Changes in the ecological condition of Ebiil Channel Conservation Area in Ngarchelong State between 2014 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. Ebiil Channel Conservation Area (CA), a marine protected area (MPA) in Ngarchelong State, is a known spawning aggregation site for groupers and was legislated in 1999 as a marine protected area to preserve the aggregation site. In 2014, Palau International Coral Reef Center (PICRC) conducted a baseline study at the Ebiil Channel CA. Then in 2018, PICRC conducted a follow-up assessment of the same sites to determine change of resources over time and the effectiveness of Ebiil Channel CA as a conservation tool. Ecological surveys were conducted at two habitats (fore reef and channel) in the conservation area as well as a reference site, which is an adjacent reef that is open to fishing activities. Findings of the study showed that in the channel habitat, fish biomass in the MPA was twice higher than the reference site. Moreover, clams in the fore reef of the conservation area increased twofold over time. These results indicate a positive effect of Ebiil Channel CA as a conservation tool. Benthic coverage in the conservation area overall remained stable through time, despite a minor but significant increase in macroalgae to ~5% coverage in 2018 for the Channel habitat. The most dominant substrate in both habitats were non-living substrates (carbonate, sand, and rubble). Continued monitoring is crucial to obtaining a better understanding of Ebiil Channel CA, and to help stakeholders improve their resource management in the MPA.

Introduction

Coral reefs are important for numerous reasons. To humans, fish and other edible marine organisms are the main source of protein for human populations on an island (Johannes, 1981). Reefs also provide shelter and food for fish and other 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). Therefore, the conservation of marine resources is essential for the survival of communities, especially to communities dependent on these resources.

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 area (Johannes 1981). The temporal closure enables the declining population of a resource to recover.

Through the modern government, numerous traditionally managed areas have been legislated as conservation areas. Ebiil Channel located in Ngarchelong State was known traditionally by the locals as a spawning aggregation site for groupers. The Ngarchelong community saw the importance of the site and how vulnerable it can get under high fishing pressure, especially to the aggregating groupers fish species (*Plectropomus areaolatus, Epinephelus polyphakadion, Epinephelus fuscoguttatus*). Therefore, Ebiil Channel Conservation Area (CA) was established in 1999 under state legislature, and was closed to any fishing activity. Following its legislation, the state government passed the Ngarchelong State Resources Management Regulations in 2016, which describes all activities allowed inside the Ngarchelong State waters and the penalties when breaking these regulations. Ebiil Channel was then opened to tour activities, but strictly managed by the state government.

Clearly, the community in Ngarchelong state is making necessary actions to manage their marine resources, like establishing conservation areas and fishing regulations. However, monitoring of the natural resources is also important for their management. In 2014, Palau

International Coral Reef Center (PICRC) conducted a baseline study on marine resources in Ebiil Channel CA. For the present study, ecological surveys were conducted at Ebiil Channel CA (referred to as Marine Protected Area, MPA) as well as an adjacent reference site to 1) monitor resources over time, and 2) determine effectiveness of Ebiil Conservation Area as a conservation tool. Note that this survey was not designed to monitor groupers during aggregations seasons. Another study by PICRC is designed specifically to monitor grouper aggregation in Ebiil during the right months of the year and moon phase.

Method

In April 2018, PICRC conducted a follow up assessment in Ebiil Conservation Area, which is a Marine Protected Area (MPA) of an area 19.1 km^2 in Ngarchelong State. Surveys were conducted in the MPA and the reference site, which is at Ngebard, a nearby reef of similar reef structure as the MPA but is open to fishing activities. Refer to Figure 1 for map of study sites. All surveys were conducted at 10m depth in two habitats, channel and fore reef. A subset of 3 sites in the channel habitat and 4 sites in the fore reef were chosen from the baseline assessment (Rehm et al. 2014). For the reference area, sites were chosen according to the spatial arrangement of the sites in the CA.

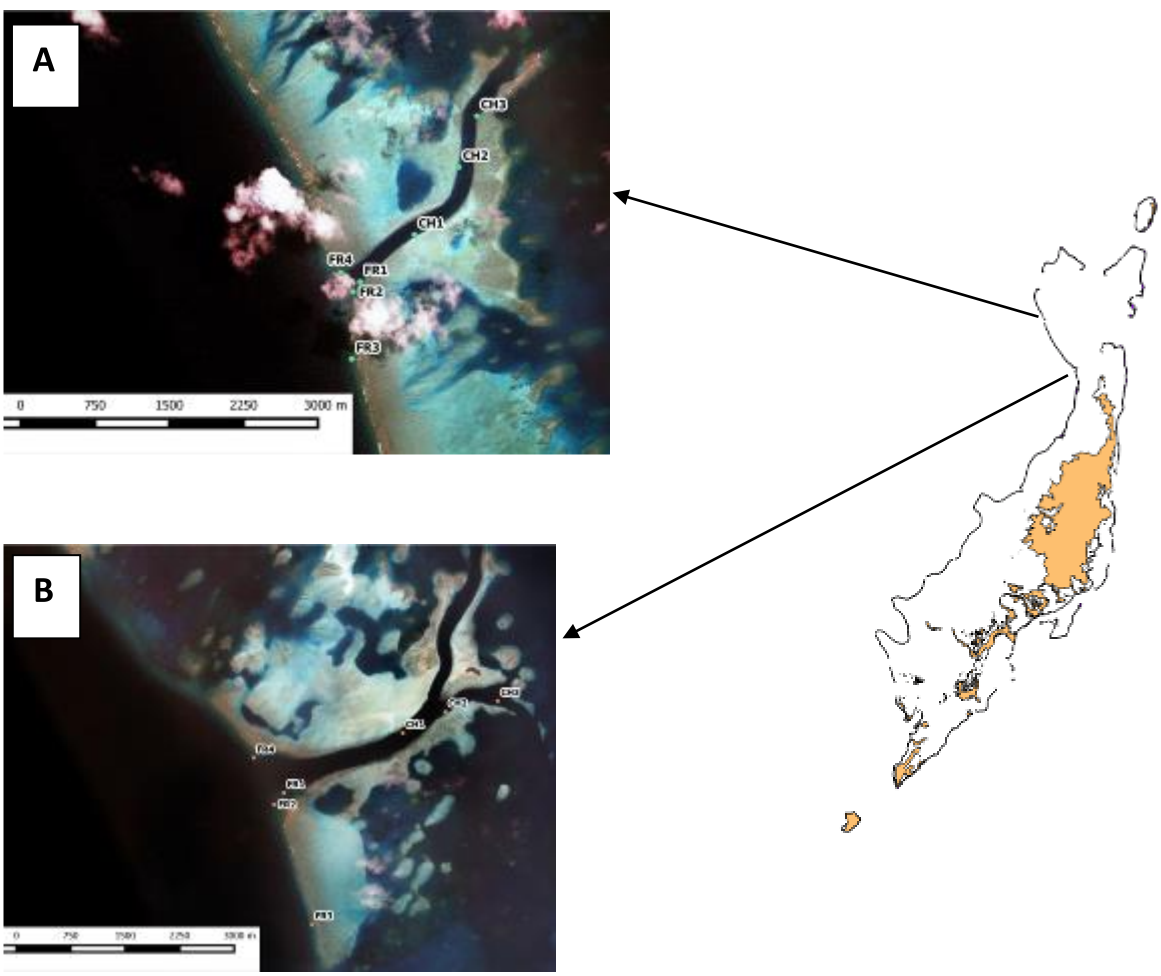

Figure 1. Map of study sites - Reference site (A) and Ebiil CA (B).

Refer to Rehm et al. 2014 for method used during baseline study of the site in 2014. For the present study, surveys were conducted along five 50m transects at each site. 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 targeted fish species (Appendix A) were identified and theirlength accurately measured and recorded. Commercially important invertebrate species (Appendix B) were also 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) that is 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 response variable 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 from visual census (in 2014) to stereo-video systems (in 2018). As a result, fish data showed higher density and biomass in 2014 compared to 2018. All data analyses were done using R Program (R Core Team 2018).

Results

A. Channel

1. Fish Abundance

Fish density was similar in the MPA and the reference site (Mann Whitney, p = 0.057, Fig. 2). Over time, mean fish density was similar between 2014 and 2018 (Mann Whitney, p = 0.0456, Fig. 2).

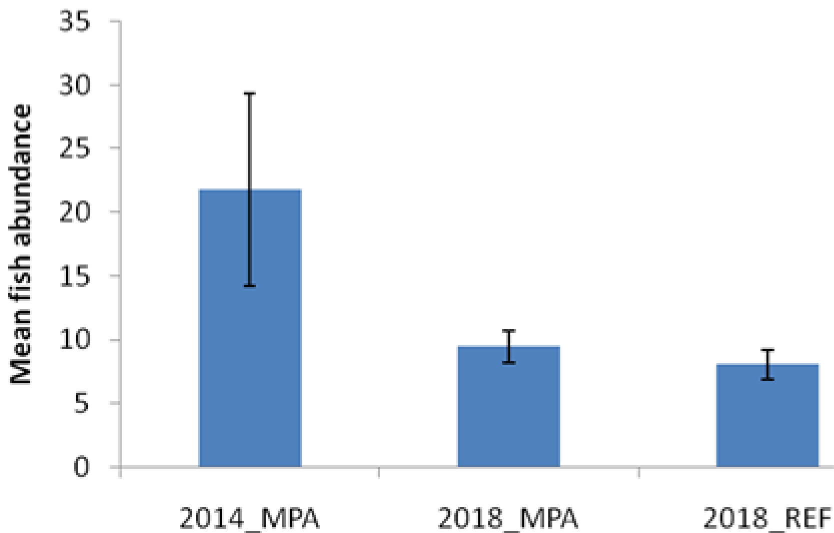

Figure 2. Fish density (mean ± SE) in the channel habitat. Note that survey method differ in 2014 (n=9) and 2018 (n=15).

2. Fish biomass

Fish biomass was greater in the MPA (10.2 ± 1.1grams/sq.m.) than the reference site (5.1 ± 1.1grams/sq.m., Mann Whitney, p < 0.01, Fig. 3). *Scarus* spp. (Melemau) and *Lutjanus bohar* (Kedesau) composed most of the fish biomass observed in the MPA. Moreover, fish biomass was greater in 2014 compared to 2018 (Mann Whitney, p< 0.0, Fig. 3).

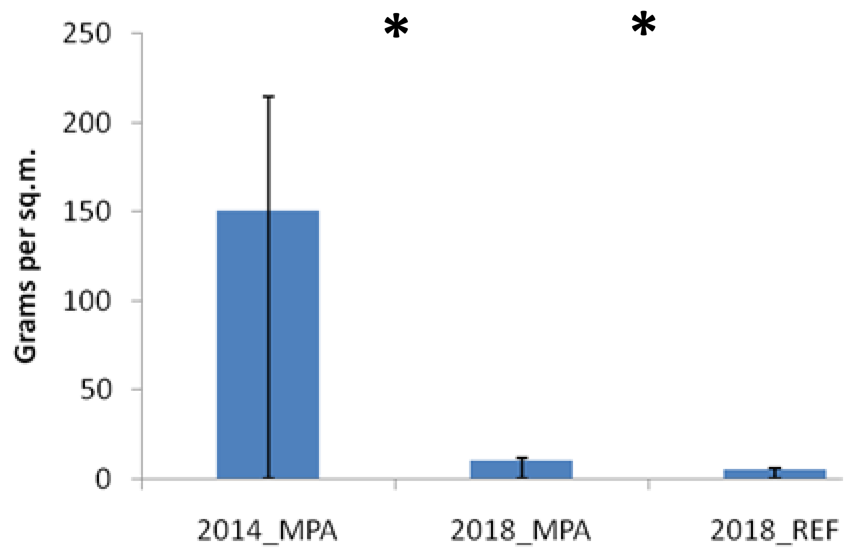

Figure 3. Fish biomass (mean ± SE) in the channel habitat. Note that survey method differ in 2014 (n=9) and 2018 (n=15). Asterisk (*) shows significant difference.

3. Inverts

Density of macro-invertebrates in the Channel was similar over time (Kruskal-Wallis, $p > 0.05$, Fig. 4). Also, density of invertebrates was not different between the MPA and reference site (Kruskal-Wallis, $p > 0.05$, Fig. 4). Giant clams were most abundant at both sites with *Tridacna crocea* (Oruer) being abundant in the MPA, while *Tridacna maxima* (Melibes) was most abundant at the reference site.

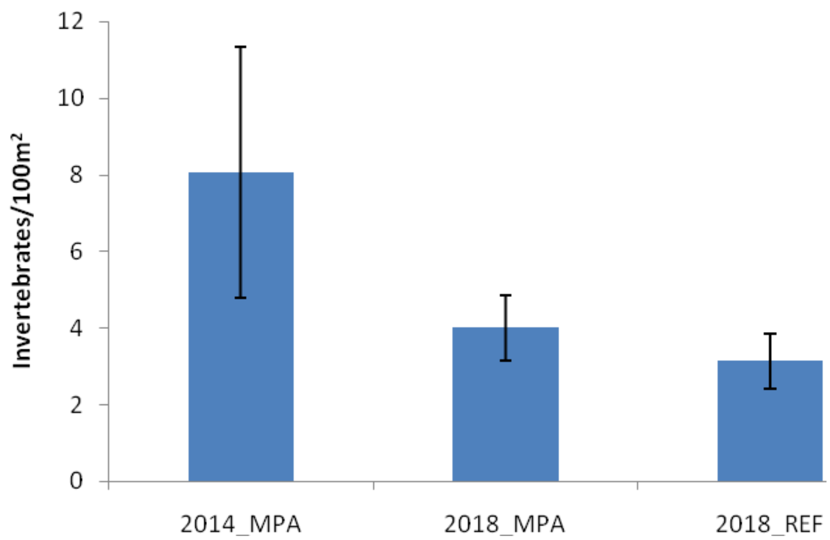

Figure 4. Density of invertebrates (mean ± SE) in the channel habitat. n=15

4. Coral recruits

Density of coral recruits was similar over time (Kruskal-Wallis, $p > 0.05$, Fig. 5). Moreover, density of coral recruits was not different between the MPA and the reference site (Kruskal-Wallis, $p > 0.05$, Fig. 5).

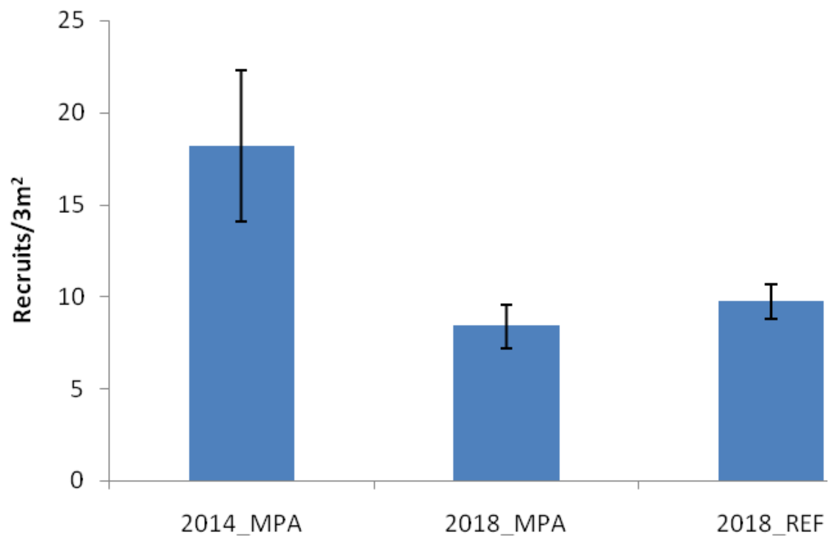

Figure 5. Density of coral recruits (mean ± SE) in the channel habitat.

5. Benthos

Coral cover was similar over time (Kruskal-Wallis, $p > 0.05$). Coral cover was also similar between MPA and reference site (Kruskal-Wallis, $p > 0.05$, Fig. 6). Cover of macroalgae was significantly higher in 2018 (5 ± 1 %) than in 2014 (0.27 ± 0.13 %, Kruskal-Wallis, $p < 0.05$). Moreover, macroalgae was higher in the MPA (5 ± 1 %) than the reference site (1 ± 0.35 %, Kruskal-Wallis, $p < 0.05$, Fig. 6). Finally, carbonate was similar over time (Kruskal-Wallis, $p > 0.05$). However, it was lower in the MPA (19 ± 1 %) compared to the reference site (41 ± 2 %, Kruskal-Wallis, $p < 0.05$).

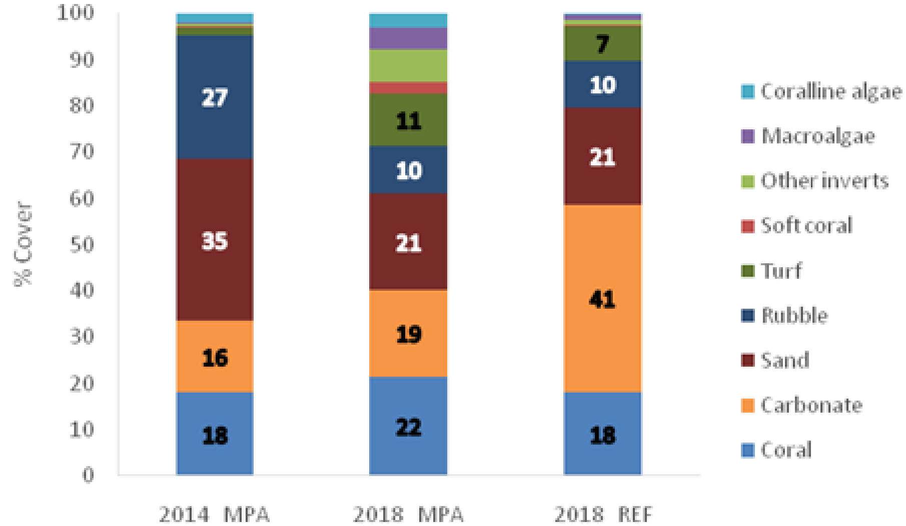

Figure 6. Mean percent cover of major benthos in the channel habitat.

B. Fore reef

1. Fish Abundance

Fish density was not different between MPA and reference site (Kruskal-Wallis, $p > 0.05$, Fig. 7). A large school of *Lutjanus gibbus* (Keremlal), with a total of 504 individuals, was observed in a single transect. As a result, the error bar greatly increased for the reference site in the following figure.

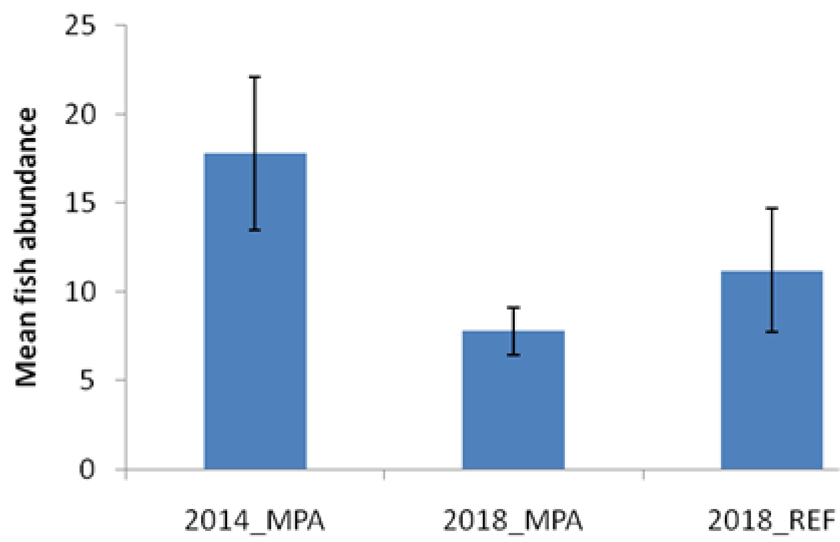

Figure 7. Fish density (mean ± SE) in the fore reef habitat. Note that survey method differ in 2014 (n=9) and 2018 (n=20).

2. Fish Biomass

Fish biomass was similar between MPA and reference site (Mann Whitney, $p > 0.05$, Fig. 8). Most of the fish observed in the reference site were *Lutjanus gibbus* (Keremlal) and *Scarus* spp. (Melemau). Fish biomass in the MPA was greater in 2014 (79.9 ± 21.5 grams/sq.m.) than 2018 (11.4 ± 15.3 grams/sq.m., Mann Whitney, $p < 0.01$, Fig. 8).

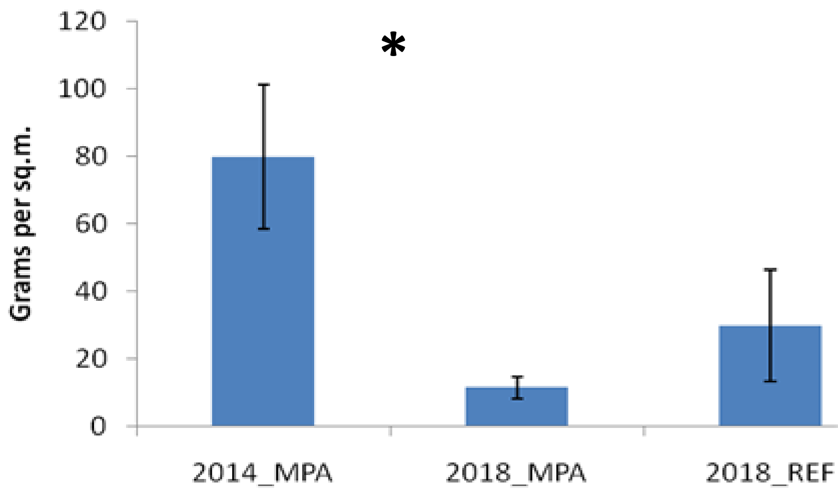

Figure 8. Fish biomass (mean ± SE) in the fore reef habitat. Note that survey method differ in 2014 (n=9) and 2018 (n=20). Asterisk show significant difference.

3. Inverts

Density of macro-invertebrates was significantly higher in 2018 (12 ± 2 invertebrates/100m^2) than 2014 (5 ± 1invertebrates/100m^2, ANOVA, $p < 0.05$, Fig. 9). The most abundant macro-invertebrate was the *Tridacna maxima* (Melibes). In addition, density of macro-invertebrates was similar in the MPA and the reference site (ANOVA, $p > 0.05$, Fig. 9).

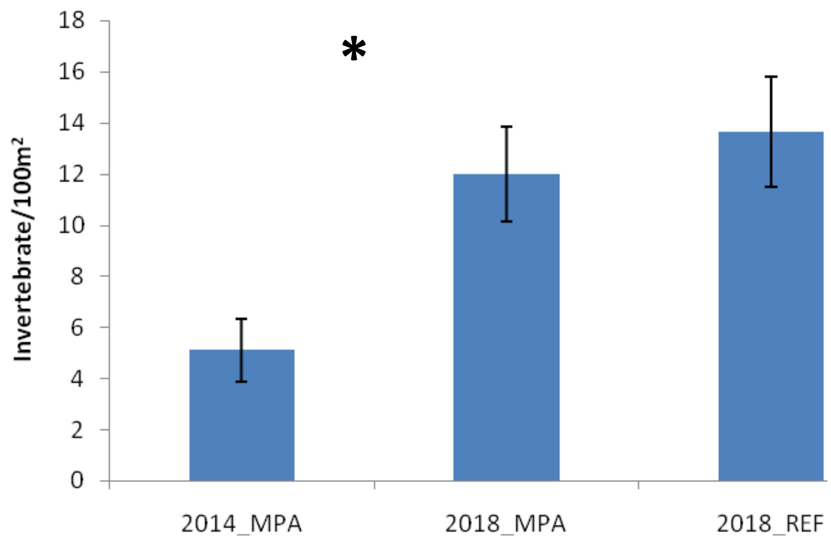

Figure 9. Density of invertebrates (mean ± SE) in the fore reef habitat. Asterisk shows significant difference. n=20

4. Coral recruits

There was no significant difference of coral recruits over time (ANOVA, $p > 0.05$, Fig. 10). Similarly, there was no difference of coral recruits between the MPA and reference site (ANOVA, $p > 0.05$, Fig. 10).

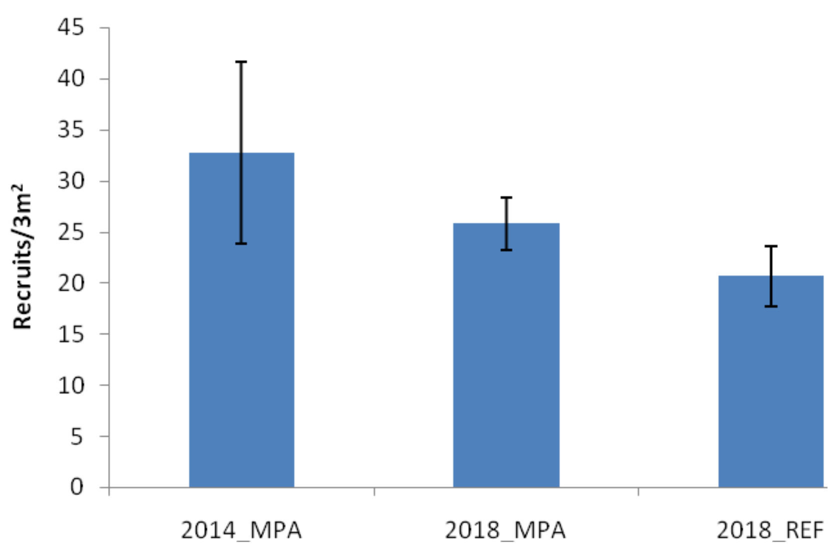

Figure 10. Density of coral recruits (mean ± SE) in the fore reef habitat. n=20

5. Benthos

There was no difference on coral cover over time (ANOVA, $p > 0.05$) nor between the MPA and reference site (ANOVA, $p > 0.05$). Similarly, cover of macroalgae was similar over time (Kruskal-Wallis, $p > 0.05$). Moreover, macroalgae cover was lower in the MPA (2 ± 0 %) compared to the reference site (7 ± 2 %, Kruskal-Wallis, $p < 0.05$, Fig. 11). Finally, carbonate was similar over time (ANOVA, $p > 0.05$). Between protection status, carbonate was higher in the MPA (56 ± 2, ANOVA, $p < 0.05$) than the reference site (42 ± 4, ANOVA, $p < 0.05$, Fig. 11).

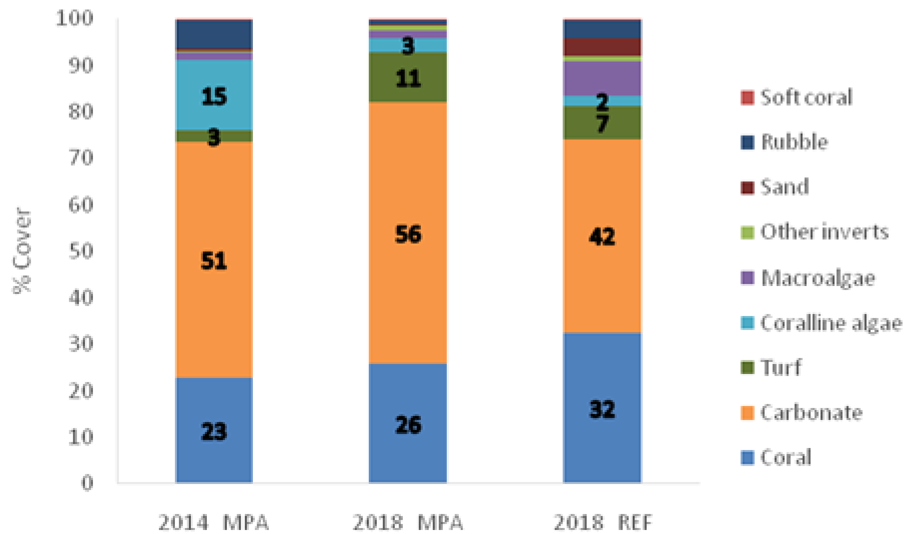

Figure 11. Mean percent cover of major benthos in the fore reef habitat. n=20

Discussion

The current study sets out to achieve two objectives, which were 1) to determine trends in resources over time and 2) to determine whether or not Ebiil is an effective conservation tool. Most of the ecological indicators showed no significant difference over time and between protection statuses, except, a higher fish biomass in the channel habitat and a higher density of macro-invertebrates in the fore reef of the conservation area.

Results from our fish surveys showed same abundance of fish inside the MPA and the reference site, but higher biomass at the MPA within the Channel habitat. This means that in this habitat, there are larger fish inside the MPA compared to the reference site. Our findings support previous studies that showed higher biomass in Ebiil Channel compared to adjacent reefs that are open to fishing activities (Friedlander et al. 2017, Lindfield 2015). Moreover, fish biomass seem to be declining from 2014 to 2018 in both habitats. However, the observed difference is due mainly from the difference in survey method, visual census in 2014 compared to stereovideo in 2018.

On the fore reef habitat, the abundance of invertebrates doubled in a period of four years. Macro-invertebrates are very easy to harvest, since they are sessile. They are slow-growing, especially clams species. Therefore, they can get overharvested quickly, particularly on nearshore reefs. Ebiil is located 7 to 10 km from shoreline and travelling to the area requires a boat. Most fishermen collecting macro-invertebrates do so along inshore reefs, like seagrass beds or lagoon fringing reefs, not out on the fore reef. Since Ebiil and reference areas are on a fore reef, fishing pressure on macro-invertebrates must be low for the reference site and none within Ebiil, which allowed clam populations to increase over time. Moreover, the increase in clam abundance within Ebiil Channel CA over timemust be a positive effect of the conservation effort. Clams take time to recover from harvesting because they grow slowly, and they may not recruit on the protected reef due to their planktonic larval phase. Therefore, for the reefs around Ebiil, 18 years may be necessary to see a positive effect of protection on clam abundance. As mentioned above, this would be dependent on the supply of clam larvae and their recruitment to the reef through water circulation in the area.

Coral cover in both habitats were less than 30%, and the reefs were dominated by non-living substrates, including carbonate, rubble and sand. The fore reef was composed mostly of carbonate, which are consolidated reef structures. Finally, there was a minor but significant increase in macroalgae coverage in the channel of Ebiil CA that is not alarming (<5%) but should be monitored in case of a macroalgal phase shift in the future.

Conclusion

This study shows that Ebiil Channel CA is effective at conserving fish and invertebrates in the channel and fore reef, respectively. Other indicators such as fish abundance, coral coverage, or coral recruits did not differ between the MPA and the reference area. Since 2015, there has been only one follow up survey of this MPA, so continued monitoring of this MPA would provide a better understanding of the Ebiil Channel CA and its inhabitants over time, and contribute to improved resource management.

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	Oruidel	*Caranx ignobilis*
2	Giant trevally	Erobk	*Caranx melampygus*
3	Bicolor parrotfish	Beadel/Ngesngis	*Cetoscarus bicolor*
4	Parrotfish species	Melemau	*Cetoscarus/Chlorurus/Scarus* spp.
5	Yellow cheek tuskfish	Budech	*Choerodon anchorago*
6	Indian ocean long nose parrotfish	Osuchelui	*Hiposcarus hariid*
7	Pacific long nose parrotfish	Ngeaoch, Berkism	*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	*Plectorhinchusalbovittatus*
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 macro-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	Cheremrum, Cheremrumedelekelek	*Actinopyga miliaris*
Hairy greyfish	Cheremrum	*Actinopyga spp.*
Deepwater red fish	Cheremrum	*Actinopyga echinites*
Deepwater blackfish	Cheremrum	*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*
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