Status of seagrasses fishes and macro-invertebrates at Teluleu Conservation Area from 2011 to 2018

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Abstract

Palau has a protected area network (PAN), established in 2003, which consists of 14 marine protected areas. Palau International Coral Reef Center (PICRC) conducts ecological monitoring at these MPAs to observe the ecological conditions within their different habitats and their effectiveness at protecting marine resources. This study was conducted at Teluleu Conservation Area (CA), located in Peleliu state, which has been protected since 2001. Surveys recording the status of fish, macro-invertebrates, juvenile corals, seagrass cover and benthic cover were conducted within three stations in the reef flat habitat both inside and outside the conservation area. Our findings demonstrate that the protection benefited fish populations in Teluleu over time. The fish biomass was high (~ 7kg/ 125m^2) and relatively stable through time and remains the highest of all other protected seagrass beds in Palau. The protection effect did not seem to have benefited seagrass species over time. We suspect that there may be other parameters such as water quality that need to be measured due to the proximity of land development. The population of sea cucumbers inside Teluleu has not recovered since fishing / harvest closure and is unlikely to improve in the future due to the life history traits of these species and the small size of the conservation area.

Introduction

Natural resource conservation is anchored deep in Palau’s traditions (Johannes 1981). The concept of ‘bul’ which traditionally prohibited the use of natural resources for restricted periods of time (Johannes 1981), has now evolved into modern conservation management through the concept of Marine Protected Areas (MPAs) or also called Conservation Areas (CAs). The first MPA to be established in Palau was Ngerukuid in the southern lagoon of Koror State in 1956. Later, spawning aggregation areas such as Ngerumekaol and Ebiil channel became MPAs. Today, there are 35 Marine Protected Areas in Palau (Friedlander et al. 2017) and 22 of them are full no- take zones. In 2003, the government of Palau established the Protected Area Network (PAN), which currently consists of 14 no-take MPAs and 13 terrestrial protected areas. The PAN is one tool used by the government of Palau to protect the country's biodiversity and resources from overuse, and to participate in regional and global conservation initiatives such as the Micronesia Challenge (Houk et al. 2015). The PAN is constantly evolving by using novel research findings to improve its design in order to make it as effective as possible.

Palau International Coral Reef Center (PICRC) is monitoring PAN MPAs to provide scientific support on their effectiveness. In 2014 and 2015, PICRC gathered baseline information at all PAN MPAs in Palau (Gouezo et al. 2016). Subsequently, every two years, PICRC will re-visit the PAN MPAs to monitor the status and trends of natural resources and assess their effectiveness over time.

This study was conducted in Teluleu Conservation Area (CA) in Peleliu (7°3.137’ N, 134°16.189’ E) (Fig.1), which has been protected since 2001 under state legislation and became a PAN site in 2012. Teluleu CA is a strict nearshore no-take zone that encompasses a seagrass bed which acts as a nursery ground for several species of fish and macroinvertebrates (Peleliu Management Team and PCS 2012).

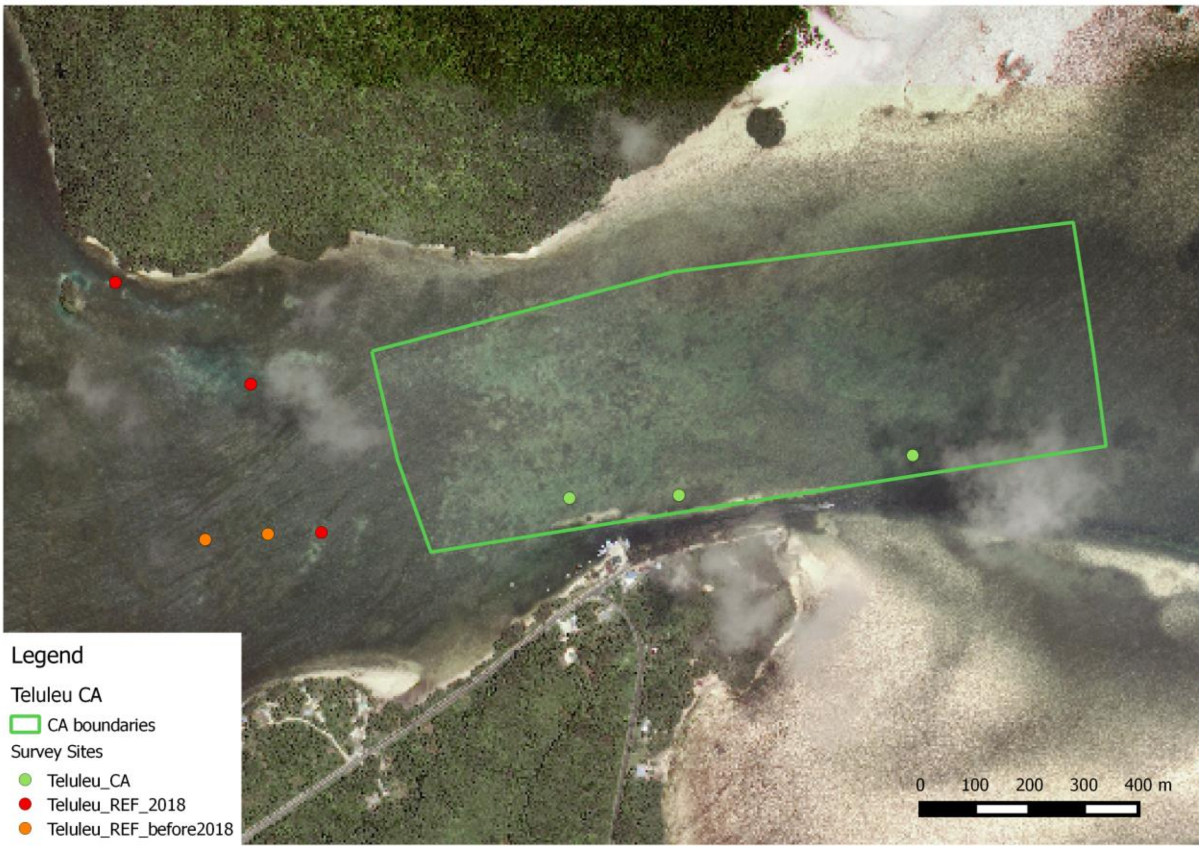

Figure 1: Satellite view of Teluleu Conservation Area (green boundaries) with surveys sites inside and outside the protected area. Sites outside the CA changed over time.

The objectives of this study are (1) to show the status of natural resources within the main habitat (reef flat) of the conservation area, (2) to compare them to available historical data, and (3) to compare them to a nearby non-protected reference area in 2018.

Methods

1. Study sites

Teluleu CA covers an area of 540,016 m^2 which encompasses one habitat: reef flat. Three survey sites were surveyed both inside and outside the CA (Fig. 1). In 2018, survey sites in the reference areas were moved to seagrass beds more similar to the one inside the CA.

2. Ecological surveys

Ecological surveys were conducted at each study site. In the reef flat, five 25 m transects were laid consecutively, with a few meters separating each transect. Data recorded along these transects included seagrass percentage cover (at the species level) in 0.5 m quadrat placed every 5 meters, fish size and abundance in 5 m wide belt, and edible macroinvertebrates in 2 m wide belt.

3. Data processing and analysis

Data were entered into excel spreadsheets. The biomass of fish was calculated using the total length-based equation:

$$W = aTL^b$$

where W is the weight of the fish in grams, TL the total length of the fish in centimeters (cm), and a and b are constant values from published biomass-length relationships (Kulbicki et al. 2005) and from Fishbase (http://fishbase.org).

Prior to running statistical tests, the data was checked for normality using histograms and Shapiro-Wilk W test. When non-normal, data was Log(x+1) transformed and re-tested. When data were normal, linear models were used to compare the different ecological indicators (1) between CA and reference area and (2) within CA through time. When data were non-normal, non-parametric Mann-Whitney U and Kruskal Wallis tests were used instead.

Results

Findings from the 2018 monitoring surveys are presented below, comparing this year's results with available monitoring data from previous years for each ecological indicator.

1. Seagrass beds

PICRC's long-term monitoring data at seagrass beds in Peleliu showed that the coverage of seagrass has been fluctuating through time (LM, $p < 0.001$) (Figure 2). The fluctuation was found to be similar in the CA and reference area. Throughout time, the coverage of seagrass was always higher in the reference area compared to the CA (LM, $p < 0.001$). References sites in 2018 were changed for that reason.

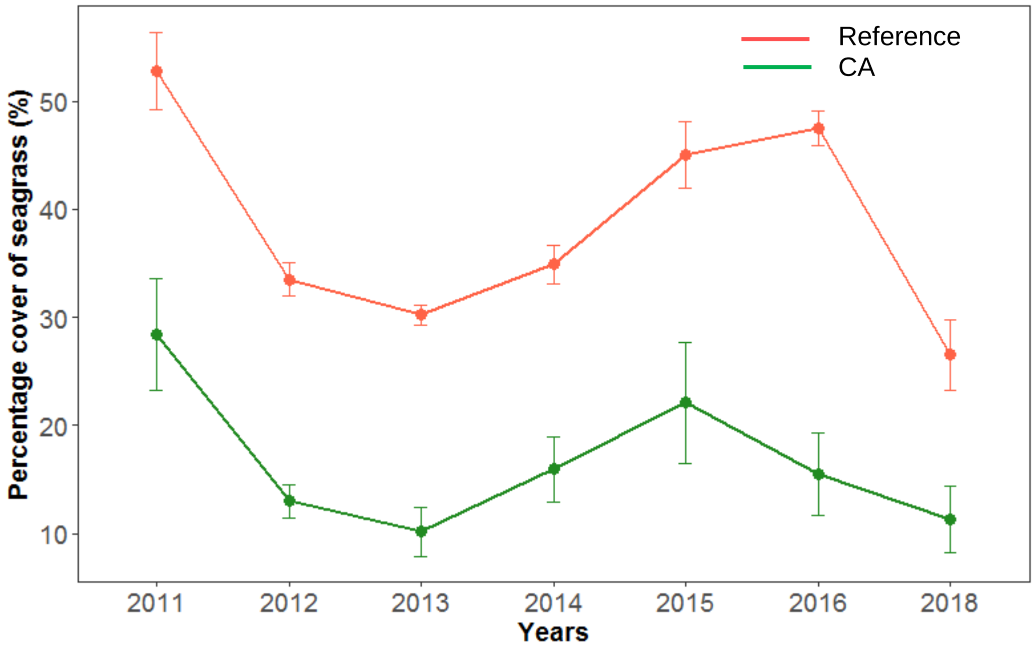

Figure 2: Bar plots showing the mean percentage cover (± SE) of seagrass through time, green is CA and red is reference zone

The two areas surveyed were majorly dominated by *Thalassia hempirichii* and *Enhalus acoroides* (Figure 3) while the other three species occurred in low abundance (< 5% cover). Through time, *E. acaroides* cover remained quite stable. The coverage of *T. hempirichii* was the species that fluctuated the most through time.

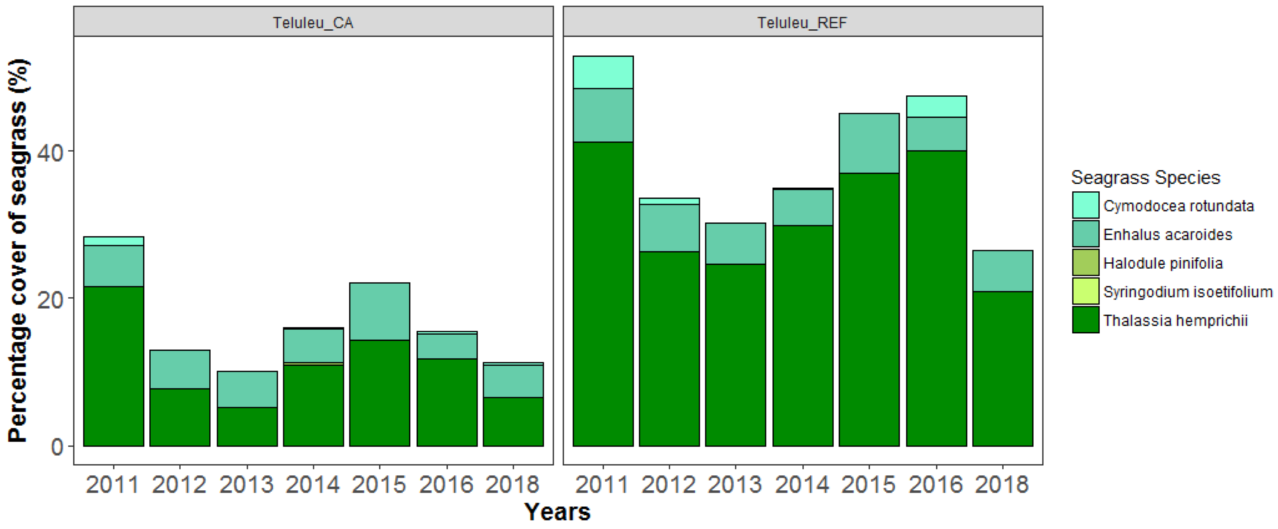

Figure 3: Stacked bar plot showing the mean percetnage cover of recorded seagrass species at the CA and reference area through time.

2. <u>Fish abundance and biomass</u>

The biomass of commercially important fish species fluctuated through time but was consistently higher in the CA than in the reference area (Mann Whitney U, P < 0.001), except in 2018 (Mann Whitney U, P = 0.29) (Fig.4, Fig.6), when the reference sites location was changed.

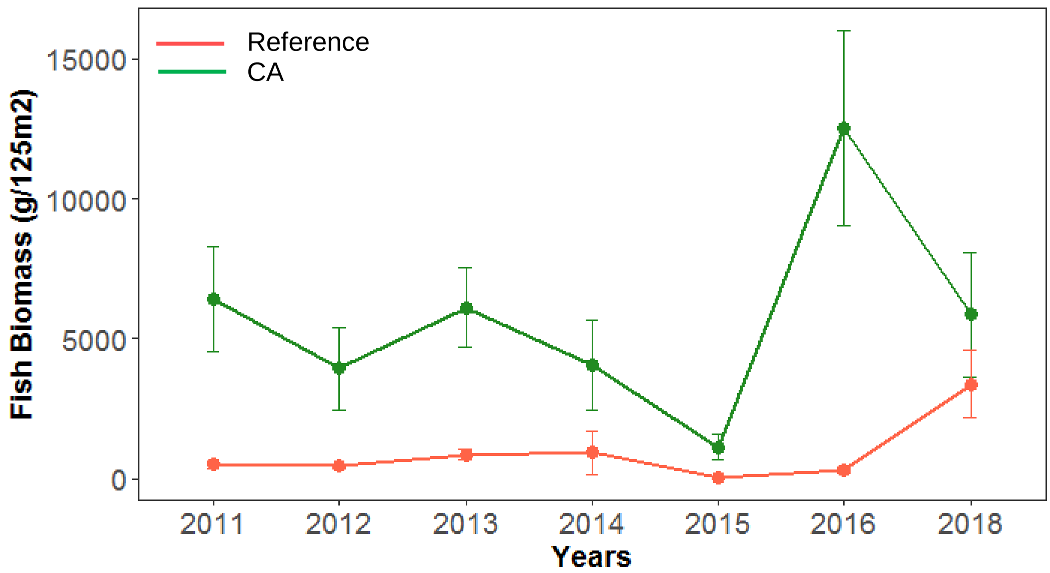

Figure 4: Trends in biomass (± SE) of commercially important fish species inside and outside the CA

Teluleu CA had a consistently more diverse and abundant fish community than the reference area through time. Kemedukl (*Bolbometopon muricatum*) was rarely observed in the reference area but were observed in all but one year in the CA. Siganids increased in the reference area in the 2018 surveys. During the 2018 surveys, both fish abundance and biomass was not significantly different inside or oustide the conservation area (Mann Whitney U, P > 0.3) (Fig. 6).

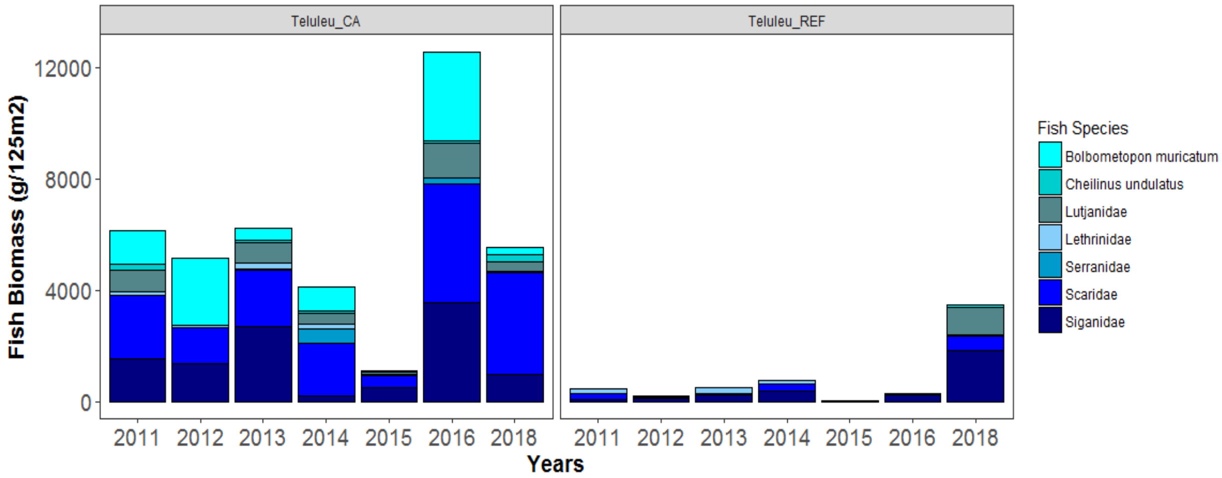

Figure 5: Stacked bar plot showing the average biomass of the major fish families inside and outside the CA.

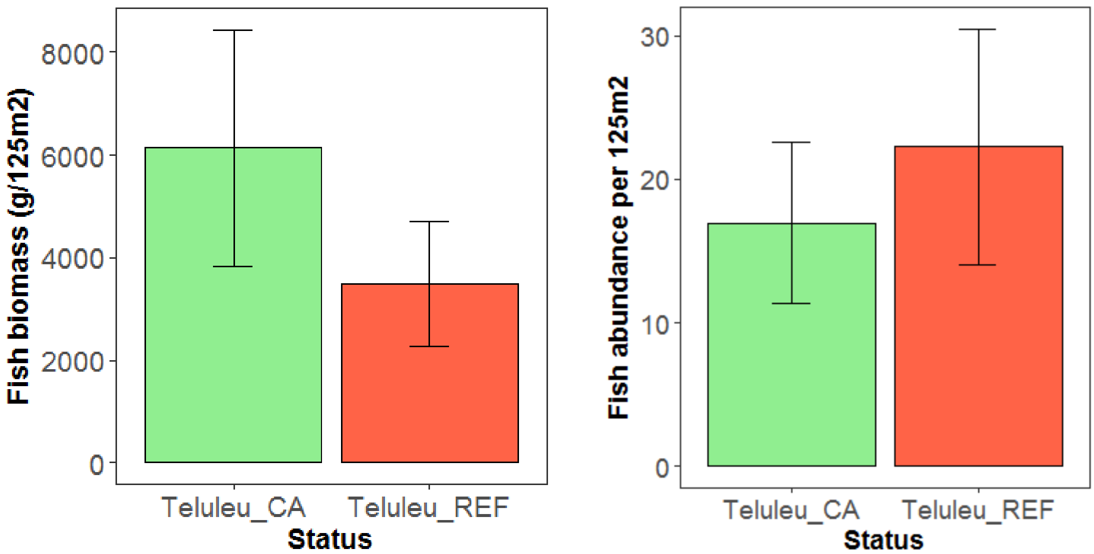

Figure 6: Bar plot showing the biomass (right) abundance (left) of food fish (± SE) in the MPA (green) and the reference area (red) in 2018 surveys.

3. Edible macro-invertebrates

Most edible macroinvertebrates surveyed were sea cucumbers. Their abundance fluctuated through time in the reference area but not in the CA (Fig. 7). Since 2014, the abundance of sea cucumbers has remained relatively steady, both inside and outside the protected area (Kruskal Wallis, $P > 0.05$) (Fig. 7). Low abundance of clams was observed through time, with less than 0.2 individuals per 50 m^2.

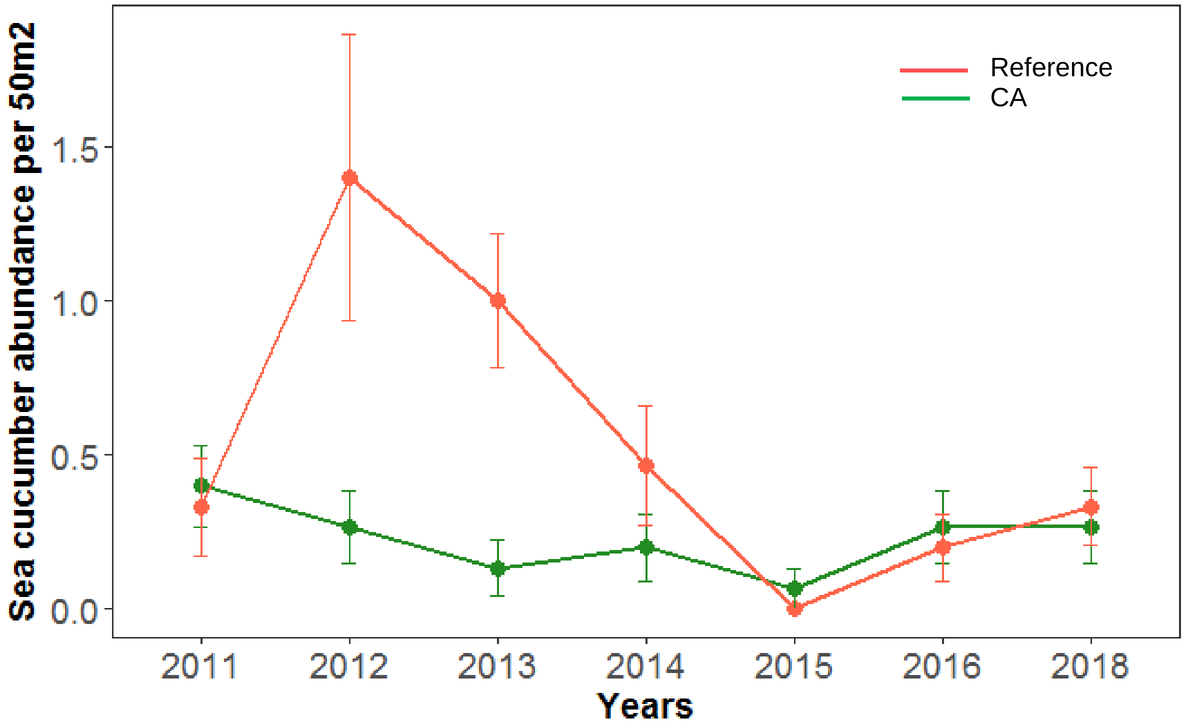

Figure 7: Trends in abundance (± SE) of sea cucumbers inside and outside the CA

Discussion

PICRC has been monitoring the reef flat in Teleleu and the surrounding area since 2011. Our findings show that the biomass of commercially important fish species was high in the conservation area, the seagrass coverage has decreased over time, and the macro-invertebrates' abundance remained low through time.

Commercially targeted fish populations have benefited the most from protection. Despite some fluctuations through time, the overall fish biomass remained around 7kg/ 125m^2, which is the highest biomass recorded in protected seagrass beds in Palau (Sampson et al. 2014; Rehm et al. 2015). The fish communities consisted mainly of large and small parrotfish and rabbitfish. One of the reasons for biomass fluctuations through time is the schooling behavior of certain groups of fish, especially Siganid species. In 2018, the location of reference sites changed as the previous ones did not have a consistently similar habitat compared to Teluleu. In 2018, the biomass and abundance of fish was not significantly higher in the CA compared to the reference area, but remains very high for a seagrass bed. This implies that there might be a spillover effect to the surrounding areas of Teluleu.

The coverage of seagrass has been decreasing in Teluleu since 2011, and now averages around 11%. The reasons for this decline are not very clear. Typhoon Bopha in December 2012 led to the destruction of coral reefs on the exposed eastern reefs (Gouezo et al. 2015). It is not clear whether the storm inflicted any damage in the sheltered location of Teluleu or modified the current flow in the area Another possibility, is that the water quality in Teluleu has been degrading since 2011 as the main port and sewage outflow is located nearby. Seagrass beds are susceptible to anthropogenic impacts such as nutrient enhancement and terrestrial run-off (Duarte 2002). Therefore, we suggest that additional water quality measurements should be incorporated into monitoring MPAs, and seagrass beds to be able to track changes in turbidity and nutrients through time that may coincide with land development.

The abundance of edible sea cucumbers has remained low in Teluleu throughout the study and has decreased in the reference area. It appears that sea cucumber populations have been depleted in the area due to the proximity of the reef flat to the main village. For instance, edible sea cucumber densities in un-poached location in the Chagos in the Indian ocean ranged from 4.25 to 27.7 per 100 m^2 (Price et al. 2010), which is 4 to 27 times higher than in Teluleu. There has been no sign of recovery in the past seven years inside Teluleu. Sea cucmber stocks can be depleted rapidly because of their sedentary behavior, late sexual maturation, density-dependent reproduction traits and lengthy pelagic larval stages (e.g. 14 days for *H. scabra*) (Uthicke and Benzie 2001; Uthicke et al. 2009). As a result, many sea cucumber fisheries worldwide have collapsed. Studies have shown slow -- or even no recovery following fishing closure because of the life history traits of sea cucumbers mentioned above (Uthicke et al. 2004, 2009; Cariglia et al. 2013). The small size of the Teluleu CA will limit the recovery of sea cucumber because of (1) their inability to find mates to sexually reproduce and (2) recruitment failure inside Teluleu due to the length of the larval stage. It was shown that 10-50 individuals per hectare of the same species is required to ensure successful density-dependent sexual reproduction (Bell et al. 2008). Restocking with hatchery-reared juveniles could provide a fast track to the recovery of sea cucumbers inside Teluleu. However, it is costly and may not last over time due to the small size of the conservation area (~ 0.5 km^2) and future recruitment likely occurring outside its boundaries.

Our study shows that the protection provided by the CA benefited fish populations in Teluleu. Fish biomass was relatively stable through time and remains the highest of all protected seagrass beds in Palau. The protection effect did not seem to benefit seagrass species and measuring certain water quality parameters will likely provide valuable information about the pressures on seagrass inside and outside the CA. Lastly, the population of sea cucumbers has not recovered since fishing / harvesting closure and is unlikely to occur in the future due to the small size of the conservation area and the life history traits of sea cucumbers. Other measures would have to be taken to increase the likelihood of sea cucumber population recovery, such as expanding the conservation area boundaries and restocking it with juvenile sea cucumbers.

Acknowledgment

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