The status of Ngeruangel Marine Reserve after 22 years of protection and a major typhoon disturbance

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Abstract

In 2003, Palau established a Protected Areas Network (PAN) that consists of 15 marine protected areas (MPAs). Every two years, the Palau International Coral Reef Center (PICRC) conducts ecological monitoring at these MPAs to track the ecological conditions of the different habitats within these MPAs and their effectiveness at protecting marine resources. This study was conducted at Ngeruangel Marine Reserve located in Kayangel State, which has been protected since 1996. Surveys were also conducted in the nearby atoll of Kayangel for comparison with an unprotected atoll. Surveys recording the status of fish, macro-invertebrates, juvenile corals, and benthic cover were conducted within three stations in the fore reef habitat and three stations in the lagoon habitat, both inside and outside the marine reserve. Our findings demonstrated that this MPA is very effective at protecting fish displaying a high abundance and biomass in both habitats. The protection, however, did not influence the abundance of macro-invertebrates. Both Ngeruangel and Kayangel eastern reefs have been heavily disturbed by typhoon Haiyan in 2013 where corals have not yet recovered. However, the observance of a 5-fold increase in juvenile coral density (of size ≤ 5cm) between 2014 and 2018, within the MPA, gives hope for a faster recovery in the fore reef habitat in the coming years –compared to the previous four years. Coral recovery projections in the lagoon habitat of Ngeruangel are not as hopeful due to the high coverage of loose substrate; likely contributing to coral settlement failure. Therefore, we recommend that, while maintaining good enforcement levels, the state of Kayangel could consider partaking in some reef restoration activities, such as substrate stabilization, to assist the natural recovery of corals in the lagoon of Ngeruangel Marine Reserve.

Introduction

Natural resource conservation is deeply anchored in Palau's traditions (Johannes 1981). The concept of 'bul,' which traditionally prohibited the use of natural resources for restricted periods of time (Johannes 1981), has now evolved into modern conservation management through the concept of Marine Protected Areas (MPAs). The first MPA to be established in Palau was Ngerukeuid in the southern lagoon of Koror State in 1956. Later on, spawning aggregation areas, such as Ngerumekaol and Ebiil channel, became MPAs. Today, there are 35 Marine Protected Areas in Palau (Friedlander et al. 2017) and 22 of them are full no-take zones (Gouezo et al. 2016). In 2003, Palau established a Protected Areas Network (PAN), that today consists of 14 marine protected areas (MPAs). The PAN is one tool used by the government of Palau to protect the country's biodiversity and resources from overuse, and to participate in regional and global conservation initiatives, such as the Micronesia Challenge (Houk et al. 2015). The PAN is constantly evolving by using novel research findings to improve its design to make this network of MPAs as effective as possible.

The Palau International Coral Reef Center (PICRC) is monitoring PAN MPAs to provide scientific support on the effectiveness of protected areas. In 2014 and 2015, PICRC gathered baseline information at all PAN MPAs in Palau (Gouezo et al. 2016). Subsequently, every two years, PICRC re-visits PAN MPAs to monitor the status and trends of coral reefs, natural resources and assess their effectiveness over time.

This study was conducted in Ngeruangel Marine Reserve (8.172°N, 134.628°E), hereinafter referred to as Ngeruangel MPA, in Kayangel State between July and September 2018 (Figure 1). This MPA is located at the southern tip of the sunken atoll of Velasco which has a small islet used as a breeding area for the Great Nested Tern, and a nesting area for Green and Hawksbull sea turtles. Ngeruangel MPA was designated as a protected area; first under the traditional 'bul' closure, and later, it became a legislated MPA through the Ngeruangel Reserve Act of 1996 (Kayangel Protected Areas Network, five-year management plan, 2013-2018).

This study focuses on the two main marine habitats of Ngeruangel MPA: the lagoon and the fore reef. The main scope of the study was to assess the overall effectiveness of the MPA. The objectives of this study were (1) to show the status of natural resources within the two main habitats (reef flat and fore reef) of the conservation area, (2) to compare them to available baseline data, and (3) to compare them to nearby non-protected reference areas.

Methods

1. Study sites

Ngeruangel MPA covers an area of 10.6 km^2 and encompasses two main habitats: lagoon and fore reef (Figure 1). A subset of 4 sites from the baseline assessment conducted in May 2014 (Koshiba et al. 2014) were chosen for each habitat. The nearby atoll of Kayangel was chosen as a reference area allocating the sites in a similar ordination to Ngeruangel MPA.

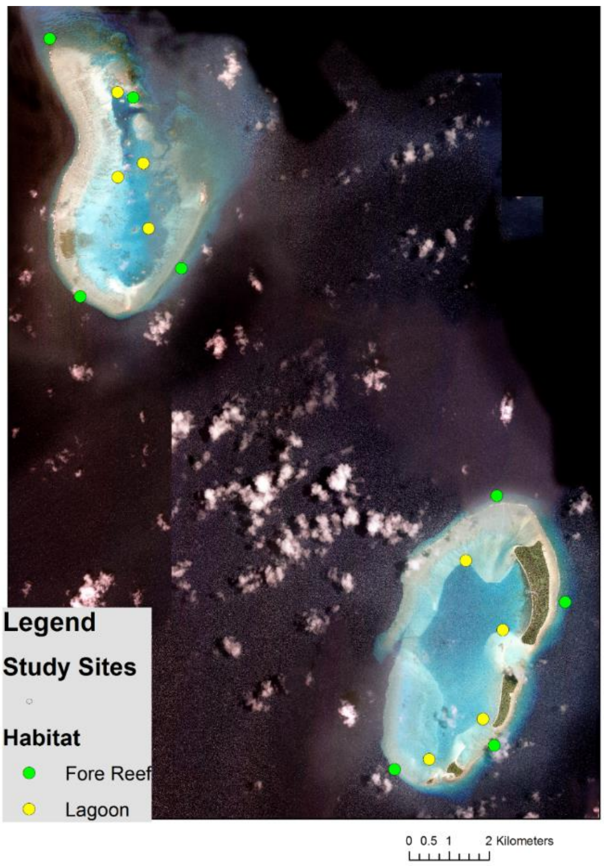

Figure 1: Satellite view of Ngeruangel MPA (top-left) and Kayangel (bottom-right) with the location of monitoring sites in the fore reef (green points) and lagoon habitats (yellow dots)

2. Ecological surveys

Ecological surveys were conducted at each study site. In both habitats, five 50 meter transects were laid consecutively with five meters in between them at 8-10 m depth. To estimate benthic cover, photographs were taken every meter along the transect using an underwater camera (model: Canon G16, mounted on a 0.5 m x 0.5 m photo-quadrat PVC frame), for a total of 50 photos per transect. Juvenile corals (size ≤ 5 cm) were recorded in the first 10 m of each transect in 0.3 m belt. Commercially-valuable fish abundance and size were recorded using stereo-DOV in 5 m wide belt, and edible macro-invertebrates were recorded in 2 m wide belt, along each transect.

3. Data processing and analysis

Juvenile corals and macro-invertebrate's data were entered in excel spreadsheets. To estimate benthic cover, the photo-quadrats were analyzed using CPCe software (Kohler and Gill 2006). Five random points were allocated to each photo and the substrate below each point was classified into benthic categories (see benthic categories list in Appendix). The mean percentage benthic cover of each category was calculated for each transect (n = 50 photos per transect, n = 5 transects per site). Fish videos were processed using the software EventMeasure. All fish that have an economic and/or subsistence importance were counted and measured (excluding butterflyfish and damselfish). 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 (g), TL is the total length of the fish in centimeters (cm), and a and b are constant values from published biomass-length relationships (Kulbicki et al. 2005) and from Fishbase (http://fishbase.org).

Prior to running statistical tests, the data was checked for normality using histograms and the shapiro test. When non-normal, data was transformed and re-tested. When data were normally distributed, One-way ANOVA was used to compare MPA with reference area. When data were non-normal, non-parametric Mann-Whitney U test was used instead. As the typhoon Hayian had a large impact on the north-eastern reefs of Palau (Gouezo et al. 2015), the difference in benthic cover and juvenile corals between eastern and western facing reef were also investigated on the fore reef habitat only.

Results

Findings from the 2018 monitoring surveys are presented by habitat type; comparing this year's results with data from previous years of available monitoring data for each ecological indicator. As Typhoon Hayian had a large impact on the eastern reefs, benthic data was explored separately for the eastern and western sites on the fore reefs

1. Fore Reef Habitat

1.1. Commercially-important fish

The mean abundance of food fish was significantly higher in the MPA with 7.7 (± 3.1 SE) individuals per 100m^2, compared to the reference area with 1.62 (± 0.4 SE) individuals per 100m^2 (ANOVA, P<0.05, Figure 2). The biomass of food fish was more than 4 times higher in the MPA, with on average of 3.4 kg/100 m^2 (± 1.1 SE), compared to the 0.8 kg/100m^2 in the reference area. This difference, however, was marginally significant (ANOVA, P = 0.07).

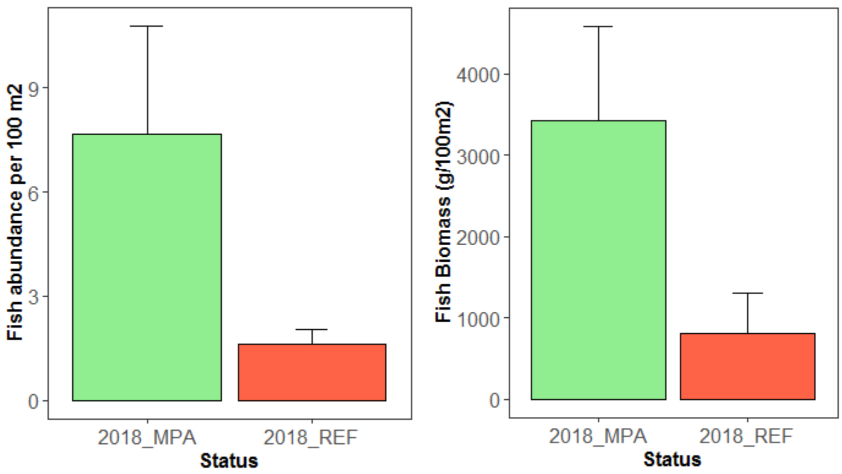

Figure 2: Bar plot showing the mean abundance (left) and biomass (right) of food fish (± SE) in the MPA (green) and the reference area (red)

The difference in biomass between the two areas was majorly attributed to predatory fish such as emperors and snappers (Figure 3). The biomass of herbivorous fish, such as parrotfish and rudderfish, was also higher in the MPA compared to the reference area.

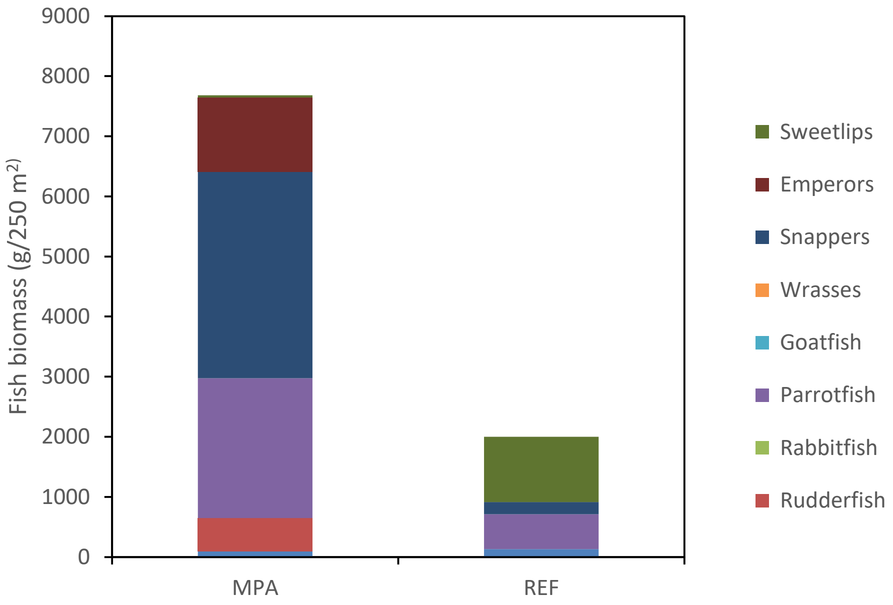

Figure 3: Bar plot showing the mean biomass of major fish groups in the MPA and Reference area

1.2. Edible macro-invertebrates

The abundance of macro-invertebrates, which mostly consisted of clams (*Tridacna crocea* and *Tridacna maxima),* remained the same in the MPA through time and, compared to the reference area, at approximately 5 to 9 individuals per 100 m^2 (ANOVA, $P > 0.05$, Figure 4).

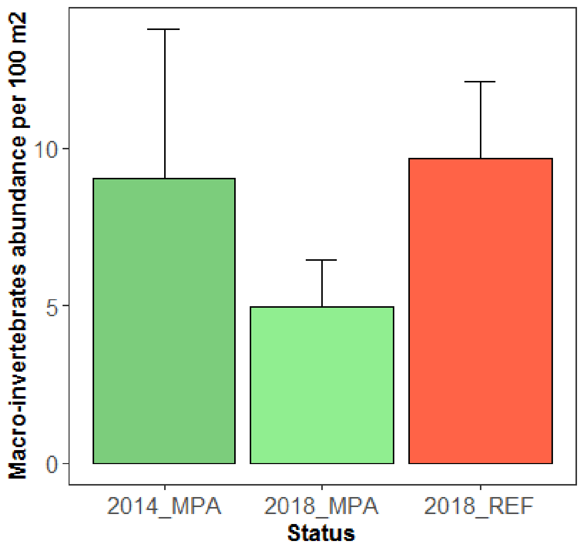

Figure 4: Bar plot showing the abundance of macro-invertebrates (± SE) in the MPA (green) and the reference area (red)

1.3. The benthos

The benthic community in the fore reef habitat on the east consisted mostly of rubble, sand and carbonate > 75% and live corals coverage was overall low < 11%. In contrast, on the western reefs the coral cover was above 20 %. In both east and west fore reefs, macroalgal and CCA cover decreased in the MPA through time.

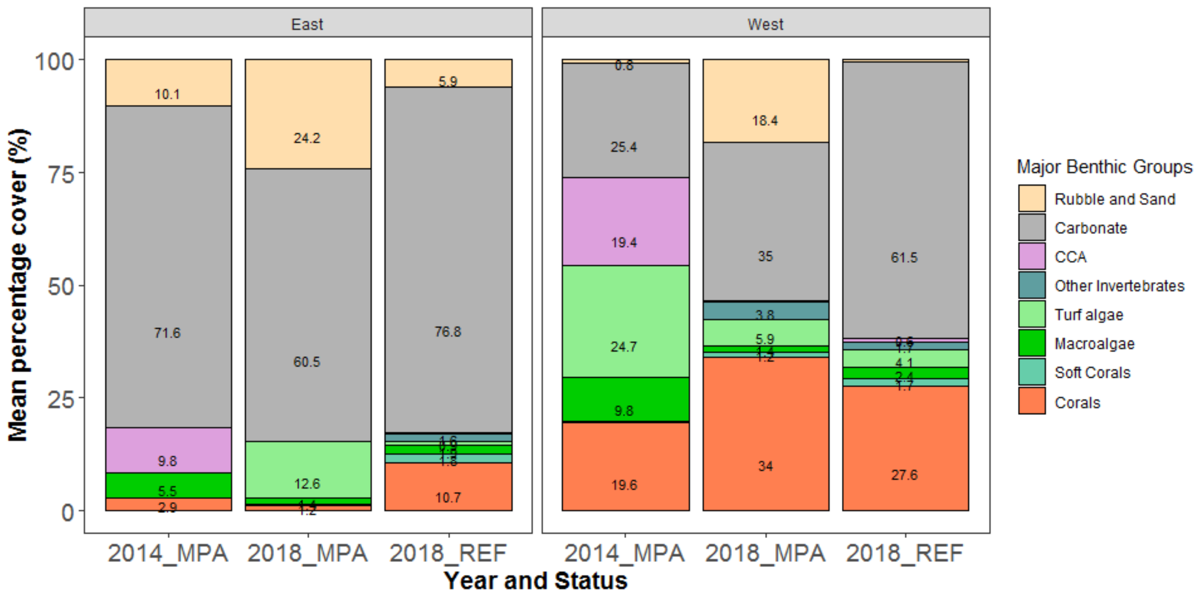

Figure 5: Stacked area bar plot of main benthic categories found in the MPA in 2014 and 2018 and the reference area in 2018 for eastern exposed reefs (left) and western exposed reefs (right). Numbers show the mean percentage cover.

The live coral coverage did not significantly change in the MPA through time but was very different in the west-oriented fore reef (~20-35 %) compared to the east-oriented fore reefs (~1-3%) (ANOVA, significant interaction, P < 0.001). The coral cover was significantly higher in the reference area than the MPA, but only on the east-facing reefs (ANOVA, P<0.001).

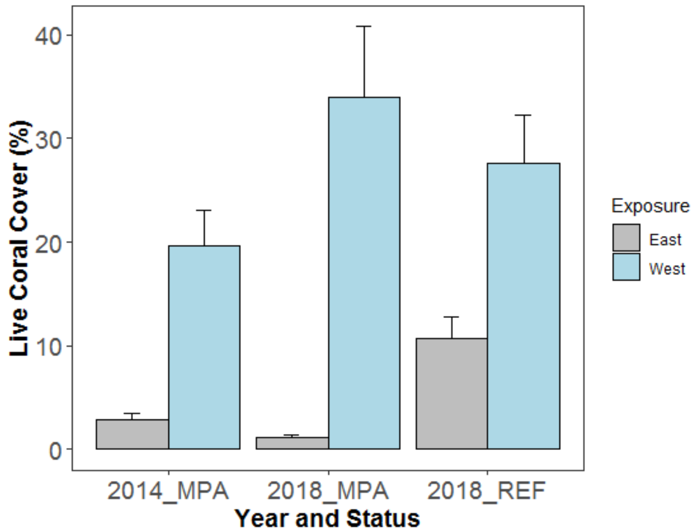

Figure 4: Bar plot showing the mean percentage of live corals coverage (± SE) in the MPA and the reference area through time for eastern exposed reefs (grey) and western exposed reefs (blue)

1.4. Juvenile corals

The density of juvenile corals (size ≤ 5cm) significantly increased 5-fold in the MPA between 2014 and 2018, now averaging at 20.3 (± 6.2) corals per $3m^2$ (ANOVA, significant interaction, P < 0.001, Figure 6). The density of juvenile corals in 2018 was similar on the east between the MPA and the reference area, but significantly higher in the reference area on the west –compared to the MPA (ANOVA, significant interaction, P < 0.001). The dominant juvenile corals recorded in the fore reef habitat belong to the following genera and families: Merulinidae, Pocilloporidae, and *Porites*.

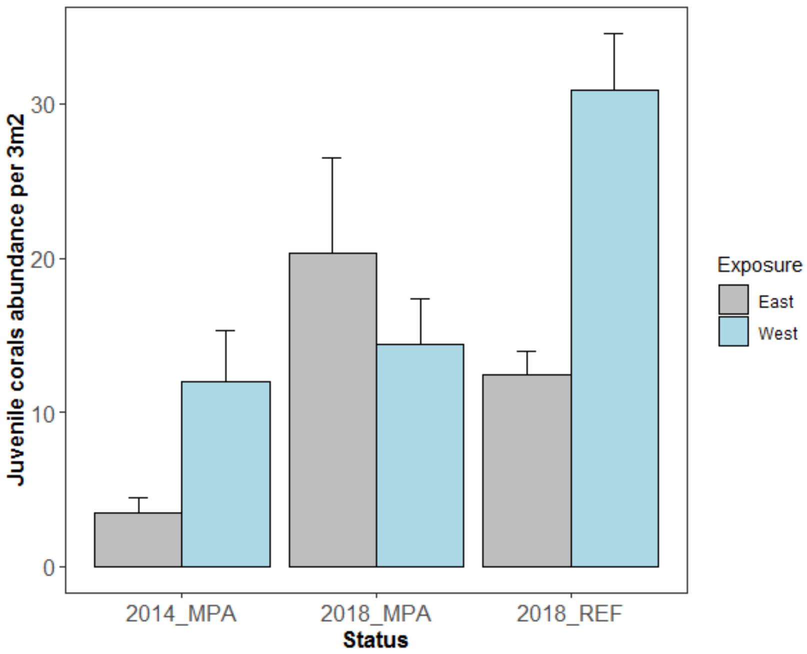

Figure 6: Bar plot showing the mean density of coral recruits (± SE) in the MPA (green) in 2014 and 2018 for eastern exposed reefs (grey) and western exposed reefs (blue)

2. Lagoon Habitat

2.1. Commercially-important fish

The mean abundance of food fish was overall low (< 2.5 fish per 100 m^2) but significantly higher in the MPA with 2.2 (± 0.6 SE) individuals per 100m^2 compared to the reference area with 0.7 (± 0.1 SE) individuals per 100m^2 (ANOVA, P<0.05, Figure 7). The biomass of food fish was more than 40 times higher in the MPA, with an average of 1.9 kg/100 m^2 (± 0.8 SE), compared to the 0.05 kg/100m^2 (± 0.02 SE) average in the reference area (ANOVA, P <0.05, Figure 7).

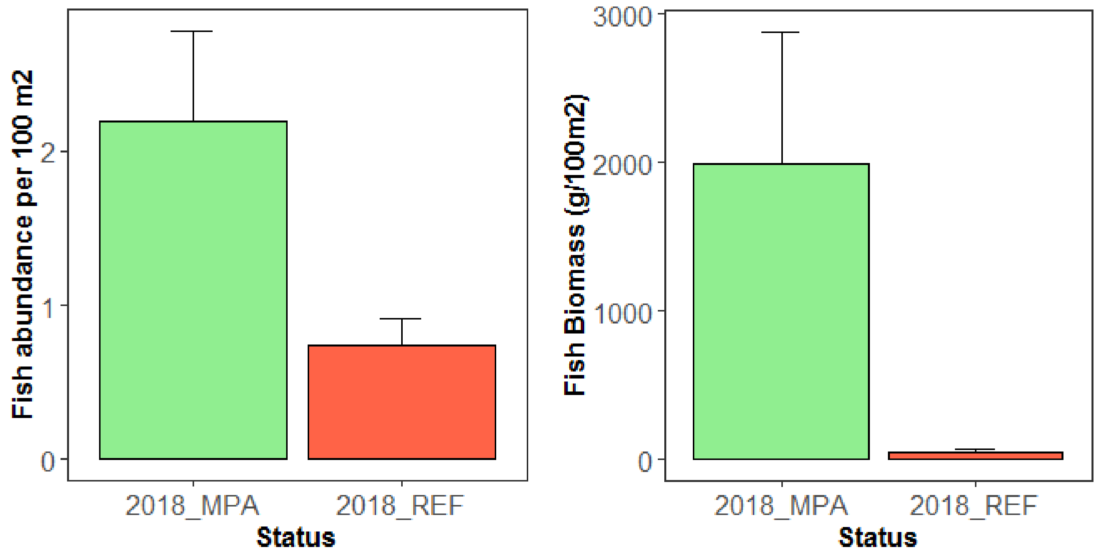

Figure 7: Bar plot showing the mean abundance (left) and biomass (right) of food fish (± SE) in the MPA (green) and the reference area (red)

The MPA hosted high biomass of predatory fish such as sweetlips, emperors and snappers, as well as good biomass of herbivorous reefs fish. In the reference area, however, low biomass of all fish groups, including herbivores, was observed.

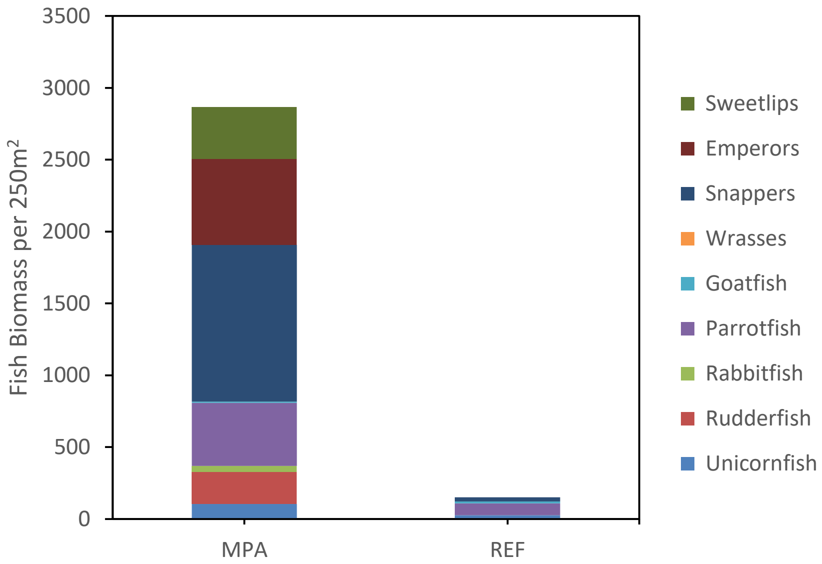

Figure 8: Bar plot showing the mean biomass of major fish groups in the MPA and Reference area

2.2. Edible macro-invertebrates

The abundance of macro-invertebrates, which mostly consisted of clams (*Tridacna crocea* and *Tridacna maxima*), remained the same in the MPA through time and, compared to the reference area in 2018, at ~ 1 to 2 individuals per 100 m^2 (Kruskal-Wallis, P > 0.05, Figure 9).

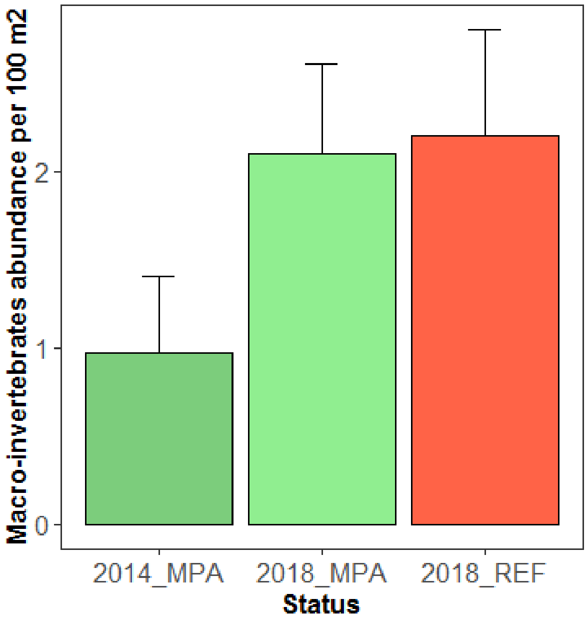

Figure 9: Bar plot showing the abundance of macro-invertebrates (± SE) in the MPA (green) and the reference area (red)

2.3. The benthos

The lagoon habitat was dominated by rubble and sand in both the MPA and reference area (>80% in 2018). There was also a slight decrease in turf algae and an increase in carbonate in the MPA through time. The live coral coverage was overall extremely low (< 5%), but still higher in the reference area (Kruskal-wallis, P < 0.05), and remained the same in the MPA through time.

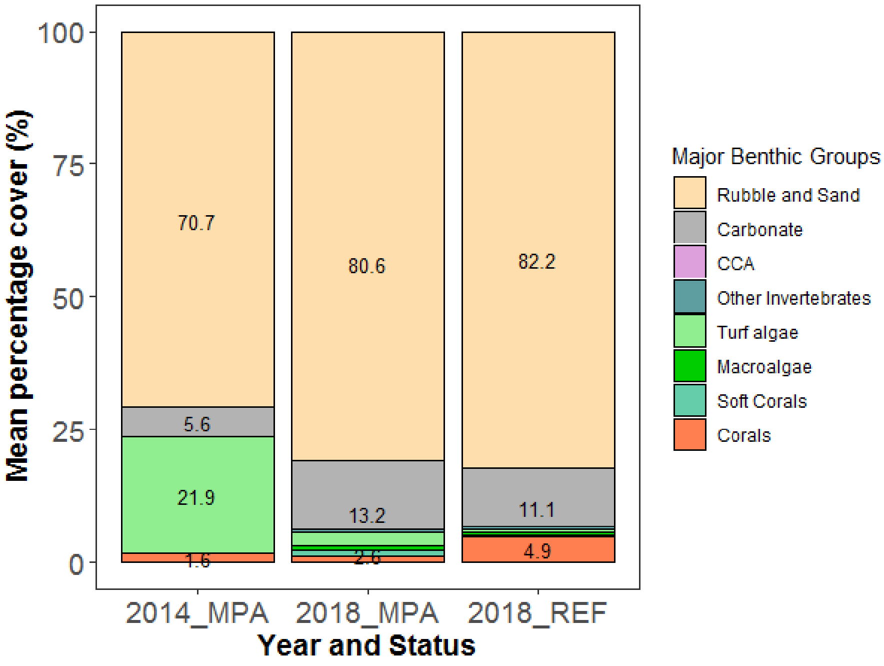

Figure 5: Stacked area bar plot of main benthic categories found in the MPA in 2014 and 2018 and the reference area in 2018. Numbers show the mean percentage cover.

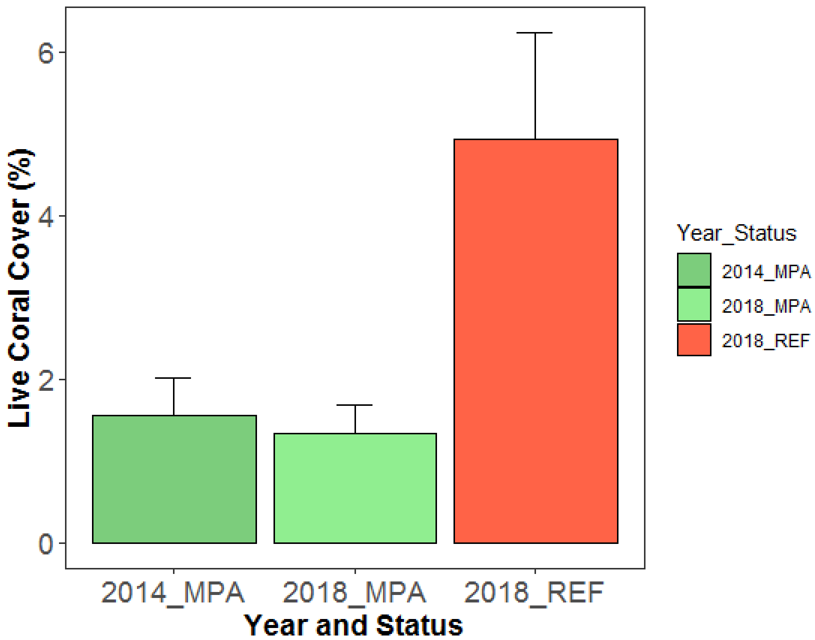

Figure 4: Bar plot showing the mean percentage of live corals coverage (± SE) in the MPA and the reference area through time

2.4. Juvenile corals

The juvenile corals density remained the same within the MPA through time, and also, between the MPA and Reference area in 2018 (Kruskal wallis P >0.05). The dominant juvenile corals recorded in the fore reef habitat belong to the following genera and families: Merulinidae and Pocilloporidae.

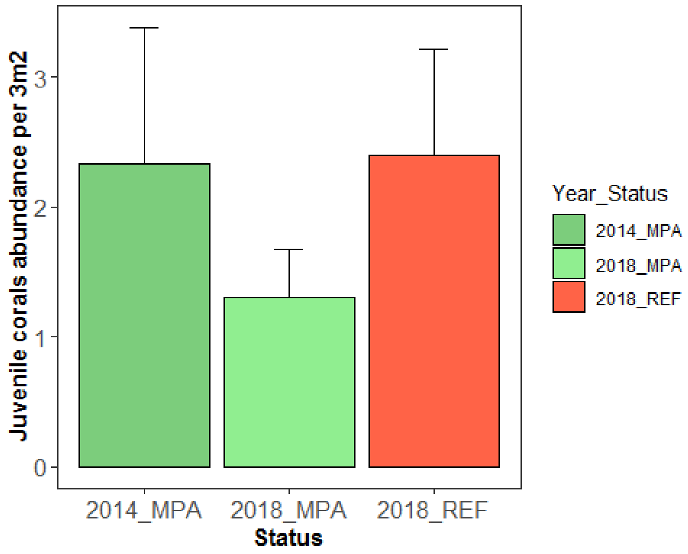

Figure 6: Bar plot showing the mean density of coral recruits (± SE) in the MPA (green) in 2014 and 2018 and the reference area (red) in 2018.

Discussion

Ngeruangel MPA has been protected under traditional and state laws for over 22 years. Our study shows that this MPA is very effective at protecting fish; displaying a high abundance and biomass in both habitats. The protection, however, does not appear to have an effect on macro-invertebrates. Both Ngeruangel and Kayangel eastern reefs have been heavily disturbed by typhoon Haiyan in 2013, where corals have not yet recovered. But, the observance of a 5-fold increase in juvenile corals density (of size ≤ 5cm) between 2014 and 2018 within the MPA gives hope for a faster recovery in the fore reef habitat in the coming years. Coral recovery predictions in the lagoon habitat of Ngeruangel are not as hopeful due to the high coverage of loose substrate; which is likely to be contributing to coral settlement failure.

Edible resources: fish and macro-invertebrates

Our study shows that Ngeruangel hosts four times higher abundance of fish on the fore reefs and 40 times higher biomass of fish in the lagoon— compared to the nearby inhabited atoll of Kayangel. For an MPA closed to fishing for over 20 years, this finding is very encouraging. According to McNeil et al. (2015), pristine levels of reef fish biomass on the fore reefs should average around 700 kg per hectare when fishing closure had been implemented for ~ 20 years, as is in Ngeruangel. Our data shows good biomass levels of 340 kg per hectare but this does not include biomass estimates of all fish species as used in MacNeil et al. (2015) study. Therefore, it is difficult to compare these two values. Nonetheless, a recent report published by PICRC showed pristine levels of fish biomass on the fore reefs of the remote and protected atoll of Hotsarihie with close to 1,500 kg per hectare (Marino et al. 2019). Certainly, other parameters besides fishing pressure –levels of primary productivity, sea surface temperature or larval supply– influence fish populations biomass among different islands, as demonstrated by Harborne et al. (2018), in Micronesia. Comparatively, this implies that fish populations within Ngeruangel, although displaying good biomass levels, may still be recovering from past over-exploitation, and/or, may have already recovered. The natural environmental characteristics of the atoll, however, may have an influence on fish population biomass. It is also likely that the large typhoon disturbance that damaged the eastern outer reefs may have diminished the structural complexity needed for fish (Graham and Nash 2013), hence, impacting their abundance in space. Coral recovery following typhoon Haiyan is further discussed in the next section.

In contrast to fish, the abundance of macro-invertebrates did not differ between the MPA and reference area. This observation is possibly related to typhoon damages, the limited recruitment of these species due to the isolation of both islands (discussed below) and/or some levels of poaching within Ngeruangel MPA.

Coral reef recovery following typhoon disturbance

Overall, our findings showed that coral coverage was at medium level (~25%) on the western outer reefs, but low (<10%) on the eastern outer reefs and the lagoon regardless of where the sites were located— inside or outside the MPA. This spatial difference is clearly the result of typhoon Haiyan that decimated north-eastern outer reefs (Gouezo et al. 2015) and the lagoon area of Ngeruangel (Koshiba et al. 2015). Four years after the typhoon disturbance, live coral cover on the eastern-oriented reefs averaged around 10 % in the reference site while still hovering around 1% in the MPA. A similar trend was also observed in the lagoon. This is unlikely related to protection; instead, the recovery of reefs is often context-specific, depending on larval supply levels and successful coral recruitment through space (Connell et al. 1997; Gilmour et al. 2013). Here, it is possible that the isolation of these two islands led to divergent connectivity patterns with nearby reefs. Following spawning events, coral larvae remain in the plankton for a few weeks with their peak competency for settlement usually occurring 3 -10 days post fertilization (Connolly and Baird 2010). As coral larvae have poor swimming abilities, currents carry them over, or away from, reef habitats during that time. If the substrate is suitable for settlement when competent, and are carried over reefs, this often leads to a 'recruitment pulse'. Therefore, we hypothesize that Kayangel's eastern reefs may have been more supplied with larvae between 2014 and now; explaining the present coral coverage of ~10% in 2018. In contrast, Ngeruangel eastern reefs may have been successfully supplied with larvae only in the past 2 to 3 years; explaining the five-fold increase in juvenile corals since 2014, but still observing low coverage of adult corals. Considering the high coverage of substrate space suitable for coral settlement and the present high juvenile coral densities, we are hopeful to see corals recover on the fore reef of Ngeruangel in the next few years— given that no additional disturbance occurs. It is also important to mention that the present juvenile coral communities are not dominated by the fast-growing *Acropora* corals, but instead, by slower growing genera such as Merulinidae and *Porites*. Therefore, the pace of recovery of the eastern reefs in Kayangel waters might be slow.

While our recovery predictions might be accurate for the fore reefs, that have high coverage of solid substrata suitable for coral settlement, the recovery of corals in the lagoon habitat is questioned. In fact, most of the substrate in the lagoon is composed of rubble and sand, which would lead to recruitment failure even if larvae were supplied. Therefore, the substrate has to consolidate before expecting any signs of recovery. Substrate consolidation naturally occurs through the growth of organisms secreting carbonate such as CCA, or through the cementation process (also called diagenesis of sediments) (Rasser and Riegl 2002). However, if rubbles are too light and moving constantly, they need to be stabilized first for consolidation to occur. In a low wave energy environment, rubble stabilization can be simply achieved by covering the lose substrate with large limestone rocks, boulders, or with stabilization mats fixed over rubble fields (Edwards 2010; Fox et al. 2019). Lastly, It is also possible that corals inhabiting the lagoon have a mixed reproductive strategy, and use fragmentation (Highsmith 1982) or clonal dispersion through corallith formation, as also observed on reef flats in Australia (Roff 2008). In that case, the local population loss would have a detrimental effect on their recovery, and active coral restoration should be considered.

Conclusion and recommendations

To conclude, our study demonstrates that Ngeruangel MPA is very effective at protecting fish populations, displaying good biomass levels despite the heavy typhoon impact on the corals located on the eastern and lagoonal reefs. The good levels of recruitment on the eastern fore reefs project a faster recovery in the coming years— compared to the previous 4 years. However, it is unknown whether the lagoonal reef will regain coral-dominance due to the high coverage of loose substrata; which is unhospitable for coral larvae to recruit.

Therefore, we recommend the following:

- To maintain good enforcement levels within Ngeruangel Marine Reserve
- The state of Kayangel could consider the establishment of reef restoration actions to help corals recover in the lagoon habitat. Such practice could include substrate stabilization, such as covering the lose substrate with large limestone rocks, boulders (as in Fox et al. 2019) or with stabilization mats fixed over rubble fields (Edwards 2010), to assist natural recovery followed by active restoration using coral gardening techniques

Acknowledgement

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References

Connell JH, Hughes TP, Wallace CC (1997) A 30-year study of coral abundance, recruitment, and disturbance at several scales in space and time. Ecological Monographs 67:461–488

Connolly SR, Baird AH (2010) Estimating dispersal potential for marine larvae: dynamic models applied to scleractinian corals. Ecology 91:3572–3583

Edwards AJ (2010) Reef rehabilitation manual. Coral Reef Targeted Research & Capacity Building for Management Program, St. Lucia, Qld.

Fox HE, Harris JL, Darling ES, Ahmadia GN, Estradivari, Razak TB (2019) Rebuilding coral reefs: success (and failure) 16 years after low-cost, low-tech restoration. Restor Ecol rec.12935

Gilmour JP, Smith LD, Heyward AJ, Baird AH, Pratchett MS (2013) Recovery of an isolated coral reef system following severe disturbance. Science 340:69–71

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 Progress Series 540:73–85

Graham NAJ, Nash KL (2013) The importance of structural complexity in coral reef ecosystems. Coral Reefs 32:315–326

Harborne AR, Green AL, Peterson NA, Beger M, Golbuu Y, Houk P, Spalding MD, Taylor BM, Terk E, Treml EA, Victor S, Vigliola L, Williams ID, Wolff NH, zu Ermgassen PSE, Mumby PJ (2018) Modelling and mapping regional-scale patterns of fishing impact and fish stocks to support coral-reef management in Micronesia. Divers Distrib 24:1729–1743

Highsmith R (1982) Reproduction by Fragmentation in Corals. Mar Ecol Prog Ser 7:207–226

Koshiba S, Gouezo M, Rehm L, Olsudong D, Mereb G, Jonathan R (2014) Baseline Assessment of Ngeruangel Marine Reserve. PICRC technical report 15-03

MacNeil MA, Graham NAJ, Cinner JE, Wilson SK, Williams ID, Maina J, Newman S, Friedlander AM, Jupiter S, Polunin NVC, McClanahan TR (2015) Recovery potential of the world's coral reef fishes. Nature 520:341–344

Marino L, Gouezo M, Dochez M, Otto EI, Jonathan R, Olsudong D, Parker A (2019) Survey indicate that Hotsarihie MPA took 10 years to recover from 1998 bleaching event. PICRC Technical Report No. 19-10. Palau International Coral Reef Center. Koror, Palau.

Rasser M, Riegl B (2002) Holocene coral reef rubble and its binding agents. Coral Reefs 21:57–72

Roff G (2008) Corals on the move: morphological and reproductive strategies of reef flat coralliths. Coral Reefs 27:343–344

Appendix

Table: Benthic categories used when analyzing benthic photos

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)	