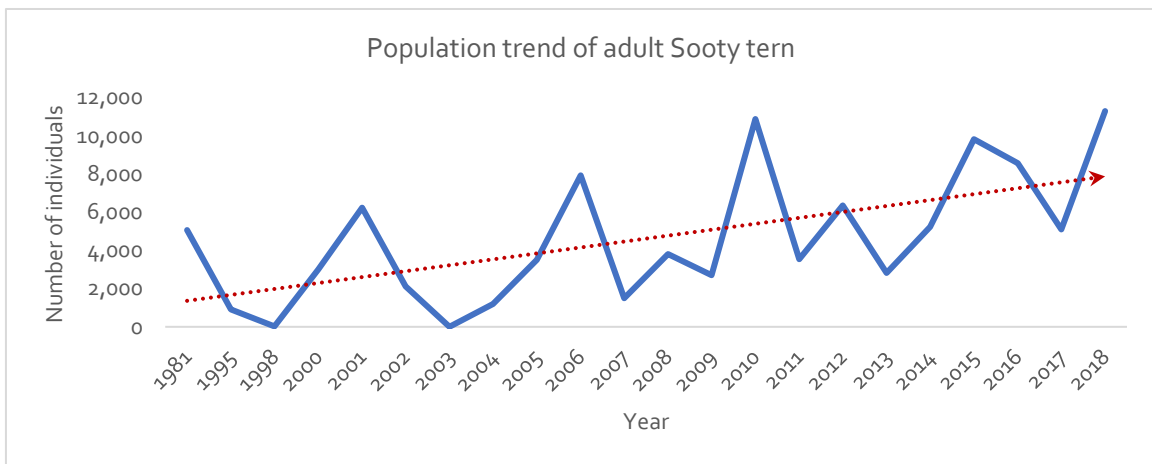


Figure 27. Population trend of adult Sooty Tern from 1981 to 2018.

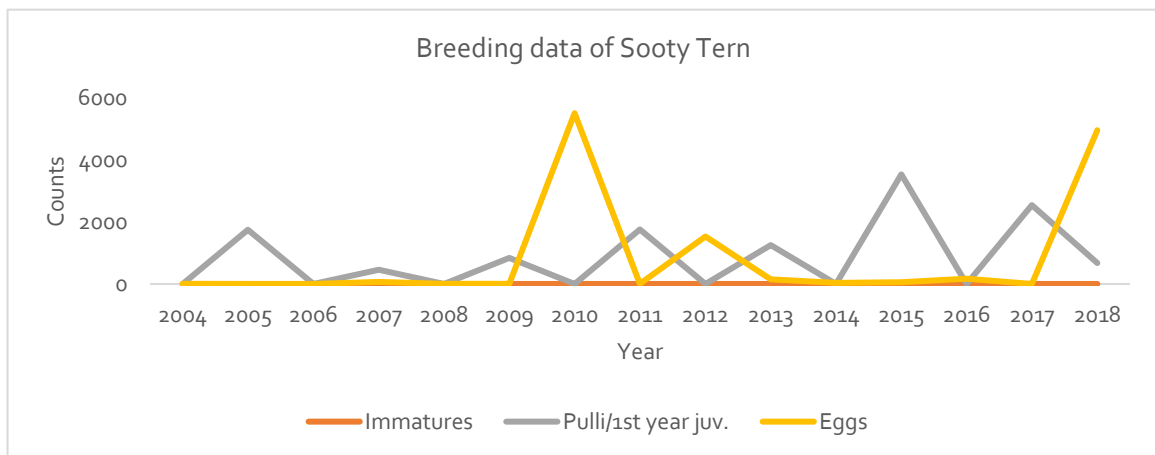


Figure 26. Breeding data of Sooty Tern from 2004 to 2018.

Pacific Reef Heron: The total adult population in May 2018 was only 9 adult individuals compared to 16 individuals in 2017 and 19 individuals in 2016. Four birds were recorded on South Islet together with one nest containing 3 eggs and two empty nests. On Bird Islet four adult birds but no nests were found. All birds recorded in May 2018 were of the dark phase.

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

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

Results of examination of dead birds in Bird Islet

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

4.4 Management recommendations for 2018 and beyond

Habitat

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

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

Species

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

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

Methodology

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

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

4.5 References

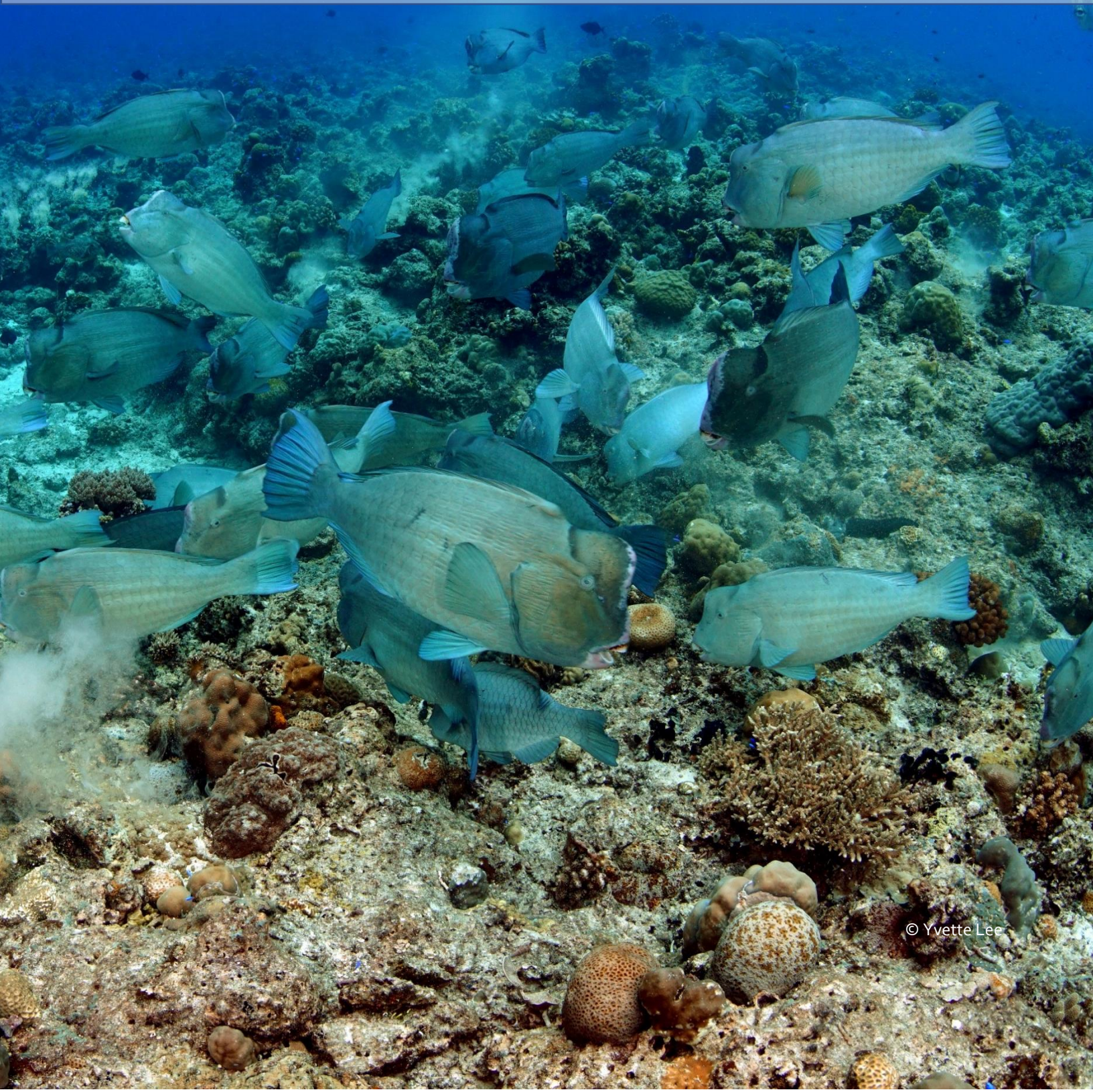
HENNICKE, J.C., KING, B., DRYNAN, D., HARDY, L.J., STOKES, A. AND TAYLOR, S. 2012. New lifespan records of the Brown Booby *Sula leucogaster*. *Marine Ornithology* 40: 125–126 (2012).

HEEGAARD, M. AND JENSEN, A.E. 1992. Tubbataha Reef National Marine Park – a preliminary ornithological inventory. *Enviroscope* Vol. VII, 7: 13-19. *Haribon Foundation*.

- CONALES JR, S. AND PAGLIAWAN, M.R.C. 2017 Masked Booby *Sula dactylatra* returns to Tubbataha Reefs Natural Park, Palawan, Philippines. *Birding Asia* 28 (2017): 61-62.
- GONZALES, J.C.T . *ET AL* 2018. Scientific review and update of the National List of Threatened Terrestrial Fauna of the Philippines. *Sylvatrop*, The Technical Journal of Philippine Ecosystems and Natural Resources 28 (1): 73-145.
- JENSEN, A. E. 2004. Monitoring and inventory of the seabirds of Tubbataha Reef Marine National Park and Cawili Island, the Sulu Sea. With notes on the population development and habitat status. May 2004. *Tubbataha Protected Area Management Board and WWF- Philippines*. Unpublished Report.
- JENSEN, A. E. 2005. Monitoring and Inventory of the Seabirds of Tubbataha Reef Marine National Park, Cagayancillo, Palawan, the Philippines, May 7-11, 2005. *Tubbataha Protected Area Management Board*. Unpublished Report.
- JENSEN, A.E. 2006. Monitoring and Inventory of the Seabirds and their Breeding Areas in Tubbataha Reef Marine National Park, Cagayancillo, Palawan, the Philippines, April 27 - May 1, 2006. *Tubbataha Protected Area Management Board and WWF-Philippines*. Unpublished Report.
- JENSEN, A. E. 2009. Population development of the breeding seabirds from 1981 to 2009 in Tubbataha Reefs Natural Park & World Heritage Site, Palawan, the Philippines. *Tubbataha Management Office, Puerto Princesa City, Philippines*. Unpublished Report.
- JENSEN, A. E. 2010. Monitoring and inventory of the seabirds and their breeding areas in Tubbataha Reefs Natural Park & World Heritage Site, Cagayancillo, Palawan, Philippines May 12-16, 2010. *Tubbataha Management Office, Puerto Princesa City, Philippines*. Unpublished Report.
- JENSEN, A. E. 2011. Monitoring and inventory of the seabirds and their breeding areas in Tubbataha Reefs Natural Park & World Heritage Site, Cagayancillo, Palawan, Philippines May 12-16, 2011. *Tubbataha Management Office, Puerto Princesa City, Philippines*. Unpublished Report.
- JENSEN, A. E. 2012. Monitoring and inventory of the seabirds and their breeding areas in Tubbataha Reefs Natural Park & World Heritage Site, Cagayancillo, Palawan, Philippines May 8-11, 2012. *Tubbataha Management Office, Puerto Princesa City, Philippines*. Unpublished Report.

- JENSEN, A. E. 2013. Monitoring and inventory of the seabirds and their breeding areas in Tubbataha Reefs Natural Park & World Heritage Site, Cagayancillo, Palawan, Philippines May 8-11, 2012. *Tubbataha Management Office*, Puerto Princesa City, Philippines. Unpublished Report.
- JENSEN, A. E. 2014. Monitoring and inventory of the seabirds and their breeding areas in Tubbataha Reefs Natural Park & World Heritage Site, Cagayancillo, Palawan, Philippines May 8-11, 2012. *Tubbataha Management Office*, Puerto Princesa City, Philippines. Unpublished Report.
- JENSEN, A. E. 2015. Monitoring and inventory of the seabirds and their breeding areas in Tubbataha Reefs Natural Park & World Heritage Site, Cagayancillo, Palawan, Philippines May 8-11, 2012. *Tubbataha Management Office*, Puerto Princesa City, Philippines. Unpublished Report.
- JENSEN, A.E. and Songco, A. 2016. Population development of the breeding seabirds and a systematic list of birds recorded from 1981 to 2009 in Tubbataha Reefs Natural Park and World Heritage Site, Palawan, the Philippines. *FORKTAIL- Journal of Asian Ornithology* 32: 2016.
- JENSEN, A. E. 2016. Monitoring and inventory of the seabirds and their breeding areas in Tubbataha Reefs Natural Park & World Heritage Site, Cagayancillo, Palawan, Philippines May 8-11, 2012. *Tubbataha Management Office*, Puerto Princesa City, Philippines. Unpublished Report.
- JENSEN, A.E., Songco, A.M., Pagliawan, M.R Jensen, A. E. 2017. Monitoring and inventory of the seabirds and their breeding areas in Tubbataha Reefs Natural Park & World Heritage Site, Cagayancillo, Palawan, Philippines May 8-11, 2012. *Tubbataha Management Office*, Puerto Princesa City, Philippines. Unpublished Report.
- KENNEDY, R. S. 1982. The last of the Seabirds. *The Filipinas Journal of Science and Culture*, Filipinas Foundation Vol III: 40 – 49.
- MANAMTAM, A.S. 1996. Survey of Seabirds in Tubbataha, Cavili and Cagayancillo, the Sulu Sea. Haribon Foundation, Danish Ornithological Society, BirdLife International and DENR.
- PALAGANAS, V. AND PEREZ. 1993. Observations on the Tubbataha Reef National Marine Park. *Silliman Journal* 36(2) p. 5-13. 26).
- WILD BIRD CLUB OF THE PHILIPPINES. 2017. Checklist of Bird of the Philippines. Version 2017.
- WORCESTER, D.C. 1911. Newly Discovered Breeding Place of Philippine seabirds. *Philippines Journal of Science* 6: 167-177.

OTHER STUDIES



5 CORAL RECRUITMENT

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

5.1 Overview

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

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

5.2 Materials and Methods

Monitoring Site

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

Sampling Design

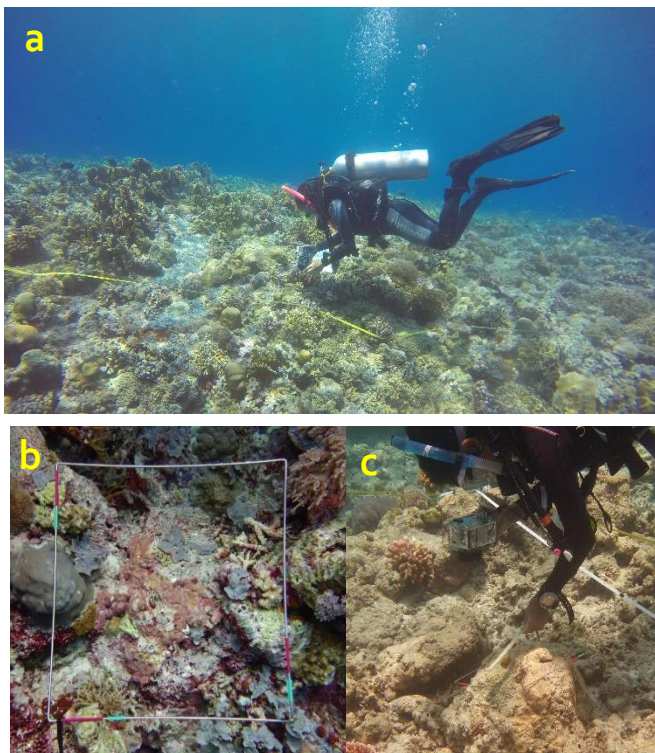


Figure 28. Coral recruitment sampling. (a) randomized quadrat sampling within the transect. (b) close-up shot of the quadrat with scale bars (c) multiple photos were taken using underwater camera.

At each transect, a diver randomly placed a 34 x 34 cm (0.12 m²) quadrat, with scale bars attached (2 and 5 cm) on both sides, on the substrate along the transect to get representative samples of the station (Figure 28.a-b). For each quadrat, five photos were taken (four close-up shots at each corner and one full quadrat shot) to provide more detailed images of juvenile corals (Figure 28-c). This process was randomly repeated 10 to 20 times along the transects at both depths in each of the stations. Images were taken using a 12-megapixel camera with underwater casing and red filter for white balance.

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

Data from a total of 20 quadrats (10 from the shallow depth and 10 from the deep) were processed per station. All photos were downloaded, grouped, and labeled according to quadrat number per station and per site for the post-processing and scoring using the Coral Point Count with Excel Extension® (CPCe) software. Only coral colonies measuring <5cm were considered recruits (Burgess *et al.* 2009).

Data Analysis

Quantitative data on coral recruits were obtained using CPCe 4.1 (Kohler and Gill 2006). In the CPCe software, each photo was calibrated using the 5-cm scale bar located on each side of the quadrat. This scale bar provided an adequate size estimate of the coral recruits. The identified recruits were classified to the closest possible taxonomic level (usually the genus level) provided in the modified Taxonomic Amalgamation Unit (TAUs) (Appendix 11). The Indo-Pacific Coral Finder version 3.0 and the Guide to the Corals of Bolinao Anda-Reef Complex served as references for coral identification. Small coral fragments that were deemed remnants of adult corals were excluded.

Estimates of coral recruit density was then calculated for each quadrat as the number of recruits per 0.12 m². Differences in densities of recruits across stations and depths were tested using block One-way ANOVA. Post hoc pair-wise comparisons were performed using the Tukey test when significant differences were found. Densities and mean percentage covers were plotted in Microsoft Excel across depths and stations.

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

5.3 Results and Discussion

A total of 945 coral recruits from 605 photographs were processed, covering a total of 24 m² for the whole park. This survey recorded twenty-nine (29) coral genera belonging to nine families. The average estimated coral recruit density (pooled taxa) across all sites were 45.56 ind/m² (±4.56 SE) at 10 meters, with values ranging from 0.83 ind/m² (±0.26 SE) to 20 ind/m² (±11.59 SE). It is six times higher than in Great Barrier Reef (Keppel and Lizard Island) with 6.92 ind/m² (±0.25 SE)

at 10 meters (Traçon *et al.* 2013). In the shallow areas of TRNP (five meters), the average density is 30.50 ind/m² (± 5.54 SE) and values ranged from 0.10 ind/m² (± 0.09 SE) to 6.87 ind/m² (± 1.95 SE). Generally, a lower density of coral recruits was observed in the shallow areas.

Coral recruitment at 10 meters

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

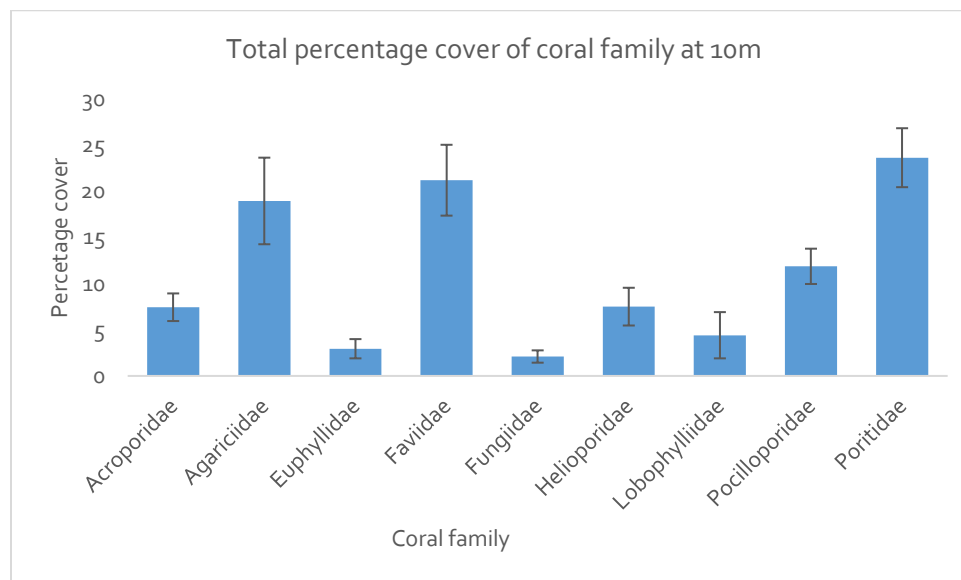


Figure 29. Mean percentage cover of coral families at 10 meters. Error bars represent standard error of the mean.

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

These stations are mainly composed of corals belonging to genus *Acropora*, *Pavona* and *Porites*. Stations 4B and 4A recorded 56.66 ind/m² and 50 ind/m², respectively, and were dominated by encrusting *Porites* (Figure 30). The lowest density was observed in Station JBA covering only 27.5 ind/m². Station JBB is the only station which recorded a high density of the genus *Caulastrea*, which is not common in all the other stations. Variability of coral recruit density at this depth showed no significant difference among the sites (block ANOVA $p=0.616$).

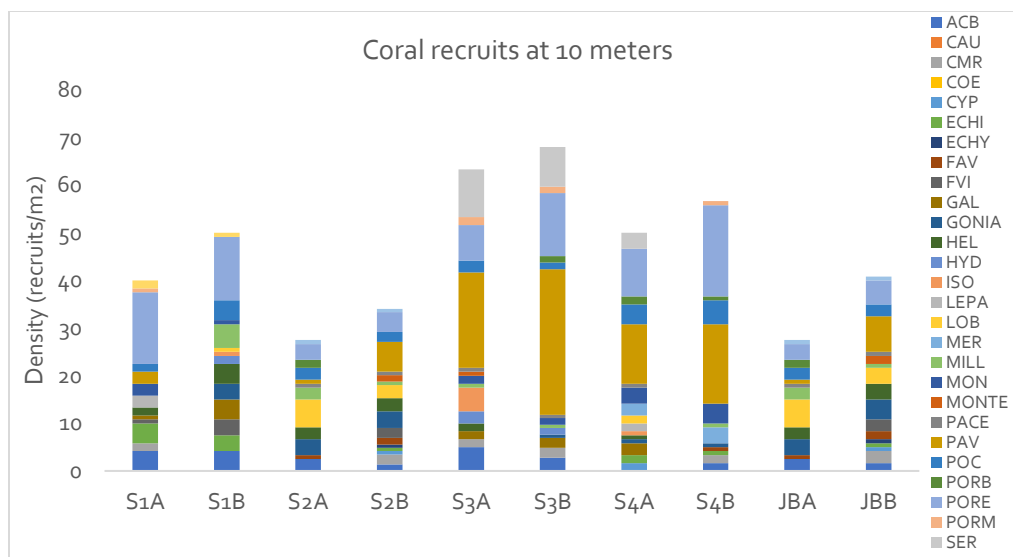


Figure 30. Average density of coral recruits in m² for 10 stations at 10 meters.

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

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

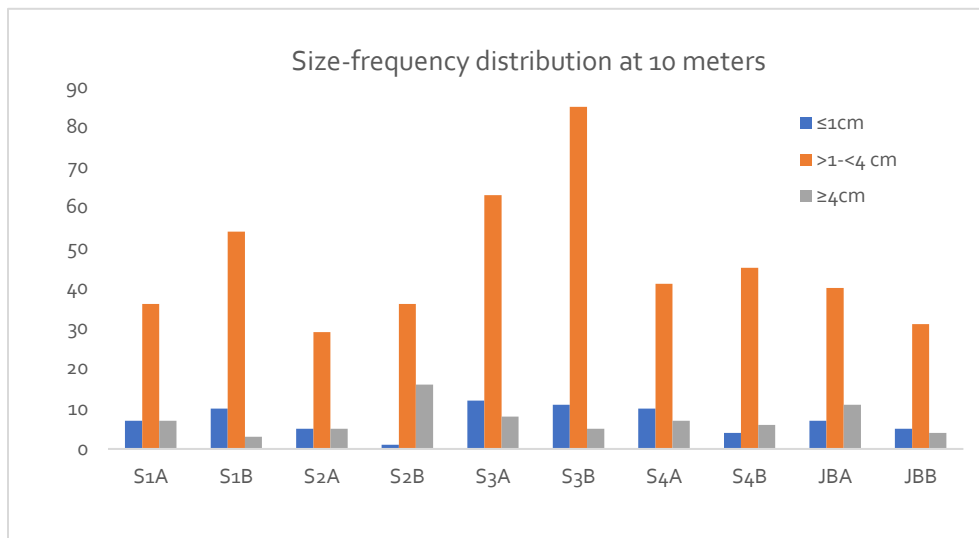


Figure 31. Size-frequency distribution of coral recruits per Station. Bars represent the number of recruits in each size class.

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

Coral recruitment at 5 meters

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

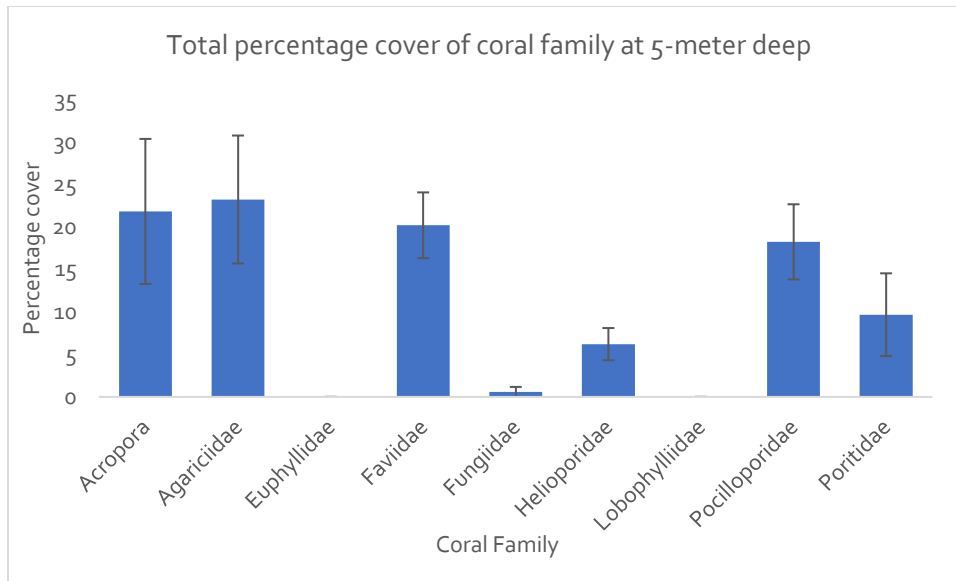


Figure 32. Mean percentage cover of coral families at five meters. Error bars represent standard error of the mean.

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

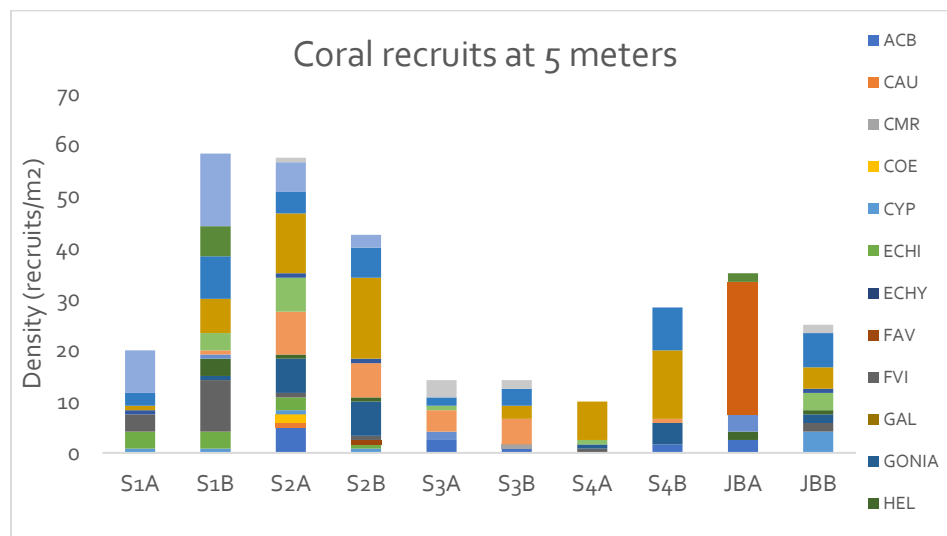


Figure 33. Average density of coral recruits per m² for 10 stations at five meters.

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

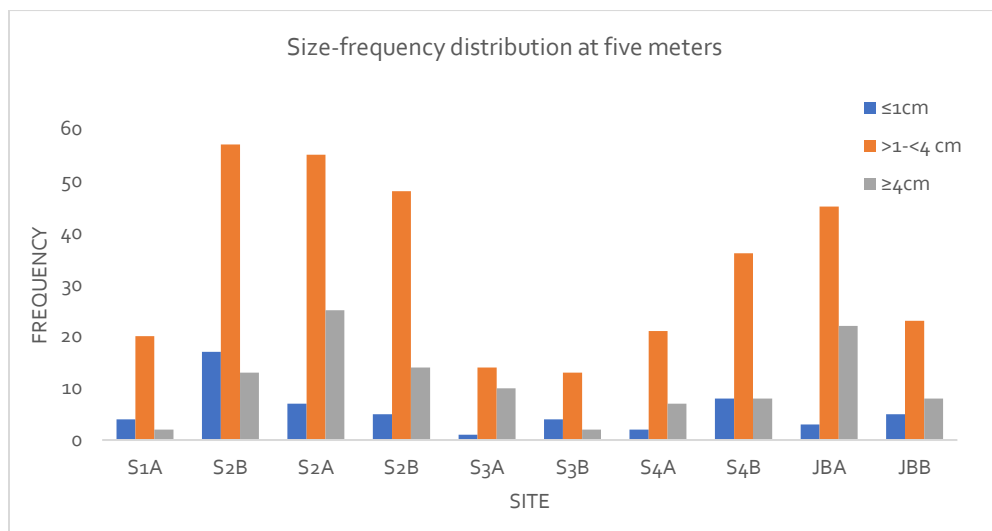


Figure 34. Size frequency distribution of coral recruits by station. Bars represent the number of recruits in each size class.

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

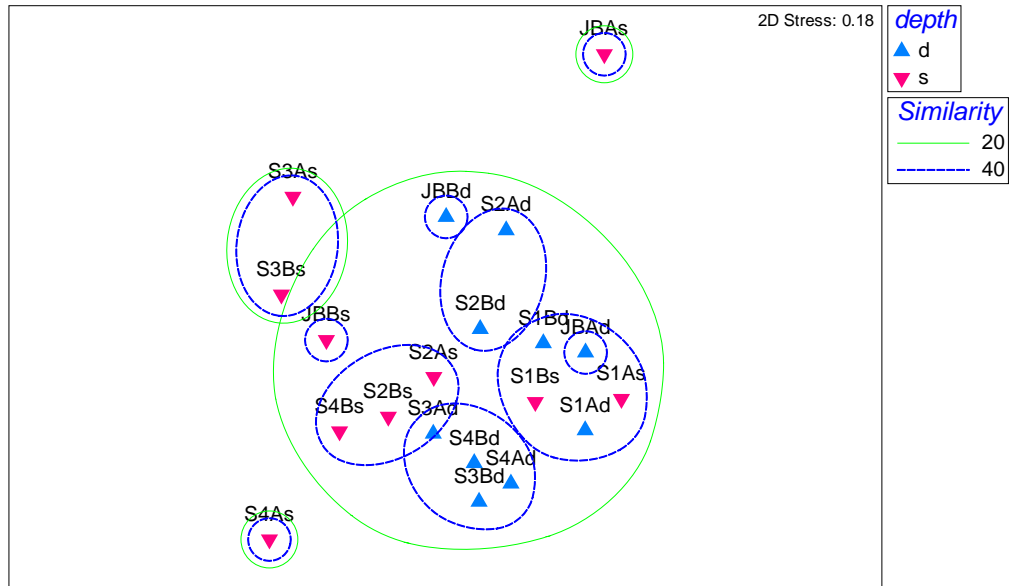


Figure 35. Non-metric multi-dimensional scaling (MDS) plot of Bray-Curtis similarity index of recruit species composition across the sites at both depths. Green dotted line implies 20% similarity of the stations; blue dotted line implies 40% similarity.

A non-metric multi-dimensional scaling (MDS) plot was used to visualize the Bray-Curtis similarity of sites based on the generic abundance at each station and depth (Figure 35). As expressed in the MDS plot, stations that shared almost the same generic composition formed a cluster. Four major clusters with 40% similarity were formed: (1) Stations 3A, 3B, 4A and 4B at 10 meters; (2) Stations 2A, 2B and 4B at 5 meters; (3) Stations 2A and 2B; and (4) combination of all stations at both depths of Site 1 and Station JBA. ANOSIM revealed a significant difference among depths indicating that depth is a factor affecting coral recruit structure in TRNP ($r=0.2$, $p=0.007$). However, it failed to show the differences among stations due to too many small values generated even after the computation of the log-transformation (square root) of the data. Presumably, the coral juveniles found were mostly seeded by the mature colonies at each depth. The shallow areas of Stations 3A, 3B, 4A and JBA seem to be separate from the group, which might have been influenced by the low number of coral genera and densities found in those areas.

5.4 Conclusion

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

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

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

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

Most of the coral recruits at both depths were between $>1\text{cm}$ to $\leq 4 \text{ cm}$, which for most coral families are considered to be the juvenile stage. Family *Poritidae* was observed to be the most abundant coral recruit in the deep sites, while family *Acroporidae* dominated the shallow

sites. This result coincides with the studies conducted in Fiji and other Pacific Islands by Quinn and Kojis (2008).

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

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

5.5 Recommendations

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

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

5.6 References

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

- BAK, R.P.M. & M.S. ENGEL. 1979. Distribution, abundance and survival of juvenile hermatypic corals (Scleractinia) and the importance of early life history strategies in the parent coral community. *Mar. Biol.* 54: 341-352.
- BURGESS, S.C., OSBORNE AND SFILIGOJ K.B. 2010. *Environ Monit Assess.* 171: 345. <https://doi.org/10.1007/s10661-009-1282-1>
- CHIAPPONE, M., & SULLIVAN, K. M. 1996. Distribution, abundance, and species composition of juvenile scleractinian corals in the Florida reef tract. *Bulletin of Marine Science*, 58, 555–569.
- DARLING ES, MCCLANAHAN TR, CORTE IM. 2013. Life histories predict coral community disassembly under multiple stressors. *Global Change Biology* 19: 1930–1940.
- HUANG Z.G. 2008. *Marine Species and Distribution of China* (updated version). Ocean Press, Beijing, China
- HUGHES, T.P. AND CONNELL, J.H. 1999. Multiple stressors on coral reefs: a long-term perspective. *Limnol. Oceanogr.* 44, 932–940.
- KEGLER P, KEGLER HF, KUNZMANN A, GÄRDES A, ALFIANSAH YR, LUKMAN M, HASSENRÜCK C, FERSE SCA. 2016. Different levels of anthropogenic impact influence coral larvae settlement and bacterial biofilm communities in the Spermonde Archipelago, Indonesia. *Proceedings of the 13th International Coral Reef Symposium*, Honolulu: 145-157.
- KOHLER, K.E. AND S.M. GILL. 2006. Coral Point Count with Excel extensions (CPCe): A Visual Basic program for the determination of coral and substrate coverage using random point count methodology. *Computers and Geosciences*, Vol. 32, No. 9, pp. 1259-1269, DOI:10.1016/j.cageo.2005.11.009
- MOULDING A.L., KOSMYNIN V.N. AND GILLIAM D.S. 2012. Coral recruitment to two vessel grounding sites off southeast Florida, USA. *Rev. Biol. Trop. (Int. J. Trop. Biol.* ISSN-0034-7744) Vol. 60 (Suppl. 1): 99-108, March 2012
- MOULDING A.L. 2004. Coral Recruitment Pattern in Florida Keys. *Rev. Biol. Trop. (Int. J. Trop. Biol.* ISSN-0034-7744) Vol. 53 (Suppl. 1): 75-82, May 2005 (www.tropiweb.com)

- NAKAMURA T. AND VAN WOESIK R. 2001. Water-flow rates and passive diffusion partially explain differential survival of corals during the 1998 bleaching event. *Mar Ecol Prog Ser* 212:301–304
- QUINN N.J. AND KOJIS B.L. 2008. Variation in coral recruitment on Fijian reefs. Proceedings of the 11th International Coral Reef Symposium, Ft. Lauderdale, Florida, Session number 14. 7-11 July 2008
- RAPHAEL RITSON-WILLIAMS, SUZANNE N. ARNOLD, NICOLE D. FOGARTY, ROBERT S. STENECK, MARK J. A. VERMEIJ, AND VALERIE J. PAUL. 2009. New Perspectives on Ecological Mechanisms Affecting Coral Recruitment on Reefs
- RUIZ-ZÁRATE M. A. & ARIAS-GONZÁLEZ, J. E. 2004. Spatial study of juvenile corals in the Northern region of the Mesoamerican Barrier Reef System (MBRS). *Coral Reefs*, 23, 584–594.
- SMITH D.J. 2006. Wakatobi, Indonesia field report. Technical Report. Unpublished.
- TABUGO S. R. M., MANZANAREZ D.L. AND MALAWARE A.D. 2016. Coral reef assessment and monitoring made easy using Coral Point Count with Excel extensions (CPCe) software in Calangahan, Lugait, Misamis Oriental, Philippines.
<https://www.researchgate.net/publication/297343990>
- TRAPON M.L., PRATCHETT M.S., HOEY A.S. 2013. Spatial Variation in Abundance, Size and Orientation of Juvenile Corals Related to the Biomass of Parrotfishes on the Great Barrier Reef, Australia. Sandin SA, ed. *PLoS ONE*. 2013;8(2):e57788. doi:10.1371/journal.pone.0057788.
- WILSON, J. & HARRISON, P. 2005. Coral Reef: Post-settlement mortality and growth of newly settled reef corals in a subtropical environment. 24: 418.
<https://doi.org/10.1007/s00338-005-0033-1>
- VAN MOORSEL, G.W.N.M. 1988. Early maximum growth of stony corals (Scleractinia) after settlement on artificial substrata on a Caribbean reef. *Mar. Ecol. Prog. Ser.* 50: 127-135.
- Szmant, A.M. 1986. Reproductive ecology of Caribbean reef corals. *Coral Reefs* 5: 43-54.
- VAN WOESIK, R., GILNER, J., & HOOTEN, A. J. 2009. Standard Operating Procedures for repeated measures of process and state variables of coral reef environments. Coral Reef Targeted Research and Capacity Building for Management Program, Centre for Marine Studies, Gerhmann Building, The University of Queensland, St Lucia, Qld, 4072.

6 REEF FISH INVENTORY

Gerlie Gedoria¹, Dr. Kent Carpenter², and Dr. Jeffrey Williams³

¹ *Tubbataha Management Office, Puerto Princesa City*

² *Old Dominion University, Virginia, U.S.A.*

³ *National Museum of Natural History, Smithsonian Institution, Washington, D.C., U.S.A.*

6.1 Overview

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

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

6.2 Methods

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

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

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

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

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

The roving diver survey method is more useful for comprehensive species listing as it covers a wider spatial range than a fish visual census (which is limited to the transect) and can record large fish that are wary of divers, cryptic species, and roving pelagic fishes that require an intensive

search of the reef (Hill and Wilkenson 2004). Additionally, this does not require the divers to make an actual count of the fishes, unlike the fish visual census which needs an estimated value. Instead, the divers take note of the species abundance by using the following logarithmic-based categories (Schmitt and Sullivan 1996):

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

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

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

Species were classified into three frequency categories based on the percentage of dives where each species was observed: frequent ($\geq 70\%$), common ($< 70\% \times > 20\%$), and uncommon ($\leq 20\%$).

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

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

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

These numbers indicate which abundance category in which each species was most often recorded. For example, if the abundance index of a species is 2.2, this means that in most of the

dives the species occurred in 'few' numbers (2 to 10 individuals) but was also observed to be 'many' or 'abundant' in other dives.

6.3 Results and Discussion

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

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

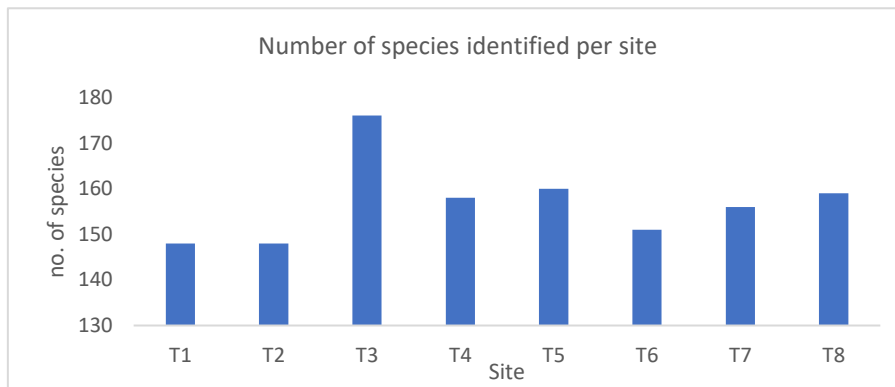


Figure 36. Total number of species identified in each site, including cryptic species.

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

It could not be generally assumed that each species recorded under the uncommon category are only present in the specific site where it was observed or can only be observed in lower sighting

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

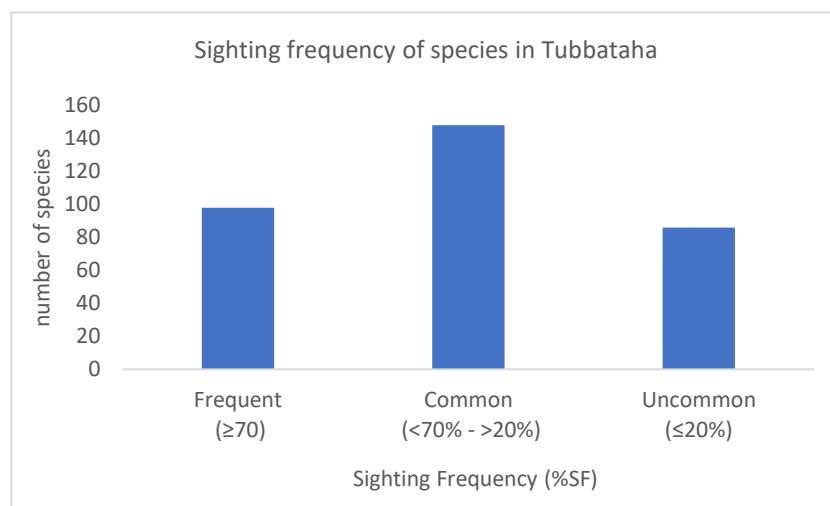


Figure 37. The number of species in each sighting frequency in the Tubbataha Reefs.

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

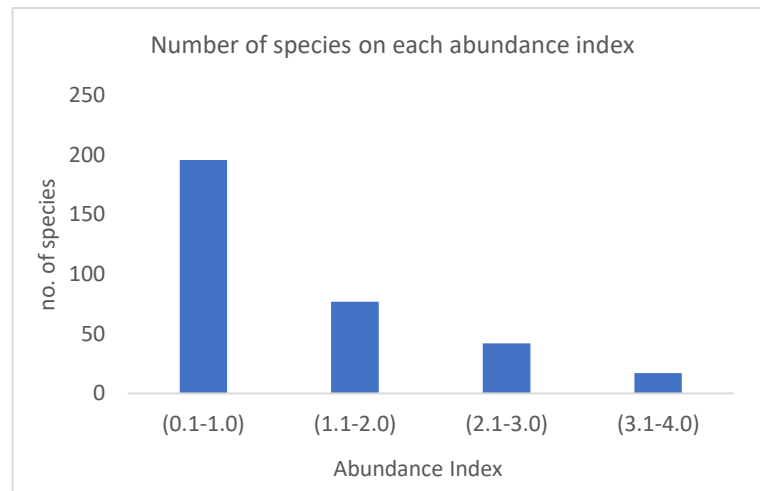


Figure 38. Number of species on each abundance index range.

Abundance and Sighting Frequency. Table 10 provides the list of the number of species under different sighting frequency categories and their corresponding abundance index ranges. It was observed that the most frequently recorded species also occurred in high abundance, while most of the common and all the uncommon species tend to have low abundances (Table 10). Schmitt and Sullivan (1996) argued that although the sighting frequency and abundance are strongly related, sighting frequency could not be an absolute indicator for the abundance of a species. For example, in this survey, Yellowface angelfish (*Pomacanthus xanthurus*) was frequently observed but in low abundance (0.1-1.0). Thus, each species can be described independently by either its sighting frequency or its abundance in the area (Schmitt and Sullivan 1996).

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

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

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

Tubbataha vs. other sites (excluding cryptic species)

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

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

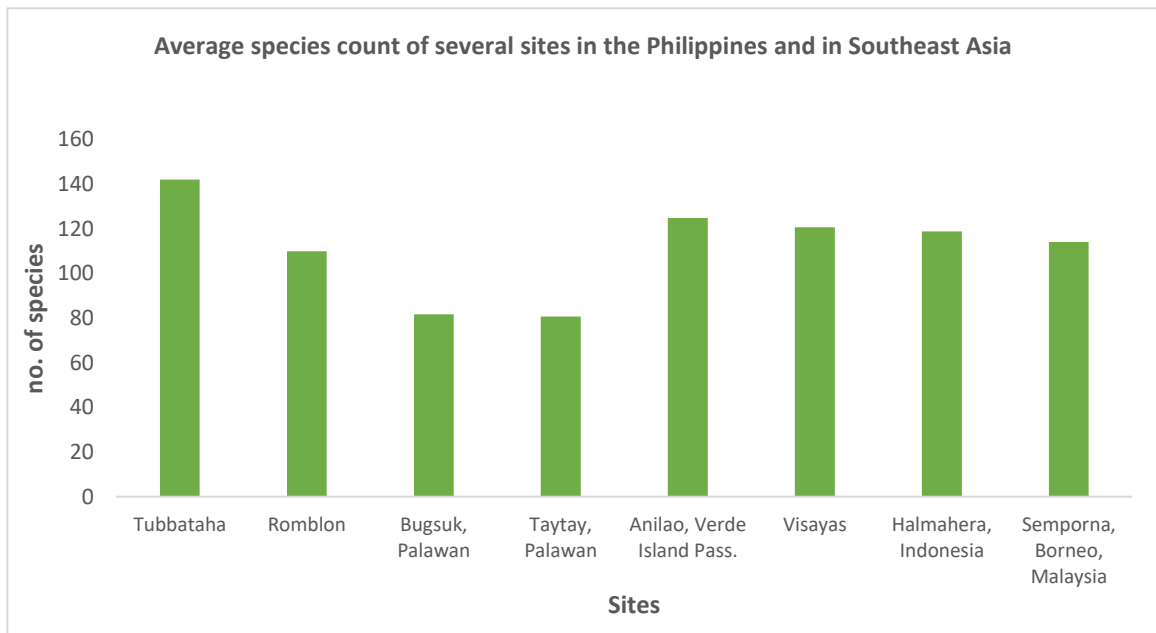


Figure 39. Comparison of averages for species identified in different sites in the Philippines and in Southeast Asia, employing the Roving Visual Census method. Cryptic species were not included in the count. (Data obtained from Dr. Kent E. Carpenter)


6.4 Conclusion and Recommendation

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

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

6.5 References

- ALLEN G.R., WERNER T.B. 2002. Coral reef fish assessment in the 'Coral Triangle' of Southeast Asia. *Environ Biol Fish* 65 (2):209–214
- ALLEN, G.R. 2007. Conservation hot spots of biodiversity and endemism for Indo-Pacific coral reef fishes. *Aquatic Conservation: Marine and Freshwater Ecosystem*. Volume 18, Issue 5.
- ASIAN DEVELOPMENT BANK. 2004. *State of the Coral Triangle: Philippines*. Mandaluyong City, Philippines
- BONE, Q. AND R.H. MOORE. 2008. *Biology of Fishes*. 3rd edition. Taylor and Francis Group. ISBN 0-203-88522-8
- CARPENTER, K.E. 2018. Report on Tubbataha Fish Roving Census from Kent and Jeff & Tubbataha Fish Book Proposal. [email on May 5 2018].
- DIZON, E.C., R.C. GERONIMO, R. QUICHO JR. 2013. Benchmarking the management effectiveness of nationally-managed marine protected areas in the Philippines and policy recommendations. Final Report for USAID Coral Triangle Support Partnership (CTSP) and Conservation International – Philippines. September 2013
- FAO. 2003. The ecosystem approach to fisheries. *FAO Technical Guidelines for Responsible Fisheries*. No. 4, Suppl. 2. Rome, FAO. 112 pp.
- HELFMAN, G.S., B.B. COLLETTE, D.E. FACEY, AND B.W. BOWEN. 2009. *The Diversity of Fishes: Biology, Evolution, and Ecology*. 2nd edition. Wiley-Blackwell; Wiley & Sons Ltd., ISBN 978-1-4051-2494-2.
- HILL, J. AND WILKINSON, C. 2004. Methods for ecological monitoring of coral reefs. *A Resource for Managers*. Australian Institute of Marine Science, pp. 78
- Pauly, D., R. Froese and V. Christensen. 1998. How pervasive is "Fishing down marine food webs": response to Caddy et al. *Science* 282: 183.
- RASHID, U.S., ALDER, S.G.J., POLLARD, D., AND CHUENPAGDEE, R. 1994. *Marine protected areas and managing fish ecosystems*. Chr. Michelsen Institute. Development Studies and Human Rights.



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

Schmitt, E.F., Sluka, R.D., and Sullivan-Sealey, K.M. (2002). Evaluating the use of roving diver and transect surveys to assess the coral reef fish assemblage off southeastern Hispaniola. *Coral Reefs* 21: 216-223. DOI 10.1007/s00338-002-0216-7

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

7 REEF BENTHIC SURVEY

Jennifer Deauna, Giannina Feliciano and Wilfredo Licuanan

Br. Alfred Shields FSC Ocean Research Center, De La Salle University, Manila

7.1 Overview

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

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

7.2 Methods

Resurvey activities were carried out in May 3 to 8, 2018 by staff of the Br. Alfred Shields FSC Ocean Research (ShORe) Center of De La Salle University, in coordination with personnel of the Tubbataha Management Office. Five (5) regular monitoring sites were visited in the 2018 resurvey: Site 1, Site 2, Site 3, Site 4, and Jessie Beazley (Figure 1). These sites have two (2) stations each, and they have been monitored since 2012. However, Jessie Beazley has insufficient data from 2012 and 2013; thus, the report for this site will only cover the years 2015 to 2018. In

addition, two (2) ship grounding sites (i.e., those of the USS Guardian and Min Ping Yu) were also resurveyed (Figure 1). These two (2) stations have been monitored since 2014. Lastly, a new station was assessed this year, Southwest Wall (Figure 1), because there were reports of a crown-of-thorns outbreak in the reef.

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

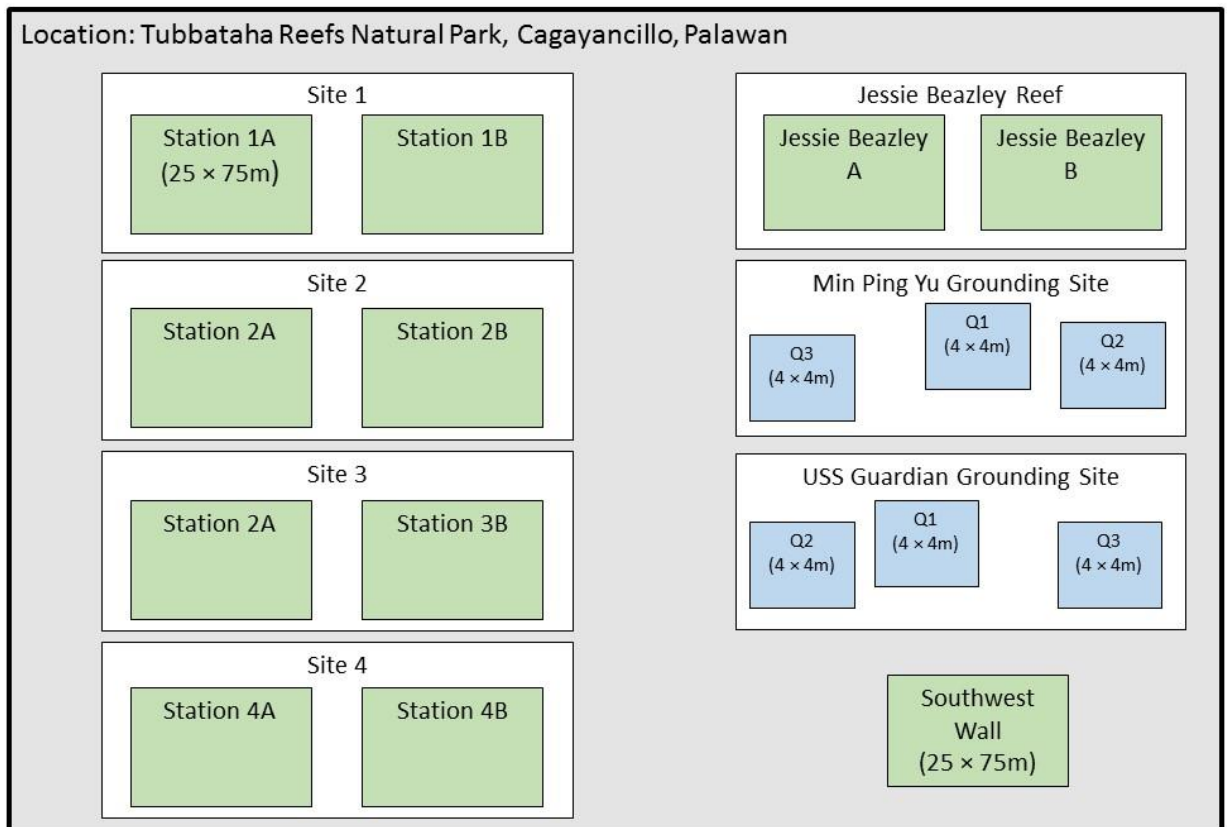


Figure 40 Sampling scheme of sites and stations in the Tubbataha Reefs Natural Park.

The photo-transect method indicated in the CRTR protocol was used describe the state of benthic communities in Tubbataha (van Woesik et al. 2009). A 75-m base transect was deployed

at the deepest end of each monitoring station (5-7 m depth) to demarcate the sampling area. Four 50-m belt transects were then deployed parallel to the base transect at randomly determined starting points (x,y-meter coordinates) within the monitoring station (Figure 41).

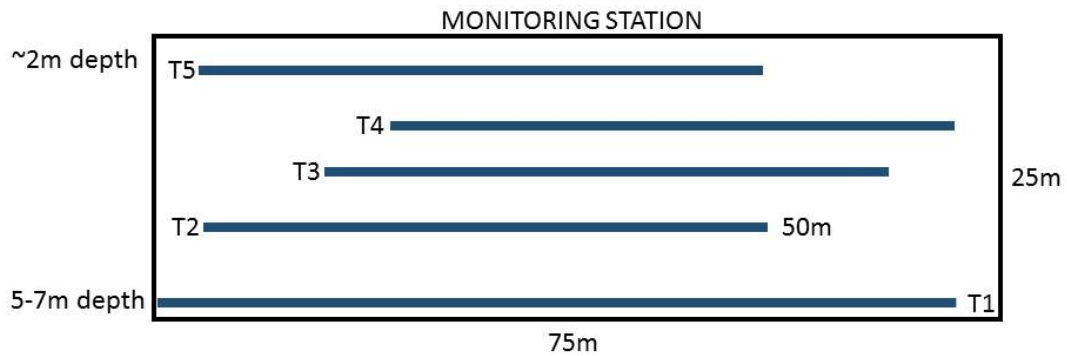


Figure 41. Five belt transects were deployed to describe the benthic communities in each monitoring station.

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

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

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

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

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

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

7.3 Results and Discussion

HCC Categories

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

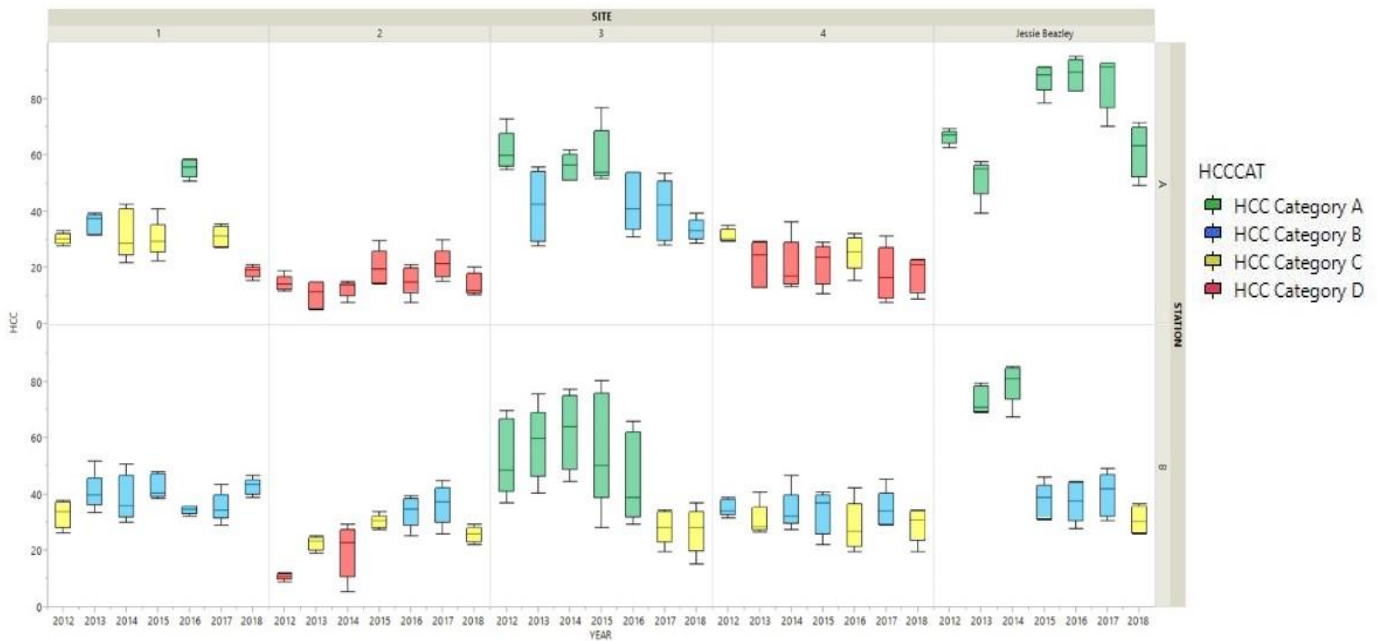


Figure 42 Box and whiskers plot of coral cover for Tubbataha stations from 2012 to 2018. Error bars indicate +/- 1 standard error.

7.4 Change in Hard Coral Cover

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

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

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

TAUs Diversity

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

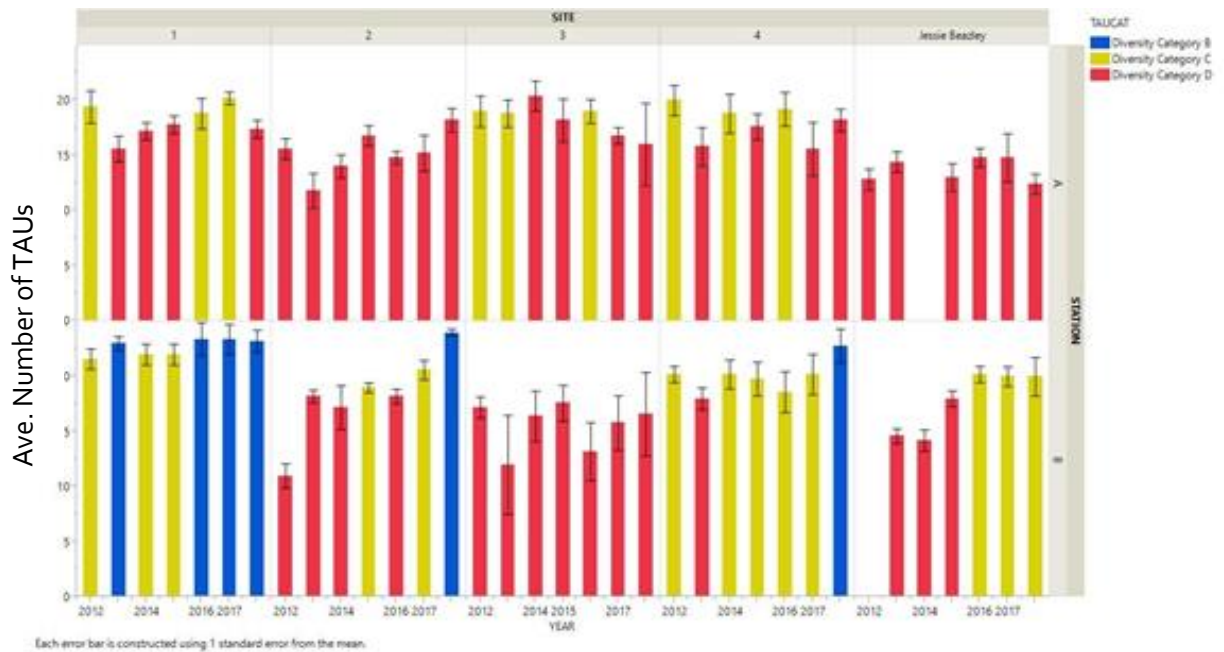


Figure 43 Bar graphs of TAU diversity per year for all sites/stations. Error bars indicate +/- 1 standard error.

7.5 Change in TAUs diversity

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

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

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

Discussion

The stations that have a decreasing trend in hard coral cover (HCC) i.e., Stations 3A, 3B, 4A, and Jessie Beazley A have moderate to moderately strong Pearson's correlation coefficients. This indicates that these stations should be carefully observed for any more changes in the succeeding resurveys. The changes in HCC in Stations 3A and 3B could be related to large fields of *Isopora brueggemanni* rubble in the deeper portions of the stations (Plate 11), which may have been created by logs and payao floats that hit the reef (Eneria and Licuanan, 2017). Rubble moving around due to strong water movement could further destabilize the substrate and damage more coral. A similar situation may exist in Jessie Beazley A where foliose growth forms of *Montipora* dominate the reef. Foliose colonies of *Montipora* are considered 'competitive' corals (Darling,

Alvarez-Filip, Oliver, McClanahan, & Cote, 2012). These types of corals are more competitive for space against other corals. They have faster growth rate, they can dominate a reef rapidly and they create canopies to get more sunlight. However these types of corals are more vulnerable to disturbances such physical breakage (Darling et al., 2012).

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

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

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

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

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

The protection of Tubbataha has proven effective, as indicated by the stable coral cover and diversity at the location level. Other indicators of a healthy reef ecosystem include the large sizes,

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

Plates



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



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



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

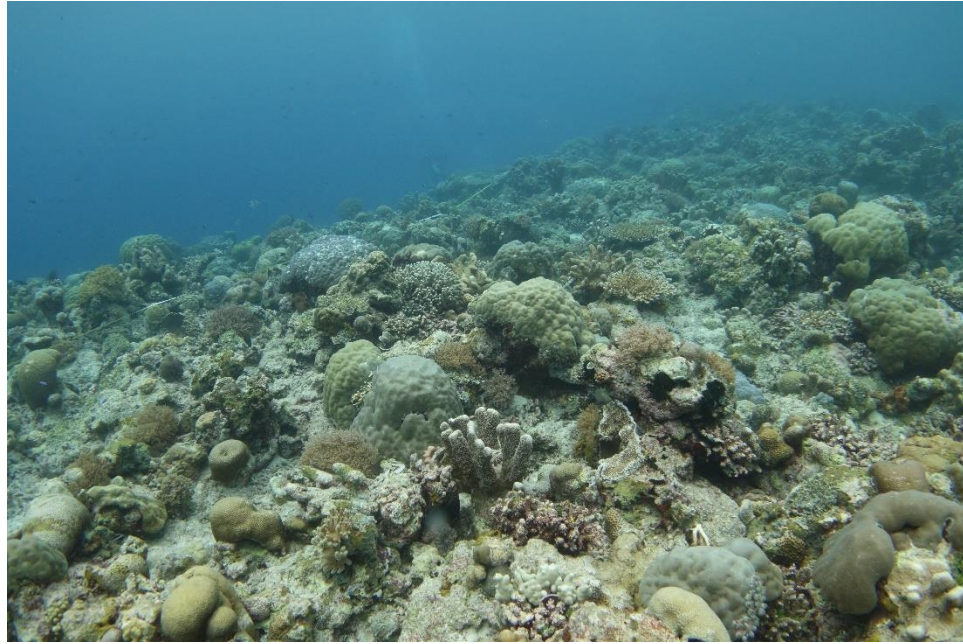


Plate 4 Reef shot of Station 2B. A 75-m base transect is used to demarcate the deepest part of the monitoring station.



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

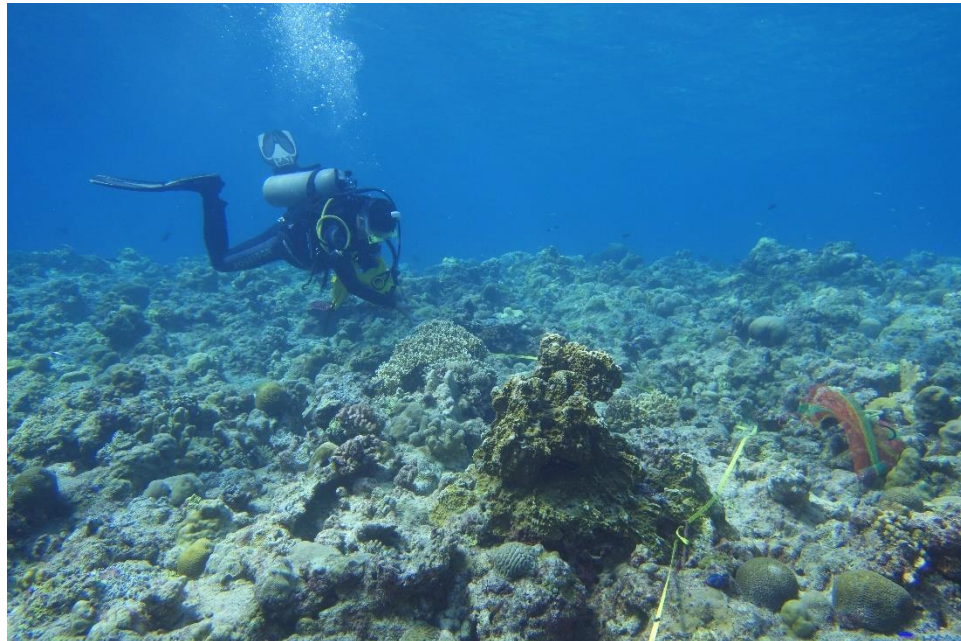


Plate 6 Reef shot of Station 4B, with a diver for scale.

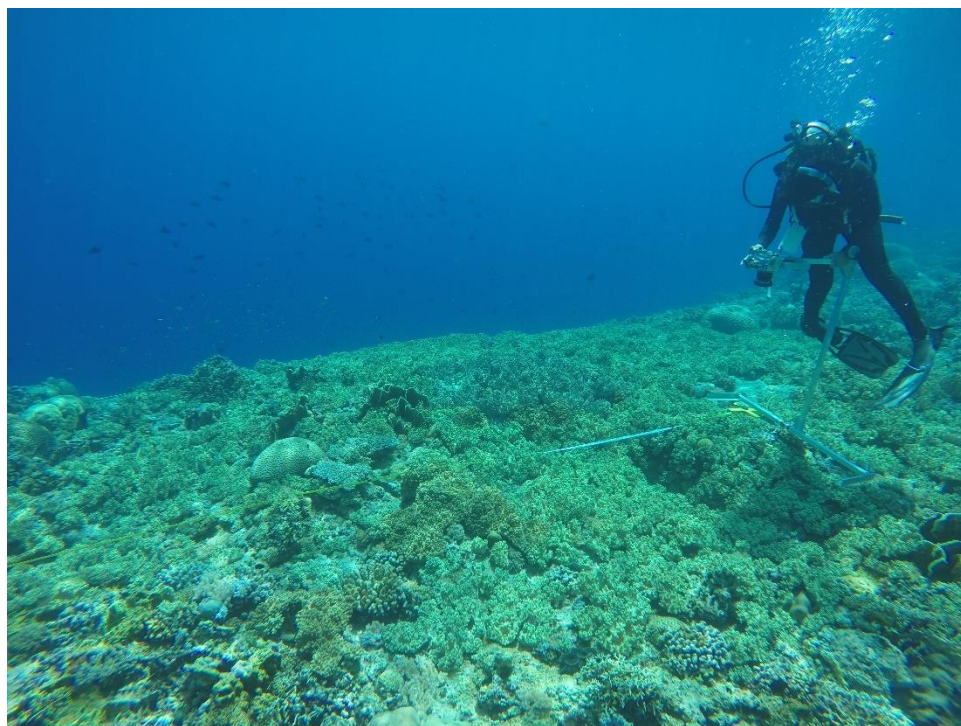
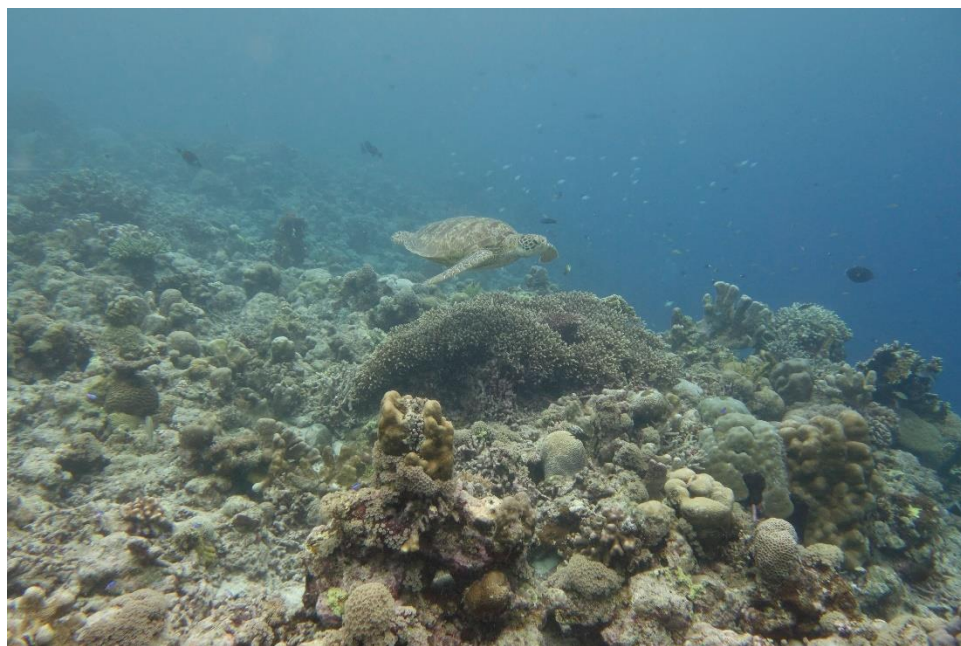


Plate 7 Reef shot of Jessie Beazley B, showing a diver taking photographs of the benthos using an aluminum monopod. Deeper parts of the reef are dominated by soft corals.



Plate 8 Reef shot of Station 1A.



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



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



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



Plate 12 Discarded fishing lines observed in Jessie Beazley A.

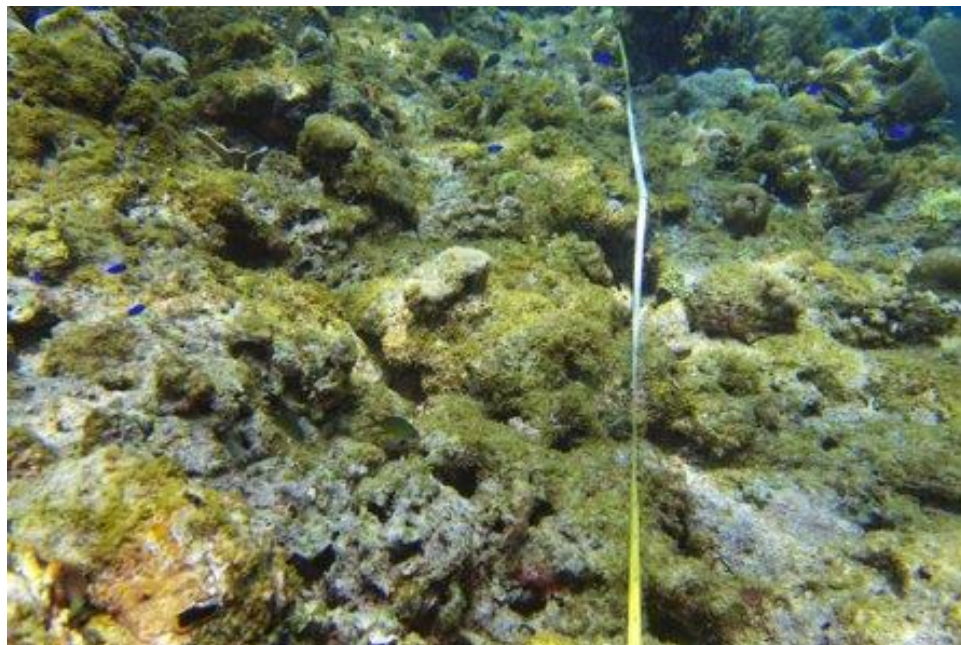


Plate 13 A layer of turf algae on the carbonate substrate observed in Station 4A.

7.6 Ship Grounding Sites

Method

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

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

Results

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

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

The quadrats in Min Ping Yu were established in similar situations as those at the USS Guardian site. The ‘small fragments’ quadrat represent the most damaged area in the reef. This is because the ship repeatedly hit the reef and the corals there were reduced to small fragments. These fragments were then subsequently scraped together by the ship to one side. Adjacent areas from

the immediate grounding consisted of larger fragments created when ship's rudder hit massive corals. These areas are represented by the 'large fragments' quadrat. 'Adjacent control' quadrat represents part of the same reef that was not directly damaged by the grounding. None of the quadrats in Min Ping Yu show statistically significant changes in HCC, but the 'small fragments' quadrat shows a significant increase in algal assemblage cover of 8.1% (p-value < 0.0001) based on a simple linear regression analysis.

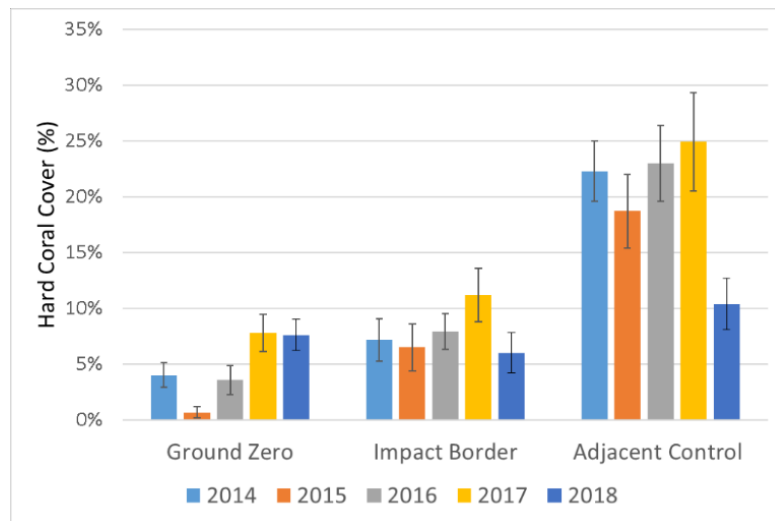


Figure 44. Hard coral cover (HCC) at and around the grounding site of the USS Guardian at the South Atoll of the Tubbataha Reefs. Error bars indicate +/- 1 standard error.

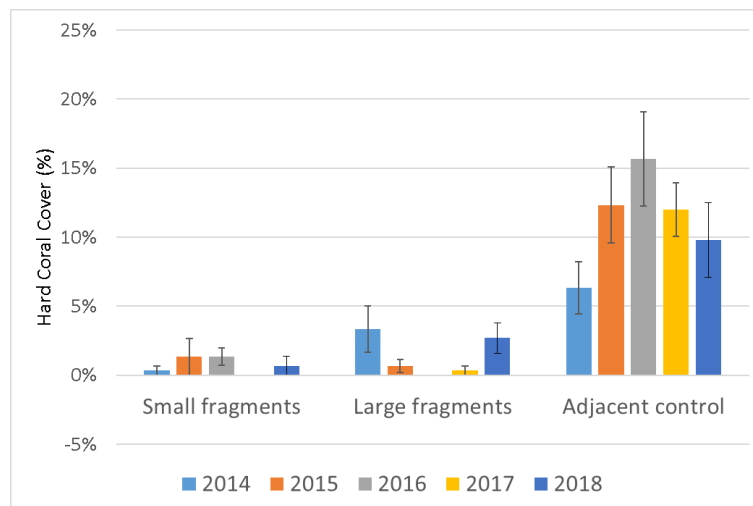


Figure 45. Hard coral cover (HCC) in fixed plots at and around the Ming Ping Yu grounding site at the North Atoll of the Tubbataha Reefs. Error bars indicate +/- 1 standard error.

Discussion

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



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

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



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

7.7 Southwest Wall

Method

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

Results

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

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

Discussion

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



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

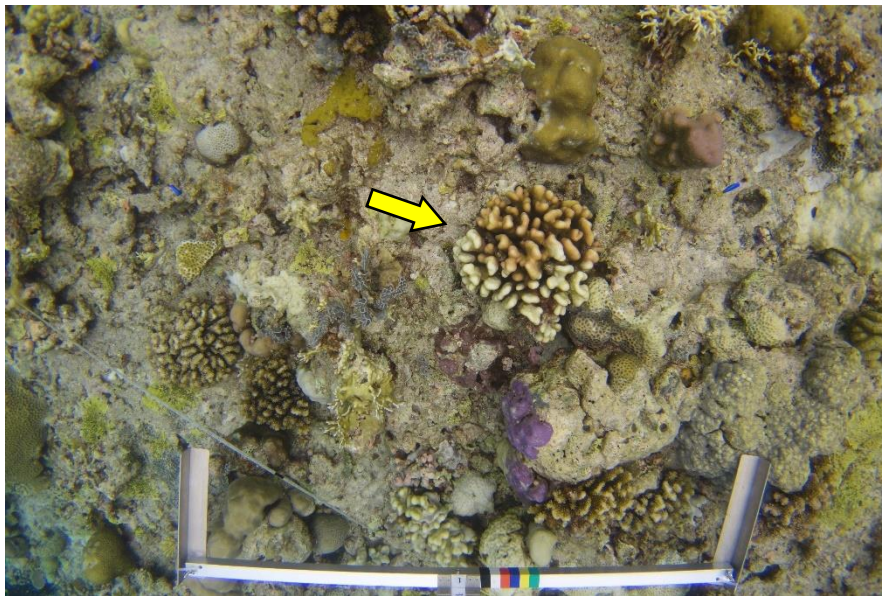



Figure 49 Stylophora sp. colony that seems like it was freshly eaten by crown-of-thorns sea star.

Conclusion and Recommendation

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

References

- Biodiversity (n.d.) Retrieved from <http://tubbatahareef.org/wp/biodiversity>
- Darling, E. S., Alvarez-Filip, L., Oliver, T. A., Mcclanahan, T. R., & Cote, I. M. (2012). Evaluating life-history strategies of reef corals from species traits. *Ecology Letters*, *15*(12), 1378–1386. <https://doi.org/10.1111/j.1461-0248.2012.01861.x>
- Flower, J., Ortiz, J. C., Chollett, I., Abdullah, S., Sanguino, C. C., Hock, K., ... Mumby, P. J. (2017). Interpreting coral reef monitoring data : A guide for improved management decisions. *Ecological Indicators*, *72*. <https://doi.org/10.1016/j.ecolind.2016.09.003>
- Kohler, K.E. & Gill, S.M. (2006). Coral Point Count with Excel extensions (CPCe): A Visual Basic program for the determination of coral and substrate coverage using random point count methodology. *Computers and Geosciences*, *32*(9), 1259-1269. DOI:10.1016/j.cageo.2005.11.009.
- Licuanan, A. M., Reyes, M. Z., Luzon, K. S., Chan, M. A. A., & Licuanan, W. Y. (2017). Initial Findings of the Nationwide Assessment of Philippine Coral Reefs. *Philippine Journal of Science*, *146*(June), 179–187.
- Licuanan, W. Y., Robles, R., Dygico, M., Songco, A., & van Woosik, R. (2017). Coral benchmarks in the center of biodiversity. *Marine Pollution Bulletin* *114*:1135-1140. <https://doi.org/10.1016/j.marpolbul.2016.10.017>
- Licuanan, W.Y., Reyes, M. Z., & Robles, R.C. (in prep). Status and Recent Trends in Coral Reefs In The Philippines.

- 
- Province Takes Custody of the Chinese Vessel, Min Ping Yu (2014) Retrieved from <http://tubbatahareefs.org/province-takes-custody-of-the-chinese-vessel-min-ping-yu/>
- SAS Institute, Inc. (2013). Using JMP 11. Cary, North Carolina, USA: SAS Institute, Inc.
- Subade, R. F. (2007). Mechanisms to capture economic values of marine biodiversity: The case of Tubbataha Reefs UNESCO World Heritage Site, Philippines. *Marine Policy*, 31(2), 135–142. <https://doi.org/10.1016/j.marpol.2006.05.012>
- van Woesik, R., Gilner, J., & Hooten, A. J. (2009). Standard Operating Procedures for repeated measures of process and state variables of coral reef environments. Coral Reef Targeted Research and Capacity Building for Management Program, Centre for Marine Studies, Gerhmann Building, The University of Queensland, St Lucia, Qld, 4072.
- What Went Before: Damage wrought by USS Guardian (2014) *Philippine Daily Inquirer*. Retrieved from <http://globalnation.inquirer.net/95629/what-went-before-damage-wrought-by-uss-guardian>



APPENDICES

Appendix 1. Monitoring Team

REEF FISH

Gerlie Gedoria, TMO
Segundo Conales, Jr., TMO
Cresencio Caranay, Jr., TMO
Cleto Nañola, Jr., University of the Philippines - Mindanao
Denmark Recamara, Jose P. Rizal Memorial State University, Dapitan City Campus

REEF BENTHOS

Rowell Alarcon, TMO
Maria Retchie Pagliawan, TMO
Noel Bundal, TMO
Jeffrey David, TMO
Wilfredo Licuanan, De La Salle University
Jennifer Deauna, De La Salle University
Giannina Feliciano, De La Salle University

SEABIRDS

Arne Jensen, Ornithologist
Angelique Songco, TMO
Rowell Alarcon, TMO
Noel Bundal, TMO
Cresencio Caranay Jr, TMO
Segundo Conales Jr, TMO PR
Jeffrey David, TMO
Gerlie Gedoria, TMO
Maria Retchie C. Pagliawan, TMO
Darius Cayanan, WWF-Philippines
Ronald de Roa, WWF-Philippines
SNI April Jay Santuelle PCD
SGT Rudy N Tani PN
Angelito Y. Favila
Teri Aquino, Marine Wildlife Watch of the Philippines
Bonifacio Ganotice Jr., Field Assistant
Juan Carlos Gonzales, Professor and Curator, University of the Philippines, Los Baños
Philip Godfrey Jakosalem, Ornithologist, Philippines Biodiversity Conservation Foundation, Inc.
Lisa Paguntalan, Director, Philippines Biodiversity Conservation Foundation, Inc.

Appendix 2. Fish and Benthos Monitoring Sites

| Sites | Stations | Latitude (N) | Longitude (E) |
|-----------------|-------------|--------------|---------------|
| Site 2 | Station 1A | 8.93532 ° | 120.01302 ° |
| | Station 1B | 8.93781 ° | 120.00851 ° |
| Site 4 | Station 2A | 8.89236 ° | 119.90627 ° |
| | Station 2B | 8.89128 ° | 119.90453 ° |
| Site 6 | Station 3A | 8.75591 ° | 119.82881 ° |
| | Station 3B | 8.75186 ° | 119.82784 ° |
| Site 7 | Station 4A | 8.80850 ° | 119.81907 ° |
| | Station 4B | 8.80656 ° | 119.82169 ° |
| Jessie Beazley | Station JBA | 9.04393 ° | 119.81599 ° |
| | Station JBB | 9.04557 ° | 119.81348 ° |
| Grounding sites | USSG | 8 49.297° | 119 48.187° |
| | MPY | 8 51.183° | 119 56.188° |

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

| Parameter | Measure | Category |
|------------------|---|-----------------|
| Species Richness | Number of species per 1000m ²) | |
| | <26 | Very poor |
| | 27-47 | Poor |
| | 48-74 | Moderate |
| | 75-100 | High |
| | >100 | Very High |
| Density | Number of fish per 1000m ²) | |
| | < 201 fish | Very Poor |
| | 202-676 | Low |
| | 677-2267 | Moderate |
| | 2268-7592 | High |
| | > 7592 | Very High |
| Biomass | mt/km ² | |
| | 0-10 | Very Low to Low |
| | 11-20 | Moderate |
| | 21-40 | High |
| | >40 | Very High |

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

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

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

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

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

Anova: Two-Factor Without Replication

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

ANOVA

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

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

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

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

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

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

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

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

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

Appendix 11. Taxonomic amalgamation units (TAUs)

| | |
|------------------------------|----------------------------------|
| CORAL (HC) | Other foliose corals (CF) |
| Acanthastrea (ACAN) | Other free living fungiids (FOT) |
| Acropora branching (ACB) | Other massive corals (CM) |
| Acropora corymbose (ACC) | Oulastrea (OULA) |
| Acropora digitate (ACD) | Oulophyllia (OULO) |
| Acropora hispidose (ACH) | Oxypora (OXY) |
| Acropora plate (ACT) | Pachyseris encrusting (PACE) |
| Acropora robusta group (ACR) | Pachyseris foliose (PACF) |
| Astreopora (AST) | Pavona (PAV) |
| Attached fungiids (AF) | Pectinia (PEC) |
| Caulastrea (CAU) | Platygyra (PLAT) |
| Coelosseris (COE) | Pocillopora (POC) |
| Coscinarea (COS) | Porites branching (PORB) |
| Cyphastrea (CYP) | Porites encrusting (PORE) |
| Diploastrea heliopora (DIP) | Porites massive (PORM) |
| Echinophyllia (ECHY) | Seriatopora (SER) |
| Echinopora (ECHI) | Stylophora (STY) |
| Euphyllia (EUP) | Symphyllia (SYM) |
| Favia (FAV) | Tubipora musica (TUBI) |
| Favites (FVI) | Turbinaria (TURB) |
| Fungia (CMR) | SOFT CORAL (SC) |
| Galaxea (GAL) | Soft coral (SC) |
| Goniastrea (GONIA) | ALGAE (AA) |
| Goniopora (GONIO) | Algal assemblage (AAA) |
| Heliopora branching (HELB) | Crustose Coralline algae (CA) |
| Heliopora encrusting (HELE) | Halimeda (HA) |
| Heliopora submassive (HELS) | Turf (TU) |
| Hydnophora branching (HYDB) | MORTALITIES (MOR) |
| Hydnophora encrusting (HYDE) | Dead coral (DC) |
| Isopora (ISO) | Dead coral with algae (DCA) |
| Leptoria (LEPA) | ABIOTIC (AB) |
| Leptosseris (LEPS) | Rubble (R) |
| Lobophyllia (LOB) | Sand (S) |
| Merulina (MER) | Silt (SI) |
| Millepora (MILL) | Rock (RCK) |
| Montastrea (MON) | OTHER INVERTEBRATES (OT) |
| Montipora branching (MONTB) | Corallimorpharian (COR) |
| Montipora encrusting (MONTE) | Sponge (SP) |
| Montipora foliose (MONTF) | Zoanthid (ZO) |
| Mycidium (MYC) | Ascidian (ASC) |
| Other branching corals (CB) | Gorgonian (GORG) |
| Other bubble corals (BUB) | Invertebrates (INV) |
| Other encrusting corals (CE) | |

Appendix 12. Distance count estimate: objectives and methods

| | |
|---------------------|--|
| Objective | Documentation of: a) presence or absence of seabird species, and, b) the relative population trend variation throughout the year. |
| Method | <p>Distance counts include all species of boobies, frigatebirds and terns including noddies.</p> <p>Distance counts are carried out as a monthly patrol routine at both Bird Islet and South Islet.</p> <p>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.</p> <p>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.</p> <p>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.</p> |
| Analysis | The average estimated figures are used to determine the population variation trend of the different species throughout the year. |
| Data storage | The results are reported on a quarterly basis to the TMO in Puerto Princesa. The TMO is responsible for storing and safeguarding the data. |

Appendix 13. Inventory and population calculation methods per breeding species

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

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

| | |
|-------------------------------------|---|
| <p>Great Crested Tern</p> | <p>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 are counted and added to the figure for North Islet in order to express the total population of species present at TRNP.</p> |
| | <p>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.</p> |
| | <p>Reproduction rate is expressed as the number of eggs and/or pulli and juveniles found.</p> |
| <p>Sooty Tern</p> | <p>Population size is expressed as the number of eggs and/or pulli and juveniles recorded multiplied by two = minimum number of active breeding birds. This result is compared to the day-time number of adult birds counted next to the eggs/pulli/juveniles and to the average results of two to three late afternoon/evening estimates of the total adult population present at that time. Whichever of these three results is the highest is used to express the breeding population.. In years with very high population density, adult birds should be photo-documented using structured picture-taking of clearly demarcated and numbered sub-sections of the breeding areas.</p> |
| | <p>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.</p> |
| | <p>Reproduction rate is expressed as the number of eggs and/or pulli and juveniles found during the inventory.</p> |
| <p>Eurasian Tree Sparrow</p> | <p>Population size is expressed as presence of adult birds since nests have not yet been found.</p> |

Appendix 14. Bird Islet Beach Erosion Assessment

Cesar Villanoy, Fernando Siringan, Justin de la Cruz
Marine Science Institute, University of the Philippines

Introduction

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

Methods

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



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



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

Results

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

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

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

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



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

Recommendations

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Source: WWF Philippines 2004 and TMO 2004 to 2018

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

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

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

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

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

Note 1: Predominantly Black Noddy

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

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

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

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

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

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

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

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

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

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

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

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

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



CMS



CONVENTION ON MIGRATORY SPECIES

Distribution: General

UNEP/CMS/COP12/Doc.25.1.12
15 June 2017

Original: English

12th MEETING OF THE CONFERENCE OF THE PARTIES
Manila, Philippines, 23 - 28 October 2017
Agenda Item 25.1

PROPOSAL FOR THE INCLUSION OF THE BLACK NODDY (*Anous minutus*) SUBSPECIES *worcesteri* ON APPENDIX II OF THE CONVENTION

Summary:

The Government of the Philippines has submitted the attached proposal* for the inclusion of the Black Noddy (*Anous minutus*) subspecies *worcesteri* on Appendix II of CMS.

*The geographical designations employed in this document do not imply the expression of any opinion whatsoever on the part of the CMS Secretariat (or the United Nations Environment Programme) concerning the legal status of any country, territory, or area, or concerning the delimitation of its frontiers or boundaries. The responsibility for the contents of the document rests exclusively with its author.

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

A. PROPOSAL

This proposal is for the inclusion of Black Noddy (*Anous minutus*) subspecies *worcesteri* in Appendix II. The species is classified as Endangered on account of a very small population which breeds within a tiny area of occupancy on just two islets, and is projected to decline by more than 70 per cent over the next 10 to 15 years.

B. PROPONENT: Government of the Republic of the Philippines

C. SUPPORTING STATEMENT

1. Taxonomy

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

2. Overview

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

3. Migrations

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

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

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

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

4. Biological data (other than migration)

4.1 Distribution (current and historical)

Breeding: Philippines (Bird Islet and South Islet, Tubbataha Reefs Natural Park, Sulu Sea, Palawan). The subspecies may also breed on Ashmore Reef off NW Australia (Gochfeld et al 2017).

Migrant/ wintering range: Malaysia and Indonesia

Vagrant: Occasionally west to Sri Lanka (Dickinson 1991).

Historical: Described from Philippines Cavili Island, Cagayancillo in 1911 (Worcester 1911). It abandoned Cavili around 1987, apparently due to increased anthropogenic disturbances and conversion of its breeding habitat. Rediscovered in October 1991 as breeding on Bird Islet, Tubbataha Reefs Natural Park (Jensen and Songco 2016). Extensive search for breeding seabirds in the Philippine part of the Sulu Sea and in the Balabac Strait 2007 revealed absence of the subspecies from all reefs and atolls (Jensen 2007, Matillano et al 2006). Also absent from Lawak Island, Kalayan (Spratleys) where other seabird species are breeding (Bim Quemado pers. comm. 2016).

4.2 Population (estimates and trends)

The first population estimate is from South Islet, Tubbataha Reefs Natural Park in 1981 where 147 adults were counted (Kennedy 1982). In October 1991 more than 3,000 birds and in 1995 about 7,128 adults were found breeding. The population on Bird Islet fluctuated between 3,250 and 4,552 in the period 1997 to 2000. Before, about 7,000 were recorded in 2001, although it then collapsed to about 800 in 2004. In 2005 most of the breeding population, 6,400 adults, were still on Bird Islet but thereafter the Bird Islet breeding population declined due to loss of breeding habitat – only 795 adults were present in 2016 (Jensen et al 2016). On South Islet a corresponding increase was noted: 215 in 2005, 3,300 in 2006 and 8,250 in 2013, when a record number of 10,656 adults were counted on both islets (Jensen and Songco 2016). Since then a continued decline to only 3,716 adults with 920 nests could be found in May 2017 (Tubbataha Management Office, pers. comm. 2017). The proportion of nesting adults has fallen from about 50 per cent (2014) to 19 per cent (2016).

The only other known breeding site was found on Cavili Island, Cagayanscillo (Kennedy et al 2000). The species, however, abruptly disappeared from the island in 1987 presumably due to increased anthropogenic disturbances and substantial reduction in its breeding habitat (W. Dosong pers. comm. 2007).

4.3 Habitat (short description and trends)

The two breeding islets of Tubbataha Reef Natural Park have undergone progressive development from barren to fully vegetated habitats. The breeding habitat for the Black Noddy subspecies is dominantly composed of tropical almond *Terminalia catappa*, lettuce tree *Pisonia alba*, and octopus bush *Argusia argentea*. In 1911 Bird Islet was barren and remained so at least until 1981 (Kennedy 1982). By 1991 more than 100 trees were noted and bush and tree numbers increased to about 500 by 2004. Since then a massive influx of breeding Red-footed Booby *Sula sula* has destroyed most of the breeding habitat on Bird islet. It caused most of the Noddy population to move to South Islet which was thickly forested until 2011 (Jensen and Songco 2016). In 2017 only about 36 trees in a severely deteriorating condition remained on South Islet (Tubbataha Management Office, pers. comm.2017).

Outside of the breeding period the subspecies is strictly pelagic.

4.4 Biological characteristics

The subspecies breeds mainly from April to August and in some years also from September to October (1991, 1997, 2008, and 2009) The October breeding population is smaller with peak counts of 3,500 individuals (1997) (Jensen and Songco 2016). It lays normally one egg and

nests are re-used in subsequent years. Survival rate is unknown although there are several cases of dead adult birds found entangled in fishing lines used as breeding material. Predation by migratory individuals of Peregrine *Falco peregrinus* takes place regularly. The scarcity of breeding habitat has caused the subspecies to breed in two annual cycles as a reproductive strategy.

4.5 Role of the taxon in its ecosystem

The guano produced by the subspecies adds large quantities of nutrients to the soil which is of great importance to the plant communities on the two breeding islets. This again contributes to protecting the islets from velocity of waves and reduces impacts from storms and sea level rise.

5. Conservation status and threats

5.1 IUCN Red List Assessment (if available)

Not applicable. The proposal is for the geographically separate endemic subspecies *Anous minutus worcesteri*

5.2 Equivalent information relevant to conservation status assessment

The subspecies has a very restricted breeding range of 1.6 hectares. Combined with a rapidly deteriorating breeding habitat enabling less than 10 per cent of the adult population to reproduce and increasingly a declining breeding population, its conservation status is proposed as Endangered based on the following:

- a. A projected population size reduction of ≥ 50 per cent over the next 10 years or three generation period following i) area of occupancy, ii) quality of breeding habitat, and iii) declining number of mature individuals due to lack of replenishment of adult individuals;
- b. Projected extreme fluctuations caused by i) reduction in area of occupancy and locations of population, and ii) number of mature individuals.
- c. Lack of alternate breeding sites free of predators making the subspecies extremely vulnerable to loss of breeding habitats and breeding areas.

5.3 Threats to the population (factors, intensity)

The main threat to the population at the two breeding sites is a continued loss of breeding habitats, e.g. in 2016 and 2017 only 19 per cent and 25 per cent of the present adult population respectively, could breed due to lack of breeding trees and foliage for nesting materials. In 2017 only 39 per cent of the peak population (10,656 in 2013) were present. As remaining trees are projected to die within less than five years, it will leave a fragment of the adult population with just a few bushes for continued reproduction (A.E. Jensen pers. comm. 2017).

A longer-term threat is reduction in the land area of Bird Islet suspected to be caused by sea level rise and increased wave velocity due to increase in storms and their intensity. In 2016 the land area was reduced by 17 per cent (Jensen et al 2016).

5.4 Threats connected especially with migrations

No known threats

5.5 National and international utilization

National: Prior to management and protection of Tubbataha Reefs Natural Park, fishermen were known to collect the subspecies and its eggs for subsistence (Jensen and Songco 2016). Many fisherfolk also kept the subspecies as a pet on board their fishing boats (A.E. Jensen pers. comm. 2017).

International: Unknown

6. Protection status and species management

6.1 National protection status

Protected in the Philippines against hunting under Republic Act 9147, otherwise known as the Wildlife Resources Protection and Conservation Act which provides general prohibition of hunting wildlife.

The subspecies is indirectly protected under the Republic Act No. 10067 - Tubbataha Reefs Natural Park (TRNP) Act of 2009.

It is listed with status as Endangered in the Philippine Red List of Threatened Species (DENR 2017).

6.2 International protection status

None

6.3 Management measures

Under the Philippines Republic Act NO. 10067 the subspecies is protected in its breeding area, e.g. a zoning plan prevents visits to the breeding islet and utilization of the subspecies. Hence, the measures take into consideration effective protection of the species, its habitats, and ecosystems it is dependent on.

6.4 Habitat conservation

Within the subspecies' breeding area in the Philippines, the management of the protected area where it exists, is entitled to implement activities to manage the population. In 2017 consideration is being given to start building artificial nesting platforms and provide the subspecies with nesting materials as a temporary substitute for loss of most of its breeding habitat.

As the subspecies only occur pelagic outside of the breeding season, there are no known joint programmes between the range states Philippines, Malaysia and Indonesia.

6.5 Population monitoring

The breeding population in the Philippines is monitored monthly by the park rangers of the Tubbataha Reefs Natural Park. In addition, quarterly breeding inventories are undertaken (Jensen and Songco 2016).

7. Effects of the proposed amendment

7.1 Anticipated benefits of the amendment

Increase in management action plans, funding of these and increased collaboration within range states

7.2 Potential risks of the amendment

None

7.3 Intention of the proponent concerning development of an Agreement or Concerted Action

The intention is to seek full legal protection of the subspecies in Indonesia and Malaysia and further develop a concerted action plan with focus on a) satellite tracking of the subspecies during migration to determine main non-breeding areas, and b) based on results from satellite-tracking further determine appropriate conservation actions.

8. Range States

Breeding: Philippines

Migration: Malaysia and Indonesia

9. Consultations

Preliminary consultations have been undertaken with Narelle Montgomery, Government of Australia, and with Wetlands International, BirdLife International and BirdLife Philippines. Other consultations will be undertaken with the EAAFP Seabird Working Group.

10. Additional remarks

11. References

- BirdLife International 2017. Species factsheet: *Anous minutus*. Retrieved from <http://www.birdlife.org> on 10/05/2017.
- Department of Environment and Natural Resources (DENR) (2017). Red list of Philippines threatened species (in prep.)
- Dickinson, E.C., R.S. Kennedy and K.C. Parkes 1991. The birds of the Philippines: An annotated check-list. British Ornithologists' Union Check List No. 12.
- Gauger, V. 1999. Black noddy (*Anous minutus*). Pp. 1-32 in A Poole, F Gill, eds. The Birds of North America, Vol. 412. Philadelphia: The Birds of North America, Inc.
- Gochfeld, M., Burger, J., Kirwan, G.M. & Garcia, E.F.J. 2017. Black Noddy (*Anous minutus*). In: del Hoyo, J., Elliott, A., Sargatal, J., Christie, D.A. & de Juana, E. (eds.). Handbook of the Birds of the World Alive. Lynx Edicions, Barcelona. Retrieved from <http://www.hbw.com/node/54050> on 10 May 2017.
- International Union for Conservation of Nature and Natural resources (IUCN) 2017. Red List of Threatened Species. Gland, Switzerland and Cambridge, UK: Species Survival Commission, IUCN.
- Jensen, A.E. 2007. Conservation of seabirds and threatened avifauna in the Cagayan Ridge Marine Biodiversity Conservation Corridor, the Sulu Sea, Philippines. With notes on the occurrence of seabirds in the Balabac and the Tri-national Sea-turtle Marine Biodiversity Conservation Corridors. Conservation International Philippines. Downloaded from <http://www.conservation.org/archive/philippines/publications/Documents/Seabirds-Cagayan Ridge> on 10 May 2017.
- Jensen, A. E. 2014. Monitoring and inventory of the seabirds and their breeding areas in Tubbataha Reefs Natural Park & World Heritage Site, Cagayancillo, Palawan, Philippines May 8-11, 2012. Tubbataha Management Office, Puerto Princesa City, Philippines. Unpublished Report.
- Jensen, A. E. 2015. Monitoring and inventory of the seabirds and their breeding areas in Tubbataha Reefs Natural Park & World Heritage Site, Cagayancillo, Palawan, Philippines May 8-11, 2012. Tubbataha Management Office, Puerto Princesa City, Philippines. Unpublished Report
- Jensen, A.E., Songco, A.M. and Paliawan, M.R. 2016. Field Report: Monitoring and inventory of the seabirds and their breeding areas in Tubbataha Reefs Natural Park and World Heritage Site, Cagayancillo, Palawan, Philippines May 2016.
- Jensen, A. E. & Songco, A. 2016. The Birds of Tubbataha Reefs Natural Park and World Heritage Site, Palawan province, Philippines, including accounts of breeding seabird population trends. FORKTAIL 32 (2016): 72-85.
- Kennedy, R.S. 1982. The last of the Seabirds. The Filipinas Journal of Science and Culture. Filipinas Foundation Vol III, 40-49.
- Kennedy, R.S. Gonzales, P.C., Dickinson, E.C., Miranda Jr., H.C. and Fisher, T.H. 2000. A Guide to the Birds of the Philippines. OXFORD University Press.
- Matillano, J.D., Faburada, A.F., Cayetano, C.B., Alava, M.N.R., & Froyalde H. 2006. Technical report of seabird survey conducted in Balabac Strait marine biodiversity conservation corridor. Cagayan: Conservation International Philippines
- McGregor, R.C. 1911. Record of a Puffinus new to Philippine waters and description of a new species of Micranous. Phil. J. Sci 6: 183-184.
- Republic of the Philippines. Republic Act No. 10067. An Act Establishing the Tubbataha Reefs Natural Park in the Province of Palawan as a Protected Area Under the Nipas Act (R.A. 7586) and the Strategic Environmental Plan (Sep) for Palawan Act (R.A. 7611), Providing for its Management and For Other Purposes. Tubbataha Reefs Natural Park (TRNP) Act of 2009.
- Worcester, D.C. 1911. Newly discovered breeding places of Philippine sea birds. Phil. J. Science 6: 167-177.

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

Bird Islet



Viewing angle for photo: facing NW 180°

Comments: panoramic view

Photo name code: BI 01

Photo Doc Site NI No. 01 - 2004

Film no: 33, 34, 35, 36

Date: May 7, 2004

Photo no (camera): 4 shots



Photo name code: B1 01

Comments: 7 shots (Stitched by Microsoft ICE)

Date: May 15, 2018

Photo Doc Site NI No. 01 - 2018

Photo nos.: DSC 7926 – 32

Photo credit: Teri Aauino



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

Comments: 7 shots

Photo Doc Site NI No. 02 - 2018

Photo nos.: DSC_7876 - 83

Date: May 15, 2018



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: 10 shots stitched (Microsoft ICE) Photo credit: Teri Aquino

Date: May 15, 2019

Photo no (camera): DSC_7900_10



Photo Doc Site NI No. 04 - 2004

Viewing angle for photo: facing E 067°

Film no: 14

Photo name code: BI 04

Comments: 1 shot plaza

Photo no (negative):

Photo no (camera):

Date: May 7, 2004



Photo name code: BI 04

Comments: 1 shot plaza

Date: May 15, 2018

Photo nos.: DSC_7851

South Islet:



Viewing angle for photo: facing S 060°

Comments: shot includes view of parola at the background

Photo name code: SI 01



Photo name code: SI 01

Date: May 15, 2018

Comments: single shot including parola at the background

Photo no. (camera): DSC_7851

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

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

| | |
|-----|---|
| 75% | <i>Labroides bicolor</i> (1.5) |
| 75% | <i>Thalassoma amblycephalum</i> (2.625) |
| 75% | <i>Thalassoma janseni</i> (1.5) |
| 75% | <i>Thalassoma purpuraceum</i> (1.5) |
| 75% | <i>Cetoscarus bicolor</i> (now <i>ocellatus</i>) (1.5) |
| 75% | <i>Siganus vulpinus</i> (1.5) |
| 75% | <i>Acanthurus japonicus</i> (1.75) |
| 75% | <i>Acanthurus nigrofasciatus</i> (2) |
| 75% | <i>Naso brevirostris</i> (1.875) |
| 75% | <i>Naso hexacanthus</i> (2.25) |
| 75% | <i>Arothron meleagris</i> (1.375) |

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

| Hard Coral (HC) | |
|-------------------------------------|-------------------------------------|
| <i>Acanthastrea</i> (ACAN) | <i>Oxypora</i> (OXY) |
| <i>Acropora</i> branching (ACB) | <i>Pachyseris</i> encrusting (PACE) |
| <i>Acropora</i> corymbose (ACC) | <i>Pachyseris</i> foliose (PACF) |
| <i>Acropora</i> digitate (ACD) | <i>Pavona</i> (PAV) |
| <i>Acropora</i> hispidose (ACH) | <i>Pectinia</i> (PEC) |
| <i>Acropora</i> plate (ACT) | <i>Platygyra</i> (PLAT) |
| <i>Acropora robusta</i> group (ACR) | <i>Pocillopora</i> (POC) |
| <i>Astreopora</i> (AST) | <i>Porites</i> branching (PORB) |
| Attached fungiids (AF) | <i>Porites</i> encrusting (PORE) |
| Bleached coral (BLEC) | <i>Porites</i> massive (PORM) |
| <i>Caulastrea</i> (CAU) | <i>Seriatopora</i> (SER) |
| <i>Coeloseris</i> (COE) | <i>Stylophora</i> (STY) |
| <i>Coscinaraea</i> (COS) | <i>Symphyllia</i> (SYM) |
| <i>Cyphastrea</i> (CYP) | <i>Tubipora musica</i> (TUBI) |
| <i>Diploastrea heliopora</i> (DIP) | <i>Turbinaria</i> (TURB) |
| <i>Echinophyllia</i> (ECHY) | Algal Assemblage (AA) |
| <i>Echinopora</i> (ECHI) | Algal assemblage (AA) |
| <i>Euphyllia</i> (EUP) | Crustose/coralline algae (CA) |
| <i>Favia</i> (FAV) | Dead coral (DC) |
| <i>Favites</i> (FVI) | Dead coral with algae (DCA) |
| <i>Fungia</i> (CMR) | Disease (DIS) |
| <i>Galaxea</i> (GAL) | Abiotic (AB) |
| <i>Goniastrea</i> (GONIA) | Gravel (GRV) |
| <i>Goniopora</i> (GONIO) | Rubble (R) |
| <i>Heliopora</i> (HEL) | Sand (S) |
| <i>Hydnophora</i> (HYD) | Sedimentary rock (RCK) |
| <i>Isopora</i> (ISO) | Silt (SI) |
| <i>Leptoria</i> (LEPA) | Macroalgae (MA) |
| <i>Leptoseris</i> (LEPS) | <i>Codium</i> (COD) |
| <i>Lobophyllia</i> (LOB) | <i>Kappaphycus</i> (KAPP) |
| <i>Merulina</i> (MER) | Macroalgae (MA) |
| <i>Millepora</i> (MILL) | <i>Sargassum</i> (SARG) |
| <i>Montastrea</i> (MON) | Halimeda (HA) |
| <i>Montipora</i> branching (MONTB) | <i>Halimeda</i> (HA) |
| <i>Montipora</i> encrusting (MONTE) | Other biota (OT) |
| <i>Montipora</i> foliose (MONTF) | <i>Acanthaster</i> (COTS) |
| <i>Mycedium</i> (MYC) | Corallimorpharian (COR) |
| Other branching corals (CB) | <i>Diadema</i> (DIA) |
| Other bubble corals (BUB) | Gorgonian (GORG) |
| Other encrusting corals (CE) | <i>Isis</i> (ISIS) |
| Other foliose corals (CF) | Other invertebrates (OT) |
| Other free-living fungiids (CMR) | Seagrass (SG) |
| Other massive corals (CM) | Soft coral (SC) |
| <i>Oulastrea</i> (OULA) | Sponge (SP) |
| <i>Oulophyllia</i> (OULO) | Zoanthid (ZO) |

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

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