Baseline Assessment of Ngerumekaol Spawning Area

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PICRC Technical Report No. 15-01

May 2014

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 survey aimed at gathering information on commercially important fish density and biomass, coral cover, coral recruit density and invertebrate density within Ngerumekaol Spawning Area (NSA). NSA has been closed to fishing since 1999 and is a known area of fish spawning aggregations for several species. Our results demonstrate that there was a high abundance of scarids species, an important group for reef resilience. In addition, coral cover was high, especially in the channel habitat. The overall density of coral recruits was high, with the highest density on the fore reef. However, several targeted invertebrates species were absent or appeared in very low densities. Further monitoring data collected over the coming years will help determine the reason for low invertebrate densities and assess the effectiveness of the MPA in protecting the NSA coral reef community.

1. Introduction

Marine Protected Areas have been widely used as an effective conservation tool against anthropogenic threats and biodiversity loss [1-3]. 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 species, and in 2003 the Palauan government established the Protected Area Network (PAN). This network aimed 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 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 Report 4]. 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 (CBD) 5].

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 the PAN Marine Protected Areas (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 at PAN MPAs sites.

Ngerumekaol Spawning Area (NSA), also known as Ulong Channel, is located on the west coast of Palau. In addition to being a popular snorkeling and diving tourist site, it is an important area for fish spawning aggregations, especially Epinephelidae species (groupers) during the summer months. In 1976, a national law was established to protect grouper populations during their spawning season from April 1st to July 31st. This period has recently been extended until October 31st after surveys showed that grouper were still forming spawning aggregations during August and September. Additional research demonstrated that other species of fish also aggregated to spawn at different times of the year. Therefore, Koror State closed fishing completely within the area in 1999. The fishing ban includes no killing, no collection and no trapping at any time of the year.

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 three different habitats (back reef, fore reef, channel) of the NSA and examine differences among them. Over the coming years, subsequent sampling at the same sites will allow assessment of the effectiveness of the MPA at protecting biodiversity and increasing fish biomass over time.

2. Methods

2.1 Study site

NSA covers an area of 3.51 km^2 located at N7.283143, E134.251388 (Figure 1) and has been protected from fishing for 15 years. The monitoring protocol followed a stratified sampling design. Random stations locations were allocated within each habitat present in the MPA (back reef, channel and fore reef) depending on their size using Hawths Tools (Arcview Extension) (Figure 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 three sites in the fore reef habitat (n = 9 transects), a total of three sites in the channel habitat (n = 9 transects), and a total of fifteen sites in the back reef habitat (n = 45 transects). The survey was conducted in May 2014 over four days.

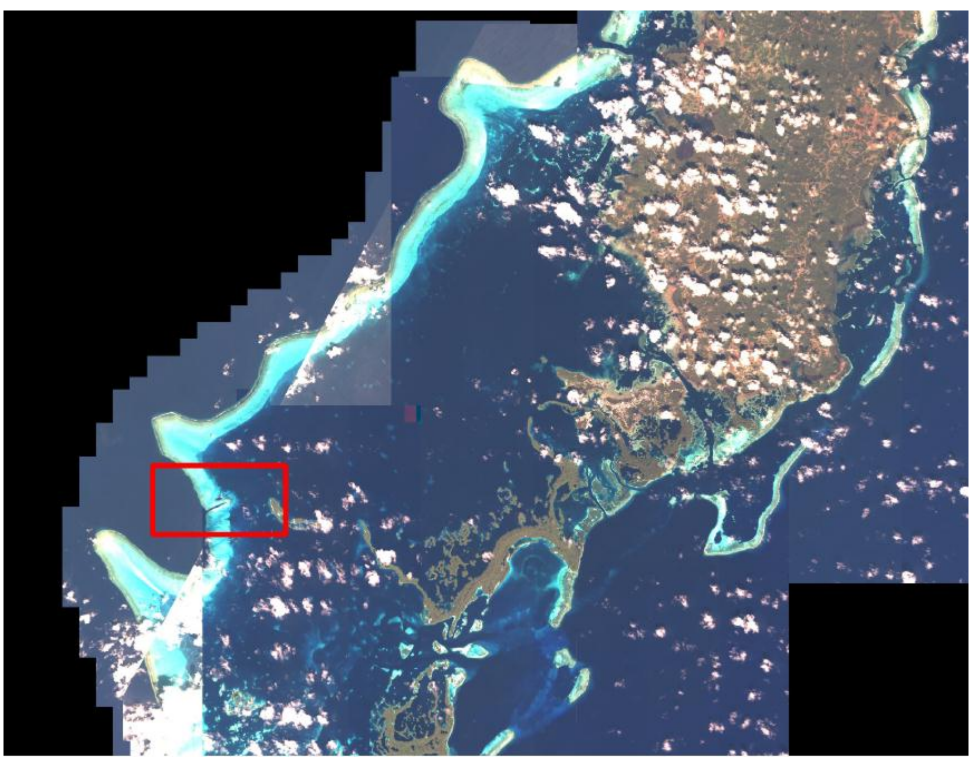

Figure 1: Location of Ngerumekaol Sapwning Area (red rectangle) in Palau

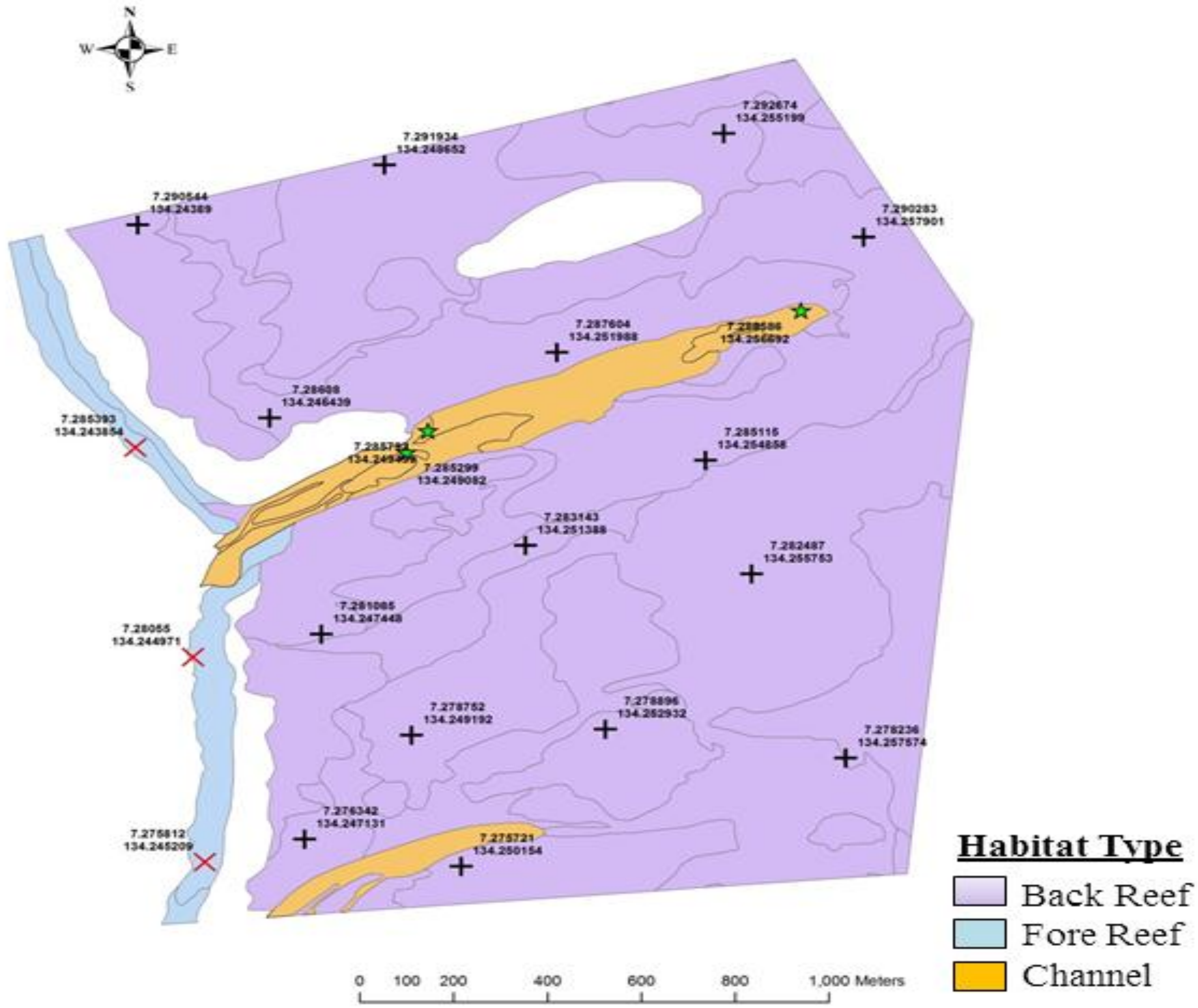

Figure 2: A map of Ngerumekaol Spawning Area, showing the three different habitat types (purple = back reef, blue = fore reef, and orange = channel) found there, and the locations of sampling stations within each habitat (black cross = back reef, red cross = fore reef, and green stars = channel). The white area was too shallow to be surveyed.

2.2 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 and benthic cover. 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.

2.3 Data analysis

To estimate benthic cover, photo-quadrats were analyzed using CPCe software [6]. 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 every 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 taken from Fishbase (http://fishbase.org). Biomass data were converted into kilograms.

This study collected baseline data on fish abundance and biomass, benthic cover, coral recruit density and invertebrate density in each of the three habitats of NSA: back reef, channel, and fore reef. For this survey, we were interested to see whether ecological variables differed amongst the three habitats within the MPA. Differences among habitats in terms of fish biomass and abundance, invertebrates' abundance, benthic cover, and coral recruits' density were tested using single factor Analysis of Variance (ANOVA). Data were checked for normality using Shapiro-test and were transformed if needed. When there were significant differences in ecological variables among habitats, a *post hoc* Tukey test was used to distinguish which habitats differed significantly. All graphics and analysis was done using R statistical software (R Core Team, 2014).

3. Results

3.1 Fish abundance and biomass

The biomass of the 34 recorded fish species (Appendix 1) was significantly higher on the fore reef compared to the back reef habitat of NSA (Figure 3, Table 1) with a mean of 8.1 kg (± 3.1 SE) of fish per 150 m^2. This was mainly due to the higher biomass of *Scaridae* species (parrotfish) in the fore reef habitat compared to the back reef habitat (Figure 3). The comparison of fish abundance among habitats did not show any differences. There were no protected fish species present in our surveys.

Table 1: Results from ANOVA analysis and post-hoc TUKEY tests to examine the differences among the three habitats at NSA: fore reef, channel and back reef.

Variable	Df	MeanSq F	F-value	Pr (>F)	TukeyHSD
Commercially-valued Fish Abundance	2	0.6169	1.598	0.23	N/A
Commercially-valued Fish biomass	2	4.049	4.392	0.028*	Fore Reef > Back Reef
Scaridae spp Abundance	2	0.8091	1.457	0.259	N/A
Scaridae spp biomass	2	5.394	4.051	0.0353*	Fore Reef > Back Reef
Coral Cover	2	1903.3	13.09	0.00030	Channel > Back

				9 ***	Reef
Acropora Cover	2	392.0	6.849	0.00614 **	Channel > Back Reef
Montipora Cover	2	3.0251	7.482	0.00432 **	Fore Reef > Back Reef
Porites Massive Cover	2	1.301	1.208	0.322	N/A
Pocillopora Cover	2	1.9354	7.628	0.00399 **	Fore Reef > Back Reef
Macoalgae cover	2	1.7156	4.853	0.0206 *	Channel > Back Reef
Turf Algae Cover	2	15.231	4.546	0.0252 *	Channel > Back Reef
Sand Cover	2	2512.9	4.791	0.0215 *	Back Reef > Fore Reef
Carbonate Cover	2	17.831	5.894	0.0107 *	Fore Reef > Back Reef
Rubble Cover	2	18.536	6.51	0.00746 **	Back Reef > Channel
Soft Coral Cover	2	0.4986	2.551	0.106	N/A
Ascidians Cover	2	2.3397	6.064	0.0097	Back Reef > Channel
Coral recruits density (all genera)	2	5.580	9.284	0.0017 **	Fore reef > Back reef
Coral recruits density- *Acropora*	2	5.840	11.84	0.000523 ***	Fore reef > back Reef & Channel
All invertebrates abundance	2	1.193	0.871	0.435	N/A
Tridacna maxima abundance	2	1.1606	1.692	0.212	N/A

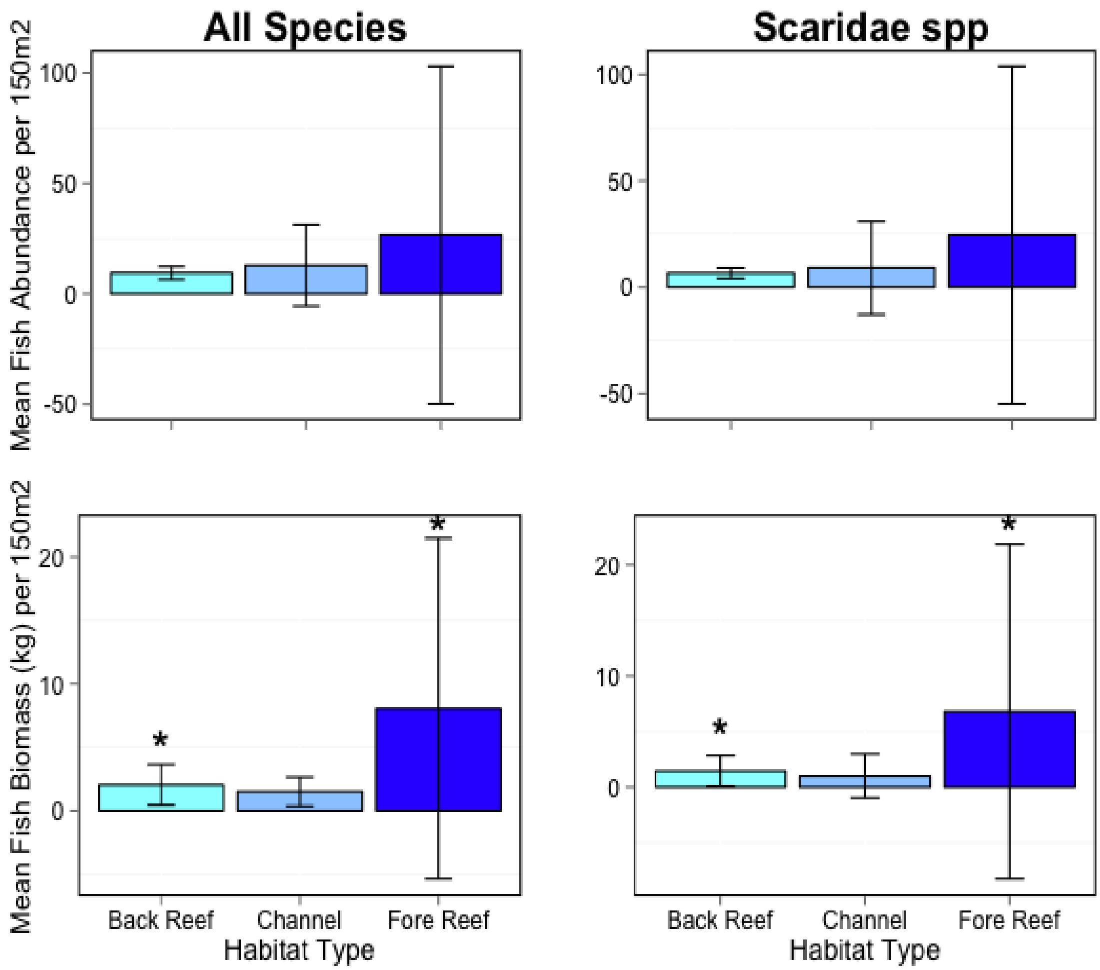

Figure 3: The mean abundance and biomass per 150 m^2 (±SE) of commercially-important fish species and *Scaridae* species in the three different habitats within NSA. Stars indicate significant differences amongst the sites as determine by post hoc Tukey's tests.

3.2 Benthic cover

The most abundant broad benthic categories were compared to examine any differences among the three NSA habitats. Coral cover was significantly higher in the channel habitat compared to other habitats with a mean cover value of 55.6% (± 3.1 SE) (Figure 4, Table 1). The fore reef habitat demonstrated the highest carbonate substrate cover with 57.6% (± 4 SE) (Figure 3, Table 1).

The back reef habitat showed a significantly higher cover of sand and rubble than other habitats (Figure 4, Table 1). Macroalgae and turf algae cover was higher in the channel habitat but was low overall (less than 5.5% cover) (Figure 3, Table 1). The cover of ascidians was greater in the back reef habitat compared to the channel habitat and soft coral cover did not differ among habitats (Figure 4, Table 1).

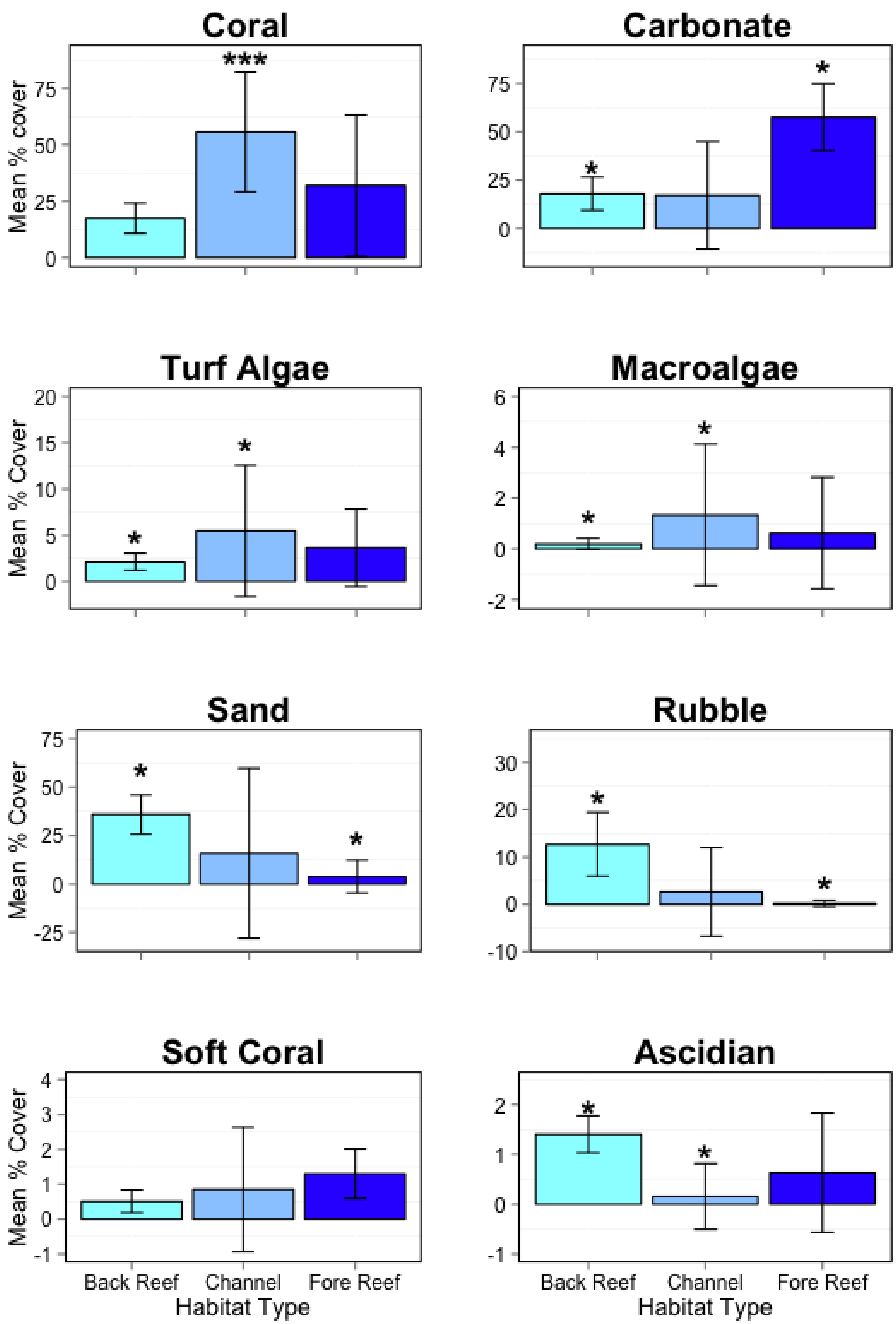

Figure 4: The mean percentage cover (±SE) of broad benthic categories amongst the three different habitats of NSA. Stars indicate significant differences amongst the sites as determine by post hoc Tukey's tests.

Coral cover data was further examined to look at the percentage cover of different coral genera among habitats. There were a total of 29 genera recorded at NSA (Figure 5). The most abundant coral genus was *Acropora* with greater than 10.6% cover in the three habitats and the highest cover in the channel habitat with 28.3% (± 2.5 SE) (Figure 5, Table 1). The most abundant genera after *Acropora* were *Montipora*, *Porites* (massive) and *Pocillopora* (Figure 5 and 6). Both *Montipora* and *Pocillopora* cover was significantly higher in the fore reef habitat (Figure 6, Table 1).

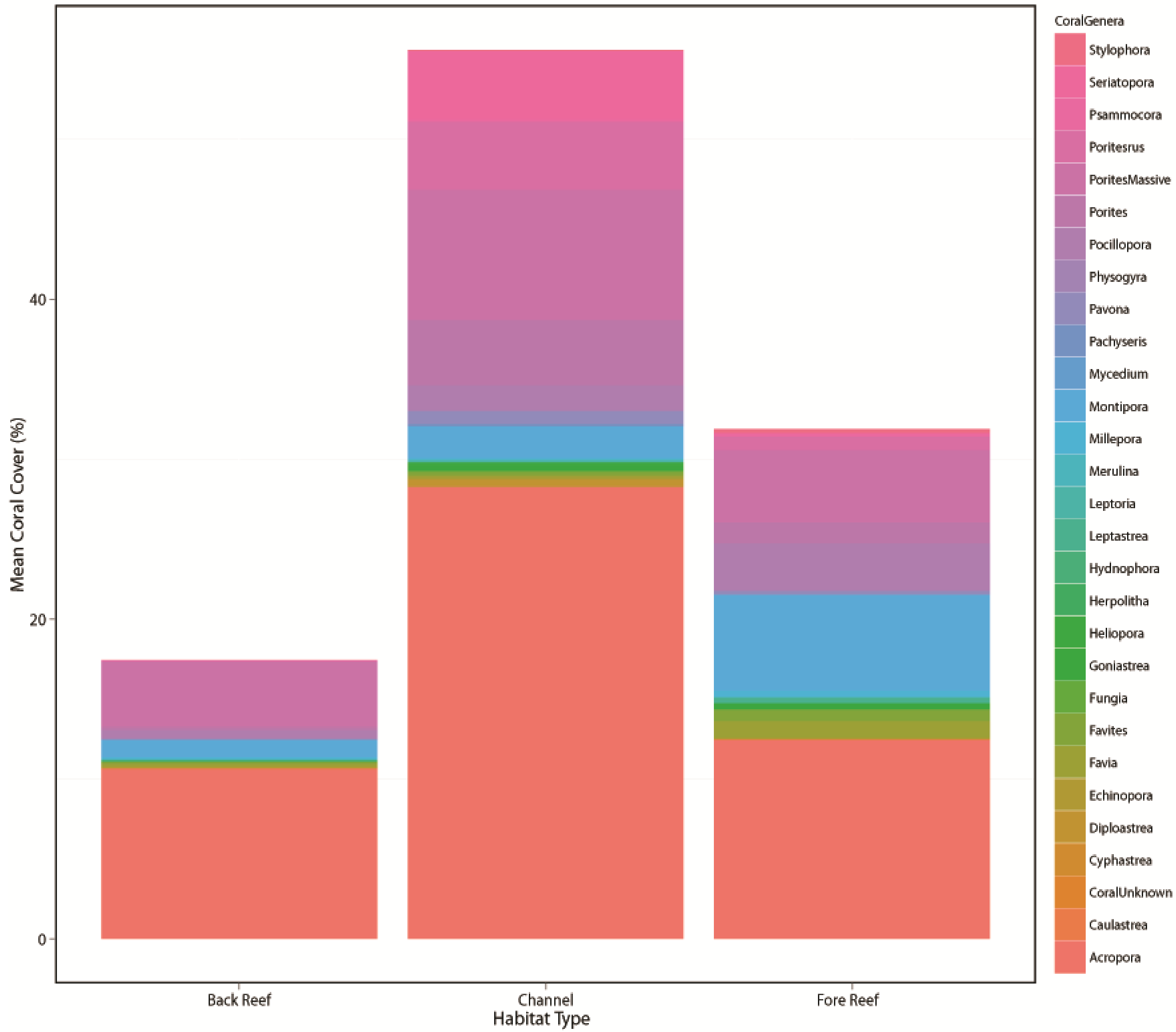

Figure 5: The mean percent cover of each of the coral genera present in the three habitats of NSA.

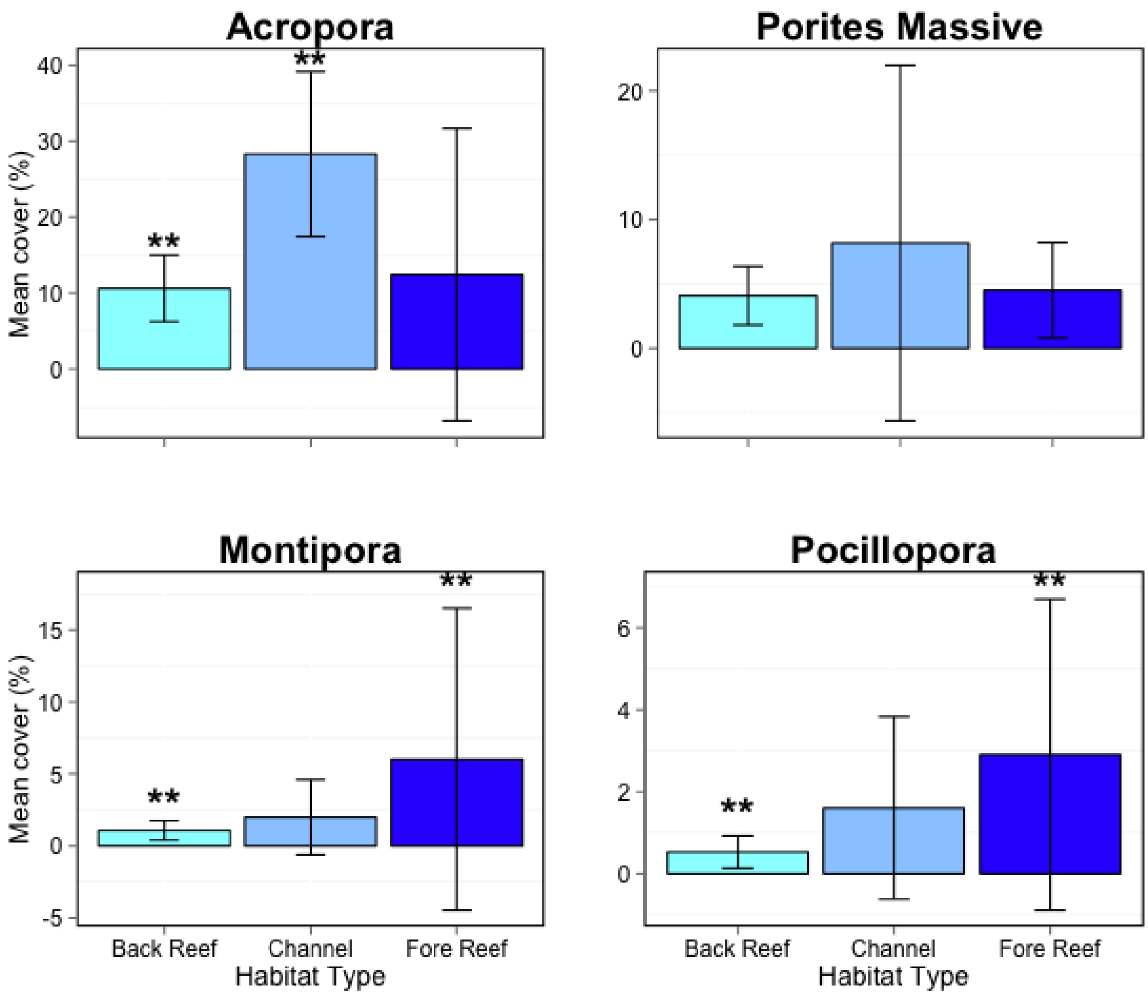

Figure 6: The mean percent cover (± SE) of the four most abundant coral genera in the three habitats of the NSA. Stars indicate significant differences amongst the sites as determine by post hoc Tukey's tests.

3.3 Coral recruits density

Within the three habitats of NSA, there were 19 genera of coral recruits less than 5 cm (Figure 6). Recruit density (all genera included) was significantly higher in the fore reef habitat when compared to the back reef habitat (Figure 7 and 8, Table 1). A large proportion of coral recruits were from the genus *Acropora* with densities higher than 2.8 recruits per 3 m^2, and significant higher densities in the fore reef habitat with an average of 24.3 (± 4.5 SE) recruits per 3 m^2 (Figure 7 & 8, Table 1).

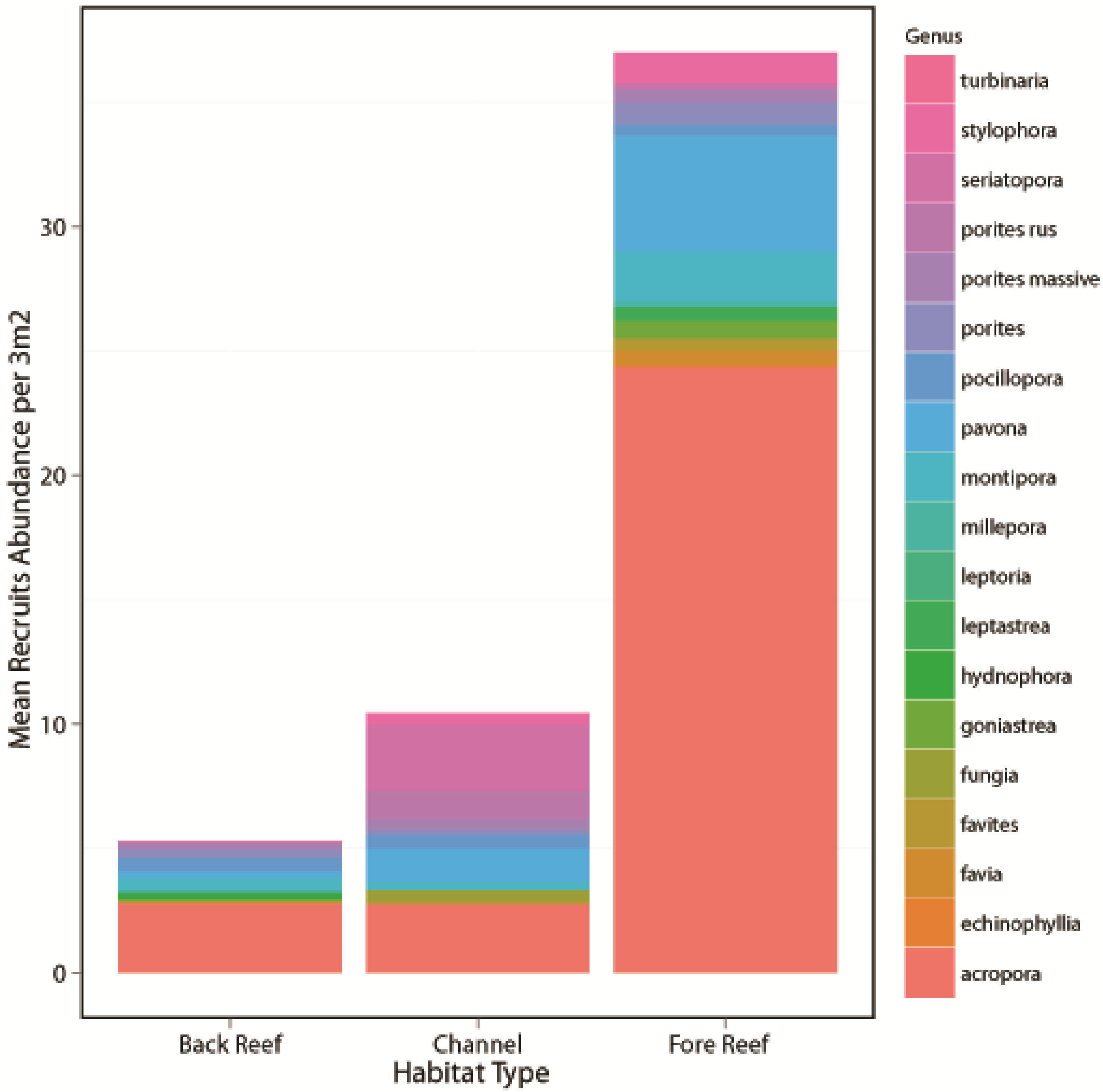

Figure 7: The mean coral recruit density of each coral genus in the three habitats of NSA.

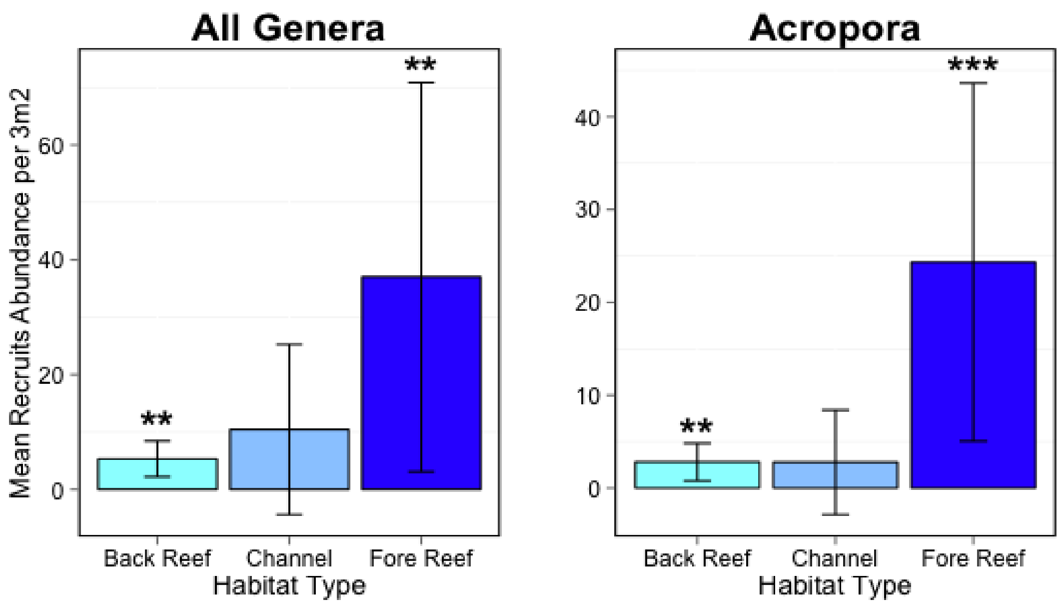

Figure 8: The mean coral recruit density (± SE) per 3m^2 in the three habitats of NSA for a) All Genera and b) Acropora. Stars indicate significant differences amongst the sites as determine by post hoc Tukey's tests.

3.4 Invertebrate abundance

Four different species of invertebrates were recorded in this survey: brown sandfish, *Bohadschia vitiensis*, brown curryfish, *Stichopus vastus*, crocus giant clam, *Tridacna crocea*, and elongate giant clan, *Tridacna maxima*. The species *Tridacna maxima* was the most abundant overall with 6.55 (± 1.25 SE) individuals per 60 m^2 in the fore reef habitat (Figure 9). Both species of sea cucumber had a low density with less than 0.2 (± 0.02 SE) individuals per 60 m^2. The abundance of invertebrates did not differ among the three habitats (Figure 9, Table 1).

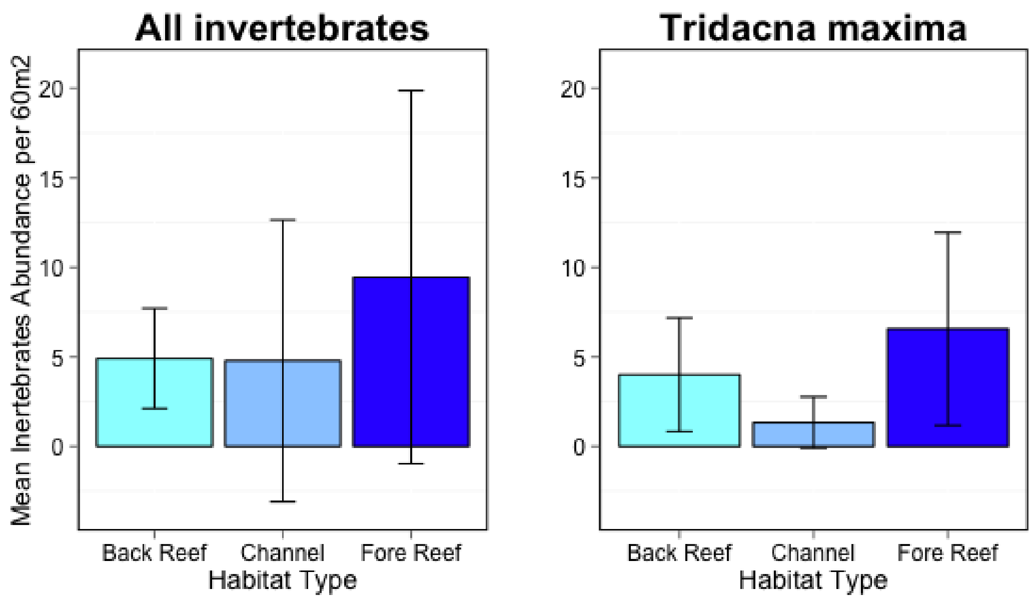

Figure 9: The mean invertebrate abundance (± SE) per 60 m^2 in the three habitats of NSA.

4. Discussion

The overall goal of this study was to collect baseline ecological information within the marine protected area NSA. This site has been closed to fishing since 1999 and is part of the PAN network since 2006, which aims to effectively protect 30% of Palau's nearshore habitats set by the MC. This study highlights interesting differences among the three habitats of NSA: fore reef, channel and back reef.

The fish biomass of commercially important species was significantly higher in the fore reef habitat compared to the back reef. The higher fish biomass in the fore reef habitat was mostly attributed to species belonging to the Scaridae family. A study by Mumby et al. (2013) examined the potential drivers structuring fish assemblages in Micronesia and found that herbivorous fish biomass was higher in high wave exposure reef habitat with low coral cover. The fore reef of NSA hosted a higher biomass of Scaridae as well as a lower coral cover than other habitats within the MPA, consistent with the findings of Mumby et al. [7]. The mean biomass of Scaridae species in closed fishing locations worldwide is 14.4 g per m^2 (± 1 SE) [8]. Within the three habitats of the NSA, there was a mean biomass of Scaridae species of 2.164 kg (± 0.75 s.e.) per 150 m^2, which equals 14.42 g per m^2. This matches the worldwide average of Scaridae species in MPAs and demonstrates that NSA supports healthy populations of an important group of herbivorous fish species, which play a key ecological role in promoting coral reef resilience to increasing disturbances.

The overall biomass of commercially important fish species remained low for a 15-year old MPA, with a mean of 1,239 kg per $150m^2$, excluding the Scaridae species. Studies of MPAs older than 10 years demonstrated greater biomass of targeted fish [9-11]. One potential explanation could be the small size of NSA (less than $10\text{-}km^2$). Also, many targeted species by the local fisheries (Epinephelidae, Lutjinidae, Lethrinidae) are highly mobile and known to travel to spawning sites monthly or seasonally [12], which could explain the low biomass of targeted species in the area. In addition, our survey was conducted over only a few days in May, outside the spawning season for Epinephelidae species, which may explain the absence of these species in our surveys. PICRC unpublished data does show that NSA supports a very high fish biomass of Epinephilidae species during the spawning season (from June to September) and is therefore effective at protecting these species during this important period.

Overall the mean coral cover was greater than 17.45%, which indicates the relatively good state of the reef - especially in the channel habitat with a mean cover of 55.6%. In addition, the macroalgae and turf algae cover appeared very low in all habitats with mean values less than 5.5%. High coral cover and low algae cover are in accordance with previous surveys done in 2005 and 2007 around Palau to assess the recovery of coral communities after the 1998 bleaching event [13, 14]. During the 2010 thermal stress event, about 20 to 25% of coral reef colonies bleached on the exposed west coast [15] but recovered rapidly, which indicates that the NSA is highly resilient. The fore reef habitat of NSA had the highest carbonate cover and significantly differed from the back reef habitat which was mostly dominated by rubble and sand. Our study surveyed reef communities at a maximum depth of 5m. At this depth, on the fore reef, the high-energy environment is probably the cause of the dominance of carbonate cover. Further attention should be taken on the classification of bare substrate as carbonate cover, as it would most likely be covered by very small turf algae –here, supporting the high biomass of scarids.

The coral genera diversity at NSA was high with 29 recorded genera. The most dominant genus was *Acropora* and showed a significant higher cover in the channel habitat compared to other habitats. Both *Montipora* species and *Pocillopora* species were more abundant on the fore reef due to the high energy environment. Overall, a total of 19 genera of coral recruits were recorded during this survey. Their density was significantly higher on the fore reef habitat which could be related to the availability of space to settle (highest carbonate cover). In this habitat, a large proportion of recruits belong to the genus *Acropora*. This possibly implies that *Acropora* colonies at NSA are self-seeding and that therefore, these individuals will benefit from the protection status of the area. However, further research on the genetics of *Acropora* species would be needed to confirm the previous assumption, as other variables than larval supply and hydrodynamics influence coral cover [16].

Only four commercially important invertebrates species were recorded at NSA, including two species of sea cucumbers and two species of clams and their density did not differ among habitats. Sea cucumbers densities were very low. These findings highlight that populations might still be harvested illegally within the MPA or are still recovering from previous exploitations or might just not be found at high abundance in the habitats of NSA. Long-term monitoring data over the coming years will help identify the cause of the state of the present population size and the absence of other commercially important invertebrate species.

This study demonstrated that population of fish and the coral communities at NSA are healthy compared to other studies in Palau and worldwide. However, invertebrate populations remained very low for a 15-year old MPA and further monitoring data will allow us to determine the cause. Future surveys using the same monitoring protocol will assess the effectiveness of the MPA at protecting each of the studied variables. Such information is needed to improve the PAN network in Palau and meet to goals of the MC to efficiently protect 30% of nearshore marine habitats by 2020.

Acknowledgement

PICRC would like to thank Koror State rangers for their help with field work and Dr. Alyssa Marshell for reviewing this report.

References

1. Edgar, G.J., Stuart-Smith, R.D., Willis, T.J., Kininmonth, S., Baker, S.C., Banks, S., Barrett, N.S., Becerro, M.A., Bernard, A.T., and Berkhout, J. (2014). Global conservation outcomes depend on marine protected areas with five key features. Nature *506*, 216-220.

2. Halpern, B.S. (2003). The impact of marine reserves: do reserves work and does reserve size matter? Ecological Applications *13*, 117-137.

3. Halpern, B.S. (2014). Conservation: Making marine protected areas work. Nature *506*, 167-168.

4. Committee, M.C.S. (2011). A Report on Progress to Implement the Micronesia Challenge 2006-2011. (Micronesia Chief Executives Summit), pp. 1-33.

5. Nations, U. (1992). Convention on Biological Diversity. pp. 1-30.

6. Kohler, K.E., and Gill, S.M. (2006). Coral Point Count with Excel extensions (CPCe): A Visual Basic program for the determination of coral and substrate coverage using random point count methodology. Computers and Geosciences *Vol. 32*, 1259-1269.

7. Mumby, P., Bejarano, S., Golbuu, Y., Steneck, R., Arnold, S., van Woesik, R., and Friedlander, A. (2013). Empirical relationships among resilience indicators on Micronesian reefs. Coral reefs *32*, 213-226.

8. Edwards, C.B., Friedlander, A., Green, A., Hardt, M., Sala, E., Sweatman, H., Williams, I., Zgliczynski, B., Sandin, S., and Smith, J. (2014). Global assessment of the status of coral reef herbivorous fishes: evidence for fishing effects. Proceedings of the Royal Society B: Biological Sciences *281*, 20131835.

9. Russ, G.R., Stockwell, B., and Alcala, A.C. (2005). Inferring versus measuring rates of recovery in no-take marine reserves. Marine Ecology Progress Series *292*, 1-12.

10. Stockwell, B., Jadloc, C.R.L., Abesamis, R.A., Alcala, A.C., and Russ, G.R. (2009). Trophic and benthic responses to no-take marine reserve protection in the Philippines. Marine Ecology Progress Series *389*, 1-15.

11. Clements, C., Bonito, V., Grober-Dunsmore, R., and Sobey, M. (2012). Effects of small, Fijian community-based marine protected areas on exploited reef fishes. Marine Ecology Progress Series *449*, 233-243.

12. Sale, P.F., Cowen, R.K., Danilowicz, B.S., Jones, G.P., Kritzer, J.P., Lindeman, K.C., Planes, S., Polunin, N.V.C., Russ, G.R., and Sadovy, Y.J. (2005). Critical

science gaps impede use of no-take fishery reserves. Trends in Ecology & Evolution *20*, 74-80.

13. Golbuu, Y., Bauman, A., Kuartei, J., and Victor, S. (2005). The state of coral reef ecosystems of Palau. The state of coral reef ecosystems of the United States and Pacific freely associated states, 488-507.

14. Golbuu, Y., Victor, S., Penland, L., Idip Jr, D., Emaurois, C., Okaji, K., Yukihira, H., Iwase, A., and Van Woesik, R. (2007). Palau's coral reefs show differential habitat recovery following the 1998-bleaching event. Coral reefs *26*, 319-332.

15. Woesik, R., Houk, P., Isechal, A.L., Idechong, J.W., Victor, S., and Golbuu, Y. (2012). Climate-change refugia in the sheltered bays of Palau: analogs of future reefs. Ecology and evolution *2*, 2474-2484.

16. Golbuu, Y., Wolanski, E., Idechong, J.W., Victor, S., Isechal, A.L., Oldiais, N.W., Idip Jr, D., Richmond, R.H., and van Woesik, R. (2012). Predicting coral recruitment in Palau's complex reef archipelago. PloS ONE *7*, e50998.

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	Orangspine unicornfish	Cherngel	*Naso lituratus*
5	Longface enperor	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	Erobk	*Caranx ignobilis*
11	Giant trevally	Oruidel	*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	*Kamedukl*	*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	*Kesau'temekai*	*Epinephelus polyphekadion*

Appendix 2: Invertebrates targeted by the local fisheries

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	
Trochus	Semum	

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"