Using Benthic Imagery to Assess the Coral Reef Community Around Wake Atoll

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[We / I] certify that [we / I] have read this thesis and that, in [our / my] opinion, it is satisfactory in scope and quality as a thesis for the degree of Bachelor of Science in Global Environmental Science.

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For: My loving ohana

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ABSTRACT

Wake Atoll is a remote island located approximately 2,300 miles southwest of the main Hawaiian Island chain in the central Pacific. Due to the isolation and military control over the atoll, few comprehensive studies about the surrounding reefs have been conducted. This work addresses the coral reef community structure surrounding Wake Atoll utilizing benthic image data collected from 2017 cruise to Wake by the Ecosystem Sciences Division (ESD), of the NOAA Pacific Islands Fisheries Science Center, and analyzed using the software, CoralNet. Benthic cover was estimates of basic functional groups indicate that macroalgae was found to be more dominant over the coral reef followed by coral, suggesting that the overall resilience of the reef is lower than one that is dominated by coral. An nMDS plus cluster analysis, suggest that most of the differences observed in the community structure appear to be depth based and not exposure based. The benthic substrate ratio was used to roughly estimate the overall condition of the coral reef by dividing the proportion of calcifying to non-calcifying organisms.

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1.1 Background

Coral reefs hold an immense portion of the world's ocean biodiversity and provide many ecosystem goods and services, including coastal protection and fisheries. Most of the world's coral reefs are located in tropical and sub-tropical waters between 30° N and 30° S of the equator due to temperature intolerance below 18°C (NOAA, 2017). Over the past few decades, there has been an increase in the bleaching events of the world's coral reefs. Environmental disturbances such as a rise in water temperature, pH or salinity may cause coral reefs corals to become overly stressed and expel zooxanthellae causing a bleaching event. The sensitivity to these disturbances make coral reefs ideal indicators of environmental change (Hoegh-Guldberg et al., 2007). Regular monitoring of coral reef community structures, especially those in remote areas that have little anthropogenic activity, are important to understand how different environmental stressors affect these communities.

1.1.1. Study Area

Located in the northern central Pacific Ocean, Wake Atoll (19°17'N, 166°36'E) is a tiny, closed coral atoll that is extremely isolated (Figure 1). The atoll is made up of three individual islands: Peale, Wilkes and Wake, with Wake being the main island. The closest reef system is Bokak (Taongi) Atoll (14°39'N, 168°58'E) of the Marshall Islands at 546 km southeast (Tsuda et al., 2006; Lobel and Lobel, 2008; Kenyon et al., 2013). Wake Atoll is part of a larger collection of seven shallow reef islands and atolls known as the U.S. Pacific Remote Islands. Starting from the northernmost islands and moving towards the equator, the Pacific Remote Islands consist of Wake Atoll, Johnston Atoll, Kingman Reef, and Palmyra, Howland, Baker and Jarvis Islands. The U.S. Pacific Remote Islands was declared a Pacific Remote Islands Marine National Monument (PRIMNM) in 2009 by Presidential proclamation (Boyle et al., 2017).

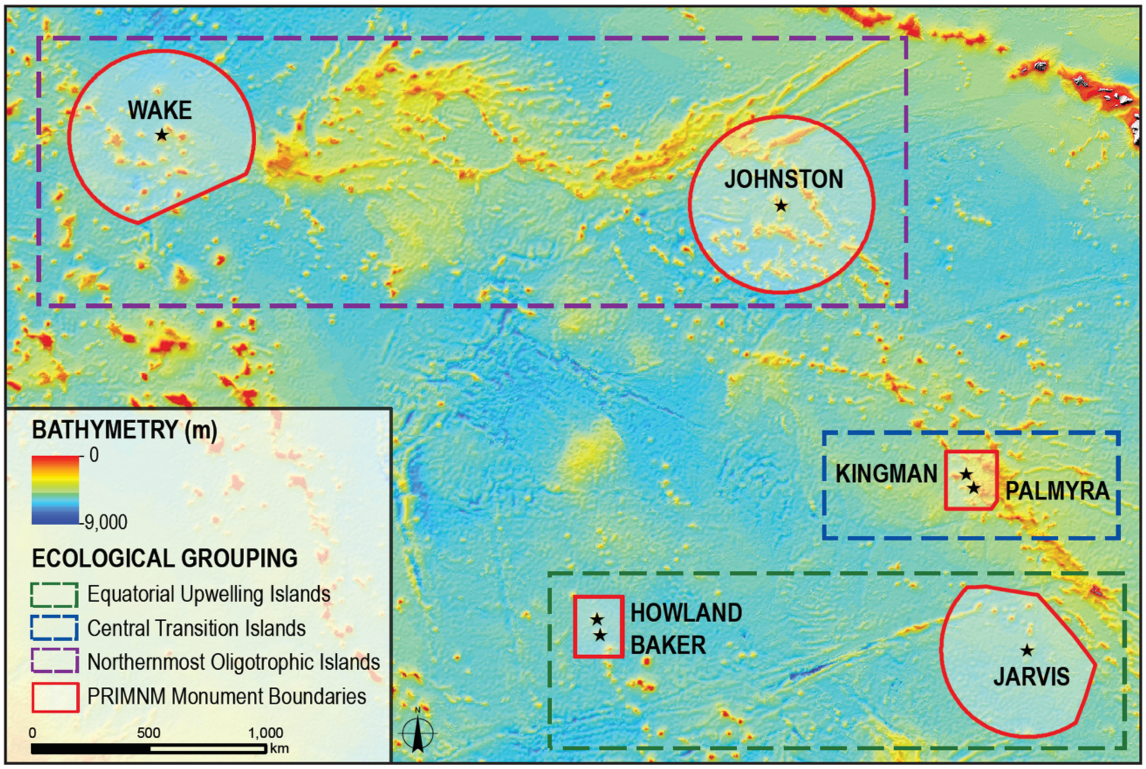

Figure 1 Map of the Pacific Remote Islands Marine National Monument. From Boyle et al 2017.

Unlike most other islands and atolls of the Pacific Remote Islands which are located in nutrient-rich areas of upwelling and high biological productivity near the equator, Wake Atoll is considered to be an oligotrophic island because it is located in the area of nutrient-poor waters with low biological productivity of the central gyre (Boyle et al., 2017). Coral reefs generally thrive in nutrient-poor waters which may offer a competitive advantage to slow growing organisms. In contrast, while nutrient-rich waters have the ability to easily provide corals with all of the nutrients needed for growth, they also stimulate the growth of faster growing organisms such as algae. Algae proliferate at a much faster rate than corals and impedes on the growth of coral communities by blocking off access to rock foot holdings, space, and sunlight (Sebens, 1994). By impeding the ability of coral to grow and expand, the algae can essentially cripple the community structure of the coral reef.

1.1.2. History

Wake Atoll has an extensive history involving its discovery by man. According to Kenyon, et al. (2013), it is thought that the first humans to arrive on the atoll were early navigators from the Marshall Islands, who came to hunt birds and sea turtles. The first Westerners to discover Wake Atoll were still being debated due to several factors that led to many recorded inaccuracies. There were varying reports on where the atoll was located due to the periods' inaccurate navigational tools; additionally, the names used to record the atoll varied. In fact, there were so many alternate names and misspellings including, Helsion, Waker's, Wreck, Wilson and Halcyon, that the accuracy of early accounts became impossible to determine (Lobel and Lobel, 2008). The first European sighting of Wake Atoll was report in 1568 by Captain Alvaro de Mandaña, a Spanish explorer who named it San Francisco; however, Mandaña recorded inaccurate coordinates. By 1796, the atoll would be renamed for the British captain William Wake who documented its correct location (Bryan, 1959; Kenyon et al. 2013).

In 1841, the first formal U.S. exploring expedition was conducted by Lieutenant (Commodore) Charles Wilkes. During this expedition, the first detailed descriptions of Wake Atoll were made, including maps and surveys. In 1898, during the Spanish American War, the U.S. formally claimed Wake Atoll. However, it was not until January 1899 that the U.S. formally took possession of the atoll. Approximately 24 years later, a second scientific expedition, the *Tanage*r Expedition and was led by Alexander Wetmore, during which time the two other islands (Wilkes and Peale) were given names. By 1934, the responsibility of Wake was transferred to the U.S. Navy (Lobel and Lobel, 2008).

During World War II, Wake Atoll served as a transpacific refueling base until it was captured by the Japanese military soon after the bombing of Pearl Harbor in December, 1941. Wake Atoll would remain under Japanese possession until the war ended in September of 1945, when it was returned to the possession of the U.S. military. Back in the U.S. military's possession Wake resumed its role as a transpacific refueling station (Kenyon et al., 2013).

In 1985, Wake Atoll was designated as a National Historic Landmark to preserve the historic structures of World War II (Lobel and Lobel, 2008). In 2009, President George W. Bush created the Pacific Remote Island Marine National Monument, which extends the protection of the Pacific Remote Islands to 50 nautical miles from beyond the low tide line (Tsuda et al., 2010; Kenyon et al., 2013).

1.1.3. Geomorphology & Climate

Wake Atoll is the largest of the Pacific Remote Islands with an approximate width of 3 km and a length of 6.5 km and a land area of 7 km^2 (Tsuda et. al., 2006; Lobel and Lobel, 2008; Kenyon et al., 2013; Boyle et al., 2017). The average elevation across Wake Atoll is 3.7 m with the highest elevation being Wake Island at 5.5 m. Consistent with other atolls, most of the area of Wake Atoll is found underwater in its reef (0-30 m) with a calcium carbonate substrate (Perry et al., 2012).

The islands, Peale, Wilkes and Wake, almost fully enclose a large lagoon at the center of the atoll on the north, east and south sides. The western side of the atoll is covered by an emergent reef which is where the only real water exchange occurs between the lagoon and the open ocean, due to the construction of a seawall for a causeway between Wilkes and Wake Islands. The construction of the causeway and the loss of a major inlet of water triggered a severe loss of water circulation in the lagoon, which caused an increase in the temperature of the lagoon, and subsequently, low levels of dissolved oxygen, resulting in major fish die-offs within the lagoon. Despite the lagoon receiving limited boosts in water circulation from a small submarine channel and another channel that opens between Peale and Wake Islands during high tide, the circulation in the lagoon remains poor (Bryan, 1959; Lobel and Lobel, 2008).

At 19°N of the equator, Wake Atoll falls within the tropical climate zone where there is little variation in temperature over the course of the year. The average temperature ranges between a high of 30°C and a low of 24°C with an average humidity of 76% and prevailing winds blowing from the east-northeast (Kenyon et al., 2013). The average annual rainfall is approximately 89 cm (Lobel and Lobel, 2008). Located within the Northwestern Pacific basin (180°-100°E), Wake is located in one of Earth's most active tropical cyclone basins (Neumann, 1993). The months from late summer to autumn are considered Wake Atoll's typhoon season when the atoll is threatened by tropical cyclones. These cyclones can reach wind speeds upwards of 33 m/s, at which time, it is officially categorized as a typhoon. Wake Atoll has been hit at least six times by typhoons since 1957. The worst typhoon was in 2006 when Typhoon Ioke passed close to Wake Atoll as a category 4 typhoon. It so severely damaged the infrastructure of the atoll that the military decided to place it under caretaker status, evacuating nonessential personnel (Lobel and Lobel, 2008).

1.1.4. Current Reef Monitoring Programs

In order combat the degradation of coral reef ecosystems in U.S. waters, the Coral Reef Conservation Act was created in 2000. This piece of legislation enables NOAA to consistently research and monitor coral reef ecosystems in efforts to mitigate further reef ecosystem loss. To achieve this task, the NOAA Pacific Islands Fisheries Science Center (PIFSC), established the Pacific Reef Assessment and Monitoring Program (Pacific RAMP) in 2000 and the Coral Reef Ecosystem Program (CREP) in 2001. Pacific RAMP focuses on the long-term monitoring and interdisciplinary studies of the Pacific Islands including the Pacific Remote Island Area (PRIA). Currently, the PISFC Ecosystem Sciences Division conducts triennial Pacific RAMP monitoring surveys at Wake Atoll; prior to 2011 it was conducted biennially. Unlike other PRIA sites that were surveyed beginning in 2000, Wake was not surveyed by Pacific RAMP until 2005 due to military jurisdiction. Surveys on Wake were conducted for the years 2005, 2007, 2009, 2011, 2014, and 2017 (Kenyon et al., 2012; Boyle et al., 2017). To get the most current understanding of the coral reef community around Wake Atoll, the 2017 dataset was selected for the purpose of this thesis.

1.2 Objective

This thesis aims to supplement the baseline description produced by Kenyon et al. (2013) of the coral reef community structure around Wake Atoll using benthic imagery collected during the 2017 Pacific RAMP to assess the effects of depth and wave exposure factors as potential drivers of coral reef community structure.

Chapter 2. Methods

2.1 Benthic Surveys

2.1.1. Sampling Design & Collection Methods

The optical data was collected following a rapid ecological assessment (REA) method using a stratified random sampling (StRS) approach where the benthic domain (0-30 m) is divided by into three depth strata, shallow (0-6 m), mid (6-18 m), and deep (18-30 m) (Figure 2) (Swanson et al., in review). The sampling effort of each stratum was proportional to the hard bottom area of that stratum relative to the overall benthic domain. Images are collected using a monopod every meter along the fish and benthic monitoring sites. For the 2017 Pacific RAMP, 83 sites were surveyed.

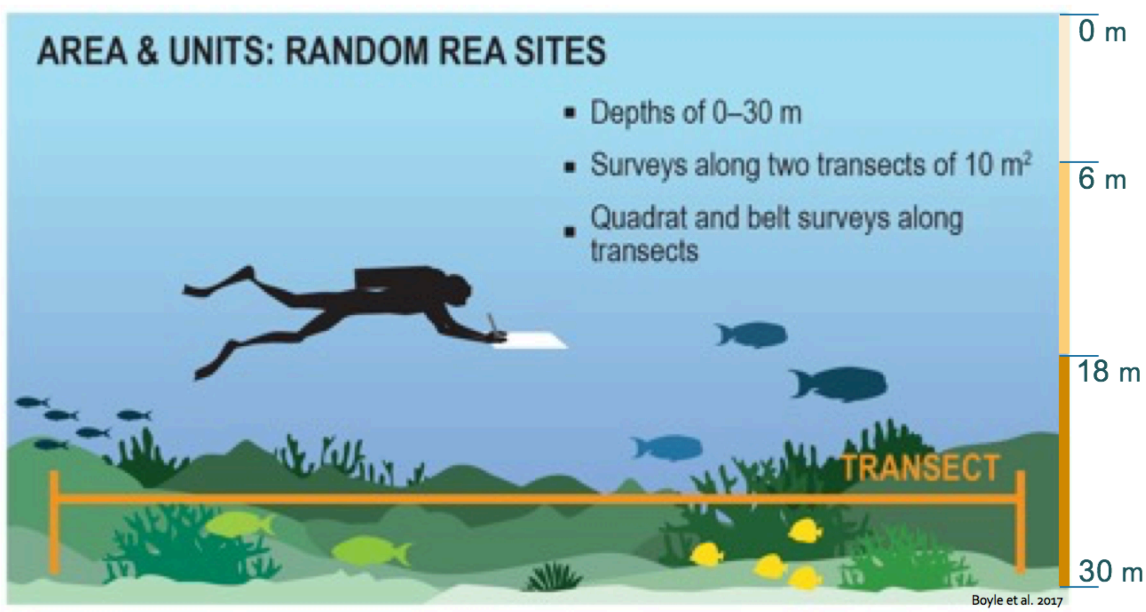

Figure 2 Diagram of the Rapid Ecological Assessment (REA) method. Modified from Boyle et al. 2017. The colored bar on the right-hand side shows the division of depth strata with ivory- shallow (0-6 m), tan- mid (6-18 m), and brown- deep (18-30 m).

2.2 Image Analysis

2.2.1. CoralNet

In order to analyze the photographs collected, the images were uploaded to a web-based annotation program called CoralNet (Figure 3). CoralNet is an archival and resource tool created by researchers at the University of California at San Diego in order to help alleviate the bottleneck that occurs when scientists need to annotate a large number of images (Beijbom et al., 2015).

2.2.2. Image Annotation

Using the CoralNet software, photographs are analyzed to functional group (tier 3b) (Figure 3). For the purpose of this thesis, the predictive annotation function was not implemented. Calibrations were also made to minimize the inter-observer variability for the annotations. Annotation were made following methods provided by Lozada-Misa, et al. (2016).

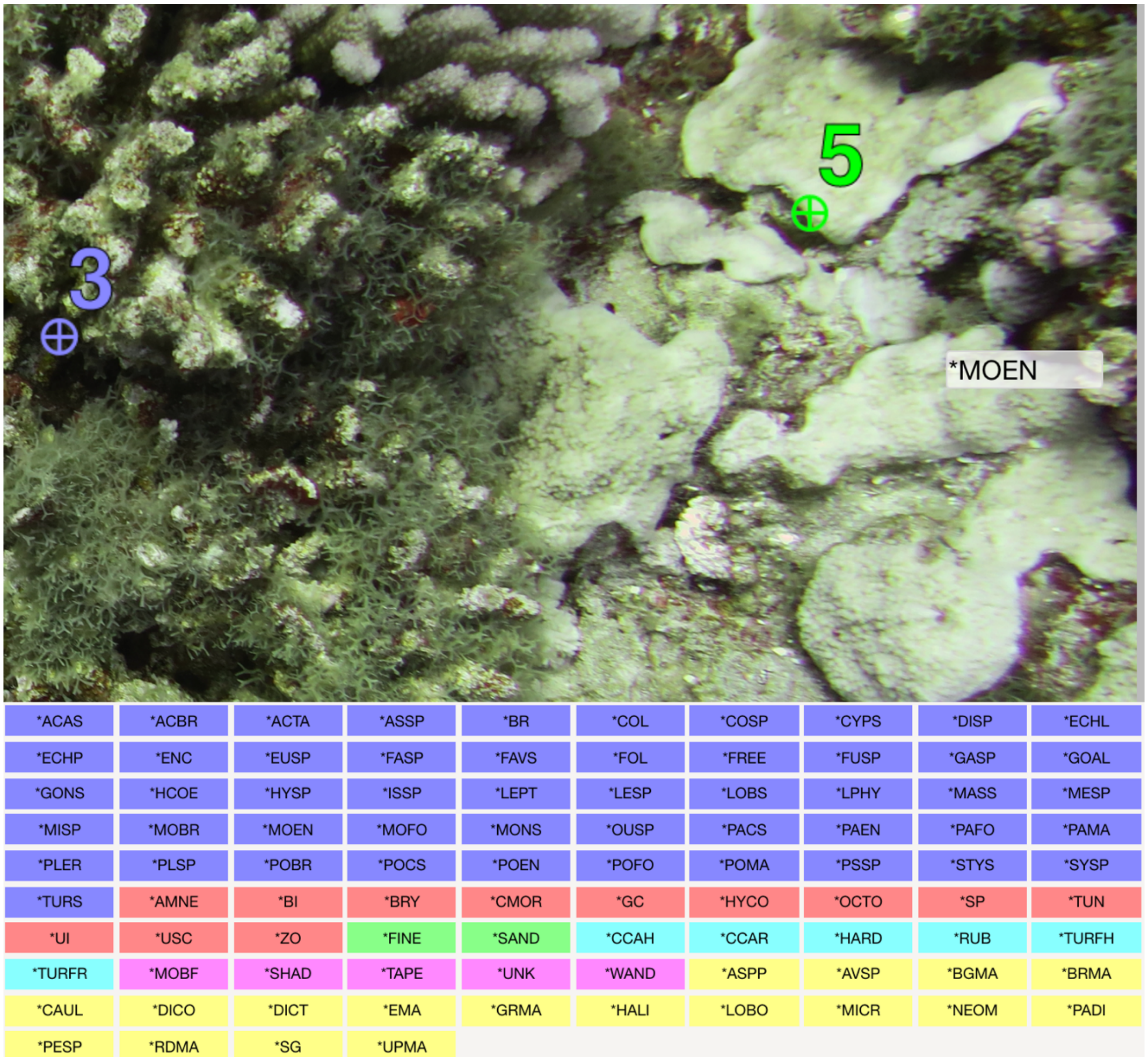

Figure 3 CoralNet image with randomly selected points and annotation tool.

2.3 Data Analysis

2.3.1. Statistics

After all of the images are annotated, the resulting data was downloaded and put into an Excel spreadsheet. To make the data easier to interpret, a pivot table was generated to summarize and sort the data so that the characteristics of each site can be easily perceived. A pivot table is a feature that summarizes a large, cumbersome dataset into a user-specific set of attributes (columns) and measurements (rows) that is much easier to read and interpret. This method also allows the data to be viewed from a different perspective without changing the data. Once the pivot table is made, the sites are then organized by exposure: leeward and windward. The boundary for exposure was created following Kenyon et al. (2013) (Figure 4). Survey sites are then aggregated by depth; shallow, mid, and deep.

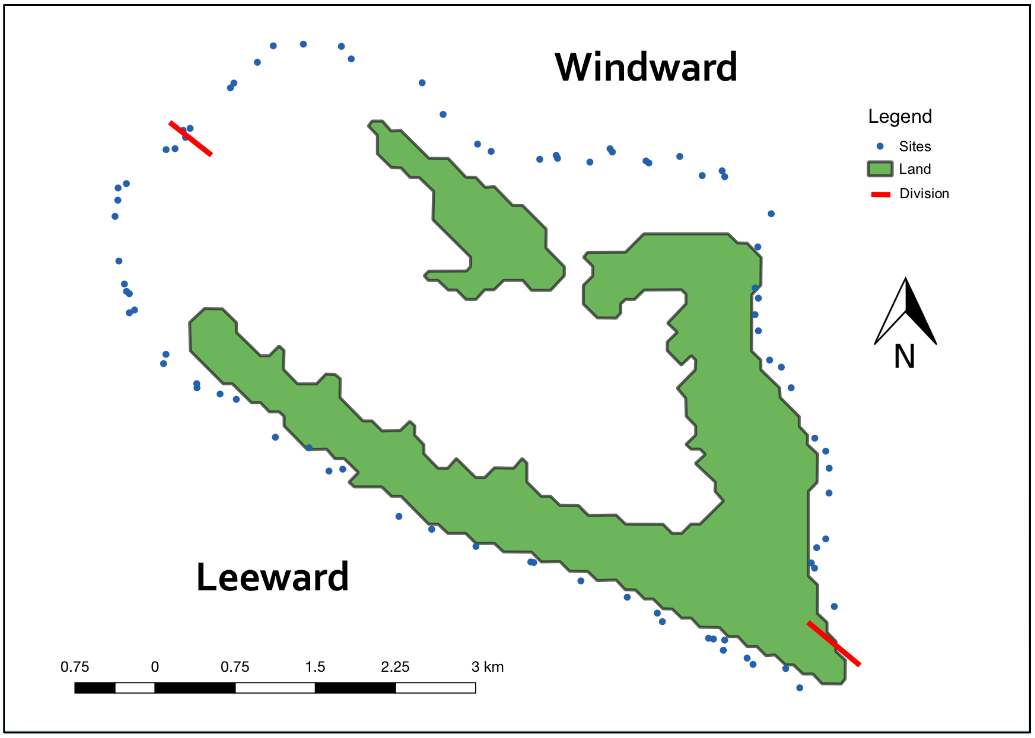

Figure 4 Wake Atoll with the 83 study sites. The red lines represent the division of leeward and windward wind exposure sites as defined by Kenyon et al. (2013).

To calculate an estimation of the benthic cover, counts of basic benthic elements were used. Using Excel, estimations for mean cover were calculated for each exposure and depth stratum, as well as six of the most abundant coral genera (*Acropora, Astreopora, Favia, Montipora, Pocillopora*, and *Porites*) and the main algal functional groups (e.g., Crustose coralline algae [CCA], *Halimeda*, turf, encrusting macroalgae [EMA] and upright macroalgae [UPMA]).

After the summary statistics have been determined, the data is then organized into stacked cluster graphs based on exposure and depth using the chart function in Excel. To graphically visualize the relative abundance and distribution of the benthic functional groups around the atoll as a whole, the Quantum Geographic Information System program (QGIS was implemented to assemble bubble plots for each of the three main functional groups; i.e., coral, CCA, and macroalgae.

Additionally, to visualize the multivariate similarities (or lack there of) between study sites, a non-metric multidimensional scaling (nMDS) ordination plot was assembled based on ecologically important benthic components (i.e., CCA, *Astreopora*, *Acropora, Montipora, Favia, Pocillopora, Porites,* fleshy upright macroalgae, turf algae *Halimeda*, and EMA). Based on fourth-root transformed dataset, a Bray-Curtis similarity matrix was calculated and subsequently, an nMDS was computed. Next, a separate hierarchal cluster analysis with complete linkage was calculated from the Bray-Curtis similarity matrix and was subsequently, overlaid on the nMDS to objectively visualize the sites based on similarities defined by the cluster analysis (Vargas-Ángel and Schumacher 2018). The nMDS ordination and Cluster analysis were computed using the PRIMER-E v.6. software (Clarke and Gorley 2006).

Finally, to gain a general understanding of the resilience potential and general health condition of the coral reef community, a benthic substrate ratio (BSR) was computed. The BSR was calculated by dividing the percent cover of carbonate accreting organisms (CCA + coral + EMA) by the cover non-carbonate accreting organisms (turf + fleshy macroalgae). A value ≥ 1, means that there is a higher proportion of calcifying organisms to non-calcifying organisms, implying that the reef building community has higher resilience potential than those with a value of <1 (Vargas-Ángel & Schumacher, 2018).

3.1 Benthic Cover and Composition

To better visualize the overall benthic composition of the 3 main functional groups over the entire island, a bubble plot was created (Figure 5 & 6). Figure 5a. illustrates a more spatially homogenous island wide distribution and abundance of coral as compared to macroalgae (Figure 5b.) and CCA (Figure 6). CCA showed greatest variability with the highest cover in the areas of greatest exposure with greater presence in the windward sites than in the leeward sites.

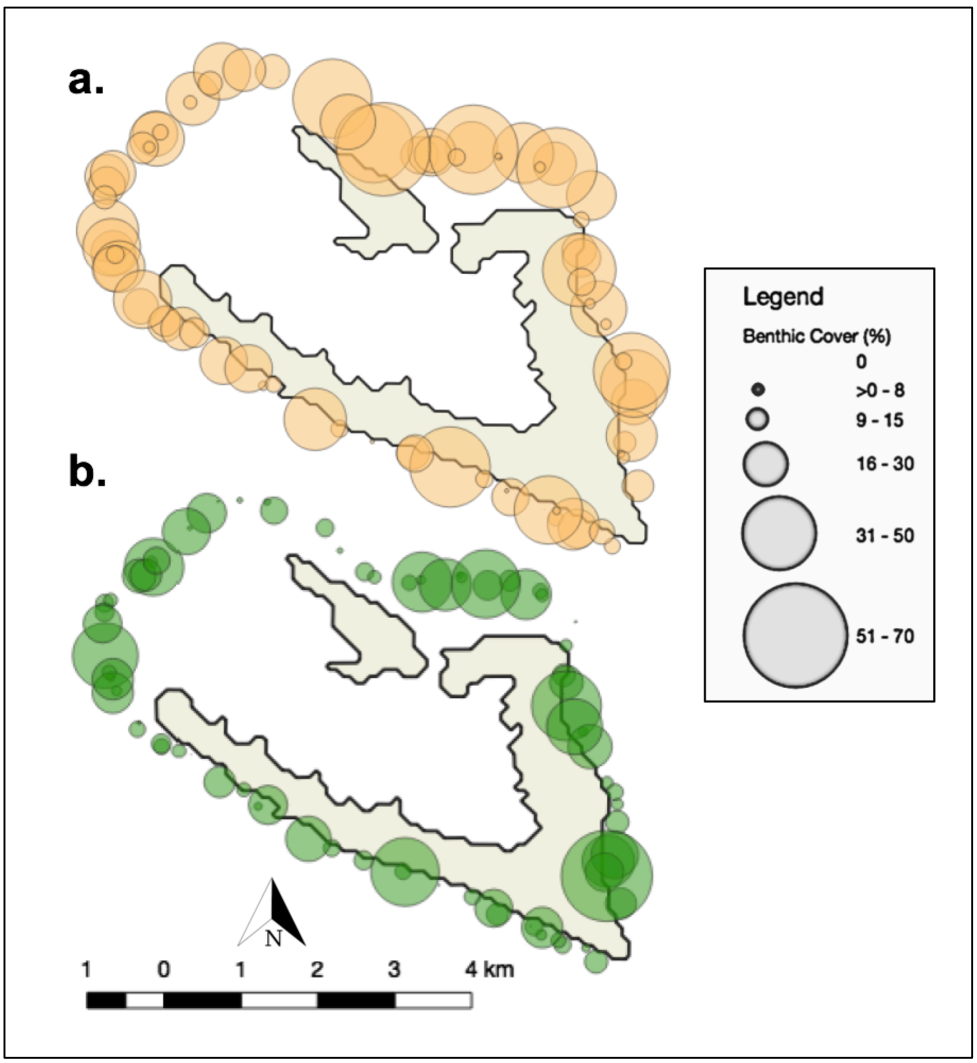

Figure 5 Percent benthic cover: a.) Coral b.) Macroalgae

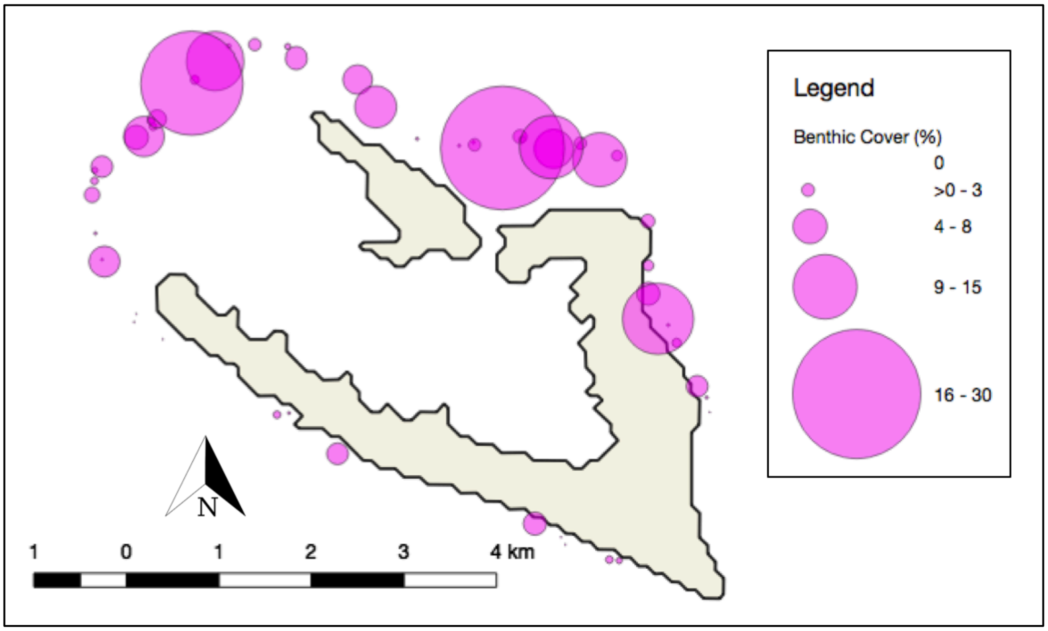

*Figure 6 Percent benthic cover: CCA   *Note the change in legend scale*

Figure 7 shows that the leeward sites displayed a reduced variation in percent coral and upright macroalgae cover and a higher variation in CCA, EMA and OCTO, compared to windward sites. The greatest variation was displayed by EMA, with the percent cover starting at 11.68% in the shallows and dropping to 0.33% in the deep.

Comparatively, windward sites exhibited greater variation for almost all functional groups, except octocorals. For windward exposure, corals showed the greatest variation in percent cover from the shallow at 10.66% to mid depth at 46.54%. Despite having a large variation in percent cover, overall, the windward sites displayed a higher average percentage of coral cover at than the leeward sites in the mid and deep strata.

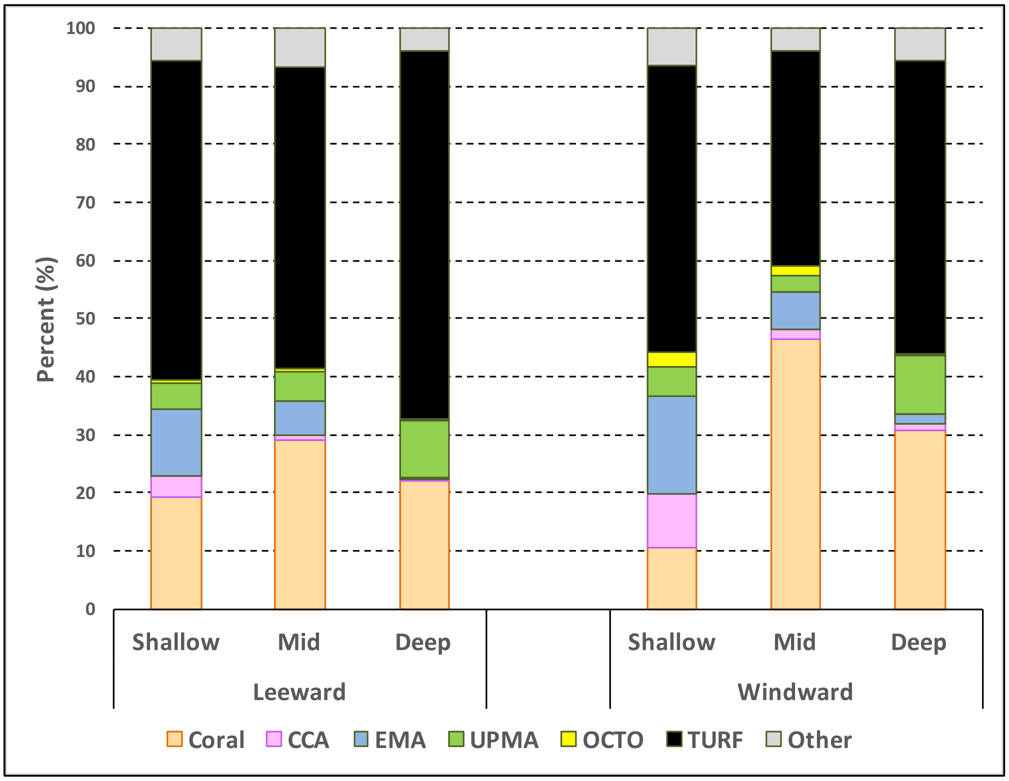

Figure 7 Leeward and windward benthic percent composition cover looking at basic functional groups, coral, upright macroalgae (UPMA), crustose coralline algae (CCA), encrusting macroalgae (EMA), octocoral (OCTO) and turf

3.2 Coral Cover and Composition

In Figure 8, *Pocillopora* presented the least variability in percent cover over the different depths and exposures with percentages that ranged from 4-6%. *Montipora* displayed the most variability over the different depths and exposures, especially the shallow to mid windward sites where the average percent cover ranged from 3-23%. Both exposures exhibited the highest coral cover in the mid depths and the lowest in the shallow. *Porites* had the lowest percent cover in the shallow strata and abundance increased with depth. *Acropora* had an overall low abundance around the atoll; however, it displayed the highest abundance in the shallow stratum. *Astreopora* exhibited different variability patterns between the different exposures. In the leeward exposure, it displayed the greatest abundance in the mid depth and little to no abundance in the shallow and deep depths. In the windward exposure sites, *Astreopora* showed an increase in abundance from the shallow to deep depths. *Favia spp.* presented a relatively homogenous abundance between the exposures except for the shallow stratum on the windward exposure where the percent cover dropped.

Figure 9 shows that the percent composition of coral branching morphology exhibited little variation in the different depth strata and exposure. While the encrusting morphology displayed the largest variation in percent cover over the different exposures and depths with the most notable variation seen between the windward shallow and mid depths which increased from 4.8% to 33.9%, respectively. Massive morphology displayed the greatest variation in abundance between the shallow and mid strata on the windward exposure and the highest abundance in the mid strata of both exposures. The foliose morphology demonstrated an increase in abundance with depth in both exposures.

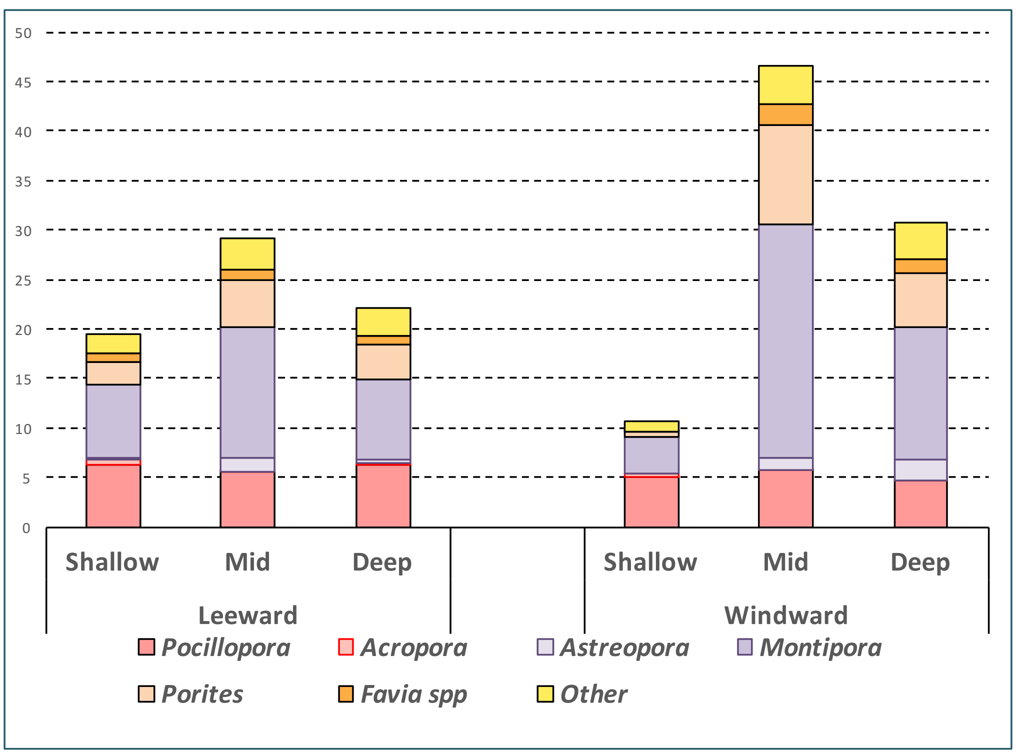

Figure 8 Leeward and windward percent composition cover looking at the 6 main coral taxa, Acropora, Astreopora, Favia spp., Montipora, Pocillopora, and Porites. "Other" represents the percent cover that is comprised of the other coral taxa

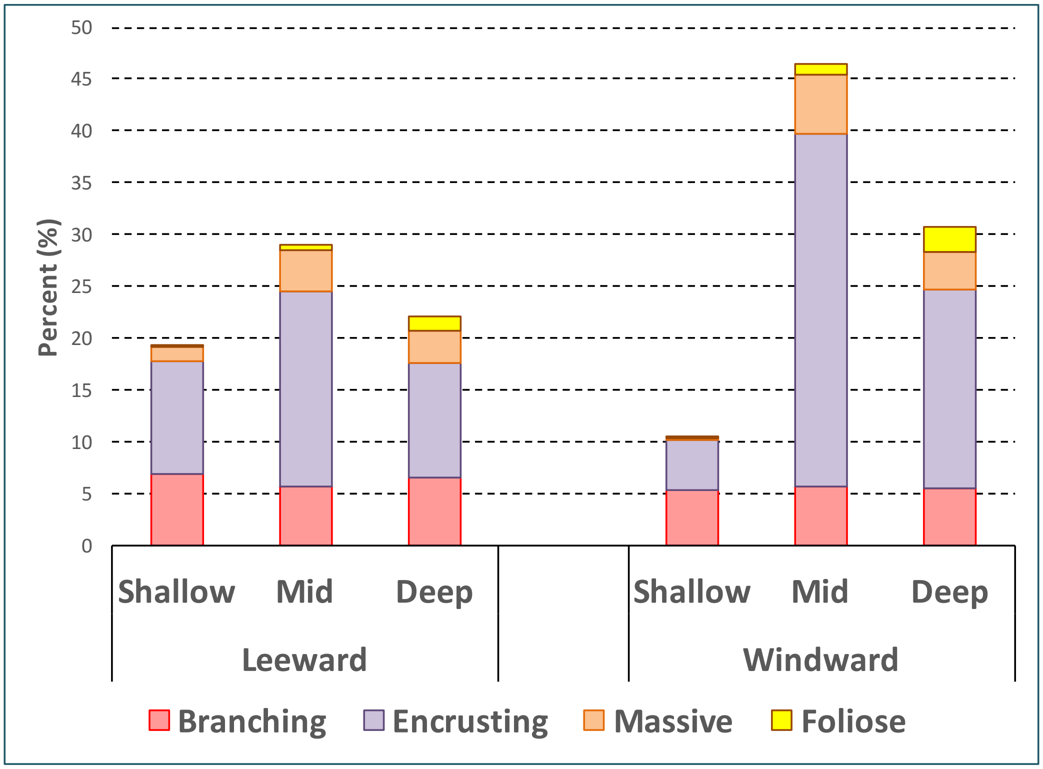

Figure 9 Leeward and windward percent composition cover looking at the 4 main coral morphologies over the depth strata

3.3 Algal Cover and Composition

For algal composition, Figure 10 shows that both leeward and windward exposures displayed a decrease in CCA and EMA, and an increase in fleshy macroalgae percent coverage, with depth. EMA showed the most noticeable decrease in percent cover from the shallow to deep depths, from 11.7% to 0.33% on the leeward sites and 16.7% to 1.8% on the windward sites, correspondingly. In contrast, fleshy macroalgae displayed the largest increase in percent coverage from shallow to deep depths in both exposures. The percent profiles of fleshy macroalgae for the shallow and deep depths are very similar, with the leeward sites at 4.5% and 9.5% and the windward sites at 4.8% and 9.4%, respectively.

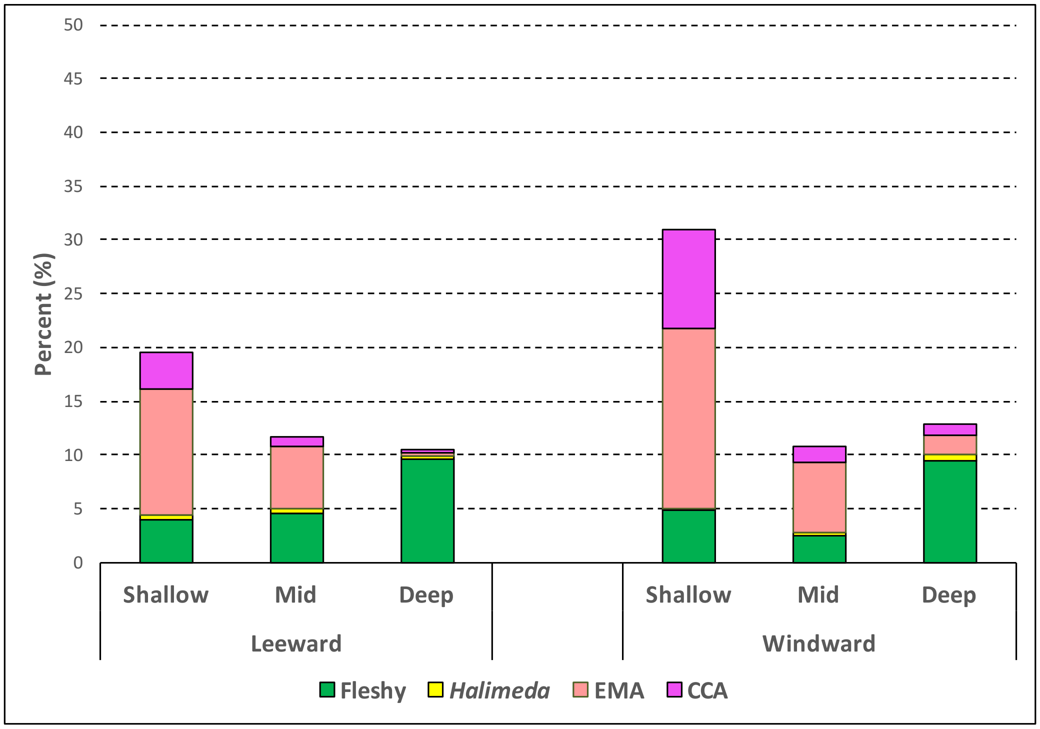

Figure 10 Leeward and windward percent composition cover looking at the 6 main coral taxa, Acropora, Astreopora, Favia spp., Montipora, Pocillopora, and Porites. "Other" represents the percent cover that is comprised of the other coral taxa.

3.4 nMDS

The nMDS plot shows the relative multivariate similarity among sites with an overlay of groups objectively defined by their similarity in a separate cluster analysis. See methods for details (Figure 11). The figure shows that the overall benthic composition of the mid and deep depth sites was relatively similar and comparatively distinct from the shallow depth for both the leeward and windward sites. Shallow sites exhibited lower coral cover, , and higher EMA and CCA cover. Contrastingly, mid depth and deep showed greater percentage of overall coral cover.

When the nMDS ordination was formatted by exposure, no clear separation in sites was observed, indicating that depth appears to be a more important driver than exposure to the structure of the coral reef community.

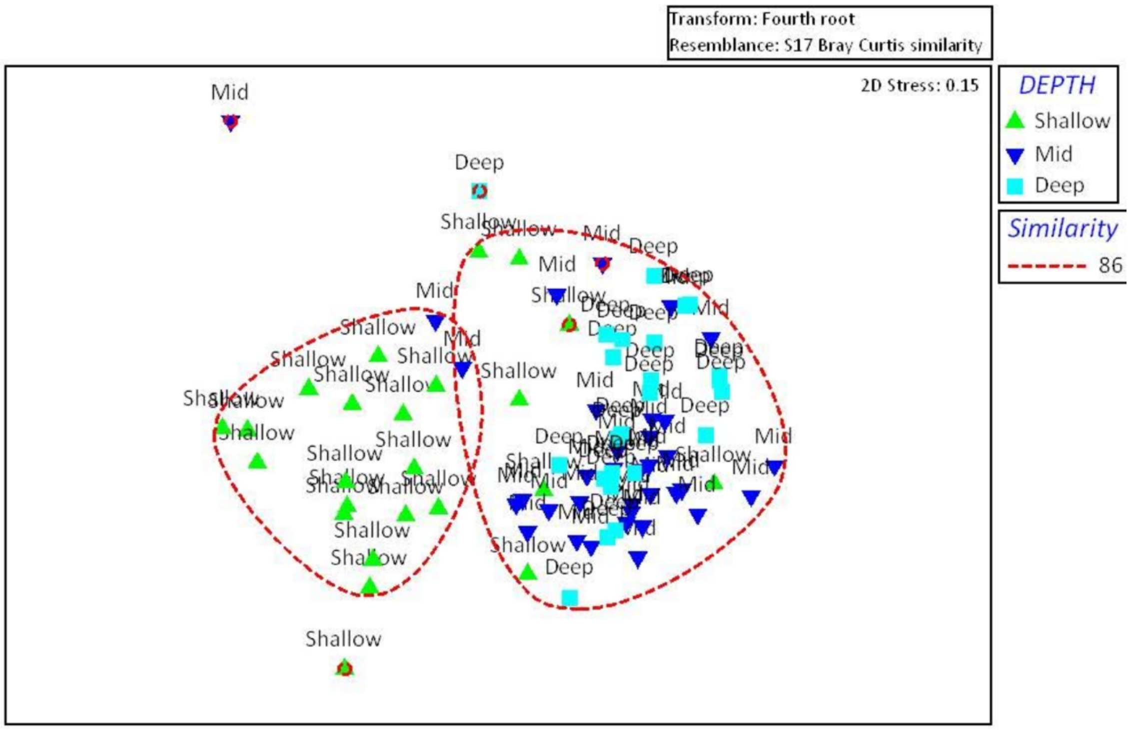

Figure 11 Non-metric multi-dimensional scaling analysis illustrating the relative ecological similarity between study sites based on the benthic cover of the most abundant taxa, see methods for details..

3.5 Benthic Substrate Ratio

Figure 12 displays the BSR for the leeward and windward exposures and the mean BSR for the entire atoll. The BSR for the leeward exposure ranged between 0.32 and 0.67 with a mean value of 0.52. The windward exposure, the BSRs ranged between 0.50 and 1.40 and a mean value of 0.82, which is promising. For the different depth strata, the mid depth had the highest mean BSR of 0.87 while the deep had the lowest mean BSR of 0.47. Overall Wake Atoll displayed a BSR values between 0.46 and 0.98 with a mean BSR of 0.66.

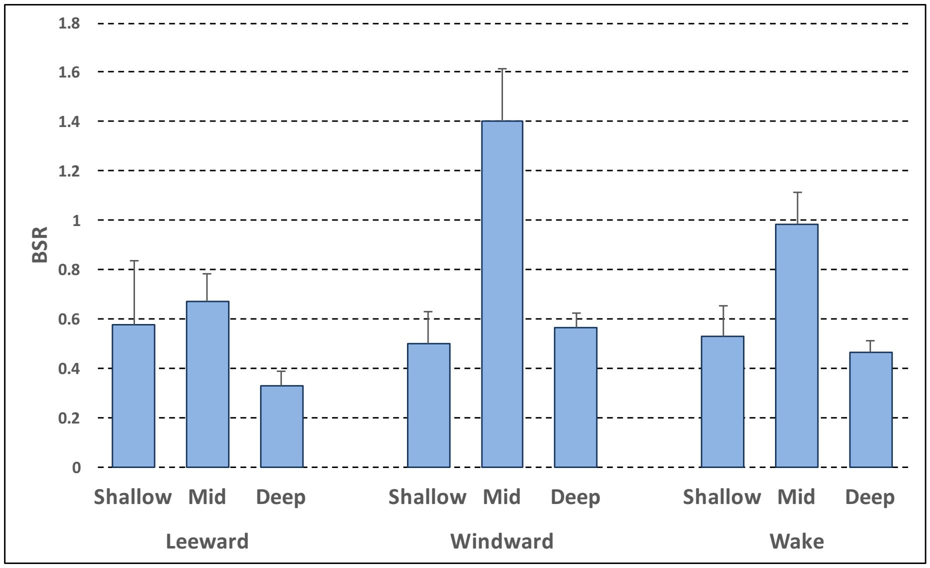

Figure 12 Benthic substrate ratio (BSR) showing a rough estimate of the condition of the coral reef

Chapter 4. Discussion

Kenyon et al. (2013) brings attention to the fact that the amount of published and unpublished data regarding the benthic functional group composition of Wake Atoll is very inadequate. The following discussion will provide supplementary descriptions to enhance the few previous studies done on the coral reef communities around Wake Atoll.

The difference in exposure by wind and waves was thought to be potential drivers of coral community structure. However, despite Figure 7 showing large differences in variation of coral and EMA cover between the leeward and windward sites, an nMDS plot separated by exposure, revealed that depth appears to be a stronger driver of community structure compared to exposure. From the nMDS plot, it can be inferred that the overall benthic composition is different between the leeward and windward sites.

The percent cover of basic functional groups is commonly used as an indicator of the condition of the coral reef and live coral (>20% is fair, >30% is very good, >40% is excellent) cover can be indicative of a healthy coral reef (Boyle et al. 2017). According to Figure 7, the leeward side of the atoll is in fair condition with mid and deep strata exhibiting >20% coral cover and a mean of 23.5% coral cover throughout. In contrast, the windward side of the atoll exhibits coral cover >30% in both the mid and deep depth and only 10% in the shallow depths. This pattern is most likely to be attributed to wave energy, as the shallows on the windward side are constantly exposed to large waves that slam into the reef. Although corals rely on water currents for nourishment, waste removal and propagation, corals will tend to avoid areas with high water motion to minimize the risk of breakage and colony overturn. This allows for only those corals that have high mechanical strength and are well suited for high wave energy areas, such as

Pocillopora to establish and thrive (Storlazzi et al. 2004, Chamberlain and Graus 1975). Figure 8 illustrates this concept, in which foliose morphology is almost nonexistent in the shallow strata, whereas the encrusting morphology is almost always found there in abundance. According to studies conducted by Massel and Done (1993), Rogers (1993) and Storlazzi et al. (2004), there is compelling qualitative evidence that that shows a correlation between wave energy and the species distribution of coral in which more delicate morphologies such as foliose and branching are distributed in areas with lower wave energy and sturdy morphologies such as encrusting, are found in all areas including those with high wave energy.

Branching morphology is shown in Figure 9, to have the second highest coral percent cover by morphology throughout the different depth strata. This result is unusual because branching morphologies are vulnerable to mechanical damage in high wave energy areas (Rogers 1993). However, this can be explained by the results presented in Figure 8, that shows that the composition of the branching morphology is comprised almost entirely of *Pocillopora*, which as previously stated, has a high mechanical strength, making it more robust, which allows it to thrive in high wave energy environments.

Similar to coral, a high percent cover of CCA is an indicator of the reef health. CCA is a significant contributor to the calcification of coral reefs, they contribute to limestone formation and cementation of the coral reef pavement (Chalker and Barnes 1990; Fabricius and De'ath 2001). In a healthy reef, more than 10% is considered to be very good and more than 20% is considered excellent (Boyle et al. 2017). On both leeward and windward sides of Wake Atoll, the average percent coverage of CCA is well below the 10% threshold for a healthy reef, only the shallow depth strata of the windward side come close at 9.1%. The cell walls of CCA are heavily embedded with calcite crystals making the cell walls extremely tough and rigid, making it ideal for protecting against high wave energy environments (Fabricius and De'ath 2001) allowing it to survive in exposed locations (Littler & Littler, 1985).

The windward exposure has an overall mean BSR of 0.82, with the mid depth having a value that is >1, displaying a dominance in carbonate accreting organisms. In contrast, the leeward exposure has an overall mean BSR of 0.52 with the mid depth having the highest value of 0.67, showing that there is a dominance in non-carbonate accreting organisms. The BSR suggests that the resilience potential on the windward exposure may be higher than that found in the leeward exposure due to the dominance in carbonate accreting organisms. Relatively, coral reef communities that have a BSR value >1 will most likely have a more effective community resilience. While Wake Atoll has an overall BSR value of 0.70, in the event of a disturbance, specific sites may have exhibit different resilience potentials, so the resilience of the atoll maybe driven more by individual sites rather than a cumulative BSR.

Prior to this study, most of the work that has been done has mainly concentrated on the benthic algae community of Wake and not necessarily the coral community or the survey methods were not regular or cohesive with other studies being done around Wake. This study highlights the benthic community as a whole, covering both coral and algal components with methods that are consistent with other research teams working on the Atoll, while also using newer statistical methods like the BSR to a quick rough idea of the condition of the reef.

Chapter 5. Conclusion

- Coral cover was consistently higher in the mid and deep strata for both exposures.
- Crustose coralline algae and encrusting macroalgae was greater in the shallow strata vs mid and deep strata, while fleshy upright macroalgae was more abundant in the deep, and the octocoral was more abundant in the windward exposures.
- Most of the branching coral found on Wake Atoll is *Pocillopora,* most of the encrusting morphology is *Montipora*, a majority of the massive morphology is *Porites*, and lastly, no obvious patterns were found between the foliose morphology and the main taxa.
- *Pocillopora* was found to have a relatively homogenous presence throughout the different strata and exposure; *Montipora* was shown to have the highest variation between the shallow and mid strata on the windward exposures, *Porites* generally exhibited low abundance in the shallows but increased in abundance with depth; *Acropora, Astreopora* and *Favia spp*., presented a low abundance throughout the Atoll.
- nMDS displays a relatively high similarity between the leeward and windward exposures despite the differences found.
- Mean BSR for Wake Atoll is approximately 0.70, indicating that the coral reef is dominated by non-calcifying organisms, such as algae, and may exhibit a lower resilience.

- Currently, there is an inadequate amount of data about the benthic community around Wake Atoll and more work needs to be done to compensate.

Appendix

Basic Benthic Classification (Tier 3b): Coral

Functional Group	Genus (Tier 3b)	Abbreviation
Branching Coral		BR
	Acropora spp.	ACBR
	Montipora spp.	MOBR
	Pocillopora spp.	POCS
	Porites spp.	POBR
	Stylophora spp.	STYS
Encrusting Coral		ENC
	Acanthastrea spp.	ACAS
	Astreopora spp.	ASSP
	Cyphastrea spp.	CYPS
	Leptastrea spp.	LEPT
	Leptoseris spp.	LESP
	Montipora spp.	MOEN
	Pavona spp.	PAEN
	Porites spp.	POEN
Foliose Coral		FOL
	Merulina spp.	MESP
	Montipora spp.	MOFO
	Porites spp.	POFO
	Turbinaria spp.	TURS
Free Coral		FREE
	Fungia spp.	FUSP
Massive Coral		MASS
	Favia spp.	FASP
	Favites spp.	FAVS
	Goniastrea spp.	GONS
	Lobophyllia spp.	LOBS
	Montastrea spp.	MONS
	Platygyra spp.	PLSP
	Porites spp.	POMA
	Symphyllia spp.	SYSP
Non-scleractinian Coral		NS
	Millepora spp.	MISP
Octocoral		OCTO

Basic Benthic Classification (Tier 3b): Upright Macroalgae (UPMA)

Functional Group	Genus (Tier 3b)	Abbreviation
Green Macroalgae		GRMA
	Caulepa spp.	CAUL
	Dictyosphaeria spp.	DICT
	Halimeda spp.	HALI
	Microdictyon spp.	MICR
Brown Macroalgae		BRMA
	Dictyota spp.	DICO
Red Macroalgae		RDMA
Blue-Green Macroalgae		BGMA
Encrusting Macroalgae		
	Lobophora spp.	LOBO
	Peyssonnelia spp.	PESP

Basic Benthic Classification (Tier 3b): TURF & CCA

Functional Group	Abbreviation
Turf growing on hard substrate	TURFH
Turf growing on rubble substrate	TURFR
Crustose Coralline algae on hard substrate	CCAH
Crustose Coralline algae on rubble substrate	CCAR

Basic Benthic Classification (Tier 3b): Other

Functional Group	Genus/Name (Tier 3b)	Abbreviation
Invertebrates		
	Sponge	SP
	Zoanthid	ZO
Mollusks		
	Giant clam	GC
	Bivalve	BI
Chordata		
	Tunicate	TUN
Mobile fauna		MOBF

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