Ecological assessment of Ngermedellim Marine Sanctuary

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Abstract

Palau has a strong conservation history. Traditional conservation knowledge is being applied in modern times, in the form of the marine protected areas (MPA). In 2003, the national government of the Republic of Palau established the Protected Areas Network (PAN). The PAN is a nationwide conservation effort, geared towards effective conservation and management of natural resources in Palau's marine and terrestrial environments. In 2015, PICRC researchers conducted baseline surveys in fourteen PAN MPAs. And starting in 2017, PICRC researchers continue the study of MPA effectiveness by conducting follow-up surveys in order to assess their effectiveness in terms of management and protection. This study was conducted in Ngermedellim Marine Sanctuary, located in Melekeok State and has been protected since 1999 and was inducted into the PAN in 2015. Surveys were conducted on the reef flat habitat, consisting of a seagrass bed and coral reef habitat. In order to assess effectiveness, surveys were conducted in a nearby reference sites to compare results. Data collection consisted of recording the status of fish, macro-invertebrates, juvenile corals, seagrass cover, and benthic cover. Results show a slight increase in nearly all ecological indicators. Live coral cover and juvenile coral density showed increasing trends, indicating a slow recovery process post-typhoon disturbance. Food fish abundance and biomass were also recorded and were found to be higher in the MPA than in the reference sites, though not a statistically significant difference. Finally, macro-invertebrates were more significantly more abundant in the MPA than its reference area. These positive results show a good recovery rate for Ngermedellim since the typhoon in 2012. However, continued monitoring will provide better insights and information on the reef recovery within and outside the MPA and reference sites.

Introduction

Palau has a long history of environmental stewardship and natural resource conservation. It is deeply rooted into the Palauan culture. Through the concept of 'bul'- where traditional chiefs prohibited use of or harvesting of resources for restricted periods of time- Palauans were able to conserve their resources (Johannes 1981). Today, the concept of 'bul' has evolved into modern day conservation techniques like the Marine Protected Areas (MPA). In Palau, the first MPA was established in 1956, called Ngerukewid, located in the Rock Islands Southern Lagoon in Koror State. Since then, Ngerumekaol – in Koror State- and Ebiil Channel – in Ngarchelong State- were later regulated to be MPAs. Since 2003, when the National Government created the Protected Areas Network (PAN), the PAN has grown to include 14 no-take MPA's and 13 terrestrial protected areas. The PAN is constantly growing to include more protected areas in order to meet the goals of the regional conservation targets of the Micronesia Challenge to effectively manage and protect its marine and terrestrial resources.

Starting in 2014, Palau International Coral Reef Center (PICRC) began monitoring all MPA's in Palau, gathering baseline data for each MPA (Gouezo et al. 2016). After these baseline surveys were conducted, every two years after, follow up assessments will be done to monitor long-term trends and status and effectiveness of the resources in the MPAs. This study was conducted in Ngermedellim Marine Sanctuary which is in Melekeok (7°31.2200'N, 134°38.1900'E) (Fig.1). At first, it was traditionally designated as a clam conservation area by the Melekeok traditional leaders (Melekeok Conservation Network Management Plan 2017-2021). And in 1999, after concerns from the local residents, the Melekeok State Legislature officially declared Ngermedellim Marine Sanctuary a protected area, a full no-take zone (Melekeok Conservation Network Management Plan 2017-2021). In 2015, the site was inducted into the PAN, adding a marine protected area to Melekeok's conservation network (Melekeok Conservation Network Management Plan 2017-2021). The objectives of this study are (1) to collect data that will illustrate the status of the natural resources within the two main habitats of the conservation area, (2) to compare the follow-up data to the baseline data and (3) to make comparisons between resources within the conservation area with a nearby non-protected reference area.

Methods

1. Study sites

Ngermedellim Marine Sanctuary is located in Melekeok State. It covers approximately 0.45km^2 and has two major habitats, a reef flat with coral reefs and a reef flat with seagrass beds (Figure 1).

Figure 1: Map of Ngermedellim Marine Sanctuary with monitoring sites inside and outside the protected area.

2. Ecological surveys

Ecological surveys were conducted at each of the sites, in the two main habitats. In the seagrass beds, five 25 m transects were laid consecutively, with a few meters separating them. Along these five transects, data on various ecological factors were collected. These included seagrass percentage cover (at the species level) in 0.5 m quadrats that were placed every 5 meters; fish abundance and size data was collected with the use of a stereo-DOV recording in a 5 m wide belt; and any edible macro-invertebrates found in a 2 m wide belt were also recorded. On the reef flat, five 50 meter transects were laid consecutively with five meters separating each transect. In addition to fish and invertebrate data, benthic photos were taken along the transect using an underwater camera (model Canon G16), mounted on a 0.5 m x 0.5 m photo quadrat PVC frame. A total of 50 photos were taken each transect. Furthermore, juvenile corals, measuring less than 5 cm, were recorded in the first 10 meters of each transect in a 0.3 m belt. Since the site was set in a shallow area, the maximum depth was approximately 5 m.

3. Data processing and analysis

Juvenile corals and macro-invertebrate data were entered into excel spreadsheets. In order to estimate benthic cover, the photos taken were analyzed using CPCe software (Kohler and Gill 2006). In CPCe, five random points were allocated to each photo, and the substrate below each point was classified into the appropriate benthic category (see the benthic categories list in Appendix 1). In the end, the mean percentage of the benthic cover of each category was calculated for each transect (n= 50 photos per transect, n= 5 transects per site). The fish videos were processed using the software, EventMeasure. Only the fish with economical, subsistence and/or ecological importance were counted and measured. If the measurement precision was too low to be accurate, the fish was counted and the mean fish size within the site was attributed for biomass estimate. The biomass of fish was calculated using the total length-based equation:

$$W = aTL^b$$

where W is the weight of the fish in grams, TL the total length of the fish in centimeters (cm), and a and b are constant values that derive from published biomass-length relationships (Kulbicki et al. 2005) and from Fishbase (http://fishbase.org).

Before analyzing and testing the data, they were checked for normality using histograms and the Shapiro test. However, when the data was non-normal, the data was transformed and re-tested. When data was normal, Welch Two-sample t-test was used to compare the MPA with the reference area. When the data was non-normal, the non-parametric Mann-Whitney U test was used instead.

Results

The findings from the 2017 monitoring surveys are presented by each habitat and wherever possible, comparisons are made between the 2017 data and the data from the baseline surveys.

1. *Seagrass Habitats*

In the seagrass habitats, the main species of seagrass found were *C. rotundata, C. serrulata, S. isoetifolium, E. acoroides,* and *T. hemprichii*. The most abundant species recorded were *C. rotundata* and *T. hemprichii*. The coverage of seagrass was significantly greater in the MPA than it was in the reference area (Welch Two-sample T-test, $p < 0.001$) (Figure 2).

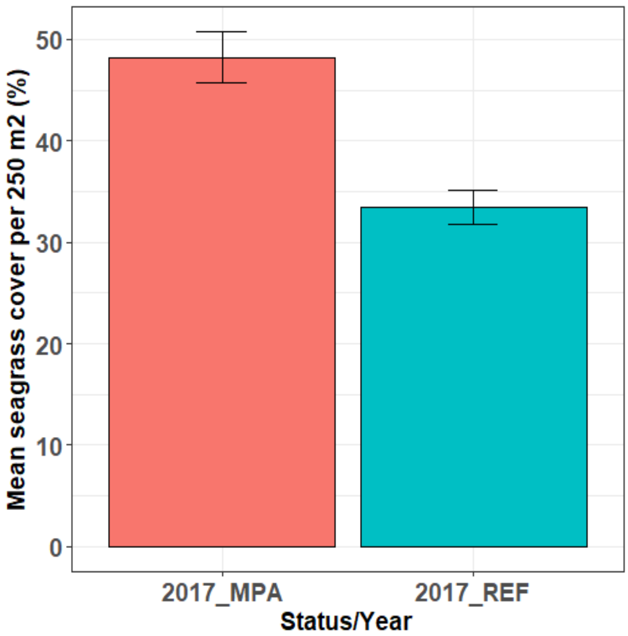

Figure 2: Mean percentage cover (± SE) of seagrass in MPA and reference sites

In 2017, there were no recorded commercial important fish in either the MPA or the reference sites. Furthermore, in 2015 and 2017, the only recorded edible macro-invertebrates recorded in the MPA and the reference sites was the giant clam species, duadeb (*Hippopus hippopus*), accounting for <1 individual per 125 m^2.

2. Reef Flat Habitat

The coral reef flat habitat mainly consisted of carbonate, turf algae, sand, rubble, and crustose coralline algae (Figure 3). The coverage of carbonate, turf algae, sand, and crustose coralline algae increased in 2017 in the conservation area; however, percentage of rubble had decreased significantly since 2015 in the conservation area (Welch Two-Sample T-test, p=0.0011), but there was no significant difference between the MPA and reference area in 2017.

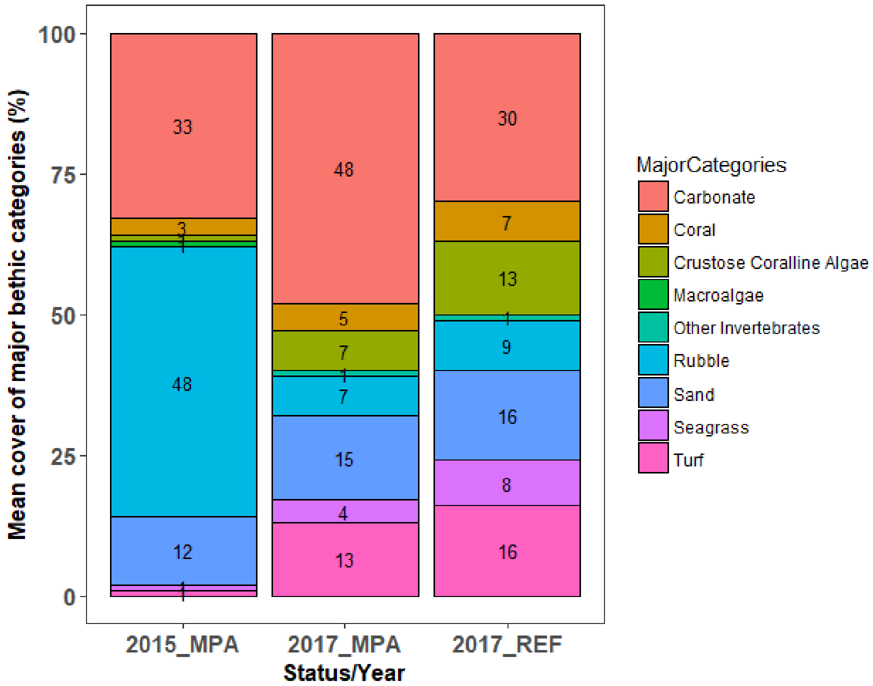

Figure 3: Mean of major benthic categories found in the reef flat habitat inside and outside of the conservation area

Live coral cover was very low due to damaged done by the typhoons that occurred in 2012 and 2013. However, as seen in Figures 3 and 4, the live coral cover has increased slightly, from 3% (±1%) in 2015 to 5% (±1%) in 2017 in the MPA (Figure 4). While there is a very slight increase in the percent cover of live coral, there is no statistical significance between the 2015 and 2017 MPA data (Welch Two Sample T-test, $p = 0.179$). The reference area has more live coral than the MPA, at 7% (±1%), but even with this small increase, there is only a marginal significant difference between the two sites (Welch Two Sample T-test, $p=0.07$).

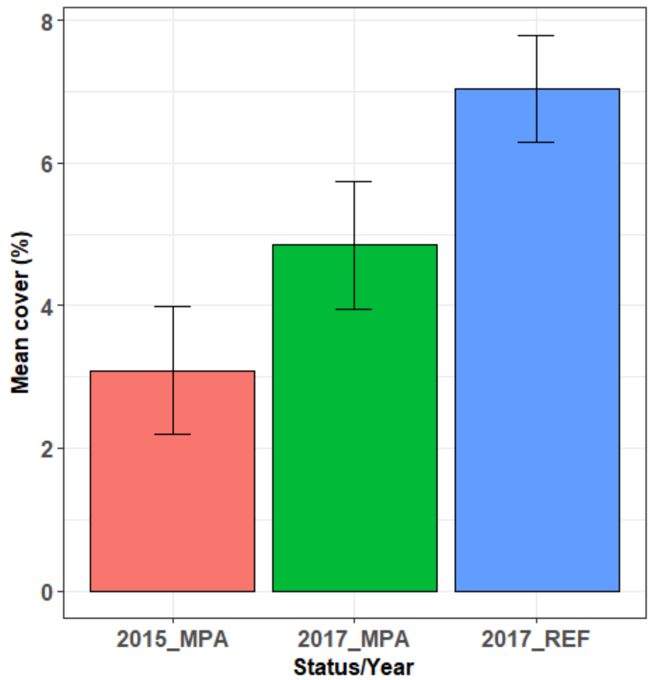

Figure 4: Mean live coral cover over time inside and outside the MPA

The density of juvenile corals has increased since 2015 – 2.5 (±1.09) juvenile corals per 3m^2 in 2015 to 4 (±0.96) juvenile corals per 3m^2 in 2017 within the MPA (Figure 5). However, even with this increase in recruit density, it is still not a significant increase (Mann-Whitney U test, p = 0.304). In 2017, the mean density of juvenile corals in both the protected area and reference area is not significant (Mann-Whitney U test, p = 0.933) (Figure 5).

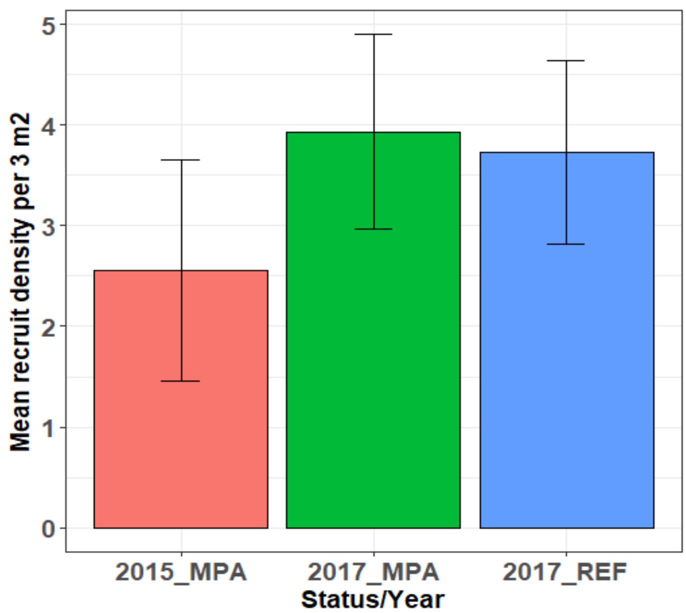

Figure 5: Mean density of coral recruits (± SE) inside and outside of the protected area

In 2015, the abundance of food fish was higher than was found in 2017 (Mann-Whitney test, p = 0.256) (Figure 6). In 2017, abundance of food fish in the coral reef flat was higher in the conservation area than in the reference area, however, it was not a statistically significant difference (Welch Two-Sample T-test, p = 0.611) (Figure 6).

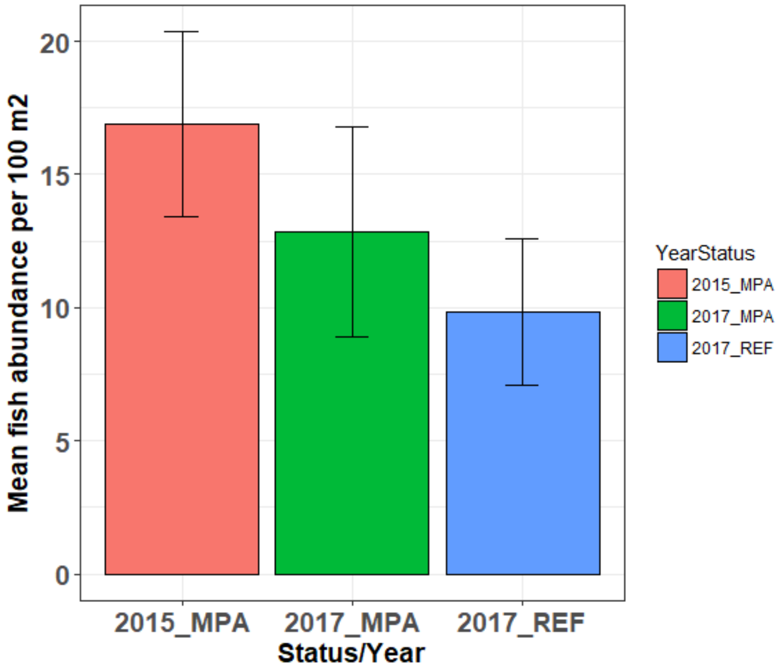

Figure 6: Mean abundance of food fish (± SE) in the MPA and reference area

The biomass of food fish was higher in the protected area with 0.82 (±0.31 kg) per 250 m^2 than the reference area with 0.39 kg (±0.15 kg) per 250 m^2 (Figure 7). However, it was not found to be significantly different (Mann-Whitney test, p = 0.966). Some of the fish recorded within the reef flat habitat were mellemau (*Scarus spp*. and *Chlorurus spp*.), keremlal (*Lutjanus gibbus*), masech (*Ctenachatus striatus*), elas (*Acanthurus trigostegus*), and itotech (*Lethrinus harak*).

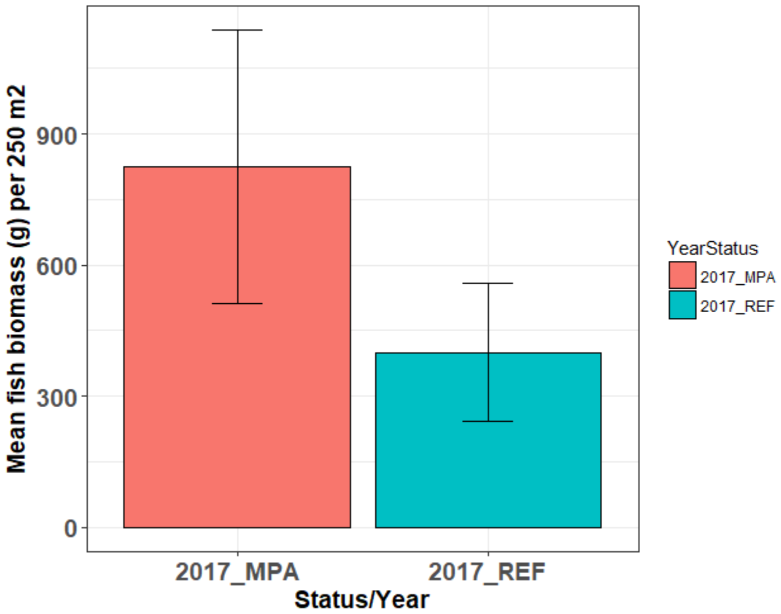

Figure 7: Mean fish biomass (g) (± SE) inside and outside of MPA

Abundance of edible macro invertebrates were basically the same from 2015 to 2017 in the protected area, recording about 2.5 individuals (±1 individual) per 100 m^2 (Figure 8). There is no statistical difference between 2015 and 2017 macro-invertebrate abundance in the MPA (Welch Two-sample T-test, $p = 0.692$). However, there is a significant difference in the abundance of edible macro-invertebrates between the protected area and reference sites in 2017 (Mann-Whitney test, $p < 0.001$), where in the MPA, about 2 individuals were found per 100 m^2, and <1 individuals found per 100 m^2 in the reference area (Figure 8).

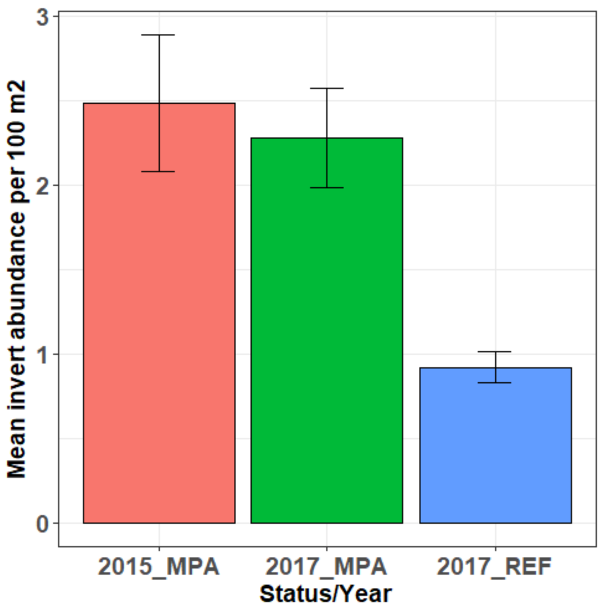

Figure 8: Mean abundance of invertebrates (± SE) in MPA and reference site

Discussion

The data collected from the Ngermedellim Marine Sanctuary baseline and follow up assessments indicated that, though there is no significant difference between both habitats – seagrass bed and coral reef flat—whether it's a protected area or a reference site, there is still an increasing trend in the data within the various ecological factors over time. Several indicators showed significant increase since 2015.

The Eastern reef of Palau was devastated by two consecutive Super Typhoons-Bopha (2012) and Haiyan (2013) (Gouezo et al, 2015). These major disturbances are the cause for the low coral cover recorded in the 2015 baseline assessment in Ngermedellim (Rehm et al, 2015). During the 2017 follow-up study, live coral cover was still low in the MPA, at about 5% and about 7% in the reference area, but it still a slight increase since 2015, which was recorded at 3%. In addition to the increase in live coral cover, the density of juvenile corals was also found to be increasing inside and outside the protected areas. This upward trajectory is encouraging, showing signs of recovery, however slow, of the reef post-typhoon disturbances.

The overall abundance of food fish in the MPA was significantly higher in 2015 than in 2017. The abundance within the MPA still remained higher than the reference area in 2017, but it is not a significant difference. In addition, the fish biomass was greater within the protected area, but again, it is not a significant difference.

The seagrass beds were relatively healthy, showing nearly 50% coverage in the MPA and about 35% in the reference area. Maintaining a healthy and thriving seagrass habitat is essential to the overall health of the ecosystem, as it is an important nursery ground for juvenile fish. Furthermore, as the seagrass beds are the most susceptible to negative impacts from development, it is recommended that minimal development along the coastline is undertaken. Coastal runoffs and sedimentation can have devastating and long-term impacts on the seagrass bed if not maintained properly.

Overall, the study shows that the Ngermedellim Marine Sanctuary is productive as seen by the increasing trends of ecological indicators. Though recovery is slow post the two major disturbances, it is still recovery, thus it is vital to continue protecting this area to maximize on its recovery potential.

Acknowledgment

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References

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Appendix 1. Table of 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)	