Ngerkebesang Marine Protected Area: Status and Trends 2019

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Palau International Coral Reef Center

PICRC Technical Report No.20-01

July 2019

Abstract

Marine Protected Areas (MPAs) have been used globally for conservation of marine resources, however it can be challenging to determine the different effects an MPA has on an ecosystem. In order to better understand the effectiveness of protection on the Ngerkebesang MPA, data was collected from three randomly selected sites within the area. Fishes, invertebrates, coral recruits, and benthic cover were all observed and measured within Ngerkebesang MPA. The observed values were then used to calculate abundance values for each, as well as biomass and size values for fishes. These values were compared to previous data collected in 2015 and 2016. It was found that invertebrate abundance appeared to increase since 2016, but not significantly whereas coral recruit and fish abundance had significantly decreased since 2016. Fish biomass also showed a decrease when compared to 2015 and 2016 but was not significant. However, coral cover and carbonate coverage increased significantly in 2019 compared to 2016, whereas rubble and turf algae coverage decreased. The changes in benthic cover observed in 2019 were tested as significant. These results may have been impacted by many possible factors. It is important to continue monitoring this MPA in order to better understand the trends and changes of the marine resources overtime.

Introduction

Coral reefs are extremely vital to the environment, community and tourism economy of Palau. Coral reefs provide food security, economic benefits, and play a significant role in Palau's cultural traditions. Corals are a delicate animal, with a low tolerance to changes in temperature. If the temperature increases past what the corals can tolerate, (usually above 30°C), they will become bleached (Water Temperatures, 2018). Bleached corals are unable to provide a sustainable habitat for the other organisms that depend on them, such as fish and invertebrates. With increasing global temperatures, coral reefs are facing a serious threat. Palau has a long history of traditional fishing regulations, which include *bul* or areas designated for natural resource conservation purposes. This traditional practice, called a *bul*, prohibits fishing in designated areas for a certain amount of time (Johannes, 1978). Many areas that become placed under a *bul* are also a Marine Protected Area (MPA).

MPAs can be used to ensure the protection and biodiversity of natural resources in a designated area. MPAs have been shown to be an effective tool for conservation, especially when concerning commercially important fish (Freidlander, 2017), as well as coral (Mellin, 2016). In 2003, the government of the Republic of Palau established the Protected Areas Network (PAN) which consists of both marine and terrestrial protected areas. Moreover, the establishment of the PAN later became Palau's main mechanism for achieving goals of regional initiatives such as the Micronesia Challenge. The Micronesia Challenge is a regional initiative that aims to conserve 30% of the nearshore marine area along with 20% of terrestrial area by 2020 (Houk, 2015). Previous studies have shown that MPAs can result in an increase in organism biodiversity (Wantiez, 1997), abundance, biomass and size (Lester, 2009). Many factors can influence the result of an MPA. The size (Claudet, 2008), location (Gouezo, 2016), age (Selig, 2010) and enforcement (Agardy et al. 2003) of the MPA, can all impact the effectiveness of a protected area in preserving marine resources. This study focuses on the trends and changes of the marine resources within Ngerkebesang MPA, a protected area designated in 2002, located in close proximity to the Palau Pacific Resort (PPR). Monitoring of the Ngerkebesang MPA by the PICRC began in 2015, with follow-up surveys in 2016. Results presented in this report show the overall trends and changes throughout the years until 2019.

By monitoring the biodiversity, size, biomass and abundance of organisms in a given MPA over time, we can assess the overall trends and changes. These results can also be used to help inform policy makers and to increase the success of future MPAs.

Methods

The Ngerkebesang MPA was officially established in 2002, and includes the waters located west of the Palau Pacific Resort (PPR). These waters consist of lagoon and reef flat habitats. Using QGIS, 3 sites were randomly chosen within the Ngerkebesang MPA (Figure 1). See Appendix – Table 4 for site coordinates. Each site was located at a depth of between 1-5 m, in which three 30 m transect tapes were laid out consecutively with a 1-3 m gap between each tape. Commercially valuable fish, invertebrates, coral recruits, and benthic cover found within these transects were all identified and measured.

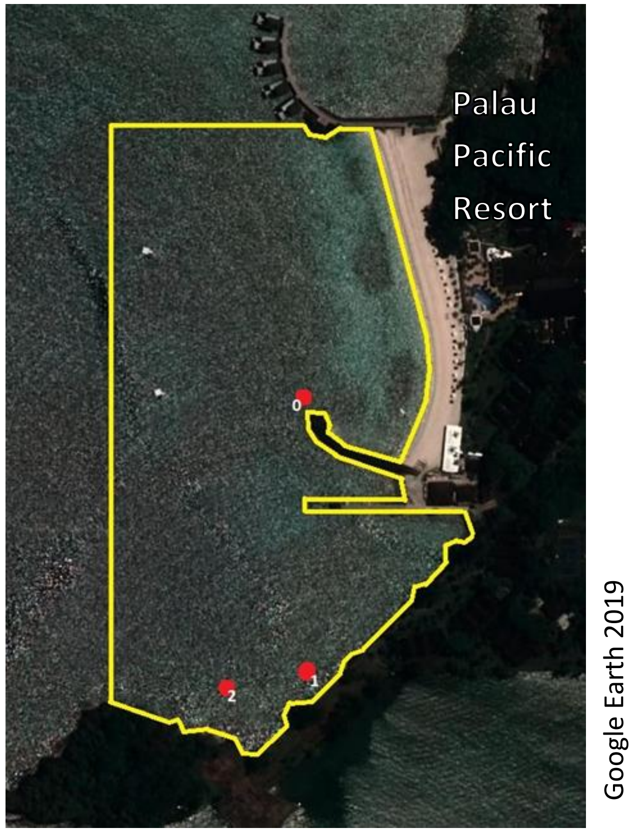

Figure 1. A map of the Ngerkebesang MPA (yellow polygon) with the three randomly selected areas in which data was collected.

Fish survey

Commercially important fish were visually observed within a 5 m belt along each transect at each site (see Appendix – Table 1 for list of commercially important fish). Fish were counted, identified to the lowest possible taxonomic level and their length in cm estimated. Fish biomass was calculated using the weight-length equation below.

$$\text{Biomass} = a \cdot L^b$$

Where L is the fish length in cm, and a and b are constants determined by fish species retrieved from Kulbicki et al. (2005) and the website Fishbase (www.fishbase.org).

Invertebrate survey

Commercially important invertebrates were visually identified within a 2 m belt along each transect at each site (see Appendix – Table 2 and 3 for list of commercially important invertebrates). Invertebrates were counted, identified to the lowest possible taxonomic level and their length in cm recorded.

Coral Recruits

Coral recruits were counted, identified and measured in the first 10 m of each transect within a 0.3 m belt at each site.

Benthic cover

At each site, a wide angle lens camera was used along with a 1 m^2 photo-quadrat to photograph the benthic community at every meter along the transect. A total of 30 photos were taken on each transect. These photos were then analyzed using the Coral Point Count with Excel extension program. In each photograph, 5 points were randomly selected automatically, and then manually categorized as hard coral, turf algae, carbonate, rubble or other.

Analysis

The data collected at each site was first tested for normality, using the Shapiro-Wilk test (http://sdittami.altervista.org/shapirotest/ShapiroTest.html) and then tested for significance using a Mann-Whitney U (http://www.socscistatistics.com/tests/mannwhitney/Default2.aspx) test. All data was non-normal. All data was stored and graphed using Microsoft Excel.

Results

Fish survey

The mean abundance of commercially important fish showed a decrease from 39.2 (± 13.3 SE) fish per $150m^{-2}$ in 2015 and 43.8 (± 22.2 SE) fish per $150m^{-2}$ in 2016 to 11.6 (± 2.1 SE) fish per $150m^{-2}$ in 2019. Statistical analysis showed that the difference between 2015 and 2019 was significant (Mann-Whitney, $p = 0.00714$). The difference between 2016 and 2019 was also shown to be significant (Mann-Whitney, $p = 0.01928$). However, the difference between 2015 and 2016 was not significant (Mann-Whitney, $p > 0.05$) (Figure 2). The size distributions for 2015, 2016 and 2019 all show a higher frequency for smaller fish between 15 cm and 30 cm in size. Although the abundance values for 2019 were lower than the previous abundance values, the size distribution of commercially valuable fish was similar throughout 2015, 2016 and 2019. However, the mean fish size from 2019 was 24.0 cm, which increased when compared to both 2016, which was 21.9cm, and 2015, which was 22.5 cm (Figure 3, Figure 4, and Figure 5).

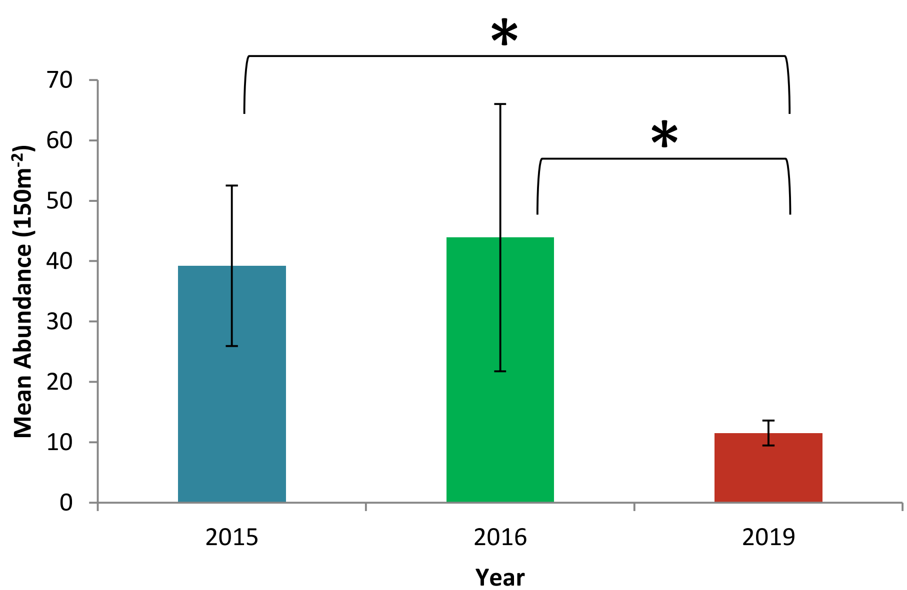

Figure 2. The mean abundance of commercially important fish (mean ± SE) observed within $150m^{-2}$ for 2015, 2016, and 2019. The asterisk indicates a significant difference, n=3.

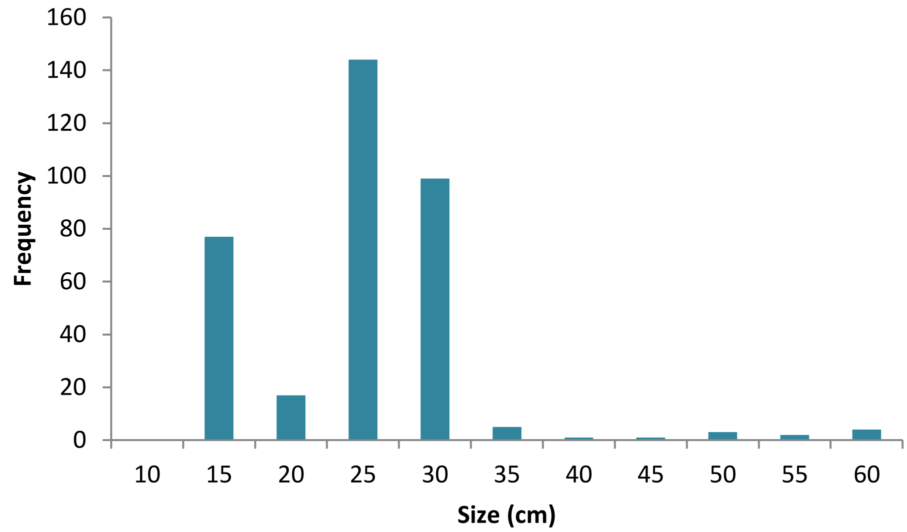

Figure 3. The size distribution of commercially important fish observed within $150m^{-2}$ for 2015, n=3.

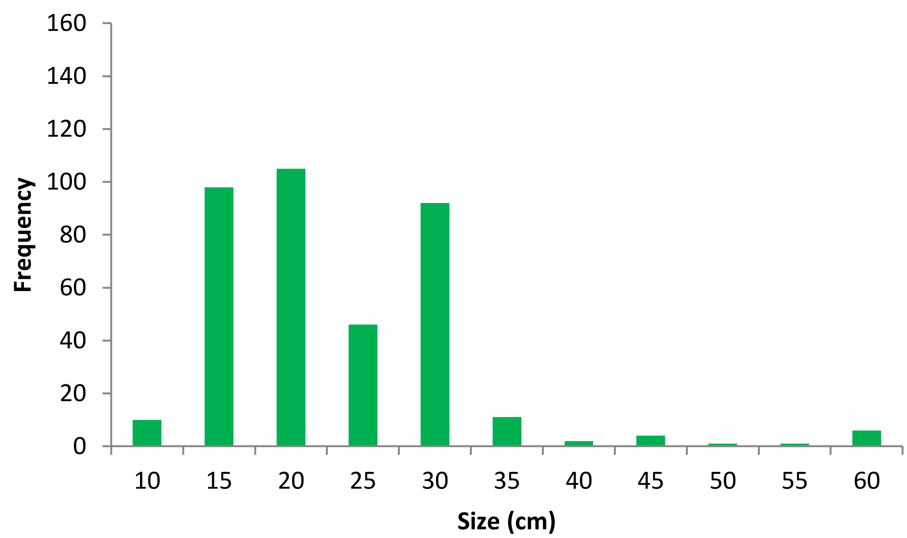

Figure 4. The size distribution of commercially important fish observed within $150m^{-2}$ for 2016, n=3.

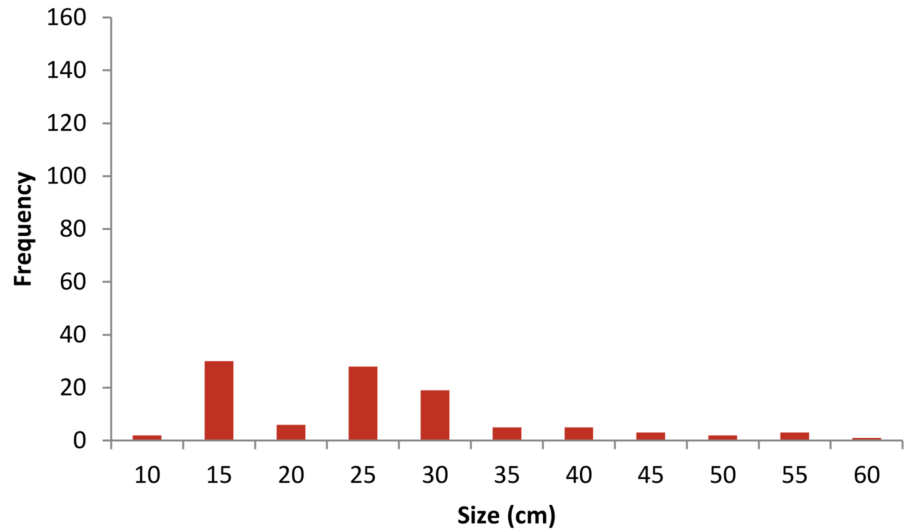

Figure 5. The size distribution of commercially important fish observed within 150m^{-2} for 2019, n=3.

The mean biomass of all fish observed in 2015 was 13.4 kg per 150m^{-2} (± 4.0 SE), which slightly increased to 14.5 kg per 150m^{-2} (± 5.2 SE) in 2016. The mean fish biomass calculated from 2019 decreased to 5.4 kg per 150m^{-2} (± 1.8 SE), however statistical testing showed no significance between years for fish biomass (Mann-Whitney, $p > 0.05$) (Figure 6).

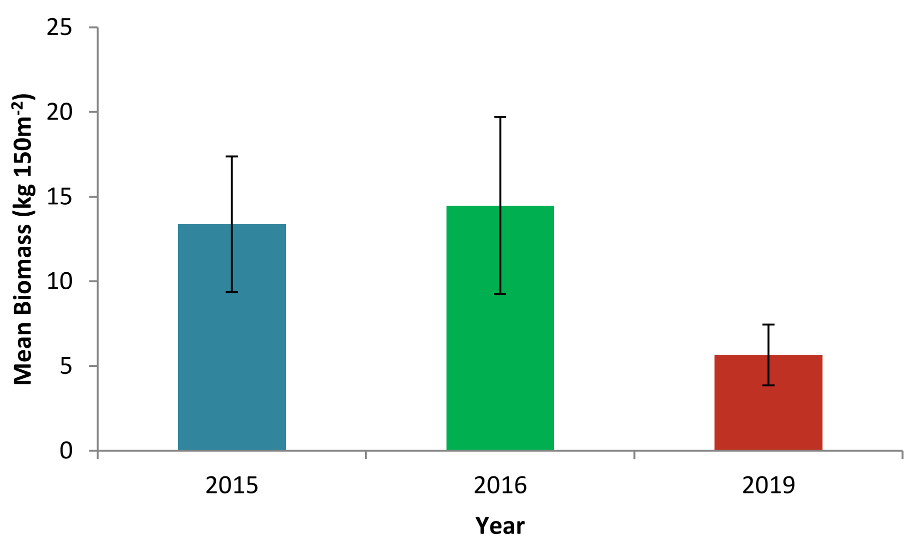

Figure 6. The mean biomass of commercially important fish (mean ± SE) observed within 150m^{-2} for 2015, 2016 and 2019, n=3.

Invertebrate Survey

The mean invertebrate abundance observed showed an increase from 19.2 (± 4.3 SE) invertebrates per 60m^{-2} in 2016 to 29.9 (± 3.3 SE) invertebrates per 60m^{-2} in 2019. However, the mean invertebrate abundance observed in 2019 was similar to the abundance observed in 2015 of 27.1 (± 3.9 SE) invertebrates per 60m^{-2} (Figure 7). Statistical analysis showed no significance difference between the abundance values observed in 2015, 2016 and 2019 (Mann-Whitney, $p > 0.05$).

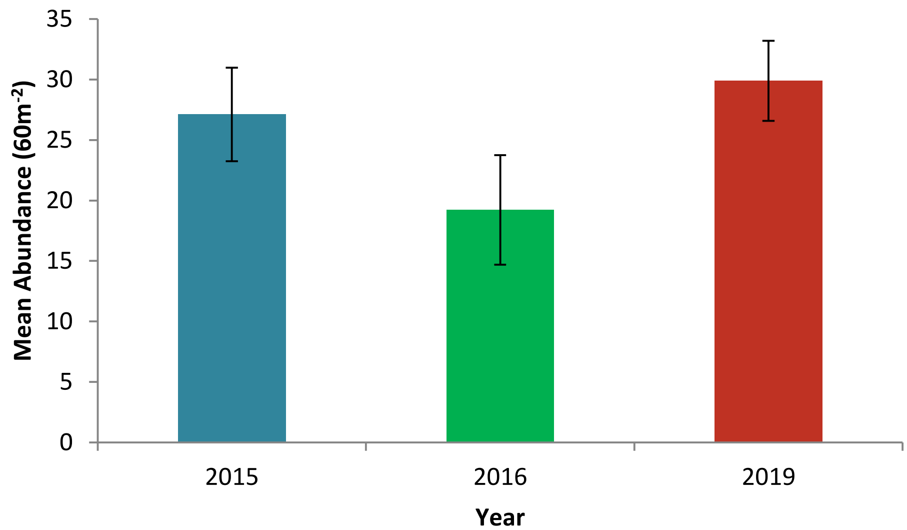

Figure 7. The mean abundance of invertebrates (mean ± SE) observed within 60m^{-2} for 2015, 2016 and 2019, n=3.

Coral recruits

The mean abundance of coral recruits observed decreased from 5.0 (± 1.0 SE) recruits per 3m^{-2} in 2015 and 8.2 (± 1.0 SE) recruits per 3m^{-2} in 2016 to 3.1 (± 0.7 SE) recruits per 3m^{-2} in 2019 (Figure 8). Using a Mann-Whitney test to compare values from 2016 to 2019, this data was shown to be significant ($p = 0.0027$). When using a Mann-Whitney test to compare values from 2015 to values from 2016, this data was also shown to be significant (p = 0.04236). However, when comparing the values from 2015 to 2019, no significance was shown (p > 0.05).

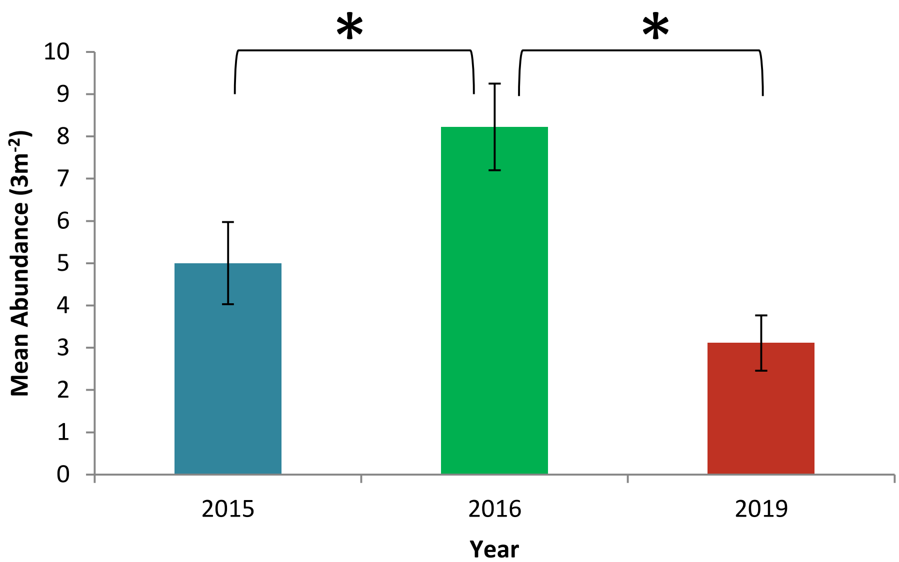

Figure 8. The mean abundance of coral recruits (mean ± SE) observed within $3m^{-2}$, for 2015, 2016 and 2019. The asterisk represents significant difference, n=3.

Benthic cover

The mean percent cover of prominent benthic factors including coral cover, carbonate, rubble and turf algae was measured for 2019 and compared to the previous years. The coral cover in 2015 was 28 ± 4 %, which slightly increased in 2016 to 30 ± 1 %, and in 2019 to 40 ± 1 %. When using a Mann-Whitney test to compare the coral coverage values for 2015 and 2019, this difference was shown to be significant (p = 0.008). The difference between 2016 and 2019 also showed significance (p = 0.005), whereas the difference between 2015 and 2016 was not significant (p > 0.05). The mean percent carbonate cover decreased from 18 ± 4 % in 2015 to 16 ± 2 % in 2016, but increased in 2019 to 31 ± 1 %. The difference between 2015 and carbonate cover in 2016 was not significant (Mann-Whitney, p > 0.05). However, the difference between

2016 and 2019 was shown to be significant (Mann-Whitney, p = 0.005), as well as the difference in carbonate cover between 2015 and 2019 (Mann-Whitney, p = 0.02).

The percent cover of rubble slightly increased in 2016 to 25 ± 3 % from 23 ± 3 % in 2015, but decreased in 2019 to 12 ± 1 %. Although the increase from 2015 to 2016 was not significant (p > 0.05), the difference between 2015 and 2019 (p = 0.008), as well as the difference between 2016 and 2019 (p = 0.01) were both shown to be significant (Mann-Whitney). The percent cover of turf algae was 27 ± 2 % in 2015, which deceased in 2016 to 25 ± 2%, and in 2019 to 4 ± 0.3% (Figure 9). The difference in turf algae cover from 2015 to 2016 was shown to be not significant (p > 0.05), but the difference from 2015 to 2019 (p = 0.0004), as well as the difference between 2016 and 2019 (p = 0.0004) were both significant (Mann-Whitney), (Figure 9). While coral cover, carbonate, rubble, and turf algae make up the majority of the benthic cover, other components consisting of abiotic and biotic factors also make up a small percentage. This remaining percentage of benthic cover is primarily made up of unidentified invertebrates, mud, macroalgae, sand and seagrass (Figure 9).

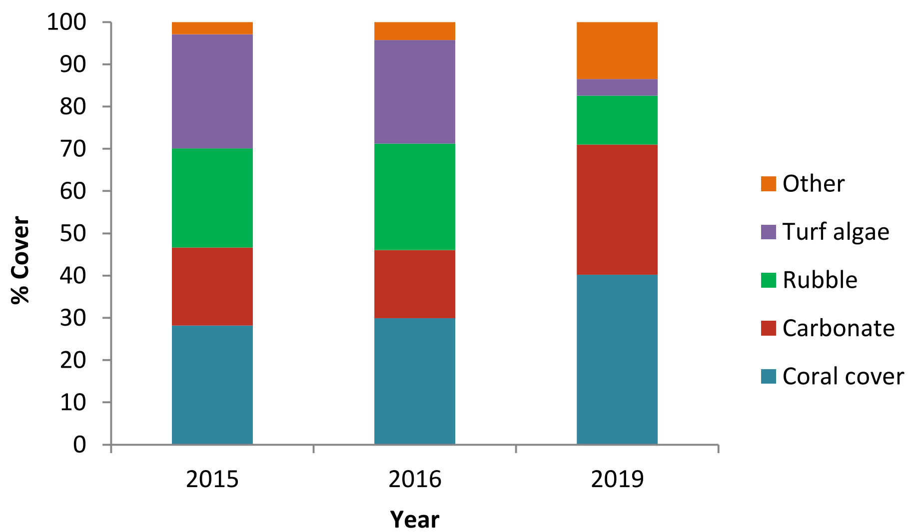

Figure 9. The percent cover of hard corals, carbonate, turf algae, rubble, and other components observed within 30m^{-2} for 2015, 2016, and 2019, n=3.

Discussion

In order to determine the effectiveness of the Ngerkebesang MPA, it is important to monitor this site over time. Commercially valuable fish abundance, size, and biomass, as well as invertebrate abundance were measured so to better estimate the impact of the no fishing regulations on the MPA. Coral recruit abundance and benthic cover percentages were measured in order to better understand the health of the benthic ecosystem.

Fish abundance slightly increased over time between 2015 and 2016, although this change was shown to be not significant after further testing. However, fish abundance decreased significantly between 2016 and 2019 and between 2015 and 2019. Although fish abundance decreased in 2019, the average fish size was larger. This may be a positive result of the MPA. Larger fish will not be removed from the population due to fishing, which may result in a more even size distribution over time. This may also be due to natural variation, or may be a result of factors such as changes in prey or predator abundance. Fish biomass was calculated for each year, and showed a slight increase in 2016, and a decrease in 2019. These differences were shown to be not significant between the years.

Invertebrate density appears to have slightly increased in 2019 since 2015 and 2016. However, this difference was shown to be not significant after further statistical testing. The amount of coral recruits observed in 2019 decreased overall since 2015 and 2016, with a significant decrease seen from 2016 to 2019. In order to determine if these differences are an effect of the MPA regulations, rather than natural variation, further monitoring over time is needed.

Benthic cover consists of many components that may each depend on different factors. Coral cover and carbonate cover both increased in 2019 when compared to 2015 and 2016. However, rubble cover and turf algae cover both decreased in 2019 compared to 2015 and 2016. The differences between 2015 and 2016 were not significant after statistical testing. However, the differences between 2019 and 2015, as well as the differences between 2019 and 2016 were shown to have significance after statistical testing.

These slight changes may be due to many different factors. Organisms that move, likely account for some natural variation among fish abundance over time. Increased coral cover and decreased rubble cover could both be a positive effect of the MPA. Benthic cover changed slowly over time and any variation within this section may be natural. Since the Ngerkebesang MPA only consists of 0.12 km^2, some of the abundance results calculated from this area may have been affected by the resource availability of the area outside of this MPA (Claudet, 2008). The enforcement, monitoring, and establishment time all play a role in the effectiveness of this MPA, as well as the variation in organism abundance and coral cover seen over the years (Agardy et al. 2003). While fishing is prohibited in this area, boats and tourists are still allowed access, which may have some effect on the reef health. Overall, while some variation is likely due to natural factors, some variation may also be due to anthropogenic factors.

In order to determine the sources of variation, it is important to continue monitoring the Ngerkebesang MPA over a longer period of time. More data can help to determine a better pattern of abundance, as well as help to determine what sources may be impacting the variance of these measurements. However, the process of identifying sources of variation may be sped up by further monitoring of the surrounding area, increasing the enforcement, or placing permanent transects for future monitoring.

Acknowledgement

The Palau International Coral Reef Center would like to thank the Government of Koror State, Koror State Rangers, and Palau Pacific Resort, for their cooperation and assistance with this project.

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Appendix

Table 1. List of commercially important fish, including the protected fish for seasonal harvests and fish closed for harvest.

<table>
<tr><th>Species</th><th>Palauan name</th><th>Note</th></tr>
<tr><td>Caranx ignobilis</td><td>Erobk</td><td>_</td></tr>
<tr><td>Caranx melampygus</td><td>Oruidel</td><td>_</td></tr>
<tr><td>Cetosacarus bicolor</td><td>Beadel, Ngesngis</td><td>_</td></tr>
<tr><td>Cetoscarus/Scarus spp.</td><td>Melemau</td><td>_</td></tr>
<tr><td>Choerodon anchorago</td><td>Budech</td><td>_</td></tr>
<tr><td>Hipposcarus harid</td><td>Bekism</td><td>_</td></tr>
<tr><td>Hipposcarus longiceps</td><td>Ngiaoch</td><td>_</td></tr>
<tr><td>Kyphosus spp. (vaigiensis)</td><td>Komud, Teboteb</td><td>_</td></tr>
<tr><td>Lethrinus obsoletus</td><td>Udech</td><td>_</td></tr>
<tr><td>Lethrinus olivaceus</td><td>Melangmud</td><td>_</td></tr>
<tr><td>Lethrinus rubrioperculatus</td><td>Rekruk</td><td>_</td></tr>
<tr><td>Lethrinus xanthochilis</td><td>Mechur</td><td>_</td></tr>
<tr><td>Liza vaigiensis</td><td>Uluu</td><td>_</td></tr>
<tr><td>Lutjanus argentimaculatus</td><td>Kedesau'l iengel</td><td>_</td></tr>
<tr><td>Lutjanus bohar</td><td>Kedesau</td><td>_</td></tr>
<tr><td>Lutjanus gibbus</td><td>Keremlal</td><td>_</td></tr>
<tr><td>Naso lituratus</td><td>Cherangel</td><td>_</td></tr>
<tr><td>Naso unicornis</td><td>Chum</td><td>_</td></tr>
<tr><td>Plectorhinchus albovittatus</td><td>Melim ralm, Kosond, Bikl</td><td>_</td></tr>
<tr><td>Plectorhinchus crysotaenia</td><td>Merar</td><td>_</td></tr>
<tr><td>Scarus microrhinos</td><td>Otord</td><td>_</td></tr>
<tr><td>Siganus argenteus</td><td>Beduut</td><td>_</td></tr>
<tr><td>Siganus lineatus</td><td>Kelsebuul</td><td>_</td></tr>
<tr><td>Siganus puellus</td><td>Reked</td><td>_</td></tr>
<tr><td>Siganus punctatus</td><td>Bebael</td><td>_</td></tr>
<tr><td>Valamugil seheli</td><td>Kelat</td><td>_</td></tr>
<tr><td>Bolbometopon muricatum</td><td>Kamedukl</td><td rowspan="8">Protected Fish (seasonal harvest and species closed for harvest)</td></tr>
<tr><td>Cheilinus undulatus</td><td>Maml</td></tr>
<tr><td>Epinephelus fuscoguttatus</td><td>Meteungerel'temekai</td></tr>
<tr><td>Epinephelus polyphekadion</td><td>Ksau'temekai</td></tr>
<tr><td>Plectropomus areolatus</td><td>Tiau</td></tr>
<tr><td>Plectropomus laevis</td><td>Tiau, Katuu'tiau, Mokas</td></tr>
<tr><td>Plectropomus leopardus</td><td>Tiau</td></tr>
<tr><td>Siganus fuscescens</td><td>Meyas</td></tr>
</table>

Table 2. List of commercially important bivalves (invertebrates).

Species	Palauan name
Hippopus hippopus	Duadeb
Tridacna crocea	Oruer
Tridacna derasa	Kism
Tridacna gigas	Otkang
Tridacna maxima	Melibes
Tridacna squamosa	Ribkungel

Table 3. List of commercially important sea cucumber, sea urchin, and trochus.

Species	Palauan name
Actinopyga echinites	Eremrum
Actinopyga lecanora	Ngelau
Actinopyga mauritiana	Badelchelid
Actinopyga miliaris	Eremrum, cheremrum edelekelk
Actinopyga palauensis	Eremrum
Actinopyga sp.	Eremrum
Bohadschia argus	Mermarech, esobel
Bohadschia similis	Mermarech
Bohadschia vitiensis	Mermarech
Holothuria impatiens	Sekesaker
Holothuria atra	Cheuas
Holothuria coluber	Cheuas
Holothuria edulis	Cheuas
Holothuria fuscogilva	Bakelungal-cherou
Holothuria fuscopunctata	Delal a molech
Holothuria lessoni	Delal a molech
Holothuria leucospilota	Cheuas
Holothuria nobilis	Bakelungal-chedelkelek
Holothuria scabra	Molech
Holothuris falvomaculata	Cheuas
Pearsonothuria graeffei	Meremarech
Stichopus chloronotus	Cheuas
Stichopus hermanni	Delal a ngimes, ngimes ra tmolech
Stichopus horrens	Irimd
Stichopus vastus	Ngimes
Thelenota ananas	Temetamel
Thelenota anax	Belaol

Tripneustes gratilla	Ibuchel
Trochus maculatus	Semum

Table 4. Coordinates of study sites at Ngerkebesang MPA.

Site	Latitude	Longitude
0	7.353747	134.4433
1	7.352498	134.4431
2	7.352191	134.4428