REEF FISH ASSEMBLAGES AND FEEDING GUILD COMMUNITIES IN RELATION TO DEPTH, REEF PROFILE AND SUBSTRATE COVER AT TUNKU ABDUL RAHMAN PARK, KOTA KINABALU, SABAH

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BORNEO MARINE RESEARCH INSTITUTE
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Tarikh : 11 November 2022

DECLARATION

I hereby declare that this thesis entitled 'Reef Fish Assemblages and Feeding Guild Communities in Relation to Depth, Reef Profile and Substrate Cover at Tunku Abdul Rahman Park, Kota Kinabalu, Sabah' has been carried out and written by me and the work has not been submitted to any other degree or professional qualification. I testify that the work submitted is my own and acknowledge that excepts, references and publications from other sources have been duly acknowledged.

17th May 2022

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ABSTRACT

Understanding reef fish ecology and its dynamic interaction with its habitats plays a crucial role in manifesting effective marine park management strategies as well as navigating insights of possible problems. This thesis investigated the spatial distribution of reef fish assemblage, feeding guild and substrate composition across the two most influential environmental gradients in marine habitat, depth, and reef profile. Underwater visual census (UVC) combined with baited remote underwater station (BRUVS) surveys between 5-20 m found that depth and reef profile play significant roles in influencing reef fish assemblage, however, both factors fail to show interaction as co-factors. Depth was found to significantly affect fish species richness in which greater species richness was observed at shallower depths whereas reef profile significantly affected reef fish abundance where it was observed to be greater at slope profile. Multitudes of different individual species responses were recorded on 24 representative species, in which 13 showed significant interaction with depth and/or profile while other species remained ambiguous. Composition of feeding guild communities were found to be significantly dissimilar between depths in which higher abundance of roving carnivores was recorded at 20 m. An order of magnitude of more snappers and ten times more groupers were sampled at deeper depths, thus raising some evidence for "depth refuge hypothesis". Higher abundance of planktivores at the reef slope and higher abundance of omnivores at the reef shelf drive dissimilarities of feeding guild composition between reef profiles. Substrate composition changed significantly across depth and profile, however, showed relatively low correlation with patterns of reef fish assemblage and feeding guild composition. This thesis describes the dynamic interaction of reef fish assemblage across environmental gradients within its habitat and highlights the importance of understanding this ecological interaction to create better strategies in marine resource management.

Keywords: reef fishes, depth, reef profile, feeding guild, depth refuge hypothesis, MPA

ABSTRAK

VARIASI SPASIAL IKAN KARANG DAN KUMPULAN PEMAKANAN BERKAITAN DENGAN KEDALAMAN, PROFIL TERUMBU DAN LITUPAN SUBSTRAT DI TAMAN TUNKU ABDUL RAHMAN, KOTA KINABALU, SABAH

Memahami ekologi ikan karang dan interaksi dinamiknya dengan habitat memainkan peranan penting dalam mewujudkan strategi pengurusan taman laut yang berkesan serta memberi kayu ukur untuk sebarang kemungkinan masalah. Tesis ini mengkaji taburan ikan karang, kumpulan pemakanan ikan karang dan komposisi substrat pada dua factor persekitaran iaitu kedalaman dan profil terumbu. Tinjauan Visual Bawah Air (UVC) yang digabungkan dengan Tinjauan Stesen Bawah Air Terpencil (BRUVS) antara kedalaman 5-20 m mendapati bahawa kedalaman dan profil terumbu memainkan peranan penting dalam mempengaruhi taburan ikan karang, namun kedua-dua faktor gagal menunjukkan interaksi sebagai faktor bersama. Kedalaman didapati mempengaruhi kekayaan spesis ikan secara signifikan di mana kekayaan spesis yang lebih tinggi diperhatikan pada kedalaman yang lebih dangkal manakala, profil terumbu secara signifikan mempengaruhi kelimpahan ikan karang di mana ia dilihat lebih tinggi pada profil terumbu lereng. 13 spesis daripada 24 spesis perwakilan, menunjukkan interaksi yang signifikan dengan kedalaman dan/atau profil sementara selebihnya tidak menunjukkan interaksi signifikan. Komposisi taburan kumpulan pemakanan ikan karang didapati sangat berbeza antara kedalaman di mana jumlah ikan karnivor yang lebih tinggi dicatatkan pada kedalaman 20 m. Kelimpahan ikan siakap didapati meningkat dua kali ganda manakala, kerapu didapati sepuluh kali ganda pada kedalaman yang lebih dalam, seterusnya menimbulkan beberapa bukti untuk "hipotesis perlindungan terumbu dalam". Kelimpahan ikan planktivor yang lebih tinggi di profil terumbu lereng dan kelimpahan ikan omnivor yang lebih tinggi di terumbu mendatar mendorong perbezaan antara komposisi kumpulan pemakanan antara profil terumbu. Komposisi substrat berubah dengan ketara antara kedalaman dan profil, bagaimanapun, menunjukkan saling-kait yang rendah dengan corak taburan ikan karang dan komposisi kumpulan pemakanan. Tesis ini menyimpulkan bahawa interaksi dinamik kumpulan ikan karang merentasi pelbagai faktor persekitaran di habitatnya dan menekankan kepentingan memahami interaksi ekologi untuk merangka strategi yang lebih baik dalam pengurusan sumber laut.

Kata kunci: ikan karang, kedalaman, profil terumbu, kumpulan pemakanan, hipotesis perlindungan terumbu dalam, taman laut

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LIST OF ABBREVIATIONS

BRUVS	-	Baited Remote Underwater Video Stations
DRRH	-	Deep Reef Refuge Hypothesis
MCEs	-	Mesophotic Coral Ecosystems
MPA	-	Marine protected area
SCUBA	-	Self Contained Underwater Breathing Apparatus
TARP	-	Tunku Abdul Rahman Park
UVC	-	Underwater Visual Cencus

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CHAPTER 1

INTRODUCTION

1.1 Research Background

One of the major goals in ecology is to explain spatial patterns in the distribution of organisms within their habitat (Krebs, 2006) and many different factors are usually implicated. Some of the prominent patterns of spatial distribution commonly occur along environmental gradients (La Peyre *et al.,* 2001; Mark *et al.,* 2001) such as elevation, latitude, and depth. Coral reef fish assemblage commonly characterizes the habitat that they reside in, which results in patterns of different assemblages seen across reef zones (Arias-Gonzalez *et al.,* 2006; Lecchini *et al.,* 2003), exposure (Green, 1996), light attenuation (Gonzalez-Sanson *et al.,* 2009; Brokovich *et al.,* 2008; Srinivasan, 2003), latitude (Stevens, 1996) and depth (Gonzalez-Sanson *et al.,* 2009; Brokovich *et al.,* 2008, 2006).

Spatial pattern of distribution however varies, depending on species responding to multitude of intersecting factors. Commonly distinguished reef zones such as reef flats, reef crests and reef slopes are defined in relation to several factors including depth, exposure, and reef profile. Reef crest areas as an example, which are sometimes exposed during low tides and vulnerable to wave action, would host distinct fish assemblages as opposed to deeper, less exposed reef zones. In most places, reef profile systematically changes with depth, where shallower regions form horizontal flats before increasing in depth with gradual slopes or steep drop-offs. Reef profile, however, can also change independently, within the same depth contour, such as the formation of a submerged reef or underwater canyon.

The role of depth as one of the prominent gradients in influencing reef fish spatial distribution is well recognised (Gonzalez-Sanson *et al.,* 2009; Brokovich *et al.,* 2008; Srinivasan, 2003) due to its governing influence on physical, chemical, and biotic factors. Following increasing depth gradients, reduced light attenuation may hinder biochemical processes of most coral species thus translating to reduced abundance of corals at greater depths or prompting different morphs of corals to adapt to reduced sunlight growth (Russ, 2003). This consequently modifies the overall habitat structure (Brokovich *et al.,* 2006; Wantiez & Chauvet, 2003) that ultimately influences reef fish assemblage. In recent years, the role of depth has been widened to provide refuge to marine organisms amidst increasing pressure on shallow reefs. Deep reef refuge hypothesis (DRRH) has gained traction in the scientific community, discussing the role of mesophotic depth as the last frontier of habitat for vulnerable species impacted in shallow reefs (Bongaerts *et al.,* 2010; Brokovich *et al.,* 2008). There are documentations of fish species exhibiting vertical migration to greater depths as a response to an anthropized shallow water habitat (Turner *et al.,* 2017; Linfield *et al.,* 2016; 2014; Goetze *et al.,* 2011). While depth gradient is well recognised in influencing biotic components, it may be overestimated as depth has been shown to only provide partial contribution in explaining the pattern in a controlled laboratory setting (Srinivasan, 2003).

Although there is mounting literature on the role of depth, there remains a lack of studies investigating the relationship between reef profile and reef fish assemblages (Jankowski *et al.,* 2015). Reef profile can vary over 90º with multitude degrees of steepness; from horizontal flat, to ranges of gradients of slope as well as straight wall formation. Comparable to depth as a factor, reef profile potentially plays a key role in determining reef fish assemblage due to its potential in sculpting the underlying substratum and governing the biochemical processes. Considering that many species of reef fish hold close association with coral cover (Coker *et al.,* 2014), physical gradients that affect coral cover are expected to have a significant influence over fish distribution. Coral cover may be influenced by bottom profile with extensive coral development on horizontal flats over steep slopes and even lesser on vertical walls. Coral lifeforms may also differ with reef profile with branching and massive corals on reef flats as opposed to steeper areas that are potentially dominated by plating and encrusting corals. Steeper reefs have a proportionately smaller area exposed to wave surges as compared to flatter reefs, which shapes sediment size and type, where a smaller substrate size is found on steeper slopes (McGehee, 1994). There are limited studies conducted on reef fish habitat preference in relation to reef profile explicitly. Anecdotally, it is recognized that some fish species may have varying preferences towards reef profiles. Jankowski *et al.,* (2015) reported that rare species such as *Chromis delta* and *Pictichromis paccagnellae* were found to be restricted to wall profiles exclusively. This raises speculation that species rarity may be attributed to the fact that certain habitat types are particularly rare to begin with, such as drop-off wall structures. Therefore, it is imperative to understand the relationship between reef profile and the underlying habitat and consequently residing assemblage of reef fishes.

Underlying substrate composition is indisputably one of the most important factors governing the distribution and abundance of coral reef fish (Bonin *et al.,* 2011; Brokovich *et al.,* 2006; Garpe *et al.,* 2006; Graham *et al.,* 2006; Wilson *et al.,* 2006; Gratwicke & Speight 2005). More than 25 percent of marine fish species are associated with coral reefs (Allen, 2008) with some species heavily reliant on live coral for food, habitat, and refuge (Cole *et al.,* 2008; Simpson *et al.,* 2008 a, b). Meanwhile, there are reef-associated fishes that do not exhibit close association with live corals (Pratchett *et al.,* 2008; Wilson *et al.,* 2006; Jones *et al.,* 2004) as these species rely on other substrate type such as intact coral skeleton, turf algae beds and sandy bottoms (Pratchett *et al.,* 2008; Garpe *et al.,* 2006; Wilson *et al.,* 2006; Lindahl *et al.,* 2001). Habitat dependence varies between species and often emulates behavioural decisions regarding predation pressure, foraging requirement, and reproductive opportunity. As an example, prey species exhibit higher specialisation with limited coral cover at deeper depth due to increased predation pressure (Jankowski *et al.,* 2015; Jordan *et al.,* 2012). Shelter provided by high structural complexity of substratum, mainly branching coral (Cole *et al.,* 2008) in the shallow reef lures larger predatory fishes due to high densities of small prey fishes residing there (Stewart & Jones, 2001). Roving predators constitutes a large percentage of fishes that shelter under plating and table corals (Kerry & Bellwood, 2012), often to conceal themselves from prey when hunting

(Samoilys, 1997) and for protection from larger predators while resting (Munday & Jones, 1998).

Substrate composition changes across environmental gradient such as depth and profile are contributed by fluctuations of other physical properties that governs it, where light attenuation (Irisson *et al.,* 2010; Brokovich *et al.,* 2008), water movement (Fulton *et al.,* 2005), nutrient upwelling (Williams *et al.,* 2013; Leichter & Salvatore, 2006; Smith *et al.,* 2004) and larval supply (Hendriks *et al.,* 2001); are among the range of factors that are widely affected. However, insufficient studies are conducted on highly influential factors such depth and reef profile as co-factors and its influence in structuring spatial distribution of reef fishes. Most studies focus on habitat characteristics such vertical relief or reef rugosity (Brokovich *et al.,* 2006); which are the closest proxy to reef profile to distinguish different fish assemblages. Commonly, reef fish assemblage is quantified according to reef zones such as back reef, fore reef, and reef crest (Medeiros *et al.,* 2010; Lecchini & Tsuchiya, 2008) or entirely different habitat zones such as seagrass bed, intertidal and kelp forest (Willis & Anderson, 2003), which do not enable effects depth and profile to be distinguished. The degree to which benthic habitat structure explains fish distributions in relation to both depth and reef profile has also not been widely investigated. One recent literature by Jankowski *et al.,* (2015) explicitly investigated the matter, distinguishing reef fish assemblage across different depth and reef profiles. To address this research gap, stratified sampling method in relation to depth and profile may help identify the relative contribution of these factors in explaining the underlying substrate composition as well as the reef fish communities.

1.2 Problem Statement

Protecting biological resources and environmental values have always been the main objectives of marine protected area (MPA) establishment, which also serve as a tool for fishery management in efforts to make fishing more sustainable by recovering overexploited populations (Ali *et al.,* 2013; Christie, 2004). Despite the importance of sustainable management of MPA, only a few studies have addressed quantitatively biodiversity composition in marine waters in Malaysia (Ahmad, 2009; Man, 2008; Lim, 1997) and even lesser studies have been conducted to understand the marine ecosystem and its ecological interaction within (Gjertsen, 2005; Balmford *et al.,* 2004).

The general problem lies in the lack of research being conducted locally, in examining ecological interactions between fish assemblage and the surrounding environmental components. This results in limited understanding of spatial distribution of reef fishes in relation to their habitat parameters. Lack of compound studies connecting the gaps between existing literature signifies much needed data to better understand how fish behave in response to their surrounding habitat at a much smaller, in-situ scale. As an example, studies conducted on coral reef diversity and threats (Waheed & Hoeksema, 2014; Praveena *et al.,* 2012) as well as diversity and conservation status of reef fishes in Malaysia (Arai, 2015; Mazlan *et al.,* 2005) yielded data independently, pertaining to the matter. These past studies however did not investigate further on the interaction between the underlying habitat use by reef fishes residing in the area.

The specific problem is the limited exposure on how crucial environmental gradients such as depth, reef profile and/or underlying substrate influence reef fish spatial distribution in Malaysia's MPA. This limit understanding and management strategies to better govern marine resources. One major hindrance in optimizing MPA management is the lack of robust scientific monitoring incorporated in management strategies as merely 13% of 433 MPA worldwide are implementing the approach (Gill *et al.,* 2017). Understanding fish interaction with its surrounding habitat can yield useful information to pinpoint crucial areas or hotspots. Such information provides a better insight on ecological changes that are happening and allow swift mitigation strategies. Hence, this study is conducted to investigate the influence of depth, reef profile and substrate composition on spatial distribution of reef fish assemblage and feeding guild communities at Tunku Abdul Rahman Park (TARP), Kota Kinabalu, Sabah.

1.3 Research Questions

This research seeks to answer the following research questions:

1. How does reef fish species richness and abundance change across depths and reef profiles?
2. How does reef fish assemblage composition and feeding guilds community change across depths and reef profiles?
3. How does substrate cover change across depths and reef profile, and how does that influence reef fish assemblage composition and feeding guild community?

1.4 Research Objectives

This research aims to:

1. To compare reef fish species richness and abundances across depths and reef profiles.
2. To investigate the reef fish assemblage composition and feeding guilds community across depths and reef profile.
3. To investigate the relationship between the reef fish assemblage composition and feeding guild community with substrate cover across depths and reef profiles.

1.5 Significance of Research

The findings of this study will promote a better understanding of the interaction of reef fishes with its surrounding environmental parameters at a localized scale and illuminate the role of depth and reef profile in influencing underlying substrate composition and consequently, spatial distribution of reef fish at Tunku Abdul Rahman Park (TARP). This information is contributary in terms of linking existing literatures, focusing on the dynamic interaction of habitat components and fish distribution, which are limited in Malaysia. Better management and governing policy can be made pertaining to marine protected area (MPA) in identifying critical habitat components that will influence fish spatial distribution which are crucial to track changes and recovery of marine habitat as well as effectiveness of MPA. Results from this study also hope to illuminate a new perspective on the role of environmental gradients such as depth and reef profile that may have been undermined in marine resources management.

CHAPTER 2

LITERATURE REVIEW

2.1 The Role of Depth Gradient in Influencing Substrate Composition and Reef Fish

Studies on the effects of depth to fish assemblage structure can be challenging due to technological limitations as well as physiological SCUBA constraints resulting in limited understanding (Pyle, 2000). Many studies that investigate marine life and its abiotic environment have been limited to shallower depths across coral reefs (Kahng *et al.,* 2014). Depth plays an important role in determining the general structure of reefs through coral morphology as light availability and temperature regimes vary with depth. As an example, branching coral morphs can be found shallower while flatter lifeforms of corals generally dominate deeper zones due to solar availability (Chow *et al.,* 2019; Muko *et al.,* 2000; Willis, 1985). A shift in coral lifeforms on a reef strongly affects community structure of other marine life such as reef fishes and invertebrates (Jankowski *et al.,* 2015). Change in species composition then characterized the ecological niche of a habitat across different depth and reef zones (Lurgi *et al.,* 2012; Clavel *et al.,* 2011).

As an example, herbivorous fish species are often segregated by depths due to the substratum change across the gradient that reflects their food availability. Scraper herbivores such as parrotfish from the genus *Scarus* are exhibiting high abundance at the reef crest less than 10 m depth as compared to grazer herbivores such as surgeonfish that forage at reef slope less than 30 m depth (Cure *et al.*, 2021). Fish assemblage in the Red Sea has also shown a to shift with the reduction of branching coral cover as depth increases to mesophotic zones (Brokovich *et al.,* 2008). Fish assemblage across depth gradients can also be affected by physiological factors through ontogenetic shifts, where they incorporate different depth into their life stages (Macpherson & Duarte, 1991) that revolve around the balance of food availability and refuge from predators (Coker *et al.,* 2012; Dahlgren & Eggleston, 2000). As an example, *Zebrasoma flavescens*, *Ctenochaetus strigosus*, *Acanthurus nigrofuscus*, and *Chaetodon multicinctus*, recruits and juveniles were most abundant in deeper coral-rich and sandy rubble habitats while adults were more abundant on shallow turf-rich boulder habitats along the shallow reef flat that reflect predator refugia and food availability respectively for each life stages (Ortiz *et al*., 2012).

Fish assemblage structure is known to change with depth (Kahng *et al.,* 2017; Love *et al.,* 2009; Brokovich *et al.,* 2008) but there are also other abiotic factors to confound these changes such as light availability, shelter factor and coral cover (Francini-Filho *et al.,* 2013, Burke *et al.,* 2012; Wilson *et al.,* 2006). The abiotic habitat changes with depth in which lesser branching corals are generally found with higher abundance of flatter coral forms. This creates lesser vertical relief topography with lesser hideouts, thus shelter (Mass *et al.,* 2007). Lower light levels may also inhibit the movement of mobile marine life to forage (Rickel & Genin, 2005) and limit algae growth rates (Russ, 2003), thus changing the habitat environment.

Some studies indicate that depth of 30 m may be the tipping point, where above and below this point respectively possess separate assemblages of reef fishes by presence and absence as well as abundance (Kahng *et al.,* 2014, Loya *et al.,* 2016, Coleman *et al.,* 2018, Crosbie *et al.,* 2019). This transition zone leads to the mesophotic coral ecosystems (MCEs), which ranges between 30 - 150 m in tropical and subtropical regions (Kahng *et al.,* 2014). Since these deeper reef ecosystems are less impacted by direct anthropogenic stressors compared to shallow reefs they act as a shelter for reef fishes seeking refuge (Bongaerts & Smith, 2019; Hughes & Tanner, 2000). This idea is also known as deep reef refugia hypothesis (DRRH), which deep reefs are speculated to function as refuge and provide reproductive input for affected species to shallow reef areas after disturbances (Bongaerts *et al.,* 2010).