Baseline Assessment of IleyaklBeluu Conservation Area

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PICRC Technical Report No 15-14

June 2015

Abstract

Marine Protected Areas (MPAs) have been used worldwide to protect biodiversity and increase marine resources' yields. In 2003, the Republic of Palau established the Protected Areas Network (PAN) to help improve the management and effectiveness of Palau's MPAs. In 2006, Palau made a commitment to effectively conserve 30% of its near shore habitat through the Micronesia Challenge. Yet, very few data on the baseline status of MPAs that are part of this network have been collected. This present study was conducted to collect baseline ecological data within the different habitats of IleyaklBeluu Conservation Area (CA) located in Ngardmau State of Palau, to assess the effectiveness of the MPA over time. Findings demonstrated that IleyaklBeluu CA had high coral cover, high recruitment rates and high Scaridae abundance and biomass, which are essential components to coral reef resilience. IleyaklBeluu CA is an important link to the PAN on the west coast of Palau.

Introduction

Marine Protected Areas have been widely used as an effective conservation tool against anthropogenic threats such as overfishing (Halpern et al. 2009; Lester et al. 2009; Edgar et al. 2014). MPAs have been proved to increase fish biomass, abundance, mean size and species biodiversity (Friedlander and DeMartini 2002; Abesamis et al. 2006; Hamilton et al. 2011). In addition, it has been shown that they also benefit adjacent non-protected areas (McClanahan and Mangi 2000; Agardy et al. 2003). The Republic of Palau, located in western Micronesia, has made great advances in its marine protective management. In 1994, the Marine Protection Act implemented fishing restrictions on several commercially-important species, and in 2003 the Palauan government established the Protected Areas Network (PAN). This network aims to effectively protect both terrestrial and marine habitats of Palau. In 2006, an international initiative called the Micronesia Challenge (MC), required Micronesian nations (The Federated States of Micronesia, The Republic of Marshall Islands, Guam, The Commonwealth of the Northern Marianas Islands, and The Republic of Palau) to commit to effectively protect at least 20% of their terrestrial habitats and 30% of their marine habitats by 2020 (Micronesia Challenge Steering Committee 2011). This initiative far exceeds the current request for countries to protect 10% of their marine and terrestrial habitats through international conventions and treaties (United Nations 1992). The Palauan government is using its PAN to meet the goals of the MC and to effectively expand its protected areas.

Despite these great advances since 2006, very little information has been gathered on the baseline status of MPAs. As an organization that is committed to guide efforts supporting coral reef stewardship through research and its applications for the people of Palau, Palau International Coral Reef Center (PICRC) collects baseline ecological data for all MPAs sites. IleyaklBeluu Conservation Area (CA) is located in Ngardmau State at 7°38.998’N, 134°32.799’E. The conservation area includes 4 marine habitats: fore reef, reef crest, reef flat and lagoon; the total area is 359,333 m^2. IleyaklBeluu CA became a marine reserve under Ngardmau State Law in 2004 where dredging, dumping, aquaculture and harvesting of the mother-of-pearl snail *Trochus niloticus* (Semum) were prohibited. Fishing for community purposes was still allowed until 2009 when IleyaklBeluu CA then became a no-take zone and part of the PAN.

In order to meet the goals of the MC, the Palauan government has to show that their MPAs network is effective at protecting biodiversity and increasing marine resources. A previous survey was conducted at IleyaklBeluu CA in 2010-2011 sampling three sites on the fore reef habitats and comparing the data with a reference site close-by (Nestor et al. 2013).The sampling design of this past survey only focused on one habitat (fore reef) and therefore does not represent the MPA as a whole. In addition, it is difficult to find a reference site that shows similar environmental characteristics than the MPA itself. Therefore, the main objective of this survey was to collect baseline ecological data within the different habitats of IleyaklBeluu CA. Over the coming years, subsequent sampling at the same sites will allow us to assess the effectiveness of the MPA at protecting biodiversity and increasing commercially-important species' biomass over time.

Methods

<u>Study Site</u>

Baseline ecological surveys were conducted within IleyaklBeluu CA (359,333 m^2) that has been entirely protected from fishing for 6 years. The monitoring protocol followed a stratified sampling design. Random stations' locations were allocated within each habitat present in the MPA depending on their size using QGIS (QGIS Development Team 2015) (Fig. 2). Areas smaller than 900,000 m^2 were allocated three random points; areas from 1 km^2 to 5 km^2 in size were allocated one random point per 300,000 m^2. The reef crest habitat could not be surveyed because it was too shallow (less than 0.5 m deep at high tide). There were a total of three sites in the fore reef habitat (n = 9 transects), a total of three sites in the lagoon (n = 9 transects) and a total of 3 sites in the reef flat (n = 9 transects) (Fig. 1). The survey was conducted in May 2015 over two days at high tide.

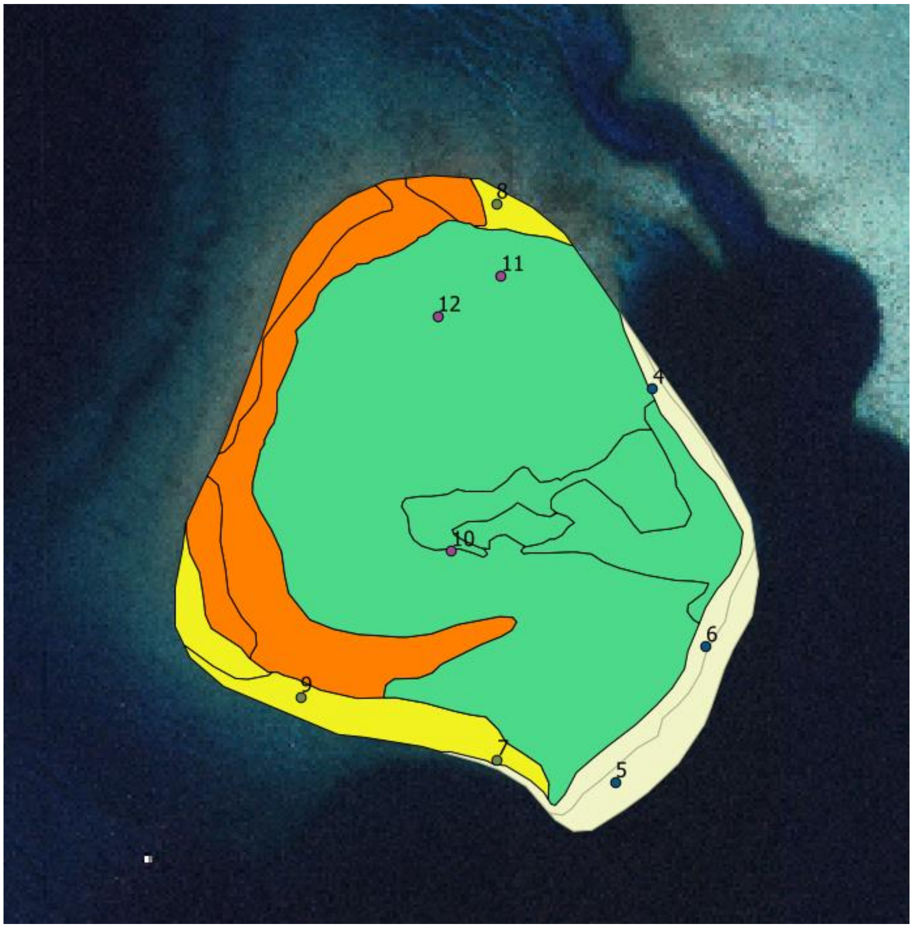

Figure 1: Map of IleyaklBeluu CA showing the four different habitat types (yellow = fore reef, orange= reef crest, beige = lagoon, green = reef flat), and the locations of sampling stations within each habitat (see GPS coordinates in Appendix 4)

Measurements of ecological variables

At each site, three 30-m transects were laid at a maximum depth of 5-m, following the same direction as the current, and consecutively with a few meters separating each transect. Along each 30-m transect, four surveyors recorded data on fish, invertebrates, benthic cover and coral recruitment. The first surveyor recorded the abundance and size estimates of the most common commercially important and protected fish species within a 5-m wide belt (see fish list in Appendix 1). The second surveyor recorded the abundance of macro-invertebrates within a 2-m wide belt (see invertebrates list in Appendix 2). For the estimation of benthic cover, the third surveyor took a photo every meter along the 30-m transect using an underwater camera (model: Canon G16, mounted on a 1-m x 1-m photo-quadrat PVC frame), for a total of 30 photos per transect. The fourth surveyor recorded the abundance of coral recruits smaller than 5-cm diameter (to genera) within a 30-cm wide belt of the first 10-m of each transect.

Data extraction and analysis

To estimate benthic cover, photo-quadrats were analyzed using CPCe software (Kohler and Gill 2006). Five random points were allocated to each photo and the substrate below each point was classified into benthic categories (see benthic categories list in Appendix 3). The mean percentage benthic cover of each category was calculated for each transect (n = 30 photos per transect, n = 3 transects per site).

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).

Mean values with standard errors of each of the measured ecological variables were calculated and plotted into bar charts using R and excel.

Results

Fish abundance and biomass

The abundance of commercially-important species (see list in Appendix 1) was the highest in the reef flat with 27.8 (± 6.6) individuals per 150 m^2 while the biomass was the highest in the lagoon with 7,920 (± 3,318) grams per 150 m^2 (Fig. 2). The lowest fish abundance was found in the lagoon with 12.3 (± 3) individuals per 150 m^2 and the lowest biomass in the fore reef habitat (3,755 (± 1,016) grams per 150 m^2) (Fig. 2).

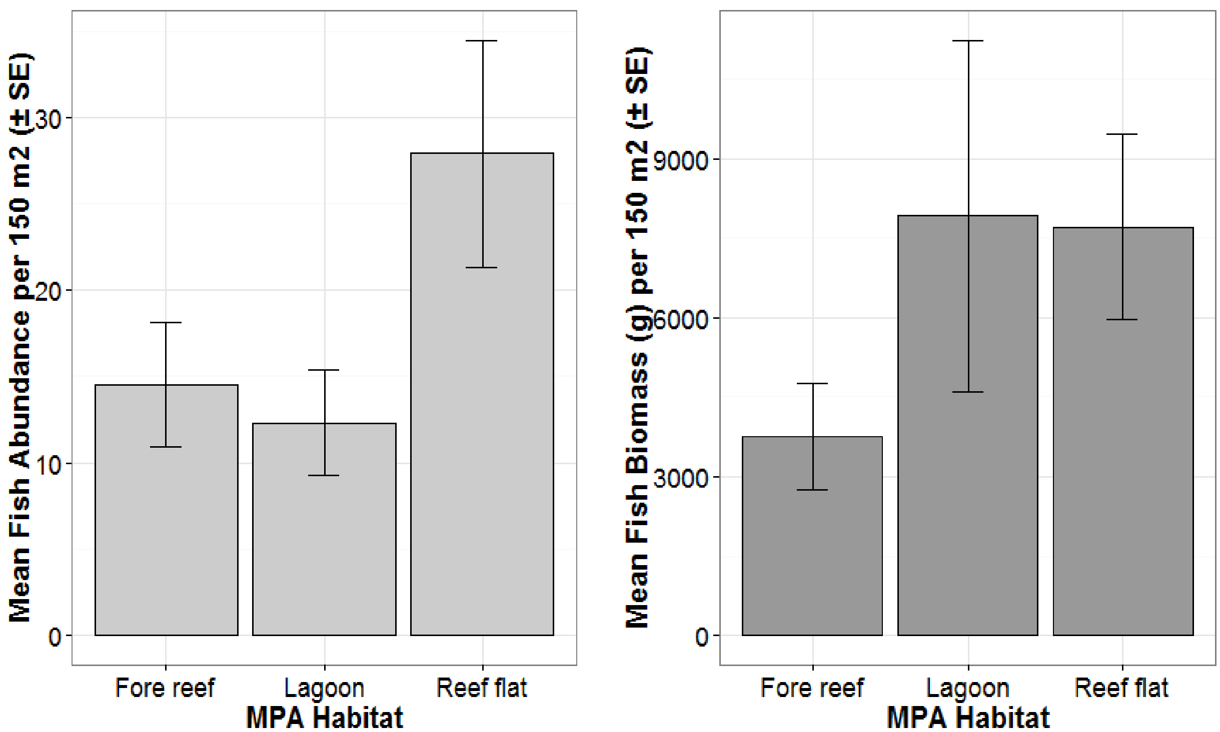

Figure 2: Mean abundance (left) and biomass (right) (± SE) of commercially-important species within the different habitats of the MPA

From all the surveyed fish species, the dominant fish family was Scaridae in the three habitats (Fig. 3); the highest abundance was found in the reef flat (24 (± 6.9) individuals per 150m^2). Other families appeared in lower abundance (< 4 individuals per 150 m^2) (Fig. 3).

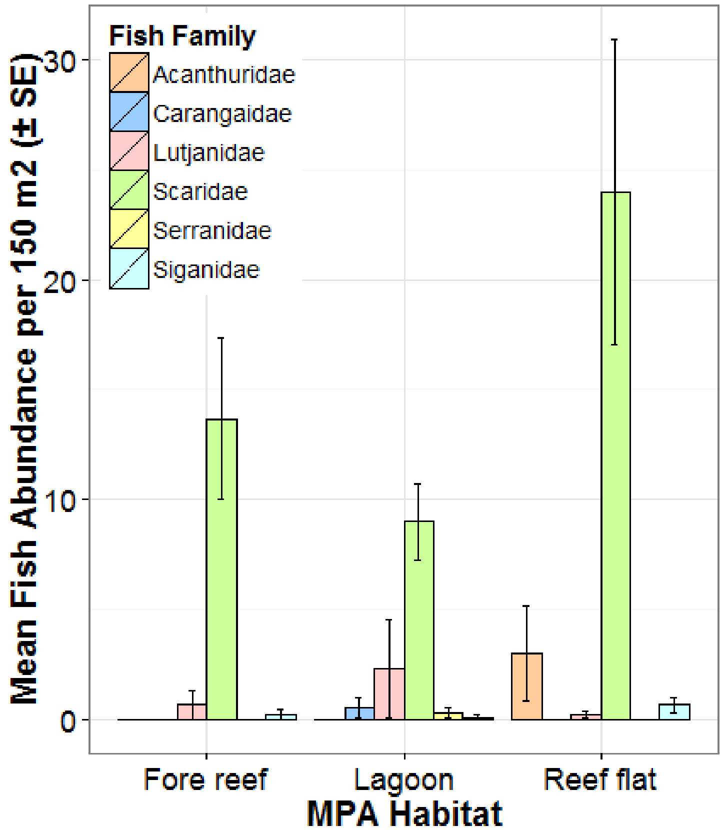

Figure 3: Mean fish abundance (± SE) grouped into family within the three habitats of the MPA

Benthic cover

Coral cover was high in the three habitats (> 20% cover) but the highest live coral cover was found in the reef flat with 49 %. All habitats were mostly dominated by *Acropora* spp. (Fig. 4 & 5). All habitats had a high cover of bare carbonate substrate (> 30%) and relatively low cover of turf (< 17%) and quasi-absence of macroalgae (Fig. 4). A total of 31 coral genera were recorded within the MPA. The highest genus diversity was found in the fore reef and lagoon habitats (18 genera) while the lowest genus diversity was recorded in the reef flat (8 genera).

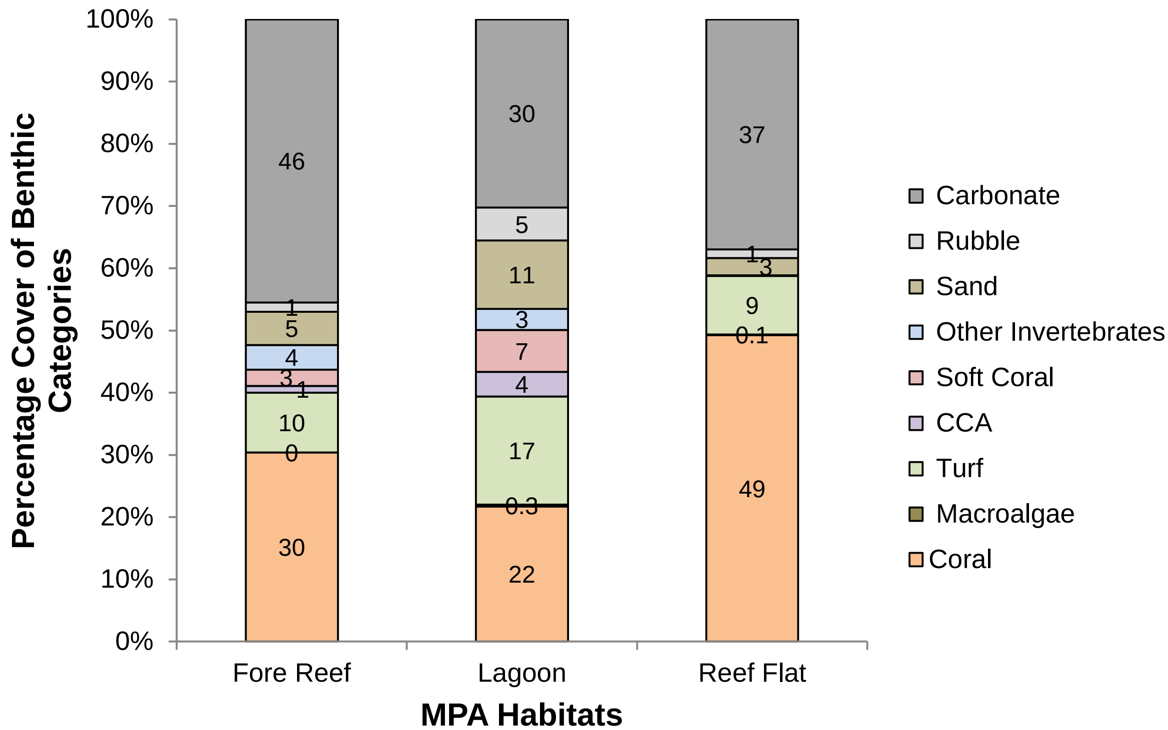

Figure 4: Mean percentage cover of main benthic categories present in the three habitats of the MPA. Numbers inside bars indicates percentage values of each benthic category

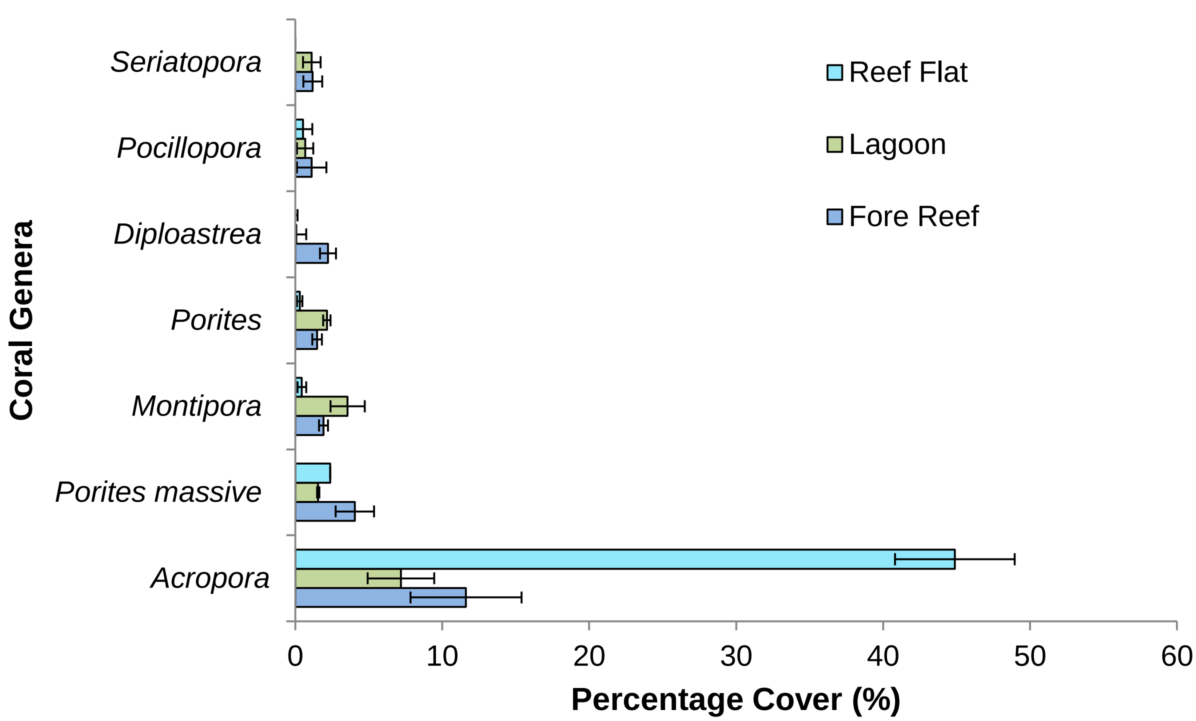

Figure 5: Mean percentage cover (± SE) of the most dominant coral genera present within the three habitats of the MPA.

Coral recruitment

Coral recruitment was high in all habitats of the MPA but especially in the fore reef and lagoon habitats with a coral recruit density greater than 34 coral juveniles per 3 m^2 (Fig. 6). There were a total of 24 recorded coral recruit genera. Coral recruit community was highly dominated by *Acropora* spp., followed by *Monitpora*, *Pavona* and *Seriatopora* spp.

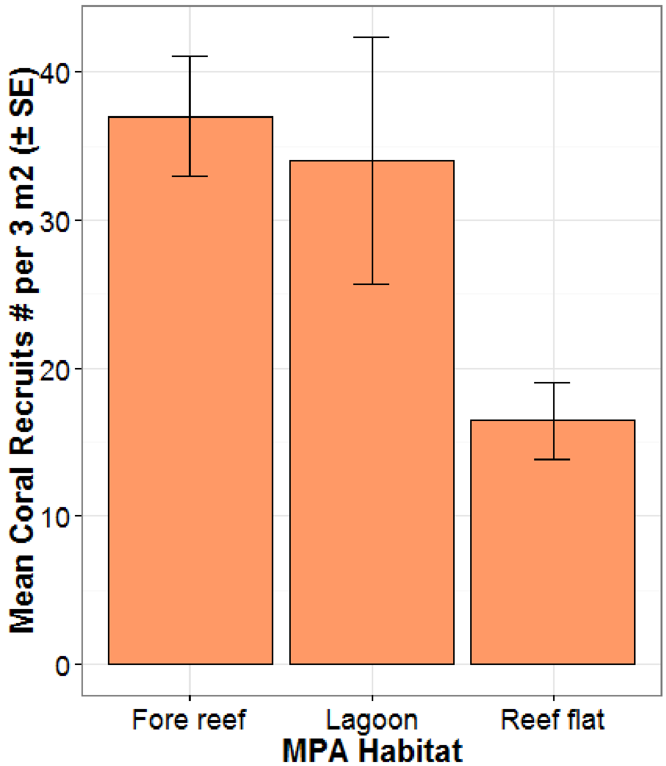

Figure 6: Mean coral recruit density (± SE) within the three habitats of the MPA

Macro-invertebrates' density

The abundance of macro-invertebrates was relatively similar in the three habitats with densities greater than 1.3 individuals per 60 m^2 (Fig. 7). The macro-invertebrates communities were mostly composed of *Tridacna* spp. (*T. Maxima, T. crocea*, and *T. squamosa*). Few *Trocus* spp. individuals were recorded in the reef flat.

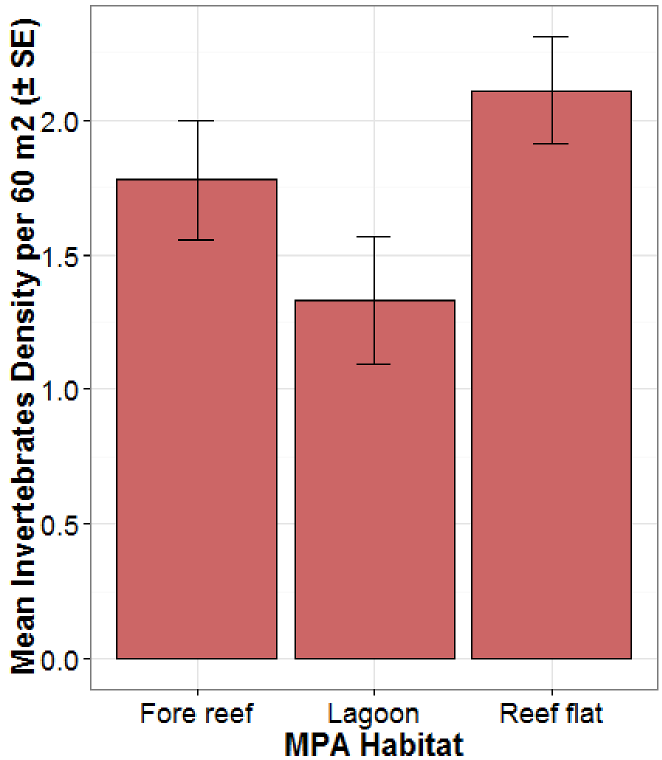

Figure 7: Mean macro-invertebrates density (± SE) within the three habitats of the MPA

Discussion

The overall goal of this study was to collect baseline ecological information within the IleyaklBeluu CA. Since 2004, the site was closed to the harvest of the mother-of-pearl snail *Trochus niloticus* (Semum) but fishing for community purposed was still allowed. It was only in 2009, that the CA became a complete no-take zone and part of the PAN.

The fish abundance and biomass of targeted fish species was high especially in the reef flat with more than 27 individuals per 150 m^2 and a total biomass of 7.7 kg/ 150m^2. The lagoon had fewer fish but bigger in size as the biomass there was the highest. The lowest density and biomass was found in the fore reef habitat. Previous surveys done in April 2011 (similar time of the year than this study) in the fore reef show a mean abundance of 24.2 individuals/250 m^2 (which equals 14.5 individuals/150 m^2) and a mean biomass of 13,043 g/250 m^2 (which equals 7,825 g/150 m^2) (Nestor et al. 2013). For fore reef habitat only, our study reveals similar fish density but lower biomass than from 2011 observations. This implies that fish observed in 2015 were smaller in size than the one observed in 2011 in this habitat. Our study shows that high density and biomass of commercially-important fish are present in the other two habitats, and especially the reef flat. This habitat hosted a high abundance of parrotfish (Scaridae, Melemau) which are an important component to coral reef resilience through their grazing activity that facilitates the opening of substrate for juvenile coral settlement (Mumby 2006). The lagoon habitat harbored the highest abundance of piscivorous fish (Lutjanidae, Serranidae); their presence demonstrated that the MPA hosted predatory fish and may indicate signs of recovery from fishing pressure. In addition, one of the protected species, Tiau (*P. leopardus*) was sighted within this same habitat.

Live coral cover was high in all habitats (> 22%) and the fore reef exhibited similar cover than in previous years (approx. 35% coral cover) (Nestor et al. 2013). All habitats, but especially the reef flat was dominated by *Acropora* corals. The dominance of *Acropora* species make the MPA vulnerable to thermal-stress events as these species of corals are more sensitive to temperature warming than other coral genus such as *Porites* spp. (Hoegh-Guldberg et al. 2007). Even though found in lower abundance, 18 other genera were recorded in the fore reef and lagoon habitats which make the coral community diverse.

Coral recruitment was very high (37 recruits/3 m^2 in the fore reef habitat) compared to Nestor et al. (2013) (21 recruits/3 m^2) and had a similar recruitment rate than in Ngerumekaol Spawning Area (Gouezo et al. 2015). Coral recruit community was dominated by *Acropora* spp. Complementary to high abundance and biomass of herbivorous fish, high recruitment rate is an essential component to coral reef resilience (Mumby 2006). Our study highlights a high recruitment rate as well as a high Scaridae biomass which was found correlated together with algae turf in a previous study throughout Micronesia (Mumby et al. 2013)

The macro-invertebrates community was dominated by *Tridacna* spp. Few edible sea cucumbers were spotted due to the quasi-absence of soft-sediment substrate within the MPA. In 2004, IleyaklBeluu CA was closed for the harvest of the mother-of-pearl snail *Trochus niloticus* (Semum). Few specimens of this gastropod mollusk were spotted on the reef flat within our survey area which could potentially show signs of population recovery.

Despite its small size (359,333 m^2), IleyaklBeluu CA encompasses 4 different reef habitats and exhibited high coral cover, high recruitment rate and high parrotfish biomass. These components are essential to reef resilience and make the MPA an important link to the PAN on the west coast of Palau.

Acknowledgment

PICRC would like to thank Ngardmau State rangers and Ngardmau State Government for allowing us within their MPA. This publication was made possible with support from NOAA's Coral Reef Conservation Program, PEW charitable trusts, and the GEF Small Grant ProgrammeGEF Small Grant Programme.

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Appendix 1:

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	Beyadel/Ngesngis	*Cetoscarus bicolor*
4	Parrotfish species	Melemau	*Cetoscarus/Chlorurus/Scarus* spp
5	Yellow cheek tuskfish	Budech	*Choerodon anchorago*
6	Indian ocean longnose parrotfish	Bekism	*Hiposcarus harid*
7	Pacific longnose parrotfish	Ngeaoch	*Hipposcarus longiceps*
8	Rudderfish	Komud, Teboteb	*Kyphosusspp (vaigiensis)*
9	Orangestripe emperor	Udech	*Lethrinus obsoletus*
10	Longface emperor	Melangmud	*Lethrinus olivaceus*
11	Red gill emperor	Rekruk	*Lethrinus rubrioperculatus*
12	Yellowlip 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	Orangespine unicornfish	Cherangel	*Naso lituartus*
18	Bluespine unicornfish	Chum	*Naso unicornis*
19	Giant sweetlips	Melimralm,Kosond/Bikl	*Plectorhinchus albovittatus*
20	Yellowstripe sweetlips	Merar	*Plectorhinchus crysotaenia*
21	Pacific steephead parrotfish	Otord	*Scarus micorhinos*
22	Greenthroat parrotfish	Udouungelel	*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	Humpheadwrasse	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 2: Macro-invertebrates list

Common names	Palauan name	Scientific name
Black teatfish	Bakelungal-chedelkelek	*Holothuria nobilis*
White teatfish,	Bakelungal-cherou	*Holothuria fuscogilva*
Golden sandfish	Delalamolech	*Holothuria lessoni*
Hairy blackfish	Eremrum, cheremrum edelekelk	*Actinopyga miliaris*
Hairy greyfish	Eremrum, cheremrum	*Actinopyga sp.*
Deepwater red fish	Eremrum, cheremrum	*Actinopyga echinites*
Deepwater blackfish	Eremrum, 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/ngimes ra tmolech	*Stichopus hermanni*
Brown curryfish	Ngimes	*Stichopus vastus*
Greenfish	Cheuas	*Stichopus chloronotus*
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*
Lolly fish	Cheuas	*Holothuria atra*
Pinkfish	Cheuas	*Holothuria edulis*
White snakefish	Cheuas	*Holothuria leucospilota*
Snakefish	Cheuas	*Holothuria coluber*
Red snakefish	Cheuas	*Holothuris falvomaculata*
Surf red fish	Badelchelid	*Actinopyga mauritiana*
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*

Appendix 3: Benthic categories

CPCe Code	Benthic Categories
"C"	"Coral"
"SC"	"Soft Coral"
"OI"	"Other Invertebrates"
"MA"	"Macroalgae"
"SG"	"Seagrass"
"BCA"	"Branching Coralline Algae"
"CCA"	"Crustose Coralline Algae"
"CAR"	"Carbonate"
"S"	"Sand"
"R"	"Rubble"
"FCA"	"Fleshy Coralline algae"
"CHRYS"	"Chrysophyte"
"T"	"Turf Algae"
"TWS"	"Tape
"G"	"Gorgonians"
"SP"	"Sponges"
"ANEM"	"Anenome"
"DISCO"	"Discosoma"
"DYS"	"Dysidea Sponge"
"OLV"	"Olive Sponge"
"CUPS"	"Cup Sponge"
"TERPS"	"Terpios Sponge"
"Z"	"Zoanthids"
"NoIDINV"	"Not Identified Invertebrate"
"AMP"	"Amphiroa"
"ASC"	"Ascidian"
"TURB"	"Turbinaria"
"DICT"	"Dictyota"
"LIAG"	"Liagora"
"LOBO"	"Lobophora"
"SCHIZ"	"Schizothrix"
"HALI"	"Halimeda"
"SARG"	"Sargassum"
"BG"	"Bluegreen"
"Bood"	"Boodlea"
"GLXU"	"Galaxura"
"CHLDES"	"Chlorodesmis"
"JAN"	"Jania"
"CLP"	"Caulerpa"
"MICDTY"	"Microdictyton"
"BRYP"	"Bryopsis"
"NEOM"	"Neomeris"
"TYDM"	"Tydemania"

"ASP"	"Asparagopsis"
"MAST"	"Mastophora"
"DYCTY"	"Dictosphyrea"
"PAD"	"Padina"
"NOIDMAC"	"Not ID Macroalgae"
"CR"	"C.rotundata"
"CS"	"C.serrulata"
"EA"	"E. acroides"
"HP"	"H. pinifolia"
"HU"	"H. univervis"
"HM"	"H. minor"
"HO"	"H. ovalis"
"SI"	"S. isoetifolium"
"TH"	"T.hemprichii"
"TC"	"T. ciliatum"
"SG"	"Seagrass"
"ACAN"	"Acanthastrea"
"ACROP"	"Acropora"
"ANAC"	"Anacropora"
"ALVEO"	"Alveopora"
"ASTRP"	"Astreopora"
"CAUL"	"Caulastrea"
"CRUNK"	"Coral Unknown"
"COSC"	"Coscinaraea"
"CYPH"	"Cyphastrea"
"CTEN"	"Ctenactis"
"DIPLO"	"Diploastrea"
"ECHPHY"	"Echinophyllia"
"ECHPO"	"Echinopora"
"EUPH"	"Euphyllia"
"FAV"	"Favia"
"FAVT"	"Favites"
"FAVD"	"Faviid"
"FUNG"	"Fungia"
"GAL"	"Galaxea"
"GARD"	"Gardininoseris"
"GON"	"Goniastrea"
"GONIO"	"Goniopora"
"HELIO"	"Heliopora"
"HERP"	"Herpolitha"
"HYD"	"Hydnophora"
"ISOP"	"Isopora"
"LEPT"	"Leptastrea"
"LEPTOR"	"Leptoria"
"LEPTOS"	"Leptoseris"
"LOBOPH"	"Lobophyllia"

"MILL"	"Millepora"
"MONT"	"Montastrea"
"MONTI"	"Montipora"
"MERU"	"Merulina"
"MYCED"	"Mycedium"
"OULO"	"Oulophyllia"
"OXYP"	"Oxypora"
"PACHY"	"Pachyseris"
"PAV"	"Pavona"
"PLAT"	"Platygyra"
"PLERO"	"Plerogyra"
"PLSIA"	"Plesiastrea"
"PECT"	"Pectinia"
"PHYSO"	"Physogyra"
"POC"	"Pocillopora"
"POR"	"Porites"
"PORRUS"	"Porites-rus"
"PORMAS"	"Porites-massive"
"PSAM"	"Psammocora"
"SANDO"	"Sandalolitha"
"SCAP"	"Scapophyllia"
"SERIA"	"Seriatopora"
"STYLC"	"Stylocoeniella"
"STYLO"	"Stylophora"
"SYMP"	"Symphyllia"
"TURBIN"	"Turbinaria"
"CCA"	"Crustose Coralline"
"CAR"	"Carbonate"
"SC"	"Soft Coral"
"Sand"	"Sand"
"Rubble"	"Rubble"
"Tape"	"Tape"
"Wand"	"Wand"
"Shadow"	"Shadow"
"FCA"	"Fleshy-Coralline"
"CHRYOBRN"	"Brown Chysophyte"
"TURF"	"Turf"
"BCA"	"Branching Coralline general"
"BC"	"Bleached Coral"

Appendix 4: GPS coordinates of survey sites (UTM)

ID	Lat	Long
1	845555.547	449703.936
2	845906.369	450008.919
3	845922.04	449887.521
4	845696.657	450225.003
5	845233.119	450181.02
6	845392.976	450288.005
7	845259.375	450041.352
8	845914.789	450040.446
9	845333.671	449809.272
10	845505.441	449987.457
11	845829.555	450045.897
12	845781.838	449970.936