Changes in the Condition of Oruaol Ibuchel Conservation Area in Ngatpang State between 2015 and 2018

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Abstract

Coral reefs are important resources, especially for island communities. As societies develop, marine ecosystems usually deteriorate, mainly due to pollution, bad fishing practices, and climate change. Communities throughout Palau have established Marine Protected Areas to conserve and manage their marine resources. Nationally, the Protected Areas Network (PAN) was established to bring all the local MPAs into a national network. Oruaol Ibuchel Conservation Area in Ngatpang State, a PAN site, was surveyed by Palau International Coral Reef Center in 2015. Then, in 2018, PICRC conducted a follow-up assessment within the same conservation area, in addition to a corresponding non-protected reference (REF) area. Our findings show that macroalgae in the lagoon reef increased while hard corals decreased between 2015 and 2018. In addition, invertebrates and coral recruits in the lagoon reef had decreased since 2015. In the reef flat, invertebrates, mainly clams, increased while coral recruits decreased over time. Moreover, the reef flat had similar coral cover and macroalgal cover through time and between protection status. Therefore, coral to algae phase shift may only be occurring in the lagoon reefs, probably because of eutrophication. Eutrophication is also known to trigger crown-of-thorn (COTS) outbreak due to high nutrient concentration, which supports the survival of abundant COTS larvae. Therefore, it is best to monitor the population of COTS and the environmental factors that can cause an outbreak of COTS in the conservation area.

Introduction

Coral reefs are important for numerous reasons. To humans, reefs are sources of food and income, especially for communities in the islands. Reefs also provide shelter and food for fish and numerous marine organisms. Despite their importance, coral reefs are degrading around the world, mainly due to pollution (Eriksen et al. 2014), overfishing (Fitzpatrick et al. 2007), and climate change (Hoegh-Guldberg et al. 2007). Fish and other edible marine organisms are the main source of protein for human populations on an island (Johannes, 1981). Therefore, the conservation of marine resources is important for the survival of local communities.

Conservation has been part of Palauan society for many generations through traditional practices, such as *bul.* Bul is when the chief holds a certain area (e.g. fishing ground), or resources (like reef fish), taboo when suspecting that resources are getting scarce in a particular place (Johannes 1981). The temporal closure enables the declining population of a resource to recover.

Inspired from traditional conservation practices, in 2003, Palau established the Protected Areas Network (PAN). In 2015, Ngatpang State became a member of the PAN with three conservation areas. These conservation areas, covering a total area of 0.125 km^2, represent three ecosystems for key species, such as the rabbit fish (Fig 1). Chiul (mangrove forests) are where fish eggs hatch, Olterukl (seagrass beds) are habitats to juvenile fish, and Oruaol Ibuchel (patch reefs) are where adult fish aggregate, breed and feed (CASRUPT and PCS, 2016). All 3 conservation areas are no-entry and no-take zones (CASRUPT and PCS, 2016).

Figure 1. Map of Ngatpang Conservation Areas (CASRUPT and PCS, 2016).

In order to efficiently manage resources, long-term monitoring of resources is essential. In 2015, Palau International Coral Reef Center (PICRC) conducted a baseline assessment of resources in Oruaol Ibuchel Conservation Area. Then in 2018, PICRC re-visited the same sites from 2015 and conducted a follow-up survey. This report presents the status of resources in Oruaol Ibuchel Conservation Area after the 2018 survey and compare them to a non-protected reference area and available data from 2015 surveys within the MPA.

Method

Oruaol Ibuchel was legislated as a conservation area in 2004, NSPL No. 20-04, so it has been closed to fishing activities for 11 years before the baseline assessment was conducted in 2015. Then in May 2018, ecological surveys were conducted in the MPA and a reference site, which is adjacent to the MPA and is open to harvesting of resources (Fig 2). Surveys at both MPA and reference sites were conducted in two habitat types, lagoon reef with depth of 10m and reef flat of 5m depth. Three sites were surveyed at each depth, so a total of 6 sites were surveyed at each reef (MPA and reference site).

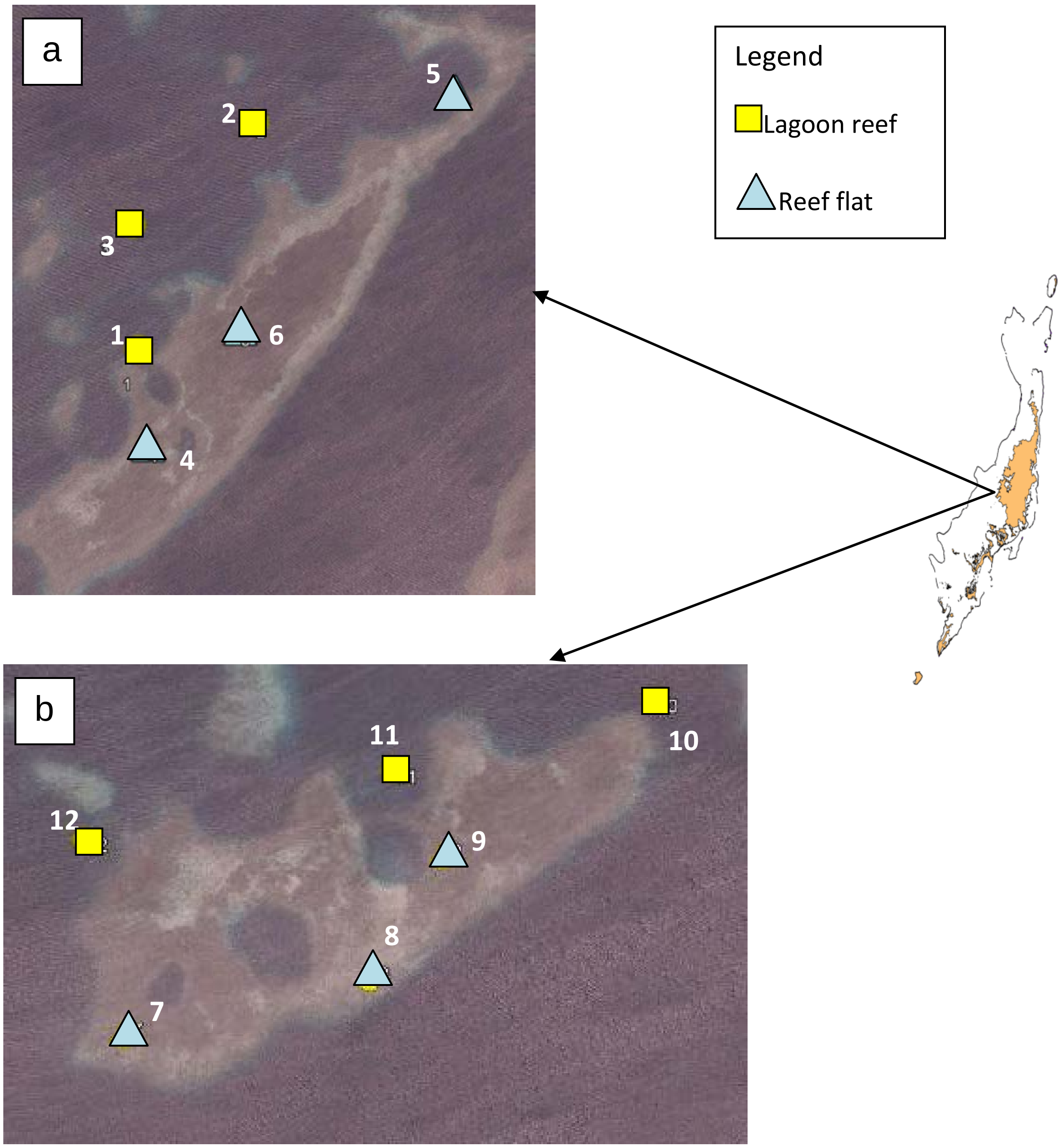

Figure 2. Map of study sites a) Oruaol Ibuchel and b) Reference site in Ngatpang State.

At each site, surveys were conducted along five 50m transects. Fish surveys were conducted within 5m wide belt using a diver-operated stereo-video (DOV) system. Videos were later analyzed in the lab using the software EventMeasure, where target fish species (Appendix A) were identified and its length accurately measured. Commercially important invertebrate species (Appendix B) were identified and their size recorded within 2m wide belts. In addition, abundance of crown-of-thorns starfish (COTS) was surveyed in 4m wide belts.

Coral recruits were surveyed on the first 10m of each transect in 30cm wide belts. Each coral recruit that had a diameter ≤5 cm was identified to the lowest taxonomic level possible and its length measured. To determine reef substrate composition, photographs of the reef were taken every meter along each transect using an underwater camera (Canon, Powershot G16) mounted on a 0.25 m^2 quadrat. A total of 50 photos per transect were taken. These underwater photos were analyzed using the software Coral Point Count with excel extension (CPCe, Kohler and Gill 2006) to determine percent cover of major reef substrate (Appendix C).

Data analysis

Each ecological indicator (e.g. invertebrate abundance) in each habitat were compared to assess 1) changes over time (between 2015 and 2018) and 2) the effect of protection on resources (between MPA and reference site). Each dataset was tested for normality using Shapiro-Wilk test. When not normal, data was log- or square root-transformed and re-tested for normality. When normal, One-Way ANOVA was used to test for changes over time (between 2015 and 2018) and the effect of protection (between MPA and reference site). When non-normal after transformation, the non-parametric Kruskal-Wallis rank sum test was used instead.

Note that due to change in the methods, fish data was not compared through time rather it was compared only between protection status. All data analyses were done using R Program (R Core Team 2018).

Results

The results are presented by habitat type: reef flat and lagoon. As mentioned above, fish data were compared only between protection status and not through time.

Reef flat

Fish abundance

The abundance of fish was similar between reefs inside MPA (20 ± 3 fish/250m^2) and at reference site (16 ± 4 fish/250m^2, Fig 3). Majority of fish observed in the MPA and reference sites were herbivorous fish, including S*carus spp.* (Melemau) and *Chlorurus sordidus* (Melemau).

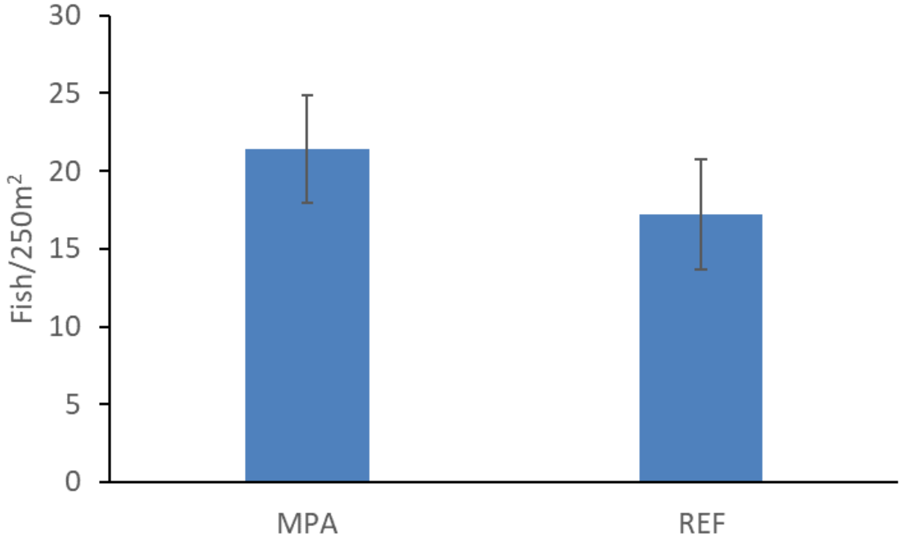

Figure 3. Abundance of fish (mean ± SE) on reef flat.

Fish biomass

The fish biomass was similar inside the MPA (707.9 ± 261.2 g/250m^2) and reference site (718.7± 258.5 g/250m^2, Fig 4).

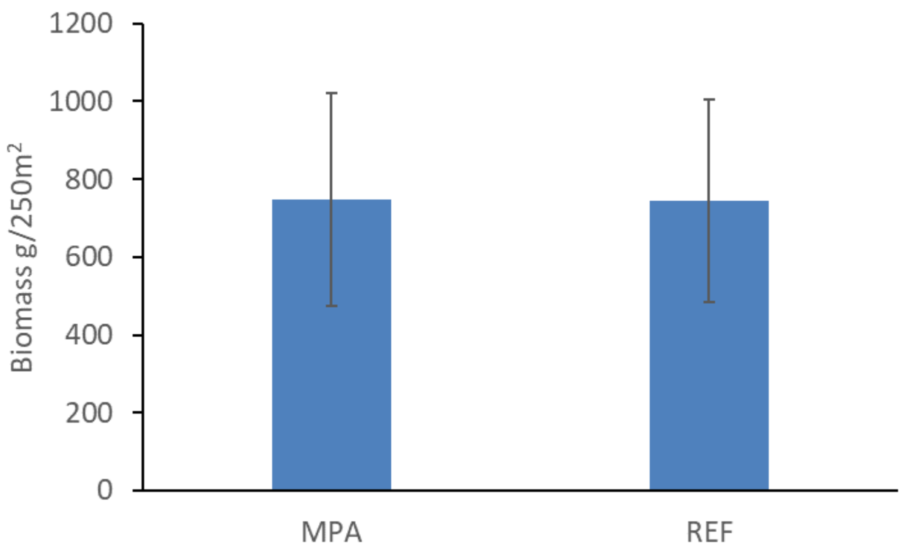

Figure 4. Fish biomass (mean ± SE) on reef flat.

Invertebrates

The abundance of invertebrates was higher in 2018 (27 ± 6 invertebrate/100m^2) than 2015 (3 ± 1 invertebrates/100m^2, Fig 5) (ANOVA, $p<0.05$). In 2018, the abundance of invertebrates was similar at the reference site and the MPA (ANOVA, $p>0.05$, Fig 5). Majority of invertebrates observed inside and outside the MPA were *Tridacna crocea* and *Tridacna maxima*.

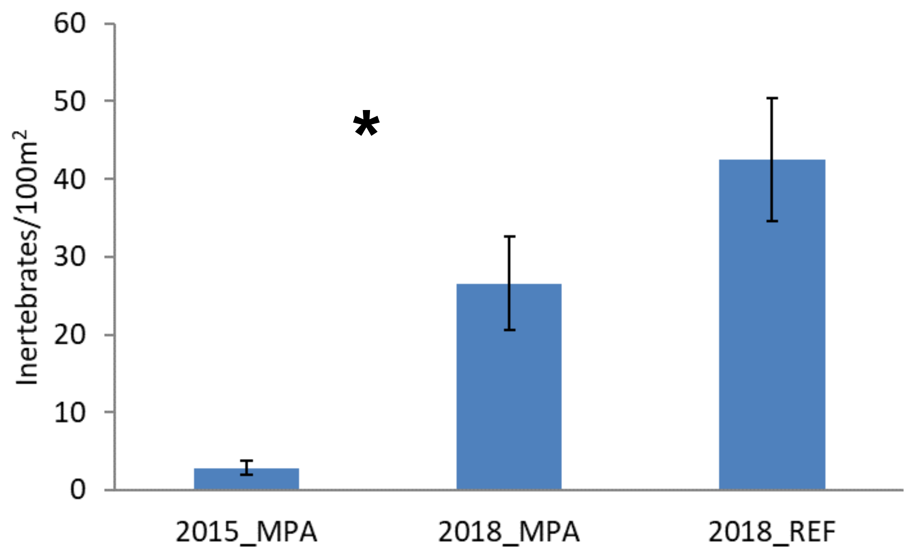

Figure 5. Abundance of invertebrates (mean ± SE) on reef flat. Asterisk shows significant difference ($p<0.05$)

Coral recruits

Abundance of coral recruits in 2015 (12 ± 2 recruits/3m^2) was significantly higher than that of 2018 (5 ± 2 recruits/3m^2, Fig 6) (Kruskal-Wallis, $p<0.05$). When comparing between protection in 2018, abundance of coral recruits was similar inside the MPA and the reference site (Kruskal-Wallis, $p>0.05$, Fig 6).

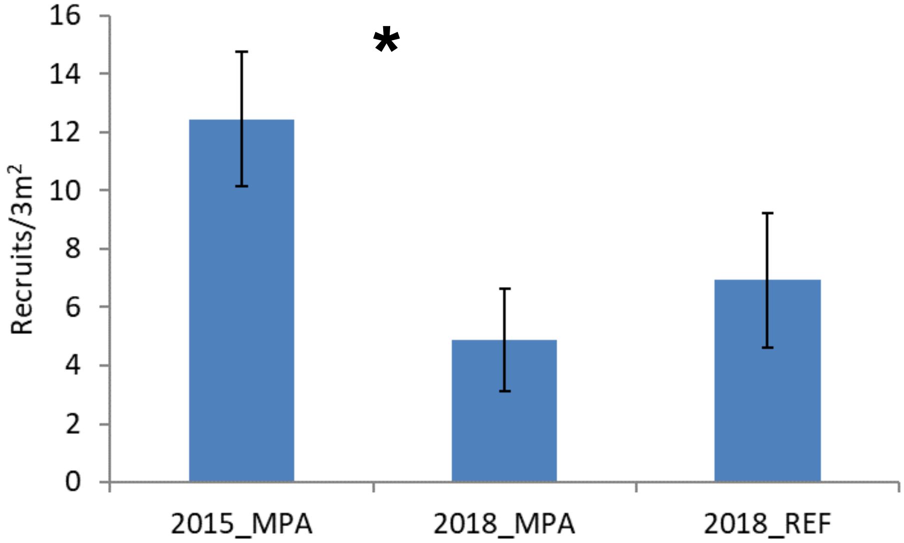

Figure 6. Abundance of coral recruits (mean ± SE) on reef flat. Asterisk shows significant difference, ($p<0.05$).

Benthos

Coral cover on the reef flat was similar between 2015 and 2018, and between the MPA and Reference site (Fig 7). Macroalgae was similar between 2015 and 2018. When compared between protection, macroalgae was higher in the reference site (11.0 ± 3.4 %) than the MPA (7.1 ± 2.5 %, Fig 7).

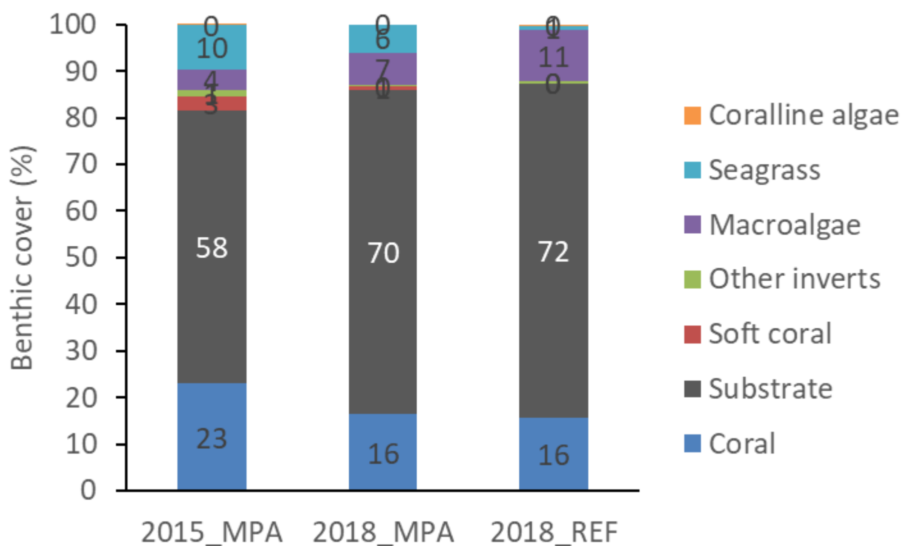

Figure 7. Mean percent cover of benthic categories on reef flat.

Lagoon

Fish abundance

The fish abundance was similar between sites (Fig 8). The majority of the fish observed in the MPA and reference sites were *Scarus spp.* (Melemau) and *Lutjanus gibbus*(Keremlal). In both habitat, when considering the herbivorous fish only, there were significantly more fish in the reef flat (15 ± 3 fish/250m^2) than the lagoon reef (7 ± 1 fish/250m^2, One-way ANOVA, p<0.001, data not shown).

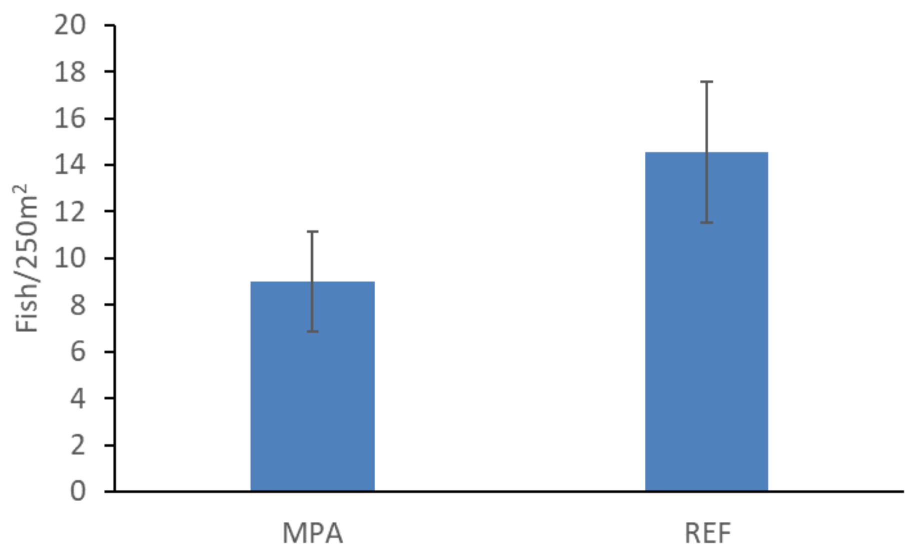

Figure 8. Abundance of fish (mean ± SE) of lagoon.

Fish biomass

Fish biomass in the MPA was similar to that of the reference site (Fig 9). When considering herbivorous fish only, fish biomass was similar between the two habitats (data not shown).

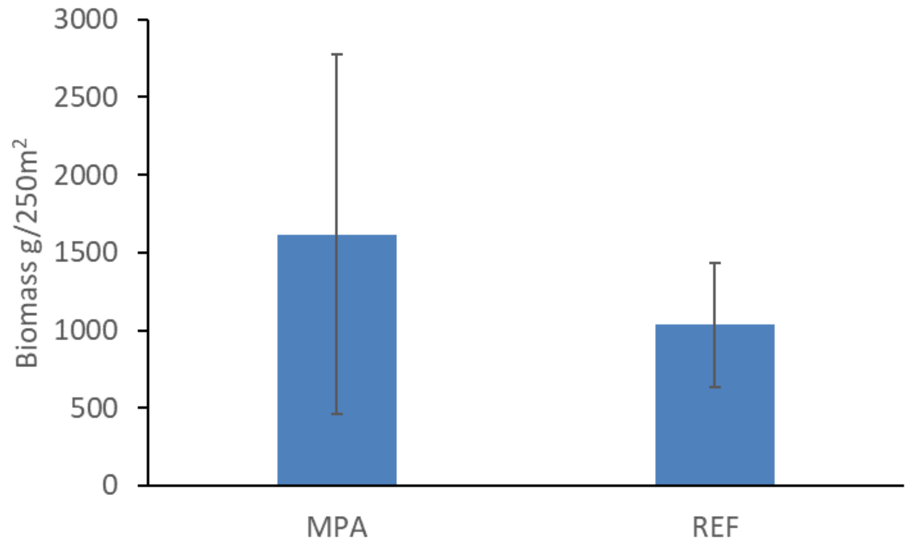

Figure 9. Fish biomass (mean ± SE) of lagoon.

Invertebrates

The abundance of invertebrates was significantly higher in 2015 (1 ± 1 invertebrates/100m^2) than 2018 (0.2 ± 0.2 invertebrates/100m^2, Fig 10) (Kruskal-Wallis, $p<0.05$). Majority of invertebrates present in the MPA was *T.* crocea (Oruer); while dominant in the reference site was *T. crocea* and *Thelenota ananas* (Temetamel). When comparing between protection, abundance of invertebrates was similar between MPA and the reference site (Kruskal-Wallis, $p>0.05$, Fig 10).

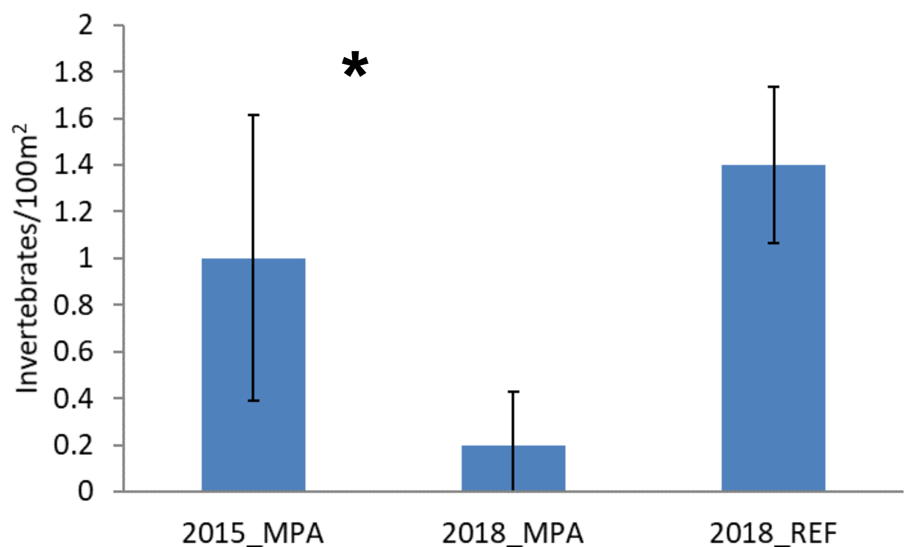

Figure 10. Abundance of invertebrates (mean ± SE) of lagoon. Asterisk shows significant difference ($p<0.05$)

Crown-of-thorns starfish (COTS) were not present in 2015. In 2018, COTS were absent on the reef flat, but a few were recorded in the lagoon reefs. An average of 0.2 ± 0.1 COTS/200m^2 was present in the MPA, while 1 ± 0.3 COTS/200m^2 was present in the reference site. Although Figure 11 may imply significant difference between sites, result of the Kruskal-Wallis test was not determined (p-value = NA).

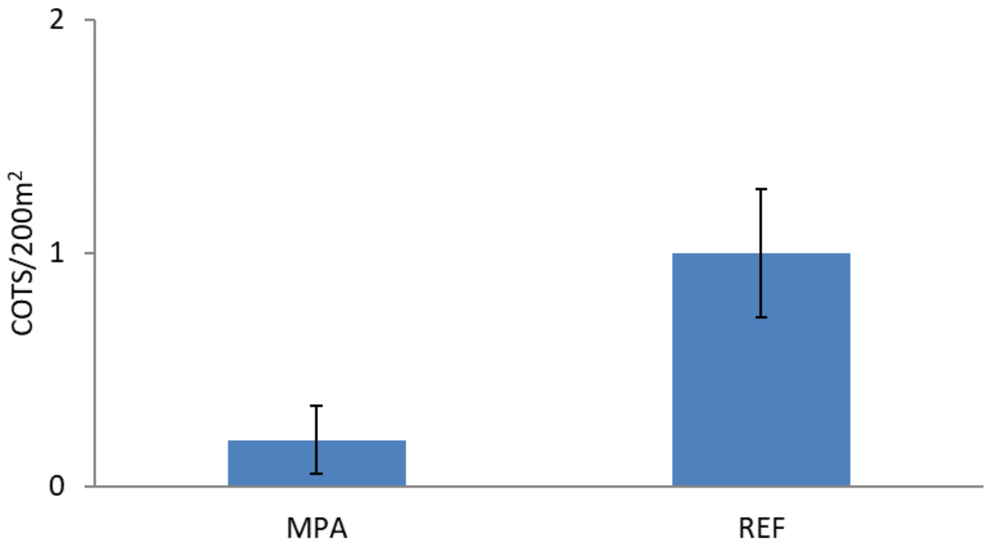

Figure 11. Abundance of Crown-of-thorns starfish (mean ± SE) in lagoon reefs.

Coral recruits

The abundance of coral recruits was significantly higher in 2015 (9 ± 2 recruits/3m^2) than in 2018 (2 ± 1 recruits/3m^2, Fig 12) (Kruskal-Wallis, $p<0.05$). In 2018, the abundance of coral recruits was higher in the MPA (2 ± 1 recruits/3m^2) than the reference site (1 ± 1 recruits/3m^2, Fig 12) (Kruskal-Wallis, $p<0.05$).

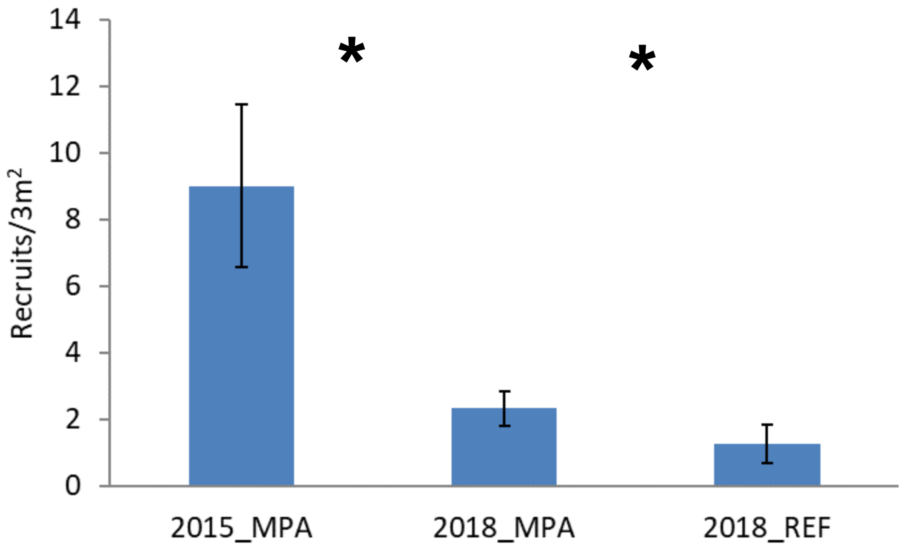

Figure 12. Abundance of coral recruits (mean ± SE) of lagoon. Asterisk shows significant difference (p<0.05)

Benthos

The coral cover was significantly higher in 2015 (42.5 ± 7.5 %) than 2018 (3.9 ± 0.6 %, Fig 13) (ANOVA, p<0.001). In addition, in 2018 the coral cover was higher in the reference site (8.6 ± 1.1 %) compared to the MPA (3.9 ± 0.6 %, Fig 13) (ANOVA, p<0.05).

Macroalgae (mainly *Lobophora* spp. and *Padina* spp.) was significantly higher in 2018 (64.7 ± 3.5 %) than 2015 (7.8 ± 3.2 %, Fig13) (Kruskal-Wallis, p<0.001). When compared between protection, macroalgae was similar between MPA and the reference site (Fig 13).

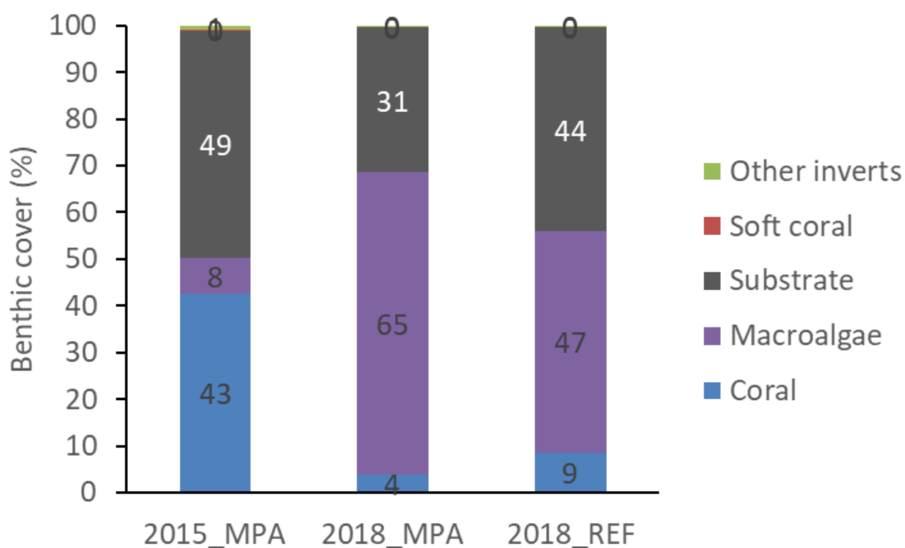

Figure 13. Percent cover (mean ± SE) of major substrates in the lagoon.

Discussion

Through this study, we were able to determine the state of marine resources in Oruaol Ibuchel Conservation Area. In the lagoon reef, from 2015 to 2018, coral cover decreased while macroalgal cover increased. In addition, density of invertebrates and coral recruits on the lagoon reef had decreased over time. Moreover, COTS was only present in the lagoon reef and not in the reef flat. Over time, the reef flat experienced an increase of invertebrates, which were mainly clams. Furthermore, reef substrate on the reef flat was similar over time. These findings suggest that a phase shift may have occurred, and in the lagoonal reef only.

Through this study we were able to determine the effectiveness of the MPA as a conservation tool. In both habitats, there was no effect of protection on fish density and fish biomass. Fish that were most abundant on the reef flat were herbivorous fish, like *Chlorurus sordidus* (Melemau) and *Scarus* spp. (Melemau), while abundant in lagoon reef were *Scarus* spp. and *Lutjanus gibbus* (Keremlal). This finding suggests that herbivory is higher in the reef flat compared to lagoon reef. Moreover, coral cover in the reef flat and macroalgal cover in the lagoon reef did not have any effect from protection. The abundance of herbivorous fish in the area may be the reason the substrate is similar between the MPA and reference site. Furthermore, the baseline survey was conducted only 3 years prior to this study, so significant difference of the ecological indicators stated above was not observed over time. Selig and Bruno (2010) pointed out that the changes in resource abundance or densities (e.g. fish density) within a 1-year period may be small; however, in the long-term (over 10 years), significant difference of resource abundance or densities can be observed.

In contrast, invertebrate abundance in both habitats, abundance of coral recruits in the reef flat, macroalgal cover in the reef flat, and coral cover in the lagoon reef showed a negative effect from protection. These may be due to chronic effect from the runoff of adjacent rivers in Ngermeduu Bay.

The only positive effect from protection was the abundance of coral recruits in the lagoon reef. Herbivorous fish has been found to create space for coral recruits to settle by grazing and clearing hard substrate of turf algae that can hinder coral settlement (Diaz-Pulido et al. 2003). The presence of abundant herbivorous fish in the lagoon reef may contribute to this positive effect for coral recruits.

This study showed that within the MPA in the lagoon habitat, macroalgae increased while coral coverage and coral recruits decreased from 2015 to 2018. In addition, COTS were recorded in the lagoon reef, both inside and outside the MPA. A total of 15 COTS was recorded in the 3 reference sites. This may be one of the most abundant COTS located on one reef. Outbreak of COTS can lead to massive coral death, as was observed in the past (Kayal et al. 2012). Brodie et al. (2005) showed that increased nutrients from runoff contributed to COTS outbreaks. Moreover, excessive nutrient input to coastal reefs can lead to eutrophication, which causes macroalgal bloom. Corals and macroalgae are constantly competing for space and food (Lirman 2001). During eutrophication, high nutrient condition favors the macroalgae. As a result, macroalgae out-competes hard corals for space and dominates the reef.

Reefs in Ngatpang are adjacent to Ngermeduu Bay, which has three rivers draining into it. This runoff could have lead to (1) the presence of COTS in the area and (2) increased growth of macroalgae. Previous studies show that herbivorous fish have a positive impact on coral reefs, because they graze on algae and keep the algae from outgrowing the corals (Bellwood et al. 2004). From this study, lagoon reefs in Ngatpang are exposed to high runoff and low herbivory (abundance of herbivorous fish), which explains the macroalgal bloom in this habitat and not at the reef flat. Therefore, COTS in Ngatpang should be monitored in case the population gets too high. More importantly, monitoring of nutrient concentration in watersheds over time is crucial to preventing or controlling COTS outbreak and algal bloom.

Conclusion/recommendation

From this study, some positive effects from protection were determined, mainly occurring in the reef flat. Over time, there was an increase of invertebrates, mainly *T. crocea* and *T. maxima* on the reef flat. The reef flat also had abundant coral recruits and less macroalgae, most likely due to the high abundance of herbivorous fish.

The observed macroalgal phase shift and increase of COTS over time are alarming, because they are indicators of excessive runoff and high nutrient water conditions. Therefore, it is highly recommended to monitor nutrient levels in Ngermeduu Bay watershed and monitor the abundance of COTS in the coastal reefs over time. Development along the coast and near rivers are inevitable, but it is crucial to limit terrestrial runoffs into watersheds and coastal waters. Other recommendations are listed below.

- Continue monitoring resources
- Improve enforcement to discourage poaching
- Involve the community's participation through public awareness
- Monitor the water quality in Ngermeduu bay watershed
- Monitor developmental projects and make sure they follow EQPB regulations in controlling runoff from project sites

Acknowledgement

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Appendices

Appendix A: Commercially important fish species

Commercially important fish species in Palau			
	Common name	**Palauan name**	**Scientific name**
1	Bluefin trevally	Erobk	*Caranx ignobilis*
2	Giant trevally	Oruidel	*Caranx melampygus*
3	Bicolor parrotfish	Beadle/Ngesngis	*Cetoscarus bicolor*
4	Parrotfish species	Melemau	*Cetoscarus/Chlorurus/Scarus* spp.
5	Yellow cheek tuskfish	Budech	*Choerodon anchorago*
6	Indian ocean long nose parrotfish	Berkism	*Hiposcarus hariid*

7	Pacific long nose parrotfish	Ngeaoch	*Hipposcarus longiceps*
8	Rudderfish	Komud, Teboteb	*Kyphosus spp. (vaigiensis)*
9	Orange stripe emperor	Udech	*Lethrinus obsoletus*
10	Long face emperor	Melangmud	*Lethrinus olivaceus*
11	Red gill emperor	Rekruk	*Lethrinus rubrioperculatus*
12	Yellow lip emperor	Mechur	*Lethrinus xanthochilis*
13	Squaretail mullet	Uluu	*Liza vaigiensis*
14	River snapper	Kedesau'liengel	*Lutjanus argentimaculatus*
15	Red snapper	Kedesau	*Lutjanus bohar*
16	Humpback snapper	Keremlal	*Lutjanus gibbus*
17	Orange spine unicornfish	Cherangel	*Naso lituratus*
18	Blue spine unicornfish	Chum	*Naso unicornis*
19	Giant sweetlips	Melimralm,Kosond/Bikl	*Plectorhinchu salbovittatus*
20	Yellowstripe sweetlips	Merar	*Plectorhinchus crysotaenia*
21	Pacific steephead parrotfish	Otord	*Scarus micorhinos*
22	Greenthroat parrotfish	Udoudungelel	*Scarus prasiognathus*
23	Forketail rabbitfish	Beduut	*Siganus argenteus*
24	Lined rabbitfish	Kelsebuul	*Siganus lineatus*
25	Masked rabbitfish	Reked	*Siganus puellus*
26	Goldspotted rabbitfish	Bebael	*Siganus punctatus*
27	Bluespot mullet	Kelat	*Valamugil seheli*
Protected Fish Species (yearly and seasonal fishing closure)			
28	Bumphead parrotfish	Kemedukl	*Bolbometopon muricatum*
29	Humphead wrasse	Ngimer, Maml	*Cheilinus undulatus*
30	Brown-marbled grouper	Meteungerel'temekai	*Epinephelus fuscoguttatus*
31	Marbled grouper	Ksau'temekai	*Epinephelus polyphekadion*
32	Squaretail grouper	Tiau	*Plectropomus areolatus*
33	Saddleback grouper	Katuu'tiau, Mokas	*Plectropomus laevis*
34	Leopard grouper	Tiau (red)	*Plectropomus leopardus*
35	Dusky rabbitfish	Meyas	*Siganus fuscescens*

Appendix B: Commercially important invertebrate species

Common name	**Palauan name**	**Scientific name**
Black teatfish	Bakelungal-chedelkelek	*Holothuria nobilis*
White teatfish	Bakelungal-cherou	*Holothuria fuscogilva*
Golden sandfish	Delalamolech	*Holothuria lessoni*
Hairy blackfish	Eremrum, cheremrumedelekelek	*Actinopyga miliaris*
Hairy greyfish	Eremrum	*Actinopyga spp.*
Deepwater red fish	Eremrum	*Actinopyga echinites*
Deepwater blackfish	Eremrum	*Actinopyga palauensis*
Stonefish	Ngelau	*Actinopyga lecanora*
Dragonfish	Irimd	*Stichopus horrens*
Brown sandfish	Meremarech	*Bohadschia vitiensis*
Chalk fish	Meremarech	*Bohadschia similis*
Leopardfish/ tigerfish	Meremarech, esobel	*Bohadschia argus*
Sandfish	Molech	*Holothuria scabra*
Curryfish	Delal a ngimes/ ngimesratmolech	*Stichopus hermanni*
Brown curryfish	Ngimes	*Stichopus vastus*
Slender sea cucumber	Sekesaker	*Holothuria impatiens*
Prickly redfish	Temetamel	*Thelenota ananas*
Amberfish	Belaol	*Thelenota anax*
Elephant trunkfish	Delal a molech	*Holothuria fuscopunctata*
Flowerfish	Meremarech	*Pearsonothuria graeffei*
Surf red fish	Badelchelid	*Actinopyga amauritiana*
Crocus giant clam	Oruer	*Tridacna crocea*
Elongate giant clam	Melibes	*Tridacna maxima*
Smooth giant clam	Kism	*Tridacna derasa*
Fluted giant clam	Ribkungel	*Tridacna squamosa*
Bear paw giant clam	Duadeb	*Hippopus hippopus*
True giant clam	Otkang	*Tridacna gigas*
Sea urchin	Ibuchel	*Tripneustes gratilla*
Trochus	Semum	*Trochus niloticus*
China giant clam	Duadou	*Hippopus porcellanus*

Appendix C: Major categories of reef substrate

Major Categories
Coral
Soft Coral
Other Invertebrates
Macroalgae
Seagrass
Coralline Algae
Substrate