GROWTH AND FEEDING HABITS OF SEA PLUME (GENUS HICKSONELLA) IN DIFFERENT ENVIRONMENT

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DECLARATION

I declare that the work presented in this thesis is to the best of my knowledge and belief, original and my own work except as acknowledged in the text. The materials in this thesis have not been submitted in any form for a degree at this or any other higher institution of higher learning.

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ABSTRACT

Sea plume growth was experiment in three locations; Sepanggar Island (control and artificial substrate), UMS Jetty and the Aquarium and Museum complex in BMRI (mini aquarium and shallow reef mangrove tank). Sample prepared by cuttings sea plume for artificial substrate, rope attachment and mini aquarium in this study were taken from a single specimen of sea plume. Each sample was measured using metal ruler and drawn in underwater drawing paper and were quarantine before settle in selected environment. Mini aquarium tank was measured in four conditions where tank A and C not provide with light while tank C and D provide with light. Tank C and D was provide with artemia while tank A and B not provide with food. All tanks were made regular water change to supply suspended particles. The tank A show high growth compared on other tank in mini aquarium. While jetty rope attachment shows greater growth compared to other locations. This may be due to this area being high with suspended particles and the area exposed with wave action and high current. All samples were show growth range between 0.3333 mm to 4.5 mm per month. There is no significant growth in the different environment and the feed provided are not a big factor of the growth of sea plume which can prey on the suspended particles in the water column. Growth in shallow reef tank and jetty show that same as in natural and artificial substrate. Gorgonian sea plume need some period to recover and adapt to the surround area to grow.

ABSTRAK

Kajian mengenai gorgonia dilakukan di tiga lokasi iaitu Pulau Sepanggar (kawalan dan pertumbuhan di artificial), jeti UMS dan Akuarium dan Museum BMRI (tanki kecil dan tangki terumbu karang bakau). Sampel disediakan dengan memotong gorgonia untuk artificial, pengikatan tali, dan tanki kecil dimana sampel diperolehi dari satu spesimen sampel. Setiap sampel kajian diukur dan dilukis pada kertas lukisan bawah air dan disimpan seminggu sebelum disimpan ke lokasi yang terpilih. Tanki kecil digunakan dalam mengkaji empat keadaan yang mana tanki A dan C tidak diberikan lampu manakala tanki B dan D disediakan lampu. Tanki C dan D disediakan makanan artemia, manakala tanki A dan B tidak disediakan makanan. Pertukaran air ditanki di lakukan sekurang-kurangnya seminggu sekali bagi menyalurkan makanan. Hasil kajian mendapati bahawa antara semua tanki mini aquarium, tanki A menunjukkan pertumbuhan yang cepat. Sampel di jeti menunjukkan pertumbuhan yang paling cepat berbanding lokasi yang lain. Ini mungkin disebabkan lokasi ini mempunyai makanan yang banyak dan lokasi ini juga terdedah kepada arus dan kesan ombak. Kesemua sampel menunjukkan pertumbuhan dalam lingkungan antara 0.3333 mm hingga 4.5 mm dalam sebulan. Ini menunjukkan pertumbuhan tidak menunjukkan secara ketara antara setiap lokasi ini dan pemberian makanan tidak menjadi faktor dalam pertumbuhan gorgonia dimana ia mampu makan makanan di sumber air yang ditukar. Pertumbuhan sampel di tanki terumbu karang bakau dan jeti adalah sama seperti di sampel kawalan dan artificial. Gorgonia memerlukan masa untuk adaptasi kawasan baru dan persekitaran.

CONTENTS

LIST OF FIGURE

LIST OF ABBREVIATIONS & SYMBOLS

^{o}C	Degree Celsius
cm	Centimeter
m	Meter
mm	Millimeter
SA	Mini Aquarium Sample
SJ	Jetty Rope Attachment Sample
SM	Mangrove Tank Sample
SN	Natural Habitat Sample
SS	Artificial Substrate Sample
BMRI	Borneo Marine Research Institute
UMS	Universiti Malaysia Sabah

CHAPTER 1

INTRODUCTION

1.1 Background

Marine ecology is the study of the relationship among plants and animals to their physical and biological environment. Among the physico-chemical environment includes light, heat, wind, oxygen, carbon dioxide, nutrients, water and other parameters found in the atmosphere. The biological environment includes organisms of the same kind as well as other organisms that share the same environment. Coral reef ecology is one example of ecological study in the marine environment.

Coral is the name for a large class of marine invertebrates characterised by a protective calcium carbonate or horny skeleton. Corals are radially symmetrical in shape, consisting of colonial or individual six-tentacled animals with an internal skeleton (Breedy & Guzman, 2005). The outer layer of reef consist of living polyps of coral within live a single-celled, round algae called zooxanthellae (Kim & Lasker, 1998).

The photosynthetic zooxanthellae manufacture and transfer food directly to the coral polyps. Coral also feed on zooplankton, which they capture with their tentacles

(Lin *et. al.,* 2002). Through digestion, coral polyps release nutrients to the algae. Coral and algae then apparently cycle these nutrients between them, reducing nutrient loss to the water. This symbiotic factor makes zooxhanthelle and coral life dependent on each other (Perez *et. al.,* 2000).

1.2 Gorgonian Coral

Gorgonian coral belongs to the kingdom Animalia, phylum Cnidaria, (Salter-Cid & Bigger, 1991). The gorgonian is divided to two sub-order which are Holaxonia and Scleraxonia. Figure 1.1 shows the gorgonian classification from Kingdom to Genus. There are a variety of gorgonian families, each having differing characteristics. Gorgonians are colonial animals consisting of individual polyps connected to its neighbors laterally in attached cylindrical sessile forms that grow together in a flat or tube like fashion. Similarly, gorgonian coral grow in vertically in tree like fashion (Sanchez *et. al.* 2003[a]).

Gorgonian coral grow in clear water as muddy water will kill it and some cannot grow at depth beyond the reach of sunlight. It is because the zooxanthellae which grow within the gorgonian coral will die due to the lower light and oxygen levels (Morgan and Lalor, 2001). Zooxanthellae can grow best in temperatures higher than 20°C (Banister and Campbell, 1993).

Phylum: Cnidaria

Class: Anthozoa

Subclass: Octocorallia

Order: Alcyonacea

Suborder: Holaxonia	Suborder: Scleraxonia
Family: Plexauridae	Family: Briareidae
Genus: Plexaura	Genus: Briareum
Pseudoplexaura	Species: *Briareum asbestinum*
Eunicea	
Muricae	
Family Gorgoniidae	Family: Anthothelidae
Genus: Pseudopterogorgia	Genus: Caribbaeorum
Pterogorgia	Erythropodium
Gorgonia	

Figure 1.1 Classification of Gorgonian According Genera

(*Source:* Adopted from ITIS Report, 1996)

Gorgonian coral secrete calcium carbonate from the bottom half of the stalk of the individual polyp, forming skeletal cups to which the polyps are anchored and into which they withdraw for protection. The tentacles extend from the cup to seize plankton that wash against them, and carry the food to the oral disk (Lin *et. al.*, 2002). Stinging cells, or nematocysts, on the tentacles can also paralyze prey.

There have two types of gorgonian; photosynthetic and non-photosynthetic. Photosynthetic gorgonian require light depending on the amount of filter feeding food that is available. Non-photosynthetic gorgonian capture food by filter feeding detritus that is available around it (Lasker, 1980; Lasker, 1984). The nematocyst in gorgonian corals tentacles are used to trap zooplankton (Ben–Yosef and Benayahu, 1999).

1.3 Importance of Research

The gorgonian coral researh are mostly related to relationships to the environment and have been studied for a long time. Most of the previous research is conducted in Caribbean water. Very little research has been conducted on Indo-Pacific gorgonian coral (Ben-Yosef and Benayahu, 1999). This study is hoped to contribute to further systematic study of Indo-Pacific gorgonian coral by looking at the growth rate of gorgonids under natural and transplanted condition as well as gorgonian culture. Many current gorgonian studies focus on its bio-chemical compound for the production of drugs. Gorgonian coral are recognized to producing chemical that can be used as drugs for the pharmaceutical industry (Sponaugle & Barbera, 1991).

1.4 Scope of Research

This study will focus mainly in waters of Sepanggar Island, the Jetty and the Aquarium and Museum complex in Borneo Marine Research Institute (BMRI) Universiti Malaysia Sabah (UMS). Multiple dives will be conducted to take measurements on growth of sea plume in its natural habitat, around the jetty and in aquarium tank transplants.

1.5 Research Objectives

This research mainly focuses on the ability to grow and survival of gorgonian sea plume in different environments. The studies are:

i) To measure growth in the natural environment.

ii) To measure growth in aquarium and sea translocations.

iii) To measure the growth in aquarium environment under different conditions.

iv) To analyze different growth rate of gorgonian coral in different environment.

CHAPTER 2

LITERATURE REVIEW

2.1 Gorgonian Growth

Gorgonians or commonly known as sea fan, sea plume or sea whip can be easily found in tropical waters. Gorgonians are sessile colonial animals that exhibit diverse tree-like structures (Sanchez *et. al.,* 2003[b]). The majority of gorgonian families comprise fan-shaped or whip-like colonies, with a narrow base attached to the substrate and mostly widely spread branches extending into the water column. This morphology provides the colony with a large surface area that exposes the polyps to water flow (Kim *et. al.*, 2004). Gorgonian growth usually depends on current intensity, feeding ability and water movement (Salter-Cid & Bigger, 1991). Gorgonian growths are also species dependent, some growing faster and also slow growers (Skoufas *et. al.,* 2000).

Gorgonian skeleton are made from sclerites. The sclerites are similar to those found in other octocorals, but it frequently a combination of sclerite and a horny but flexible core of protein called gorgonin. The tendons of vertebrates are composed of a similar protein called collagen but the axes of gorgonians have been shown to have twice the tensile strength of tendons (Lasker *et. al.,* 2003).

Gorgonian has the ability for regeneration when cut to several parts (Lasker *et. al.* 2003). Gorgonian colonies are built by generations of polyps where the whole colonies behave as integrated units (Weinbauer, & Velimirov, 1996). Gorgonian branch origination and growth generate branches and colonies of different sizes. The skeletal elements or sclerites of gorgonial coral *Briareum asbestinum* have great diversity in length and density. Based on previous research, phenotypic plasticity is defined as differential phenotypic expression of a genotype under different environmental condition (West, 1997).

Distribution ranges and abundance of gorgonians depend upon environmental factors such as type of substrate, light, temperature, current regime and flow rates (Ben-Yosef & Benayahu, 1999; Martin, 2002; Lin *et. at.* 2002; Kim *et. al.* 2004; Breedy & Guzman, 2005). Substrate is a major limiting factor for gorgonians, which typically grow on rocky sites, where algal cover is minimal. Flow and water movement also play an important role in determining their distribution and growth rate (Dai & Lin 1993; Ben-Yosef & Benayahu, 1999).

Size and age, may be a more reliable indicator of survivorship and growth in colonial gorgonian. Growth rates were largely unrelated to colony size. About 47% of colonies of all sizes grew into larger size classes per year (Yoshioka, 1994). Initially, branches exhibit high growth rates when they originate until it produces daughter branches. Growth of gorgonian daughter branches follows a predictable development where it initially grows rapidly and then slow as they age and eventually stop growing when it reach maturity to become a mother branch. Mother branches follow a sequence in which they grow and generate both daughter and mother branches, but the growth and the rate at which they generate new branches also will be slow as the colony grows. Age, generation, and colony height affect rates of branch growth and origination, but the striking differences in the growth of branches are those between mother and daughter branches (Lasker *et. al.* 2003; Kim *et. al.* 2004).

The regeneration of mid-branch scars is greater compared to the sclerite weight fraction which means sclerite weight decrease in cortex material. The sclerite length is decreased in regeneration tip but increase in mid-branch scars (West, 1997).There is a alteration in average of lengths and weight fraction of *Pseudopterogorgia bipinnata* cause of stimulated predator damage (Lasker *et. al.,* 2003; Sanchez & Lasker, 2003[a]).

Turbulence and wave exposure has great affect to the growth form of coral. It is because water motions strongly affect coral metabolism, growth, mortality and reproductive stage. By experiments, it is concluded that the water motion can cause differences in the basal metabolic rates of coral. Water motion has a more fundamental and perverse effect upon growth of coral such as gorgonian coral (Dennison & Barnes, 1994). Gorgonians colonies growth form and orientation depending upon the type and direction of currents flow. When water currents are turbulent and come from variable directions, the growth form of gorgonian is typically bushy (Kim *et. al.* 2004).

Studies in two sites in Bahamas on branches of *Pseudopterogorgia elisabethae* show growth responds to disturbances such as harvesting, grazing, and storm damage (Lasker *et. al.,* 2003). Gorgonian size-dependent on it mortality where could generate a maximum colony size and the appearance of determinate growth. Colonies are susceptible to being knocked over because drag forces increase with colony size and bio-erosion weakens the substratum around the holdfast. However, gorgonian mortality decreased with colony height. This pattern mortality would have led to the accumulation of large colonies within the population (Kiho & Lasker, 1997; Kim *et. al.* 2004). Size, rather than age, may be a more reliable indicator of survivorship and growth in colonial coral reef organisms. Growth rates were largely unrelated to colony size where colonies of all sizes grew into larger size (Lasker *et. al.* 2003).

The connections among polyps continue along the branch axis and form a branching treelike structure of higher complexity, which has numerous canals in the main stem and progressively fewer as the branches decrease in size. Branching in Caribbean gorgonian octocorals also shows apical dominance (Sanchez *et. al.* 2003[b]). The aim of this study is to compare the regenerative capability of different colony parts after breaking apical dominance, and to examine the relationship between regrowth, branching and colony organization in a Caribbean octocoral (Yoshioka & Yoshioka, 1991; Lasker *et. al.,* 1996; Sanchez & Lasker 2003[a]).

In plants, partial mortality phenomenon is characterised by overcompensation: a growth response to damage that exceeds the normal performance and is most common in species with apical dominance. These species exhibit few fast-growing mother branches that branch daughter branches just below the apex (Yoshioka & Yoshioka 1991; Skoufas *et. al.*, 2000). Gorgonian *Pseudopterogorgia bipinnata* exceed normal growth or overcompensate after partial mortality and breaking the apical dominance. The overcompensation was related to the original branching network, suggesting a connection between colony organisation and regeneration. The colony organisation and regenerative response observed in octocorals branching systems (Sanchez & Lasker, 2003[a]).

Gorgonians not have storage organs or other modes to save resources for regeneration, the regenerative response could be related to the presence of dormant branches (Ben-Yosef & Benayahu, 1999; Dube *et. al.* 2002). They can potentially start new apical fronts as well as the structures for allocating resources to injured parts and newly growing branches. Dormant daughter branches located close to the injury had a high chance of becoming new apical mother branches. These branches branched at a higher rate than the regenerating apical mother branch, which is not the normal branching of uninjured colonies (Sanchez & Lasker, 2003[a]; Sanchez *et. al.* 2003[b]).

Gorgonian grew stop growing, not according to a genetically determined developmental plan, but due to size-dependent interactions between the colony and environment, such as the balance between nutrient uptake and metabolic rates. Gorgonian size dependent on change in colony growth that mediated by metabolic rate and resource capture (Kim & Lasker, 1998; Lasker *et. al.,* 1996; Dube *et. al. 2002*). Gorgonians have low growth rates, ranging between 0.08 and 0.33 cm per month. These findings suggest that in gorgonians there may be a trade between vegetative reproduction and growth rate. Growth of gorgonian after partial mortality, respond to mortality with vigorous regrowth or overcompensation, is greater than dominant growth (Ben-Yosef & Benayahu, 1999).

2.2 Feeding Habits

Gorgonians inhibit a wide variety of depths, where the majority is found in deep waters. Some gorgonian are shallow water species which possess symbiotic zooxanthellae and benefit from their photosynthetic production. The distribution and morphology of gorgonians is probably a consequence of their being passive suspension particle feeders or phytoplankton feeders (Ben-Yosef & Benayahu, 1999). Polyp act in conjuction with colony flexibility to increase the range of current velocities over which suspension feeding is successful (Sponaugle, 1991).

Some species of gorgonian coral have great ability to trap zooplankton and attribute to the nematocysts in their tentacles. For survival in intra-species competition, gorgonian coral using sweeper tentacles, packed with nematocysts. Some species such as *Acanthogorgia biserialis* are phytoplankton feeders (Lasker 1980; Dube *et. al. 2002*). Gorgonians have two type feeders of feeding mechanism, which are photosynthetic and non-photosynthetic products. The most important mode of feeding for gorgonians in general is the filtering of plankton from the surrounding water rather than photosynthetic feeder (Kim & Lasker, 1998; Lin *et. al.*, 2002). When illuminated with sufficient light, photosynthetic gorgonians do not require much feeding to grow in captivity, but they do feed voraciously when fine particulate food is offered, and such feeding increases their growth (Yoshioka & Yoshioka, 1991). To catch enough food in a given time, filter-feeding gorgonians need a large volume of water to pass over the polyps (Lin *et. al.*, 2002).

2.2.1 Photosynthetic Gorgonian

Gorgonian are sensitive to light is widespread in living organisms, as light influences movement, photosynthesis, vision, and behavior (Martin, 2002). Self-shading is an emergent property of modular growth and has been invoked as a potential mechanism controlling the patterns of growth in animal colonies (Kim & Lasker, 1998).

Gorgonian has increased rates of photosynthesis to higher feeding rates as depth increase (Lasker 1980). This implies that feeding rates are in some way tied to photosynthetic rates. Higher respiration rate in corals with high rates of photosynthesis, and activate patterns in *Montastrea cavernosa* correlate with photosynthetic rate (Lasker 1980). Decreased feeding rates in *Pocillopora damicornis* maintained in darkness. The mechanism controlling the photosynthesis-feeding rate interaction is unknown. These assumptions show measures of photosynthesis are absolute values of gorgonian primary production. However, primary production is greater at depth when decreased of depth. *Pseudopterogorgia nina* appears to have greater rates of photosynthesis (Lasker, 1980).

2.2.2 Non-Photosynthetic Gorgonian.

Gorgonians are commonly found in benthic habitats that are subject to persistent currents. To get enough food in a given time, this type filter-feeding require a large volume of water to pass through their tentacles (Lasker *et. al.* 2003). Gorgonian colonies, particularly the sea fan types, thrive in positions that are swept by relatively vigorous currents.

Many colonial organisms feeder simultaneously; generalised treatments of modular growth often proceed from the initial assumption that resource capture is a linear function (Kim & Lasker 1998). The ability to trap zooplankton (Lasker 1981), and was attributed to the small number of nematocysts in their tentacles (Ben-Yosef & Benayahu, 1999). Feeding rates of colonial suspension feeders are controlled by both behavioral and physiological mechanisms. Colonial suspension feeders depend on ambient currents to drive particle-laden fluids within reach of their feeding structures.

There are 3 feeding strategies observed in corals; feeding by tentacle capture, feeding entanglement with mucus filaments, and feeding by a combination of tentacle capture and mucus filament entanglement (Lin *et. al.*, 2002). The current speed allow efficient feeding, a colony will retract its polyps.

Acanthogorgia vegae expanded its polyps and fed particles around it. Different gorgonian coral colonies from the same species live on the same reef with similar microhabitats, show different feeding responses: some have the polyps fully expanded, while others have the polyps fully retracted. Observations by researcher on feeding behavior of *Acanthogorgia vegae* showed that the feeding rate of a polyp slows down with repeated feeding (Lin *et. al.*, 2002). According Lin *et. al.* (2002), a great range of individual polyp responses: some polyps fed repeatedly; some polyps fed once and stopped feeding; and some polyps evidently did not feed at all. The entire colony stopped feeding after capturing a certain amount of *Artemia nauplii* the examined in aquarium analyzes. This implies that satiation is an important factor influencing the feeding rate of colonial suspension feeders. Additional research in this field must consider satiation, because it affects feeding behavior, feeding rates, and feeding periodicity (Lin *et. al.*, 2002). Gorgonian feeding rates of compared different species and depth capture similar amounts of particulate matter greater particle feeding capability. The difference capture particulate feeder between depths could be caused by responses to differences in particulate availability (Lasker 1980).

Gorgonians also can be damaged by currents however at the same time it need currents to feed effectively. These two requirements have produced between strong and flexibility, with colonies typically having the elasticity of stiff rubber. When currents threaten high to damage a colony, the gorgonian colonies have the ability to bend and then spring back into their original position (Kim & Lasker, 1998).

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