DETERMINATION OF BIOFOULER SETTLEMENT ON DIFFERENT TYPES OF SUBSTRATES AND ENVIRONMENT CONDITIONS IN PULAU BETONG, PENANG

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by

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LIST OF ABBREVATIONS

cm	Centimeter
mm	Millimeter
m	Meter
L	Liter
cm^2	Centimeter
m^2	Meter square
mL	Milliliter
mg	Milligram
ms	Millisecond
m/s	Meter per second
µg/L	Microgram per liter
mg/L	Milligram per liter
FTU	Formazin turbidity unit
°C	Degree Celsius
ppt	Part per thousands
°	Degree
‘	Minute

DETERMINATION OF BIOFOULERS SETTLEMENT ON DIFFERENT TYPES OF SUBSTRATES AND ENVIRONMENT CONDITIONS IN PULAU BETONG, PENANG

Abstract

A study on the determination of biofoulers settlement on different types of substrates and environment conditions have been conducted at Pulau Betong, Penang. A total of six biofoulers have been recorded. The biofoulers consist of barnacles, tubeworms, oyster spat, bryozoans, snails and sea urchins. The highest biomass of biofoulers settlement on oyster shells were at 0.5 m and 1.0 m depths at both shaded and unshaded area. Water turbidity and temperature were found to be affecting the settlement of the biofoulers on the shells. The biomass of barnacles showed the highest among the rest of the biofoulers when using plastic trays as collectors. At the unshaded area, most of the biofoulers tend to settle at 2 m depth on the plastic trays while at the shaded area, the biofoulers tend to settle at 1 m depth on the plastic trays. Water temperature was found to be the main factor affecting the settlement of biofoulers on plastic trays. The top surface of asbestos sheets has the highest settlement of oyster spat compared to the bottom surface of the asbestos sheet at both shaded and unshaded areas using asbestos sheets. The settlement of oyster spat was higher at the shaded area compared to the settlement of oyster spat at the unshaded area. The settlement of oyster spat on the asbestos sheets was affected slightly by salinity and chlorophyll-a. Meanwhile ammonia concentration showed strong influence on the settlement of the oyster spats on the asbestos sheets.

PENENTUAN PEMENDAPAN “BIOFOULERS” KE ATAS JENIS DAN KEADAAN PERSEKITRAN YANG BERLAINAN DI PULAU BETONG, PULAU PINANG

Abstrak

Kajian penentuan pemendapan “biofoulers” ke atas jenis dan keadaan persekitaran yang berlainan telah dijalankan di Pulau Betong, Pulau Pinang. Sebanyak enam organisma “biofoulers” telah direkodkan iaitu teritip, cacing tiub, benih tiram, bryozoa, siput dan landak laut. Pemendapan biojisim “biofoulers” yang tertinggi direkodkan di atas cengkerang tiram pada kedalaman 0.5 m dan 1.0 m di kedua-dua kawasan terteduh dan tidak terteduh. Kekeruhan air dan suhu didapati telah memberi kesan kepada pemendapan “biofoulers” di atas cengkerang tiram. Manakala, biojisim teritip menunjukkan pemendapan tertinggi di antara semua “biofoulers” apabila menggunakan bakul plastik sebagai pengumpul. Di kawasan yang terteduh, kebanyakan “biofoulers” termendap pada bakul plastik pada kedalaman 2.0 m. Manakala di kawasan yang tidak terteduh, “biofoulers” termendap pada kedalaman 1.0 m. Suhu air merupakan faktor utama yang memberikan kesan kepada pemendapan “biofoulers” pada bakul plastik. Permukaan atas plat asbestos mencatatkan pemendapan benih tiram yang tertinggi berbanding dengan permukaan bawah plat asbestos di kawasan terteduh dan tidak terteduh. Pemendapan benih tiram adalah lebih tinggi di kawasan terteduh berbanding dengan kawasan tidak terteduh dengan menggunakan plat asbestos. Saliniti dan klorofil-a mempunyai perkaitan yang rendah dengan pemendapan benih tiram pada plat asbestos berbanding dengan kepekatan ammonia di dalam air.

CHAPTER 1

1.0 General introduction

1.1 Introduction

Fouling refers to the accumulation and deposition of living organisms (biofouling) and certain non-living materials on hard surfaces, most often in an aquatic environment. This can be the fouling of ships, pilings, and natural surfaces in the marine environment (marine fouling). Fouling communities are community organisms found on the sides of docks, harbors, marinas, ships and boats throughout the world (Cheah and Chua 1979). These communities are characterized by the presence of a variety of sessile organisms including ascidians, bryozoans, mussels, tube building polychaetes, sea anemones, and more. Common predators on and around fouling communities include small crabs, starfish, fish, limpets, chitons, and other gastropods.

Fouling is any material, biological or non-biological, which smothers the cultivated stock. Excessive fouling may completely envelop bivalve and prevent access to water, food and oxygen. In addition, biofouling species may compete with bivalve for resources such as food and space.

1.2 What is biofouling?

Surfaces immersed in the marine environment became colonised by marine organisms, a process which is called biofouling (Railkin, 2004). There are several organisms that cause biofouling on many different types of surfaces affected and due to the work of scientists, engineers and others, scores of solutions to the problem.

Biofouling occurs worldwide in various industries, from offshore gas and oil industries, to fishing equipment and to cooling systems (Rolland and DeSimone, 2003). The most common biofouling site is on the hulls of ships, where biofoulers are often found. The problem of biofoulers growth on a ship is the eventual corrosion of the hull, leading to the ship's deterioration (Rolland and DeSimone, 2003). Before the corrosion occurs, biofoulers growth can increase the roughness of the hull, thereby decreasing its maneuverability and increasing drag (Rolland and DeSimone, 2003). This effect could cause the ship's fuel consumption increase (Younqlood *et al*., 2003). This has caused consequences to the economic and environmental, as the increased of fuel consumption leads to increased output of greenhouse gases (Anderson, 2002). Parts of a ship other than the hull are affected as well: propellers, water-cooling pipes, heat exchangers and even the ballast water (Brizzolara, 2002). Biofouling can cause problems to the heating and cooling systems in power stations or factories. Just like a clogged drain in your bathroom or kitchen where buildup of matter inside cooling system pipes will decrease the performance. This may cause the equipment to be cleaned frequently, at times with harsh chemicals, and the obstruction in piping can lead to a shutdown of plants causing economic losses (De Rincon *et al*., 2001).

Fish farming and fishing are also affected, with trawl and mesh cages harboring fouling organisms. In Australia, settlement of biofoulers would cost for about 80% of the pearling industry's costs. The machines in the papermaking and underwater instrumentation and pulping industries contain silicon-based and gold-based components of micro electrochemical drug delivery devices are susceptible to biofouling (Anderson *et al*., 2003). The piping and sprinkler system nozzles of fire protection systems are common places for settlement of biofoulers (Lewis *et al.*, 1997).

Biofouling includes sedentary sessile motile and sedentary species. For the purpose of fouling control, biofouling species may be classified as hard or soft bodied. Soft-bodied species include ascidians, algae, sea anemones, sponges and annelids whereas hard bodied species include the encrusting barnacles, serpulid worms, bryozoans and other species of bivalve molluscs (Littlewood, 1990). These groups are considered as the most common biofoulers. The presence of most of these is assumed to have a detrimental effect on cultured oysters (Angell, 1973). Although some biofoulers such as the filter-feeding ascidians may act as sediment traps, thereby protecting oysters from heavy silt loads (Maurer and Watling, 1973). Yet some biofoulers species can quickly overgrow and kill cultured oysters, e.g. the colonial ascidian, *Didemnum psammathodes* (Wade *et al.*, 1981; Littlewood, 1988).

In pearl oyster and oyster cultivation, biofoulers have caused a lot of problems to the farmers. There were few studies have been reported on the fouling and predation on growth and survival of pearl oysters cultivation (Taylor *et al*., 1997; Friedman and Southgate 1999a, b; Southgate and Beer 2000). There were a few drawbacks which include: reduced water flow rate to the culture unit which cause food availability decreased (Taylor *et al*., 1997); available food competition among filter feeding biofoulers and culture animals (Claereboudt *et al*., 1994); oxygen availability decreased which may affect the cultivation animals growth rate (Wallace and Reisness, 1985); the excess weight from biofoulers settlement will caused increased in strain on culture equipment. Fouling has shown affect on the growth and survival of pearl oysters (Alagarswami and Chellam 1976; Mohammad 1976; Taylor *et al*., 1997). Meanwhile, biofoulers could cause the growth rate of shell length decrease and increase the mortality if fouling developed on the ventral edge of the upper shell of *Crassostrea rhizophorae* (Lodeiros *et al.*, 2007).

The ecology of fouling communities associated with mangrove roots and cultivated mangrove oysters is very poorly understood. As Ellison and Farnsworth (1990) noted, "despite centuries of research on mangrove ecosystems, studies of mangrove root epibenthic fouling communities have rarely proceeded beyond taxonomic enumeration and description". Consequently, until more is known about these communities those involved in bivalves culture should assess the disadvantages of fouling cover for them, bearing in mind that fouling communities may add significant weight to collectors, compete with bivalves for food and space, and harbour predators and possibly parasites of bivalves.

Biofouling may act as a source of physiological stress on oysters although this has never been investigated, e.g. heavily fouled collectors presumably add to the oxygen demand in oyster culture sites. The carrying capacity for aquaculture sites is generally based on the demands of the cultivated organism. However, the carrying capacity of bays, longlines, raft and racks must surely be compromised by a greater mass of biofouling.

1.3 How does biofouling form?

Biofouling is not as simple a process as it sounds. Organisms do not easily stick onto a substrate like a suction cup. The complex process often begins with the production of a biofilm.

A biofilm is a film made of bacteria or other microorganisms which forms on a substrate when conditions are suitable (Gehrke and Sand, 2003). Nutrient availability is an important factor where bacteria require uronic acid, humic substances and dissolved organic carbon for optimum biofilm growth (Griebe and Flemming, 2000). Biofilms do not contain living material; they may instead contain such once living material as dead bacteria or secretions. Bacteria are not the only organisms that can create this initial site of attachment; diatoms, seaweed, and their secretions are also culprits.

The biofilm growth can provide as a foundation for the growth of barnacles, seaweed and other organisms. In other words, microorganisms such as diatoms, algae and bacteria form the primary slime film to which the macroorganisms such as bryozoans, seasquirts, sponges, polychaetes, mollusks, tube worms, sea anemones and barnacles attach.

This process does not occur in a random fashion. Conditions must be favorable, including proper humidity, nutrient and pH availability (Gomez de Saravia *et al*., 2001). Organisms appear to be particular; for example, bacteria creating biofilms on carbon steels and stainless and recirculating cooling systems are similar physiologically (Dobrevsky *et al*., 2000). In the case of *Vibiro alginolyticus*, a bacterium which produces organic compounds sensitive to changes in pH and temperatures, the biochemistry of the bacterium may be determined if and where the biofilm attach (Muralidharan and Jayachandran, 2003). Biology and chemistry also determine which organisms attach to the biofilm.

1.4 Types of biofoulers

There were many types of biofoulers in the marine water. According to Chai *et al*. (2008), macrofoulers consists of tubeworms, barnacles, bryozoans, algae, hydroids, mussels and oysters. In this research, four biofoulers, namely barnacles, tubeworms, oyster spat and bryozoans were chosen. Meanwhile, snails and sea urchins were chosen as anti-foulers in this research at Pulau Betong.

1.4.1 Barnacle

Barnacles are hard-shelled crustaceans found on most substrates immersed in seawater and brackish water (Plate 1.1). Barnacles are distributed worldwide and are found in all the marine environments from high intertidal zone to the depth of the ocean. Barnacles have gained economic importance owing to their presence in the hard fouling community and have been widely used in studies (Barnes and Barnes, 1975; Hurley, 1973; Crisp, 1974; Wethey, 1986).

Most of the barnacles are hermaphrodites (Charnov, 1987), they are usually capable of producing eggs and sperms and fertilization is internal at the same time. Sperms exchange between adjacent individuals which leads to cross fertilization appears among acorn barnacles. However, incidences of self-fertilization have also been reported (Barnes and Crisp, 1956; Furman and Yule, 1990; El-Komi and Kajihara, 1991).

In a polluted area, barnacles are resistant to chemical pollution where it can serve as a bioindicator organism (Niyogi *et al*., 2001). Thus, barnacles are used as biomonitors whereby the level of metal pollution can be determined by the accumulation of concentrations of poisonous metals such as cadmium, lead, chromium, copper and zinc, which in turn, helps in management plans. The sources of high metal availability can also be traced which has been applied in the significantly contaminated Hong Kong Harbour (Masala *et al.*, 2001; Rainbow *et al.*, 2003).

Plate 1.1: Barnacles (*Balanus* sp.).

1.4.2 Snail

Snail is undoubtedly the most harmful enemy among biofoulers. *Urosalpinx* sp. is a snail which was first discovered in 1920, after it had been accidentally introduced into England among the American oyster imported for relaying (Hancock, 1969). In Pulau Betong Malaysia, *Thais* sp. was found in this area (Tan and Sigurdsson, 1996) with enormous number and does tremendous damage to the aquaculture industries.

Generally *Thais* sp. (Plate 1.2) preys on barnacles, bivalves and other gastropods (Taylor, 1980). This snail feeds on oysters by drilling a hole through the shell and sucking out the flesh, and it prefers oyster spat of thumbnail size to any other food. In River Crouch (England), during only a few months over 500,000 oyster spat were drilled (Hancock, 1969). The snails themselves fall through the rigging of the dredges, and newly-born snails of little more than pinhead size are usually not detected. Drill holes may be difficult to see and the drilled valves of spat quickly disintegrate.

Plate1.2: Snail (*Thais* sp.).