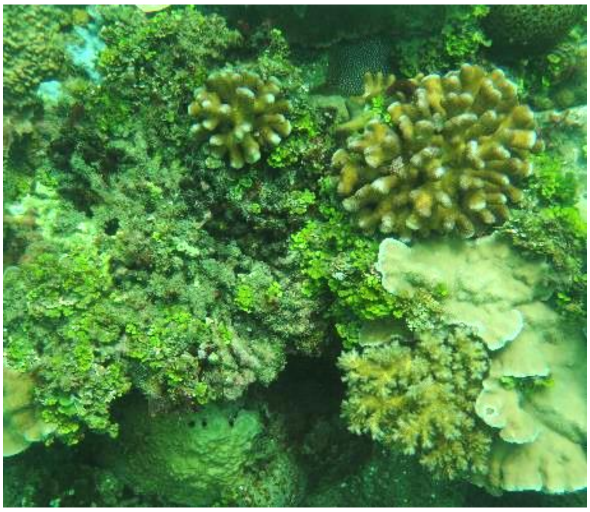
Ngemai Conservation Area:

2018 follow-up ecological assessment



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Abstract

In 2003, Palau established a Protected Areas Network (PAN) that consists of 14 marine protected areas. 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 Ngemai Conservation Area (CA) located in Ngiwal State, which has been protected since 2008 and a PAN site since 2010. Surveys recording the status of fish, macro-invertebrates, juvenile corals, seagrass cover and benthic cover were conducted within three stations in the reef flat habitat and three stations in the fore reef habitat, both inside and outside the conservation area. Our findings demonstrate that the effect of protection of Ngemai CA is mixed and varies depending on ecological indicators and marine habitats. While the seagrass coverage in the reef flat was lower in the conservation area than the reference area, the coral cover on the fore reef remained stable over the past few years. The fish abundance and biomass were not enhanced by the conservation area in either habitat. The sea cucumbers densities dramatically decreased while clams showed a small increase inside the CA over time. We recommend to further strengthen the enforcement of Ngemai CA.

Introduction

Natural resource conservation is anchored deep 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) or Conservation Areas (CAs). The first MPA to be established in Palau was Ngerukeuid in the southern lagoon of Koror State in 1956. Later, 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). The government of Palau established the Protected Areas Network (PAN) in 2003, which currently consists of 14 no-take MPAs and 13 terrestrial protected areas. 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 in order to make it 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 will re-visit the PAN MPAs to monitor the status and trends of natural resources and assess their effectiveness over time.

This study was conducted in Ngemai Conservation Area (CA) in Ngiwal in April 2018 (7°31.882'N, 134°37.55'E) (Fig.1), which has been protected since 2008 under state legislation and became a PAN site in 2010. Ngemai was consolidated to an adjacent terrestrial area consisting of Oselkesol Waterfall and Ngerbekuu Watershed, in 2010 and is now called Oselkesol Ngemai CA. This study focuses on two main marine habitats of Ngemai CA: the reef flat and the fore reef. The objectives of this study are (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

Ngemai CA covers an area of 3.25 km^2 and encompasses two main habitats: reef flat and fore reef. Three survey sites per habitat were surveyed inside the CA and outside (Fig. 1).

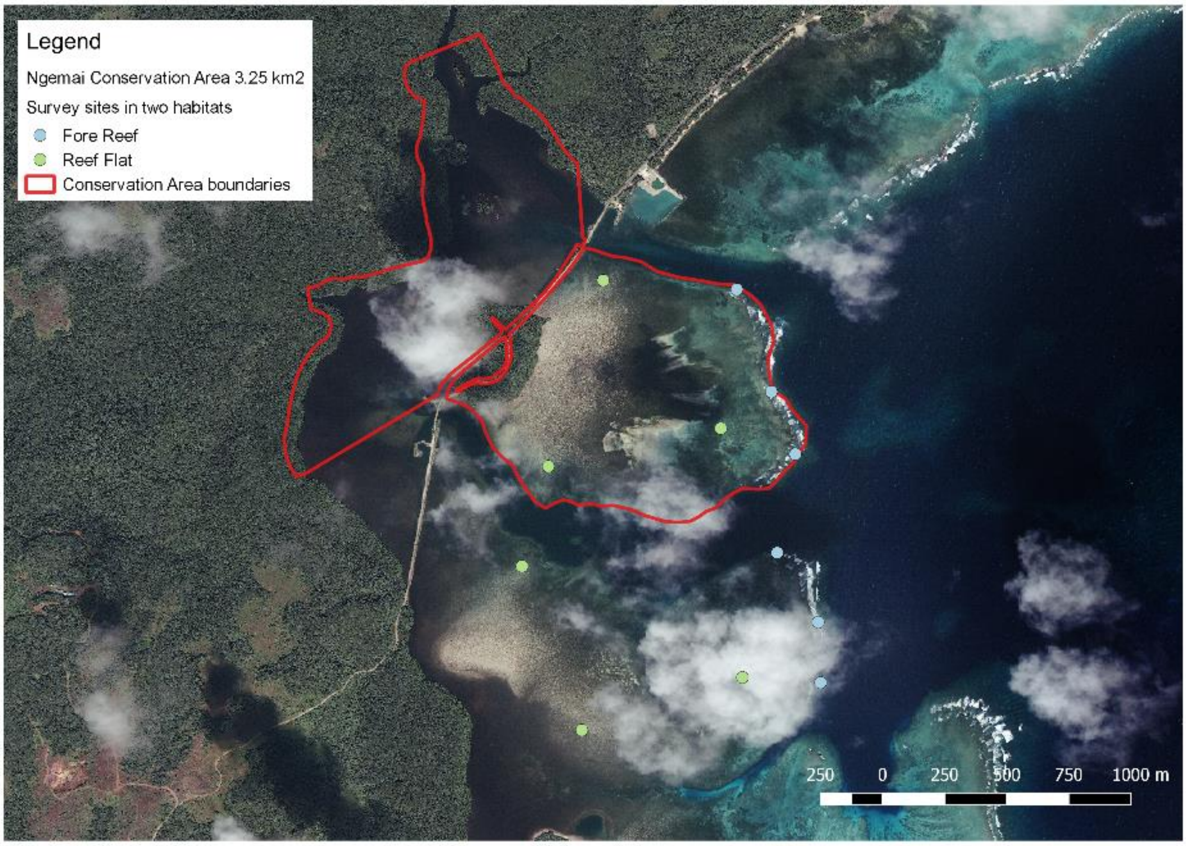

Figure 1: Map of Ngemai conservation area with monitoring sites inside and outside the protected area (red polygon)

2. Ecological surveys

Ecological surveys were conducted at each study site. In the reef flat, five 25 m transects were laid consecutively, with a few meters separating each of them. Data recorded along these transects included seagrass percentage cover (at the species level) in 0.5 m quadrat placed every 5 meters, fish size and abundance in 5 m wide belt, and edible macro-invertebrates in 2 m wide belt. In the lagoon, five 50 meters transects were laid consecutively with five meters in between them at 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 into excel spreadsheets. To estimate benthic cover, 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 1). 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 Event Measure. All fish that have an economic and/or subsistence importance were counted and measured (excluding butterflyfish, 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 normal, One-way ANOVA was used to compare CA with reference area. When data were non-normal, non-parametric Mann-Whitney U test was used instead.

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.

1. Reef Flat Habitat

The reef flat habitat of Ngemai CA is covered by seagrass beds consisting of five dominant species (Fig. 2). The coverage of seagrasses was higher (34% ± 1.7%) in the reference area than in the CA (21% ± 1.5%) (Mann Whitney test, P < 0.001, Figure 2).

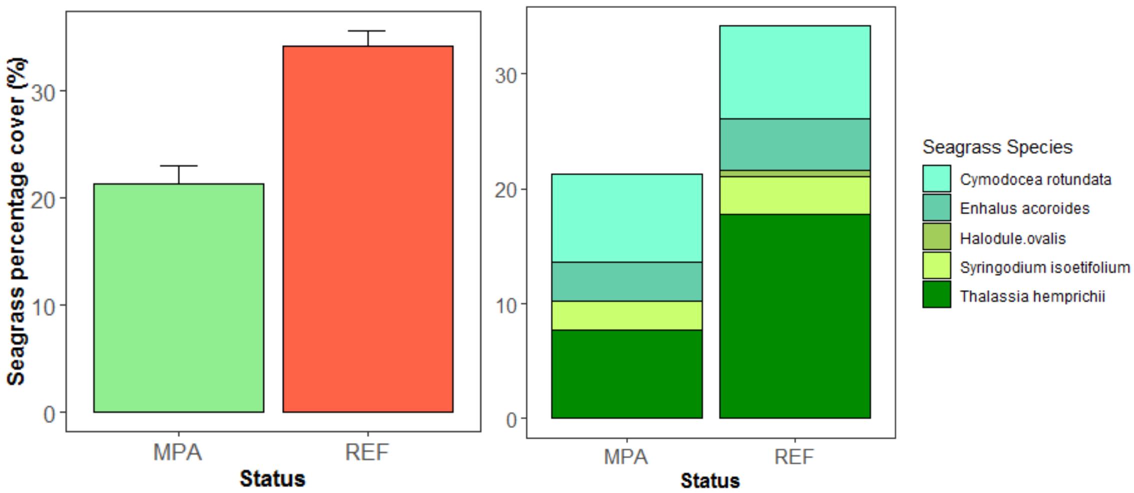

Figure 2: Bar plots showing the mean percentage cover (± SE) of seagrass in the MPA and the Reference area as well as their respective species composition.

The mean abundance and biomass of food fish in the reef flat was low overall (< 1 individuals per 100 m^2) and not significantly different between the CA and the reference area (Mann Whitney test, P > 0.05, Figure 3).

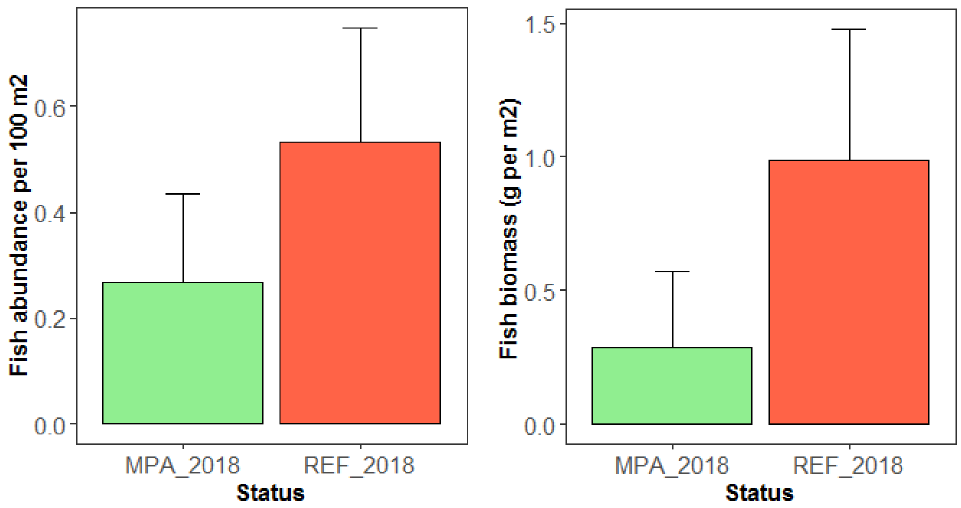

Figure 3: Bar plot showing the abundance (left) and biomass (right) of food fish (± SE) in the MPA (green) and the reference area (red)

The communities of fish was very different in both areas (Figure 4). Emperors, surgeonfish and parrotfish were mainly observed in the MPA while wrasses, rabbitfish and emperors were found in the reference area.

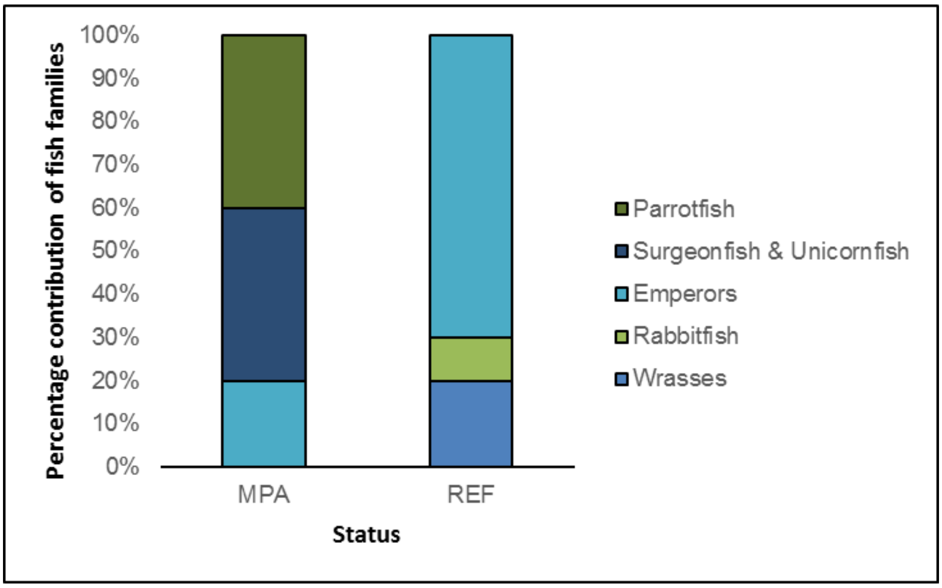

Figure 4: Bar plot showing the percentage contribution to the total abundance of different families of food fish in the MPA and the reference area

The abundance of macro-invertebrates, which consisted mostly of sea cucumbers, was 57 times higher during the baseline assessment in the MPA (Mann Whitney test, $P < 0.05$, Figure 5). The difference in macro-invertebrate abundance in 2018 between the MPA and reference area was not significant (Mann Whitney test, P > 0.05).

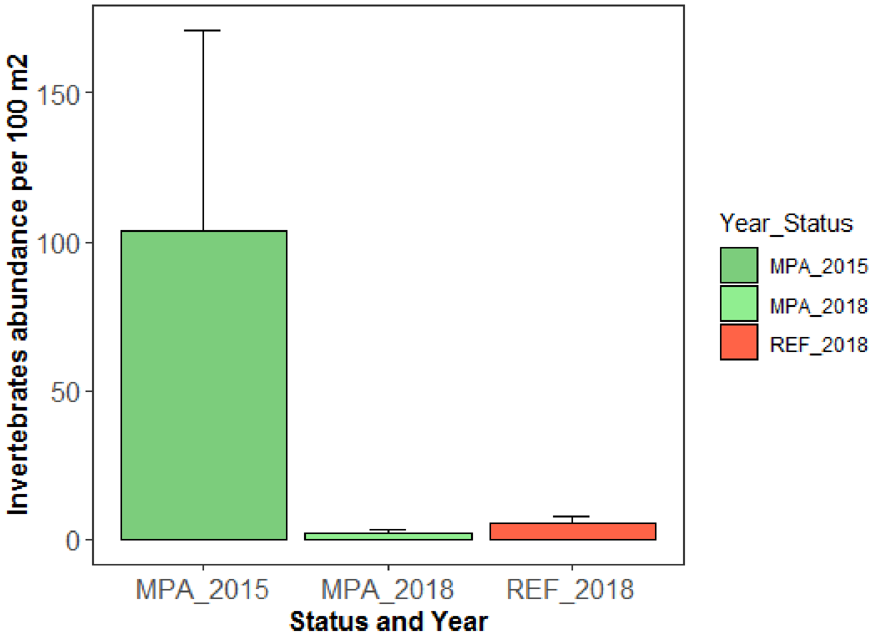

Figure 5: Bar plot showing the abundance of macro-invertebrates (± SE) in the MPA (green) and the reference area (red)

2. Fore Reef habitat

The fore reef habitat mostly consisted of live corals, turf, macroalgae, carbonate, and crustose coralline algae (CCA) (Figure 6). The live coral cover was similar between the MPA and the reference area in 2018 as well as at the MPA since 2015 (ANOVA, P>0.05, Figure 7).

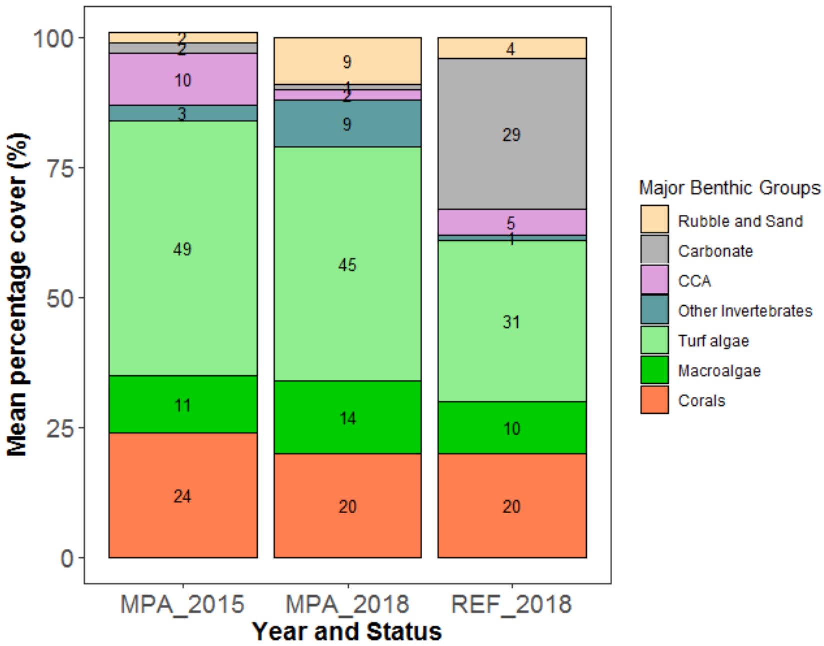

Figure 6: Stacked area bar plot of main benthic categories found in the conservation area in 2015 and 2018 and the reference area in 2018. Numbers show the percentage cover.

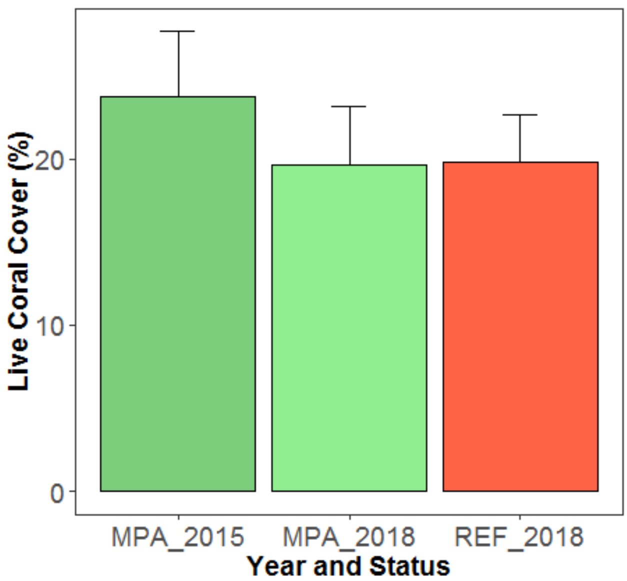

Figure 7: Bar plot showing the mean live coral cover (± SE) in the conservation area (green) in 2015 and 2018 and the reference area (red) in 2018.

The density of coral recruits (size ≤ 5cm) was not significantly different within the MPA through time, as well as in 2018 when compared to the reference area (ANOVA, $P > 0.05$, Figure 8).

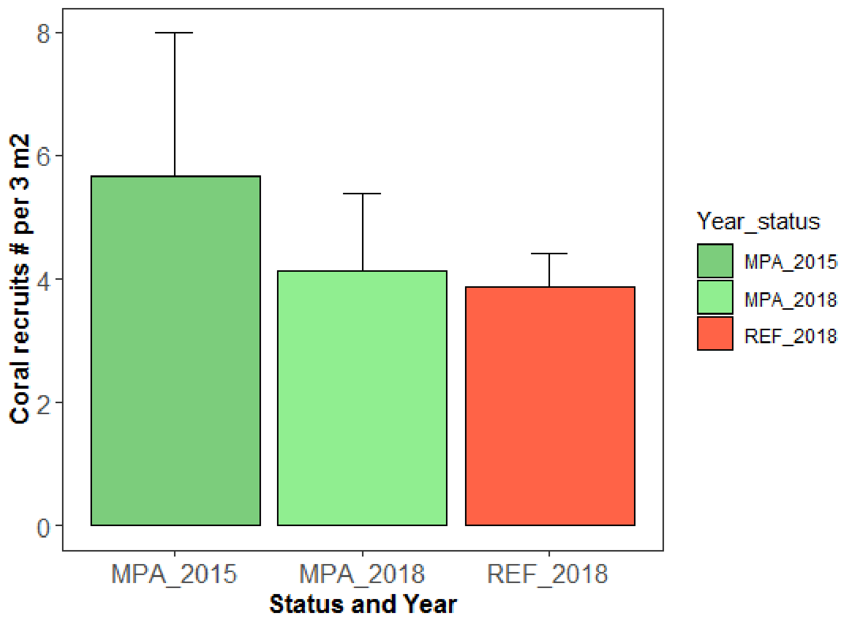

Figure 8: Bar plot showing the mean density of coral recruits (± SE) in the CA (green) in 2015 and 2018 and the reference area (red) in 2018.

The abundance and biomass of food fish was significantly higher in the reference area than in the MPA (ANOVA, $P < 0.05$, Figure 9). The fish communities were relatively similar between the MPA and the reference area (Figure 10). Rudderfish and snappers were found in higher abundance in the reference area compared to the MPA.

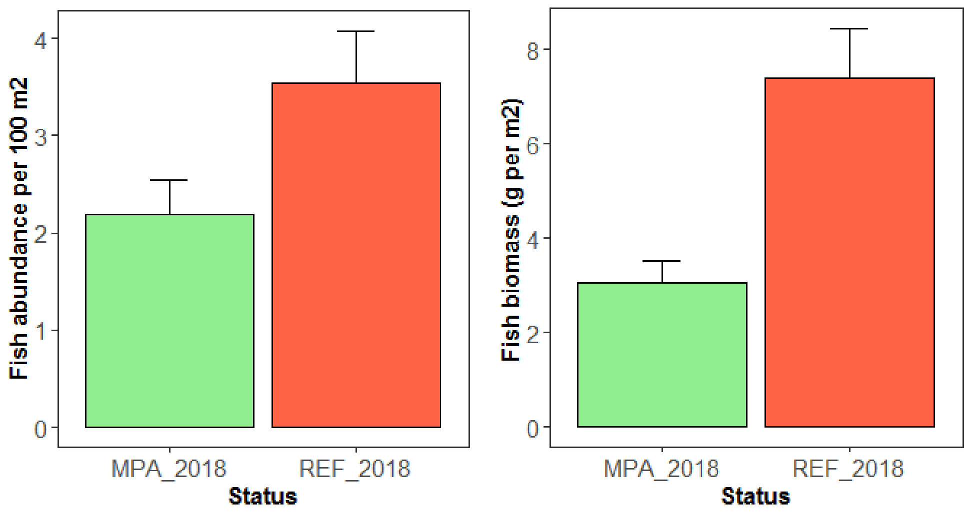

Figure 9: Bar plot showing the abundance (left) and biomass (right) of food fish (± SE) in the MPA (green) and the reference area (red)

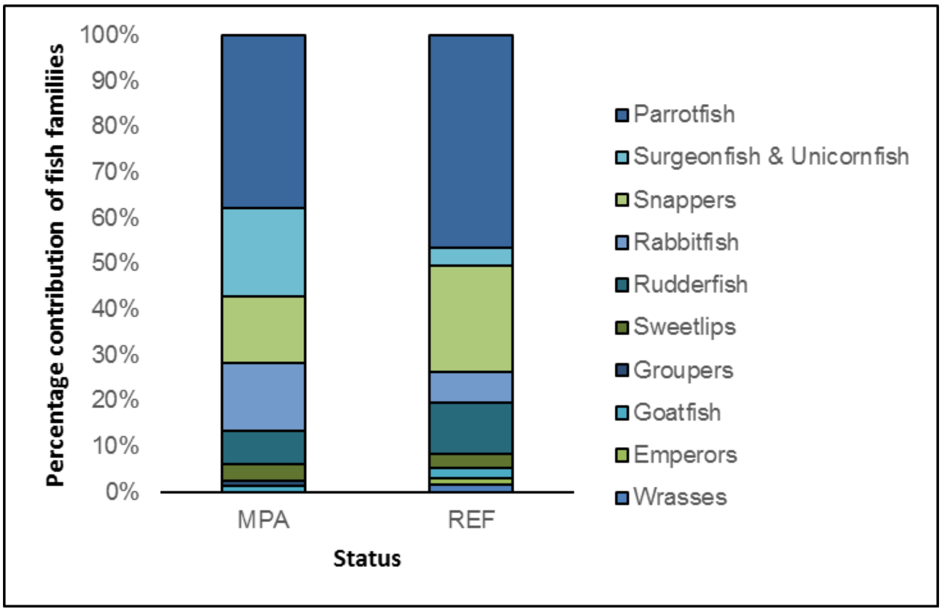

Figure 10: Bar plot showing the percentage contribution to the total abundance of different families of food fish (± SE) in the MPA and the reference area

There were more macro-invertebrates, which consisted mainly of clams (*Tridacna* spp.) in 2018 compared to 2015 in the MPA (Mann Whitney test, P < 0.001, Figure 11) and their abundance did not differ between the MPA and the reference area (Mann Whitney test, P > 0.05, Figure 11).

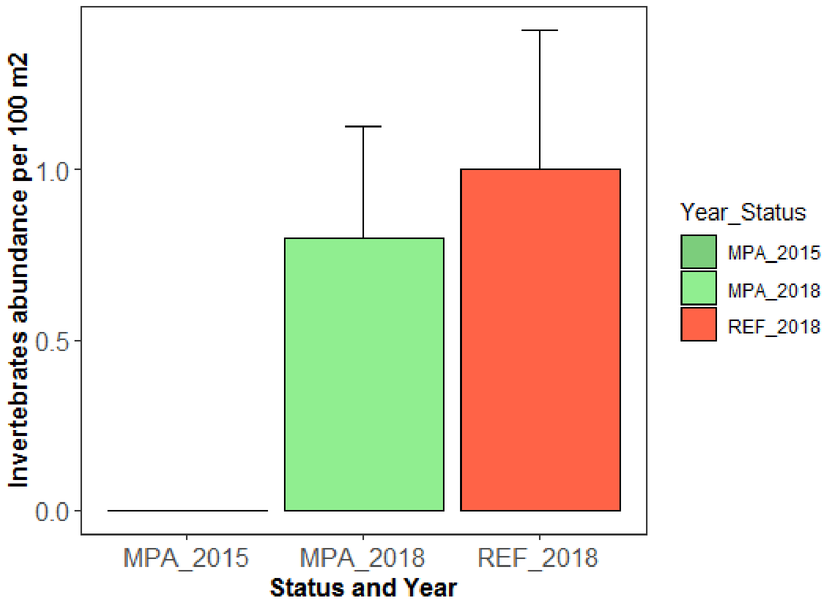

Figure 11: Bar plot showing the abundance of macro-invertebrates (± SE) in the MPA in 2015 and 2018 (green) and the reference area in 2018 (red)

Discussion

Ngemai CA has been protected for almost 10 years. PICRC monitoring data showed that the effect of protection of Ngemai CA is mixed and contrasts depending on ecological indicators and marine habitats. While the seagrass coverage in the reef flat was lower in the conservation area than the reference area, the coral cover on the fore reef remained stable over the past few years. The fish abundance and biomass were not maximized by the conservation area in either habitat. The sea cucumber density dramatically decreased while clams showed a small increase inside the CA.

Seagrass and corals important foundation species that provide habitat to many other organisms. This study shows that the coverage of seagrass is lower inside Ngemai CA compared to a nearby area (see map Figure 1). Ngemai CA is surrounded by two channels that carries sediments out of the Ngerbekuu river watershed during outgoing tides. Sediments are likely accumulating in higher quantities in the CA compared to the adjacent area as the watershed is located closer to the CA. Seagrass beds are highly susceptible to terrestrial run offs and sedimentation that block the sunlight and smother seagrass blades (Duarte 2002). Sedimentation would explain why seagrass coverage is lower inside the CA than in the reference area. While the reef flat of Ngemai CA seemed to be affected by some level of sedimentation, it does not appear to impact live corals on the fore reef. The coverage of live corals (around 20 - 24 %) and the population of juvenile corals have remained stable since 2015. This indicates that the sedimentation levels may be a typical environmental condition of the area surrounding the Ngerbekuu river watershed.

Commercially targeted fish populations do not seem to fully benefit from the CA. Fish were recorded in low abundance in the reef flat in both areas. This observation may simply be caused by the environmental characteristics typical of this habitat which is shallow, exposed at low tide, and high in sediments. Therefore, fish populations may only reside in the seagrass beds at certain times, or only in low numbers and during their juvenile stages. In contrast, fish populations were recorded higher in abundance and biomass in the fore reef in the reference area than in the CA. This observation is worrying as Ngemai CA has been protected for close to 10 years. Although this difference may be affected to the schooling behavior of certain fish groups such as rudderfish or snappers, there should still be a positive significant difference in fish biomass between the CA and the reference area as observed in other studies in Palau (Friedlander et al. 2017). The reasons why this was not observed may be due to either the small size of the CA, the turbidity of the water in the CA or poaching occurring inside the CA.

The macro-invertebrates observed in Ngemai CA consisted of sea cucumbers in the reef flat and clams in the fore reef. The populations of sea cucumbers have dramatically decreased since the baseline survey in 2015 in the reef flat. Due to the proximity of the CA from the main road, it is likely that poaching has occurred. While the abundance of clams increased slightly in 2018 inside the CA, it was not different from the reference area, meaning that clams do not appear to directly benefit from protection as the area might be too small for resident clams to recruit inside the CA. In fact, clams reproduce sexually and have a larval stage that can last up to two weeks (Blidberg 2004) – a timeframe when larvae are carried by currents. Therefore, it is unlikely that clam larvae from CA resident clams recruit inside Ngemai CA, but may help replenish clam population outside Ngemai CA.

The ecological assessment of Ngemai CA shows contrasting effects from protection, depending on indicators and habitats. While the state of the two studied marine habitats are not alarming, the marine resources (specifically fish and sea cucumbers) are not enhanced inside the CA. We, therefore, recommend strengthened enforcement levels to maximize the protection on both fish and sea cucumber populations.

Acknowledgement

PICRC would like to thank Ngiwal State Government for allowing us within their MPA and the assistance from their conservation officers. 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.

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Appendix 1: Benthic categories

HARD CORALS	SOFT CORAL (SC)
Acanthastrea (ACAN)	Soft Coral (SC)
Acropora branching (ACB)	OTHER INVERTEBRATES (OI)
Acropora digitate (ACD)	Anenome (ANEM)
Acropora encrusting (ACE)	Ascidian (ASC)
Acropora submassive (ACS)	Clams (CL)
Acropora tabular (ACT)	Corrallimorph (COLM)
Alveopora (ALVEO)	Discosoma (DISCO)
Anacropora (ANAC)	Dysidea Sponge (DYS)
Astreopora (ASTRP)	Gorgonians (G)
Caulastrea (CAUL)	Not Identified Invertebrate (NOIDINV)
Coral Unknown (CRUNK)	Sponges (SP)
Coscinaraea (COSC)	Zoanthids (Z)
Ctenactis (CTEN)	MACROALGAE (MA)

Cyphastrea (CYPH)	Asparagopsis (ASP)
Diploastrea (DIPLO)	Bluegreen (BG)
Echinophyllia (ECHPHY)	Boodlea (BOOD)
Echinopora (ECHPO)	Bryopsis (BRYP)
Euphyllia (EUPH)	Caulerpa (CLP)
Favia (FAV)	Chlorodesmis (CHLDES)
Faviid (FAVD)	Dictosphyrea (DYCTY)
Favites (FAVT)	Dictyota (DICT)
Fungia (FUNG)	Galaxura (GLXU)
Galaxea (GAL)	Halimeda (HALI)
Gardininoseris (GARD)	Liagora (LIAG)
Goniastrea (GON)	Lobophora (LOBO)
Goniopora (GONIO)	Mastophora (MAST)
Halomitra (HALO)	Microdictyton (MICDTY)
Heliofungia (HELIOF)	Neomeris (NEOM)
Heliopora (HELIO)	Not ID Macroalgae (NOIDMAC)
Herpolitha (HERP)	Padina (PAD)
Hydnophora (HYD)	Sargassum (SARG)
Isopora (ISOP)	Schizothrix (SCHIZ)
Leptastrea (LEPT)	Turbinaria (TURB)
Leptoria (LEPTOR)	Tydemania (TYDM)
Leptoseris (LEPTOS)	SEAGRASS (SG)
Lobophyllia (LOBOPH)	C.rotundata (CR)
Merulina (MERU)	C.serrulata (CS)
Millepora (MILL)	E. acroides (EA)
Montastrea (MONTA)	H. minor (HM)
Montipora branching (MONTIBR)	H. ovalis (HO)
Montipora encrusting (MONTIEN)	H. pinifolia (HP)
Montipora foliose (MONTIF)	H. univervis (HU)
Montipora other (MONTIO)	S. isoetifolium (SI)
Montipora submassive (MONTISB)	Seagrass (SG)
Mycedium (MYCED)	T. ciliatum (TC)
Oulophyllia (OULO)	T.hemprichii (TH)
Oxypora (OXYP)	CORALLINE ALGAE (CA)
Pachyseris (PACHY)	Amphiroa (AMP)
Paraclavarina (PARAC)	Crustose Coralline (CCA)
Pavona (PAV)	Fleshy-Coralline (FCA)
Pectinia (PECT)	Jania (JAN)
Physogyra (PHYSO)	SUBSTRATE (SUBS)
Platygyra (PLAT)	Carbonate (CAR)
Plerogyra (PLERO)	Mud (MUD)
Plesiastrea (PLSIA)	Rubble (RUBBLE)
Pocillopora-branching (POCB)	Sand (SAND)
Pocillopora-submassive (POCSB)	Turf (TURF)

Porites (POR)	
Porites-branching (PORB)	
Porites-encrusting (PORE)	
Porites-massive (PORMAS)	
Porites-rus (PORRUS)	
Psammocora (PSAM)	
Sandalolitha (SANDO)	
Scapophyllia (SCAP)	
Seriatopora (SERIA)	
Stylocoeniella (STYLC)	
Stylophora (STYLO)	
Symphyllia (SYMP)	
Tubastrea (TUB)	
Turbinaria (TURBIN)	