Baseline Assessment of Ngermasech Conservation Area

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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 Ngermasech Conservation Area (CA) located in Ngardmau State of Palau, to assess the effectiveness of the MPA over time. Findings demonstrated high abundance and biomass of commercially important species, good coral cover in the lagoon habitat, very low macroalgae cover, and high abundance of commercially-important macro-invertebrates within the CA. Three protected fish species were also sighted during the surveys. All of these indicators show that the CA is well respected and enforced. The enforcement should be maintained in the future to maximize the benefits of protection outside the boundaries of the CA and to the Protected Area Network.

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) collected baseline ecological data for all MPAs sites. Ngermasech Conservation Area (CA) is located in Ngardmau State at 7°35.085' N, 134°32.062'E (Fig. 1). The conservation area includes three marine habitats: mangroves, reef flat and lagoon. The study focuses on seagrass and lagoon habitats. The total area, excluding the mangrove area, is 2.92 km^2. Ngermasech CA formally became a state conservation area in 1998 (NPL 4-20) and became a PAN site in 2009 (Ngardmau Conservation Board 2011).

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. Therefore, the main objective of this survey was to collect baseline ecological data within the two different habitats of Ngermasech

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.

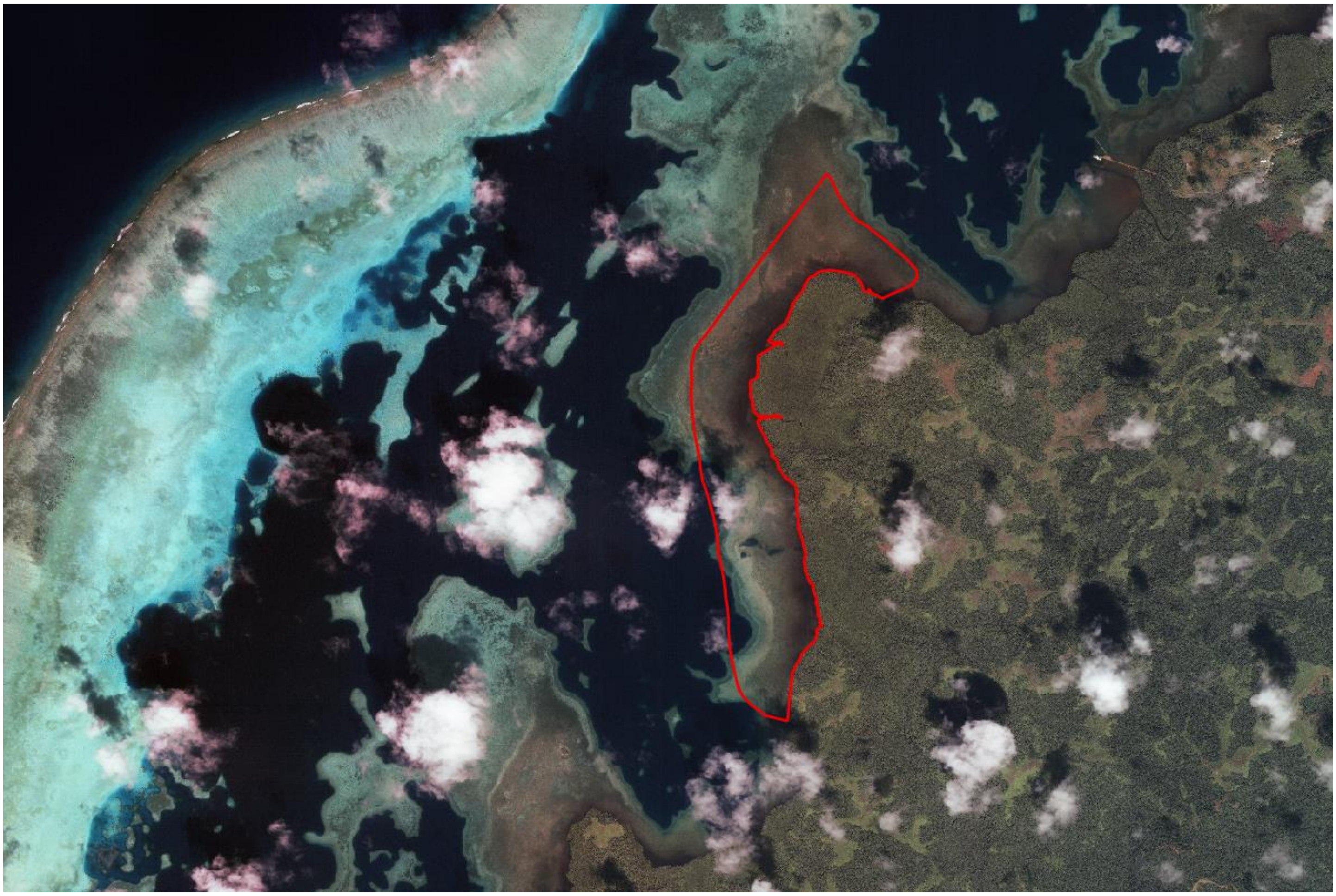

Figure 1: Satellite image showing Ngermasech CA (red boundaries)

Methods

Study Site

Baseline ecological surveys were conducted within Ngermasech CA (2.9 km^2) that has been entirely protected from fishing for 18 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 9 sites in the reef flat habitat (n = 27 transects) and a total of three sites in the lagoon habitat (n = 9 transects) (Fig. 2). The survey was conducted in November 2015 over two days at high tide.

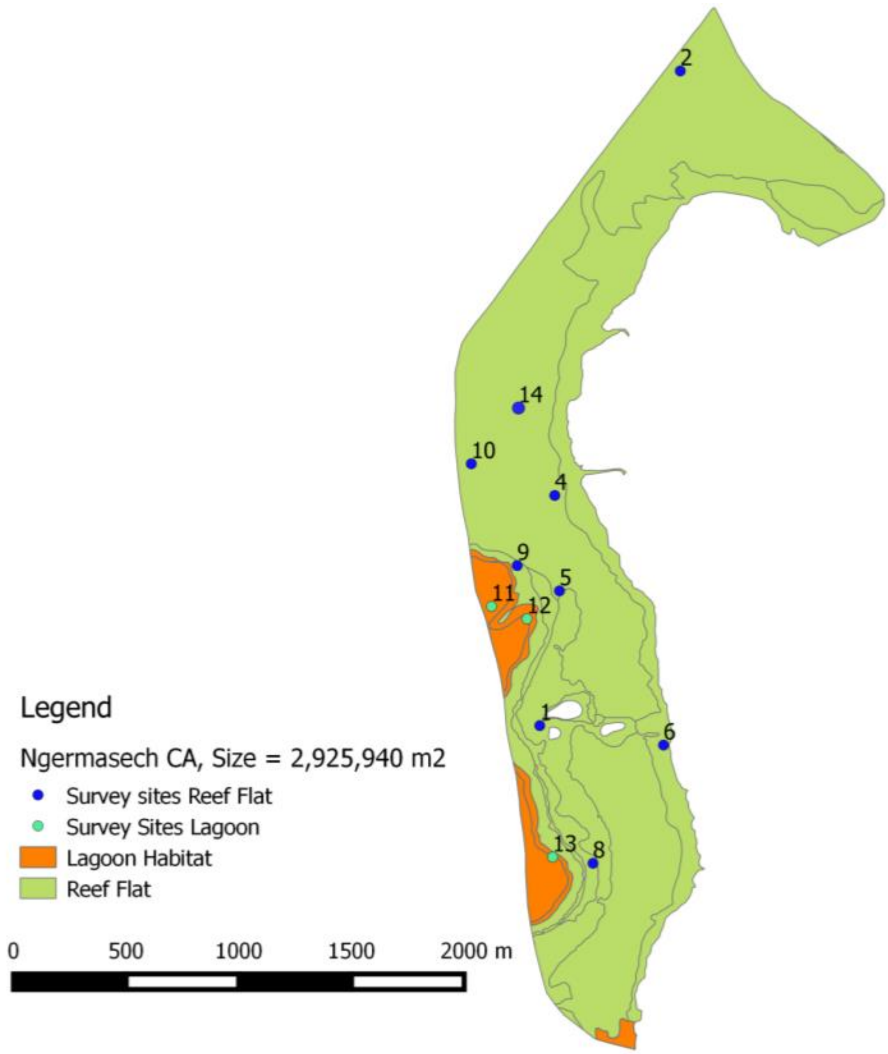

Figure 2: Map of Ngermasech CA showing the two different habitat types (green = reef flat, orange = lagoon), and the locations of sampling stations within each habitat (see GPS coordinates in Appendix 4)

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

<u>Fish abundance and biomass</u>

The lagoon habitat hosted a higher abundance and biomass of commercially important species with 18 (± 5.1) individuals and 7,400 (± 2,700) g per 150 m^2 than the reef flat habitat (Figure 3). A total of 7 fish families were observed in the lagoon and 5 families in the reef flat. Both habitats had a high abundance of rabbit fish (Siganids), with more than 4 fish individual per 150 m^2 (Figure 4). There was a high abundance of parrotfish (Scarids) in the lagoon habitat (9 ± 2.2 individuals per 150 m^2) (Figure 4).

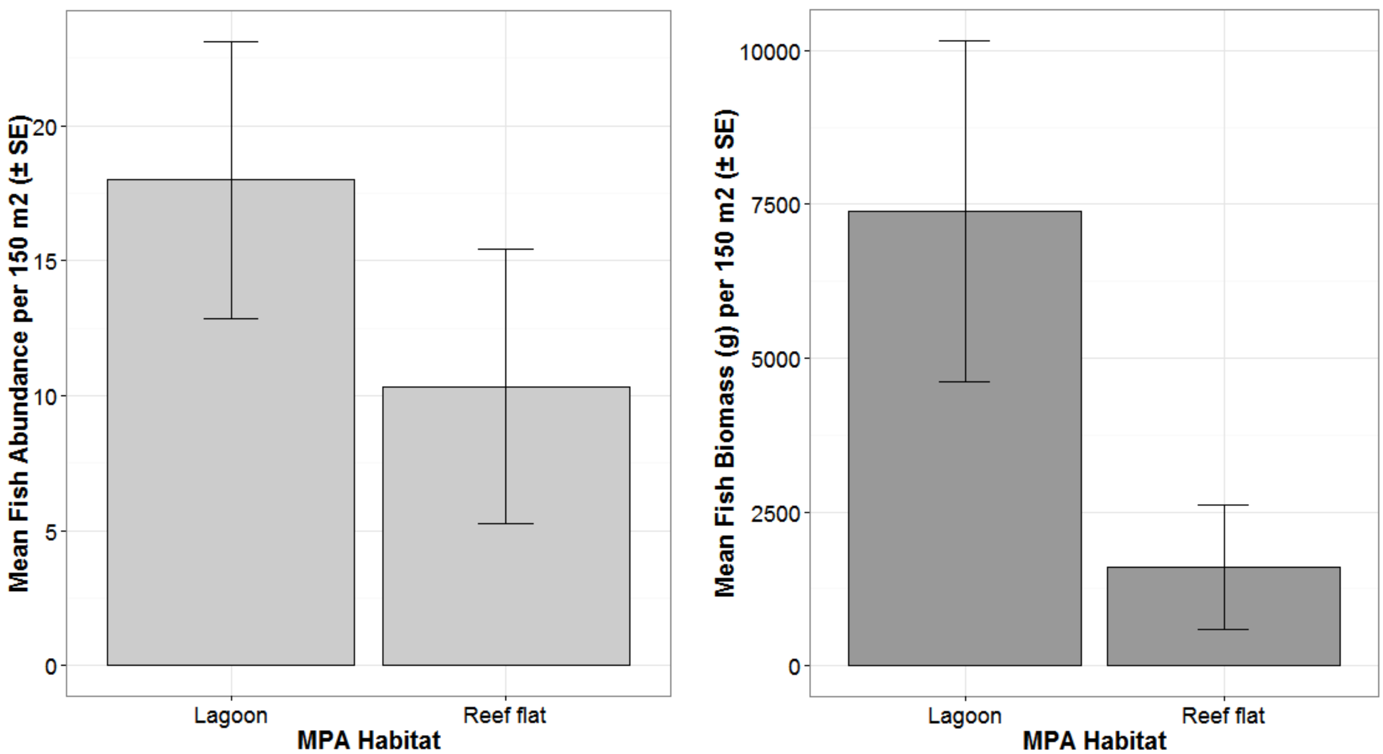

Figure 3: Mean abundance (left) and biomass (right) (± SE) of commercially-important species within the two different habitats of the MPA

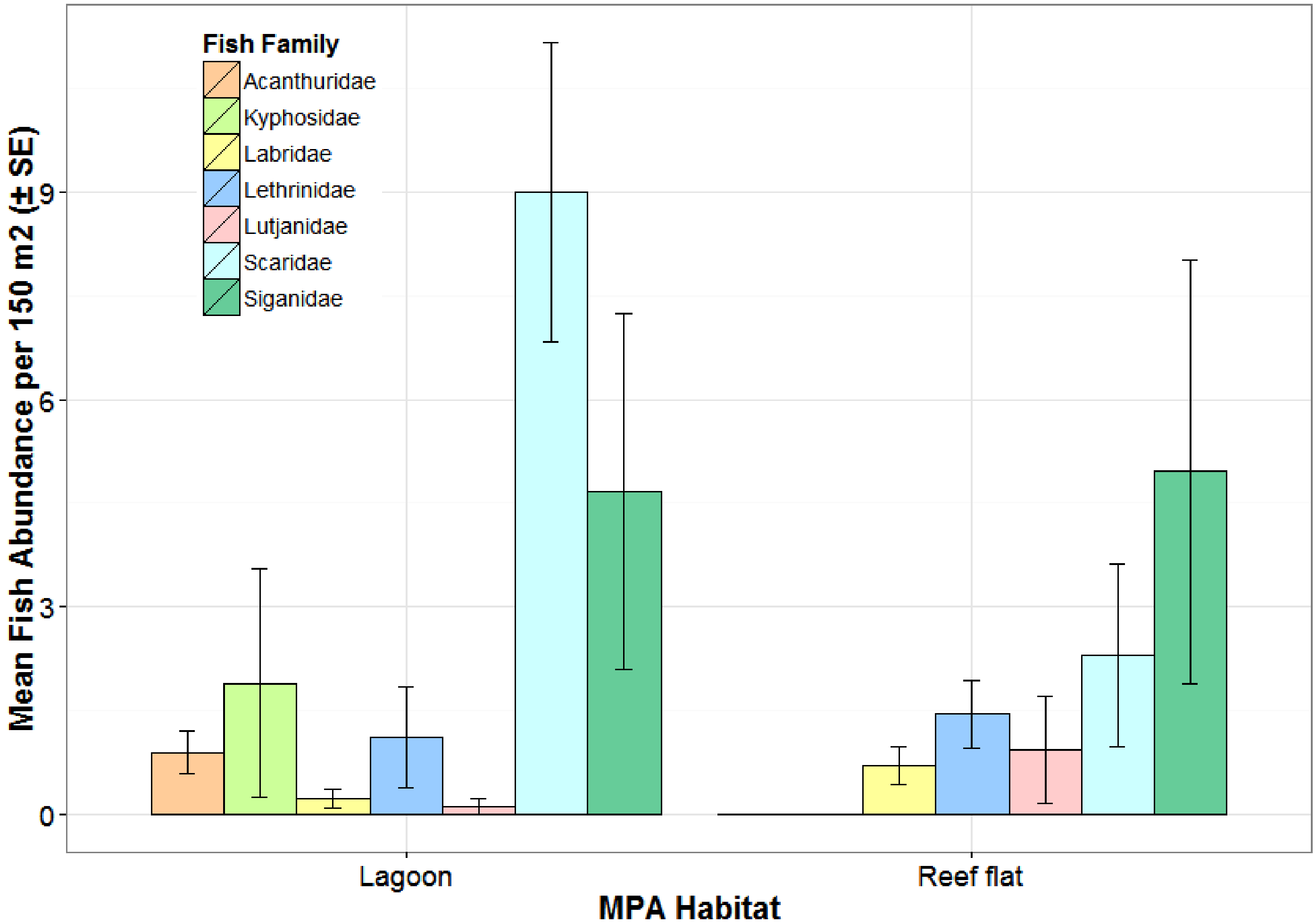

Figure 4: Mean fish abundance (± SE) grouped into family within the two habitats of the MPA

Benthic cover

The lagoon habitat was mostly dominated by carbonate (42 ± 2 %) and live corals (25 ± 3 %). The reef flat was dominated by sand (41 ± 0.4 %) and seagrass (30 ± 8%) (Figure 5). The seagrass bed mostly consisted in *Enhalus acoroides* and *Thalassia hemprichii* seagrass species. The coral reef community in the lagoon habitat had a total of 13 different coral genera and the most abundant ones (>1 % cover) were *Porites* and *Montipora* (Figure 6). The reef flat had a few colonies of *Porites* of massive morphology. A very low percentage cover of macroalgae (< 0.5 %) was present within the conservation area.

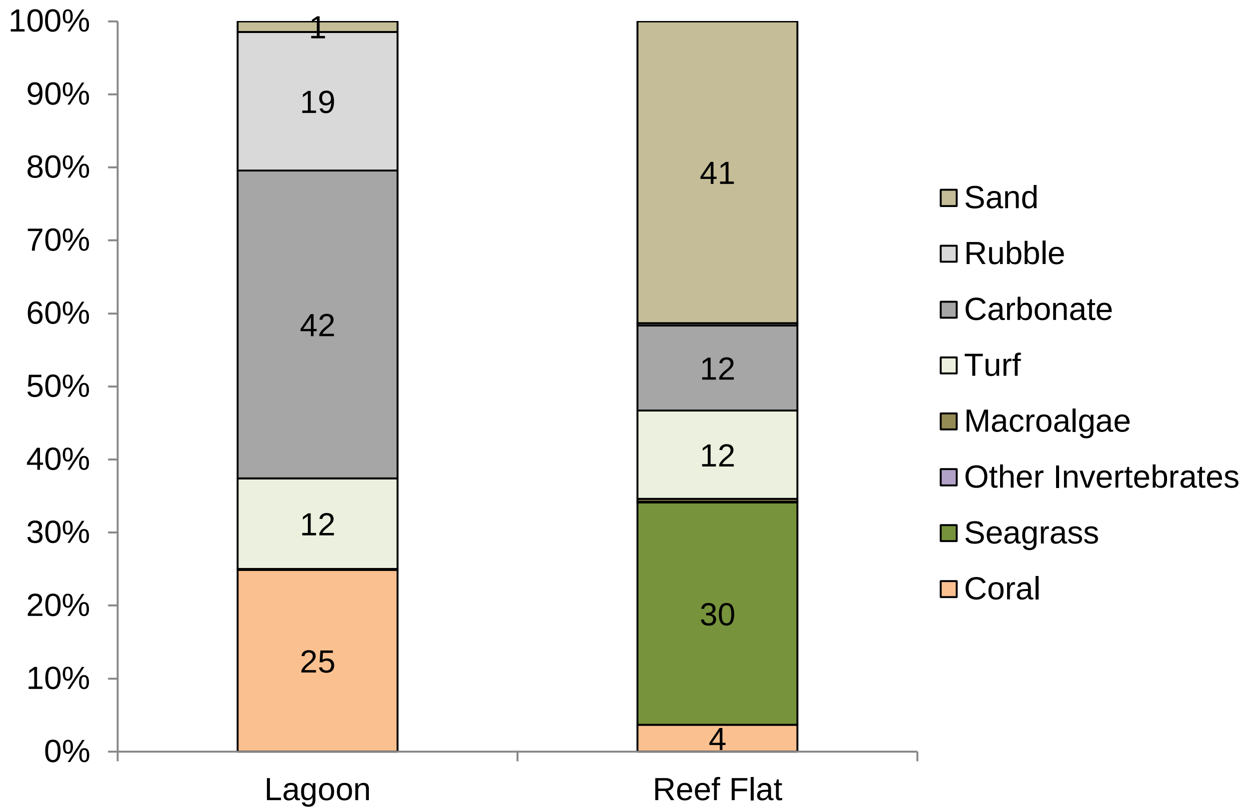

Figure 5: Mean percentage cover of main benthic categories present in the two habitats of the MPA. Numbers inside bars indicates percentage values of each benthic category

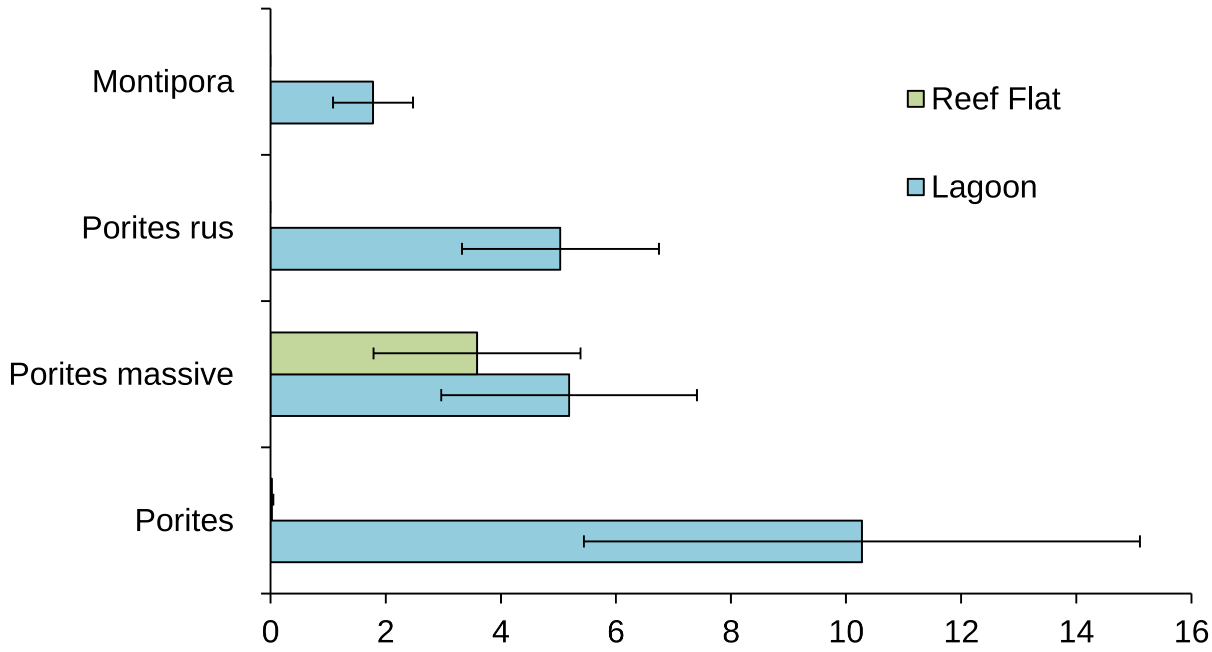

Figure 6: Mean percentage cover (± SE) of the most dominant coral genera (> 1% cover) present within the two habitats of the MPA.

Coral recruitment

The lagoon habitat had a high density of juvenile corals (7.8 ± 1 individuals per 3 m^2) (Figure 7). A total of 9 juvenile coral genera were observed during the survey. The most abundant coral genera were *Porites*, *Acropora*, *Psammocora* and *Montipora*.

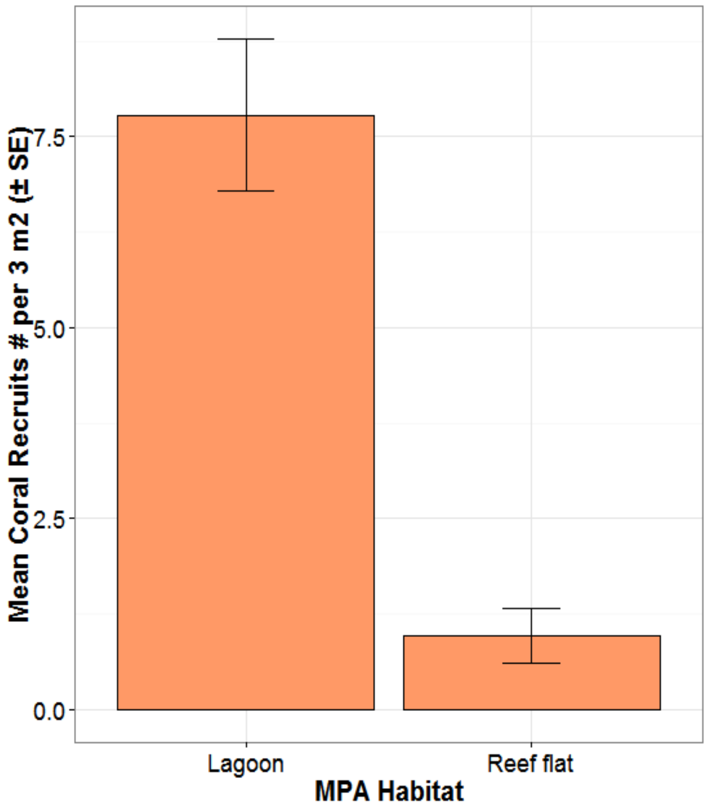

Figure 7: Mean coral recruit density (± SE) within the two habitats of the MPA

Macro-invertebrates' density

The reef flat hosted a high abundance of commercially-important macro-invertebrates with 37 ± 12 individuals per 60 m^2 (Figure 8). The northern part (site 2, Figure 2) of the conservation area had very high abundance of sea cucumber (*Actinopyga* spp.). Other sites in the reef flat and the lagoon habitats had a high density of clams, especially the species *Tridacna crocea.*

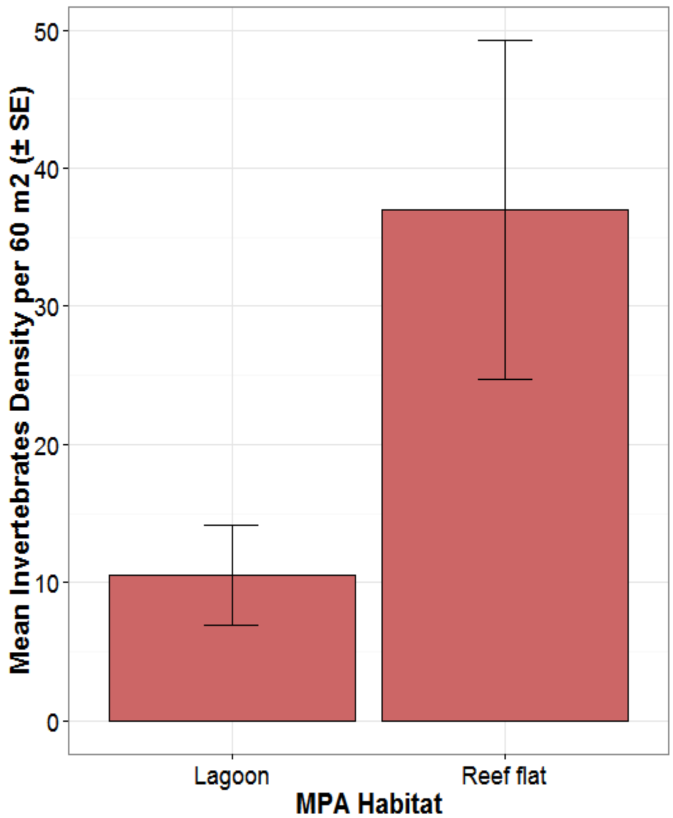

Figure 8: Mean macro-invertebrates density (± SE) within the two habitats of the MPA

Discussion

The overall goal of this study was to collect baseline ecological information within Ngermasech CA. The site was closed since 1998 and became a PAN site in 2009 (Ngardmau Conservation Board 2011). PICRC previously conducted monitoring surveys within the CA but only in the seagrass bed during sea cucumber assessments (Golbuu et al. 2012; Rehm et al. 2014).

Ngermasech CA has two main marine habitats (excluding the mangroves): reef flat and lagoon. The lagoon habitat had a high fish abundance and biomass. The fish community was dominated rabbitfish and parrotfish. These herbivorous fish have a significant role in coral reef resilience (Cheal et al. 2010) and in this case, explain the very low cover of macroalgae in both lagoon and reef flat habitats. The coral cover within the lagoon was relatively high (25 %) and was dominated by *Porites* species. The reef flat is predominantly a seagrass bed with a few *Porites* coral colonies. The seagrass cover was high (30 %) and the abundance and biomass of commercially-important species was high compared to other protected seagrass beds in Palau (Rehm et al. 2015). Protected fish species have been sighted during the surveys: Kemedukl (*Bolbometopon muricatum*), Meyas (*Siganus fuscescens*) and one individual Tiau (*Plectropomus leopardus*). The presence of protected species within a conservation area is very encouraging and shows that it is well respected and an important ground to maintain protection in the future.

Compared to other seagrass bed conservation areas in Palau (Sampson et al. 2014; Gouezo et al. 2015a, 2015b; Rehm et al. 2015), Ngermasech had the highest density of macro-invertebrates, especially sea cucumbers. Previous studies have shown that the sea cucumber density outside of Ngermasech CA collapsed after over-harvesting practices in 2011 (Golbuu et al. 2012; Rehm et al. 2014). It will take several years for the sea cucumber population to recover outside the boundaries. Similar to 2012 and 2014 studies, our results also showed that Ngermasech is effective at protecting sea cucumbers and clam populations and is well-respected and enforced by the local community.

Ngermasech CA has been protected for 18 years. The CA has habitats that are important grounds for protected fish species and commercially-valuable macro-invertebrates. In accordance with previous studies, this baseline assessment showed high abundance and biomass of commercially important species, very low macroalgae cover, and high abundance of commercially important invertebrates within the CA. All of these indicators show that the CA is well respected and enforcement should be maintained in the future to maximize the benefits of protection outside the boundaries of the CA and to the PAN network.

Acknowledgment

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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"