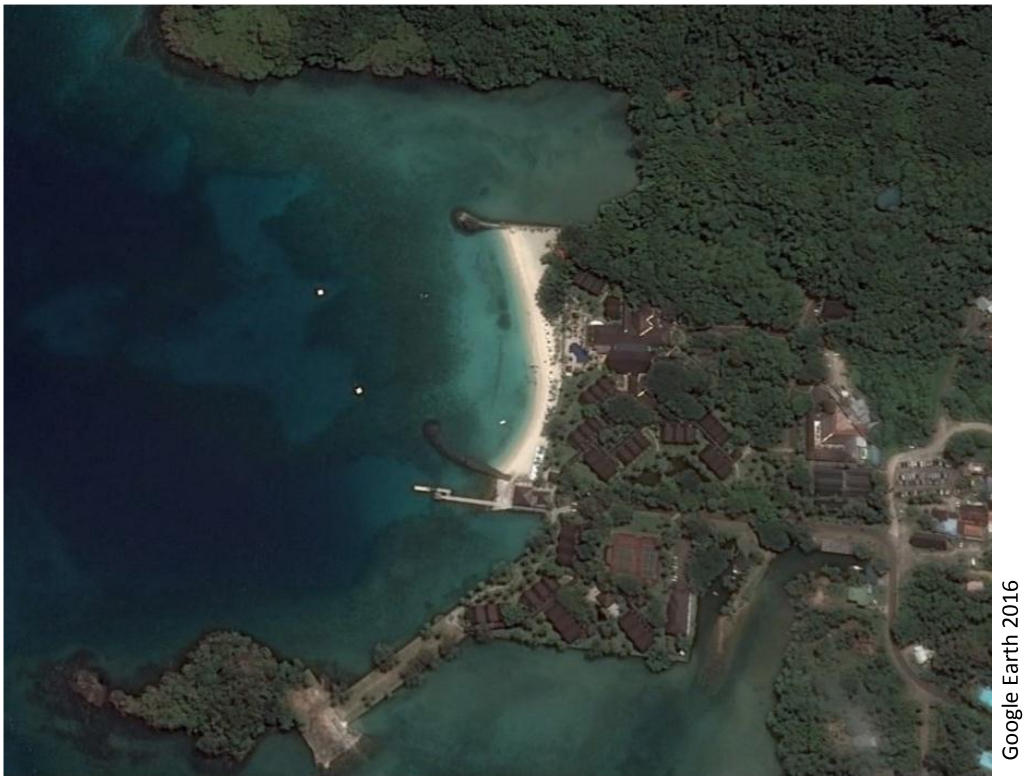
# Assessment for Ngerkebesang Marine Protected Area

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## Abstract

Many countries use marine protected areas (MPAs) as a tool in conserving and preserving their marine resources. This study presents the result of a one year monitoring project on Ngerkebesang MPA in Koror, Palau. In an effort to determine the effectiveness of this MPA, four biological indicators (fish, invertebrates, coral recruits and benthic cover) were measured over time. In March 2016, density and biomass of commercially important fish increased to 21 ± 6 fish 150m$^{-2}$ and 9.8 ± 3 kg 150m$^{-2}$, respectively. Density of commercially important invertebrates, mainly of *Tridacna crocea*, decreased in March 2016, with a mean density of 19 ± 8 invertebrates 60m$^{-2}$. Coral recruits increased to 8 ± 1 recruits 3m$^{-2}$ in March 2016. Finally, coral cover slightly increased to 30 ± 1 % in 2016. Despite the positive effects, except for invertebrate density, observed in Ngerkebesang MPA, there are many factors that can influence the effectiveness of an MPA. Although Ngerkebesang MPA has been a legislated MPA for 14 years, there was no baseline study for this MPA until March 2015. As a result, longer period of monitoring is necessary to determine if such MPA is effective in conserving marine resource.

## Introduction

Several states in the Republic of Palau have established marine protected areas (MPAs), including Palau's oldest marine reserve Ngerukeuid, which is located in Palau's Rock Islands Southern Lagoon (a UNESCO World Heritage). Although with good intention of conserving marine resources for the country, it is difficult to determine if MPAs are indeed effective in conserving natural resources. Some studies have shown positive effects of an MPA. This includes the increase of coral recruits (Mumby et. al 2007), fish biomass (Abemis et al. 2006), and fish abundance (Hamilton et al. 2011), and species biodiversity (Francis et al. 2002). In addition, spillover effect has been observed near MPAs (McGlanahan and Mangi 2000, Harrison et al. 2012).

The present study is an effort to show the effectiveness of an MPA as a conservation tool. The conservation area studied was Ngerkebesang MPA (0.12 $km^2$), which is located in Koror State. This MPA is on a reef adjacent to Palau Pacific Resort, and it has been receiving much attention by the tourists that live in the resort. In 2002, Ngerkebesang MPA was legislated as an MPA by the 7$^{th}$ Koror State Legislature to help increase tourism in Koror (Seventh Koror State Legislature, 2002). Recognized in its legislation, this MPA was a *bul,* which is a traditional practice of regulating the fishing activities and fishing grounds by traditional leaders. Within the borders of the MPA there was to be no fishing activities, and open to regulated recreational activities only (Seventh Koror State Legislature, 2002). To determine the effectiveness of this MPA, biological indicators inside Ngerkebesang MPA were compared over time.

## Methods

Ngerkebesang MPA is a shallow reef adjacent to Palau Pacific Resort (PPR) in Koror, Palau (Figure 1). Using QGIS (QGIS Development Team 2015) and the MPA's size, three study sites were randomly selected for this study (Figure 1 and Appendix Table 4). All study sites were located at depths 1-5m. At each site, three belt transects were used to survey four biological indicators: fish, invertebrates, coral recruits and benthic cover. The MPA was surveyed in March 04, 2015 and March 17, 2016. The method used for each biological indicator is described below.

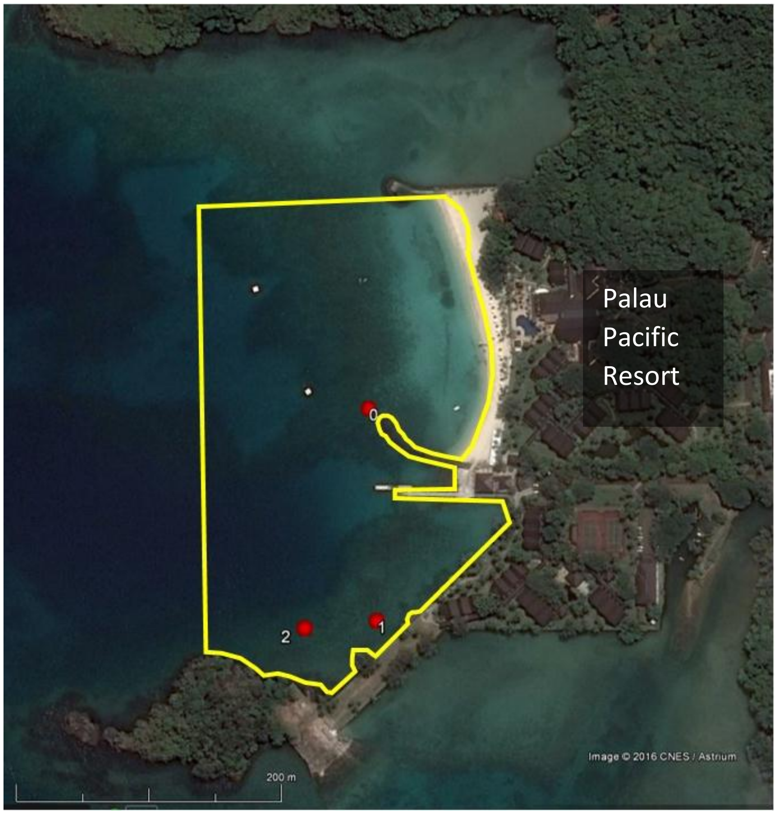


Figure 1. Map of Ngerkebesang MPA and the three sites (Otto et al. 2015) for this study (Google Earth 2016).

*Fish survey*

Fish observations were conducted within three 5m x 30m belt transects per site. Visual observation of commercially important fish (Appendix Table 1) was conducted in each belt transect (150 $m^2$). For each fish observed, its taxonomic classification (identified to the lowest taxonomic level) as well as its size were determined and then recorded. Fish biomass was determined for each fish using the length-weight relationship described below.

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

Where L = length in centimeter, and the two variables (a and b) are constant values from Kulbicki et al. (2005) and the website Fishbase (www.fishbase.org).

*Invertebrate survey*

Survey for invertebrates were done in three 2m x 30m belt transects at each study site. Targeted species for this study were commercially important invertebrates (Appendix Tables 2 and 3). Each invertebrate (identified to the lowest taxonomic level) within each belt transect (60 $m^2$) was recorded.

*Coral recruits*

Coral recruits were surveyed in three 0.3m x 10m belt transects for each site. Coral recruits within each belt transect (3 $m^2$) were identified to the lowest taxonomic level possible.

*Benthic cover*

Underwater images were taken in three 1m x 30m belt transect. The images were taken with a wide angle lens camera and a 1-$m^2$ photoquadrat. In the lab, each image was analyzed using Coral Point Count with excel extension (CPCe, Kohler and Gill 2006). Five random points were used to analyze each photo. Categories for this analysis were hard corals (identified to the lowest taxonomic level possible), macroalgae, soft coral, carbonate, sand, rubble, and turf algae.

*Analyses*

All statistical analyses were done using R program (R Core Team 2013) and Microsoft Excel. All data were tested for normality using Shapiro-Wilk test. If data was not normal, they were transformed using log (x+1) to obtain normality. Analysis of variance was used to compare observations on each biological indicator over time. If the data was not normal after transformation, a non-parametric test, Kruskal-Wallis, was used instead.

## Results

*Fish survey*

Density of commercially important fish increased from 9 ± 1 fish $150m^{-2}$ in 2015 to 21 ± 6 fish $150m^{-2}$ in 2016 (Figure 2). Statistical analysis showed no significant difference between fish density of 2015 and 2016 (ANOVA, $p > 0.05$).

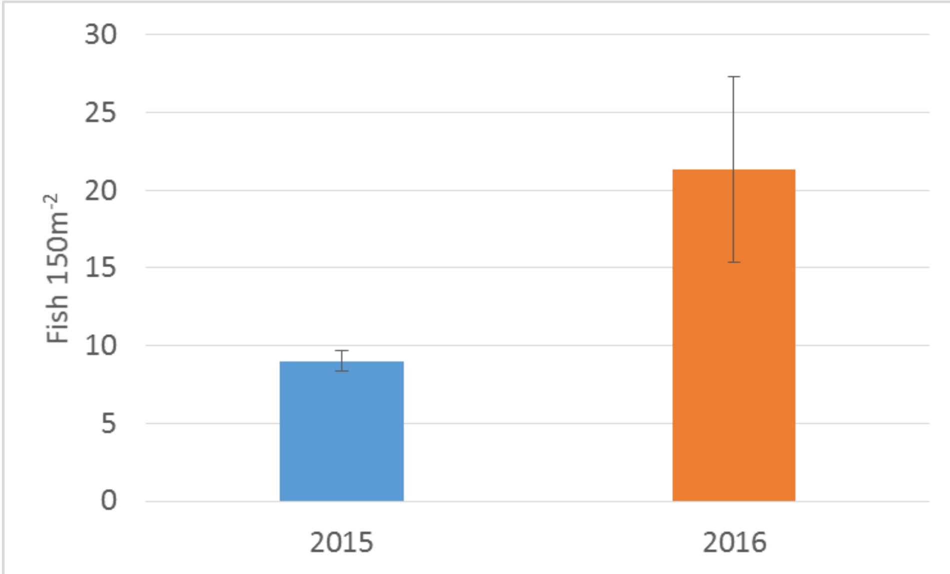


Figure 2. Average of all fish (mean ± SE) observed in 150 $m^2$ for 2015 compared to 2016, n=3.

Figure 3 shows size distribution of all commercially important fish observed in both years. The histogram shows high frequency of small bodied fish and low frequency of bigger size fish (Figure 3). The Biomass of commercial fish increased from 5.8 ± 1 kg $150m^{-2}$ in 2015 to 9.8 ± 3 kg $150m^{-2}$ in 2016 (Figure 4). However, the difference in biomass was not significantly different between the two studied years (ANOVA, $p > 0.05$).

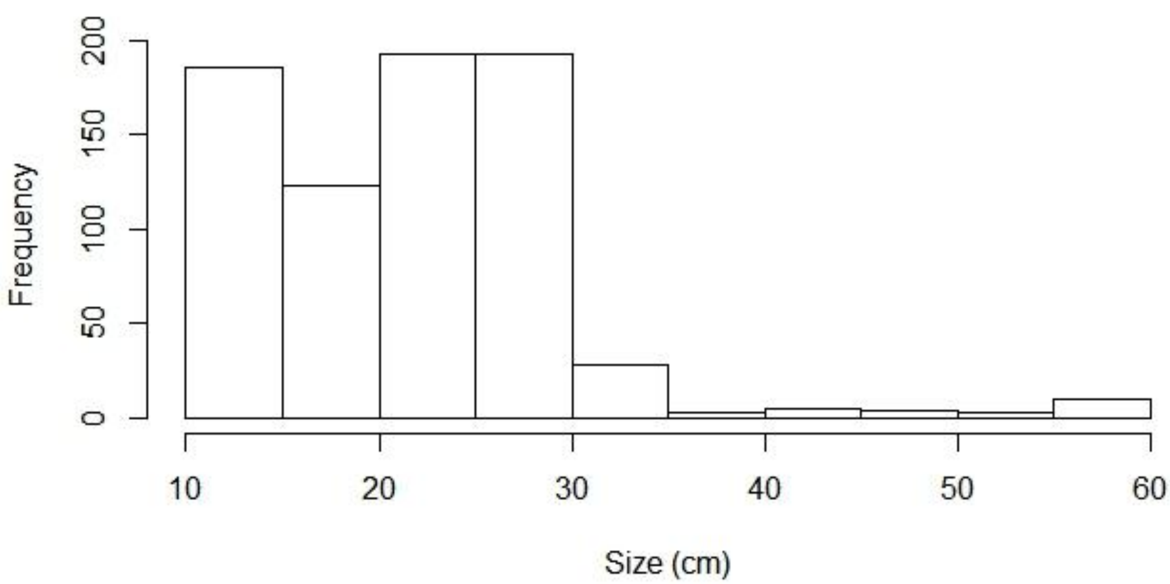


Figure 3. Size distribution of all commercially important fish observed in 2015 and 2016.

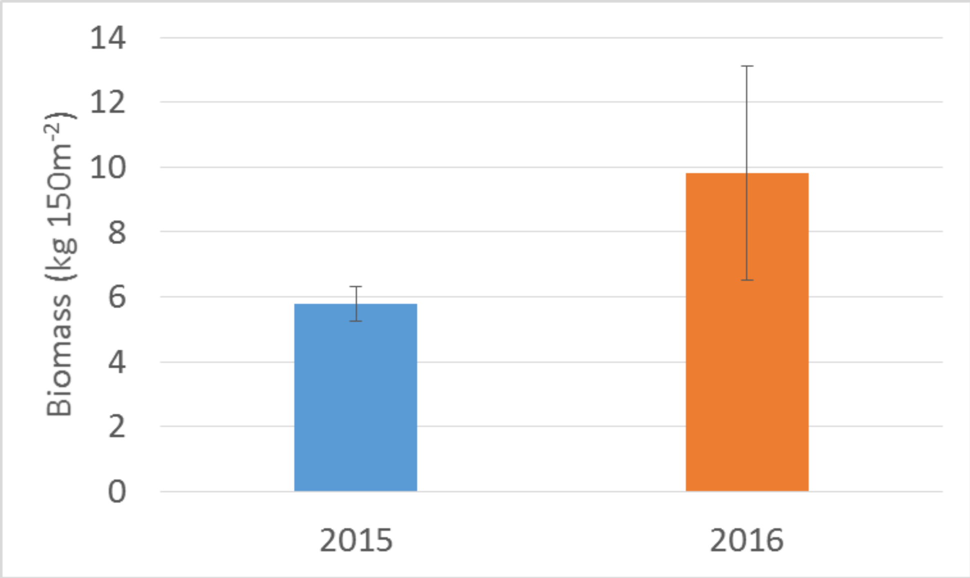


Figure 4. Fish biomass (mean ± SE) of commercially important fish observed in 150m$^2$ for 2015-2016, n=3.

*Invertebrate survey*

For all invertebrates observed, mean density of invertebrates observed in 2015 (27 ± 3 invertebrates 60m$^{-2}$) was similar to that observed in 2016 (19 ± 7 invertebrates 60m$^{-2}$, Figure 5). Statistical analysis showed no significant difference of invertebrate density over time (ANOVA, $p > 0.05$). *Tridacna crocea* was the most abundant invertebrate both in 2015 (26 ± 2 invertebrates 60m$^{-2}$) and in 2016 (16 ± 5 invertebrates 60m$^{-2}$, Figure 6). However, comparison of *T. crocea* showed no significant difference between 2015 and 2016 (ANOVA, $p > 0.05$).

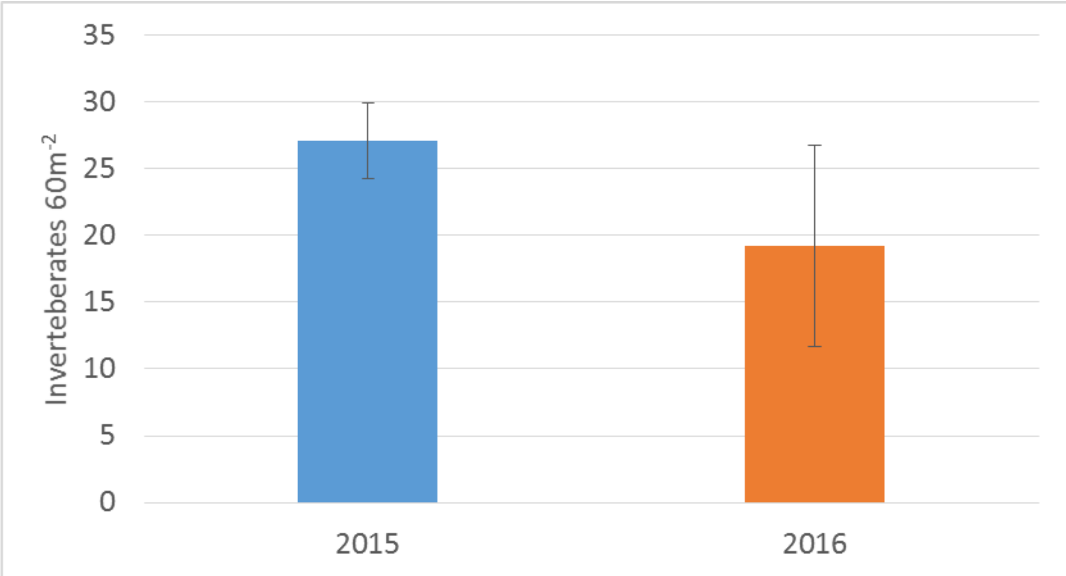


Figure 5. Abundance of all invertebrates (mean ± SE) observed in 60m$^2$ in 2015 and 2016, n=3.

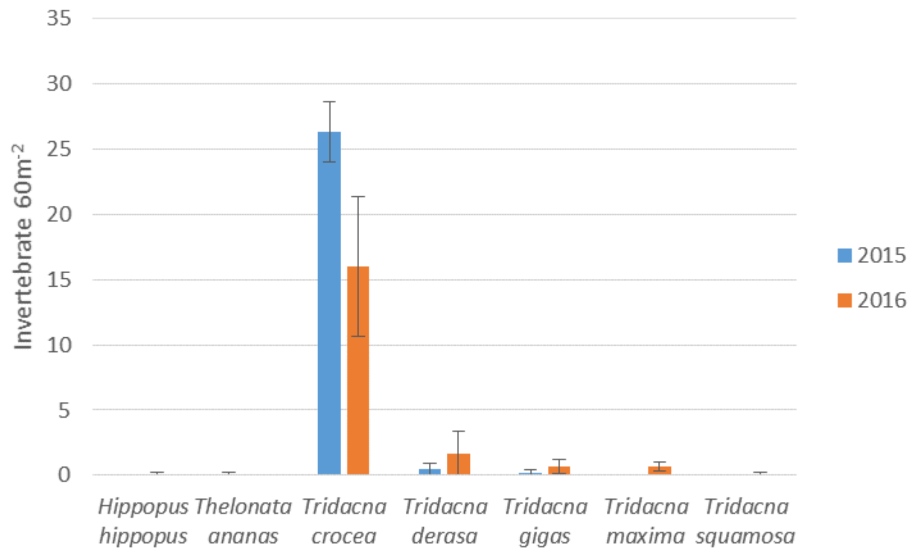


Figure 6. Abundance of each invertebrate (mean ± SE) observed in $60m^2$ in 2015 and 2016, n=3.

*Coral recruits*

Coral recruits observed in 2015 (5 ± 2 recruits $3m^{-2}$) was lower than that observed in 2016 (8 ± 1 recruits $3m^{-2}$, Figure 7). Statistical analysis showed significant difference of recruits over time (ANOVA, $p = 0.04492$). Recruitment of corals from the genus *Porites* (*P. cylindrica*, *P. rus*, and *Porites* sp.) were most dominant, and they each had an increase in density from approximately 1 recruit $3m^{-2}$ in 2015 to approximately 2-3 recruits $3m^{-2}$ in 2016 (Figure 8). Statistical test, showed no significant difference for each species and genus of recruit over time (Kruskal-Walis, $p > 0.05$).

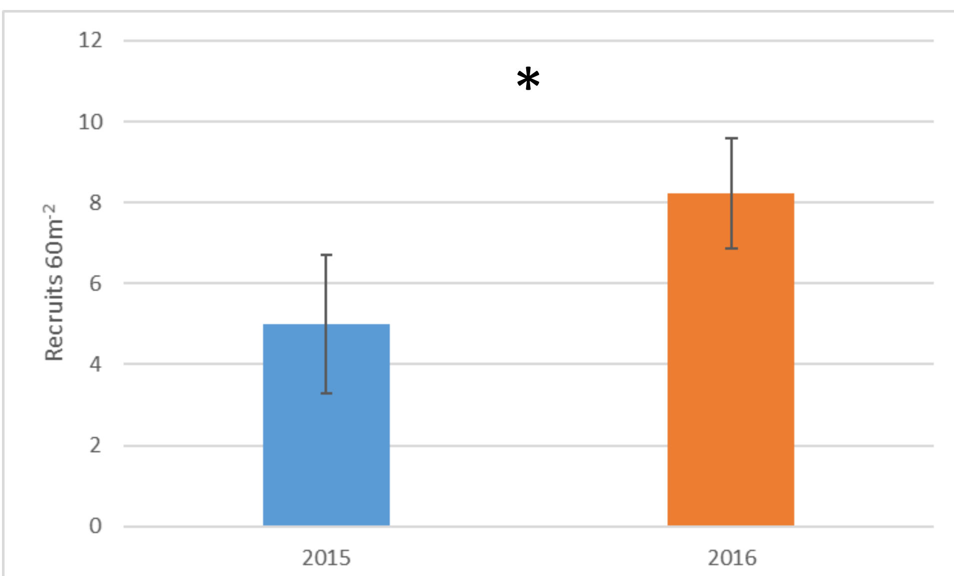


Figure 7. Abundance of all coral recruits (mean ± SE) observed in $3m^2$ in 2015 and 2016. Asterisk shows significant difference, n=3.

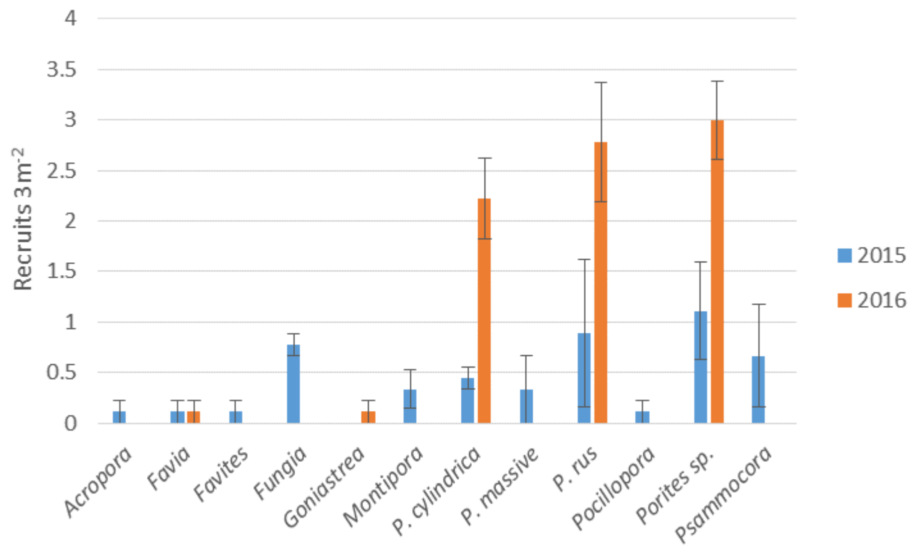


Figure 8. Abundance of coral recruits (mean ± SE) in 3m$^2$ observed in 2015 and 2016, n=3.

*Benthic cover*

The benthic cover was similar over time with hard corals, carbonate, rubble, and turf algae having the most percent cover. Percent cover of hard corals slightly increased from 2015 (28 ± 4 %) to 2016 (30 ± 1 %, Figure 9). However, the difference of coral cover between the two studied years was not significant (ANOVA, $p > 0.05$).

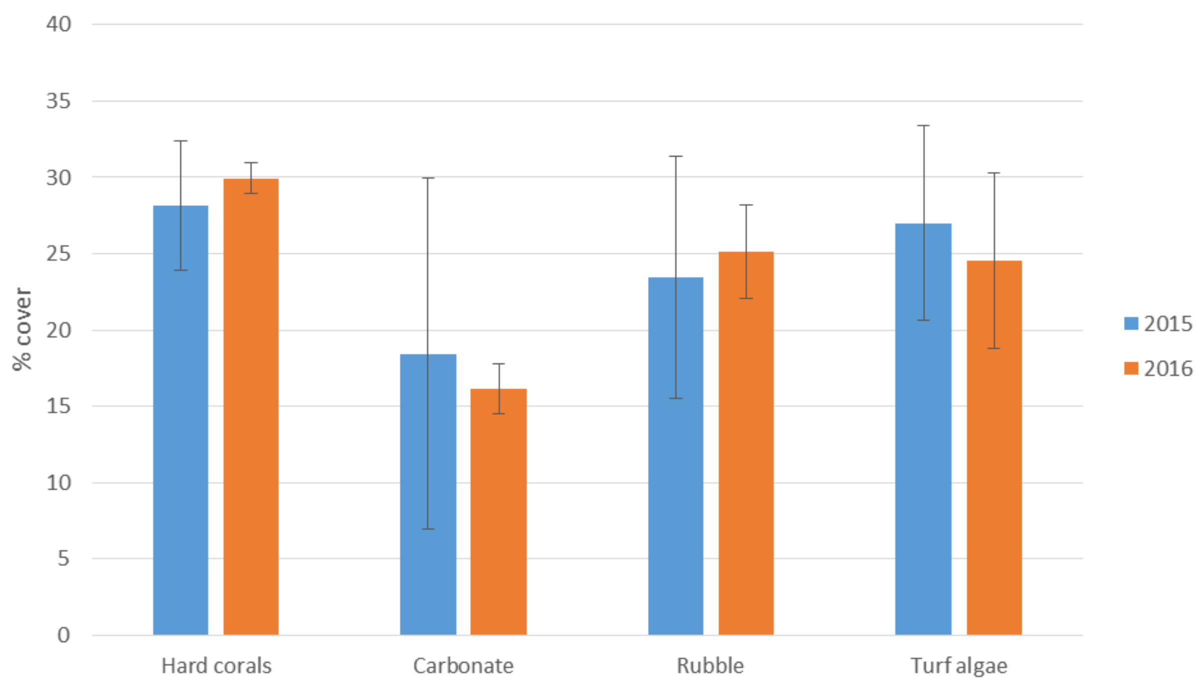


Figure 9. Percent cover (mean ± SE) of hard corals, carbonate, rubble and turf algae observed in 2015 and 2016, n=3.

## Discussion

Overall, Ngerkebesang MPA is supportive to the notion that MPAs are effective conservation tools. At first glance, our surveys showed that both fish density and fish biomass of commercially important fish increased in one year. But our statistical analyses shows that the difference between the two studied years was not significant. It is possible that commercially important fish inside the MPA are increasing in number and size, but with high variation in the data it is difficult to answer such questions. A longer period of monitoring is needed to be definite if fish in the MPA are increasing in size and abundance, or it is natural variability that we are observing in the current data. Density of coral recruits increased by 37% in one year. This may be a positive response to the recent typhoons, Bopha and Haiyan. Finally, benthic surveys showed a slight increase in coral cover over time. Unless a typhoon, massive coral bleaching, or such natural catastrophe, was to take place, benthic cover slowly changes over time. The slight difference of coral cover may show natural variability.

However, there are many factors that can influence an MPA into not achieving its goal as a conservation tool (Agardy et al. 2003). Some of these factors were observed in this study. Further analysis of the invertebrate survey showed that total count of *Tridacna crocea* (oruer) decreased in one year. Note that this study did not use permanent transects to survey invertebrates, so density of invertebrates may vary among transects. Our statistical test did not show significant difference between the studied years, so this may be natural variation. Therefore, replication over time will show in the future if there is any protection effect on clam density.

Another factor to consider is the size of the MPA. With an area of 0.12 $km^2$, Ngerkebesang MPA is one of the smallest MPAs in Palau. Most reef fish, depending on the species, travel far along coral reefs. So it is possible that observations for fish, and other organisms that travel far may show large variation over time. Moreover, with such a small area, Ngerkebesang MPA may be affected by availability of resources (such as fish and coral recruits) from the larger, adjacent reefs, or reefs connected through hydrodynamic processes (Golbuu et al. 2012). Finally, length of establishment, monitoring, and enforcement level are also important in determining MPA effectiveness (Agardy et al. 2003). Although Ngerkebesang MPA has been legislated as an MPA for 14 years, there was no baseline study during its establishment until March 2015. So it would require a longer monitoring period to determine the variation of each biological indicator, and help us answer the question on whether or not this MPA is effective in conserving marine resources.

## Acknowledgment

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*Source*: "Koror." 7 21'11.66" N 134 26'34.02"E. **Google Earth**. July 31, 2014. May 24, 2016.

## Appendix

Table1. List of commercially important fish, including the protected fish for seasonal harvests and fish closed for harvest.

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

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 |