KESAN TERNAKAN SANGKAR IKAN TERAPUNG TERHADAP CIRI-CIRI FIZIKAL AIR, KOMUNITI PLANKTON DAN TABURAN MACROBENTHOS DI TELUK SEPANGGAR, SABAH

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The materials in this thesis are original except for quotations, excerpts, summaries and references, which have been duly acknowledged.

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ABSTRACT

A study regarding the effect of cage culture on physical properties of water, abundance and distribution of plankton community and macrobenthos assemblage in Sepanggar Bay, Kota Kinabalu Sabah was conducted. Samples were collected from the nearshore, inside cage and offshore areas of the Sepanggar Bay covering three monsoons namely the North-east monsoon, Inter-seasonal monsoon and South-west monsoon. Temperature, salinity, pH and dissolved oxygen concentration were measured *in situ* using an YSI meter. Aquadrop profiler was used to measure the current velocity. Transparency was measured using a Secchi disc. Total suspended solids of collected water samples were determined in the laboratory using the drying, burning and weighing method. Phytoplankton and zooplankton were collected using a 20 μm mesh sized plankton net. Grab sampler were used to collect the macrobenthos. Current velocity, total suspended solids, temperature, salinity, pH, transparency and dissolved oxygen data ranged between 0.11m/s and 0.50m/s, 0.05g/l and 0.26g/l, 29.11^{0}C and 30.77^{0}C, 30.03‰ and 31.93‰, 6.58 and 8.10, 3.00m and 5.20m, and 65.21%-89.29% respectively. Total of 40 phytoplankton were recorded with *Coscinodiscus* spp having the highest concentration (36%). The average abundance of phytoplankton ranged between 1.19×10^6 cells/L and 6.61×10^6 cells/L. In the zooplankton community, a total 65 types of zooplankton were recorded with larval zooplankton having the highest (31%) concentration. The average zooplankton abundance ranged between 2.20×10^6 individuals/L and 5.59×10^6 individuals/L. *Nassarius* sp. were found to be highest in the macrobenthos community where, a total of 28 genera of macrobenthos were recorded. Average macrobenthos abundance ranged between 6.97×10^4 individuals/m^3 and 2.83×10^5 individuals/m^3. A significant temporal variation was observed in the physical water properties while the differences for spatial variation were found to be statistically insignificant. However, field measurements showed lower velocity inside cage area which was due to the cage structure. As a result, the suspended solids were found higher inside the cage when compared to the nearshore and offshore areas. Phytoplankton genera, abundance and diversity values showed significant temporal variation (except Margalef's Richness Index) while no significant differences were observed in the spatial distribution of phytoplankton. For zooplankton, significant temporal variation was observed only for Pielou Evenness Index and Margalef's Richness Index. No significant spatial difference was observed for genera, abundance and diversity values of the zooplankton community. Macrobenthos assemblage showed significant temporal and spatial differences in genera, abundance and diversity values. From the present study it was clear that temporal variation was present in the physical water properties, plankton community and macrobenthos assemblage in Sepanggar Bay. However, small variation in the spatial distribution of the different studied parameters indicated the insignificant effect of cage culture practices within and around the studied area.

ABSTRAK

KESAN PENTERNAKAN SANGKAR TERAPUNG TERHADAP CIRI-CIRI FIZIKAL AIR, KOMUNITI PLANKTON DAN AGREGASI MAKROBENTOS DI TELUK SEPANGGAR, KOTA KINABALU

Kajian kesan ternakan ikan dalam sangkar terhadap ciri-ciri fizikal air, kelimpahan dan taburan komuniti plankton dan makrobentos di Teluk Sepanggar telah dijalankan. Sampel telah diambil di kawasan pinggir pantai, di dalam sangkar dan kawasan luar pantai di Teluk Sepanggar pada monson Timur laut, monson peralihan dan monson Barat daya. Suhu, saliniti, pH dan kepekatan oksigen terlarut telah disukat secara in-situ menggunakan meter YSI. Aquadop profiler digunakan untuk menyukat halaju arus manakala kejernihan pula diukur menggunakan cakera secchi. Pepejal terampai dalam sampel air dianalisis menggunakan kaedah pengeringan, pembakaran dan timbang di makmal. Sampel fitoplankton dan zooplankton diambil menggunakan jaring plankton bersaiz 20 µm. Grab sampler digunakan untuk mengambil sampel makrobentos. Keputusan julat halaju arus, pepejal terampai, suhu, salinity, pH, kejernihan dan kepekatan oksigen terlarut masing-masing 0.11 m/s dan 0.50 m/s, 0.05 g/L dan 0.26 g/L, 29.11°C dan 30.77°C, 30.03 ‰ dan 31.93 ‰, 6.58 dan 8.10, 3.00 m dan 5.20 m, dan 65.21% dan 89.29 %. Terdapat 40 spesis fitoplankton telah dikenalpasti di mana Coscinodiscus spp (36%) adalah spesis yang tertinggi kelimpahannya. Purata kelimpahan fitoplankton berjulat di antara 2.20 x 10^6 sel/L dan 5.59 x 10^6 sel/L. Manakala, terdapat 65 spesis zooplankton di mana kelimpahan tertinggi adalah larval zooplankton (31%). Purata kelimpahan zooplankton berjulat di antara 1.19 x 10^6 individu/L dan 6.61 x 10^6 individu/L. Nassarius sp. merupakan kelimpahan tertinggi pada taburan makrobentos di mana 28 jenis spesis telah dicatatkan. Purata kelimpahan makrobentos berjulat di antara 6.97 x 10^4 individu/m^3 dan 2.83 x 10^5 individu/m^3. Variasi jangka masa adalah signifikan pada ciri-ciri fizikal air manakala perbezaan variasi ruang adalah tidak signifikan secara statistik. Walau bagaimanapun, pengukuran lapangan menunjukkan halaju arus yang rendah di dalam kawasan sangkar ikan disebabkan oleh struktur sangkar. Maka, pepejal terampai mencatatkan nilai yang tinggi di kawasan dalam sangkar berbanding kawasan dekat dengan daratan dan kawasan jauh dari daratan. Nombor, kelimpahan dan kepelbagaian spesis fitoplankton menunjukkan signifikan dalam variasi jangka masa (kecuali index Margalef Richness). Manakala, tiada perbezaan yang signifikan pada variasi ruang secara statistik. Variasi jangka masa pada komuniti zooplankton adalah signifikan pada index Pielou Evenness dan Margalef Richness. Tiada perbezaan yang signifikan pada taburan ruang terhadap nombor, kelimpahan dan nilai kepelbagaian spesis zooplankton. Makrobenthos menunjukkan variasi yang signifikan pada kedua-dua taburan jangka masa dan ruang terhadap nombor, kelimpahan dan nilai kepelbagaian spesis makrobentos. Daripada kajian ini, wujudnya perbezaan variasi jangka masa yang amat jelas pada ciri-ciri fizikal air, komuniti plankton dan taburan makrobentos di Teluk Sepanggar. Walau bagaimanapun, terdapat perbezaan yang kecil pada taburan ruang dalam parameter-parameter yang dikaji di mana menunjukkan kesan yang kecil terhadap persekitaran sangkar dan kawasan kajian.

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LIST OF ABBREVIATIONS AND SYMBOLS

µm	micrometer
cell/L	cell per liter
cell/m^2	cell per meter square
g/L	gram per liter
g	gram
m	meter
%	percent
m/s	meter per second
°C	degree Celsius
ha	hectare
TSS	total suspended solid
DO	dissolved oxygen
ANOVA	Analysis of Variance
BMRI	Borneo Marine Research Institute
UMS	Universiti Malaysia Sabah

CHAPTER 1

INTRODUCTION

1.1 Introduction

Coastal aquaculture especially caged fish culture has been growing worldwide in recent years, probably due to the depletion of wild fish stock and the rapid growth of profitable species in coastal aquaculture system. The socio-economic benefits arising from coastal aquaculture include the provision of food, contribution to improved nutrition and health, generation of income and employment, diversification of primary production, and foreign exchange earnings through export of high-value products (FAO, 1987; Schmidt, 1982). Aquaculture is also being promoted for its potential to compensate for the low growth rate of capture fisheries. Stocking and release of hatchery-reared organisms into inland and coastal waters support culture-based fisheries (Larkin, 1991).

Sustainable development of aquaculture can contribute to the prevention and control of aquatic pollution since aquaculture operation essentially relies on good-quality water resources. Aquaculture can contribute to the rehabilitation of rural areas through the re-use of degraded land. Culture of mollusks and seaweeds may in certain cases counteract the process of nutrient and organic enrichment in eutrophic waters. Conversely, productivity of oligotrophic waters may be enhanced due to the nutrient and organic wastes released from aquaculture farms. Driving forces in aquaculture development are the increasing demand for aquaculture produce, generating profit and income, and the urgent need for sustainable food supply (FAO, 1992).

However, with the increase in coastal aquaculture there is increasing interest and concern for the potential impact of such operations on adjacent coastal, marine and estuarine environments. Aquaculture on an industrial scale may pose a threat to marine and coastal biological diversity due to nutrient and organic enrichment. Many aquaculture operations invariably result in the release of metabolic waste products (faeces, pseudo-faeces and excreta) and uneaten food into the aquatic environment. The release of soluble inorganic nutrients (nitrogen and phosphorus) has the potential to cause nutrient enrichment (hypernutrification) possibly followed by eutrophication (increase of primary production) of a water body. As a result, related changes in phytoplankton ecology may result in algal blooms, which can be harmful to wild and farmed organisms causing wide-scale destruction and degradation of natural habitats (FAO, 1992).

A variety of chemicals (therapeutants, disinfectants, anaesthetics, biocides, hormones and growth promoters) are used in coastal aquaculture to control predators, to prevent and control diseases and parasites, and to alter sex, productive viability and growth of cultured organisms (FAO, 1992). Current concerns center on the durability of bioactive compounds in animal tissues, the fate and effect of these compounds or their residues in the aquatic environment (e.g., toxicity to non-target organisms), and the stimulation of antibiotic resistance in microbial communities.

Biological interactions alter when the introduction and transfer of species and breeds for aquaculture purposes also change or impoverish the biodiversity of marine resources. Therefore, understanding the effects of cage culture on physical, chemical and biological parameters is useful for detecting the potential ecological problems of farming operation and development.

1.2 Aquaculture Industry in Sabah

According to the Sabah Fisheries Department (2001), the aquaculture sector in Sabah has proven to be an important supplier of animal protein and has contributed significantly to the State's economy. Aquaculture has expanded tremendously in the past decade, witnessing an increased number of prawn producers, cage culture operators and seaweed farmers. The total production from aquaculture activities in year 2001 was about 15,500 metric tonnes; the 4 main contributors were freshwater fish culture, shrimp pond culture, seaweed mariculture, fish cage culture and mollusc farming (Table 1.1).

Table 1.1: Production from Aquaculture in Sabah (2001).

	2001		
Commodity	Operation	Production (Tonnes)	Value (RM)
Shrimp	3343 ha	5640	166 million
Finfish - Cage	7500 sq. meter	550	9 million
Seaweed	700 operators	4,700	7.5 million
Freshwater Ponds	5020 operators	4,330	23 million

(Modified from http://www.fishdept.sabah.gov.my)

The Sabah government is already in the process of establishing aquaculture industry zones. Table 1.2 shows the locations and types of culture being considered by the state Land and Survey Department.

Table 1.2: The locations and types of culture in the aquaculture industry in Sabah.

Culture Type	District	Acreage
Prawn Culture in Brackish Water	Tawau	12,280
	Semporna	750
Seaweed	Semporna	38,500
Mollusc	Tawau	1,000
	Kudat	250
	Kota Marudu	250
Fish Cage Culture	Kudat	1,000
	Kota Kinabalu	475
	Lahad Datu	5,850
Fish Culture in Brackish Water	Kuala Penyu	1,000
	Papar	400
	Total	61,755

(Modified from http://www.fishdept.sabah.gov.my)

1.3 Aquaculture Practices

Aquaculture can be classified into various types. Based on media of rearing facilities it can be divided into two groups; land-based grow-out facilities and water-based grow-out facilities. Land-based aquaculture includes culture in ponds, raceways, tanks and silos. Whereas, water-based aquaculture methods are enclosure, pen, and cage cultures (Mustafa & Rahman, 2000).

The marine cages used in Sabah are simple and practical. Normally, the cages are box-shaped with nets made of polyethylene line and mesh sizes ranging from 0.5" to 3.0" or 4". Two to four cages are set within a raft frame. The cages are covered with nets to prevent fish from jumping out (especially during rough weather) and for keeping birds and mammalian predators out.

1.4 Cage Culture Scenario in Sabah

Export of marine fishes for the live fish trade from Sabah began in the last 17 years. However, records of this development and cage culture are few and not readily available (Biusing *et al,* 1996). Production of marine cage culture has been increasing from 0.9 million metric tonnes in 1991 to 2.6 million metric tonnes in 1996 (Figure 1.1).

According to the Department of Fisheries, (1996) fish stocking densities in Sabah varied considerably from 0.6 kg/m^3/yr to 23 kg/m^3/yr. Several factors affect stocking density, such as the cultured species, fish availability, size-at-stocking, cage dimensions, water quality, water velocity and availability of capital (DOF, 1996). The availability of fingerlings appears to be the crucial factor that limits stocking density and production in Sabah. This situation is a reflection of the difficulty and availability of obtaining fingerlings to stock cages (DOF, 1996).

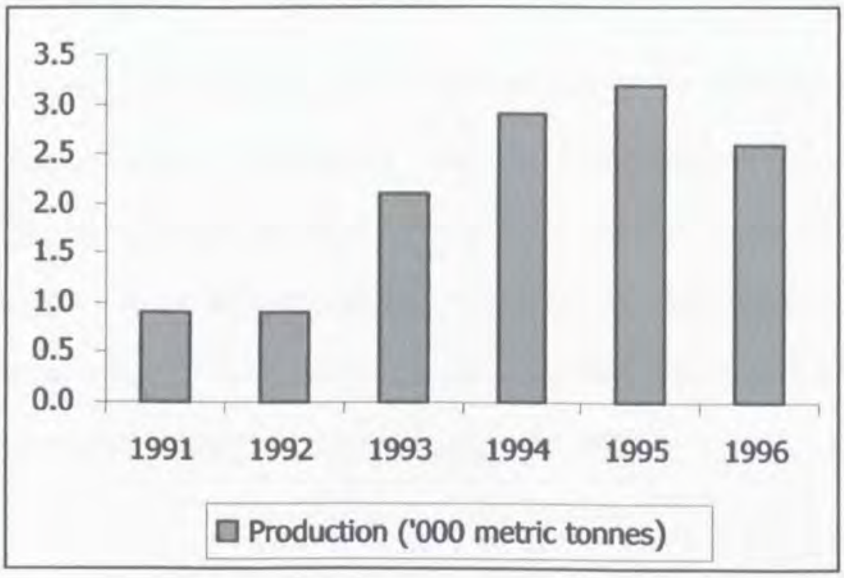

Figure 1.1: Production of Marine Fish Cage Culture (Source: Annual Fisheries Statistic, DOF Malaysia (1991-1996).

1.5 Environmental Effect of Aquaculture

Aquaculture interacts with the environment and utilises resources, causing environmental changes. During the last two decades, increasing attention has been directed toward the potential environmental hazards associated with aquaculture development (FAO, 1992). The problems normally occur in bays or coastal areas due to aquaculture activities and these activities create ecological problems related to nutrient and organic enrichment within and outside the cage culture area. The enrichment is more likely to be found in semi-intensive and particularly with intensive farming of carnivorous fishes where provision of feed is required (Mok, 1982). Nutrient and organic wastes, in dissolved and particulate forms stemming from uneaten food and excreta, are generally characterized by an increase in suspended solids (SS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), and content of carbon, nitrogen and phosphorus. Unfortunately, most of the available information on wastes released from fish farms relate to temperate species (FAO, 1992).

Aquaculture production can also be limited due to the availability of oxygen (Rosenthal *et al.*, 1988) in the culture area. An assessment of this limit for an embayment can be obtained by establishing a mass balance comparing the oxygen demand of the stock to the pool of available oxygen and the rate of supply. Therefore, oxygen availability attempts to model the production potential in relation to aquaculture management and development (Aure and Stigebrandt, 1990).

According to GESAMP (1991), the large scale cultivation (extensive system) of bivalves can interact with the marine food web by removing phytoplankton and organic detritus and thus compete with other planktonic herbivores. However, all forms of aquaculture potentially affect marine wildlife. For example, in Germany cormorant populations have increased as a result of pond farming. However, there have been few studies of the ecological effects of aquaculture operations on wildlife.

1.6 Environmental Effect of Cage Culture

Cage culture is mostly carried out in inshore areas which are sheltered coastal areas and safer from strong winds and large waves. Environmental problems normally arise in cage culture when the wave energy that comes through the floating cages is obstructed. Consequently, the low velocity of waves in the cage culture area may cause the suspended solids to be deposited at the bottom of the farm area (Hartstein *et al.*, 2006).

In addition, waste products (faeces, pseudo-faeces and excreta) and uneaten fish food which mostly contain nitrogen and phosphorus may affect the water quality in the cage culture area. Thus, cage culture has a potential to cause nutrient enrichment and consequently eutrophication of the water body.

1.7 Rationale of the Study

Cage culture has become one of the major economic activities in Sabah. Most research in cage cultures focused on increasing production. However, for the sustainable development of the aquaculture sector, more detailed studies on the impact of such operations on adjacent coastal environment are essential. Therefore, this study was conducted to investigate the effects of cage culture to the surrounding environment which included the physical water properties, plankton community and macrobenthos assemblage.

1.8 Significance of the Study

The present study provides baseline information on spatial and seasonal variations of the physical water properties as well as the plankton and benthic community within and around the caged fish culture area in Sepanggar Bay. The findings of this study could be used to develop monitoring strategies for (i) identifying beneficial and adverse environmental impacts, (ii) suggesting mitigating actions to reduce or prevent adverse impacts, (iii) recommending necessary measures for enhancing beneficial impact, and (iv) identifying the long-term residual adverse impacts which may not be mitigated.

Furthermore, this research will provide direction for further studies on hydrodynamic implications on debris dispersal, benthic community and plankton assemblage in caged fish farms, the outcomes of which can be utilized for developing sustainable aquaculture projects, controlling environmental pollution, and planning integrated coastal zone management programs.

1.9 Objectives

The major objectives of the present study were:

a. to study the physical water properties within and around the cage culture area of Sepanggar Bay.

b. to determine the abundance, distribution and diversity of plankton communities and macrobenthos assemblage within and around the cage culture area of Sepanggar Bay.

c. to evaluate the seasonal effects of cage culture on the physical environment, plankton and macrobenthos.

CHAPTER 2

LITERATURE REVIEW

2.1 Aquaculture

Aquaculture started as a traditional practice in Asia but with the passage of time it has undergone rapid transformation (Mustafa & Rahman, 2000). The enormity of water resources, the tremendous potential for cultivation of the diverse variety of organisms, and availability of labor are among the factors that have led to impressive growth of aquaculture in Asia (Mustafa & Rahman, 2000). Hence, marine aquaculture, including fish farming, is one of the fastest growing economic activities in the Asia-Pacific region (Guo *et al.,* 1999).

Aquaculture development in this region is also increasing because of the seafood demand of an overwhelming majority of the population living in coastal areas (Mustafa & Rahman, 2000). As a result, the main human protein source is obtained from aquaculture production such farming of fish, shrimp, shellfish, and seaweeds. However, fish and shellfish farming production accounts for a longer portion of aquaculture compared to seaweed farming production (FAO, 1992). Today, one fourth of the fish consumed by humans is the product of aquaculture and this tendency will continue to increase as aquaculture expands. The production of aquaculture increases even as the amount of captured fish continues to decline because of over-fishing and environmental damage worldwide (FAO, 1992).

In Malaysia, marine fish cage aquaculture is a fast growing industry, producing 6,023 tonnes annually from a total culture area of 70.72 hectares in 1998, as compared to 414.91 tonnes from 2.48 hectares in 1983 (Annual Fisheries Statistics, 1983 and 1998; Chong *et al.,* 2004). However, aquaculture practices also cause environmental damage, which restricts the development of techniques to meet food demands because of need to preserve and maintain the environmental quality in the ocean, rivers and related water bodies (FAO, 1992).

2.2 Factors to be Considered for Aquaculture Site Selection

The productivity of an aquaculture farm depends on natural water movement, water quality, as well as hydrographic and topographic site characteristics (FAO, 1992). Aquaculture practices as elaborated by FAO (1992). This property include biological environment specifically (i) Primary productivity: photosynthetic activity, (ii) local ecology: number of trophic levels, dominant species, (iii) Wild populations of desired species: adults, sources of seed stocks, (iv) Presence and concentrations of predators: land, water, airborne, (v) Endemic diseases and parasites; Location, particularly: (i) Watershed characteristics: area gradients (elevations and distances) ground cover, runoff, up-gradients activities, (ii) Tides: ranges, rates, seasonal and storm variations, oscillations round water supply: aquifers, water table depth, quality, (iii) waves: amplitude, wave length, direction, seasonal and storm variations, storm frequency, (iv) Coastal currents: magnitude, direction and seasonal variations, (v) existing facilities and characteristics, (vi) accessibility of site and (vii) history of the site: prior uses and experiences.

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