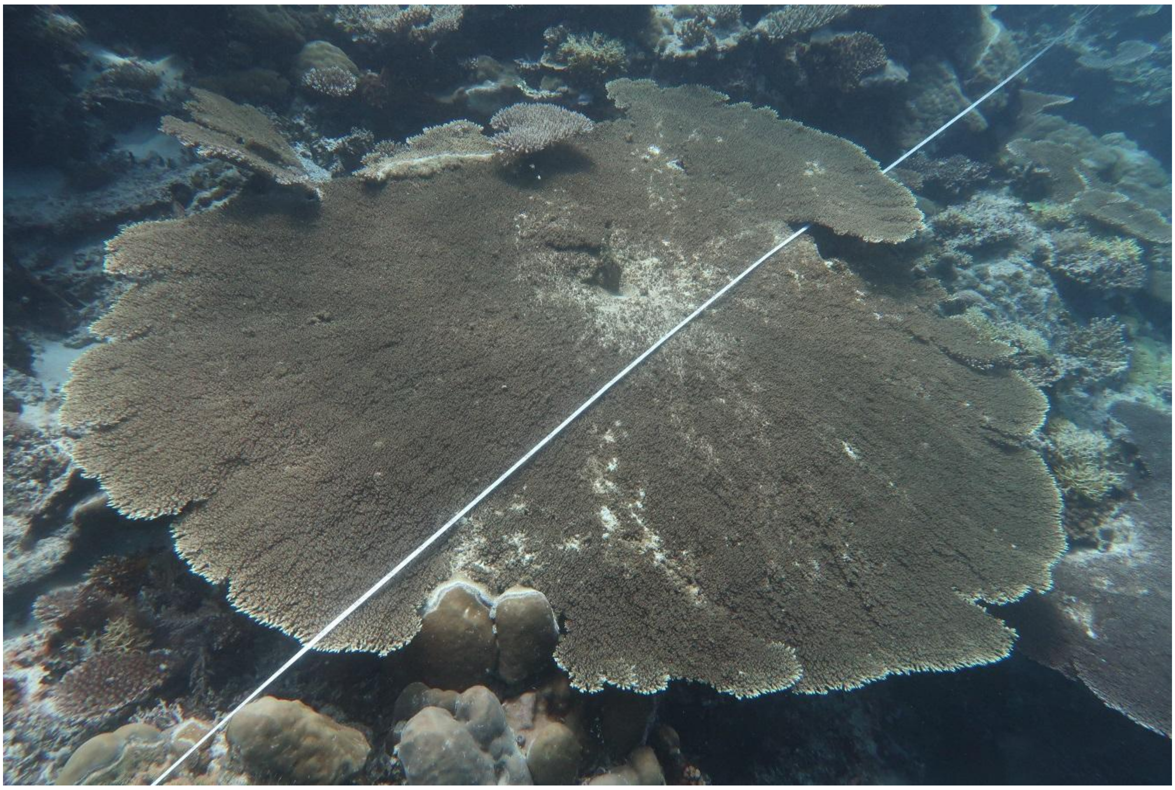
Ecological assessment of Ngerumekaol Spawning Area in 2018



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Palau International Coral Reef Center

PICRC Technical Report 19-04

April 2019

Abstract

In 2003, Palau established a Protected Areas Network (PAN) that consists of 14 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 Ngerumekaol Spawning Area (SA) located in Koror State, which has been partially protected since 1976, completely protected year-round since 1999, and finally became a PAN site in 2013. Surveys were also conducted in Ngeremlengui channel for comparison with an unprotected channel area. Surveys recording the status of fish, macro-invertebrates, juvenile corals, seagrass cover and benthic cover were conducted within three stations in the channel habitat and three stations in the fore reef habitat, both inside and outside the conservation area. Our findings demonstrate that between 2014 and 2018, the resources within the MPAs remained the same, apart from clams, which increased and juvenile corals, which decreased in the fore reef habitat. When comparing data from 2018 to Ngeremlengui channel, we found contrasting findings depending on indicators. Overall the live coral coverage and clam abundances were higher while the abundance and biomass of reef fish were lower in the MPA than the reference area. Ngerumekaol CA has been partially protected for over 40 years and fully protected for the last 20 years. Therefore, we would have expected higher fish biomass within Ngerumkaol than in unprotected reefs, with levels close to unfished reefs. Some reasons for this observation could be due to the predatory effects from pelagic fishes, schooling behavior of some fish species, the slow recovery from reef fish stocks, and/or the occurrence of some level of poaching within the MPA. Based on our findings, we suggest strengthening enforcement levels, while PICRC continues to monitor the MPA every 2 years and study the effect of protection on reef fish to better assist conservation management.

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 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 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 Ngerumekaol Spawning Area (SA), also known as Ulong Channel, in Koror State in August 2018 (7°16.988'N, 134°15083'E) (Fig.1). In addition to being a popular snorkeling and diving tourist site, it is an important area for fish spawning aggregations, especially Epinephelidae species (groupers) during the summer months. For that reason, in 1976, Ngerumekaol SA was seasonally closed to fishing from April 1st to July 31st, which then extended to October 31st, to later being closed all year-round in 1999, under Koror State legislature (Koror State Management Plan 2016-2020). It became a PAN site in 2013.

This study focuses on two main marine habitats of Ngerumekaol SA: the channel and the fore reef. The main scope of the study is to assess the overall effectiveness of the MPA. The survey was conducted outside the spawning season of groupers, so fish data do not represent biomass levels during the spawning season. Another PICRC study is designed to specifically focus on groupers. 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

Ngerumekaol SA covers an area of 3.51 km^2 and encompasses two main habitats: channel and fore reef. Three survey sites per habitat were surveyed inside the MPA and outside (Fig. 1). It was difficult to find a similar unprotected channel habitat toNgerumekaol for our reference area. Thus, the best area we could identify was Ngeremlengui channel as it was not damaged by typhoon disturbance as opposed to Dengues channel next to Ngerchong Island. Ngeremlengui channel is larger in size and located nearby a major watershed. These habitat characteristics will likely have some implications in the comparison of MPA versus reference area and will be discussed further on.

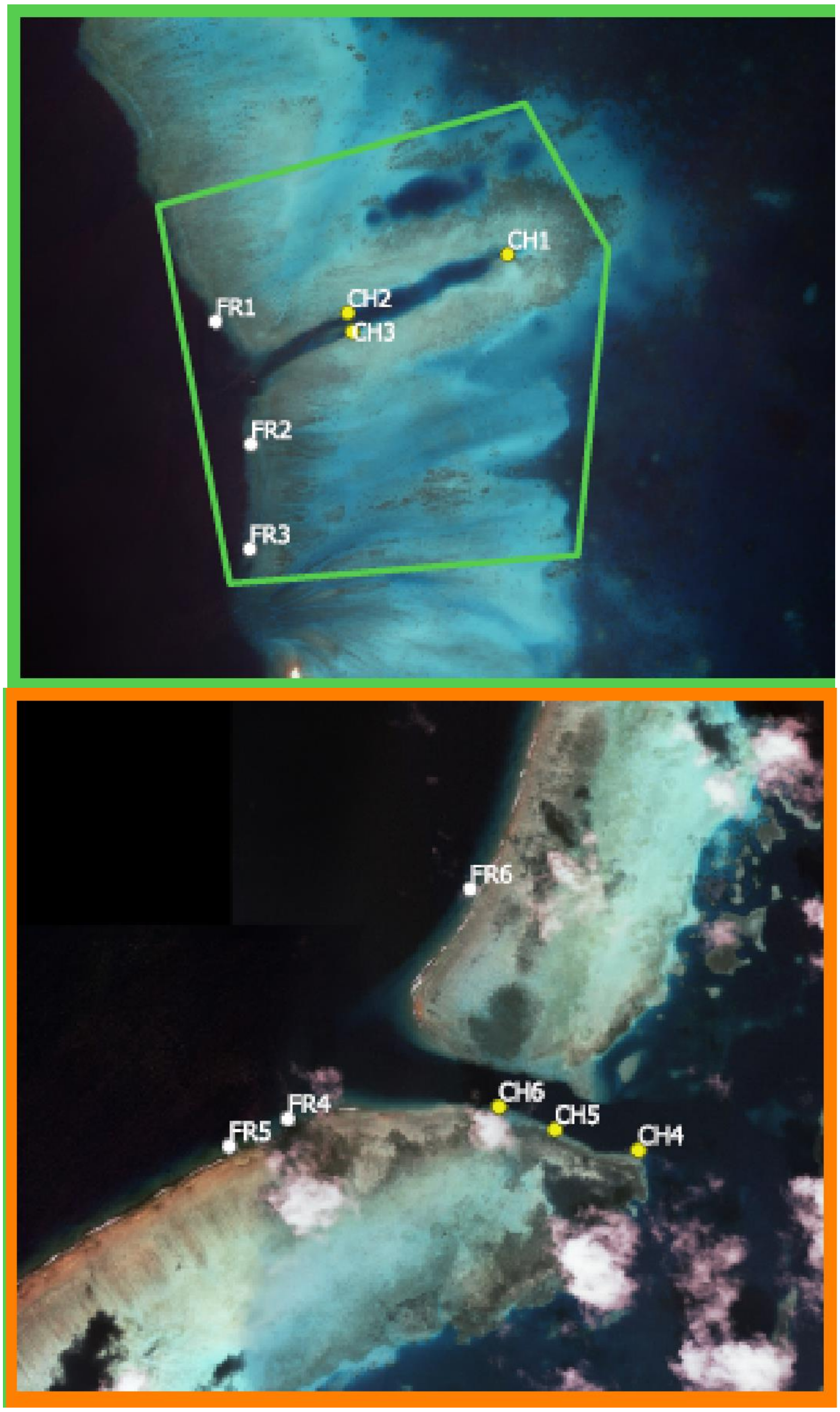

Figure 1: Satellite view of Ngerumekaol SA (green polygon) (top) and Ngeremlengui channel (bottom) with the location of monitoring sites in the fore reef (white points) and channel habitats (yellow dots)

2. Ecological surveys

Ecological surveys were conducted at each study site. In both habitat, 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 into 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 anddamselfish). 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.

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. Fore Reef Habitat

1.1. Commercially-important and pelagic fish

The mean abundance and biomass of food fish were significantly lower in the MPA with 853.5 g/100m^2 (± 143.7 SE) compared to the reference area with 3,607 g/100m^2 (± 929.5 SE) (ANOVA, P<0.05, Fig. 2)

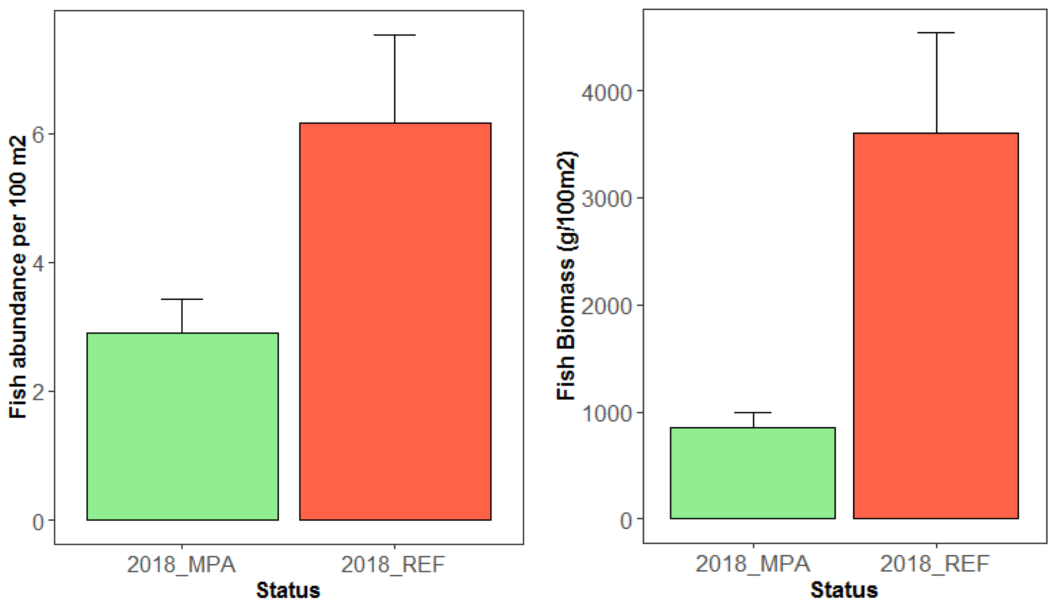

Figure 2: Bar plot showing the mean abundance (left) and biomass (right) of food fish (± SE) in the MPA (green) and the reference area (red)

The difference in biomass between the two areas was majorly attributed to schooling fish such as snappers and rudderfish, namely, keremlal (*Lutjanusgibbus*), and, tebotbe (*Kyphosus* spp.) (Fig. 3).When these fish were removed from the dataset, the MPA and reference area had similar levels of reef fish abundance (Appendix 2). The biomass of parrotfish was also higher in the reference area compared to the MPA.

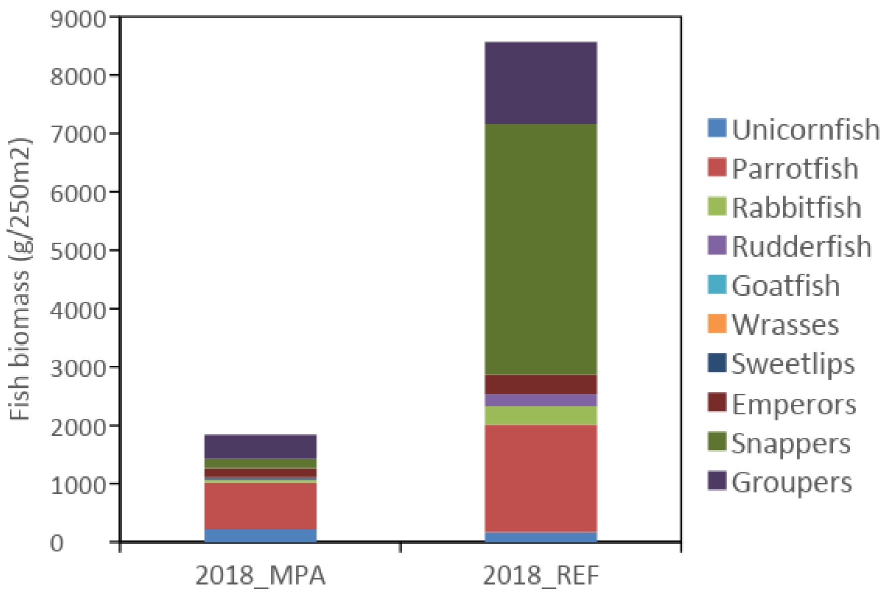

Figure 3: Bar plot showing the mean biomass of major fish groups in the MPA and Reference area

The biomass of pelagic fish such as barracudas, tunas and sharks was variable across transects due to their patchy distribution but appeared to be higher, with 16,321g/100m^2 (± 15,287 SE) in the MPA (Fig. 4), although not detected by Mann-Whitney U test (P=0.15).

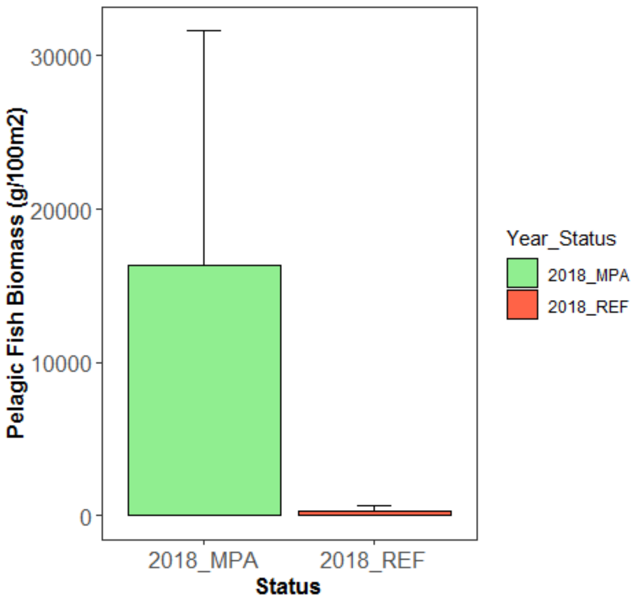

Figure 4: Bar plot showing the mean biomass of pelagic fish (± SE) in the MPA (green) and the reference area (red)

1.2. Edible macro-invertebrates

The abundance of macro-invertebrates, which mostly consisted of clams (*Tridacnacrocea* and *Tridacna maxima*), was 5 times higher in the MPA in 2018 compared to 2014, and to the reference area in 2018 (Mann Whitney test, P > 0.001).

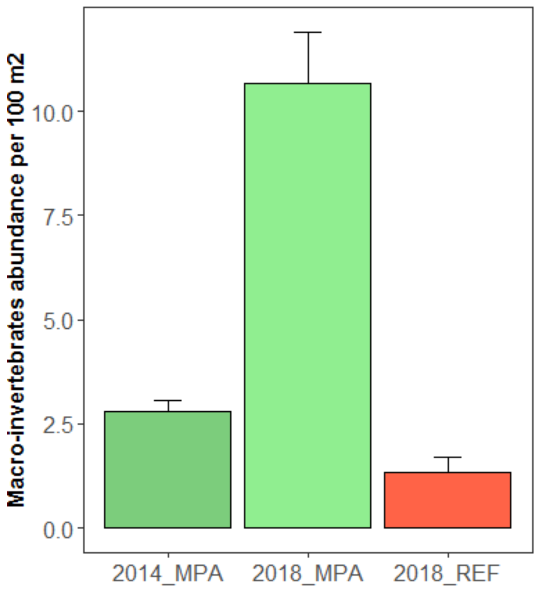

Figure 5: Bar plot showing the abundance of macro-invertebrates (± SE) in the MPA (green) and the reference area (red)

1.3. The benthos

The benthic community in the fore reef habitat consisted mostly of bare substrate (carbonate, turf algae, crustose coralline algae) and live corals in the MPA and Reference area (Fig. 6). The live coral coverage did not change in the MPA through time, averaging around 32-33%, but was significantly lower than in the reference area, averaging around 45% (ANOVA, P<0.001). The coverage of soft corals was higher in the reference area than the MPA.

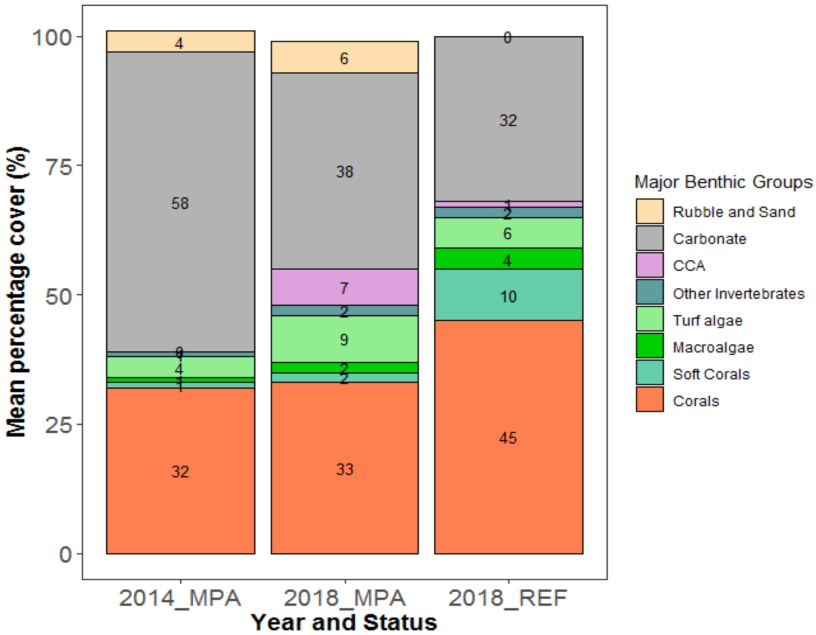

Figure 6: Stacked area bar plot of main benthic categories found in the MPA in 2014 and 2018 and the reference area in 2018. Numbers show the mean percentage cover.

1.4. Juvenile corals

The density of juvenile corals (size ≤ 5cm) decreased significantly through time within the MPA from 37 (±4.4) corals per 3m^2 to 11.1 (± 0.9) corals per 3m^2 (ANOVA, P<0.001, Fig. 8) but was not different than the reference area.

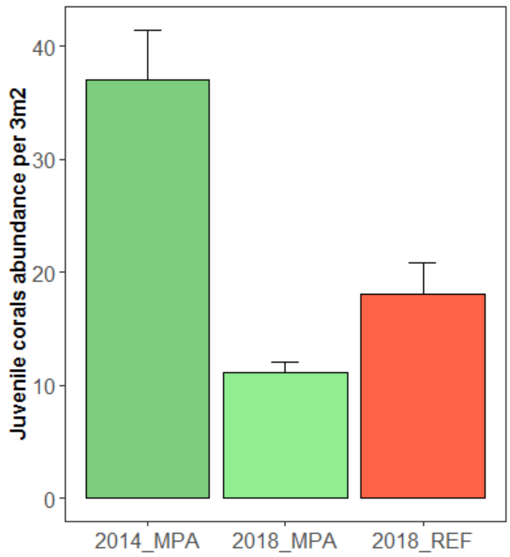

Figure 7: Bar plot showing the mean density of coral recruits (± SE) in the MPA (green) in 2015 and 2018 and the reference area (red) in 2018.

2. <u>Channel habitat</u>

2.1. Commercially-important fish

There was no significant difference in food fish abundance and biomass between the MPA and the reference area (ANOVA, P>0.05, Fig. 8)

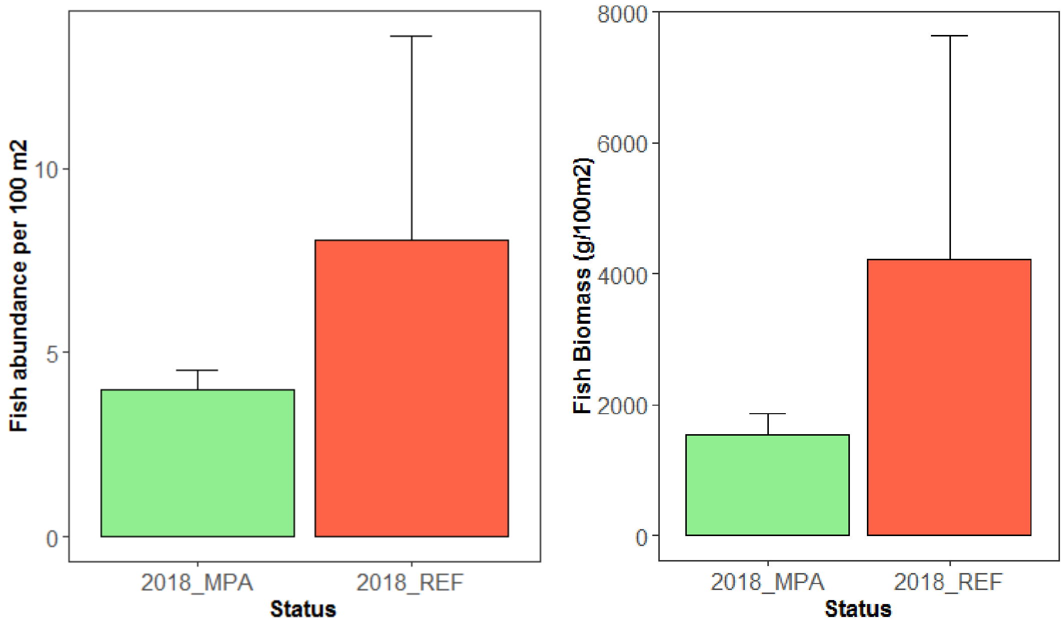

Figure 8: Bar plot showing the abundance (left) and biomass (right) of food fish (± SE) in the MPA (green) and the reference area (red)

The biomass of schooling snappers, keremlal(*Lutjanusgibbus*), was high in the reference area while the biomass of groupers and wrasses was high in the MPA (Fig. 9)

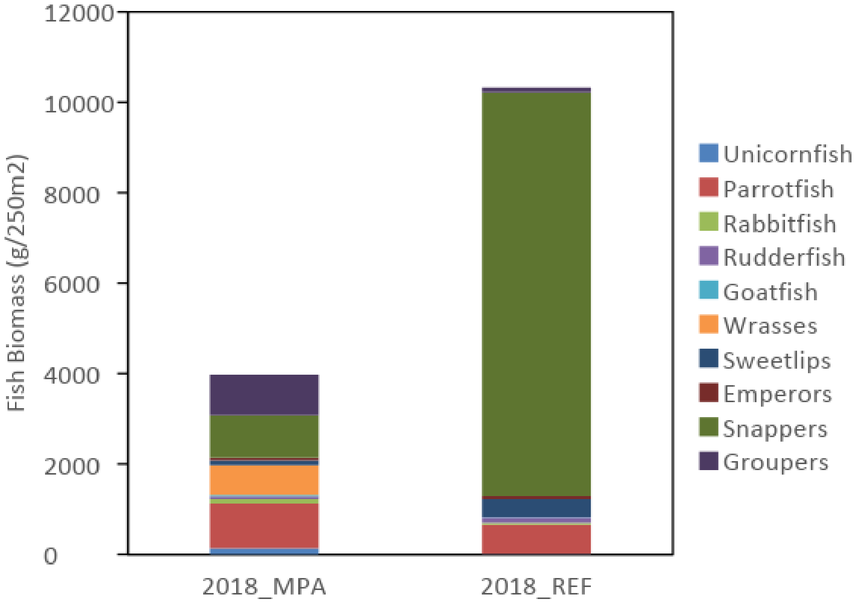

Figure 9: Bar plot showing the biomass of major fish groups in the MPA and Reference area

2.2. Macro-invertebrates

The abundance of macro-invertebrates, which consisted mostly of clams, was 3 to 5 times higher in the MPA (both years) than the reference area (Mann Whitney test, $P < 0.001$, Fig. 10). Crown-of-thorns starfish were observed in the MPA, but in low abundance: 0.33 (± 0.12 SE) individuals per 100 m^2.

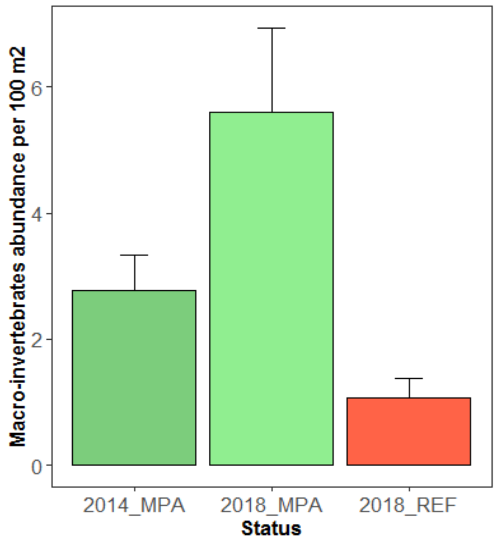

Figure 10: Bar plot showing the abundance of macro-invertebrates (± SE) in the MPA (green) and the reference area (red)

2.3. The benthic community

The benthic community in the channel habitat was mainly composed of live corals (> 40%), rubble and sand (>19%) and bare substrate (>18%, ie. carbonate, turf algae and CCA) in the MPA while in the reference area, the community was mostly composed of bare substrate (>65%, ie. carbonate, turf algae and CCA). The live corals in the reference area was significantly lower than in the MPA (Mann Whitney test, P < 0.001, Fig. 11). Live corals cover did not differ within the MPA through time (Mann Whitney test, P > 0.05)

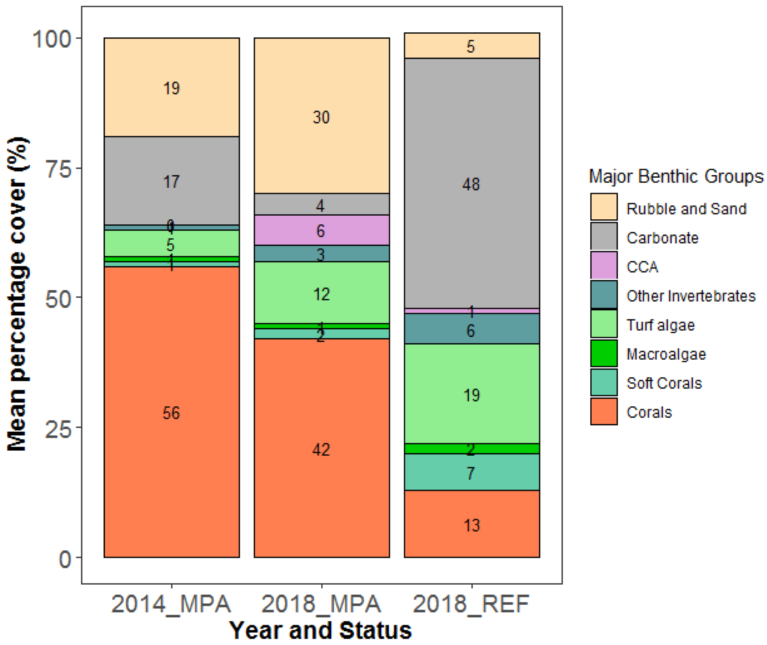

Figure 11: Stacked area bar plot of main benthic categories found in the MPA in 2014 and 2018 and the reference area in 2018. Numbers show the percentage cover.

2.4. Juvenile corals

The density of juvenile corals (size ≤ 5cm) remained the same within the MPA through time and compared to the reference area (ANOVA, P>0.05), around 7-10 individuals per 3 m^2 (Fig. 12).

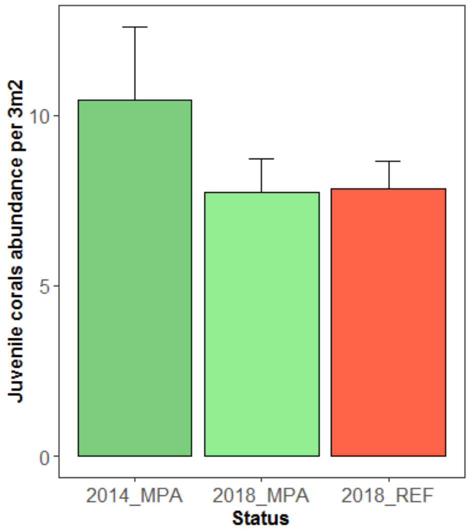

Figure 12: Bar plot showing the mean density of coral recruits (± SE) in the MPA (green) in 2015 and 2018 and the reference area (red) in 2018.

Discussion

Ngerumekaol CA has beenseasonallyprotected for over 40 years and fully protected over the past20 years. Between 2014 and 2018, the resources within the MPA remained the same, apart from clams, which increased and juvenile corals, which decreased in the fore reef habitat. When comparing data from 2018 to an unprotected channel area, Ngeremlengui channel, we found contrasting findings depending on indicators. Overall the live coral coverage and clam abundances were high in the MPA, but the abundance and biomass of reef fish were high in the reference area. Below, we discuss in details what could explain these contrasting findings.

Edible resources: fish and macro-invertebrates

Despite the very long protection time of Ngerumekaol SA, the reef fish biomass and abundance were 3 times lower than in the unprotected Ngeremlengui fore reef habitat. We suggest three potential explanations. First, in addition to reef fish, we recorded the presence of pelagic fish in Ngerumekaol during our surveys, which were high in abundance and biomass. Their presence at the time of the survey could have led to fish hiding under rocks and overhangs due to predation pressure. Secondly, we have also recorded high abundance of 2 species that have a schooling behavior (keremlal and tebotbe) in the reference area but not in the MPA. For instance, keremlal (*Lutjanusgibbus*) most commonly occur in large schools of 30-50 fish or more, and can significantly inflate the biomass values recorded at a site through time. In fact, we found that when removed from the dataset, the abundance of reef fish was the same between the MPA and Reference. Thirdly, we speculate about the potential slow recovery of fish stocks, as well as the possible occurrence of poaching. Besides the presence of pelagic fish and schooling fish that may have biased our observations, the biomass of reef fish within the 20-year-old MPA was far from the ‘pristine’ level of 1,000 kg per hectare in neither habitat (MacNeil et al. 2015). In fact, our recorded fish biomass values within the MPA translate to 80 and 180 kg per hectare in the fore reef and channel habitat respectively, which is 5 to 10 times lower than in remote unfished reefs. Due to the slow turnover rate of several reef fish species, it can take up to 35 to 60 years for stocks to recover, especially in a small sized MPA as Ngerumekaol (Edgar et al. 2014; MacNeil et al. 2015). Therefore, we highly recommend that Koror state maintains and even strengthens enforcement at the MPA while PICRC continues to monitor the MPA every 2 years and during groupers spawning season.

In contrast to reef fish, the abundance of clams was 3 to 5 times higher in the MPA compared to the reference area and clam abundance has also increased through time within the MPA. The positive effect from harvesting closure is working for this group of invertebrates and should be maintained.

The benthos

The benthic community in both habitats of the MPA remained dominated by live corals despite a storm disturbance in 2017. Since 2014, the live coral cover has remained the same, averaging around 33% in the fore reef. In 2017, there was a tropical storm that created damages on corals along the western barrier reef (Gouezo and Olsudong 2018). The damages caused by this storm were both reflected at Siaes, a monitoring site located nearby, and at Ngeremlengui barrier reef, with a loss of 10-20% coral cover. However, the damages were quite heterogeneous through space depending on the orientation of the reef to the swell created by the storm. While this damage was not alarming, it would explain why live coral cover is in the lower “healthy” end (33%) on the fore reef of the MPA. The damages caused by the storm may have also impacted the juvenile corals as juvenile coral densitydecreased 3-fold within the MPA through time. We conducted our survey in 2018, less than a year following the storm disturbance and only a few months following major coral spawning events. Therefore, that gave little time for new coral recruits to be visible to the naked eye during our surveys. In fact, the growth rate of corals at early stages hovers between 0.5-2 cm per year (Trapon et al. 2013). We know that the southwestern outer reefs of Palau are very well connected (Golbuu et al. 2012; Gouezo et al. 2019), therefore, we expect the abundance of juvenile corals to increase in the next 2 years, if no other disturbance occurs.

In the channel habitat, there were no damages from the storm as it is sheltered from the swell. Within the MPA through time, the live coral cover remained the same, averaging around 42-56%. We recorded a few Crown-of-thorns starfish. These starfish are known to eat corals and disseminate large areas of reefs (Sano et al. 1987; Adjeroud et al. 2009), but in the MPA channel, they occurred at low density (less than 1 individual per 200 m^2), which does not require taking actions as it is not at an outbreak level. However, the density of these starfish could be regularly monitored in the channel area every 6 months by Koror State rangers when on site. The live coral cover in the reference area was much lower (13%) than in Ngerumekaol channel. Whether this difference is attributed to protection or just different habitat characteristics is difficult to tear apart. Ngeremlengui channel is larger in size and located nearby a large watershed that could occasionally lead to sedimentation episodes.

Conclusion and recommendations

Despite the recent storm disturbance, the coral reefs of Ngerumekaol SA are in a good state with hopeful future coral recruitment as it was observed in the past. We have shown that the protection had a positive effect on clams which significantly increased over time. However, the biomass of reef fish was on the low end for a 20-year-old MPA. We suggest the following recommendations to Koror State:

- Maintaining and strengthening enforcement, especially at night as during the day it is often visited by divers
- Conducting biannual survey (every 6 months) in the channel to keep track of crown of thorns
- Consider increasing the size of the MPA to improve the recovery of reef fish stocks, especially on the fore reef habitat.

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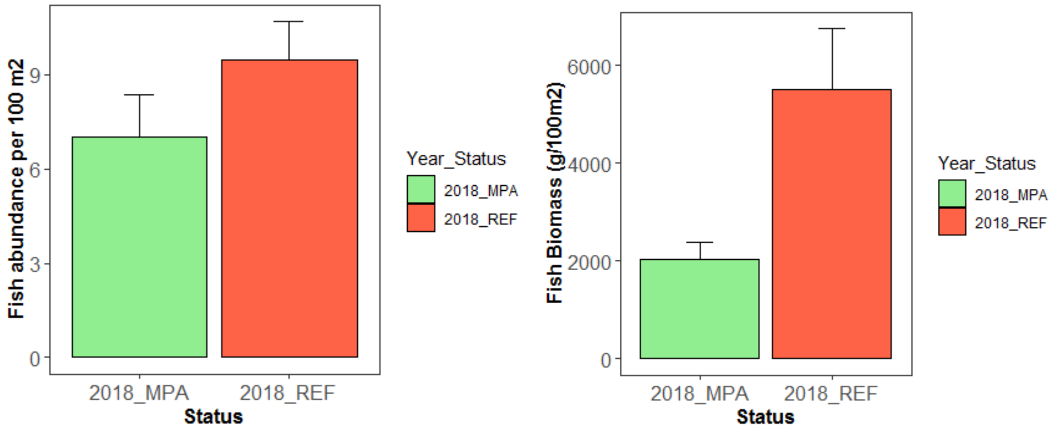
Appendix

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)	

Appendix 2



Fish abundance and biomass without schooling snappers in the MPA and Reference in 2018