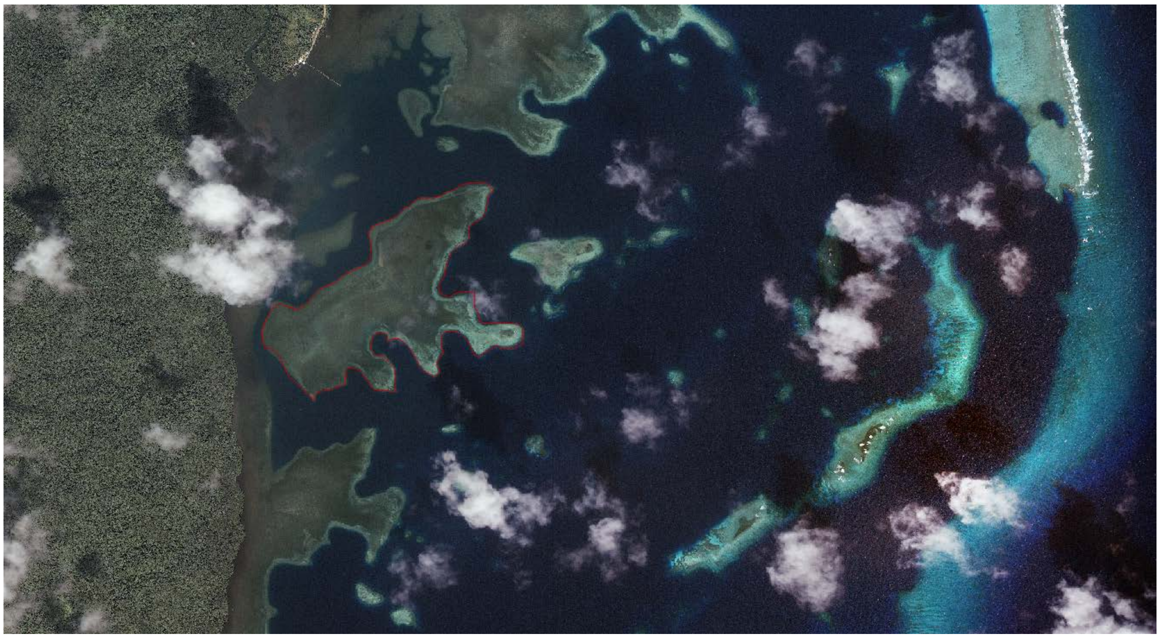
2017 Ecological Assessment of Ngelukes Conservation Area



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Palau International Coral Reef Center

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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 km^2 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 km^2 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).

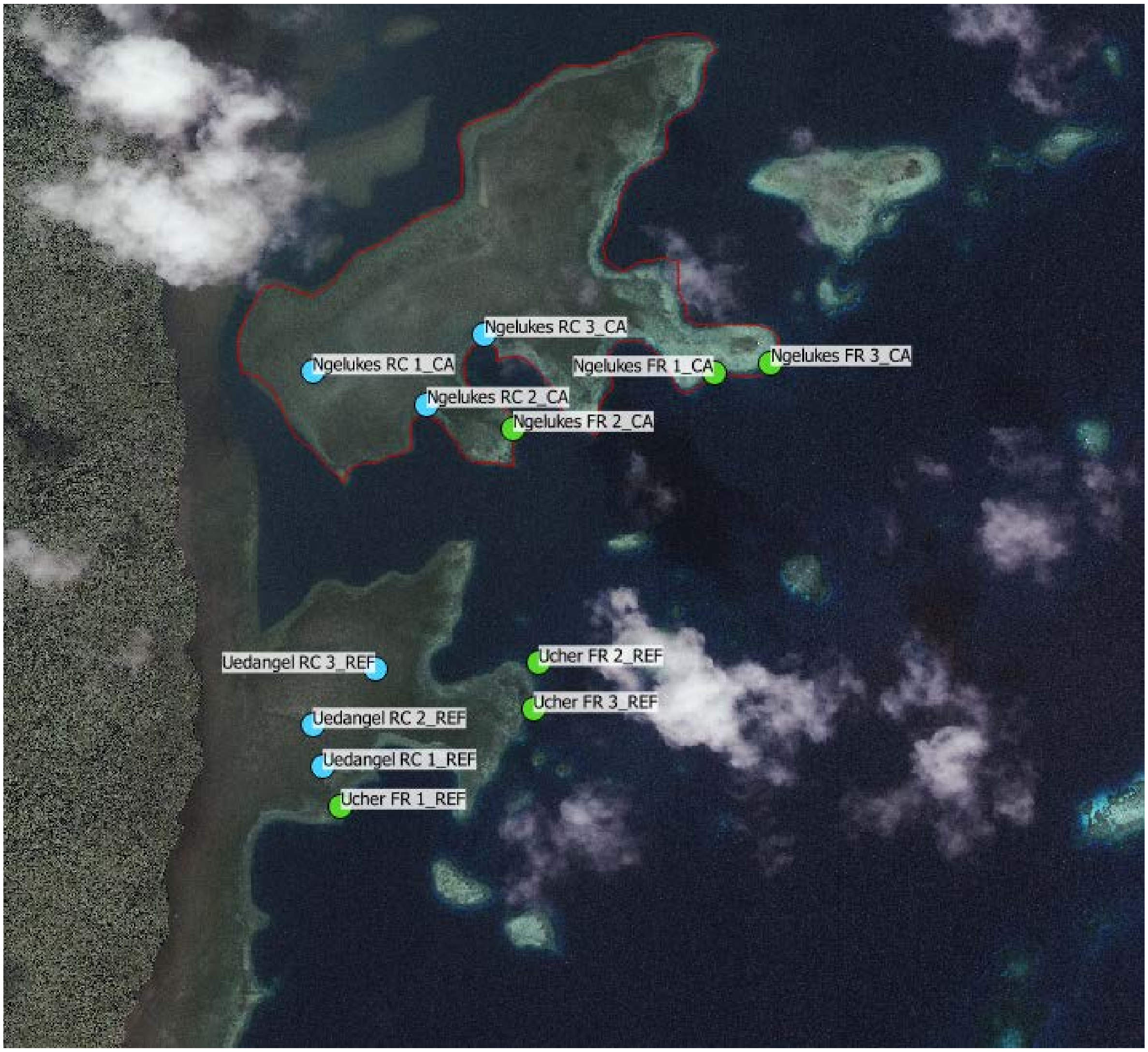

Figure 1: Map of Ngchesar's Ngelukes Conservation Area and the reference sites, Uedengel and Ucher showing the surveyed sites.

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 m^2 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 m^2 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).

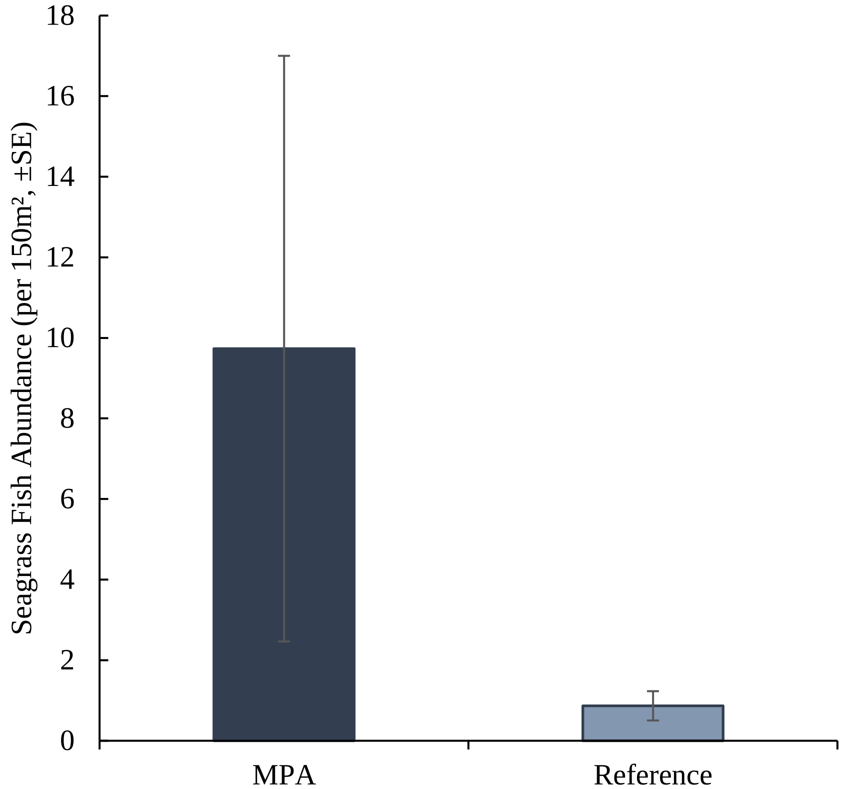

Figure 2: Mean abundance of commercially important fish recorded within the reef flat seagrass habitat. Error bars representing standard of error, with n=3.

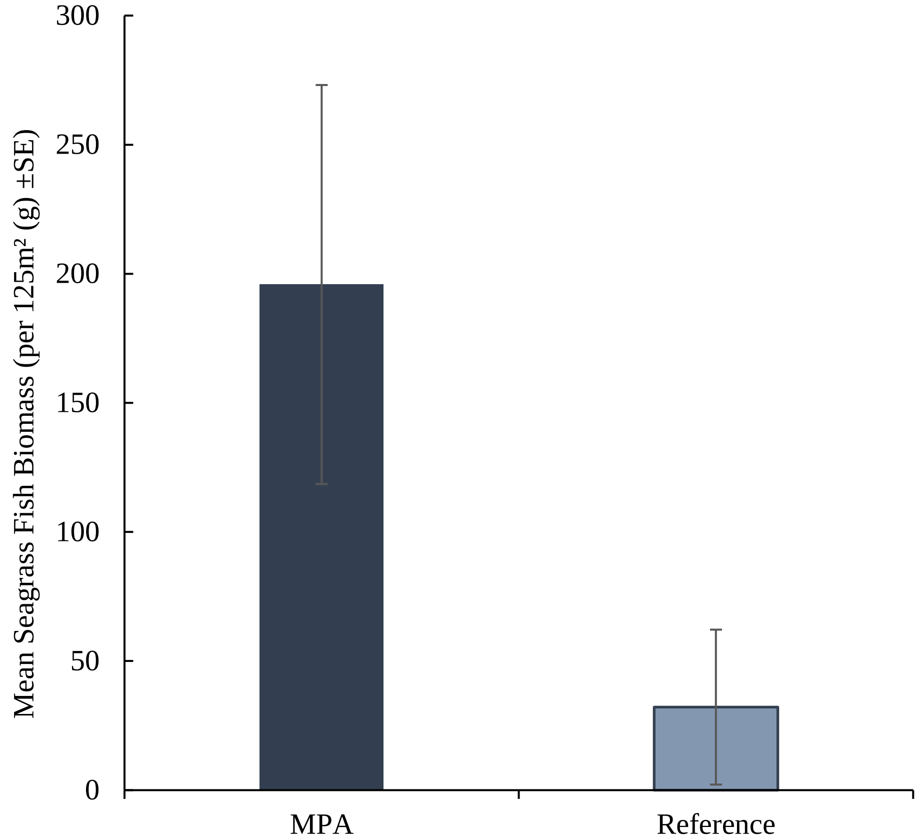

Figure 3: Mean biomass of commercially important fish recorded within the reef flat seagrass habitat. Error bars representing standard of error, with n=3.

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.

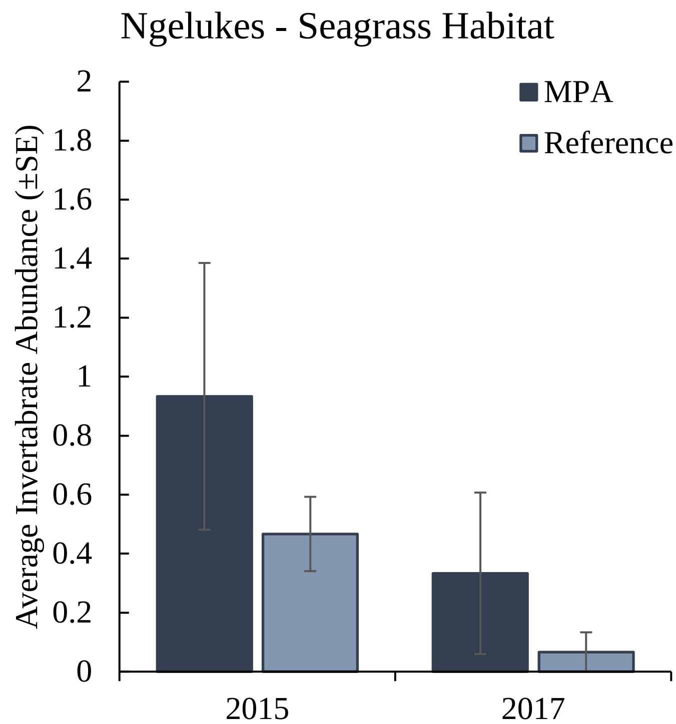

Figure 4: Mean macro-invertebrates abundance within the seagrass habitat within the MPA and the reference site in 2015 and 2017. Error bars representing standard of error, with n=3.

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 small decline in seagrass cover from 2011 to 2012 from 16% to 10% cover. After 2012, the seagrass cover remained around 10% coverage with small fluctuations (Fig. 5).

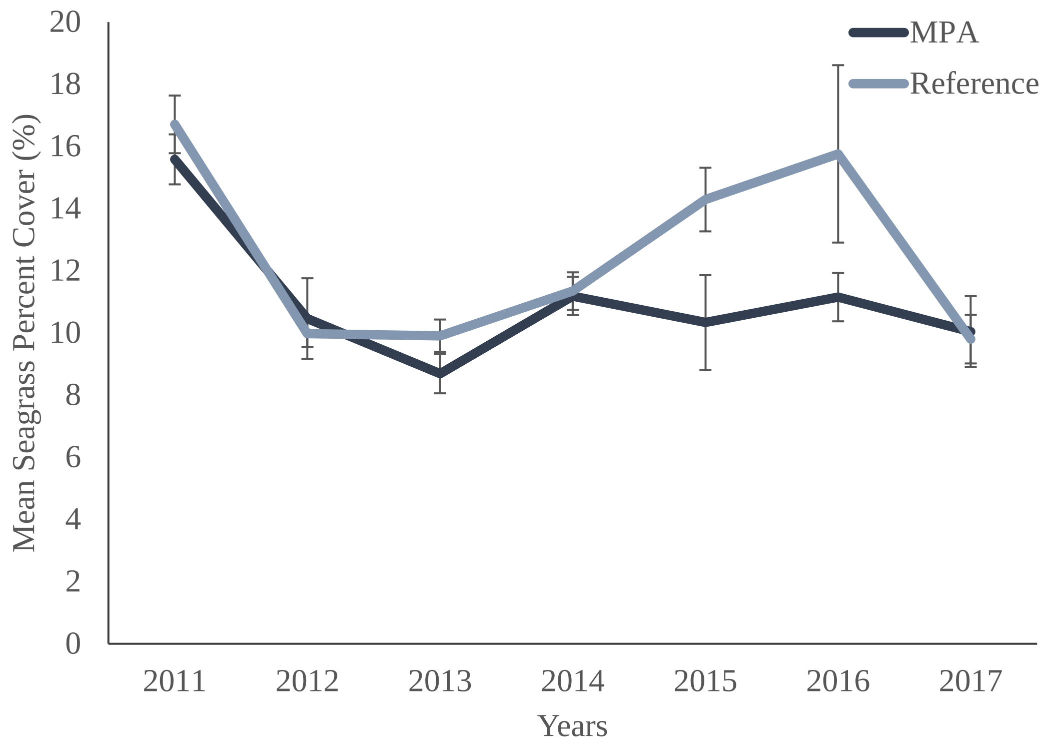

Figure 5: Mean percentage of seagrass cover at the reference site and MPA since 2011.

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).

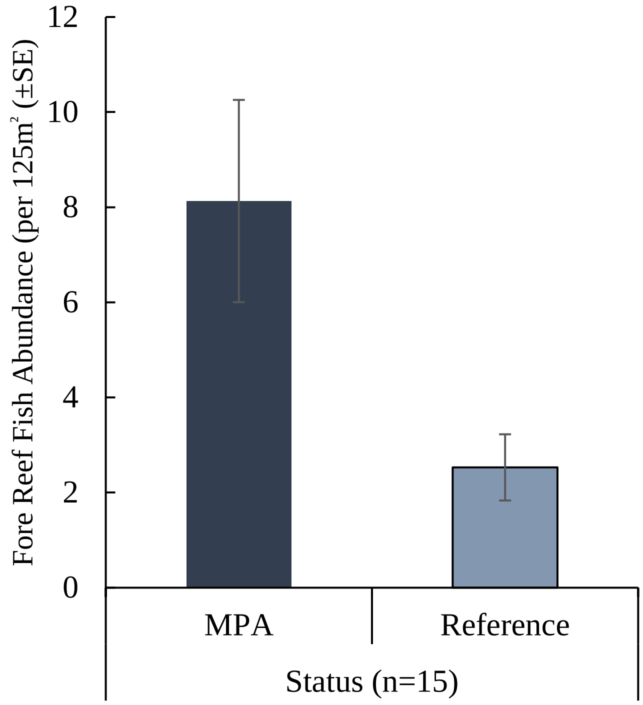

Figure 6: Mean fish abundance recorded in 2017 on the fore reef indicating significantly more fish within the MPA compared to the reference site. Error bars representing standard of error, with n=3.

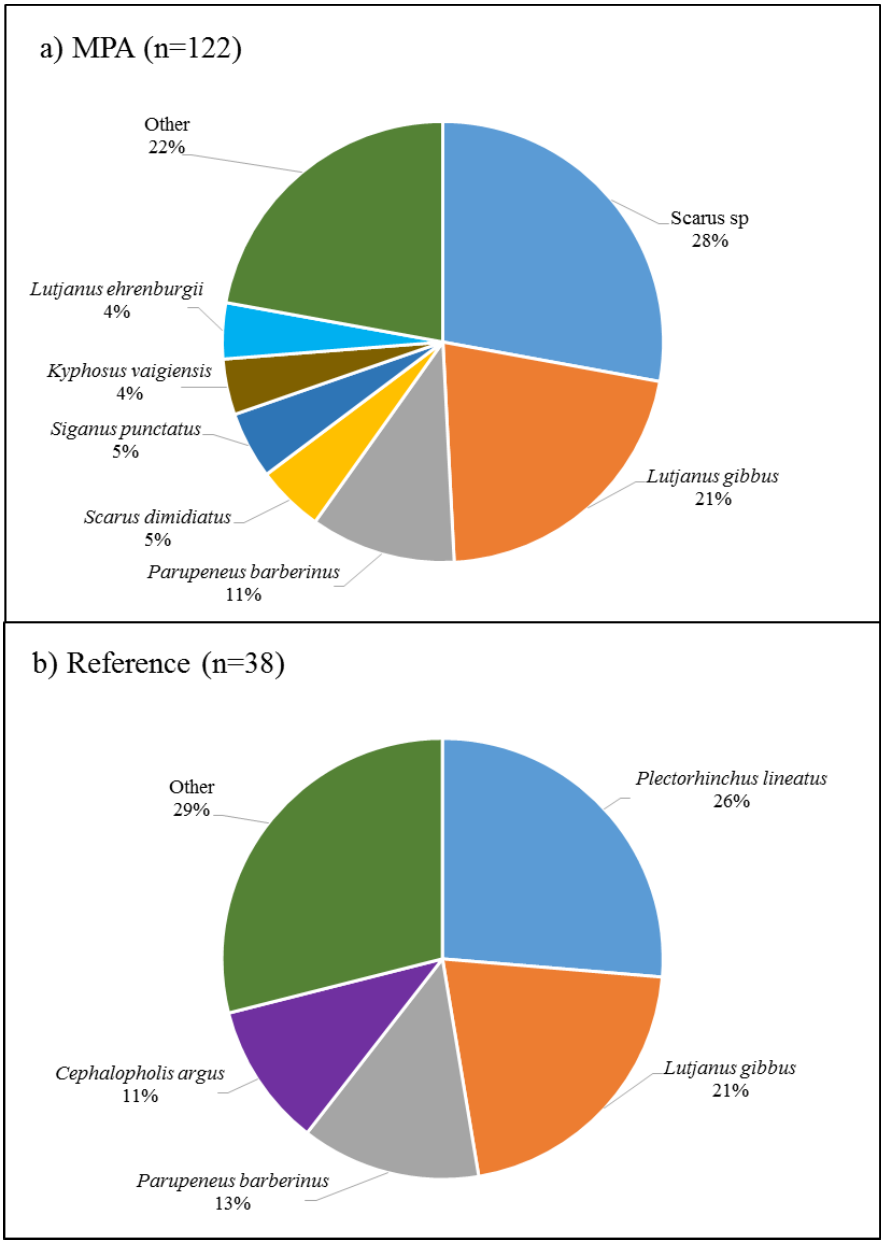

Figure 7: Pie chart indicate the most observed commercially important fish species overall observed within the fore reef of the a) MPA and b) Reference site.

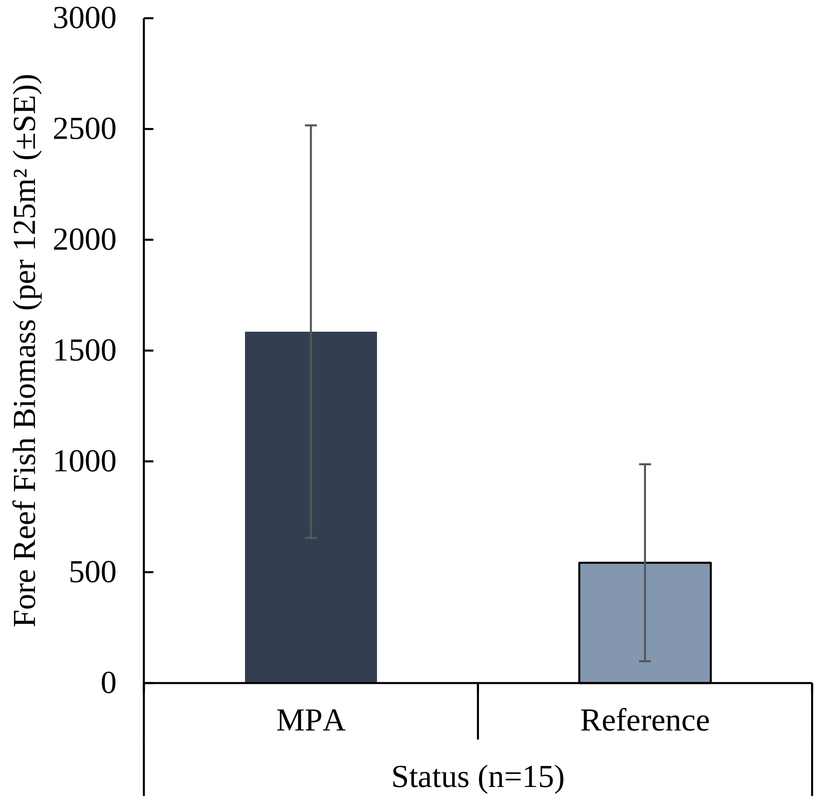

Figure 8: Mean fish biomass recorded in 2017 on the fore reef indicating no significant difference between fish biomass within the MPA and the reference site. Error bars representing standard of error, with n=3.

3.2.2. Macro-Invertebrates

The mean abundance of macro-invertebrates within Ngelukes MPA fore reef was 1.33 (±0.64) individuals per 100 m^2, which was significantly higher (ANOVA p-value < 0.05) than the reference site (mean 0.11 (±0.11) individuals per 100 m^2) and within the MPA during 2015 (mean 0.33 (±0.17) individuals per 100 m^2) (Fig. 9).

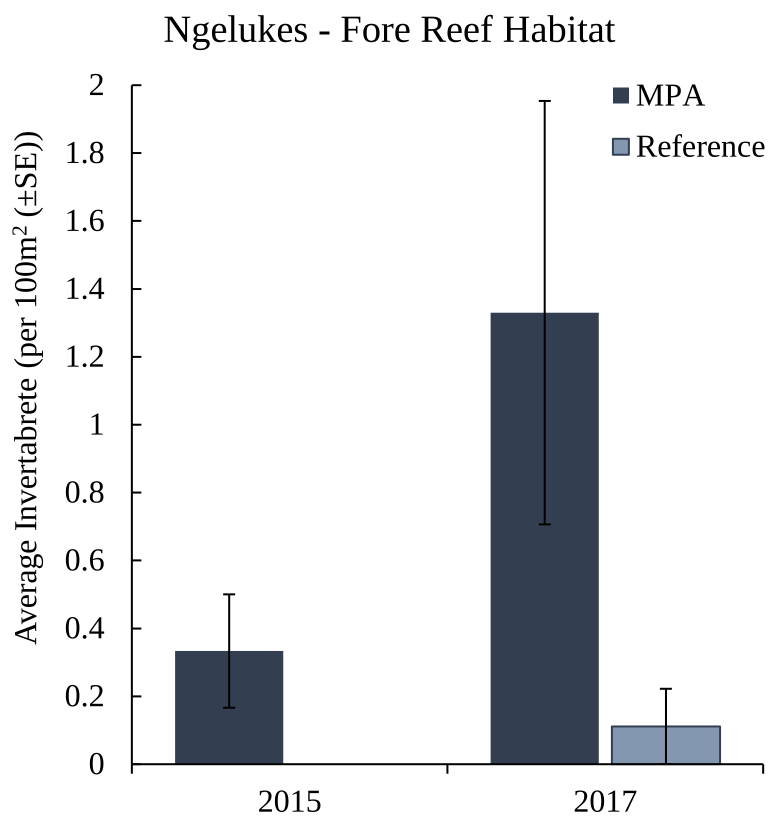

Figure 9: Mean macro-invertebrate abundance recorded on the fore reef showing significantly more macro-invertebrates within the MPA in 2017 compared to the MPA in 2015 and the reference in 2017. Error bars representing standard of error, with n=3.

3.3. Coral Recruits

Our findings indicated a significant increase of coral recruitment from an average of 1.11 (±0.46) per 3m² measured in 2015 during the baseline survey to 4.6 (±1.06) in 2017 (ANOVA p-value < 0.05) within the MPA (Fig. 10). With the increase of coral recruitment in 2017 compared to 2015, results show an increase of genera diversity (Fig. 11). In 2017, results indicated no significant difference of coral recruitment between the restricted and non-restricted sites indicating an overall increase of coral recruitment through time in the area (ANOVA p-value > 0.05).

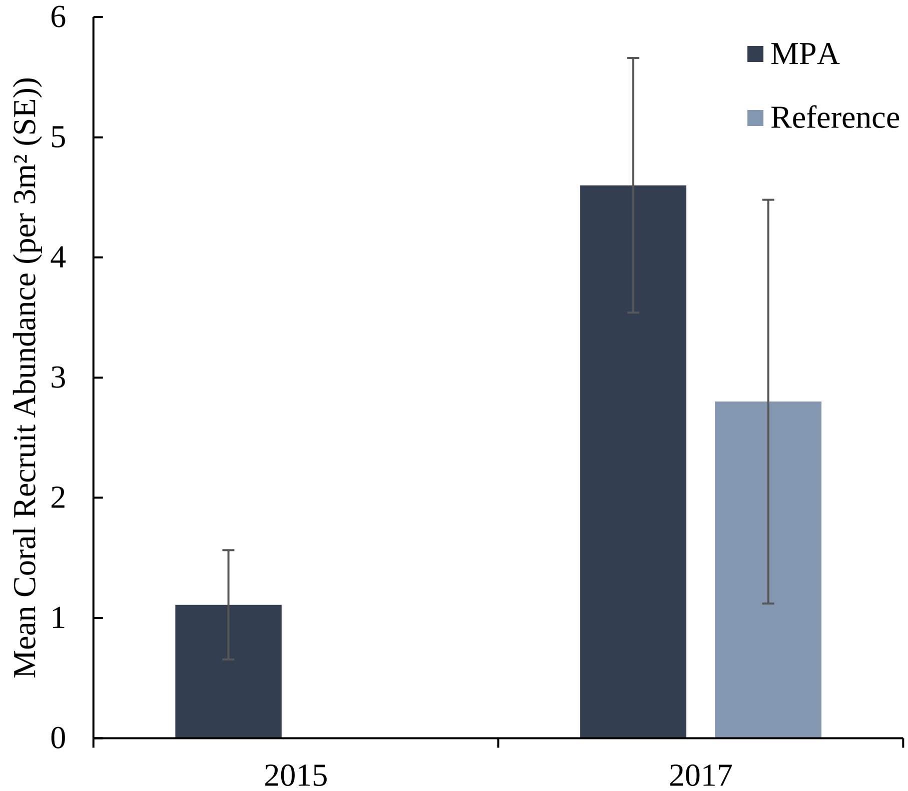

Figure 10: Mean coral recruits recorded within the MPA in 2015 and 2017 and the reference showing significanlty more coral recruitmen within the MPA in 2017 compared to 2015 and no significance between the MPA and reference site in 2017. Error bars representing standard of error, with n=3.

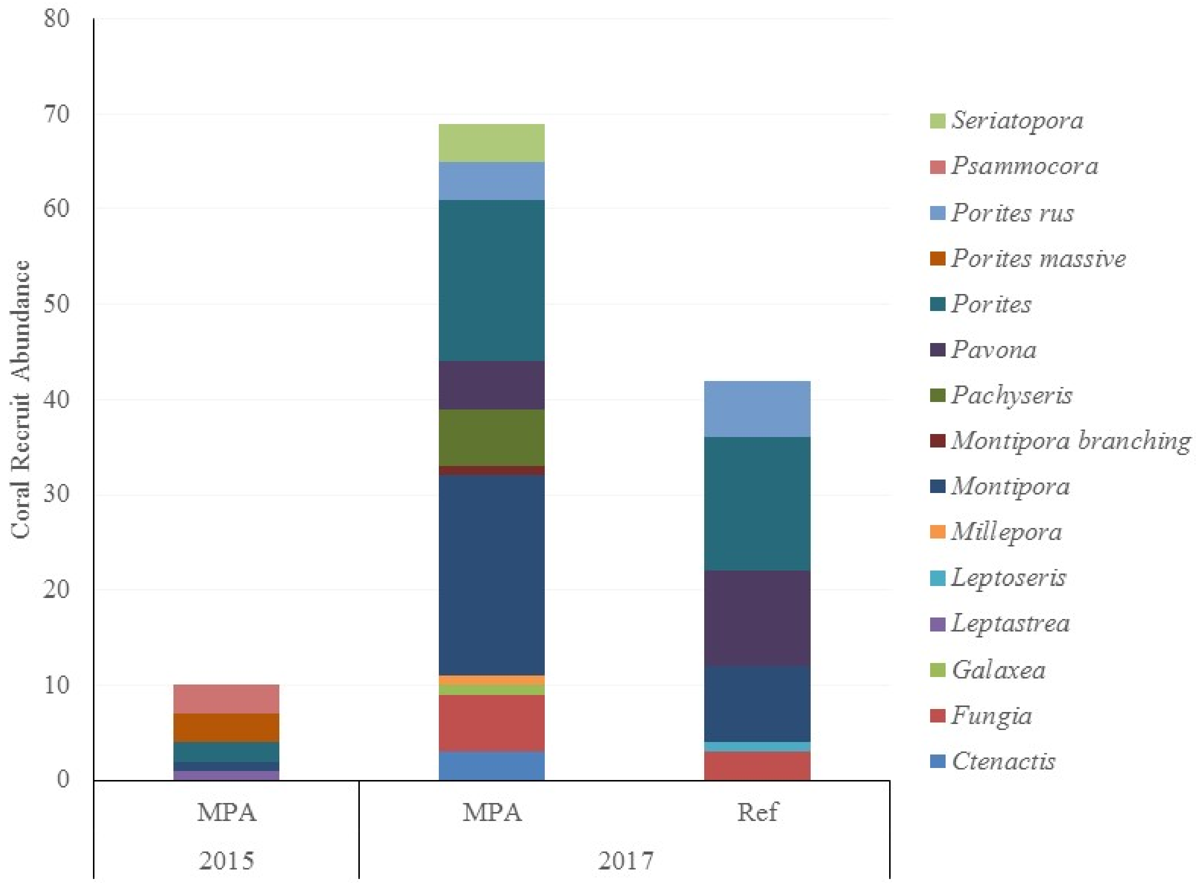

Figure 11: Stacked column indicating the different genera of recorded coral recruit.

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).

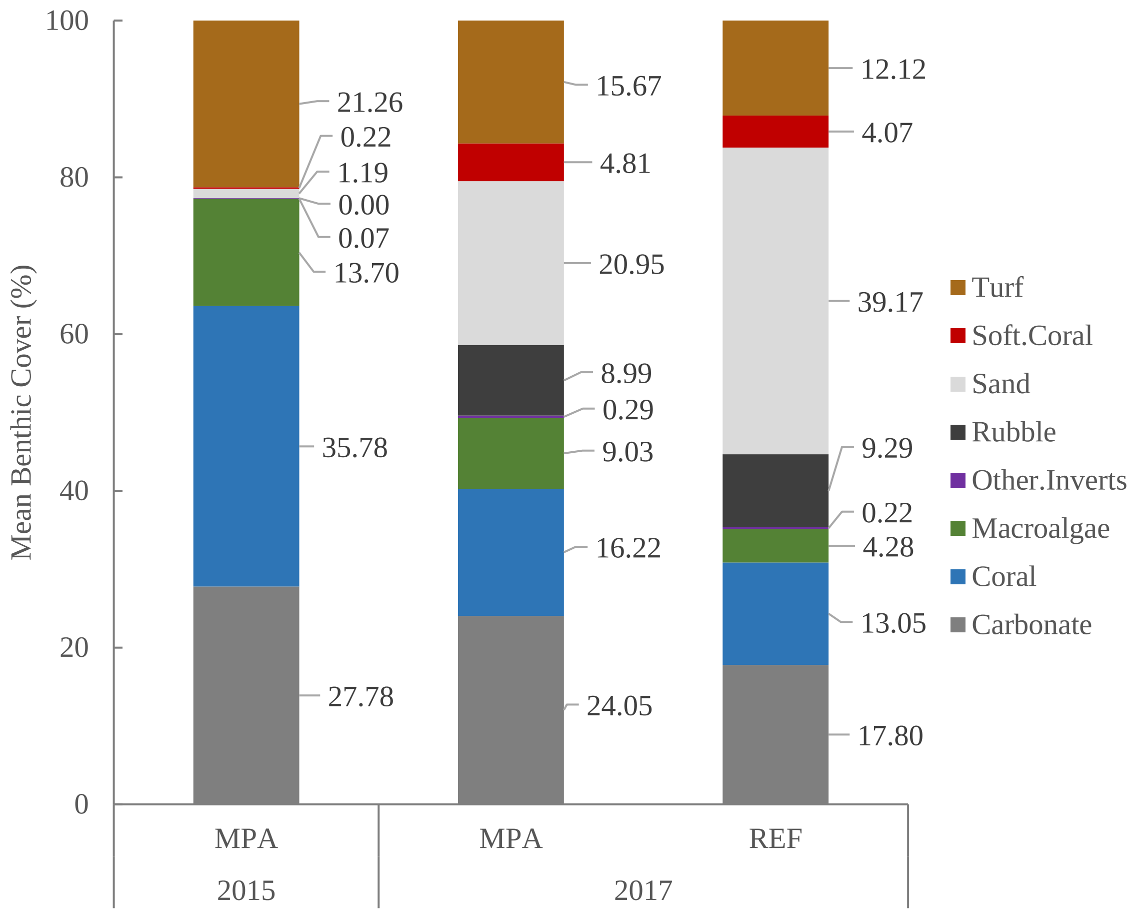

Figure 12: Stacked column indicating major benthic categories.

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. 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 previous monitoring data showed relative consistent coverage of seagrass (despite a small decrease between 2011 and 2012), on the reef flat it was considerably low with only 10% coverage. Since the difference of coverage between the MPA and the reference slightly fluctuates, the overall low coverage throughout time could possibly be an indication of other environmental factors. As seagrass habitats often border the coast, terrestrial run-off is one of the major impacts that affect these habitats (Duarte 2002). The seagrass coverage in Ngelukes CA is similar to that recorded at Airai State's Medal Ngediull Conservation Area in 2016, an area that is heavily impacted by runoff (Gouezo et al 2017). Though runoff from Ngchesar's Ngerdorch Watershed into Ngelukes CA would be a first thought to explain the low percent coverage, 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). Additionally, the significant increase of coral recruitment is a good indicator that the reefs are recovering and could possibly increase coral cover over time as long as it 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

PICRC would like to thank Ngchesar State conservation officers and Ngchesar State Government for allowing us within their MPA. This study was made possible with support from NOAA's Coral Reef Conservation Program, Global Environment Facility, and the Ministry of Natural Resources, Environment & Tourism.

6. Reference

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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)	

Table 2: GPS Coordinates

Habitat	MPA_protection	Sites	X (UTM)	Y (UTM)
Seagrass	Ngelukes_CA	Ngelukes RC 1_CA	455289	819956
Seagrass	Ngelukes_CA	Ngelukes RC 2_CA	455644	819854
Seagrass	Ngelukes_CA	Ngelukes RC 3_CA	455824	820072
Seagrass	Ngelukes_REF	Uedangel RC 1_REF	455320	818727
Seagrass	Ngelukes_REF	Uedangel RC 2_REF	455288	818856
Seagrass	Ngelukes_REF	Uedangel RC 3_REF	455484	819029
Fore Reef	Ngelukes_CA	Ngelukes FR 1_CA	456535.758	819950.185
Fore Reef	Ngelukes_CA	Ngelukes FR 2_CA	455911.69	819777.829
Fore Reef	Ngelukes_CA	Ngelukes FR 3_CA	456712.833	819981.922
Fore Reef	Ngelukes_REF	Ucher FR 1_REF	455376	818604
Fore Reef	Ngelukes_REF	Ucher FR 2_REF	455990	819049
Fore Reef	Ngelukes_REF	Ucher FR 3_REF	455974	818905