Does coral reef community structure correlate with coastal climate patterns?

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Abstract: Despite the relatively small size of the Philippines, patterns of the prevailing climate over land and in coastal areas differ greatly among the different parts of the country. These differences may be crucial in determining the potential of coral communities to resist and recover from possible impacts of climate change in the near future. As a first step in assessing this potential, a draft typology of the coastal areas in the country based on trends in sea surface temperature, sea level rise, disturbance in water balance, and rainfall were examined vis-à-vis coral community structure data from these same localities. Phototransect data from Bolinao, Pangasinan; Lian, Batangas; Sablayan, Occidental Mindoro; Sindangan, Zamboanga del Sur; the Island Garden City of Samal, and Tubbataha Reefs of Palawan were grouped among four climate types. Genus-level cover data from these localities were then subjected to multiple response permutation procedures and multi-dimensional scaling ordinations. The results indicate the coral communities in these localities do differ significantly among climate types. However, the dominant coral genera (*Acropora* and *Porites*) in a given locality do not seem to be related to their known vulnerabilities to temperature fluctuations. This suggests there are other more important factors that determine the patterns in the distribution and abundance of reef corals in the Philippines.

Key Words: coastal climate; coral community structure; climate change

1. INTRODUCTION

The Philippines is an archipelago along the western Pacific made up of approximately 7100 islands and islets (Nañola, 2004). Its climate is mostly of high temperature and high atmospheric humidity. From December-May, trade winds from the northeast predominate, while the southwest monsoon predominates during June-October, bringing in the typhoons. In the recent years, minute but observational changes in climate have been noted in the country (PAGASA-DOST, 2014).

Climate change has been noted globally over the past few years. According to Maynard et al (2010), it is the greatest long-term threat to coral reefs. Climate change brings about to the seas increase in temperature of the upper layers, increase in water level, change in water pH, increased storm intensity, among other things (Ateweberhan et al, 2013; Bijma et al, 2013). Pollution, sedimentation, and overfishing are expected to magnify the effects of climate change (Ateweberhan et al, 2013).

According to Crabbe, M. J. C. (2008), changes in climate have consequences for the survival of reef building corals as well as ecosystems associated with them. Increase in temperature has been shown to influence decline in coral growth. Moreover, prolonged above-normal temperatures cause thermal bleaching. Corals would then expel their zooxanthellae due to stress, causing the coral to bleach, making them prone to diseases which may lead to eventual death. Moreover, increased average temperature causes the water to rise, reduction in its salinity, and influences an increase in storm intensity. These cause decrease in oxygen solubility thus forming harmful algal blooms (Bijma et al, 2013). Massive and sub-massive coral growth forms (e.g. *Porites*) are relatively more resistant to bleaching effects than branching corals (e.g. *Acropora*).

Typhoons are regular occurences in the country. These natural phenomena reduce the salinity and dissolved oxygen concentration of the waters. Moreover, they amplify currents and wave action that causes sedimentation (España, N. 2013). According to Ateweberhan et al (2013), sedimentation and turbidity increases chances of coral bleaching and causes less recovery rate because it limits the settlement of coral larvae.

Rise in sea level changes the light availability across depth, wave and tide generation, and sedimentation. All of these factors may affect coral growth and development. Some slow-growing corals like massive *Porites* species drown when sea levels rise at rapid speed (Knowlton, 2001).

2. METHODOLOGY

2.1 Selection of study sites

The study has selected six locations for coral reef surveys. Each location has four to eight sites, with most sites having two stations (75m length x 25m width; except Tubbataha and Taytay) that are 250m apart in between 2m and 6m depth contours.

2.2 Data collection

Underwater phototransects were obtained using Olympus C5050 or Canon A1100 cameras with underwater casings and had an Inon UWL-100 Achromat conversion lens – Type 2 equipped to it so as to take a minimum area of $1m^2$. The camera set-up was mounted on a 1m x 1m x 1.2m polyvinyl chloride (PVC) tetrapod to maintain uniform distance in taking photographs of the reef.

2.3 Phototransects

Five 50m transects were randomly positioned (determined through random numbers generated using Microsoft Excel®) in each station. The first number denotes the starting point based on the deeper transect, while the second number denotes the distance of one transect from another. Photographs were taken at 1m intervals on the shallow side of one transect. This method was used to examine state variables (coral diversity and relative abundance) in the locations.

2.4 Data processing

Photographs were processed with the computer program Coral Point Count with Excel Extensions (CPCe; Kohler & Gill, 2012) that would plot random points that are to be scored depending on where the points land on a photograph. The scores are then recorded and exported to a file readable using Microsoft Excel®.

The data in numbers were then converted into graphs using R (R Core Team, 2012).

Data of genus-level cover were also used to create a multi-dimensional scaling (MDS) ordination using R. This was done to see the relationships in distribution and abundances between the major coral genera.

The six locations, their genus-level cover, and their climate typology were processed with a multiple response permutation procedures test using PC-Ord ® (McCune & Mefford, 2011). This was done to determine whether the six locations are correlated and if they are significantly different to each other.

3. RESULTS AND DISCUSSION

Data were collected in a year (2009) of monitoring across six locations in the country. Locations are dispersed across the archipelago and were clustered according to climate types. The expected result of the study was to find climate factors affecting the cover of corals according to their vulnerabilities. Bleaching-prone corals were not expected to be found in locations affected by extreme heating events. Sedimentation-sensitive corals were not expected to be high in numbers in locations affected by rise in sea level. But that was not the case, as results have shown otherwise.

Cluster	Exposure	Locations
2	-extreme heating events -extreme rainfall events -disturbed water budget -sea level rise	Bolinao (northwestern Luzon)
3	-extreme heating events -disturbed water budget -sea level rise	Lian & Sablayan (southwestern Luzon)
6	-sea level rise	Samal (southern Mindanao)
11	-sea level rise	Tubbataha (northwestern Mindanao) & Sindangan (northern Mindanao)

Figure 1. Table where the locations are clustered and their climate typology exposures

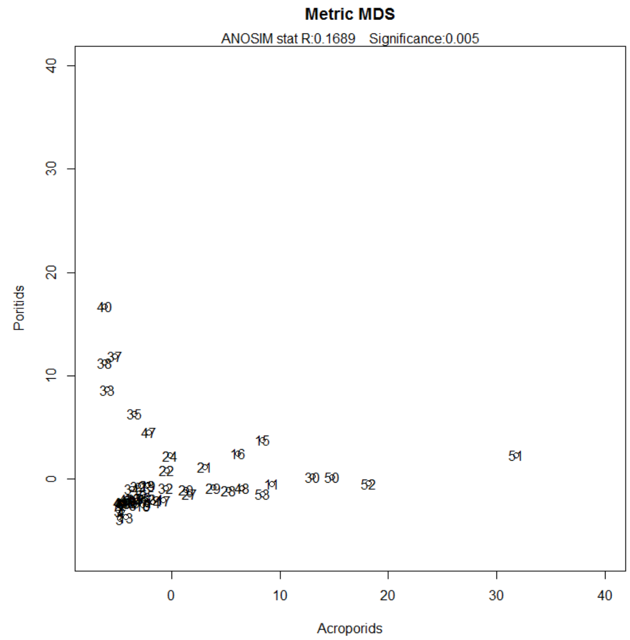

Figure 2. Metric MDS for number of TAUS in different locations over one year. The points represent the different sites of the different study locations. Points labelled 1-12 represent Bolinao; 13-25 represent Lian; 27-32 represent Sablayan; 33-40 represent Tubbataha; 41-49 represent Sindangan; 50-55 represent Samal.

The figure summarizes the first two axes of a multi-dimensional scaling analysis of the stations by TAU data matrix. The L-shaped configuration of points representing the sites, with some sites aligning with the x-axis and the rest with the y-axis, the x sites remaining near the origin of the ordination graph. The multi-dimensional scaling has shown that the two major coral families, Poritidae and Acroporidae, are inversely related to one another. Sites high in acroporids will show low poritid numbers. Conversely, sites high in poritid cover will show low acroporid numbers. This may or may not suggest competition between the two, but it is most certainly indicative of the difference of habitat preference between the two families.

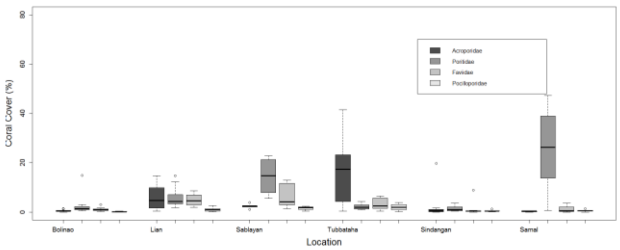

Figure 3. Levels of cover of different families of corals according to location. The error bars represent the extended range of coral cover in the different locations. The Bolinao outliers are site Caniogan, located northeast of the location. The outliers in Sindangan are site Leon Postigo, located southwest of the location. As the figure suggests, the most number of Acroporids in the study can be found in Tubbataha, while the most number of Poritids can be found in Samal. The figure also shows that there is relatively low overall coral cover in Bolinao and Sindangan as compared to the other study locations. In contrast, Tubbataha shows a good representation of all the major families involved in the study.

The corals of the Family Poritidae is the most abundant family amongst the four major families of corals in the study locations for the year. Samal has the most number of poritids among all the study locations. In contrast, Bolinao exhibits the least amount of these corals. According to España, N., species from the genus *Porites* are known to drown when sea levels rise at rapid speed. This was not the case in Samal, however. On the other hand, it may be thriving in Sablayan because poritids are known to be relatively more resistant to bleaching effects as compared to corals with branching growth forms (Bijma et al., 2013). Their abundance in Samal then appears anomalous given it should the bleaching sensitive corals (e.g., acroporids) that should be dominant here.

Acroporidae is the second most abundant family of corals amongst the four families in the study locations for the year. Tubbataha has the highest cover of corals in the Family Acroporidae amongst all locations in the study. The location with the second highest acroporid cover is in Lian, while Samal possesses the least amount of the corals. Acroporids are not known to easily drown when sea levels go up. However, they are prone to bleaching when exposed to stress brought about by high temperature (Bijma et al., 2013).

Corals from the coral Family Faviidae are most abundant in Sablayan and Lian, respectively, which both fall under cluster 3. Bolinao exhibits the least amount of faviids. Faviids are known to be sediment-intolerant (McClanahan & Obura, 1997), but are not prone to bleaching due to thermal stress.

Pocilloporids are the least abundant family amongst the four major coral families. The family Pocilloporidae is most abundant in Tubbataha and Sablayan, respectively. In contrast, it is least abundant in Bolinao. Pocilloporids are known to be sensitive to elevated temperature (Smith & Buddemeier, 1992) and are sediment-intolerant (McClanahan & Obura, 1996).

Cluster	2	3	6	11
2	--	0.00000014	0.00025915	0.00001436
3	0.00000014	--	0.0000217	0.00000001
6	0.0002592	0.0000217	--	0.00006928
11	0.00001436	0.00000001	0.00006928	--

Figure 4. Table of the p-values between clusters obtained from the multiple-response permutation procedures (MRPP)

A multiple-response permutation procedures (MRPP) test was done to see the correlation between the different clusters while factoring in coral cover. The result has shown that the coral communities in the different climate clusters sampled in the study are significantly different and not correlated with each other.

The study has shown that different locations have different coral families that are dominant. This is likely due to the different environments the different locations offer. But some results suggest that climate types may be a not be an important factor.

Bolinao has exhibited the least amount of coral cover amongst the study locations. It may probably be caused by all the stresses that climate change has brought about since it has been exposed to the most number of factors in the typologies. Trends have shown that Bolinao has been losing its coral cover in the past years.

4. CONCLUSIONS

The study has shown that different climate clusters are not correlated with each other, even if they share the same exposure.

Different coral families thrive in different locations and they have their own preferred habitats. A coral that might be thriving in one location, may be struggling in another.

It is discovered that corals may not have been responding as quick to climatic stressors as initially thought. Anthropogenic stressors may be looked into as a factor as to why coral cover has been declining in the past years.

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