A Taxonomy for Coral Reef Classification Components

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Abstract:
Coral reefs are organisms that mainly inhabit marine ecosystem. The formation of coral reefs are due to the symbiotic relationship between algae and coral animals and coral reefs have become an important element to the marine community. Coral reefs not only provides a shelter for coastal fishes and crustacean, but also protects and supply food to them. Reefs community are also useful to human that depends on marine products for their daily income. Other than that, coral reefs are one of the major attraction to tourist due to the various species of marine organisms that can be found there. The monitoring of coral reefs types, community size and health are important to ensure the ecosystem are continuous. Several attempts had been conducted to efficiently classify significant characteristics of coral reefs. The techniques used to monitor the coral reefs include on-site and remotely-sensed. All of the techniques developed have their own beneficial values and different methods are suitable for different purposes of study. This paper provides a taxonomy for coral reef classification components. The taxonomy covers the basics of coral reefs and techniques that have been used for coral reef monitoring that can be the basis for coral reef classification work in the future.

Keywords: Coral reefs, classification, on-site classification, remote sensing

I. INTRODUCTION

Coral reefs are ecosystem that were structured from calcium carbonate that was produced by corals in order to build reefs. These coral reef ecosystems were also build-up by the coated 7 macro algae and inhibit shallow water area. The corals reefs ecosystem covers approximately 0.1% of the ocean floor and provides shelter for a number of marine organisms. Coral reefs are important to marine ecosystems not only for housing organisms, but also protects coastal environment and as a tourism attraction [1].

Accumulations of remaining carbonate excretion of marine organisms and plants in warm tropical water form an abundance of coral reefs ecosystem. The symbiotic relationship between corals and zooxanthellae aids in the formation of reefs ecosystem. The algae were covered by tissues in animal inhibit the coral ecosystems that was protected by the nematocysts; the stinging cells. Symbiotically, coral animals mostly depend on the algae as their food source while algae need the animal nutrients and carbon dioxide for photosynthesis process. This relationship boosts the formation of calcium that also known as calcification and this enhance the energy and nutrient changes between marine organisms, hence allow prompt growth of coral. However, several researchers have raised a concern on the exact nature of this symbiotic relationship [2].

Coral reefs provide nutrient rich habitat and a protected shelter for marine organisms. Coral reefs contain high essential nutrients such as nitrogen for benthic organisms. The other importance of coral reefs is their structures that allows nutrient cycling with the aid of wave currents. Coral reefs structure also provides protection to coastline from destructive waves and storms [3].

The vitality of coral reefs ecosystem is undeniable. These ecosystems had been recognising as the productive ecosystem, not only in economically but also environmentally. Near-shore residents mainly consist of fishermen highly depends on coral reefs for their daily income and food sources [4].

Coral reefs play a major role in land mass or deposits. Naturally, waves that were caused by high wind speed will destroy the coral reef structure and breaks the coral into smaller piece. This calcified coral pieces were washed up to the beaches and this cause the breakdown of the coral piece to smaller pieces then become the debris, forming the beaches. Hence, coral reef reduces the impact of erosion due to the high wind-wave impact on beaches [5]. However, although the coral structure is fragile, they can grow rapidly in high wave current swept environment and build the barrier structure in order to protect the coastline.

Coral reef ecosystems can be divided into four categories based on its vicinity to land. Four categories of coral reefs are the fringing reefs, shelf reefs, barrier reefs and atoll. All of these categories highly depend on calcium carbonate deposition by coral animals and algae in order to maintain the firm platform for photosynthesis respiration process. Coral reef can grow in the condition where the deposition of carbonate exceed the rate of carbonate loss. Several factor that may contribute to the higher rate of carbonate deposition is warm seawater, high calcium and carbonate ions concentrations and finally the

calcification stimulation by photosynthesis. This is the condition where photosynthesis occurred only in the presence of sufficient sunlight and inorganic nutrients to allow high production of organic matter. The seawater pH was raised during photosynthesis and changes the equilibrium state of seawater carbonate that leads to the deposition of calcium carbonate. Hence, it can be concluded that the growth of coral reefs highly depends on the presence of sunlight that contribute to the warm temperature and photosynthesis process [6].

A. Coral Reef Structure

Coral reefs are built by sessile organisms that is immobile and permanently attached to the substrate. These organisms consist of invertebrate animals and plants where the main factor that build reefs is the corals that undergo photosynthetic process, red and green calcareous algae. Coral reefs growth have to face several obstacles due to the environmental condition that they were exposed. In order to grow, they have to adapt to their environment, and then reproduce and enhance the chances of being survived [6].

Coral reefs resilience contributes to their ability to remain unaffected to any stress or threats. Resilience can be defined as a measure of persistence ability in absorb any changes and disturbance and still contribute towards their population. As an example, massive corals can resist the storm waves as it is more resilience compared to branching corals [7]. There were few type of coral reefs that have not only different shape and structure, but also different resistance properties.

Types of Coral Reef

Corals can be divided into three major groups; fringing reefs, barrier reefs and atolls. Fringing reefs is the simplest structure of coral. They were developed from simple calcium carbonate growing upward from a coastline. The growth of reefs is rapid in shallow water where a platform is formes

around the area with the lowest tides level. The fringing reef growth is slower in offshore and mature fringing reef form a sharply defined edge that steeply shelf the reefs down to the sea floor.

Another type of coral reefs are the barrier reefs. Barrier reefs are the reefs that rises up from some distance of the shore associated with a lagoon that separating the coral population from the coast. Some of the barrier reefs may originated from fringing reefs on the coastline shelf. Then, they develop when the shoreline subsides or flooded by the tides that change the sea water level.

Atolls is the last type of coral reefs. It is the unique formation of broadly rounded and encompassing wide lagoon. Atolls usually found in oceanic locations that is far from the mainland. Initially, atolls form as a fringing reefs around islands. Then when the island subsides, the reefs keep growing and form the barrier around the island that keep sinking. Finally, when the island fades, the remaining reefs formation leave the ring-shape reef community [5].

II. CORAL REEF COMMUNITY

Peninsular Malaysia being surrounded by sea on three sides has coral reefs community in many areas; the West Coast, South Coast, and East Coast of Peninsular Malaysia. Despite the fact that coral reefs community may provide various advantages to human populations, the reefs well-being had been declining due to uncontrollable human activity with the aid of climate change and deteriorating properties of sea water. Reef Check Malaysia (RCM) had reported that the coral reefs community in East Coast of Peninsular Malaysia are exposed to high risk of sedimentation as a results of construction and coastal development activities. Furthermore, tourism sectors may also contribute to the increasing of the mortality rate of coral reefs [8]. In order to reduce the impact on coral reefs in Malaysia, several attempts had been done to preserve their community. In Malaysia for example in Pulau Tioman, the community of coral

reefs had been divided into three areas; East Coast, West Coast and isolated area. The areas were divided due to the difference in their environmental properties, coastal developments and human activities that might impact the diversity of coral reefs in the areas. An isolated area that is consist of Gado Bay, Bayan Bay, Tulai Bay, Sepoi Island and Labas Island is an area that is remotely located from Tioman Island was prohibit to any coastal development and less involved in tourism activities [8]. The coral reefs diversity in Tioman island can be classified based on the activities done nearby their community. For example, the coral reefs can be classified as good if there were less coastal development and human activities. The East Coast and isolated areas were classified as good coral condition and health with high percentage of live coral covered. The study conducted by several researchers concluded that this condition is due to the less human activity due to the distant location from resorts and residential areas [8].

A. *Factor Influencing Reef Growth*

The growth of coral reefs can be influenced by several environmental factors. Generally, they depend mainly on sea surface temperature (SST), turbidity of the sea water, dissolved oxygen concentration and ocean waves and currents.

SST is the water temperature that close to the ocean's surface to 20-meter depth. SST influence the ecosystem of marine diversity and their distribution. Most of coral reefs cannot tolerate temperatures of 16°C to 18°C [9]. In extreme cold condition, corals may experience the reduction of growth rates and die after a few hours. High temperature of sea water surface is also a threat to coral reefs community due to coral bleaching phenomena that oust algae's ability for symbiosis [10].

Turbidity of sea water near a coral reef ecosystem mainly depends on the sediment transported from terrestrial system. Turbidity

influenced the modulation of coral reef diversity. Deep understanding on the turbidity patterns, either spatially or temporally provides a thorough knowledge on reefs condition and health [11].

Other than that, the factor that influence the growth of coral reefs is the dissolved oxygen concentration as coral reefs need oxygen for respiration. High bacterial condition may occur if the oxygen level is low and this will affect the coral reefs growth. The bacteria will start to infect the reefs and this cause the death of the coral reefs [11].

III. CORAL REEF CLASSIFICATION STUDY AND TAXONOMY

There have been numerous research concerning coral reefs that have been conducted since the last few decades. One of the significant focus areas is the classification of coral reefs based on their types, live and dead reefs, healthy and unhealthy reefs and many more. There are a few methodologies used to address this. The classification procedure can be divided into two techniques; the on-site coral reef monitoring and remotely sensed coral reef monitoring.

A. On-site Coral Reef Monitoring

There were few techniques performed by researchers to implement on-site coral reef monitoring. On-site monitoring was done by performing a video capture and manual counting, develop a habitat map, and ground truth method that will discuss further in the following section.

a) Video capture manual counting

The video capture was done by two persons; one is the observer that responsible for measurement reading for the whole transect and another one is for data recording. As the size of the transect determined and secured, the second end was leave freely. The reading of the coral reefs existence and condition were started from one end at the first marking. In this measurement, all corals colony

was recorded distinctly. After the measurement reach the end of the transect, the end points were marked and the measurements were repeated at another transect [12].

b) Habitat maps (manual) – Development of automated algorithm for classification

The habitat maps can be created from aerial photographs that was taken from a plane by using known scale camera for the general view of coral reefs. There were limitations in this method as the photographs taken may not be perpendicular to the Earth's surface. This can lead to an inaccuracy measurement of coral reefs observation [13].

After photographs had been taken, all features can be distinguished from the photograph using scale markers. These habitat map is useful for the size of major habitat and zone estimation.

Ground truth

High resolution aerial photograph can be used to identify the habitat of coral reefs despite apparent changes of the coral community is not observed. This methodology was performed by diving or snorkelling to take photos of the sea floor in order to determine the exact object located at one study area. This methodology ca be used to verify the patterns of coral reefs colony and types through the photographs taken during the observation.

B. Remotely-sensed monitoring

Remotely sensed monitoring of coral reefs ecosystem is the methodology of acquiring reefs' information from a distant, without being contact with the reefs and the ocean. There were few methodology and techniques used for coral reefs classification includes pixel-based classification and object-based classification.

Pixel-based Classification

Pixel-based classification assign pixels to different class of coral reefs by assign the spectral similarities of corals in multi spectral

classification technique. This technique is well-developed and had been used widely in coral reefs monitoring and observation. However, this method was disputed to neglect the spatial concept in supervised classification. This is due to the comparison of prototype vector derived from the images consist of grey-level values resulted from the channel of multi-spectral classification [14].

Maximum Likelihood Classification (MLC) is the best method among all pixel-based classification technique. However, it was limited to the use of spectral information. Speckle noise that may be due to an atmospheric condition and land variation contained in the images underestimates the appearance of different types of land cover. This may lead to misclassification of coral reefs types, health monitoring and many more [14].

a) Object-based Classification

Due to the limitations of pixel-based classification techniques, object-based classifications were introduced by [15]. Object-based classification classifies the coral reefs colony according to information from a set of adjoining pixels with similar properties. This classification technique has an advantage over pixel-based classification for not compromised by the homogeneity of per-pixel spectral that was caused by the depth of sea water and the effects of sea surface [15].

However, the technique also has an issues in misclassification of coral reefs types. This is due to the various types of coral reefs that inhabit close to each other in one area, that was captured by satellite images in one single pixel. This leads to an error in segmentation process that may grouped mixed types of coral reefs in one class segment. In order to reduce misclassification of object-based classification technique, the statistics of each reefs colony such as their spectral resolution, texture, the size and shape of mixed

habitat should be taken into consideration for segmentation [15].

Based on the deliberations above a taxonomy of coral classification components can be made as follows:

	Taxonomic classification	Components
1	Coral reef ecosystems	i. Fringing reef ii. Shelf reef iii. Barrier reef iv. Atoll
2	Coral reef structure	Resiliency (ability to absorb any changes)
3	Coral reef growth factors	i. Sea-surface temperature ii. Turbidity iii. Oxygen concentration
4	Coral monitoring – On site	i. Video capture /Manual Counting ii. Habitat maps-aerial photograph iii. Ground truth
5	Coral monitoring – Remotely sensed	i. Pixel-based ii. Object-based

IV. CONCLUSIONS

This paper reviews and provides a taxonomy for coral reef classification components. The impact of coral reefs to marine environment is of utmost system to our ecosystem. The factor that influence the growth and mortality of the coral reefs colony was discussed in this paper. This paper also

presents the techniques used in coral reefs community monitoring that covers on-site measurement and remote sensing classification. With the taxonomy, the future work is to look into developing the classification of coral reefs surrounding Malaysia, especially in the East Coast.

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