A Biological Survey of Ngemai Marine Protected Area

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1. INTRODUCTION

Marine protected areas have become an important management tool for many coastal communities, especially in Palau and Micronesia. The primary goal of coral reef monitoring is to assess changes in resources over time. Information extracted from monitoring data is intended to guide managers of MPA sites in achieving specific objectives. As the National Government is planning to link all state-designated MPAs into a single connected network of MPAs, known as the Protected Areas Network (PAN), it is critical to ensure that MPAs successfully achieve their management objectives. Additionally, because of PAN, there is an urgent need to provide information on the different protected areas that may be included in the network, along with what criteria may be important to follow.

MPA management is a process that involves planning, design, implementation, monitoring, evaluation, communication and adaptation (Agardy et. al., 2003). Evaluation is an important part of management because it allows for the review of actions taken and assessing whether those actions were effective in producing desired outcomes. This would allow for managers to adapt their strategies and improve their management. As mentioned above, without evaluation and assessment, MPA managers may commit resources to strategies that are not effective.

MPAs have been promoted widely as an effective resource management tool. Increase in fish biomass (Abemis et. al., 2006), abundance (Hamilton et. al., 2011), mean size (Friedlander and Martini, 2002), catch-per-unit-effort (Roberts, et. al., 2001), and species biodiversity (Francis et. al., 2002) are all benefits of MPAs. Furthermore, the benefits of MPAs extend to adjacent areas that are not protected (McClanahan and Mangy, 2000; Roberts et. al., 2001; and Agardy et. al., 2003). For example, a recent study from the Great Barrier Reef, Australia, demonstrated that marine reserves covering 28% of a reef can supply approximately 50% of total fish recruits up to 30-km from the center of the reserve (Harrison et. al., 2012).

Benthic communities also benefit from MPAs. Corals play an important ecological role in coral reef ecosystems. Corals, in association with zooxanthellae, are the primary producers in a coral reef ecosystem. With their hard calcareous skeleton, corals also provide habitat for fish, invertebrates, and other marine plants. When large-scale disturbances (typhoons, El Nino, predator outbreak, etc.) lead to the loss of coral cover, coral reef ecosystems can shift to macro-algal dominated ecosystems (Mumby et. al., 2006). Mumby et. al. (2006 and 2007) demonstrated that MPAs increase coral recruits; and, as a result, increase coral cover.

The objective of this survey conducted by PICRC was to determine the benthic cover, as well as density and biodiversity of important marine resources in Ngemai Conservation Area. By measuring these biological indicators overtime, the progress and effectiveness of Ngemai MPA can be determined.

2. MATERIALS AND METHODS

Study Site

Ngemai Marine Protected Area (MPA) is a conservation area located on the east coast of Palau’s largest island of Babeldaob. It has an area of approximately 1.0 km^2, and is composed of a reef that sits in front of an estuary with channels on both sides. Recent changes around Ngemai include a new dock that has been constructed on the opposite side of one of the channels. In 1997, it was established as a marine protected area and closed to all forms of fishing for 5 years. In 2001 it was re-opened for harvesting until

2008 and in 2009 it was formally legislated as a MPA, but part of a larger protected area that included an upland forest and river. In 2010, Ngemai was officially registered as a Protected Areas Network (PAN) site, and became the second site in Palau to become nominated to the PAN.

Figure 1. Image of Ngemai MPA located in Ngiwal State, red line signifies the MPA boundary, the blue dots indicate stations within the MPA and yellow dots indicate stations in the reference site.

Monitoring protocol

Monitoring in Ngemai conservation area took place on October 15, 2010 to April 10, 2012, however the data presented in this report is only from 2011-2012 due to inconsistencies in data collection. A total of 4 sampling periods were done at both the MPA and the reference site. At each site are 3 stations, which were randomly selected and marked by GPS. Each station has replicates of 5 x 50-m transects. The following surveys were done on each replicate transect. Fish size and abundance were counted on a 5 x 50 m belt transect (each transect area=250m^2). The fish recorded are priced fish for fish markets and local consumption. There were four people doing the fish surveys over the monitoring period. At each transect, the person doing the fish survey swam at approximately 1 m sec^{-1}. Fish biomass was calculated using the length-weight relationship where TL is the total length in cm, and *a* and *b* are constants obtained from Fishbase. Invertebrate (sea cucumbers and bivalves) size and abundance were counted on 2 x 50 m belt transects (each transect area=100m^2). For benthic cover surveys, pictures of the benthos were taken with a digital camera every meter along each transect (total of 50 pictures per transect). The camera was mounted on a 1 m customized camera stand that is attached to 1 m^2 quadrat. Pictures of benthic cover were analyzed using CPCe at Palau International Coral Reef Center. Coral recruit surveys were conducted on the first 10 m of each replicate transect. Coral recruit species and size were recorded on 0.3 x 10m belt transects.

Data for fish density, fish biomass, and invertebrate density were analyzed using 3-way permutational ANOVAs, with status (2 levels) and time (2 levels) as fixed factors, and station (3 levels) as a random factor nested in status. Fish community biomass was analyzed using a 3-way permutational MANOVA, with status and time as fixed factors, and station as a random factor nested in status. Density of coral recruits was analyzed using a 2-way permutational ANOVA, with status as a fixed factor, and station as a random factor nested in status. Benthic community cover was analyzed using a 2-way permutational

MANOVA, with status as a fixed factor, and station as a random factor nested in status. Prior to all analyses, homogeneity was checked with permDISP, and where appropriate the data were transformed.

3. RESULTS

Fish Assemblages

In 2011, fish density in Ngemai MPA had a mean value of 18.7(± 7.5 SE) fish per station, while the reference site had a mean value of 25 (± 6SE) fish per station (Fig. 2). Fish density in Ngemai MPA in 2012 was 19.5 (± 8SE) fish per station, while its reference site had an average density of 9.7 (± 6) fish per station. Although there was a trend of a higher number of individuals in the MPA in 2012, it was not significant ($p > 0.05$) in comparison to the reference site.

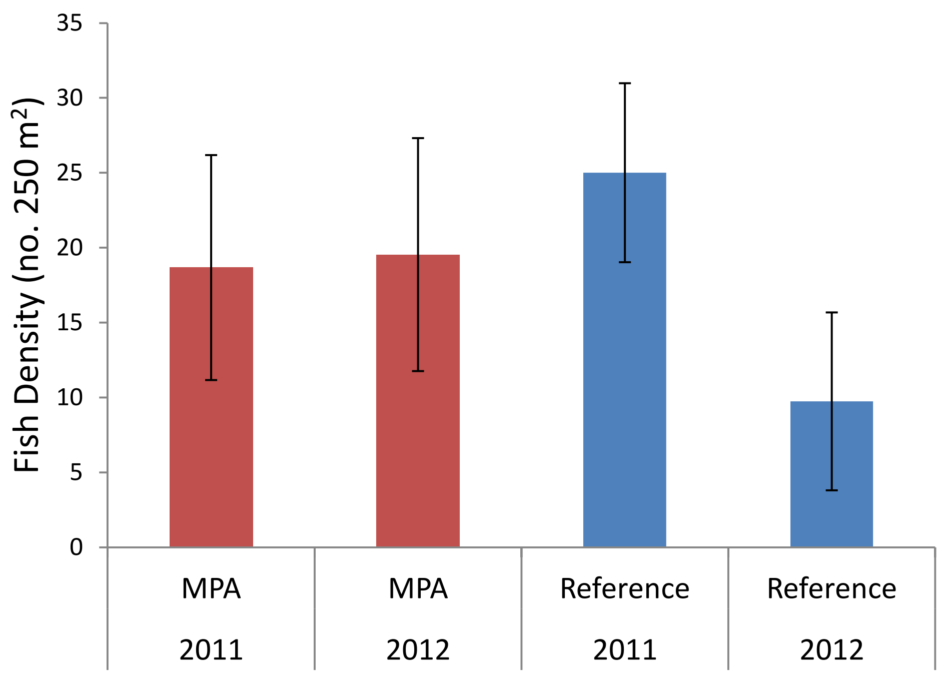

Figure2.Fish Density in Ngemai MPA and reference site in 2011-2012.Error bars indicate standard errors.

Similarly, in terms of fish biomass, there was no significant difference ($p > 0.05$) between Ngemai MPA and its reference site (Fig. 3). In 2011, Ngemai MPA had a lower fish biomass compared to its reference site, which were 21,029 and 30,026 g 250m^2, respectively. In 2012, fish biomass in the MPA was higher than the fish biomass in the reference site, which was 27,836 and 5,541 g 250m^2, respectively. While there was an overall trend for higher fish biomass in the MPA in 2012, this trend was not significant when compared to the fish biomass in the reference site.

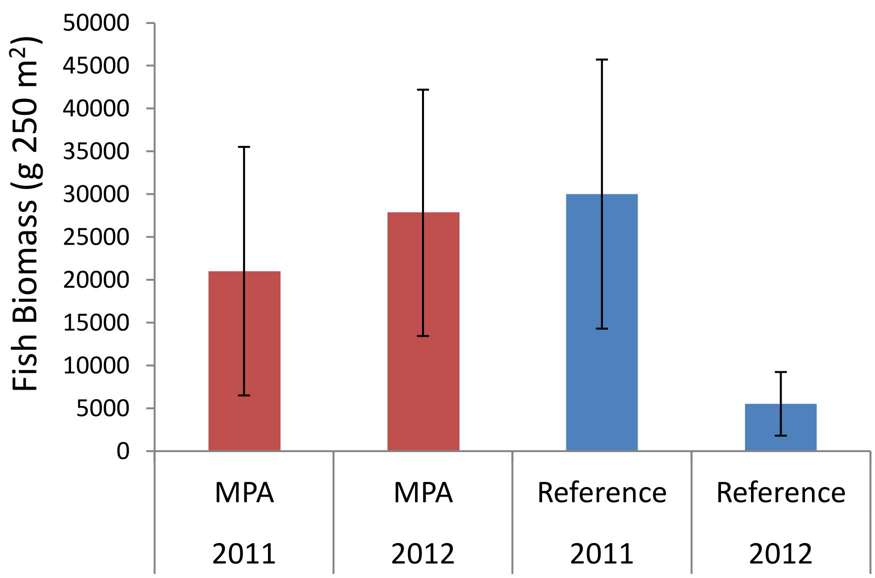

Figure 3. Fish Biomass in Ngemai MPA and reference site in 2011-2012.Error bars indicate standard errors.

Fish biomass by family followed the same pattern as fish density, with no significant difference between Ngemai MPA and the reference site (Fig. 4). Although there were no similarities or trends in biomass of fish families within the MPA and reference site, there were significant differences among stations within the MPA and reference site. Major patterns included high number of Lutjanidae and Scaridae biomass in the MPA and reference site. In 2011, mean biomass for Lutjanidae was 12,040 g 250m^2 and 20,441 g 250m^2, while biomass for Scaridae was 6,594 g 250m^2 and 1,440 g 250m^2 in the MPA and reference site, respectively. Biomass for Lutjanidae in 2012 was 16,652 g 250m^2 and 4,180 g 250m^2, while biomass for Scaridae was 7,973 g 250m^2 and 397 g 250m^2 in the MPA and reference site, respectively.

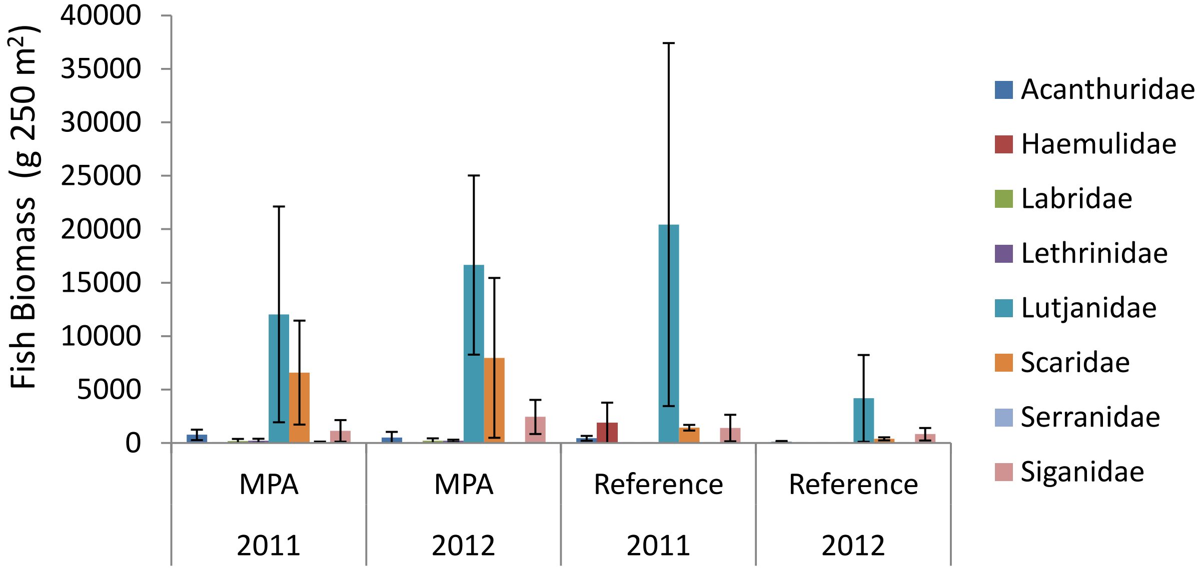

Figure4. Fish biomass in their representative families in Ngemai MPA and reference site in 2011-2012. Error bars indicate standard errors.

Benthic Assemblages

Invertebrate density in Ngemai MPA in 2011 and 2012 was less than 1 invertebrate per 100 m^2. In comparison, the reference site had average densities of 1.3 (± 0.15 SE) and 2.2 (± 0.4 SE) invertebrate per 100 m^2 in 2011 and 2012, respectively (Fig. 5).While there was a trend in higher number of individuals in the reference site, this was not significantly different ($p > 0.05$) in comparison to the number of individuals in the MPA.

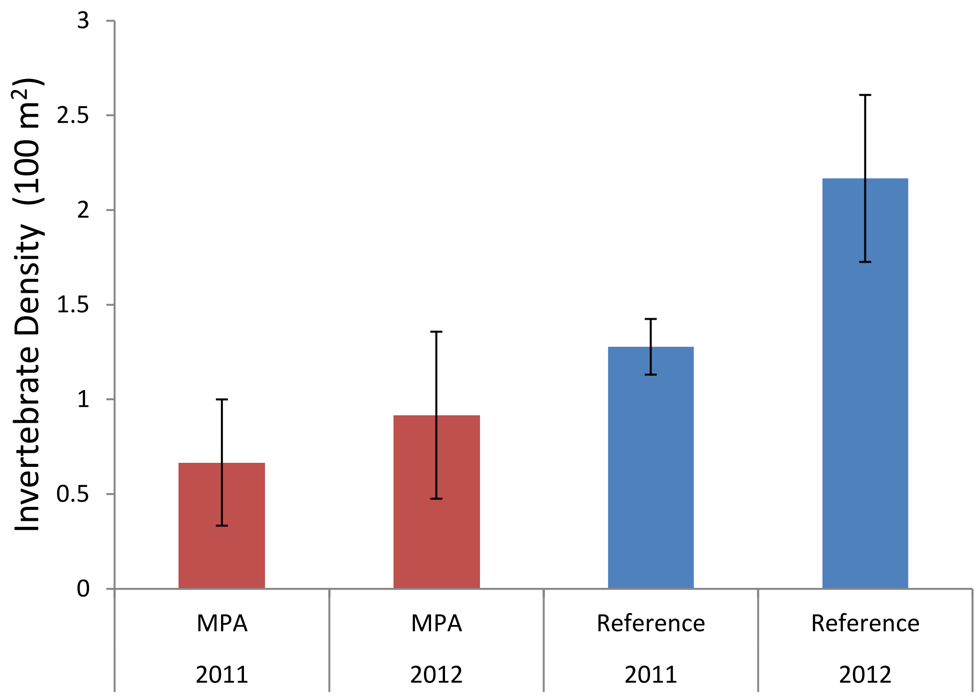

Figure5. Invertebrate density in Ngemai MPA and its reference site in 2011-2012. Error bars indicate standard errors.

In terms of invertebrate diversity, there was a trend in higher diversity of invertebrates in the reference site compared to the MPA (Fig. 6). Even though there were a higher number of individuals in the reference site, this was not significant in comparison to the MPA.

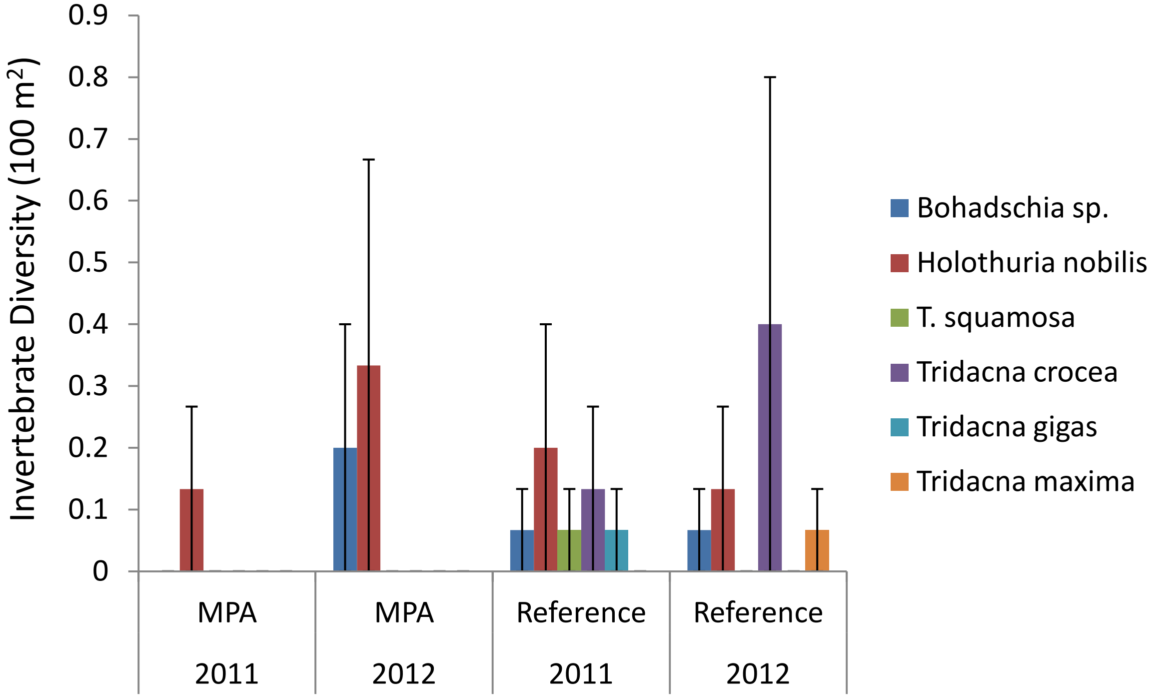

Figure 6.Invertebrate diversity in Ngemai MPA and reference site in 2011 and 2012. Error bars indicate standard errors.

Density of coral recruits in Ngemai MPA was lower than its reference site, but not significantly different (Fig. 6). The average density of coral recruits (i.e. < 5cm maximum diameter) was 4.2 (± 1.6 SE) and 6.7 (± 1.1 SE) individuals per 250 m^2 in the MPA and reference site, respectively. In general, 17% of the coral recruits in the MPA were *Porites,* followed by *Montipora*(13%), Faviidae (10%), and *Echinophyllia* (10%), while 8 other taxa made up the remaining 50% of coral recruits in the MPA. In the reference site, 31% of the coral recruits were *Porites*, followed by *Faviidae* (11%), *Echinophyllia* (9%), and *Acropora* (9%), with 18 other taxa making up the remaining 60% of coral recruits.

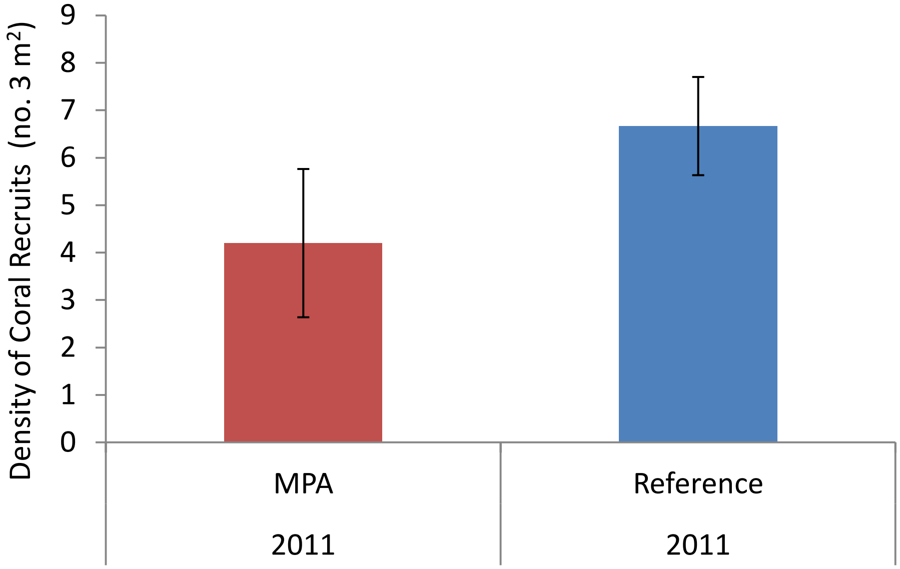

Figure7. Density of Coral Recruits in Ngemai MPA and its reference site. Error bars indicate standard errors.

In terms of benthic community, there was a significant difference between stations within the MPA and reference site, however there was no significant difference between Ngemai MPA and the reference site (Fig. 7). Coral coverage was similar in Ngemai MPA and the reference site, with Ngemai MPA having a mean coral cover of 21.4%, and the reference site having a mean coral cover of 21.3%. Crustose coralline algae (CCA) in the MPA was 0.6%, while the reference site had 36.6%. Carbonate cover in the MPA was 35%, while the reference site had a carbonate cover of 0%. In the MPA, algal cover was 8.2%, and the reference site was 19.9%.

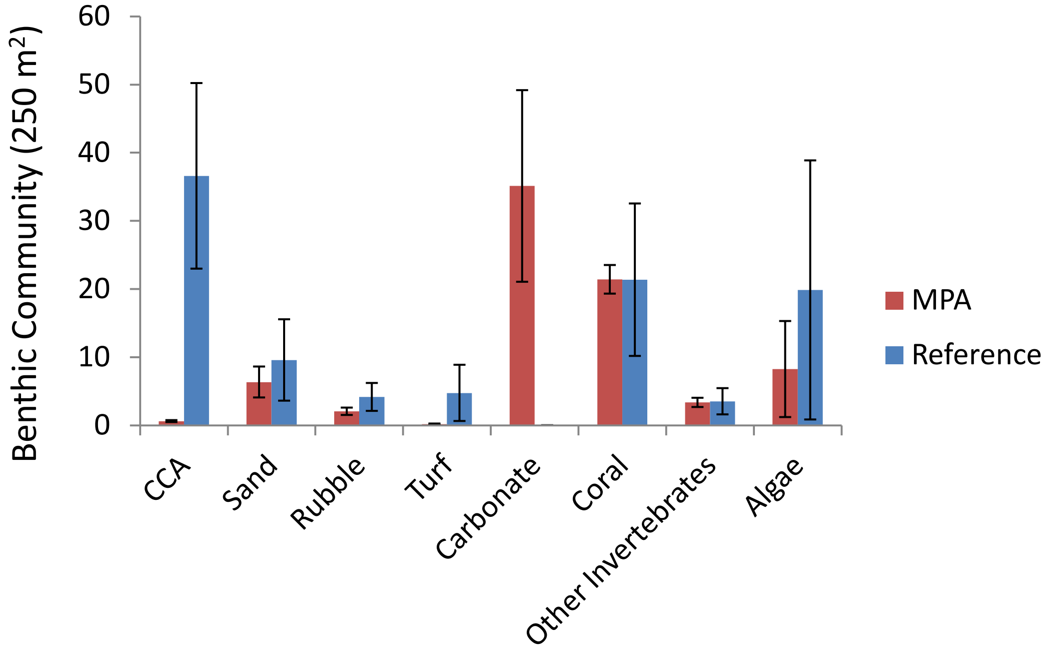

Figure 8. Benthic community cover at Ngemai MPA and its reference site. Error bars indicate standard errors.

4. DISCUSSION

Observations in Ngemai MPA show different patterns with respect to fish and benthic assemblages. Fish density in Ngemai slightly increased, while fish biomass was higher in Ngemai compared to the reference site (Figs. 2 & 3). Fish biomass by families followed the same pattern as fish density, with no significant difference between the MPA and reference site (Fig. 4). Invertebrate densities in Ngemai MPA were lower than the densities in the reference site (Fig. 5), while the density of coral recruits followed the same pattern showing a lower number of individuals in the MPA compared to the reference site (Fig. 6). Coral coverage was similar inside Ngemai MPA and the reference site (Fig. 7), with a higher number of coral diversity in the reference site compared to the MPA (Fig. 8). Although there was a trend in higher fish biomass in the MPA, none of these differences in fish and benthic assemblages were significant. This suggests that the protection of the MPA may be having an effect on fish biomass, however monitoring over a longer period of time is needed to be able to detect positive changes inside and outside the MPA.

Monitoring is an essential component of management that is needed in order to assess the overall progress and effectiveness of a Marine protected Area. Managers of such sites need monitoring information to be able to make educated decisions in order to achieve specific objectives. Currently in Palau, the Protected Areas Network serves as a tool to manage conservation areas throughout Palau, and monitoring of these sites is critical for the success of MPAs that are part of the Protected Areas Network. An important aspect of the effectiveness of no-take reserves is their benefits not only to fish populations within individual no-take reserves, but also their contributions to overall fish populations across the ecosystem, including both other no-take reserves within the network and contributions to fished areas (McCook et al, 2010).

As monitoring is an essential component for adaptive management, it is also important to implement survey methods that are consistent as well as having trained individuals to conduct the surveys. Therefore, we recommend that individuals who conduct MPA surveys, work together with PICRC in building their local capacity to monitor their MPAs. Community-based MPAs should be viewed as one of many strategies that fit within broader ecosystem-based approaches to management (Hamilton et al, 2011). Finally, in order for management of MPAs to be effective, threats that are outside of the marine ecosystem need to be taken into account when adaptively managing marine protected areas.

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