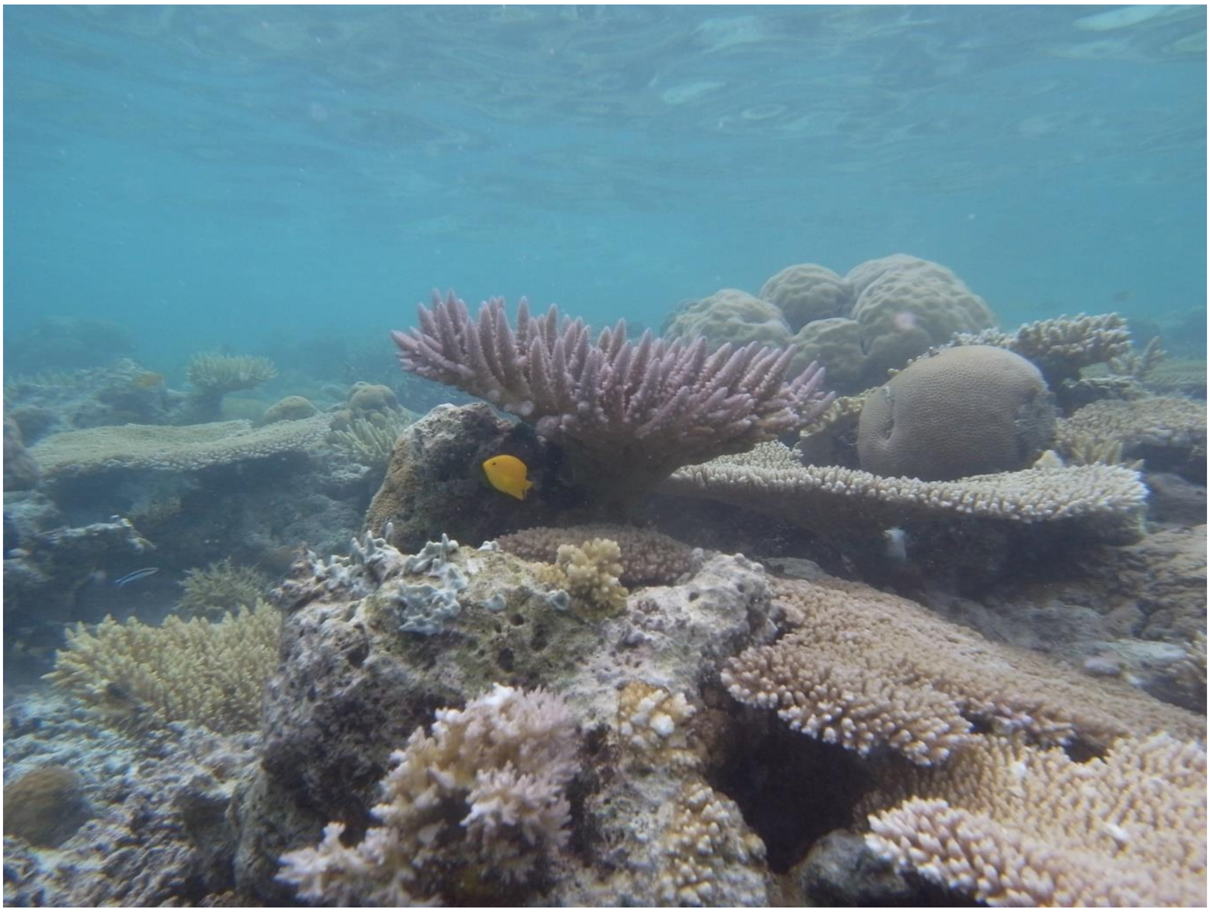
Ebiil Conservation Area Baseline Assessment



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Abstract

Marine protected areas (MPAs) are widely used as a conservation tool to protect coral reefs from human influence and to enhance marine resource availability. Advances in research and applied conservation are enhancing MPA designs and networks, making them more and more effective, thus increasing the chances of coral reef communities to better cope with various stresses. Palau has developed a network of protected areas throughout terrestrial and marine habitats to commit to the Micronesia Challenge to efficiently protect their biodiversity and natural resources. One of the goals of the PAN system is to promote resilience and effectiveness of protected areas. We conducted an ecological baseline survey for the Ebiil Conservation Area in Ngarchelong State in order to support PAN's goal of effective conservation. Results demonstrated significantly higher commercial fish biomass in the channel habitat compared to all other major habitats. The fore reef had a significantly high number of coral recruits compared to the other habitats. The information from this survey, combined with other future techniques, are critical to effectively manage the natural resources in Ngarchelong State as well as all of Palau.

Introduction

Coral-reef ecosystems are relied on throughout the tropics because of the goods and services that they provide, such as food, tourism and protection from storms (Costanza et al., 1997). Over the past half-century coral reefs have, and continue to be, threatened by the global threats of climate change and prolonged anthropogenic disturbances. In order for these important ecosystems to continue to provide the goods and services that we rely on, resources must be managed with long-term sustainability as a primary goal. Anthropogenic effects such as overfishing and increased land-use combined with climate change and ocean acidification are an extremely potent combination, so Marine Protected Areas (MPAs) can be used to buffer the anthropogenic disturbances and increase the survivability of coral reefs (Anthony et al, 2011 & Halpern 2003). MPAs have been refined over time to become more resilient, the ability for a system to absorb and recover from acute disturbances, and sustainable, the ability for a biological system to remain stable and diverse while provide the resources humans need, through spillover of adults into adjacent areas and through mapping larval connectivity (Nystrom et al, 2000). Through global and regional initiatives such as the Convention on Biological Diversity (CBD) and the Micronesia Challenge, many countries are adapting their Conservation Areas and policies to address climate change issues and promote effectiveness and resilience. The Micronesia Challenge's goal is to effectively conserve 30% of near-shore marine resources and 20% of terrestrial resources by the year 2020 to support the Aichi Targets developed by the CBD. The Micronesia Challenge is supported by the following countries: The Federated States of Micronesia, The Republic of Marshall Islands, Guam, The Commonwealth of the Northern Marianas Islands, and The Republic of Palau. In Palau, the goal of 30/20 is supported by the Protected Areas Network

(PAN). This is the framework established by the government of Palau to provide both technical and financial support for the different Palauan states and their Conservation Areas. Additionally, PAN provides the framework to develop Conservation Areas that are focused around key principles such as effectively promoting ecosystem resilience and effectiveness.

To effectively conserve the areas throughout Palau a baseline assessment of the Ebiil Conservation Area in Ngarchelong State was conducted. The Ebiil Conservation Area is located on an important channel where groupers aggregate to spawn (Fig. 1). In order to protect this important aggregation site, the Ngarchelong State Government enacted the Ebiil Conservation Area as a no-take and no-entry Conservation Area in 2000, in addition to the Palau-wide grouper sale and possession ban that runs from July 31 to October 31 over the peak reproductive season.

Ecological indicators selected for the baseline assessment were based on the Palau Protected Areas Network protocol: (1) fish density, (2) fish biomass, (3) invertebrate density, (4) benthic cover, and (5) recruit density.

Methods

Study Location

The Ebiil Conservation Area is located along the northwestern barrier reef of Palau at 07^{o} 46. 383 N, 134^{o} 34. 165 E. The Ebiil Conservation Area covers approximately 19.1 km^2 and consists of the following major habitats: back reef, fore reef, channel, and patch reefs (situated amongst predominately sandy-bottom lagoon). Within the Ebiil Conservation Area, 34 sites were randomly selected and the locations of the sites were assigned within each of the four habitats based on habitat sizes using the Hawths Tool (Arcview Extension) (Figure 1).

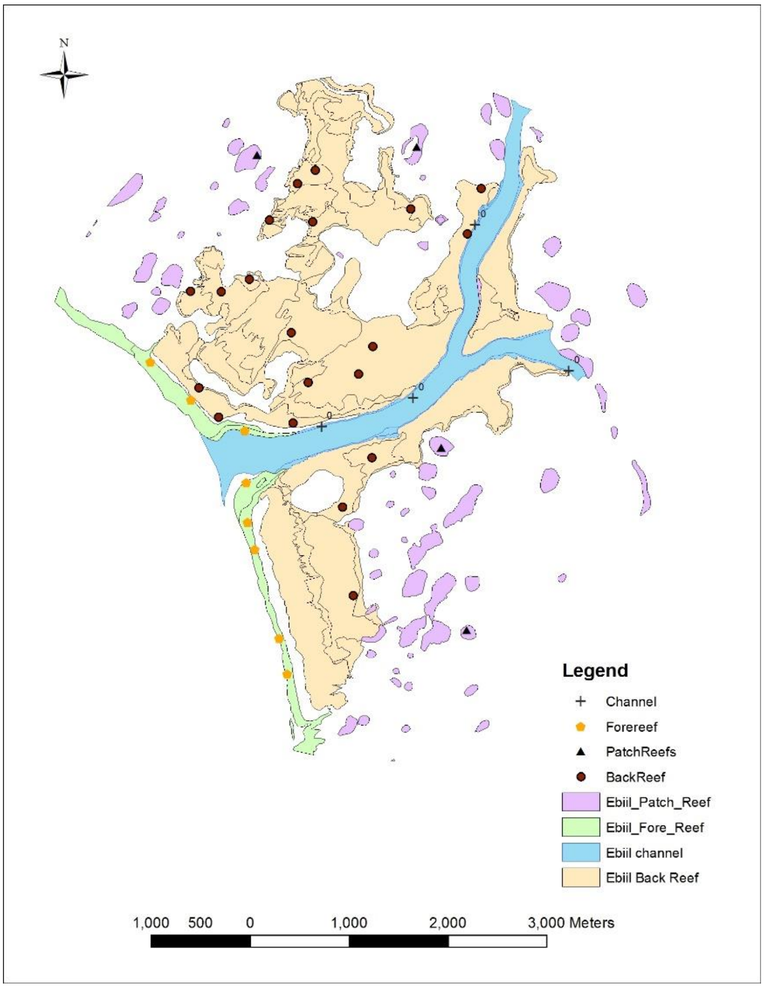

Figure 1. This is a map of the sites surveyed in the Ebiil Conservation Area.

Field Sampling

Fish, invertebrate and benthic surveys were conducted along three 30 m transects. Underwater Visual Census (UVC) was conducted along a 30 x 5 m transect and fish size and abundance was estimated. Thirty four commercially important fish species were surveyed due to their importance within Palauan fisheries (Appendix, Table 1). Invertebrate surveys were conducted along a 30 x 2 m transect, where commercially important invertebrate abundances were surveyed (Appendix, Table 2). Benthic cover was conducted using a 1 x 1 m photoquadrat sampled every meter along the 30 m transect (Appendix, Table 3). Coral recruits smaller than 5 cm along the longest axis were also recorded along a 0.30 m x 10 m transect.

Data Analysis

All analyses were conducted using R (R Core Team 2014) and Microsoft Excel unless stated.

Fish density, size and biomass.

Fish density and biomass was compared among habitat types within the Ebiil Conservation Area using ANOVA. Biomass was determined using the following total length-weight conversion:

Biomass = a*Total Length^b

Where a and b are coefficients of standard weight that were obtained from FishBase (http://www.fishbase.org). The coefficients vary depending on the shape of the body and the robustness of the fish species.

Invertebrate density

The mean density of commercially-important invertebrates was assessed among habitat types and compared using ANOVA.

Benthic cover

Photoquadrats were analyzed using Coral Point Count with Excel Extension (CPCe®). Five random points from each quadrat were selected and the benthic cover at each point was recorded, corals were identified to the genus level. Differences in benthic cover and the dominant coral genera were compared across habitat types using ANOVA.

Coral recruit density

Mean density of total coral recruits and Acropora data was assessed among habitat types within the Ebiil Conservation Area and compared using ANOVA.

Results

Fish Density and Biomass

The mean commercial fish and *Scaridae spp.* density within the four habitats were not significantly different (Figure 2A, B). However, the mean biomass of commercial fish was significantly higher in the channel compared to the back reef (17.45 kg ± 7.58 and 5.39 kg ± 5.35, respectively; p-value = 0.04; figure 3A), whereas no significant difference in biomass among habitats was detected among the *Scaridae spp.* (Figure 3B). The large-bodied parrotfish *Bolbometapon muricatum* was found mainly within the lagoon patch reef habitat, however, its abundance was not large enough to cause a significant increase in *Scaridae* biomass.

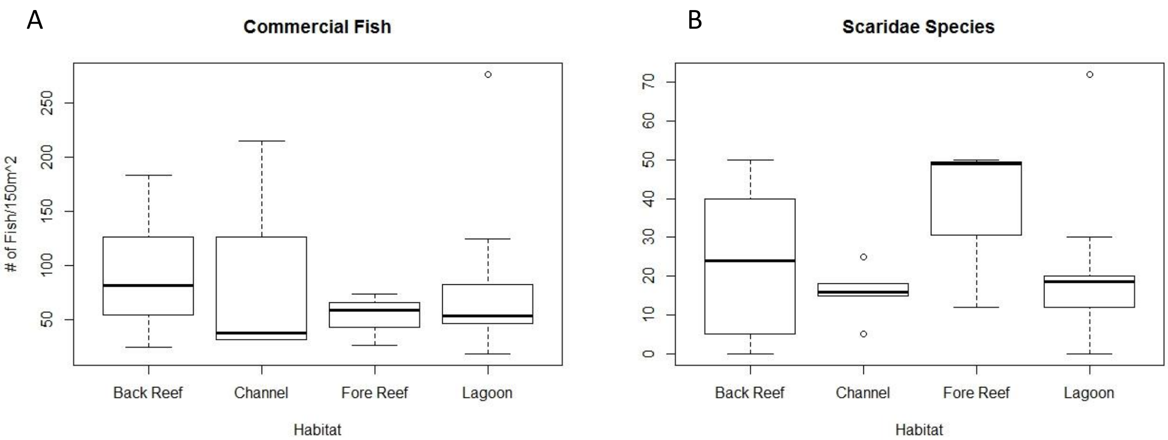

Figure 2. Mean density of commercially-important fish species (A) and *Scaridae labrids* (B) within four habitats at Ebiil Conservation Area.

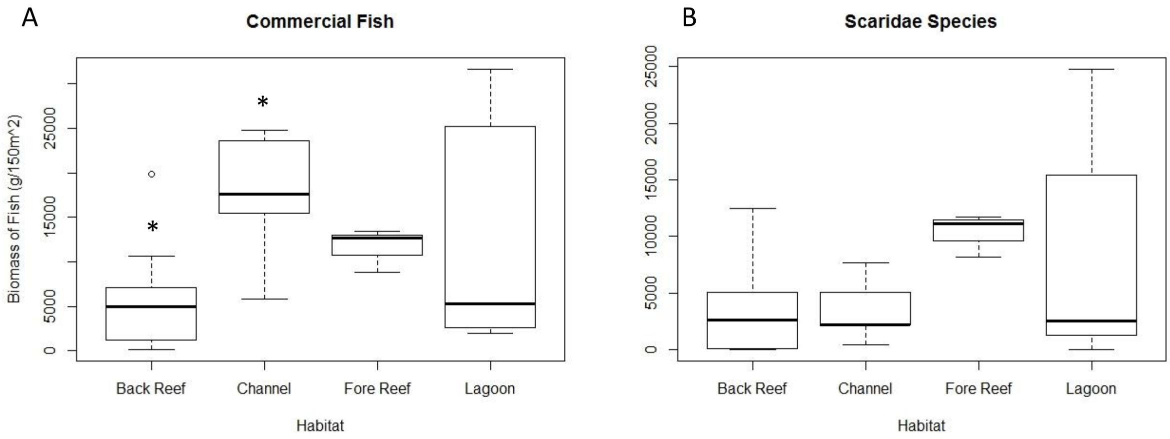

Figure 3. Mean biomass of commercially-important fish species (A) and *Scaridae spp.* (B) within four habitats at the Ebiil Conservation Area. Asterisks indicate significance (p<0.05).

Invertebrate Density

Mean invertebrate density was significantly lower within the lagoon compared to all other habitats within the Ebiil Conservation Area (3 ± 19.7, 24 ± 16.7, 16 ± 28.0, 37 ± 11.5; p-value = 0.004) (Figure 4).

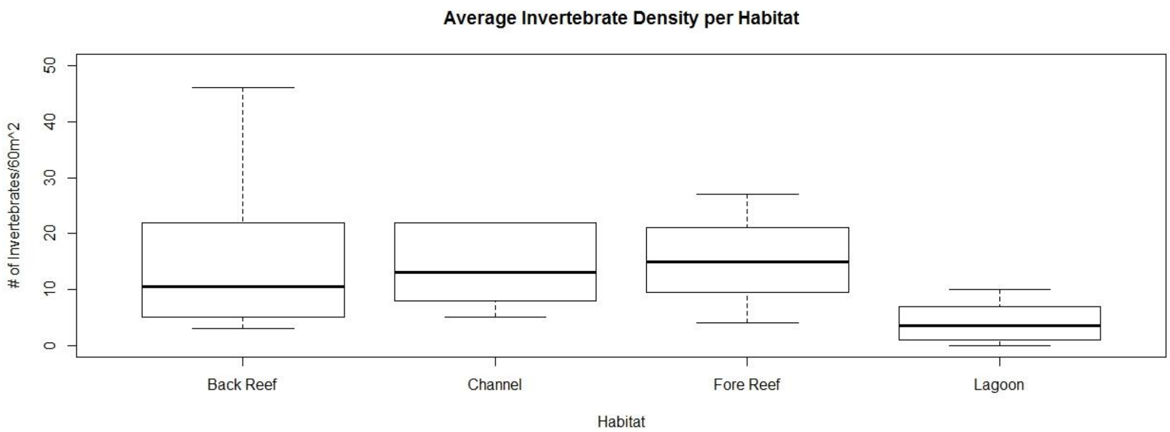

Figure 4. Mean density of commercially-important invertebrate across habitat types.

Benthic Cover

Coral cover, turf, rubble, and CCA was not significantly different among the different habitats (Figures 5A, 5B, 5C and 5F). The fore reef contained significantly lower sand cover compared to all other habitats (0.45% ± 0.78, 41.83% ± 15.67, 35.05 ± 25.10, 19.13% ± 24.76; p-value = $1.1e^{-4}$; Figure 5D). The back reef contained the highest sand cover which was significantly higher than the lagoon but not the channel habitats (41.83% ± 15.67 and 19.13% ± 24.67; p-value = 0.004; Figure 5B). Carbonate cover, which is bare concrete without coral or CCA, was significantly higher in the back reef and the fore reef compared to the lagoon (15.48% ± 11.29, 50.51% ± 8.98, 7.17% ± 15.56, p-values = 0.004 and $3.7e^{-4}$Figure 5E).

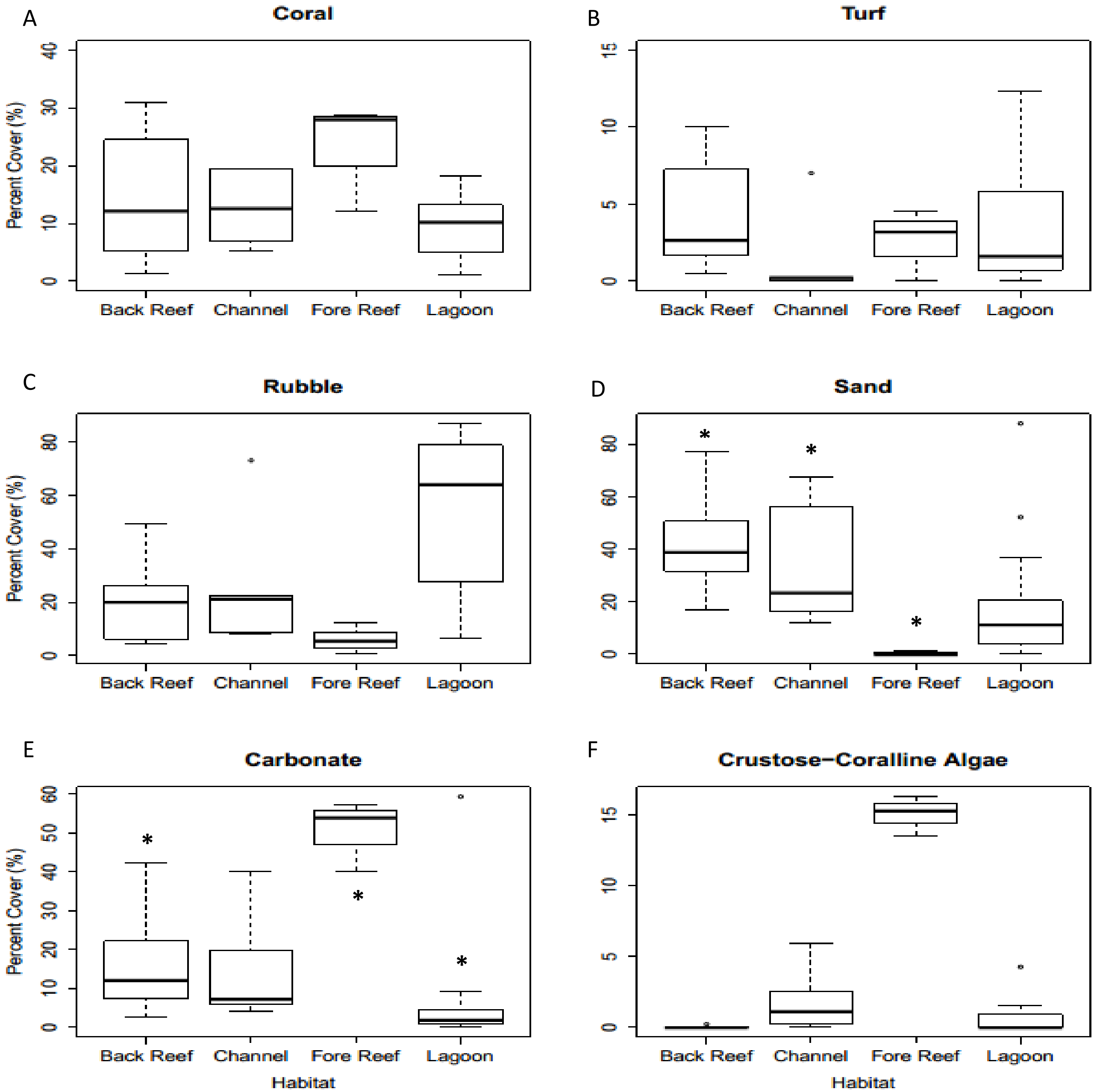

Figure 5. Boxplots showing the mean percent cover of the 6 most abundant benthic categories within each habitat at the Ebiil Conservation Area. Asterisks indicate significance (p<0.05). Hollow circles indicate outliers in the datasets.

The mean percent cover of Acroporid corals and massive Porites was not significantly different among habitats, whereas Montipora was significantly more abundant within the fore reef compared to all other habitats. Seriatopora coverage was high, but not significantly different, in the fore reef and lagoon of the Ebiil Conservation Area (Figure 6).

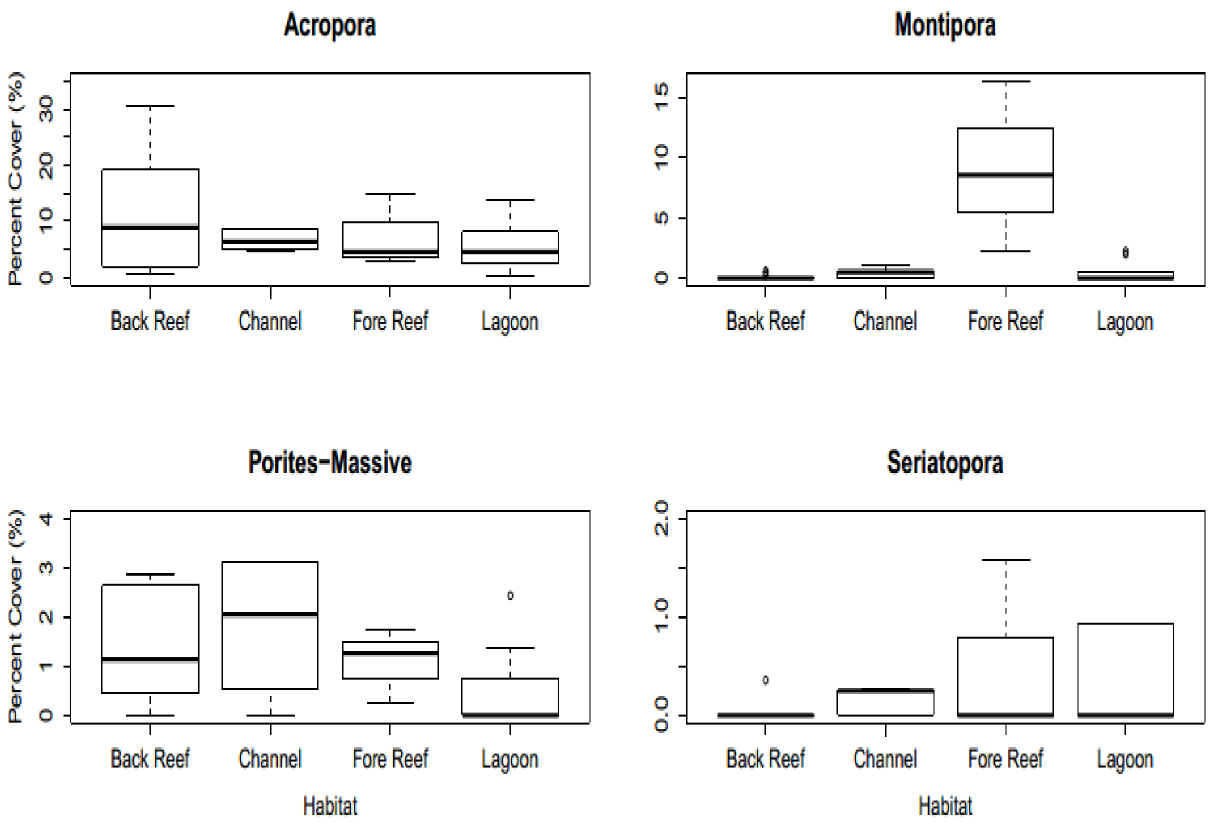

Figure 6. Boxplots comparing percent cover of the most abundant coral genera between the four different habitats in the Ebiil Conservation Area. Asterisks indicate significance (p<0.05).

Coral Recruit Density

Coral recruit density varied significantly amongst habitats (Figure 7). The fore reef (98 ± 24), had a significantly higher recruit densities when compared to the back reef, (18 ± 11), p-value = 0.03. However, the large variation in number of recruits found in both channel and lagoon habitats resulted in no differences when compared to each other or fore reef and back reef types.

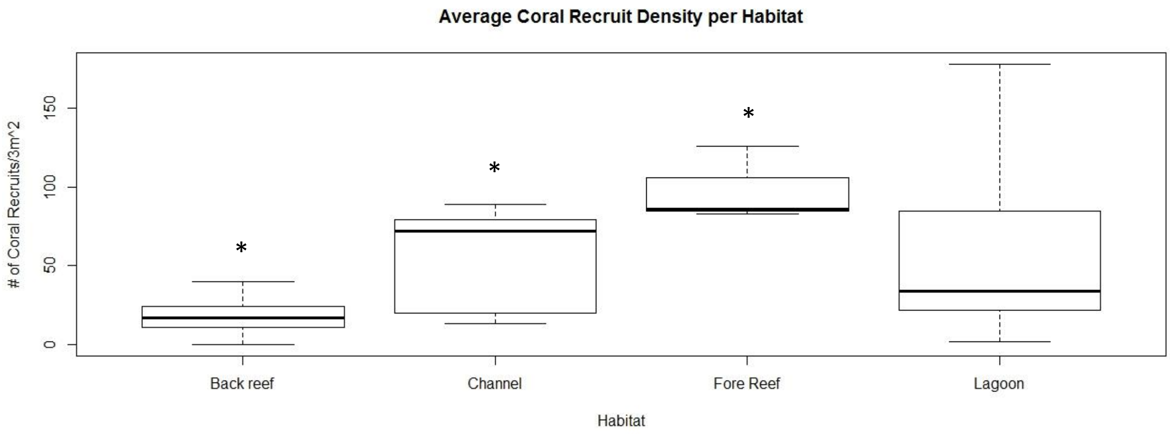

Figure 7. Mean coral recruit (<5 cm) density among four habitat types found within the Ebiil Conservation Area. Asterisks indicate significance (p<0.05).

The most abundant coral recruit species found in the Ebiil Conservation Area were from the *Acropora* genus. The channel and fore reef had significantly higher numbers of *Acropora* recruits (38 ± 5 and 41 ± 7, respectively; p-values = 0.01 and 0.008) than the back reef and the lagoon (7 ± 5 and 7 ± 6, respectively), which were not significantly different from each other (Figure 8).

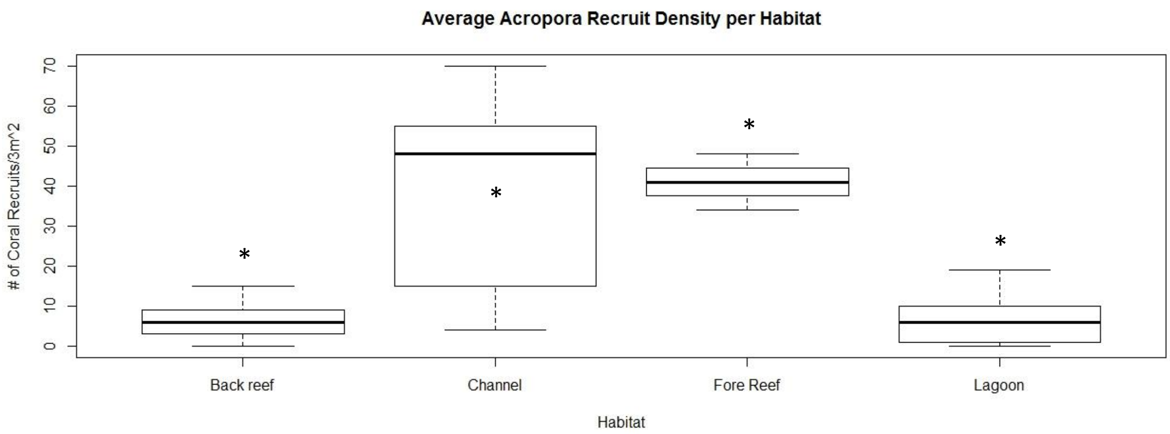

Figure 8. Mean *Acropora* recruit (<5 cm) density among the four habitats in the Ebiil Conservation Area. Asterisks indicate significance (p<0.05).

Discussion

The focus of this survey was to define baseline data for further assessments of the Ebiil Conservation Area in order to effectively conserve the natural resources of Palau.

In the fore reef, the result of the high coral cover may be due to the high *Scarid* biomass, which should lead to higher herbivory rates in that specific habitat, when compared to the other sites. Also, intense wave action on the fore reef could also lead to reduced macro algal and turf cover (Mumby & Steneck 2008). Though coral cover and coral recruitment are high (Figures 5 & 7) the relationship of high recruitment rates paired with coral cover may not be true due to the fact that the most abundant recruiting species were the *Acroporas,* which are broadcast spawners and the intense wave action paired with large dispersal area may not equate to high coral recruitment rates (Hughes, et al. 1999). However, the high herbivore fish biomass coupled with high carbonate cover may provide an ideal area for settlement due to the large area of bare substrate regularly grazed by herbivore fish, resulting in increased availability of recruitment habitat.

Coral recruitment was also significantly high within the channel which may be linked to the low turf cover in this area (Figures 7 & 5). Turf and macroalgae can smother corals, especially coral recruits, preventing the symbiotic zooxanthallae from photosynthesizing the light into nutrients increasing coral mortality. Low turf cover may be due to the constant current within the channel which prevents settlement of the turf.

Another reason for the high number of coral recruits in both the channel and fore reef may be due to the hydrodynamics of the conservation area. As seen in Golbuu, et al. 2012, the Ebiil Conservation Area is located in an area where local retention occurs and there are several seeding sites within the vicinity of the conservation area but further genetic analysis is needed to confirm if the Ebiil Conservation Area is predominately self-recruiting.

The mean coral cover in the Ebiil Conservation Area, with the exception of the fore reef, was 17% which is low, when compared to other MPA sites, and this may be due to severe bleaching that occurred in 2010 throughout Palau (van Woesik, et al 2012). Recruitment rates are high, compared to other MPAs in Palau, which may support the theory of resilience and recovery after a bleaching event but there are other factors such as water quality and species richness which contribute to coral reef recovery (Graham et al 2013) and further studies are needed to confirm if recovery is occurring.

To complement the existing results presented here and obtain a more complete baseline assessment, ocean C chemistry could also be sampled in order to assess the ecosystem's vulnerability, which is the sensitivity of the ecosystem to changes, to further increased climate change conditions (Zacharias & Gregr, 2005). Seawater C chemistry can help inform managers and scientists whether the site will be vulnerable to further bleaching events or even ocean acidification events through the stability of the present water conditions (Mcleod et al, 2012).

This survey provides the ecological baseline data needed in order to assess the resilience and effectiveness of the Ebiil Conservation Area. Seawater C chemistry, the use of other important indicators of resilience, such as herbivore fish and important adult fish populations, and long-term monitoring are strongly recommended to gain a broader perspective of the effectiveness and resilience of the Ebiil Conservation Area so management can adapt the MPA to effectively manage the reefs and natural resources of Palau.

Acknowledgements

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Appendix

Table 1. Scientific names of commercially-important fish surveyed.

Scientific Name
Acanthurus lineatus
Acanthurus maculiceps
Acanthurus nigricaudus
Acanthurus olivaceus
Acanthurus triostegus
Acanthurus xanthopterus
Aethaloperga rogaa
Aprion virescens
Balistoides viridescens
Bulbometopon muricatum
Carangoides ferdau
Carangoides orthogrammus
Caranx ignobilis
Caranx lugubris
Caranx melampygus
Caranx sexfasciatus
Cephalophalus argus
Cetoscarus bicolor
Cheilinus fasciatus
Cheilinus undulatus
Chlorurus bleekeri
Chlorurus microrhinos
Chlorurus sordidus
Choerodon anchorago
Ctenochaetus striatus
Elegatis bipinnulatus
Epibulus insidiator
Epinephelus fuscoguttatus
Epinephelus lanceolatus
Epinephelus malabaricus
Epinephelus merra
Epinephelus polyphekadion
Gymnosarda unicolor
Hipposcarus hariid
Hipposcarus longiceps
Kyphosus vaigiensis

	Leptoscarus vaigiensis
	Lethrinus erythracanthus
	Lethrinus erythropterus
	Lethrinus harak
	Lethrinus obsoletus
	Lethrinus olivaceus
	Lethrinus xanthochilus
	Lutjanus bohar
	Lutjanus ehrengbergii
	Lutjanus fulvus
	Lutjanus gibbus
	Lutjanus kasmira
	Lutjanus monostigma
	Macolor niger
	Monotaxis grandoculis
	Mulloidichthys flavolineatus
	Myrispistis adusta
	Naso brachycentron
	Naso lituratus
	Naso tuberosus
	Naso unicornis
	Parupeneus barberinus
	Plectorhinchus chaetodonoides
	Plectorinchus albovittatus
	Plectorinchus lineatus
	Plectropomus areolatus
	Plectropomus laevis
	Plectropomus leopardus
	Pomocanthus sexstriatus
	Rastelliger kanagurta
	Sargocentron spiniferum
	Scarus altipinnis
	Scarus dimidiatus
	Scarus globiceps
	Scarus gohbban
	Scarus niger
	Scarus oviceps
	Scarus prasiognathos
	Scarus psittacus

Scarus rubroviolaceus
Scarus tricolor
Scarus xanthopleura
Siganus argenteus
Siganus doliatus
Siganus fuscescens
Siganus guttatus
Siganus lineatus
Siganus puellus
Siganus punctatus
Sphyraena barracuda
Variola louti

Table 2. Scientific names of surveyed invertebrates

Invertebrates
Actinopyga echinites
Actinopyga lecanora
Actinopyga mauritiana
Actinopyga miliaris
Actinopyga palauensis
Actinopyga sp.
Bohadschia argus
Bohadschia similis
Bohadschia vitiensis
Hippopus
Hippopus porcellanus
Holothuria atra
Holothuria coluber
Holothuria edulis
Holothuria fuscogilva
Holothuria fuscopunctata
Holothuria impatiens
Holothuria lessoni
Holothuria leucospilota
Holothuria nobilis
Holothuria scabra
Holothuris falvomaculata

Pearsonothuria graeffei
Stichopus chloronotus
Stichopus hermanni
Stichopus horrens
Stichopus vastus
Thelenota ananas
Thelenota anax
Tridaacna crocea
Tridacna squamosa
Tridacna derasa
Tridacna gigas
Tridacna maxima

Table 3. Coral genera surveyed.

Acanthastrea
Acropora
Alveopora
Anacropora
Astreopora
Caulastrea
Coral Unknown
Coscinaraea
Ctenactis
Cyphastrea
Diploastrea
Echinophyllia
Echinopora
Euphyllia
Favia
Faviid
Favites
Fungia
Galaxea
Gardininoseris
Goniastrea
Goniopora
Heliopora
Herpolitha
Hydnophora

Isopora
Leptastrea
Leptoria
Leptoseris
Lobophyllia
Merulina
Millepora
Montastrea
Montipora
Mycedium
Oulophyllia
Oxypora
Pachyseris
Pavona
Pectinia
Physogyra
Platygyra
Plerogyra
Plesiastrea
Pocillopora
Porites
Porites-massive
Porites-rus
Psammocora
Sandalolitha
Scapophyllia
Seriatopora
Stylocoeniella
Stylophora
Symphyllia
Turbinaria