Baseline Assessment of Medal Ngediull Conservation Area

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PICRC Technical Report No 16-02

December 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 Medal Ngediull Conservation Area (CA) located in Airai State of Palau, to assess the effectiveness of the MPA over time. Findings demonstrated that one of the habitats of the CA, called reef hole, had a high coral cover and high abundance and biomass of commercially-important fish species. Observations also showed that this habitat hosted juvenile protected species such as Maml (*Cheilinus undulatus*) and Kemedukl (*Bolbometopon muricatum*). The reef flat of the CA had low fish abundance and biomass, low seagrass cover but high density of clams. The seagrass beds of the CA may be impacted by sedimentation loads and run-offs caused by the urban development and the river nearby.

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. Medal Ngediull Conservation Area (CA) is located in Airai State at 7°20' 46.14"N, 134°33' 2.88" E (Fig. 1). The conservation area includes two marine habitats: reef flat and reef hole (inner reef); the total area is 3.2 km^2. Medal Ngediull CA formally became a state conservation area in 2005 and became a PAN site in June 2012.

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. Bi-annual surveys were conducted at Medal Ngediull CA since 2011 part of PICRC seagrass long term monitoring plan. Surveys were only conducted in the reef flat habitat. Medal Ngediull CA has another habitat, reef

hole, which was never surveyed. Therefore, the main objective of this survey was to collect baseline ecological data within the two different habitats of Medal Ngediull 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, as well as assessing the gaps of the PAN.

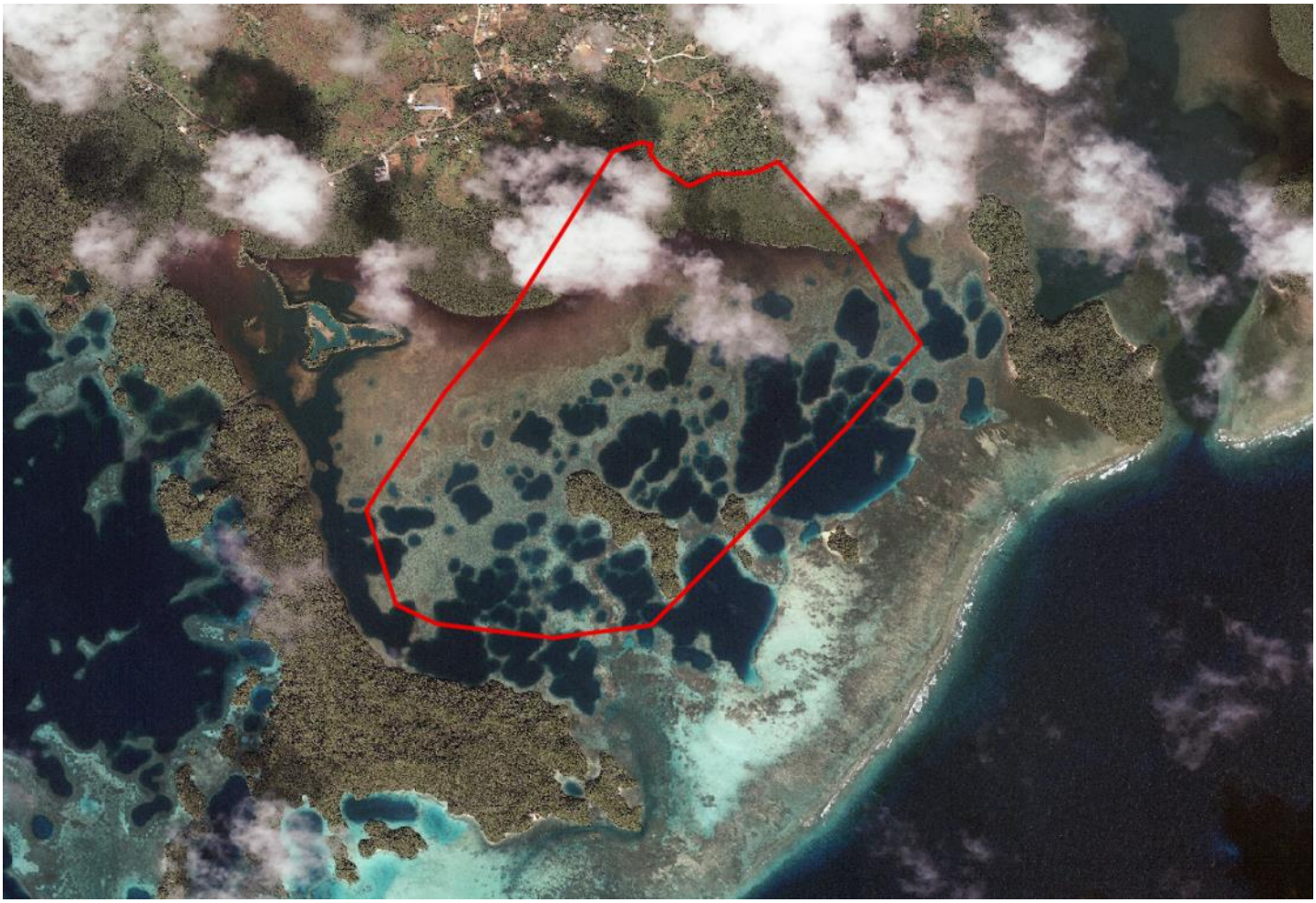

Figure 1: Satellite image showing Medal Ngediull CA (red boundaries)

Methods

Study Site

Baseline ecological surveys were conducted within Medal Ngediull CA (3.2 km^2) that has been entirely protected from fishing for 10 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. There were a total of four sites in the reef flat habitat (n = 12 transects), a total of four sites in the reef hole habitat (n = 12 transects) (Fig. 2). The survey was conducted in October 2015 over two days at high tide.

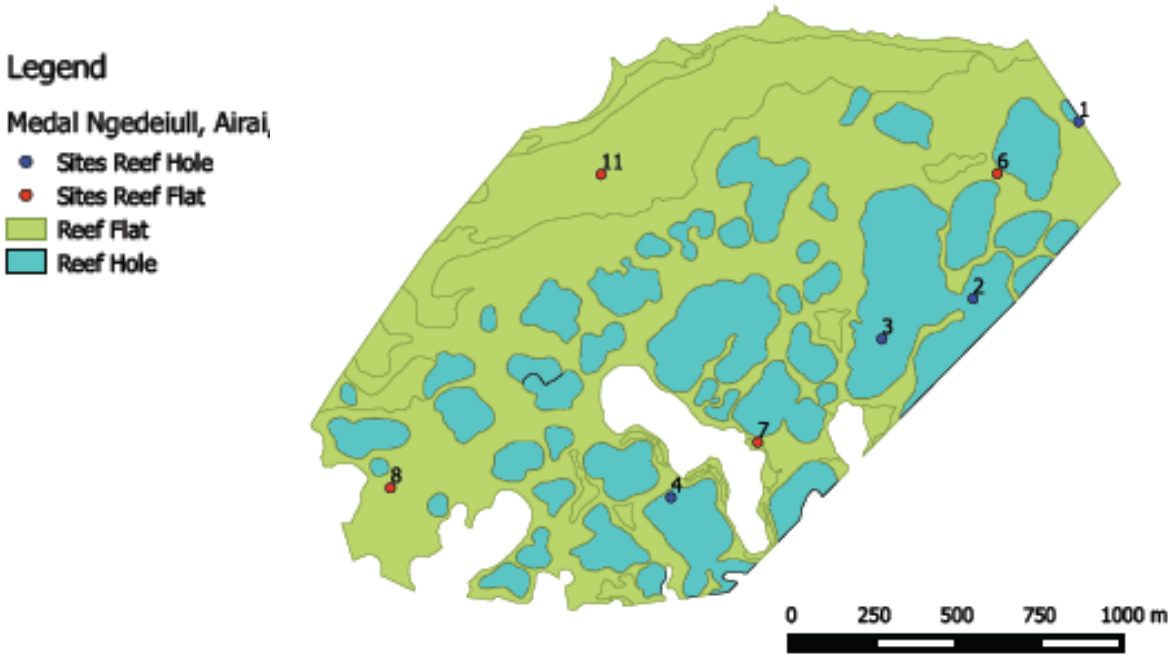

Figure 2: Map of Medal Ngediull CA showing the two different habitat types (green = reef flat, blue= reef hole), and the locations of sampling stations within each habitat (see GPS coordinates in Appendix 4)

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 hole habitat with 17.2 (± 4.6) individuals per 150 m^2 and a biomass of 4,750 (± 1,896) grams per 150 m^2 (Fig. 3). The fish abundance in the reef flat was low with 5.1 (± 2) individuals per 150 m^2 and a biomass of 231 (± 68) grams per 150 m^2 (Fig. 3).

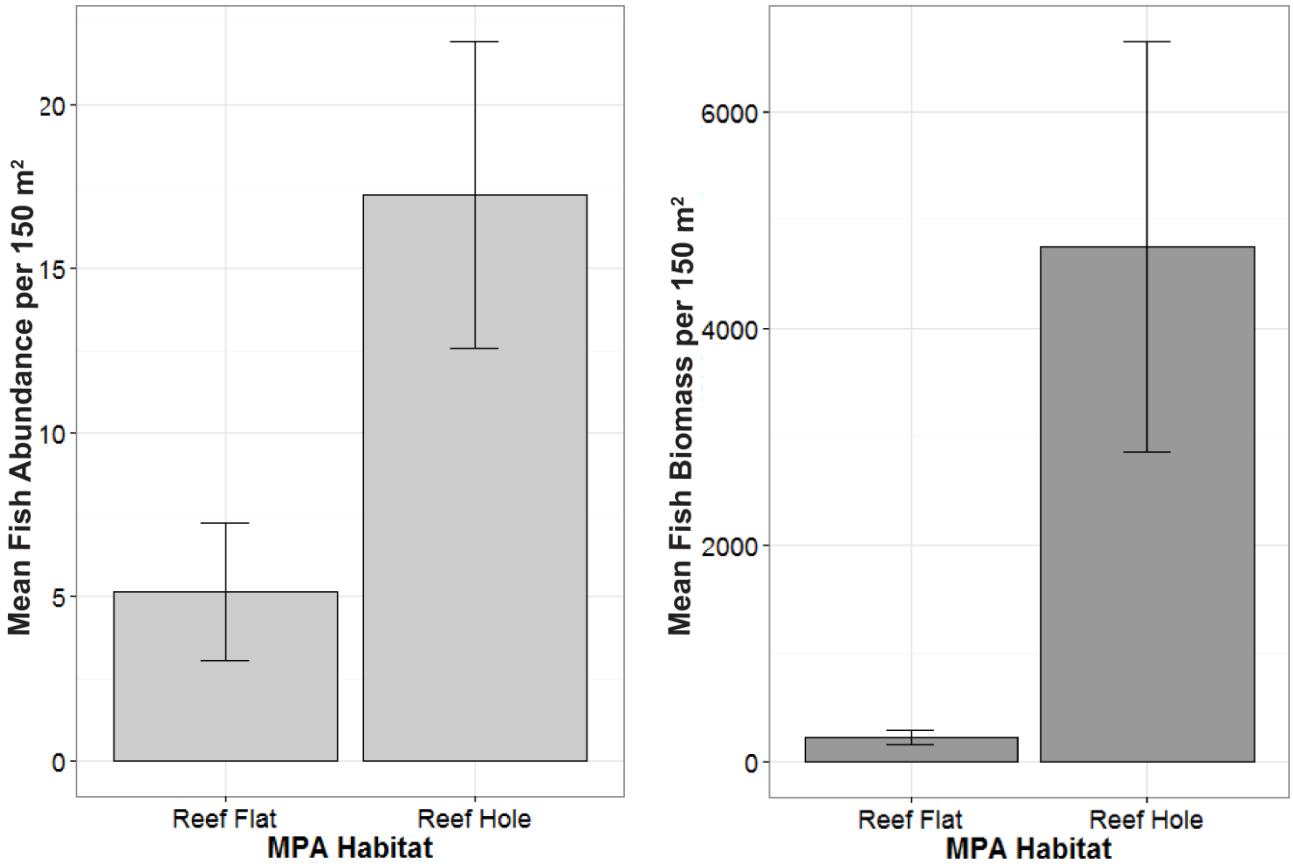

Figure 3: Mean abundance (left) and biomass (right) (± SE) of commercially-important species within the different habitats of the MPA

From all the surveyed fish species, the dominant fish family was Scaridae in the two habitats (Fig. 4); followed by siganids in the reef hole habitat and labrids in both habitats (Fig. 4). Other families appeared in low abundance (< 1 individuals per 150 m^2) (Fig. 4).

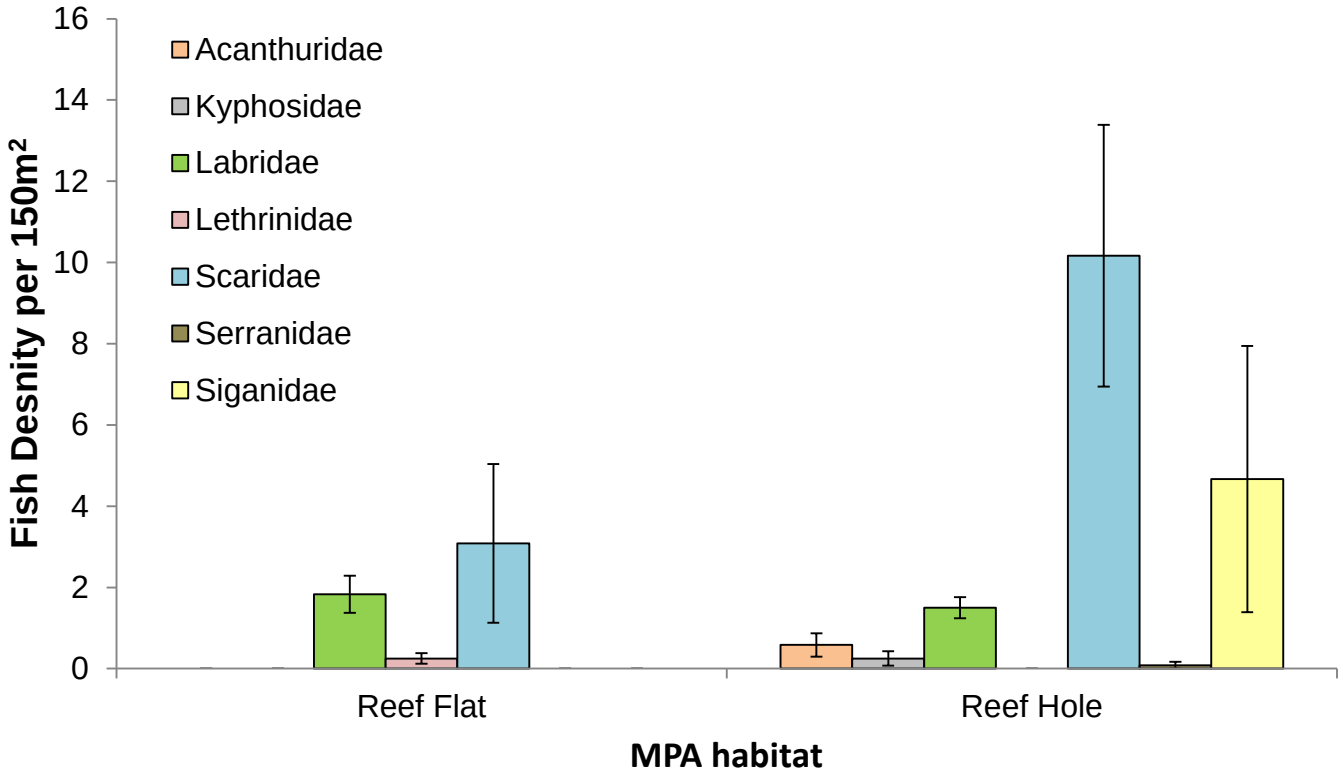

Figure 4: Mean fish abundance (± SE) grouped into family within the two habitats of the MPA

Benthic cover

The reef hole habitat was dominated by live coral (47%) while the reef flat was dominated by sand (54%) (Fig. 5). The reef hole habitat had low cover of macroalgae and turf algae. The reef flat had a very low cover of seagrass (2%) despite the dominance of sandy substrate. In the same habitat, live coral cover reached 8%, rubble cover averaged around 13 % and turf algae at 18% (Fig. 5).

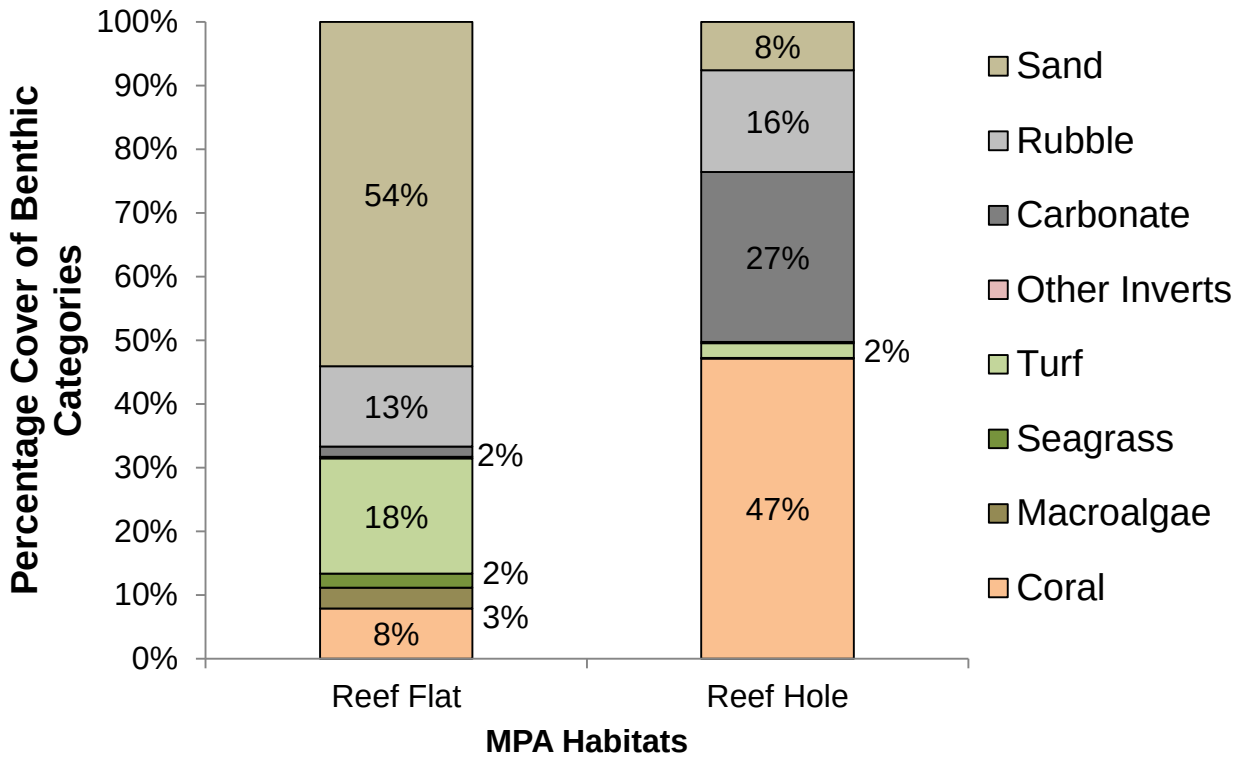

Figure 5: Mean percentage cover of main benthic categories present in the two habitats of the MPA. Numbers inside bars indicates percentage values of each benthic category

There were a total of 21 coral genera recorded in the reef hole habitat including 18 genera in less than 1 % coverage (Fig. 6). Five different genera were recorded in the reef flat.

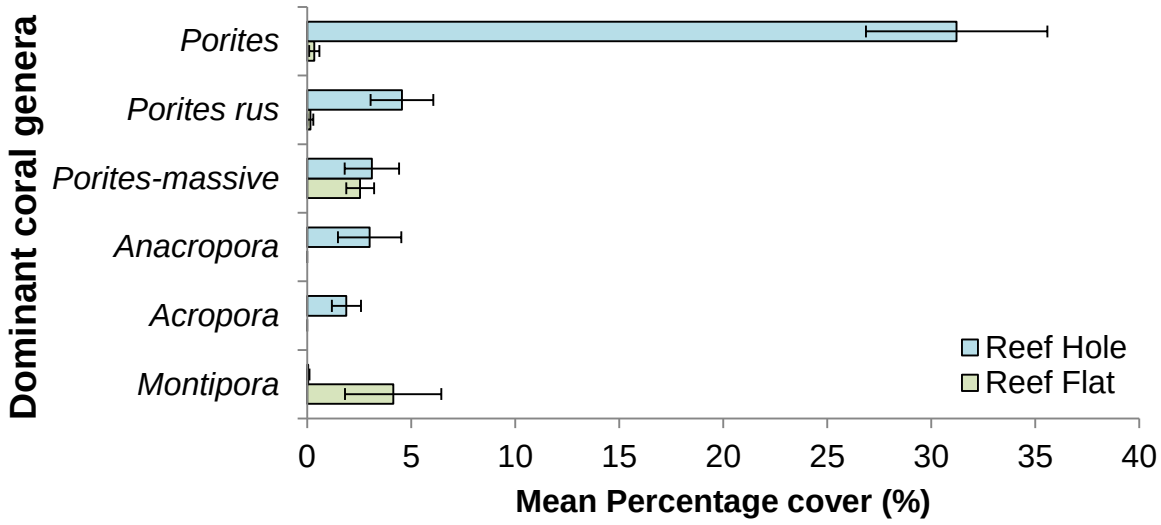

Figure 6: Mean percentage cover (± SE) of the most dominant coral genera present within the two habitats of the MPA.

Coral recruitment

The density of juvenile corals approached 5 individuals per 3 m^2 in the reef hole habitat and the community was constituted with 9 different genera (Fig. 7). The density of juvenile corals in the reef flat was much lower than in the reef hole and included 5 different coral genera.

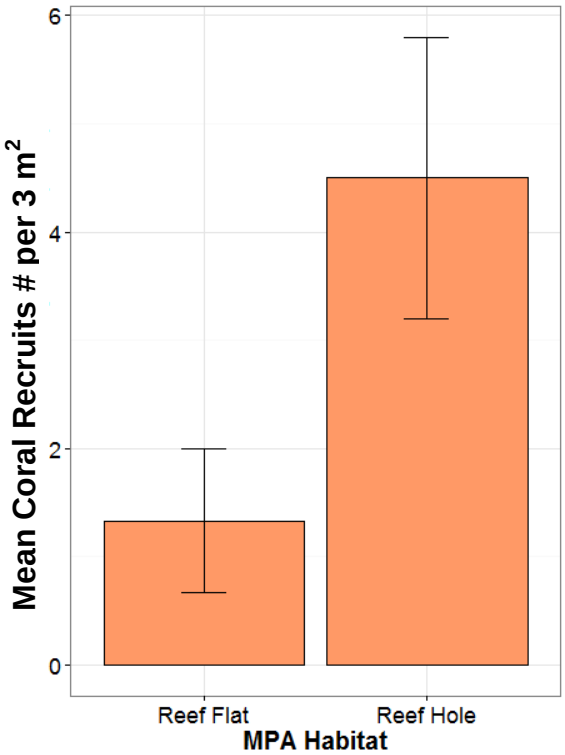

Figure 7: Mean coral recruit density (± SE) within the two habitats of the MPA

Macro-invertebrates' density

The abundance of macro-invertebrates was high in the reef flat with a density greater than 7 individuals per 60 m^2 (Fig. 8). In both habitats, macro-invertebrates consisted in one species only: *Tridacna crocea.*

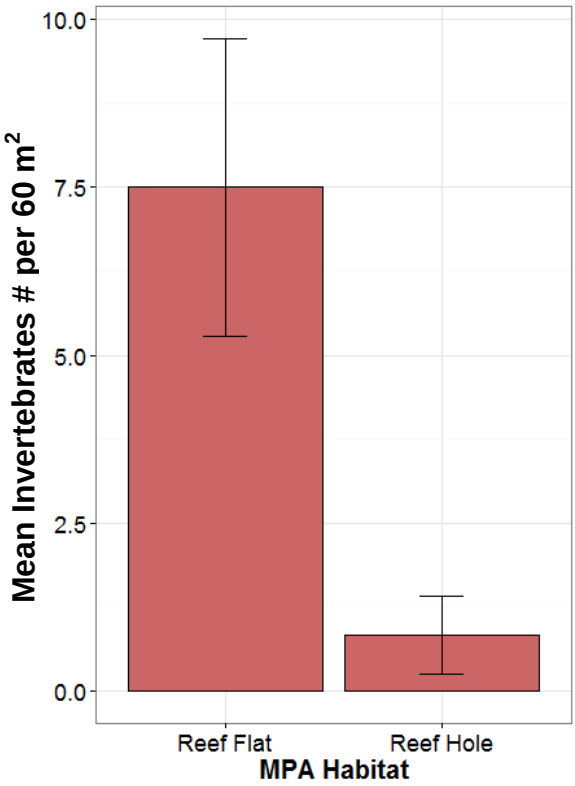

Figure 8: Mean macro-invertebrates density (± SE) within the two habitats of the MPA

Discussion

The overall goal of this study was to collect baseline ecological information within Medal Ngediull CA. The site was closed since 2005 and became a PAN site in 2012. PICRC previously conducted monitoring surveys within the CA but only in the seagrass beds (Sampson et al. 2014; Rehm et al. 2015).

Medal Ngediull CA has two main marine habitats (excluding the mangroves): reef hole and reef flat. The reef hole habitat had a high fish abundance and biomass. The fish community was dominated by parrotfish (Scaridae) and rabbitfish (Siganidae) which are important herbivorous fish for coral reef resilience (Mumby 2006). The coral cover in this habitat was high (47 % cover) and consisted of *Porites* spp. mainly. Macroalgae and turf algae cover was low which showed the high grazing rate within this habitat. All of these observations indicated that the reef hole habitat was in a good state. Furthermore, several protected species were observed during the surveys, including Maml (*Cheleinus undulatus*), Kemedukl (*Bolbometapon muricatum)* and Tiau (*Plectropomus leopardus*). The reef hole habitat of the CA also appeared to be a nursery ground for Maml (*Cheleinus undulatus*) and Kemedukl (*Bolbometapon muricatum)* as many juvenile individuals were sighted during the fish census surveys. It is therefore a key site to protect.

In contrast with the reef hole habitat, the reef flat habitat of Medal Ngediull CA had a low abundance and biomass of commercially-important fish species. It is a completely different habitat than the reef hole. It is dominated by sand and low coverage of seagrass. The habitat had a high abundance of clams (*Tridacna crocea*) but no sea cucumbers were observed during our surveys. Previous studies conducted in the same habitat of the CA have shown similar results with low fish abundance and low seagrass cover compared to other seagrass beds in Palau (Sampson et al. 2014; Rehm et al. 2015). The low coverage of seagrass in the reef flat might be due to sedimentation impacts caused by the river run-off and urban development close by (Golbuu et al. 2011). Water quality and sedimentation surveys should be the focus of future monitoring work in the area.

Medal Ngediull CA has been protected for 10 years. The CA has habitats that are important to protect such as the reef hole that hosts juvenile protected species. The seagrass beds within the CA are not in a good state and sedimentation issues should be addressed in the area. Few inner reefs in Palau

are part of the PAN network and this study highlighted their importance to be protected and to be part of the PAN.

Recommendations to Airai State:

Medal Ngediull Conservation Area five year management plan (2014-2018) states in Objective 4-1 that a baseline survey of fish, invertebrates, coral, seagrass and mangroves in the conservation area should be produced within year 1 and 2. This objective includes three different tasks:

a) Seek outside assistance to help conduct baseline survey and develop a monitoring plan
b) Develop and produce a report of the survey and submit to the Governor and state legislature
c) Plan and schedule community meetings to inform and update the community of the current survey results

This present report fulfills task b) and part of a). Task c) will be completed within the next 6 months. To fully fulfill task a), following are PICRC recommendations to Airai State PAN coordinator and State Conservation Officers.

The conservation officers of Airai State assisted PICRC during this survey and they were competent in the field. However, more guidance and training will improve their monitoring capacity. Training will be offered by PICRC in 2016 (date to be defined) to the conservation officers of Airai only. During this training, more focus and time will be spent with each conservation officer to improve their ability to collect data within Medal Ngediull CA and enter data into excel. During this time, a monitoring schedule will also be defined for them to follow.

Once trained and with the guidance of their PAN coordinator, Airai State conservation officers will be competent to conduct monitoring surveys within their MPA without the assistance of PICRC. For this to happen, they need the following equipment:

- GPS and batteries
- Underwater slates and pencils (x4)
- Underwater paper
- Five transect tapes of 50 m long (it has to be in meters)
- Snorkeling equipment (mask, fins, snorkel, rash guard)
- Boat with a boat operator

- Computer with Microsoft excel to enter their data once back from the field.
- A flash drive to share their excel file with PICRC

Airai Conservation Officers assisting PICRC during the baseline assessment of the CA

Acknowledgment

PICRC would like to thank Airai State rangers and Airai State Government for allowing us within their MPA. Monitoring surveys were made possible thanks to funding from PEW charitable trusts, MCT NOAA and the GEF small grant program.

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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*

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	812498.924	451412.852
2	811964.634	451093.861
3	811843.053	450818.641
4	811364.476	450181.458
6	812342.461	451167.08
7	811531.269	450443.156
8	811394.43	449334.966
11	812215	450208