2017 Ecological Assessment of
Ngelukes Conservation Area

Evelyn Ikelau Otto, Marine Gouezo, Lincy Lee Marino, Victor Nestor,

Dawnette Olsudong, Randa Jonathan, Geory Mereb, Christina Muller-Karanassos

Palau International Coral Reef Center

PICRC Technical Report 19-02

March 2019

(Revised December 2019)

Abstract

Since 2014, the Palau International Coral Reef Center (PICRC) has been monitoring the 14 marine protected areas (MPA) established within the Palau Protected Areas Network (PAN). Baseline assessments were conducted between 2014 and 2015 with subsequent assessments conducted two years later between 2017 and 2018. This study was conducted at the Ngelukes Conservation Area (CA) located within the state of Ngchesar. This assessment focused on recording abundance of commercially important fish and macro-invertebrates and commercially important fish biomass, benthic community, and coral recruitment on the reef flat and fore reef habitats. In the reef flat, results show that commercially important fish abundance and biomass were significantly higher within the MPA compared to reference site despite consistently low seagrass coverage (10%) since 2012. On the fore reef, macro-invertebrate abundance was higher within the MPA compared to the reference site, as well as the initial baseline in 2015. The recruitment of juvenile corals between the MPA and reference site was similar, with a significant increase in recruitment since the baseline assessment. Benthic community between 2015 and 2017 indicated a decrease in live coral cover while soft corals, sand, and rubble showed an increase. Due to a change in methodology on fish surveys, results could not be compared with the baseline. However, in 2017, comparison between MPA and reference sites indicated a significantly higher abundance and biomass of fish in the MPA than in the reference area. Despite minor changes in the benthos in the MPA through time, our findings show that Ngelukes CA is effective at protecting marine resources such as fish and macro-invertebrates.

1. Introduction

Marine Protected Areas (MPAs) are management tools used to protect marine biodiversity. This tool is increasingly being utilized in Palau, as well as throughout Micronesia. Nationwide, Palau has over 44 protected areas, 33 of which cover marine habitats (Friedlander et al 2017). The Protected Areas Network (PAN) was established in 2003 by the Palau National Government, and serves as a nation-wide system of protected areas (RPPL No. 6-39). In 2007, Palau strengthened its national conservation campaign by joining forces with the Micronesia Challenge (MC). This collaboration commits Palau to effectively conserving at least 30% of near-shore marine resources and 20% of terrestrial resources by 2020.

The Palau International Coral Reef Center (PICRC) has been conducting ecological surveys to assess the effectiveness of the PAN MPAs. Biological monitoring is an essential component of adaptive management to measure the effectiveness and progress of MPAs. Baseline assessments were conducted at all PAN MPAs between 2014 and 2015 (Gouezo et al 2016). To assess their effectiveness, PICRC has subsequently re-surveyed each of the PAN MPAs between 2017 and 2018. In order to effectively manage protected areas, resource managers and relevant stakeholders need information on the changes and trends in the condition of resources.

The state of Ngchesar passed their legislation in 2002 to close off 1.04 km² of the state's marine habitat for conservation purposes, known as Ngelukes Conservation Area (CA) (Ngirkelau et al 2010). This survey is the first subsequent follow-up assessment since the baseline in 2015, though PICRC has been monitoring Ngelukes CA seagrass habitat since 2011 (Rehm et al 2014). The objectives of this follow-up are to compare possible changes within the MPA over time (2015 and

2017) as well possible differences between the MPA and a non-protected reference site. Commercially important macro-invertebrate densities, benthic cover, and coral recruitment were compared within the MPA over time between 2015 and 2017. These same parameters as well as commercially important fish abundance and biomass were used to compare effectiveness of the restricted MPA and a similar habitat of no restrictions here after referred to as the reference site. Unlike the fore reef, where the baseline in 2015 was the first assessment of the habitat, the reef flat inhabited by seagrass beds is one of PICRC's long term seagrass monitoring sites, first surveyed in 2011. For this reason, seagrass results have both MPA and reference data from 2015 whereas on the fore reef, 2015 is represented only by MPA data.

2. Method

2.1. Study site

Ngelukes Conservation Area (CA) is a patch reef of approximately 1.04 km² in size that consists of a fore reef, reef crest, and reef flat habitat. During the baseline survey conducted in 2015, all three habitats within the MPA were surveyed. As the first follow-up assessment, two main habitats indicated in the baseline report were surveyed – the fore reef and reef flat. This study was conducted between August 1-3, 2017, at a depth of 10 m along the fore reef and maximum depth (<2 m) on the reef flat. Additionally, to examine the effectiveness of the MPA, a site featuring the same two habitats but is unprotected was used for the purpose of a reference site (Fig. 1).

Figure 1: Map of Ngchesar's Ngelukes Conservation Area and the reference sites, Uedengel and Ucher showing the surveyed sites.

2.2. Ecological survey

Two survey methods were used, specific to each habitat. On the reef flat, (five) 25 m transect tapes were laid on the reef with 1-3 m gap between each tape. Along each transect, fish size and abundance, macro-invertebrate size and abundance, and seagrass percent coverage data was measured. On the fore reef, (five) 50 m transect tapes were laid with a 1-3 m gap between each tape. Data recorded on the fore reef were fish size and abundance, macro-invertebrate size and

abundance, benthic community, and coral recruit size and abundance. All data was compared with the baseline assessment with the exception of fish size and abundance due to a change in survey method.

Fish size and abundance survey on the reef flat were done visually while on the fore reef, fish was recorded using stereo-DOV (Diver Operated Video) within a 5 m wide belt. Edible macro-invertebrates were recorded within a 2 m wide belt along each transect. Seagrass percent coverage was measured using a 0.5 m² quadrate placed at every 5 m. Benthic community was measured using photographs taken at every meter along each transect using an underwater camera (Canon G16) mounted on a 0.5 m² photo-quadrat frame. Coral recruits (juvenile corals ≤ 5 cm) were recorded in the first 10 m of each transect within a 0.3 m wide belt.

2.3. Data processing and analysis

Fish videos were processed using a software, *Event Measure*, where all commercially important fish were counted and measured in length. Biomass of fish was calculated using the total length-base equation $W = aTL^b$ where *W* is the weight of the fish in grams, *TL* is the total length of the fish in centimeters (cm), and *a* and *b* are constant values that derived from published biomass-length relationships (Kulbicki et al. 2005) and from Fishbase (http://fishbase.org). Photographs of benthic cover were analyzed using CPCe (Coral Point Count with excel extensions, Kohler and Gill 2006). Seagrass percent coverage, coral recruits, and invertebrate data were entered into excel for further analysis.

Prior to running statistical test, the data was checked for normality, visually using histograms and using Shapiro test. When data were non-normal, data was log transformed and re-tested. Normal

data was analyzed using One-Way ANOVA. Non-normal data was analyzed using Mann-Whitney-Wilcoxon test. All analysis was done using *R* software (R Development Core Team 2017).

3. Results

Data from the 2017 surveys are presented according to habitat type and compared to data obtained during the baseline assessment in 2015.
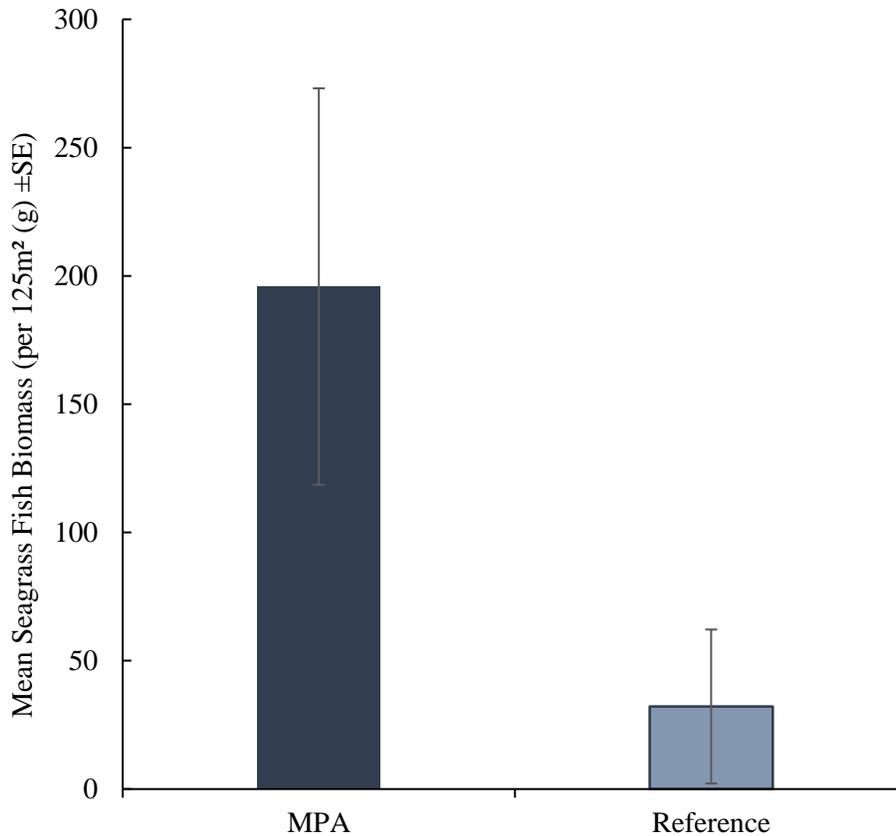
3.1. Seagrass Habitat
3.1.1. Fish

The abundance of commercially important fish within the seagrass bed was significantly higher within the MPA (9.73 (±7.27)) compared to the reference site (0.87 (±0.36)) (Mann Whitney test, $p < 0.05$, Fig. 2). Meyas (*Siganus fuscescens*) was the most abundant species observed within the MPA and itotech (*Lethrinus harak*) was the most abundant within the reference site.

The biomass of the recorded fish was significantly higher within the MPA (195.83 g (±77.28 g)) compared to the reference site (32.17 g (±30 g)) (Mann Whitney test, $p < 0.05$, Fig. 3).
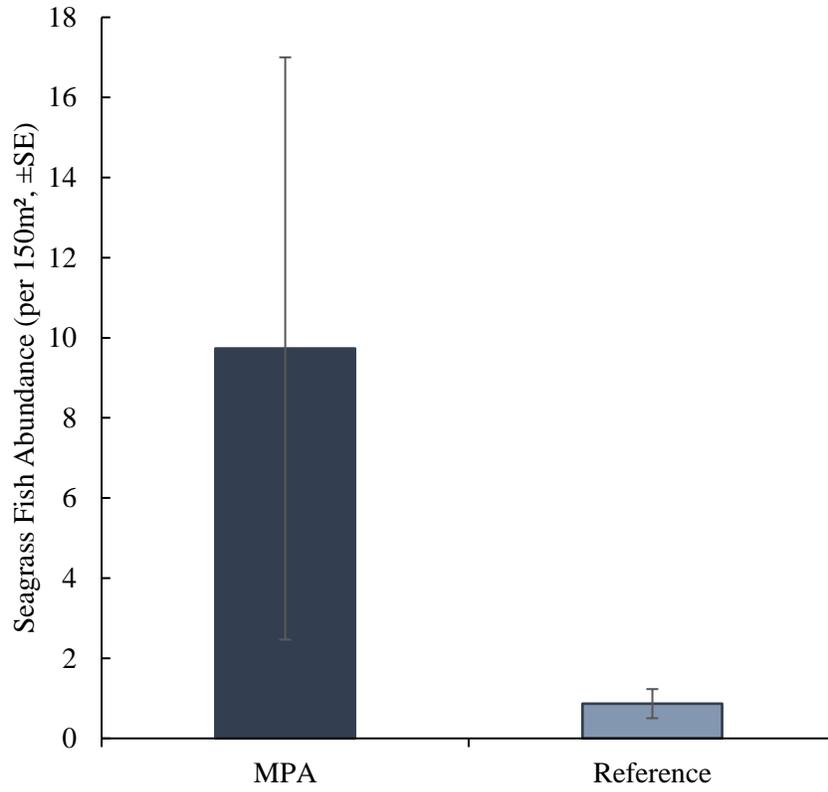
Figure 2: Mean abundance of commercially important fish recorded within the reef flat seagrass habitat. Error bars representing standard of error, with n=3.

Figure 3: Mean biomass of commercially important fish recorded within the reef flat seagrass habitat. Error bars representing standard of error, with n=3.

3.1.2. Macro-Invertebrates

Macro-invertebrate abundance within the seagrass habitat indicated no significant difference (ANOVA p >0.05) between the MPA and reference in 2017 (0.33 ±0.13, 0.07 ±0.07, respectively) and the MPA and reference in 2015 (0.93 ±0.45, 0.47 ±0.27, respectively) (Fig. 4). Over time, no significance was found between the MPA in 2015 and in 2017 (ANOVA p>0.05). In 2015, both sea cucumber and giant clam species were observed with oruer (*Tridacna crocea*) being the most abundant species recorded. Whereas in 2017, sea cucumber were the only recorded macro-invertebrates with mermarch (*Bohadschia spp.*) being the most abundant of the species.
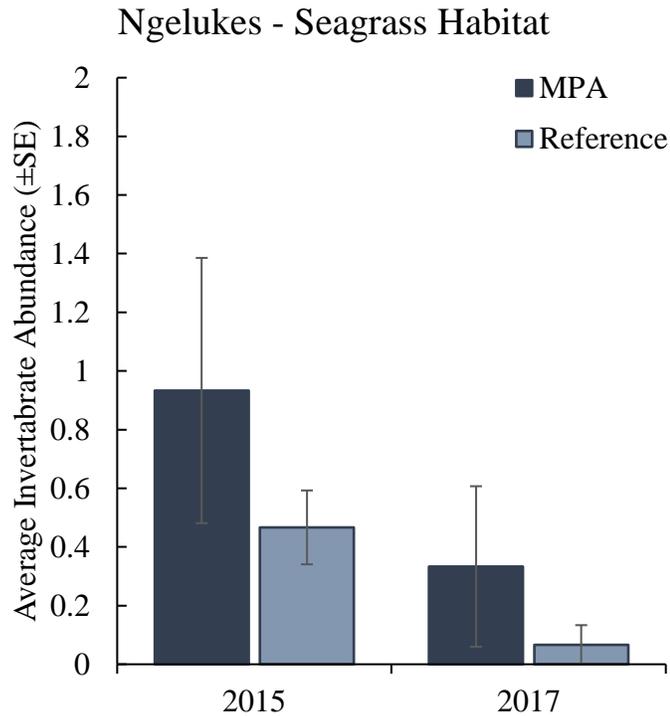
Figure 4: Mean macro-invertebrates abundance within the seagrass habitat within the MPA and the reference site in 2015 and 2017. Error bars representing standard of error, with n=3.

3.1.3.   Seagrass Cover

Ngelukes seagrass beds have been one of PICRC's seagrass beds monitoring sites since 2011. Over the past 6 years, the coverage of seagrass trends were similar between the MPA and the reference. Data show a sharp decline in seagrass cover from 2011 to 2012 both inside the MPA (39 ± 1.7% to 26 ± 1.8%) and at the reference site (49.5 ± 1.9% to 27.9 ± 1.1%). After 2012, the seagrass cover remained relatively stable within the MPA, fluctuating at ~25-30%, whereas at the reference site the seagrass cover increased from 2012 to 2015 to ~45% followed by a decrease to ~30% in 2017 (Fig. 5).
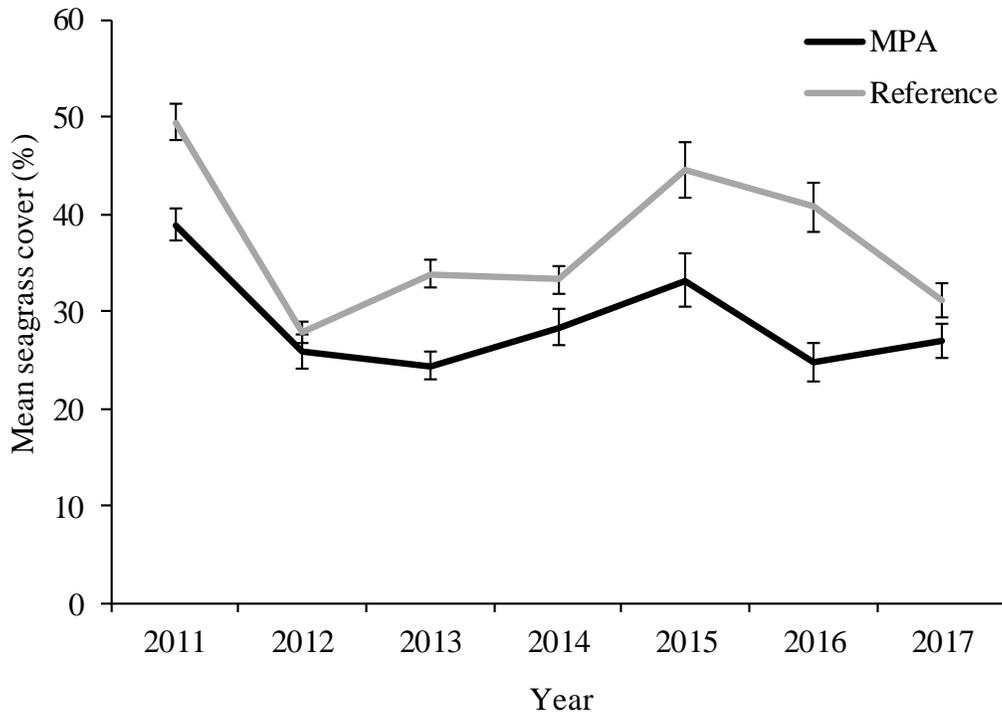
Figure 5: Mean percentage of seagrass cover at the reference site and MPA since 2011. Error bars represent the standard error.

3.2. Fore Reef Habitat
3.2.1. Fish

The MPA hosted significantly higher abundance of commercially important fish (8.13 (±2.13)) than the reference site (2.53 (±0.7)) (ANOVA p-value < 0.01). Total fish observed within the MPA was 122 fish, of which consist of 21 species while the 38 fish were observed within the Reference site consisting of 11 different species (Fig. 6). Otord and udoud ungelel (Scarus spp.) were the most abundant fish observed within the MPA while yaus (*Plectorhinchus lineatus*) was the most abundant fish observed within the reference site with keremlal (*Lutjanus gibbus*) being the second most abundant species in MPA and reference (Fig. 7).

The MPA showed significantly higher fish biomass (1585.56 g (±931 g)) than recorded in the reference site (542.84 g (±444.41)) (ANOVA p-value <0.05) (Fig. 8).
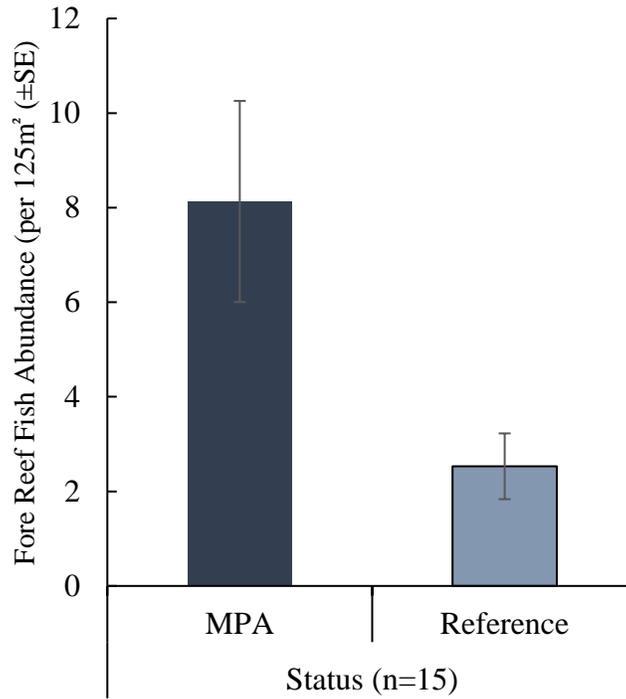
Figure 6: Mean fish abundance recorded in 2017 on the fore reef indicating significantly more fish within the MPA compared to the reference site. Error bars representing standard of error, with n=3.
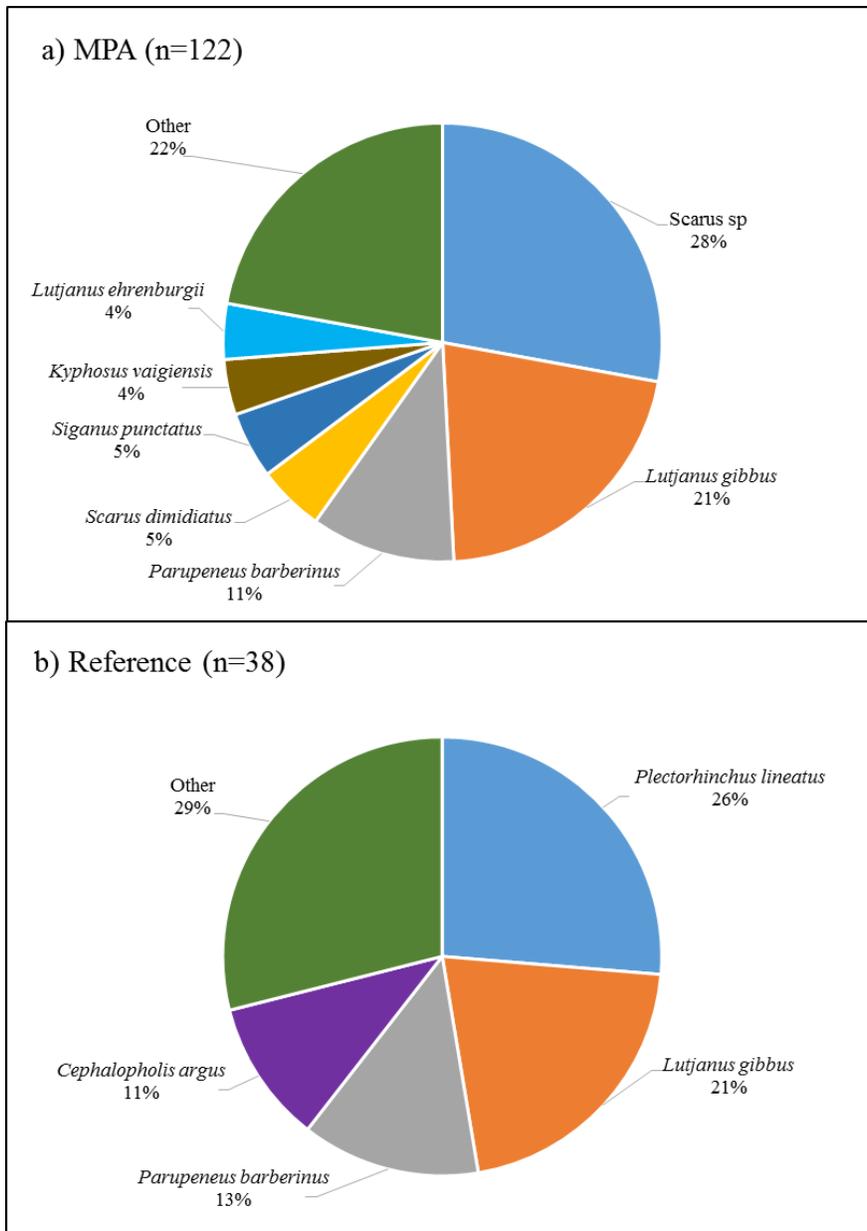
Figure 7: Pie chart indicate the most observed commercially important fish species overall observed within the fore reef of the a) MPA and b) Reference site.
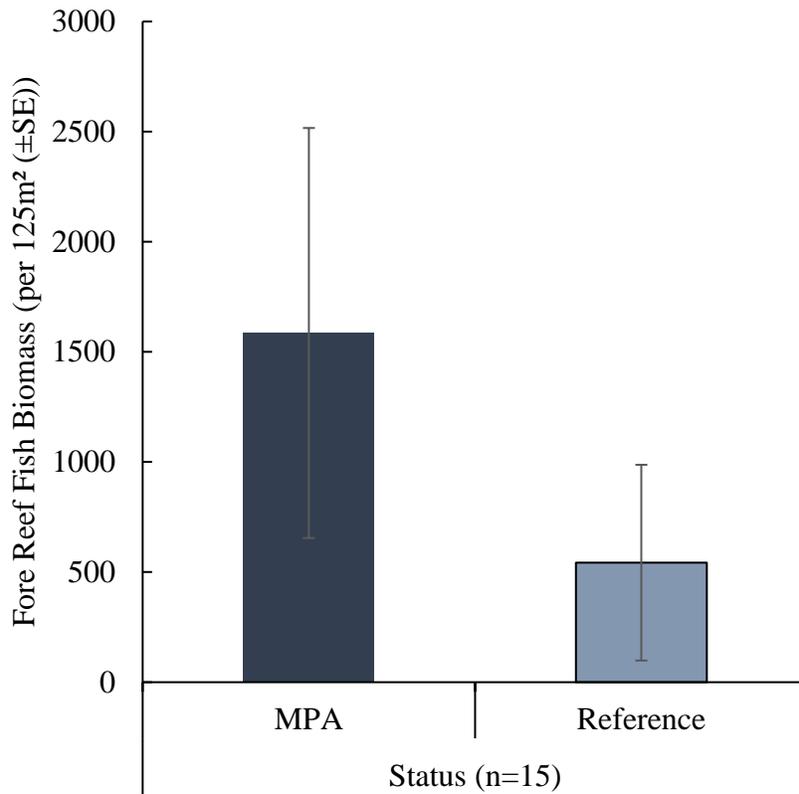
Figure 8: Mean fish biomass recorded in 2017 on the fore reef indicating no significant difference between fish biomass within the MPA and the reference site. Error bars representing standard of error, with n=3.

3.2.2. Macro-Invertebrates

The mean abundance of macro-invertebrates within Ngelukes MPA fore reef was 1.20 ($\pm$0.40) individuals per 100 m^2, which was significantly higher (Mann Whitney test, p-value < 0.01) than the reference site (0.20 ($\pm$0.11) individuals per 100 m^2) but similar to the MPA in 2015 (0.56 ($\pm$0.28) individuals per 100 m^2) (Mann Whitney test, p-value >0.05) (Fig. 9).
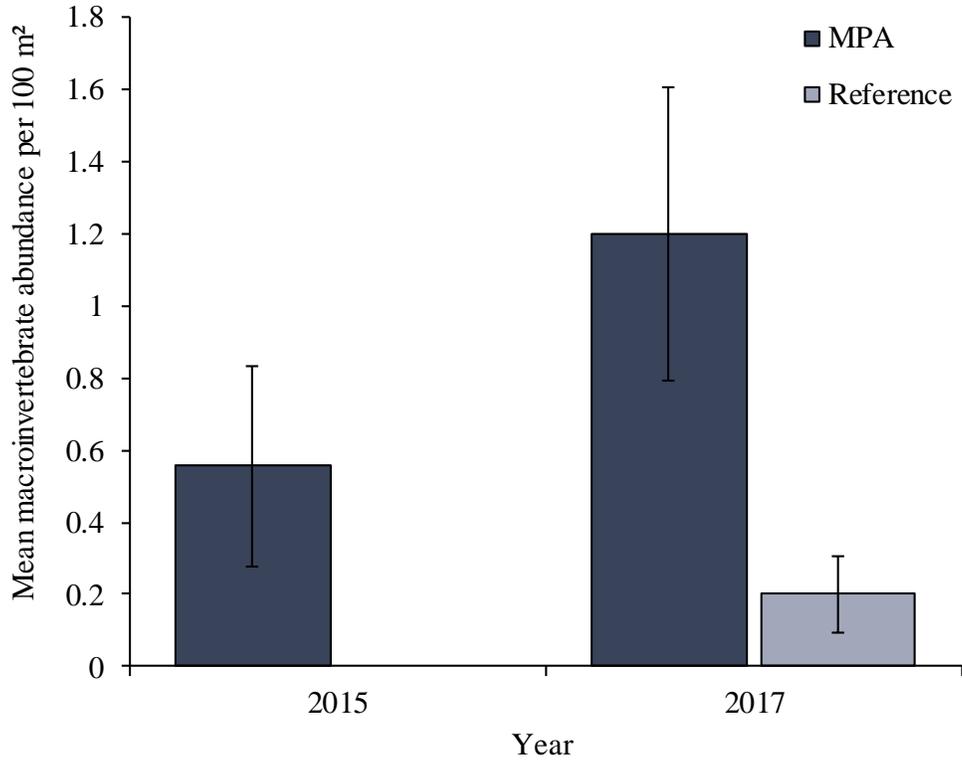
Figure 9: Mean macro-invertebrate abundance recorded on the fore reef Error bars representing standard of error, with n=3.

3.3. Coral Recruits

Our findings indicate no significant difference in mean coral recruit abundance within the MPA between 2015 (3.22 ± 0.86 per 3m^2) and 2017 (4.60 ± 1.06 per 3m^2) (Mann Whitney test, p-value >0.05) (Fig. 10), however recruit diversity was higher within the MPA in 2017 compared to 2015 (Fig. 11). Abundance was also similar between the MPA and reference site in 2017 (Mann Whitney test, p-value >0.05), with a higher diversity seen in the MPA.
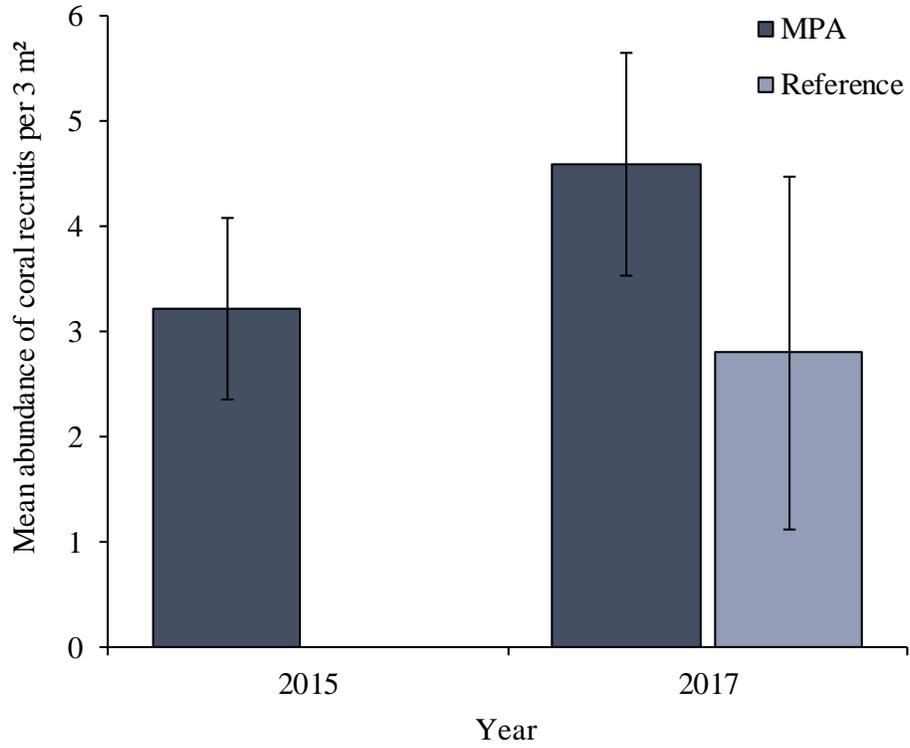
Figure 10: Mean coral recruits recorded within the MPA and reference in 2015 and 2017. Error bars representing standard of error, with n=3.
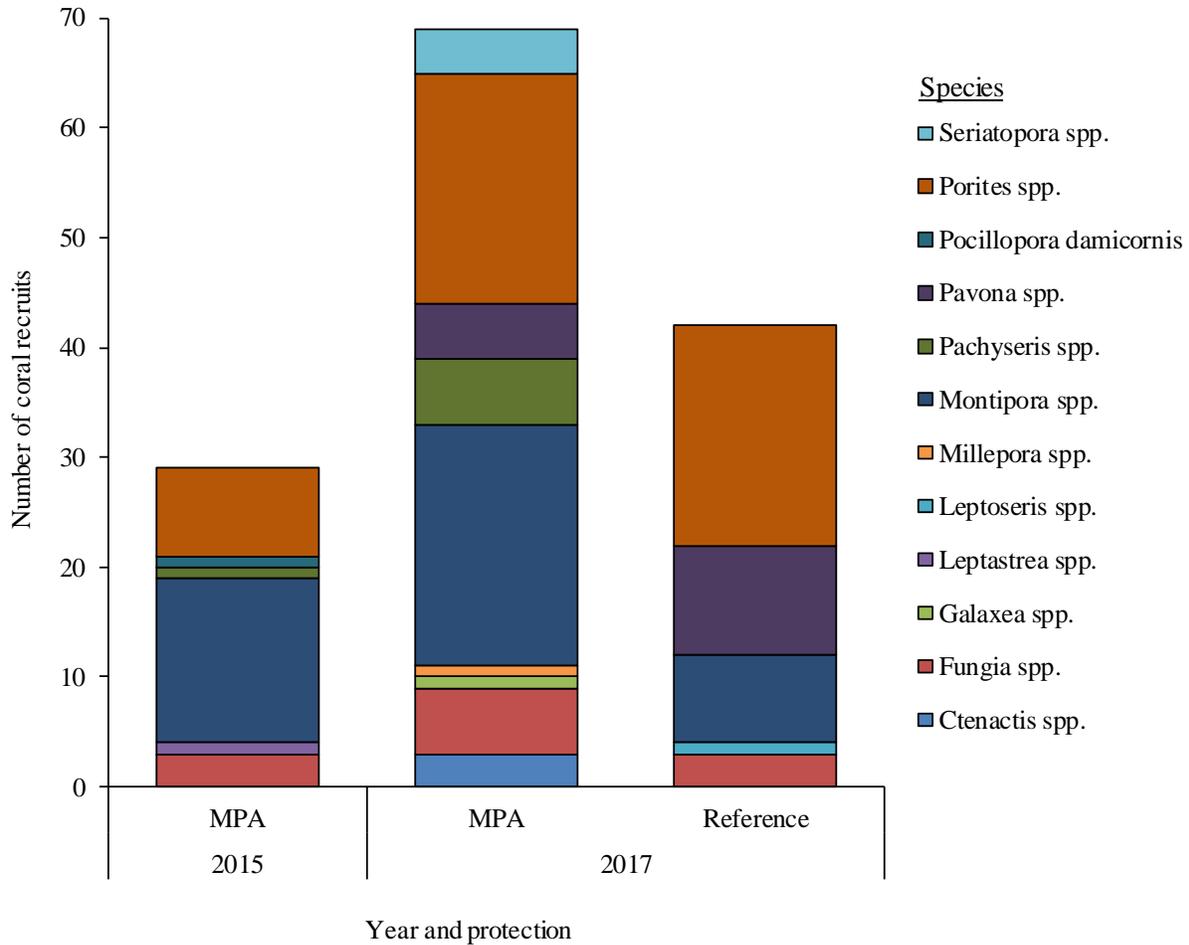
Figure 11: Stacked column indicating the different genera of recorded coral recruit.

3.4. Benthic Community

Coral cover decreased significantly (ANOVA p-value < 0.01) within the MPA in 2017 compared to the baseline in 2015, while soft corals, sand, and rubble cover significantly increased (T-test p-value < 0.001, p-value < 0.001, p-value < 0.001, respectively). Between the MPA and the reference site in 2017, sand and turf were significantly different (ANOVA p-value < 0.01, p-value < 0.05, respectively) (Fig. 12).
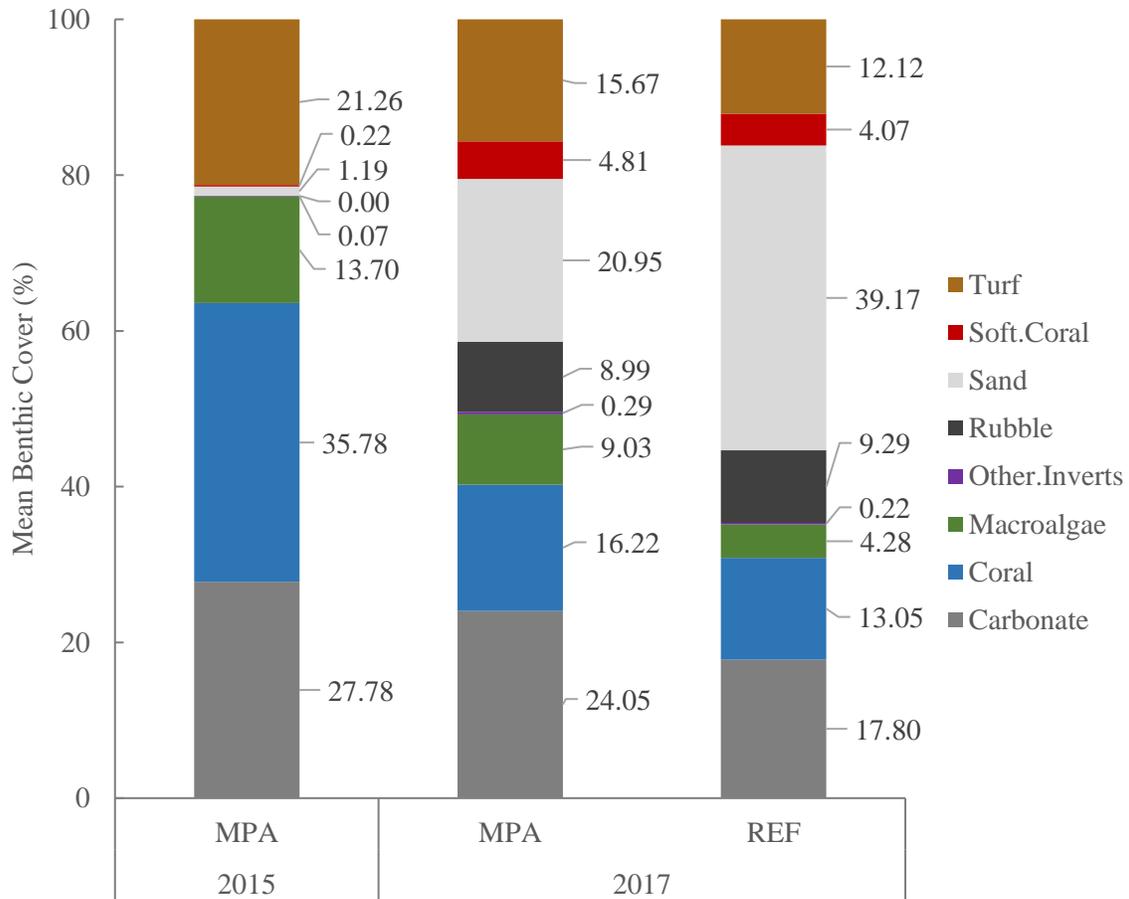
Figure 12: Stacked column indicating major benthic categories.

4. Discussion

This assessment was conducted to examine the effectiveness of Ngechesar's Ngelukes CA. Baseline data was obtained during a survey within the MPA in 2015 and was compared with the survey conducted in 2017 to examine any changes over time. In addition to the 2017 survey within the MPA, a non-protected reference site was surveyed to determine effectiveness between two similar sites. Overall, results from this assessment indicates that Ngelukes CA is an effective MPA showing higher resources than in 2015 and the reference site. Results from three

ecological parameters stand out the most and are highlighted and discussed in the following sub-sections.

4.1. Commercially important fish and macro-invertebrates

Our findings indicated that abundance and biomass of commercially important fish were significantly higher within Ngelukes CA. Results indicate Ngelukes CA effectively providing a safe habitat for fish to thrive and grow. These findings support those of Halpern 2003 where protected areas have shown to increase fish biomass and density. This is both a good sign of the effectiveness of the protected area as well as enforcement of the zone's no-fishing restrictions. Findings are supported by a previous study conducted by Friedlander *et al.* (2017) showing that higher biomass is greatly associated with the level of protection and enforcement of a no-take protected area found within the MPA's in Palau. This further supports our findings of edible macro-invertebrates being significantly greater within Ngelukes CA in the fore reef habitat. With Ngelukes CA being a no-take MPA, macro-invertebrates are protected from poaching, associating with the higher abundance found during this study.

4.2. Seagrass beds

PICRC's previous seagrass monitoring data showed a large decrease in seagrass cover from 2011 to 2012 both inside and outside the MPA. This loss in seagrass cover may have been caused by Typhoon Bopha which affected Palau in 2012. Studies have shown that typhoons can cause a reduction in seagrass cover followed by a quick recovery (Yang and Huang, 2011). Since 2012, seagrass cover has fluctuated within the reference site but remained relatively stable within the MPA, although cover has remained lower within the MPA compared to the reference site. As seagrass habitats often border the coast, terrestrial run-off is one of the major impacts that affect

these habitats (Duarte 2002). Though runoff from Ngchesar's Ngerdorch Watershed into Ngelukes CA would be a first thought to explain the lower coverage inside the MPA, a watershed study conducted in 2011 of the four watersheds surrounding Babeldaob found that Ngerdorch had the least impact from runoff and sedimentation (Golbuu et al 2011). The long-term data of coverage, along with the data showing low impact of runoff indicates that sedimentation may not have an immediate impact on the surrounding seagrass bed but could be a result of long exposure to constant sedimentation.

4.3. Benthos

Our findings show a significant change of benthic cover from the initial baseline in 2015 and this assessment. The results show that the percentage of coral cover within Ngelukes CA's fore reef significantly decreased in 2017 with a significant increase in soft coral, sand, and rubble. This shift is most likely due to a change in the survey methodology from the two survey time periods. Baseline assessments were conducted at depths between 5-6 m whereas this assessment was conducted at 10 m. Although we observed a higher non-coral substrate, the high abundance of fish especially herbivorous fish within the protected area prevents and maintains an overgrowth of turf algae (Gilby and Stevens 2014). Coral recruitment remained stable which could possibly lead to an increase in coral cover over time as long as the reef is not stressed by a future disturbance like Typhoon Bopha or Haiyan which devastated the eastern reefs of Palau in 2012 and 2013, respectively (Gouezo et al 2015).

Overall, this study indicates that the Ngelukes Conservation Area is efficient and showing to be an effective protection zone for commercially important fish and edible macro-invertebrates.

Continuous surveillance, enforcement, and public awareness of the MPAs zones will ensure the Ngelukes Conservation Area remains an effective protection area.

5. Acknowledgments

6. References

Duarte, C. (2002). The future of seagrass meadows. Environmental Conservation, 29(2), 192-206. doi:10.1017/S0376892902000127

Friedlander AM, Golbuu Y, Ballesteros E, Caselle JE, Gouezo M, et al. (2017) Size, age, and habitat determine effectiveness of Palau's Marine Protected Areas. PLOS ONE 12(3): e0174787. https://doi.org/10.1371/journal.pone.0174787

Halpern B (2003) The impact of marine reserves: Do reserves work and does reserve size matter? Ecological Application 13(1): 117-137.

Kohler KE, 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. Comput.Geosci. 32:1259–1269

Kulbicki M, Guillemot N, Amand M (2005) A general approach to length-weight relationships for New Caledonian lagoon fishes. Cybium 29:235–252

Gilby B, Stevens T (2014). Meta-analysis indicates habitat-specific alterations to primary producer and herbivore communities in marine protected areas. Global Ecology and Conservation 2:289-299.

Golbuu Y, Wolanski E, Harrison P, Richmond RH, Victor S, Fabricius KE (2011) Effects of Land-Use Change on Characteristics and Dynamics of Watershed Discharges in Babeldaob, Palau, Micronesia. Journal of Marine Biology 2011:1–17

Gouezo M, Koshiba S, Otto EI, Olsudong D, Mereb G, Jonathan R (2016) Ecological conditions of coral-reef and seagrass marine protected areas in Palau. Palau International Coral Reef Center Technical Report 16-06.

Gouezo M, Golbuu Y, van Woesik R, Rehm L, Koshiba S, Doropoulos C (2015) Impact of two sequential super typhoons on coral reef communities in Palau. Marine Ecology Press Series 540:73-85. Doi:10.3354/meps11518.

Ngirkelau V, Kotaro M, Saburo R, Kotaro K, Ngirametuker M, Eldebechel C, Moses S, Adelbai F, Kentaro S (2011-2015 ed.) (2010) Ngchesar State Protected Area System. Retrieved October 5,2015, from
http://www.palauconservation.org/cms/images/stories/resources/pdfs/Ngchesar_Mesekel at_Ngelukes_Management_Plan.pdf

R Development Core Team (2017) R: A language and environment for statistical computing. Vienna, Austria

Rehm L, Olsudong D, Mereb G, Gouezo M (2015) Gaining insight on MPA health through long-term seagrass monitoring in Palau (update 2014). Palau International Coral Reef Center Technical Report 15-10.

QGIS Development Team (2015) QGIS Geographic Information System. Open Source Geospatial Foundation Project.

Seventh Olbiil Era Kelulau (2007) *RPPL NO. 7-42: An act to amend Title 24 of the Palau National Code, Chapter 34 to clarify the intent of the "Protected Areas Network Act"; to endorse the "Micronesia Challenge"; to provide financing provisions for the Protected Areas Network; and to implement an Environmental Protection Arrival Fee ("Green Fee") for the financial sustainability of the Protected Areas Network; and for other related purposes.* Available at: http://www.palauconservation.org/cms/images/stories/resources/pdfs/2007_PAN_Leg_Gr eenFee_MicronesiaChallenge.pdf (Accessed: 25 September 2015).

Yang D and Huang D (2011) Impacts of Typhoons Tianying and Dawei on seagrass distribution in Xincun Bay, Hainan Province, China. Acta Oceanologica Sinica 30:1, 32-39.

7. Appendix

Table 1: Benthic Categories

CORAL (C)	Montiporasubmassive (MONTISB)	Boodlea (BOOD)
Acanthastrea (ACAN)	Mycedium (MYCED)	Bryopsis (BRYP)
Acropora branching (ACB)	Oulophyllia (OULO)	Caulerpa (CLP)
Acropora digitate (ACD)	Oxypora (OXYP)	Chlorodesmis (CHLDES)
Acropora encrusting (ACE)	Pachyseris (PACHY)	Dictosphyrea (DYCTY)
Acroporasubmassive (ACS)	Paraclavarina (PARAC)	Dictyota (DICT)
Acropora tabular (ACT)	Pavona (PAV)	Galaxura (GLXU)
Alveopora (ALVEO)	Pectinia (PECT)	Halimeda (HALI)
Anacropora (ANAC)	Physogyra (PHYSO)	Liagora (LIAG)
Astreopora (ASTRP)	Platygyra (PLAT)	Lobophora (LOBO)
Caulastrea (CAUL)	Plerogyra (PLERO)	Mastophora (MAST)
Coral Unknown (CRUNK)	Plesiastrea (PLSIA)	Microdictyton (MICDTY)
Coscinaraea (COSC)	Pocillopora-branching (POCB)	Neomeris (NEOM)
Ctenactis (CTEN)	Pocillopora-submassive (POCSB)	Not ID Macroalgae (NOIDMAC)
Cyphastrea (CYPH)	Porites (POR)	Padina (PAD)
Diploastrea (DIPLO)	Porites-branching (PORB)	Sargassum (SARG)
Echinophyllia (ECHPHY)	Porites-encrusting (PORE)	Schizothrix (SCHIZ)
Echinopora (ECHPO)	Porites-massive (PORMAS)	Turbinaria (TURB)
Euphyllia (EUPH)	Porites-rus (PORRUS)	Tydemania (TYDM)
Favia (FAV)	Psammocora (PSAM)	**SEAGRASS (SG)**
Faviid (FAVD)	Sandalolitha (SANDO)	C.rotundata (CR)
Favites (FAVT)	Scapophyllia (SCAP)	C.serrulata (CS)
Fungia (FUNG)	Seriatopora (SERIA)	E. acroides (EA)
Galaxea (GAL)	Stylocoeniella (STYLC)	H. minor (HM)
Gardininoseris (GARD)	Stylophora (STYLO)	H. ovalis (HO)
Goniastrea (GON)	Symphyllia (SYMP)	H. pinifolia (HP)
Goniopora (GONIO)	Tubastrea (TUB)	H. univervis (HU)
Halomitra (HALO)	Turbinaria (TURBIN)	S. isoetifolium (SI)
Heliofungia (HELIOF)	**SOFT CORAL (SC)**	Seagrass (SG)
Heliopora (HELIO)	Soft Coral (SC)	T. ciliatum (TC)
Herpolitha (HERP)	**OTHER INVERTEBRATES (OI)**	T.hemprichii (TH)
Hydnophora (HYD)	Anenome (ANEM)	**CORALLINE ALGAE (CA)**
Isopora (ISOP)	Ascidian (ASC)	Amphiroa (AMP)
Leptastrea (LEPT)	Clams (CL)	Crustose Coralline (CCA)
Leptoria (LEPTOR)	Corrallimorph (COLM)	Fleshy-Coralline (FCA)
Leptoseris (LEPTOS)	Discosoma (DISCO)	Jania (JAN)
Lobophyllia (LOBOPH)	Dysidea Sponge (DYS)	**SUBSTRATE (SUBS)**

Merulina (MERU)	Gorgonians (G)	Carbonate (CAR)
Millepora (MILL)	Not Identified Invertebrate (NOIDINV)	Mud (MUD)
Montastrea (MONTA)	Sponges (SP)	Rubble (RUBBLE)
Montipora branching (MONTIBR)	Zoanthids (Z)	Sand (SAND)
Montipora encrusting (MONTIEN)	**MACROALGAE (MA)**	Turf (TURF)
Montipora foliose (MONTIF)	Asparagopsis (ASP)	
Montipora other (MONTIO)	Bluegreen (BG)	