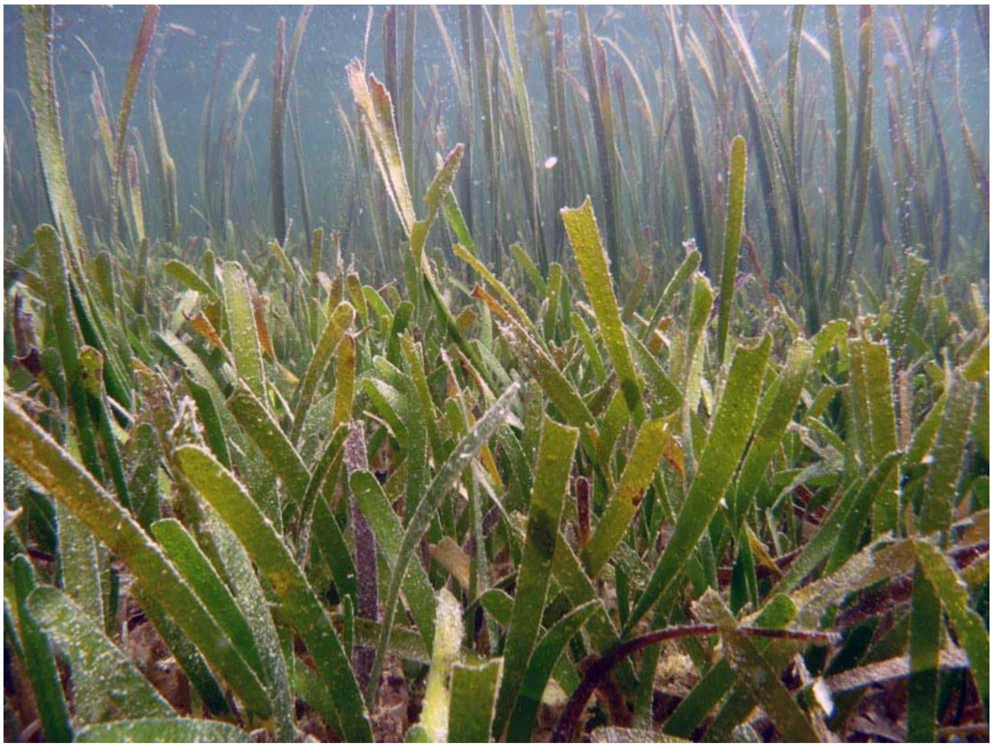
Marine Protected Area Effectiveness Report: Teluleu Conservation Area



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EXECUTIVE SUMMARY

Teluleu Conservation Area was closed to all fishing and recreational activities in 2001 by Peleliu State Government. The enclosed seagrass bed has been observed to be a nursery ground for highly valued marine resource such as humphead wrasse, bumphead parrotfish, hawksbill turtle, and sea cucumbers (*ngimes* and *eremrum*). From 2010-2012, a monitoring project was conducted by Palau International Coral Reef Center (PICRC) in an effort to describe the habitat and valued marine organisms inside Teluleu. The fish surveys showed that fish density and biomass was significantly higher inside the Teluleu Conservation Area compared with the reference site that was not protected. Inside Teluleu, fish biomass increased to 13 ± 4.8 SE kg $250m^{-2}$ in April 2012, almost 3 times greater than the first survey period (October 2010). *Hipposcarus longiceps* (ngiaoch) and *Lutjanus gibbus* (keremlal) drove the greatest difference of fish biomass inside the MPA and the adjacent unprotected area. Fish biomass in the unprotected area decreased over threefold to 2.2 ± 1.2 SE kg $250m^{-2}$ in April 2012. Invertebrate surveys determined *Stichopus vastus* (ngimes) to be dominant species inside Teluleu. Benthic community surveys inside the MPA showed that coral cover was relatively low compared to macroalgae. Seagrass surveys identified *Thalassia hemprichii* to be most dominant species inside Teluleu. Finally, coral recruits density was greater inside the MPA than the adjacent unprotected area. Although many of the valued marine resources showed positive effect from the closure, it would require longer period of monitoring to determine if the closure is significantly effective in conserving marine resources inside Teluleu over time.

INTRODUCTION

The Palau International Coral Reef Center's (PICRC) Marine Protected Area (MPA) Evaluation Project was initiated with the primary goal to improve conservation of Palau's unique marine resources, via adaptive management. The results of these evaluations are intended to guide management on what is working, and what is not, so that investments in MPAs will succeed in achieving their desired objectives. Such objectives include biodiversity conservation, fisheries management, income generation, and a combination of all these objectives.

Currently all 16 states of Palau have established at least one MPA, which now total 33, with varying levels of protection, enforcement, restriction and management. 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 then 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 zooxanthallae, contribute energy produced by the primary producers in coral reef ecosystems. With their hard calcareous skeleton, corals also provide habitat for fish, invertebrates, and other marine plants. When large-scale disturbances (e.g. typhoons, El Nino, predator outbreaks, 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.

MPAs also have positive impact on seagrass beds. Seagrass beds and mangroves are identified to be nursery grounds to juvenile reef fish. Seagrass beds being located far from main coral reefs decrease visits of predators, and with the structural complexity of the substrate allow fish to escape predators (Nagelkerken et. al., 2000). Threats to seagrass beds include high turbidity from excessive runoffs, pollution, and scars along the bottom from motor boats and anchors. Scars on seagrass bed decrease stability of the seagrass bed, and enforcing restriction of boat entry to protected seagrass bed decrease seagrass bed scars (Engeman et. al., 2008).

This study will focus on Teluleu Conservation Area located in Peleliu Island (Figure 1). With an area of 0.83 km^2 (540,016 m^2), Teluleu CA became a no-take zone for all marine resource in 2001 under Peleliu State Law. The local community observed that Teluleu is a nursery ground for key fish and other important marine organisms for potential economic benefit and local consumption. Among the many goals, Teluleu CA aims to be a good source of important marine resources, such as valuable fish and invertebrates for local consumption and fish markets (Gibbons-Decherong, 2012).

The objective of this study is to determine benthic cover as well as density and biodiversity of important marine resource inside Teluleu CA. By measuring these biological indicators, the progress Teluleu CA is making in achieving its goal as a fish reserve can then be determined.

METHODS

Monitoring at Teluleu CA took place from October 15, 2010 to April 10, 2012. A total of 4 sampling periods were conducted at both the MPA and the reference site. The reference site, which is a seagrass bed adjacent to the MPA, is open to fishing and recreational activities. At each site are 3 randomly selected replicate stations, selected and marked by GPS (Figure 1). Each station has five replicate 50-m transects.

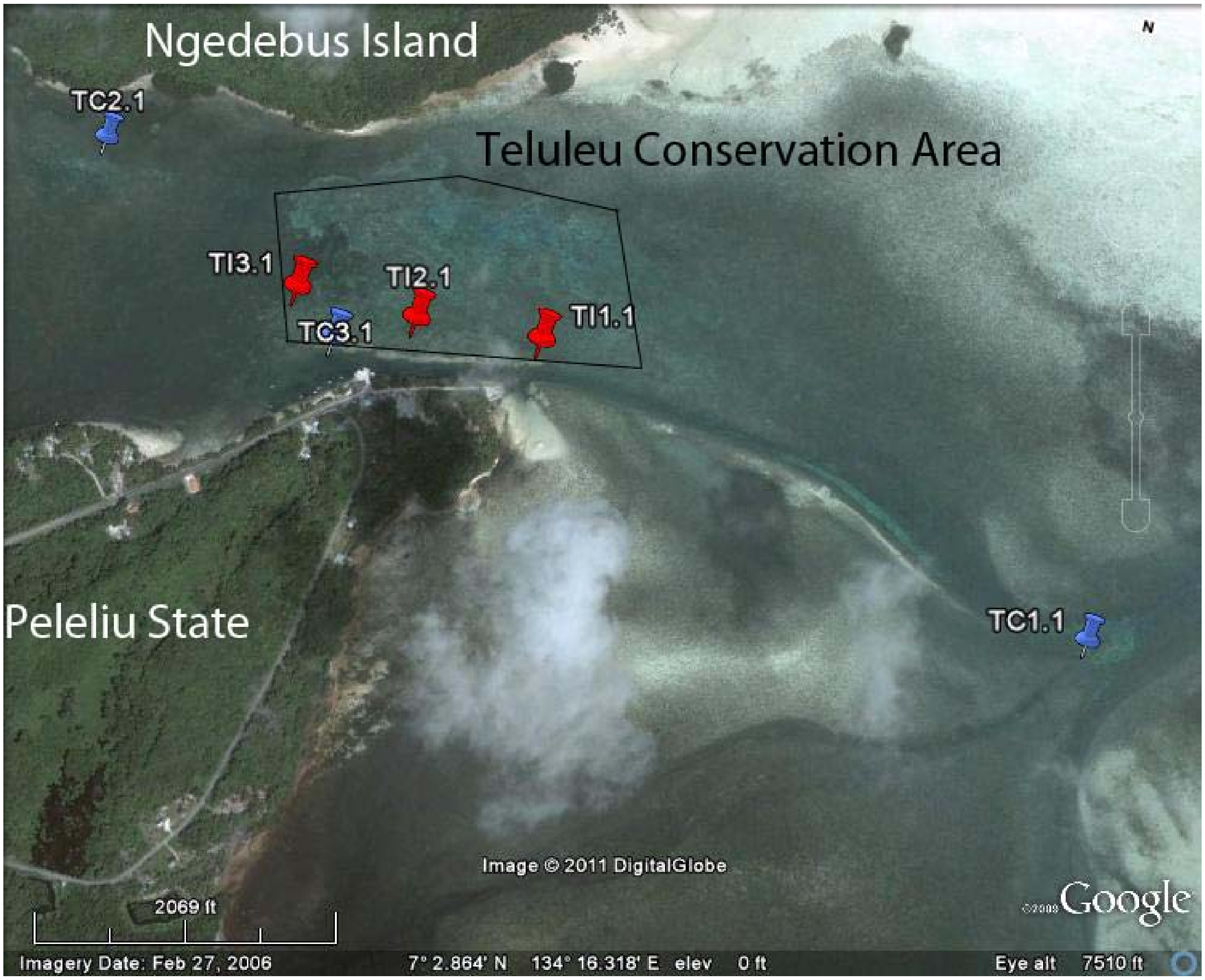

Figure 1. Survey Stations - Teluleu Conservation Area (red) and Reference site (blue).

The following surveys were done on each replicate transect. Visual census of fish size and abundance were recorded on a 5 x 50 m belt transect. The fish recorded are highly desirable species for commercial markets or subsistence use (Table 1). There were four trained surveyors doing the fish surveys during the monitoring period. At the site, the person doing the fish survey swam approximately 0.1 m sec^{-1} (8 min per transect). Fish size data was converted to biomass using a published length-weight relationship, $W = a \bullet L^b$, where W is weight in grams, L is fish length from the visual census, and parameters a and b are constants obtained from Fishbase (Froese and Pauly, 2013). Size and abundance of invertebrates (sea cucumbers and bivalves) were recorded on a 2 x 50 m belt transect (Table 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 attached to a 0.25 m^2 quadrat with a 70 cm customized camera stand. Percent cover of benthic community was determined using CPCe (Coral Point Count with Microsoft Excel). Finally, coral recruit surveys were conducted on the first 10 m of each replicate transect. Coral recruit species and size were recorded on a 0.3 x 10 m belt transects. Fish surveys were conducted every year from 2010-2012, whereas invertebrate and coral recruit surveys were conducted once every 2 years. There was only one survey of the benthic community done for this monitoring project.

A three-way permutational MANOVA was used to analyze fish community biomass, with status (2 levels) and time (4 levels) as fixed factors, and station as random factor nested in status. Principal Component Ordination (PCO) was used to visualize differences in the fish community biomass between the MPA and unprotected area, and a vector plot based on Spearman correlation (>0.6) was overlaid to determine what fish species were driving any differences. Kruskal-Wallis tests were used to analyze total fish biomass, as well as density and richness of total fish, invertebrates, and coral recruits. Kruskal-Wallis test was also used to analyze benthic community.

Seagrass surveys were conducted on May 27, 2011 and January 16, 2013 at Teluleu CA and the Control site, which is located adjacent to the MPA. At each site are 3 stations (same stations as stated above, Figure 1), and at each stations are five replicate 25-m transects. A $0.25m^2$ quadrat was used to estimate percent cover of seagrass species at the survey points on each transect. Starting at the 0m mark, survey points had 5m-intervals along each replicate transect (5 survey points per transect).

RESULTS

A. Fish

Fish biomass inside Teluleu (MPA) increased from 5.6 ± 2.8 SE kg $250m^{-2}$ in October 2010 to 13 ± 4.8 SE kg $250m^{-2}$ in April 2012. In contrast, fish biomass outside Teluleu declined from 9.7 ± 7.6 SE kg $250m^{-2}$ in October 2010 to 2.2 ± 1.2 SE kg $250m^{-2}$ in April 2012 (Figure 2). Total fish biomass was significantly different between zones (Kruskal-Wallis: $P < 0.05$), where fish biomass was greater in the MPA than the unprotected area. Further analysis of fish functional groups showed that herbivorous fish characterized the increase in total fish biomass within the MPA throughout the monitoring period. There was an increase of herbivores in the MPA from October 2010 (2.1 ± 1.5 SE kg $250m^{-2}$) to April 2012 (9.4 ± 4.7 SE kg $250m^{-2}$). The decline of total fish biomass in the unprotected area was characterized by a decrease in benthic invertivores from October 2010 (7.2 ± 7.1 SE kg $250m^{-2}$) to April 2012 (0.024 ± 0.024 SE kg $250m^{-2}$, Figure 3).

Differences in fish community biomass across status x time was not significant; however, there was a significant difference ($P < 0.05$) in fish community biomass between the statuses. As a result, fish community biomass inside Teluleu was significantly different than that of the adjacent unprotected area. Moreover, principal component ordination (PCO) determined that *Hipposcarus longiceps* (ngiaoch) and *Lutjanus gibbus* (keremlal) showed the greatest difference of biomass between MPA and the unprotected area (Figure 4). Both fish had higher biomass inside the MPA than control site.

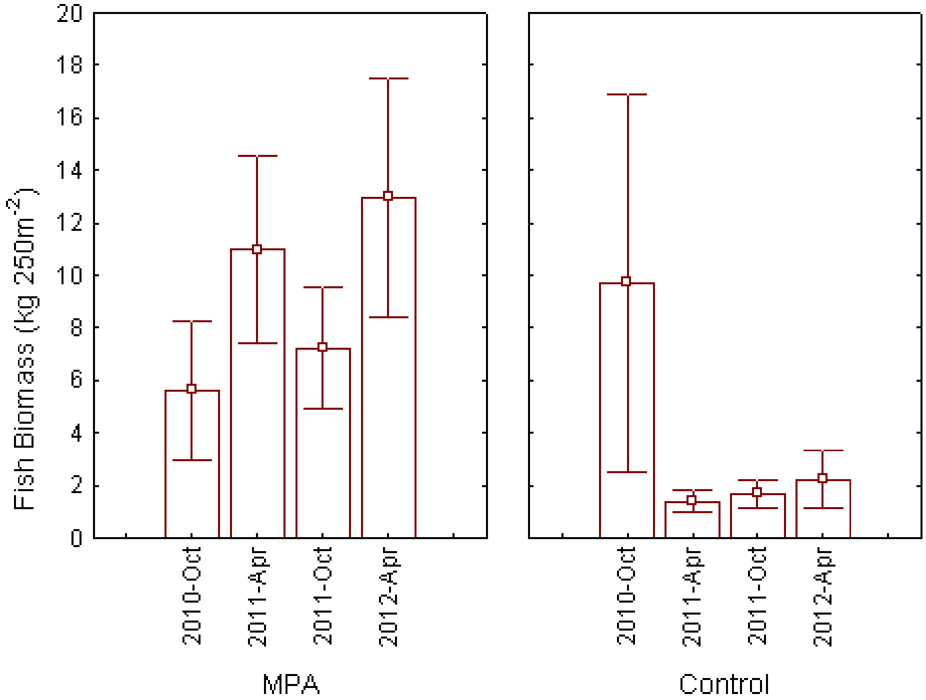

Figure 2. Fish biomass (mean ± SE) inside MPA was greater than the unprotected area (*n*=3).

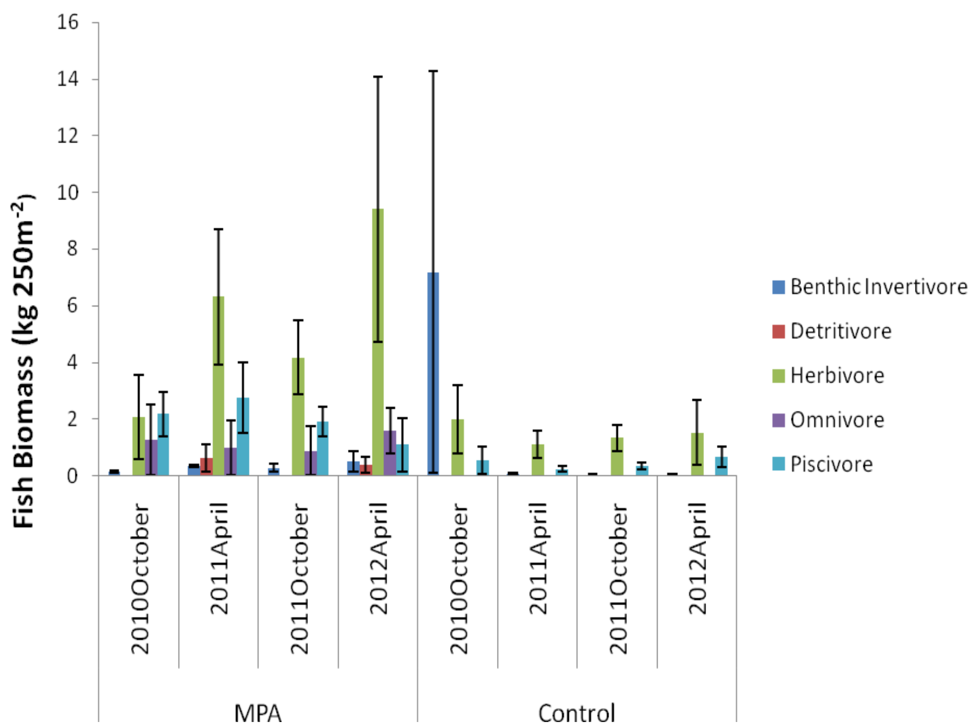

Figure 3. Fish biomass (mean +SE) in their functional group for MPA and unprotected area (*n*=3).

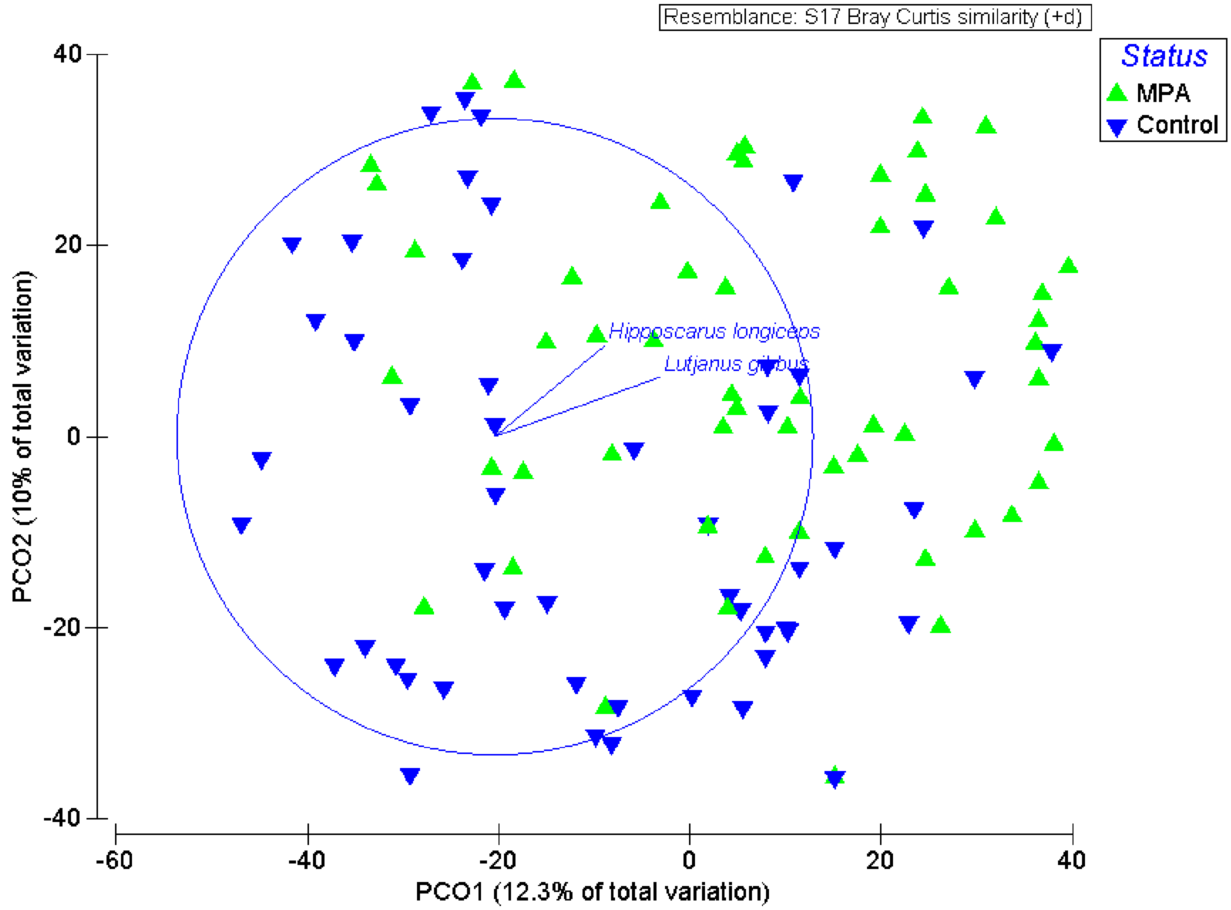

Figure 4. Principal component ordination plot of fish biomass in MPA and unprotected area (Control). *Hipposcarus longiceps* and *L. gibbus* show the greatest difference of biomass between the two statuses (*n*=3).

Fish density of Teluleu slightly decreased from October 2010 (28 ± 6 SE individual $250m^{-2}$) to October 2011, but then slightly increased in April 2012 (31 ± 7 SE individual $250m^{-2}$). In contrast, the unprotected area showed a sharp decline of fish density from October 2010 (28 ± 9 SE $250m^{-2}$) to April 2012 (6 ± 2 SE $250m^{-2}$, Figure 5). The difference in fish density was highly significant ($P < 0.001$) between zones, where fish density was greater inside the MPA than the adjacent unprotected area. There was no significant effect in fish density over time.

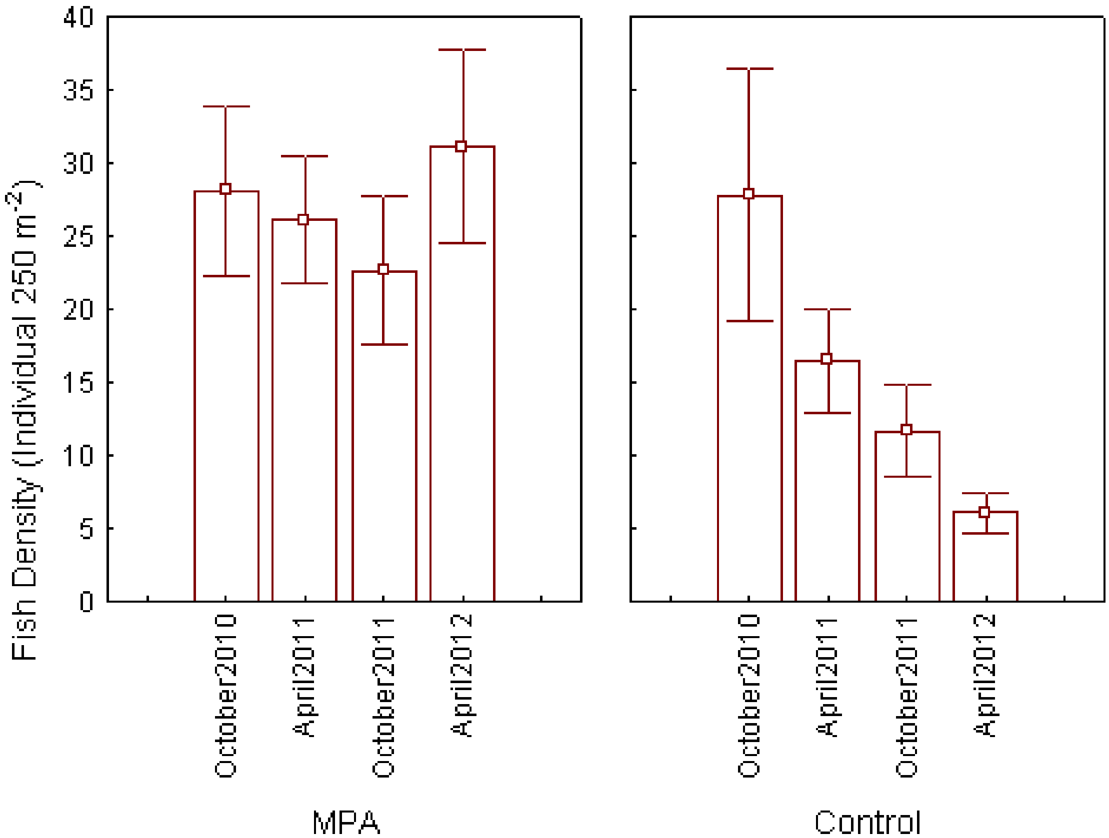

Figure 5. Fish density (mean ± SE) over time was greater inside Teluleu (MPA) than the unprotected area (*n*=3).

Fish diversity inside MPA showed a steady decline from 3 ± 0.61 SE species 250m^{-2} in October 2010 to 2 ± 0.29 SE species 250m^{-2} in April 2012, however fish species richness only slightly decreased at the unprotected area from 5 ± 0.76 SE species 250m^{-2} in October 2010 to 5 ± 0.57 SE species 250m^{-2} in April 2012 (Figure 6). Kruskal-Wallis revealed a significant difference in the effect of status on fish diversity ($P < 0.001$), such that the species richness of fish was significantly higher outside than inside of Teluleu.

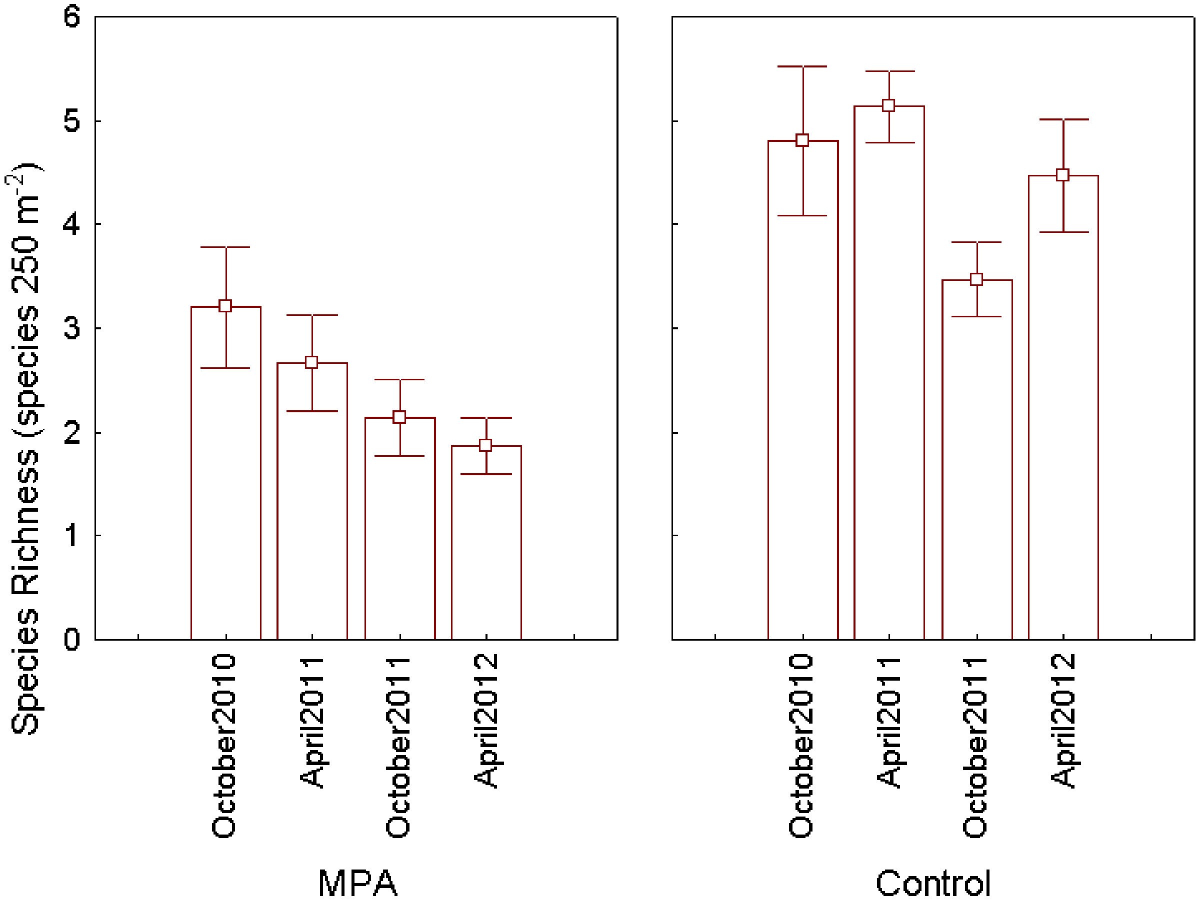

Figure 6. Fish species richness (mean ± SE) was greater at the unprotected area than the MPA (*n*=3).

B. Invertebrates

Invertebrate density was essentially similar inside the MPA from 0.6 ± 0.2 SE individual $100m^{-2}$ in 2010 to 0.5± 0.2 SE individual $100m^{-2}$ in 2012. On the other hand, the unprotected area drastically increased from 0.8 ± 0.3 SE individual $100m^{-2}$ in 2010 to 3 ± 2 SE individual $100m^{-2}$. Despite the apparent difference between the MPA and unprotected areas, this difference was non-significant (Kruskal-Wallis: $P > 0.05$). Moreover, species richness of invertebrates inside and outside the MPA was similar in 2010 and 2012 with a mean of 1 ± 1 SE species $100m^{-2}$, and the Kruskal-Wallis test demonstrated that there was no significant difference ($P > 0.05$) between the MPA and unprotected area.

Of all the major group of invertebrates, sea cucumbers were most abundant in both areas during the monitoring period, and drove most of the observed results. Inside the MPA, sea cucumber density did not change over time and remained at 2 ± 1 SE individual 100m^{-2}. In contrast, there was a huge increase of sea cucumber at the unprotected area from 4 ± 2 SE individual 100m^{-2} in 2010 to 16 ± 15 SE individual 100m^{-2} in 2012 (Figure 7). Further investigation of sea cucumber population show that *Stichopus vastus* (ngimes) density was greatest in the MPA, while *Actinopyga sp*. (eremrum) and *Bohadschia vitensis* (mermarch) dominated the reference site. In the MPA, density of *S. vastus* increased from 2010 (1 ± 0.3 SE individual 100m^{-2}) to 2012 (2 ± 1 SE individual 100m^{-2}). In the reference site, a huge increase in density occurred for *Actinopyga sp.* from 0.33 ± 0.33 SE individual 100m^{-2} in 2010 to 10 ± 10 SE individual 100m^{-2} in 2012 (Figure 8). *Stichopus vastus* had the largest mean size in both areas for both survey periods. In the MPA average size of *S. vastus* increased from 5.8 ± 0.31 SE cm in 2010 to 8.2 ± 5.3 SE cm in 2012, while in the unprotected area the mean size decreased from 5.3 ± 3.3 SE cm in 2010 to 4.9 ± 3.0 SE cm in 2012 (Figure 9).

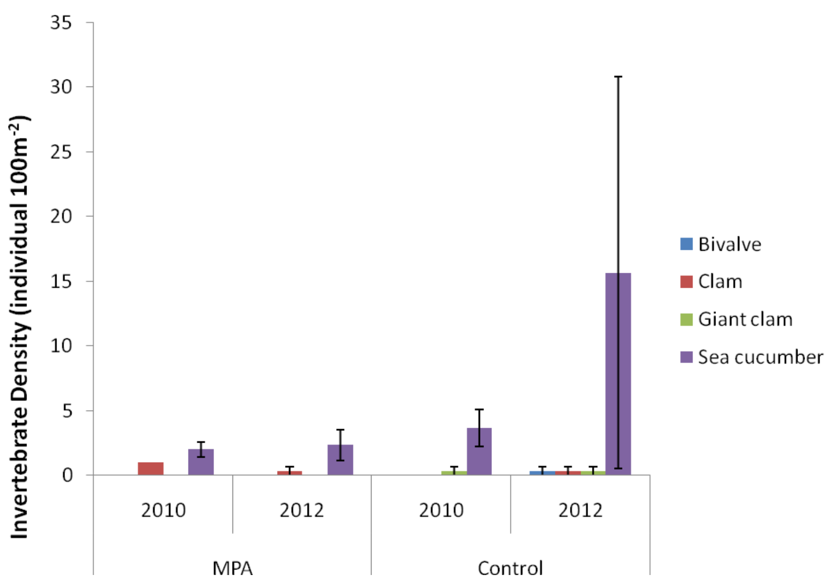

Figure 7. Invertebrate density (mean ± SE) for the MPA and unprotected area. (*n*=30)

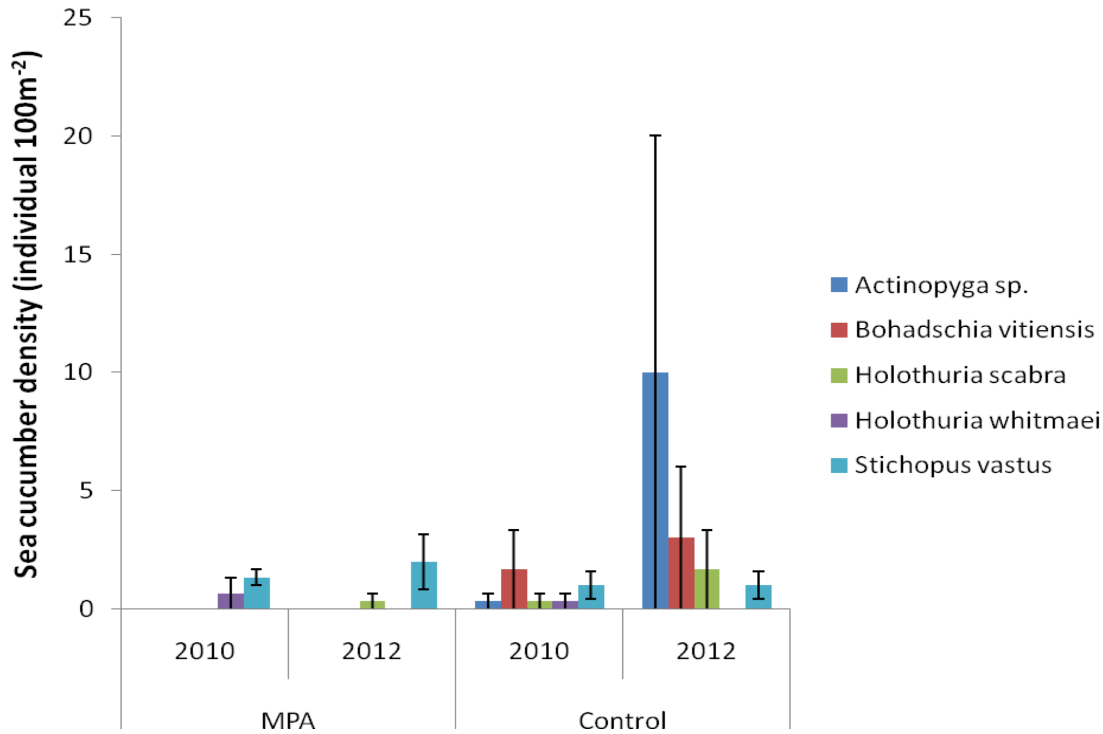

Figure 8. Density of sea cucumber (mean ± SE) of MPA and unprotected area (*n*=3).

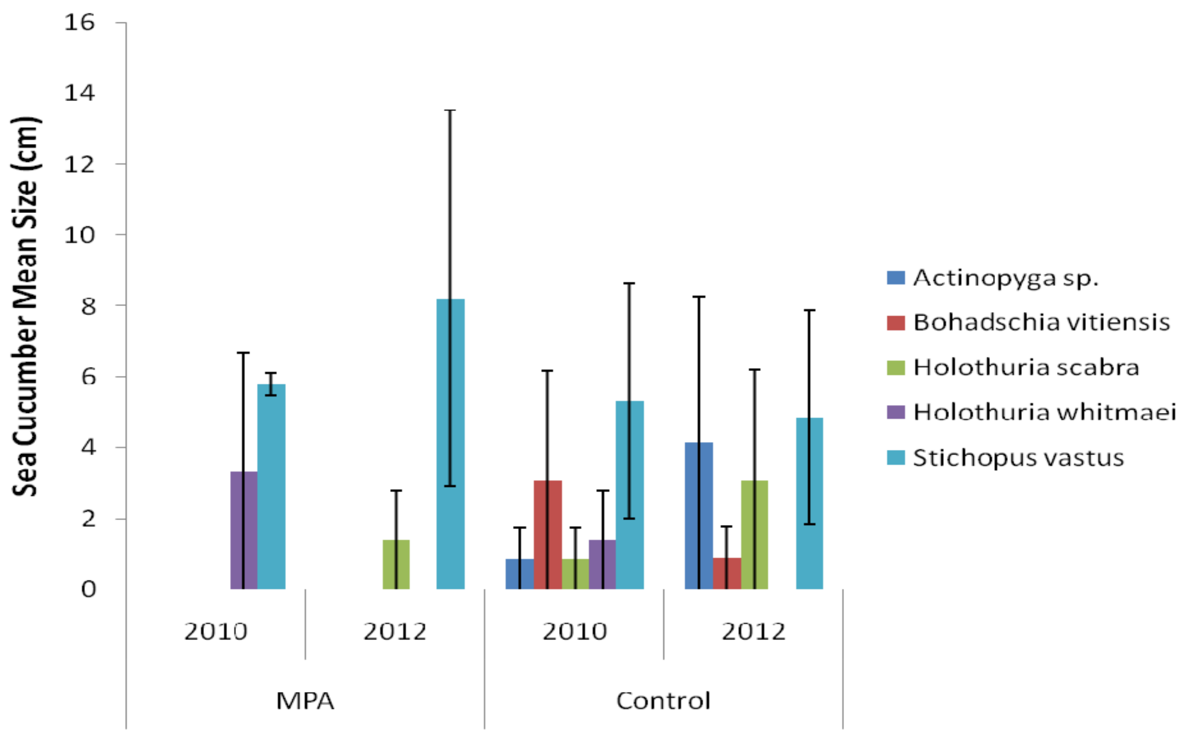

Figure 9. Sea cucumber size (mean ± SE) inside MPA and at the unprotected area (*n*=3).

C. Benthic community

Percent cover of macroalgae (37 ± 52 SE %) in Teluleu was lower than the unprotected area (53 ± 61 SE %), whereas there were more carbonates inside the MPA (29 ± 41 SE %) compared to the unprotected area (5 ± 8 SE %; Figure 10). Coral cover was slightly higher inside the MPA (9 ± 13 SE %) than the unprotected area (6 ± 9 SE %), however, the difference was not significant (Kruskal-Wallis: P > 0.05). The unprotected area had higher sand cover (27 ± 29 SE %) compared to the MPA (20 ± 24 SE %).

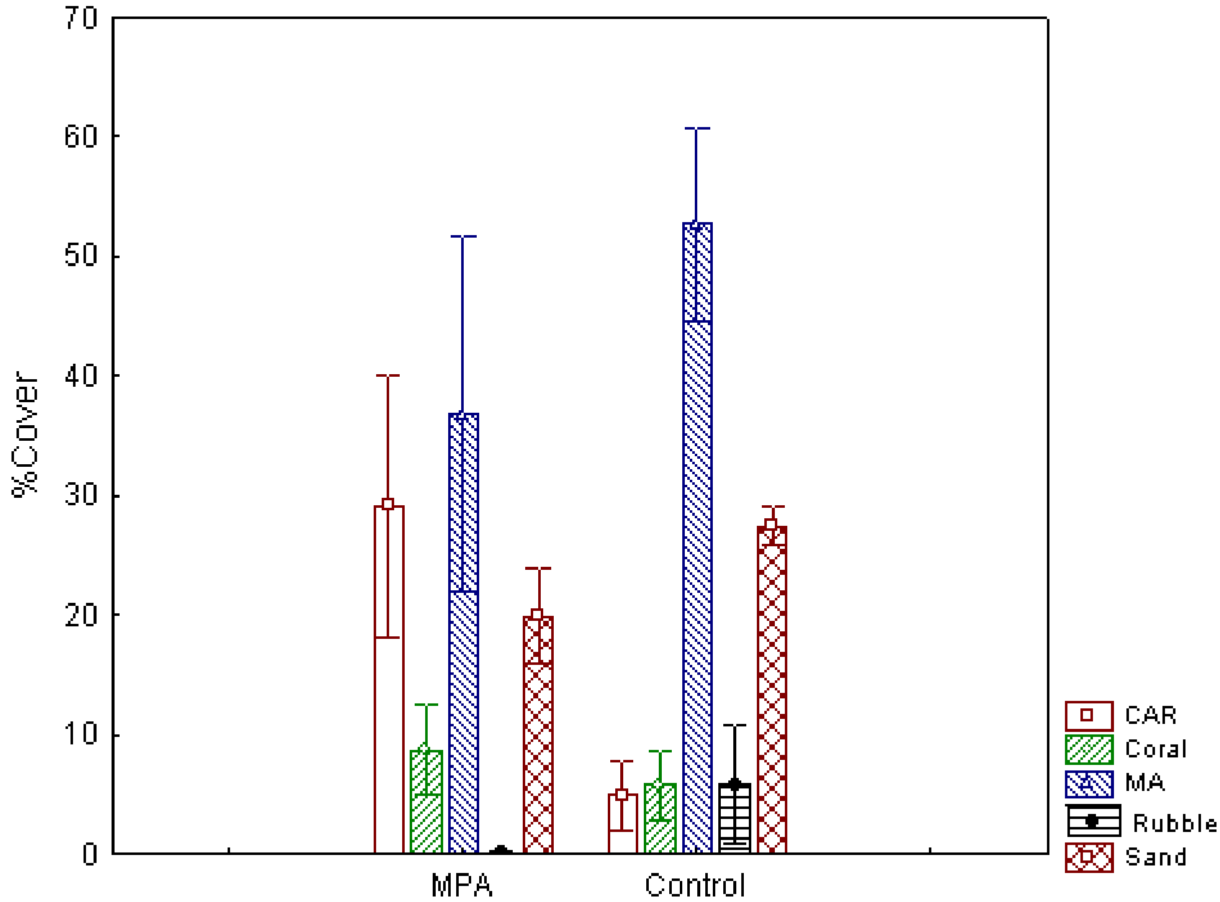

Figure 10. Benthic community cover (mean ± SE %) of the MPA and unprotected area (*n*=3).

D. Coral recruits

There was a higher density of coral recruits observed inside the MPA (7 ± 2 SE individual $3m^{-2}$) compared to the unprotected area (2 ± 1 SE individual $3m^{-2}$, Figure 11), however this difference was non-significant (Kruskal-Wallis: $P > 0.05$). Much greater diversity of coral recruits was observed inside the MPA (1 ± 0.31 SE species $3m^{-2}$) than the unprotected area (0.4 ± 0.13 SE species $3m^{-2}$, Figure 12). Despite this huge difference, species diversity was significantly similar (Kruskal-Wallis: $P > 0.05$). *Porites sp.* had the greatest mean size of all the coral recruits for both marine areas. Mean size of *Porites sp.* inside the MPA (1.3 ± 0.34 SE cm) was similar to the unprotected area (1.3 ± 0.45 SE cm, Figure 13).

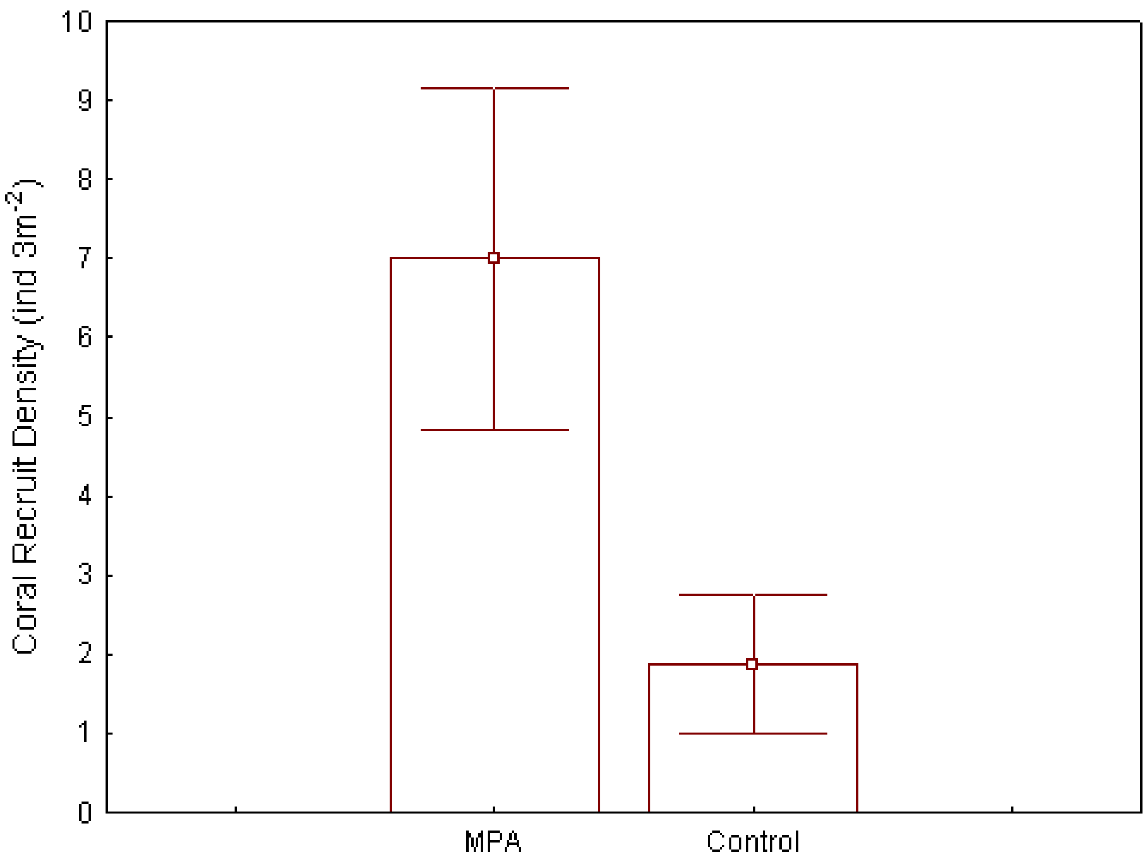

Figure 11. Density of coral recruit (mean ± SE) of the MPA and unprotected area (*n*=3).

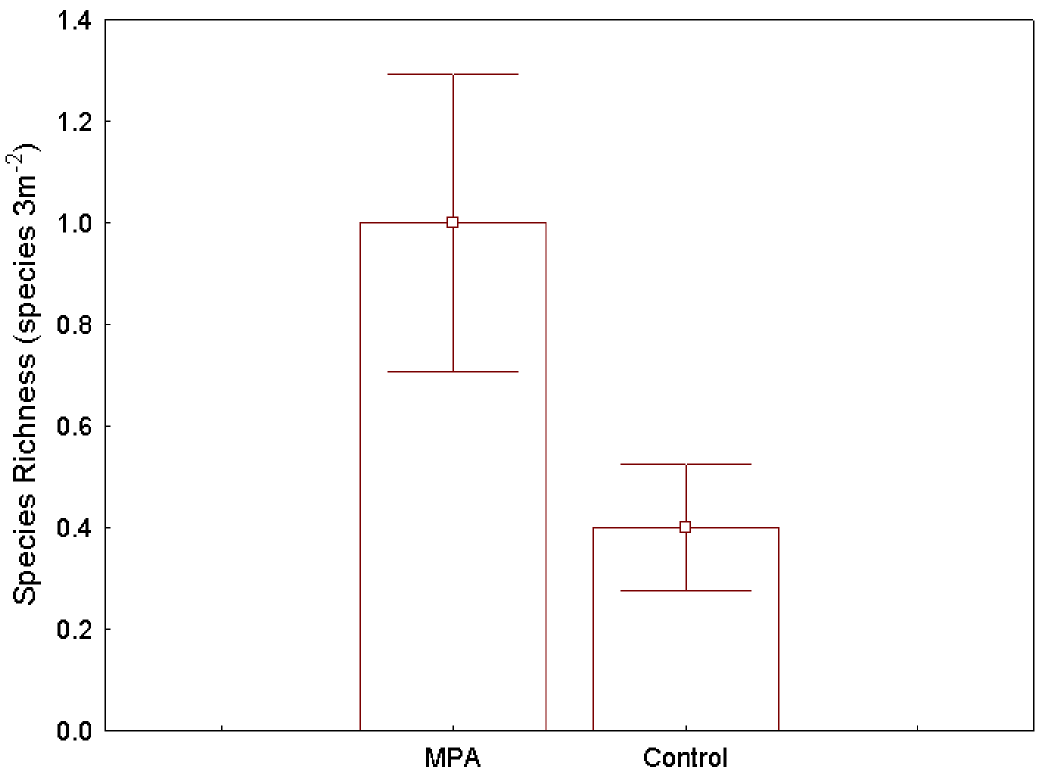

Figure 12. Species richness of coral recruits (mean ± SE) was higher inside the MPA than the unprotected area (*n*=3).

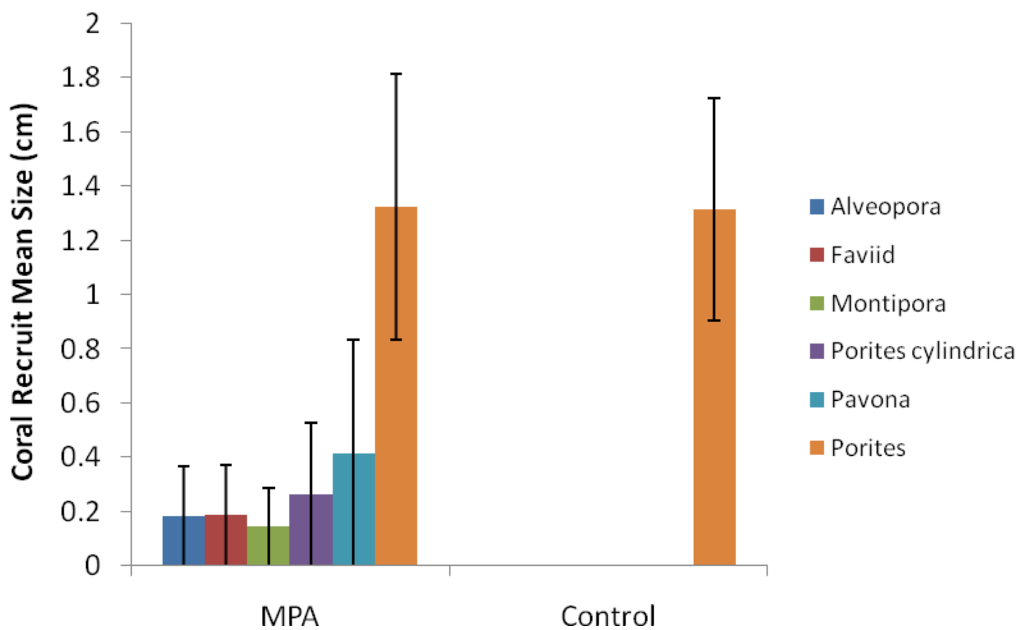

Figure 13. Average size (mean +SE) of coral recruits at MPA and the unprotected area (*n* = 3).

E. Seagrass survey

There were 3 species of seagrass surveyed, *Cymodocea rotundata* (Cr), *Enhalus acoroides* (Ea), and *Thalassia hemprichii* (Th). *Thalassia hemprichii* was the most dominant species in both survey periods. Inside Teluleu, *T. hemprichii* slightly decreased from 5.7 ± 6.4 SE % in 2011 to 4.5 ± 5.3 SE % in 2013. Similarly, the unprotected area had a slightly decreased cover of *T. hemprichii* from 7.9 ± 8.8 SE % in 2011 to 6.4 ± 7.2 SE % in 2013 (Figure 14). Percent cover of Th was significantly lower (Kruskal-Wallis: $P < 0.05$) in the MPA than the unprotected area. There was no significant difference for Th % cover over time.

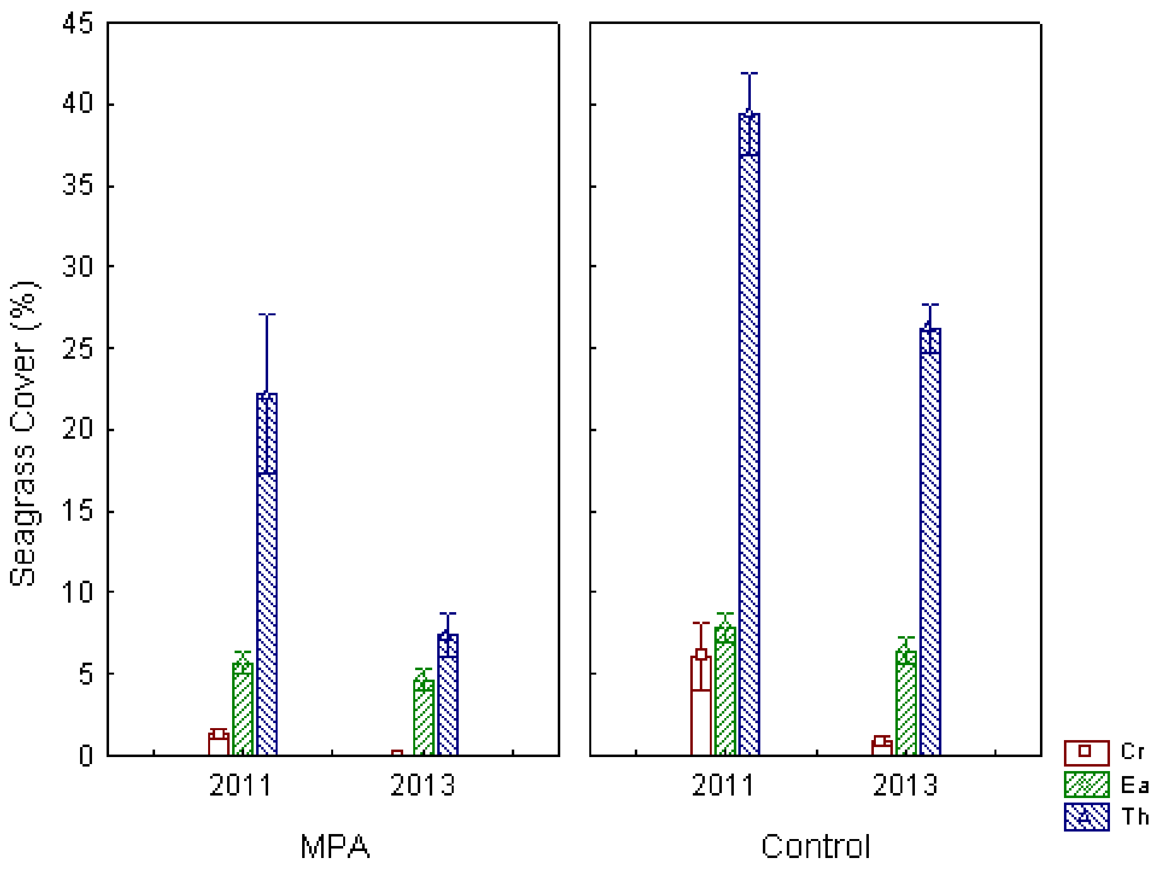

Figure 14. Percent cover of seagrass (mean ± SE %) inside MPA and the unprotected area.

DISCUSSION

Observations on fish population inside Teluleu CA showed a positive impact from protection. Fish density was greater inside Teluleu than the unprotected area. Within the MPA, fish density slightly increased but fish biomass increased almost threefold within 2 years. Therefore, not only is fish density increasing inside Teluleu after 2 years, but that the fish are increasing in size as well. Larger mature fish can reproduce offspring that have better survivorship than offspring of smaller fish (Begg et. al., 2005). Fish inside Teluleu then have the potential to increase its population, and become the source of successful offspring for all of the seagrassbed. With the biomass data, *H. longiceps* (ngiaoch) and *L.gibbus* (keremlal) were determined to be most abundant inside Teluleu. Ngiaoch (*H. longiceps*), which are herbivores, are valuable fish for local consumption and fish markets in Palau, including the residents of Peleliu State. MPAs remove fishing pressure and yield increased biomass of herbivorous fish (Mumby et. al., 2006 and 2007). Herbivores are important in seagrass because they control macroalgae from overgrowing and dominate the seagrass bed (Seastar survey Ltd., 2012). Therefore it is important to protect herbivorous fish because they play an important ecological role in sustaining a healthy seagrass bed, such as Teluleu.

Sea cucumbers were the dominant invertebrate, and drove the observed result in the analysis. *Stichopus vastus* (ngimes) was the dominant species inside Teluleu while *Actinopyga sp.* (eremrum) dominated the unprotected area. The next most dominant invertebrates were clams. Finally, giant clams (otkang) were the least abundant invertebrates and were only present in the unprotected area.

Teluleu Conservation Area is dominated by sand and macroalgae. Unfortunately, seagrass was analyzed as macroalgae (MA) with CPCe, explaining the huge cover of MA instead of seagrass. Therefore, these data need to be considered cautiously. Through the seagrass survey, however, *T. hemprichii* was determined as the dominant species in both Teluleu and the unprotected area. Coral cover is relatively small, and is not different from coral cover of the unprotected area. However, coral recruit density is greater inside Teluleu CA than the unprotected area.

Teluleu Conservation Area is definitely making progress as a successful marine reserve. When comparing the biological indicators across the statuses alone, many of the indicators show positive effect for the MPA. However, it requires a longer period of protection and monitoring to determine whether these biological indicators have a consistent positive effect over time.

Acknowledgements

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Table 1. Fish sampled

Palauan name	Scientific name	Palauan name	Scientific name
1. Mesekuuk	*Acanthurus xanthopterus*	17. Derringel	*Lutjanus monostigma*
2. Berdebed	*Bolbometopon muricatum*	18. Besechamel	*Monotaxis grandoculis*
3. Erobk	*Caranx ignobilis*	19. Cherangel	*Naso lituratus*
4. Orwidel	*Caranx melampygus*	20. Um	*Naso unicornis*
5. Ngimer	*Cheilinus undulatus*	21. Bikl	*Plectorhinchus albovittatus*
6. Budech	*Choerodon anchorago*	22. Mokas	*Plectropomus laevis*
7. Meteungerel	*Epinephelus fuscoguttatus*	23. Mertebetabek	*Scarus gohbban*
8. Ngiaoch	*Hipposcarus longiceps*	24. Mellemau	*Scarus sp.*
9. Komud	*Kyphosus sp.*	25. Beduut	*Siganus argenteus*
10. Kroll	*Lethrinus erythropterus*	26. Reked	*Siganus doliatus*
11. Itotech	*Lethrinus harak*	27. Meyas	*Siganus fuscescens*
12. Udech	*Lethrinus obsoletus*	28. Kelsebuul	*Siganus guttatus*
13. Melangmud	*Lethrinus olivaceus*	29. Reked	*Siganus puellus*
14. Kedesau iengel	*Lutjanus argentimaculatus*	30. Bebael	*Siganus punctatus*
15. Kedesau	*Lutjanus bohar*	31. Merdubech	*Sphyraena barracuda*
16. Keremlal	*Lutjanus gibbus*		

Table 2. Invertebrates sampled

Palauan name	Scientific name
1. Eremrum	*Actinopyga sp.*
2. Mermarech	*Bohadschia vitiensis*
3. Duadeb	*Hippopus hippopus*
4. Molech	*Holothuria scabra*
5. Bakelungal	*Holothuria whitmaei*
6. Ngimes	*Stichopus vastus*
7. Oruer	*Tridacna crocea*
8. Kism	*Tridacna derasa*
9. Otkang	*Tridacna gigas*
10. Melibes	*Tridacna maxima*
11. Kim	*Tridacna sp.*