Baseline Assessment of Ngemai 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 MPA. 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 Ngemai Conservation Area (CA) located in Ngiwal State of Palau, to assess the effectiveness of the MPA over time. Findings demonstrated that despite its small size and early protections status (7 years old MPA), Ngemai CA had high abundance of commercially-important fish and invertebrates. In addition, due to its position, the MPA seemed to have been protected from the two past typhoons, with live coral cover approaching 25% on the fore reef habitat. Ngemai CA is a good example of ecosystem-based management as it includes most of the marine habitats in one location. These characteristics make the MPA resilient and an essential component of the PAN, especially on the east 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 demonstrated 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 at MPAs sites. Oselkesol Ngemai Conservation Area (CA) is located in Ngiwal State at 7°31.882 N, 134°37.55 E. The conservation area includes both terrestrial and marine habitats, starting from the fore reef, to the lagoon, to the mangroves and to the Tayo river and land; the total area is 3.25km^2 (Fig. 1). Ngemai CA (marine habitats) was closed to fishing in June 1997 until 2001, when it was re-opened to fishing until 2008. In March 2010, Ngemai was consolidated with the terrestrial area, Oselkesol, when it became part of the PAN. As PICRC focuses on marine habitats, only the reef and the lagoon was surveyed; an area of 2km^2 (Fig. 2).

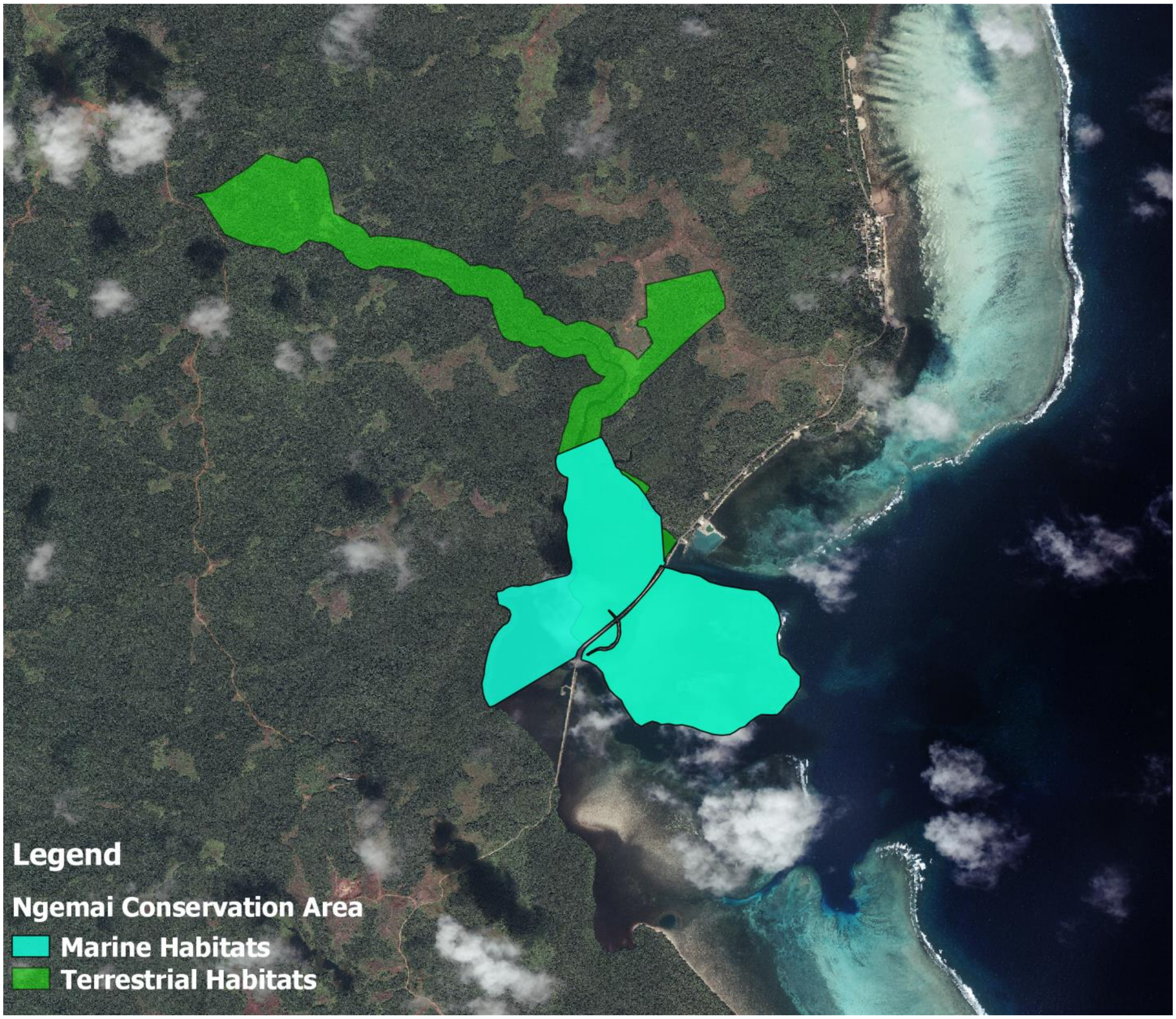

Figure 1: Satellite image showing Oselkesol Ngemai Conservation Area, including both marine and terrestrial habitats.

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 Ngemai in 2011-2012 sampling three stations on the fore reef habitat and comparing the data with a reference site close-by (Koshiba et al. 2013). The sampling design only focused on one habitat (the fore reef) and therefore do 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 Ngemai 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

1. <u>Study Site</u>

Baseline ecological surveys were conducted within Ngemai CA that has been protected from fishing for 7 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. This baseline monitoring protocol excludes mangrove forests because the methodology differs too much from other marine habitats; therefore, the mangrove area of Ngemai CA was excluded from our sampling. The reef crest habitat could not be surveyed because of persistent eastern swell. There were a total of three sites in the fore reef habitat (n = 6 transects), a total of three sites in the channel habitat (n = 9 transects), and a total of four sites in the reef flat/lagoon habitat (n = 12 transects) (Fig. 2). The survey was conducted in March 2015 over two days at high tide.

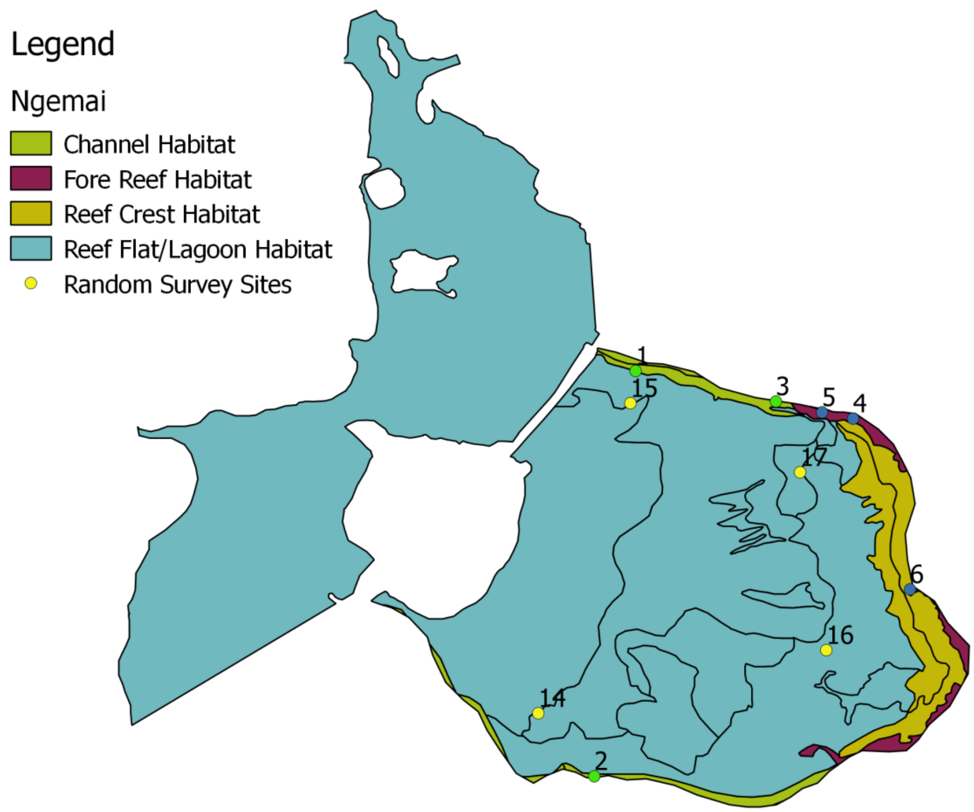

Figure 2: A map of Ngemai Conservation Area (marine habitat), showing the four different habitat types (green = channel, red = fore reef, brown = reef crest, blue = reef flat/lagoon) found there, and the locations of sampling stations within each habitat (see GPS coordinates in Appendix 4). The white area is land.

2. 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 invertebrates targeted by local fisheries 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 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.

3. 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 the 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).

The data collected at Ngemai CA were baseline data, therefore neither comparison through time nor with a reference site were possible for this study. Mean values with standard errors of each of the measured ecological variables were calculated and plotted into bar charts using excel.

Results

Fish abundance and biomass

The biomass of commercially-important species (see list in Appendix 1) was the highest in the fore reef habitat with 5,749.1g (± 2,347 SE) per 150 m^2 (Fig. 3). The lowest biomass within the MPA was found in the reef flat (Fig. 3). The highest mean abundance of fish was found in the fore reef habitat with 33.1 (± 6 SE) individuals per 150 m^2 (Fig. 3). The lowest abundance was found in the reef flat with 3.25 (± 1.4 SE) individuals per 150 m^2 (Fig. 3).

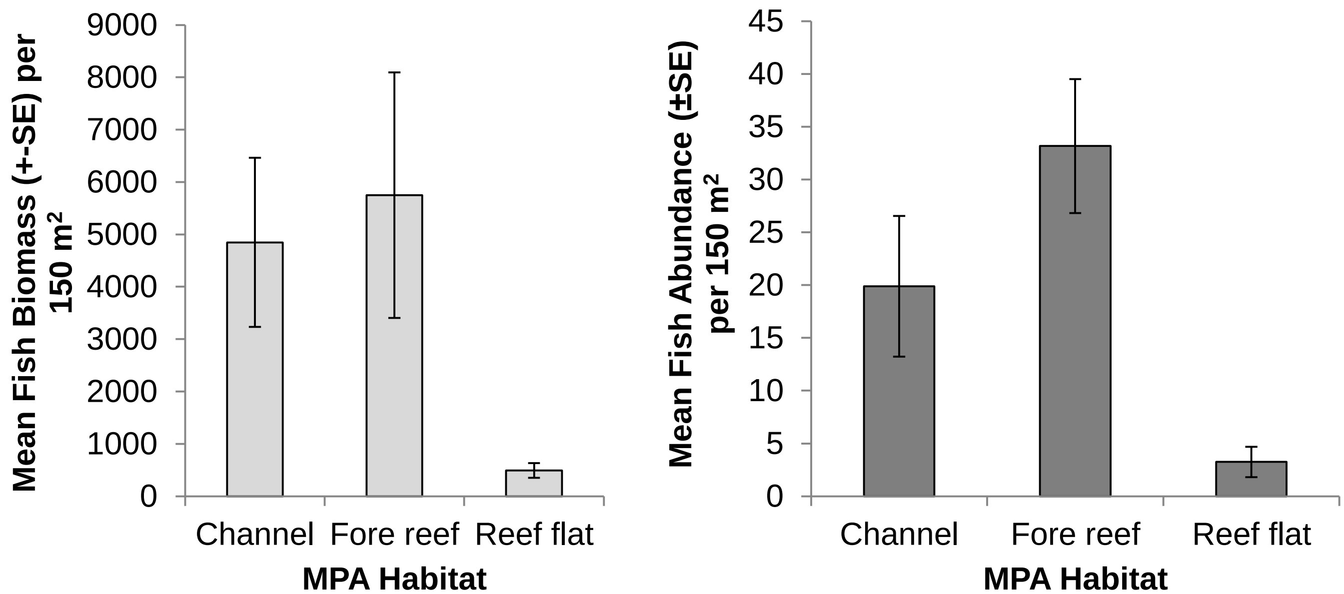

Figure 3: Mean fish biomass (left) and abundance (right) of commercially-important species within the three main habitats of Ngemai MPA

The fore reef habitat was dominated by three fish families: *Siganidae*, *Scaridae* and *Lutjanidae* while the channel hosted a high abundance of *Siganidae* species with a mean of 12.3 (± 4.7 SE) individuals per 150 m^2 (Fig. 4). The reef flat had a low abundance of the five dominant fish families (Fig. 4).

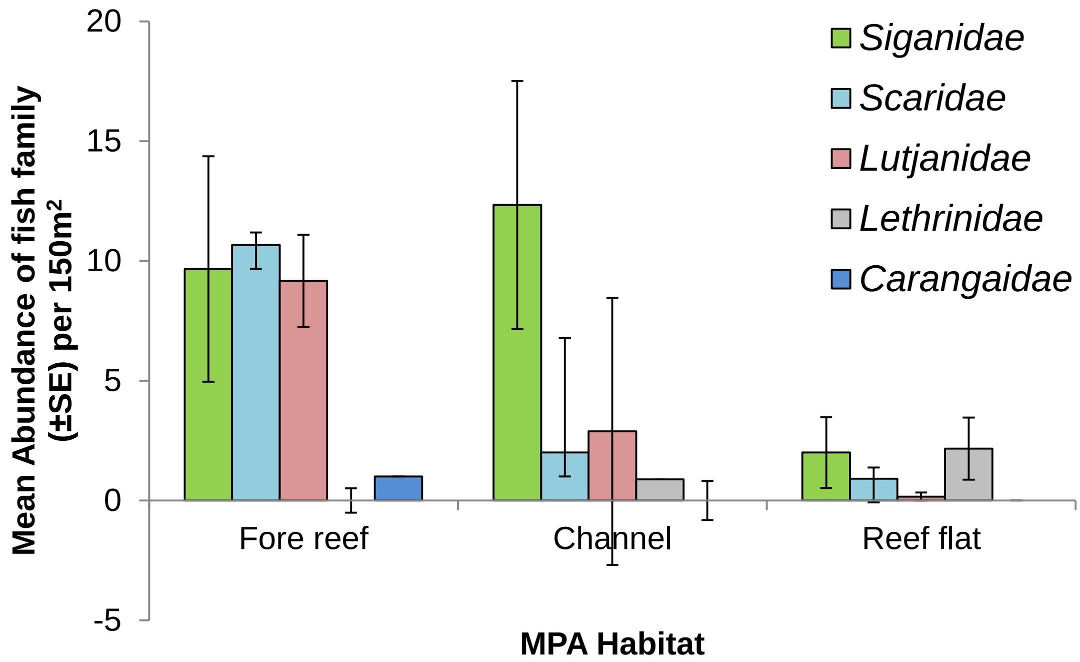

Figure 4: Mean abundance of fish belonging to the five dominant fish families encountered in the three habitats of Ngemai MPA.

Protected fish species were sighted within the surveyed area. There was a total of four *Siganus fuscescens* (Meyas), two Bolometopon muricatum (Kemedulk) and one Cheilinus undulatus (Maml).

Benthic cover

The benthic cover among the three habitats differed greatly. The channel was dominated by sand (40% ±10% SE), followed by macroalgae and turf algae (31% ± 15% SE, 14% ± 5.7% SE, respectively) (Fig. 5). The fore reef habitat was dominated by turf algae (49% ± 13.2% SE) and live corals (24% ± 3.9% SE) (Fig. 5). The reef flat habitat had the greatest cover of seagrass (39% ± 13.1% SE) and sand (33% ± 6.1% SE) (Fig. 5). This habitat also had the lowest coral cover.

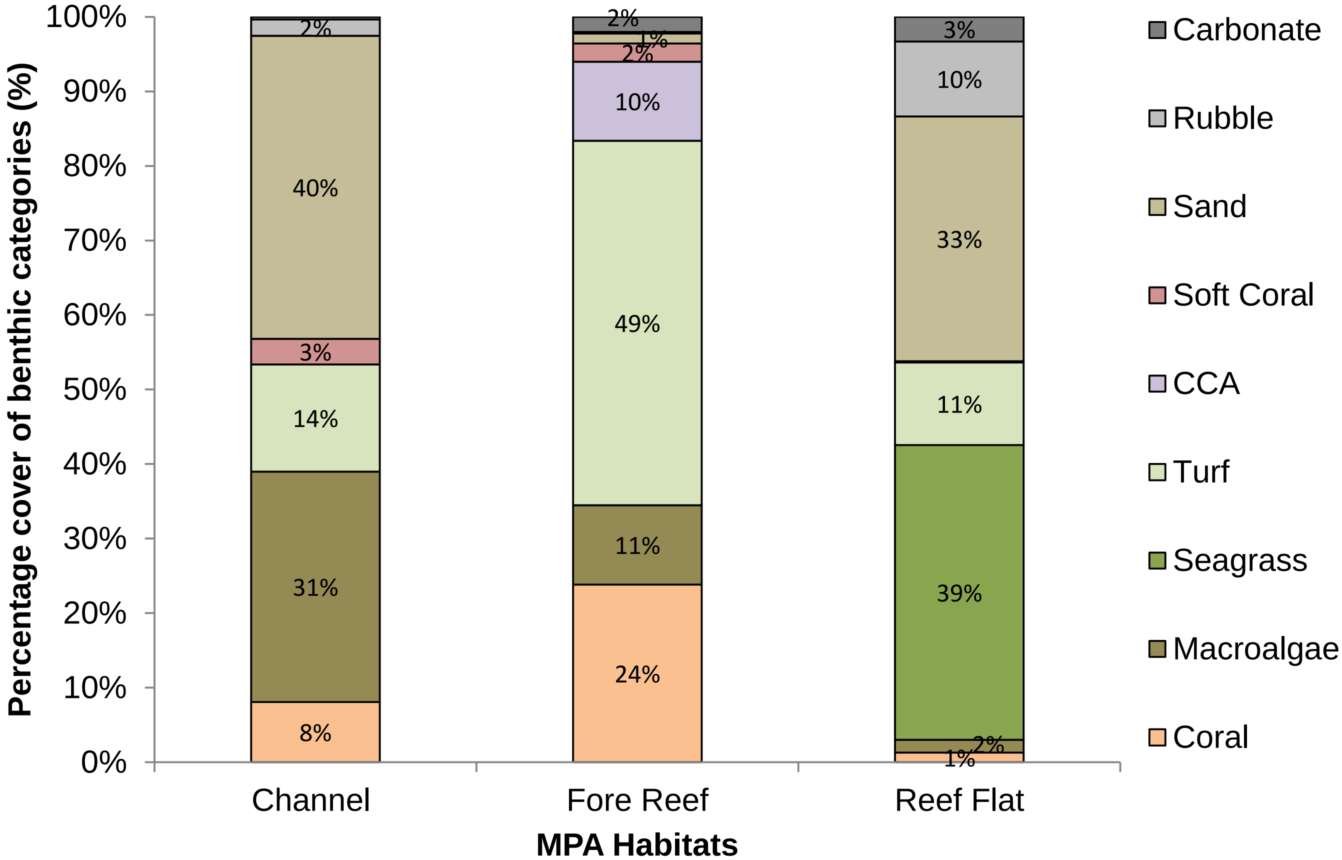

Figure 5: Mean percentage cover of main benthic cover present in the three habitats of Ngemai CA

The fore reef habitat had a total of 26 coral genera and was dominated by species from the genus *Porites* (Fig. 6). The channel habitat had a total of 16 coral general – all of them in low abundance (less than 2 % cover) (Fig. 6). The reef flat was dominated by seagrass and soft sediments. The most abundant seagrass species found in this habitat was *Enhalus acoroides* (21% ± 10.7% SE) and *Thalassia hemprichii* (10.3 % ± 4.9 SE).

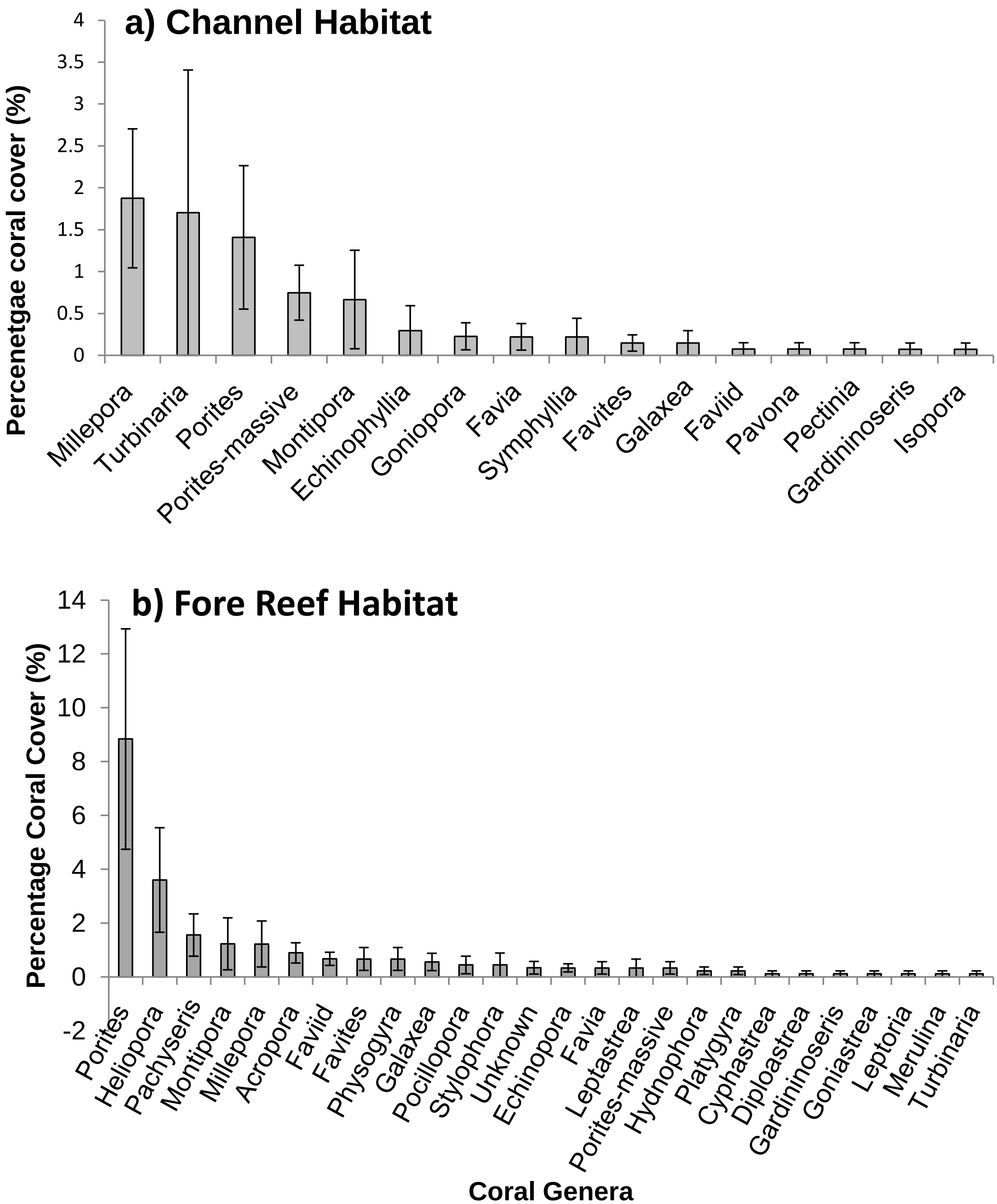

Figure 6: Mean percentage cover (±SE) of different coral genera present in the channel (a) and fore reef (b) habitats of Ngemai CA

Coral recruitment

Coral recruitment was higher in the fore reef and reef flat habitat with mean of 2.1 (± 0.7) and 1.1 (± 0.5) recruits per $3m^2$ respectively (Fig. 7). The fore reef and reef flat habitats were dominated by *Porites* species (including *Porites rus*) and *Montipora* species of coral recruits. Recruits of *Psammocora* species were also present in the reef flat habitat.

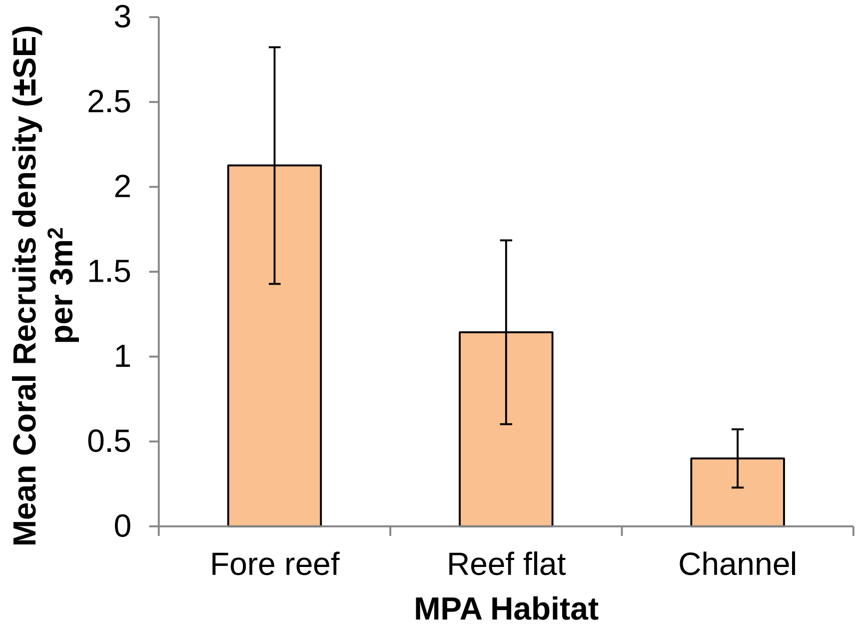

Figure 7: Mean coral recruits density in the three habitat of Ngemai CA

Invertebrates' density

The abundance of commercially-targeted invertebrates' species (see list in Appendix 2) was high in the reef flat habitat with 31 (± 22 SE) individuals per 60 m^2 (Fig. 8). The reef flat hosted high densities of sea cucumber species; the most abundant was *Stichopus vastus* (Ngimes), followed by *Holothuria impatiens* (Sekesaker) and *Actinopyga* species (Cheremrum).

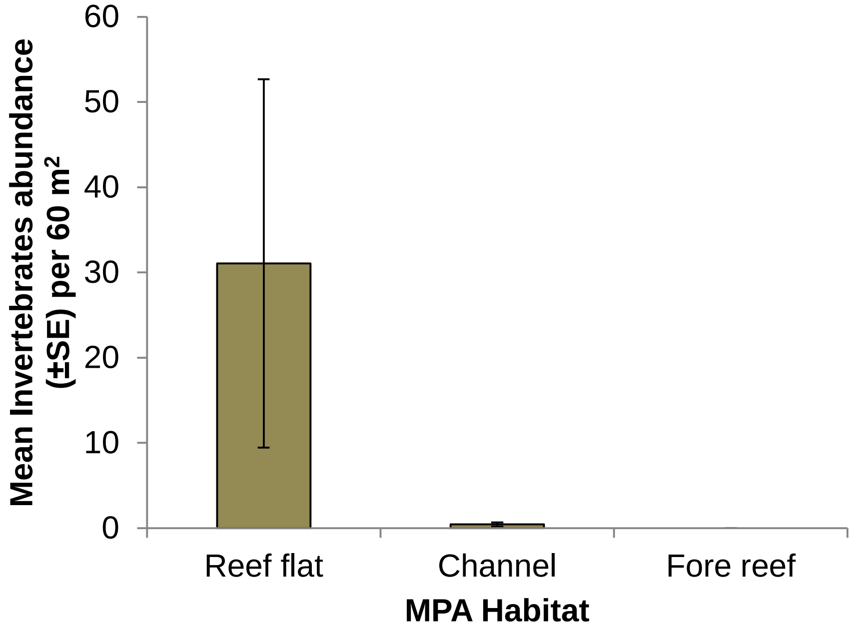

Figure 8: Mean abundance of commercially-targeted invertebrates' species in the three habitats of Ngemai CA.

Discussion

The overall goal of this study was to collect baseline ecological information within the Ngemai marine protected area. This site has been closed to fishing since 2008 and is part of the PAN since 2010. Although no comparison through time and/or with a reference site was possible for this site, our study highlights interesting results for a 7-years old MPA.

The fish abundance of commercially-targeted species was relatively high in the channel and fore reef habitats with more than 20 individuals per $150m^2$. The fore reef habitat had more fish, 33 individuals per $150m^2$ than in the previous survey done in 2011 on the fore reef (11.4 individuals per 150 m^2) (Koshiba et al. 2013) which shows that protection from fishing is working. Both the fore reef and channel habitats had high abundance of five important fish families. Herbivorous fishes, *Siganidae* and *Scaridae*, which are not only a targeted species but also important groups that play key ecological role in promoting reef resilience to increasing disturbance (Nyström et al. 2008; Mumby et al. 2013). Carnivorous fish from the family *Lutjanidae*, were also abundant in both habitats. Other carnivorous fish from the *Lethrinidae* and *Carangaidae* families appeared in lower abundance than other families but their presence shows that the MPA hosts predatory fish and might be an indication that fishing pressure has decreased. The lowest abundance and biomass of fish was in the reef flat which is due to the environmental characteristics of the habitat: shallow exposed lagoon with sediments and seagrass beds. The reef flat had smaller fish from four of the five main fish families. This shows that this area is acting as a nursery for juvenile fish and is an essential habitat of the MPA. Finally, the sighting of three protected fish species (Maml, Kemedukl and Meyas) within the surveyed area is very encouraging. This shows that even a small MPA like Ngemai CA, due to presence of different habitat types, is home to a diverse fish communities, including protected species in Palau.

Live coral cover was the highest in the fore reef habitat (24%) which has similar values than in 2011 (Koshiba et al. 2013). Despite the occurrence of the two typhoons in 2012 and 2013, live coral cover was not damaged like sites nearby (Melekeok and Ngaraard PICRC monitoring sites), where now live coral cover is lower than 5% (unpublished data, PICRC). The Ngemai fore reef positioned backwards from the adjacent fore reefs North and South (Fig. 1) must have protected it from big swells and reef destruction. The presence of live mature coral colonies inside the MPA is very encouraging for the future recovery of damaged reefs surrounding the MPAs. Depending on how well the reefs are connected, the MPA might help repopulating damaged reefs nearby (Golbuu et al. 2012). The channel habitat had very high levels of sediments because of the river nearby. Despite the high-sediment conditions, live corals were present in this habitat and relatively diverse with 16 recorded different coral genera. The adjacent consolidated terrestrial protected areas Oselkesol will be beneficial to coral reefs in the channel and fore reef helping prevent high sedimentation levels which are harmful to corals. Previous studies in Palau showed that sediments yield was significantly lower where land activities were reduced (e.g. clearing) and mangroves were present (Golbuu et al. 2003, 2011; Victor et al. 2004). Finally, the reef flat habitat was dominated by soft sediments with seagrass beds cover approaching 40% and hosted juveniles fish and high number of invertebrates (discussed below).

Coral recruitment was the highest on the fore reef habitat but was lower than in the previous surveys (2.1 recruits in 2015 against 4.2 recruits in 2011 per 3 m^2) (Koshiba et al. 2013). This decrease is possibly due to the loss of mature coral colonies nearby caused by the two subsequent typhoons in 2012 and 2013. The outer reef on the east coast has lost about 20% of coral cover (unpublished data, PICRC) and will affect recruitment rate in the following years (Doropoulos et al. 2014). Coral recruitment was low on the reef flat and channel habitat with less than 1 recruit per $3m^2$. This is due to substrate type: fine sediments and sand. The two channels had the lowest recruitment rate (less than 0.5 recruits per $3m^2$) also caused by the substrate type (sand and mud) and the sedimentation occasioned by the river close-by.

The reef flat hosted most of the commercially-important invertebrates. Sea cucumber species, especially *Stichopus vastus* (Ngimes) and *Holothuria impatiens* (Sekesaker) appeared in high abundances in the seagrass beds. This indicates that harvesting pressure have ceased as these two species are harvested by locals for their own consumption. The presence of *Actinopyga* species (Cheremrum) was encouraging as it used to be harvested for export to Asian markets.

Ngemai CA is a very good example of the application of protective management including ecosystem -connectivity in Palau. Despite its small size of 2 km^2, Ngemai CA include mangrove forests, reef flat with seagrass beds, coral reefs living in high sedimentation conditions and coral reefs on the fore reefs. All these different ecosystems connect with each other due to the larvae stages of most of marine organisms as well as their physical characteristics (e.g. nurseries for segrass beds) (Palumbi

2003; Cowen 2006; Mumby and Hastings 2008). In addition, the sheltered location of Ngemai CA, saved the reefs from the destruction caused by the two typhoons that damaged most of the exposed East coast of Palau. All of these characteristics make Ngemai CA very resilient and a key component of the PAN that will hopefully help with the recovery of surrounded damaged reef in the next years.

Acknowledgment

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Appendix 1:

Commercially important fish species in Palau			
	Common name	**Palauan name**	**Scientific name**
1	Lined rabbitfish	Kelsebuul	*Siganus lineatus*
2	Forketail rabbitfish	Beduut	*Siganus argenteus*
3	Bluespine unicornfish	Chum	*Naso unicornis*
4	Orangespine unicornfish	Cherangel	*Naso lituratus*
5	Longface emperor	Melangmud	*Lethrinus olivaceus*
6	Orangestripe emperor	Udech	*Lethrinus obsoletus*
7	Yellowlip emperor	Mechur	*Lethrinus xanthochilis*
8	Red snapper	Kedesau	*Lutjanus bohar*
9	Humpback snapper	Keremlal	*Lutjanus gibbus*
10	Bluefin trevally	Oruidel	*Caranx ignobilis*
11	Giant trevally	Erobk	*Caranx melampygus*
12	Parrotfish species	Melemau	*Cetoscarus/Scarus* spp
13	Pacific longnose parrotfish	Ngeaoch	*Hipposcarus longiceps*
14	Bluespot mullet	Kelat	*Valamugil seheli*
15	Squaretail mullet	Uluu	*Liza vaigiensis*
16	Rudderfish (lowfin)	Komud, Teboteb	*Kyphosus spp (vaigiensis)*
17	Giant sweetlips	Melim ralm, Kosond/Bikl	*Plectorhinchus albovittatus*
18	Yellowstripe sweetlips	Merar	*Plectorhinchus crysotaenia*
19	River snapper	Kedesau'l iengel	*Lutjanus argentimaculatus*
20	Yellow cheek tuskfish	Budech	*Choerodon anchorago*
21	Masked rabbitfish	Reked	*Siganus puellus*
22	Goldspotted rabbitfish	Bebael	*Siganus punctatus*
23	Bicolor parrotfish	Beyadel/Ngesngis	*Cetoscarus bicolor*
24	Indian Ocean Longnose parrotfish	Bekism	*Hiposcarus harid*
25	Red gill emperor	Rekruk	*Lethrinus rubrioperculatus*
26	Pacific steephead parrotfish	Otord	*Scarus micorhinos*
Protected Fish Species (yearly and seasonal fishing closure)			
27	Dusky rabbitfish	*Meyas*	*Siganus fuscescens*
28	Bumpead parrotfish	*Kemedukl*	*Bolbometopon muricatum*
29	Humphead parrotfish	*Maml*	*Cheilinus undulatus*
30	Squaretail grouper	*Tiau*	*Plectropomus areolatus*
31	Leopard grouper	*Tiau*	*Plectropomus leopardus*
32	Saddleback grouper	*Tiau, Katuu'tiau, Mokas*	*Plectropomus laevis*
33	Brown-marbled grouper	*Meteungerel'temekai)*	*Epinephelus fuscoguttatus*
34	Marbled grouper	*Ksau'temekai*	*Epinephelus polyphekadion*

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	Latitude	Longitude
1	832999.3	458604
2	832021.9	458504
3	832925.8	458942
4	832884.4	459128
5	832899.5	459053
6	832472.6	459265

ID	Lat	long
7	832855.7	459118.5
8	832542.3	459173.3
9	832617	459210.5
10	832777.4	458367.3
11	832237.8	458747.9
12	833144.9	458129.3
13	833034.2	458016.5
14	832173.9	458369.1
15	832921.6	458591