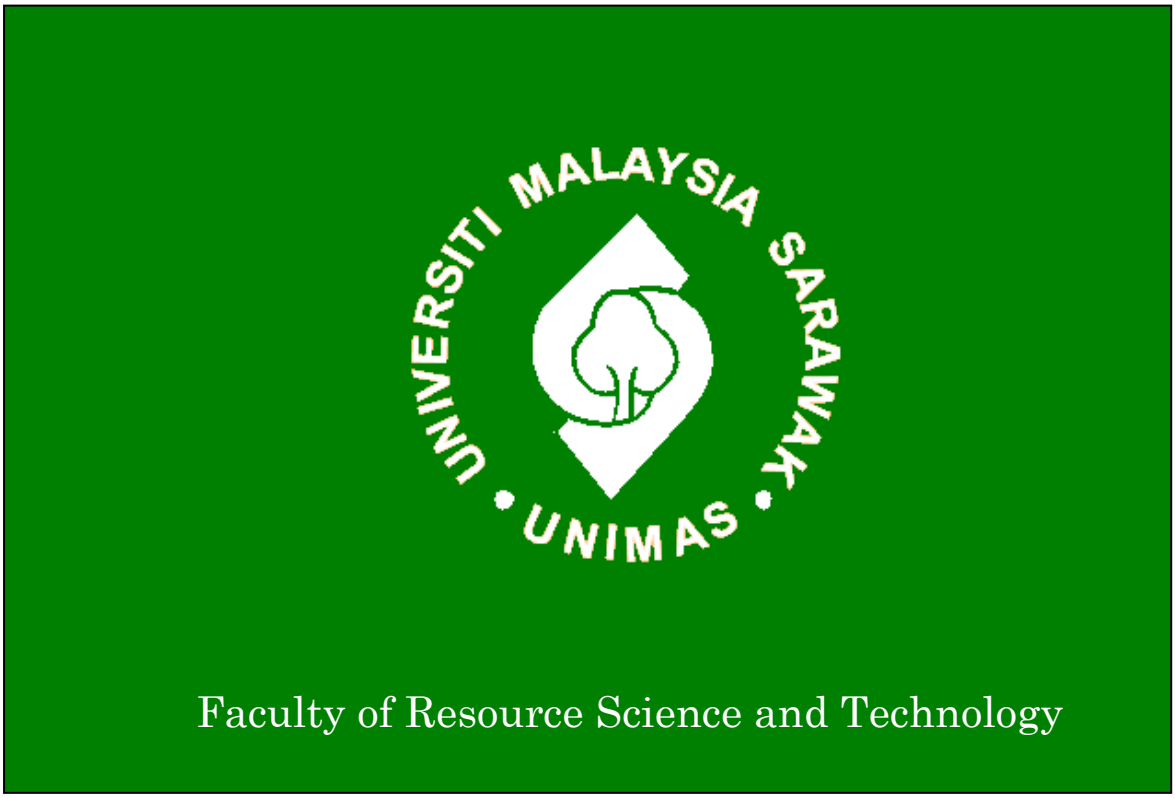

Impact of cage culture on water quality (physical and biological) parameters in Batang Ai Hydroelectric Dam

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Bachelor of Science with Honours
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IMPACT OF CAGE CULTURE ON WATER QUALITY (PHYSICAL AND BIOLOGICAL) PARAMETERS IN BATANG AI HYDROELCTRIC DAM

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DECLARATION

I hereby declare that this thesis is based on my original work except for quotation and citation, which have been duly acknowledged. I also declare that is has not been previously or concurrently submitted for any other degree at UNIMAS or other institutions.

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List of Abbreviation

µm	Micrometer
BOD	Biochemical Oxygen Demand
Chl *a*	Chlorophyll *a*
DO	Dissolved Oxygen
GPS	Global Positioning System
Mg/L	Milligram per Liters
MgO_3	Magnesium Carbonate
NWQSM	National Water Quality of Malaysia
^oC	Degree Celsius
pH	Potential of Hydrogen Ion
TSS	Total Suspended Solids
WQI	Water Quality Index

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ABSTRACT

Cage cultures are important aquaculture industry in Sarawak as they provide source of protein for the rapid growing of population and fulfilling high market demand on freshwater fishes. The Batang Ai Hydroelectric Dam is located at Lubok Antu, Sri Aman division Sarawak. The objective of this study was to evaluate the impacts of cage culture activities on the water quality (physical and biological parameters) of the Batang Ai Hydroelectric Dam. *In-situ* parameters and water samples were collected at four stations at fixed distances and depths. Temperature obtained showed that the value ranged from 25.22°C to 32.23°C, following the gradual decrease trend from the surface to the bottom water. Turbidity ranged from 0.019 NTU to 0.057 NTU whereas secchi depths were ranged from 78 cm to 190 cm and water clarity increased as distance increased from the cage. Total suspended solids falls in the range of 1.50mg/L to 9.10mg/L while pH was in the range of 6.18 to 7.34. Conductivity ranged from 33ms/cm to 89 ms/cm. Dissolved oxygen and biochemical oxygen demand increased and decreased respectively as distance was farer from the cages ranging from 0.26 mg/L to 8.45 mg/L and 6.860 mg/L² to 13.860 mg/L² . Chlorophyll *a* which ranged from 0.0044 $\mathrm{mg\ m^{-3}}$ to 0.4314 $\mathrm{mg\ m^{-3}}$ was the highest at station 3. The average low chlorophyll *a* concentration indicates that water body received low nutrient concentration to support the growth of phytoplankton. Only 3% of the samples collected recorded the presence of phytoplankton. Genus identified are *Chroroococcus* sp., *Pediastrum* sp., *Nitzschia* sp. and others. Turbidity, biochemical oxygen demand and total suspended solids were highest at station 3. This is most likely due to microbes' activity on feed residues and waste discharges which consume high amount of oxygen. pH was lowest in station 2 and followed a gradual decreasing pattern from the surface to the bottom due to anaerobic and decomposing activity of residue that settled down. Low chlorophyll *a* and phytoplankton densities implied that cage culture activities were still below the carrying capacity of this reservoir. All physical and biological parameter values fall within Class I and Class II. Controlled and proper management of existing cage cultures will continue to maintain the water quality of Batang Ai Hydroelectric Dam.

Key words: Impact, cage culture, water quality, physical parameters, biological parameters

ABSTRAK

Kultur sangkar adalah industri akuakultur penting di Sarawak di mana ia penting dalam menyumbangkan sumber protein untuk pertumbuhan pesat penduduk tempatan dan memenuhi permintaan tinggi pasaran terhadap ikan air tawar. Empangan hidroelektrik Batang Ai terletak di Lubok Antu, bahagian Sri Aman Sarawak. Objektif kajian ini adalah untuk menilai impak-impak aktiviti-aktiviti kultur sangkar pada kualiti air (parameter fizikal dan biologikal) empangan hidroelektrik Batang Ai. Parameter in-situ dan sampel-sampel air diambil pada empat stesen pada jarak dan kedalaman yang ditetapkan. Suhu yang diperolehi menunjukkan nilai berjulat dari 25.22°C ke 32.23°C, mengikuti aliran pengurangan beransur dari permukaan ke dasar empangan. Kekeruhan didapati terletak dalam julat 0.019 NTU ke 0.057 NTU manakala kedalaman secchi berjulat dari 78 cm ke 190 cm, kejernihan air bertambah dengan pertambahan jarak dari kultur sangkar. Jumlah pepejal terampai terletak dalam julat dari 1.50mg/L ke 9.10mg/L manakala pH didapati dalam julat 6.18 hingga 7.34. Kekonduksian pula terletak dalam julat dari 33ms/cm to 89 ms/cm. Nilai oksigen terlarut dan keperluan oksigen biokimia bertambah dan menurunan masing-masing dengan peningkatan jarak dari kawasan kultur sangkar dalam julat daripada 0.26 mg/L ke 8.45 mg/L dan 6.860 mg/L² ke 13.860 mg/L². Klorofil a *pula berjulat dari 0.0044* $mg\ m^{-3}$ *ke 0.4314* $mg\ m^{-3}$ *dan tertinggi di stesen 3. Purata kepekatan klorofil yang rendah menunjukkan jasad air menerima kepekatan nutrient yang rendah untuk menyokong pertumbuhan fitoplankton. Hanya 3% daripada sample air yang diambil didapati mempunyai kehadiran fitoplankton, dan genus yang dicam adalah* Chroroococcus *sp.,* Pediastrum *sp.,* Nitzschia *sp. dan lain lain. Kekeruhan, keperluan oksigen biokimia dan jumlah pepejal terampai dijumpai tertinggi di station 3. Ini disebabkan kegiatan microbe terhadap sisa makanan dan kumbahan menggunakan jumlah oksigen tinggi. pH didapati terendah di stesen 2 dan mengikuti corak penurunan beransur dari permukaan ke dasar disebabkan oleh kegiatan peguraian dan anaerob pada sisa termendak. Nilai klorofil* a *dan ketumpatan fitoplankton yang rendah menjelaskan jasad air masih dibawah keupayaan pembawaan di takungan air ini. Semua nilai biologikal dan fizikal adalah merangkumi Kelas I dan Kelas II. Aktiviti kultur yang terdapat secara kawalan dan terurus dapat terus mengekalkan kualiti air Empangan hidroelektrik Batang Ai.*

Key words: Impak, kultur sangkar, kualiti air, parameter fizikal, parameter biologikal

1.0 Introduction

Aquaculture can be defined as the farming of aquatic organisms including fish, molluscs, crustaceans and aquatic plants. Farming implies some sort of intervention in the rearing process to enhance production such as regular stocking, feeding and protection from predators (FAO, 1995). It is also a significant socio-economic activity, especially for rural communities, contributing to livelihoods, food security, and poverty alleviation through such mechanisms as income generation, employment, services, use of local resources, diversified, farming practices, domestic and international trade and other economic investments serving the sector (NACA/FAO, 2001; Edwards *et al*., 2002).

Aquaculture has grown rapidly in the past two decades. Several techniques and new species have contributed to the increased in world aquaculture production from less than 10 million tons in 1989 to more than 24 million tons in 2001 (FAO, 2002). Cage culture is the practice of farming of aquatics in cages and nets, commonly practiced worldwide in both freshwater and marine environment, including open ocean, estuaries, lakes, reservoirs, ponds and rivers (Beveridge, 1987). In Southeast Asia, cage culture plays an important role for fish production, which involves many small-scale farmers in Vietnam, Cambodia, Indonesia and Thailand (Liao and Lin, 2000).

Cage aquaculture is an old practice. It dates back to early 10^{th} century when Chinese fishermen used to fatten fish fries in cages made of bamboo sticks (Beveridge, 1996). However, expansion of cage aquaculture has taken place in the past three decades, particularly since the late 1980s. The growth is attributed to several factors which are high market value and demand for marine fishes, improvement of technology for cage culture in various oceanographic condition and going to offshore area, availability of suitable coastal area for cage culture around the world and also availability of technical support and good quality input such as feed and fry (Eng and Tech, 2002).

In Malaysia, aquaculture has developed quickly since 1920's and is now become an important activity. Food fish production from aquacultures activities increased to 179,832 tonnes in 2007 as compared to 168,826 tonnes in 2006, an increase of 6.5%. Similarity, the contribution in term of value increased from RM 1,282.8 million in 2006 to RM 1,347.6 million in 2007. Freshwater contribute 38.7% or 69,489 tonnes (DOF, 2007). Aquaculture becomes an attractive and important component of rural livelihoods in situations such as increasing population pressures, environmental degradation or loss of access and limited catches from wild fisheries (IIRR *et al*., 2001). Over the years, cage culture developed as it is becoming one of the important contributors towards the total export in Malaysia.

Cage cultures are one of the high impact activities in aquaculture field as the cage cultured fish are entirely dependent on formulated diet (Phuong, 1998), and the waste produced from this consumption is released directly to the water bodies. All this had contributed to nutrient, organic matter (BOD), and turbidity that caused the deterioration of water quality and biota of water bodies (Pillay, 1992). With increase amount of cage culture, overfeeding occurs and this will lead to deterioration of water quality (Marte *et al*., 2000).

With lack of legacy and proper management, deterioration of water quality had brought many effects towards mankind as the freshwater is the main source of drinking water, as well as to the aquatic organisms as the water environment is the natural habitat. Without clean freshwater, all diseases and infectious bacteria and parasites will grow causing the death of aquatic organisms and directly destroying the food chain of natural ecosystem. However, the environmental impact of cage culture is often ignored and rarely subjected to research or investigation. The significance of this study is to determine the level of impact from cage cultures towards the water quality in term of physical and

biological parameters at selected sites in cage cultures activities at Batang Ai Hydroelectric Dam.

2.0 Literature Review

2.1 Batang Ai Hydroelectric Dam

Batang Ai Dam is a concrete faced rockfill hydroelectric dam located in Lubok Antu, Sarawak, Malaysia and it was named after the same river it blocks. Batang Ai dam is located some 14 km from the interior town of Lubok Antu, close to the intermediate boundary with the Indonesian Kalimantan in the Division of Sri Aman. The dam construction cost RM 600 million as the planning for the dam start in 1975 and designed in 1977. Construction was started in 1982 with the river diversion work. Dam was constructed in 1984 by Kaeda Okumar Joint Venture and the last turbine completed in 1985. The dam was fully operational on 1st December 1985 (Economic Planning Unit, 1996).

Batang Ai Hydroelectric Dam consists of the main dam where the maximum height above foundation was 85m, and crest length of 90m, storage volume is 750 million cubic meters. It floods an area of 8,500 ha (21,000 acres) of forest and land and displaced 21 longhouses communities with a combined population of about 3,000. Two major rivers in upstream area contributing water to Batang Ai Dam are Batang Ai and Batang Engkilili. The crest elevation is 436m above sea level (ASL), and the maximum flood level is 126m, the maximum operating level is 86m and the minimum operating level is 56m (Economic Planning Unit, 1996).

2.2 Current status of cage culture activity in Malaysia

Cage culture had become increasingly popular alternative due to their technical, ecological, social and economical advantages as compared to traditional land aquaculture system (Schimittou, 1993; Kubitza, 2000). In Malaysia, cage culture had been a fast growing industry as it's significant increases due to demand for fish and aquatic product

(Gang *et al*., 2005). Freshwater cage culture, which contributed 10.1% to the overall freshwater production, registered an increase of 4.84% from 5,896 tonnes in 2003 to 5,611 tonnes in 2004. Major species produced are red tilapia (2,958.76 tonnes) valued at RM 15.54 million followed by river catfish (1,736.46 tonnes) valued at RM 11.39 million (Department of Fisheries Annual Report, 2004).

In Batang Ai Dam, the cage culture industry is growing and has created interest to local entrepreneurs. There are 655 ha of potential area to be developed for cage cultures. Currently, the reservoir size of Batang Ai Dam has a total area of 8,400 ha of water surface area with a maximum carrying capacity of 22,210 mt/yr. The fish cage culture was initiated by Department of Agriculture Sarawak in 1993. The main species cultured are red tilapia and currently there are 2,696 fish cages in this area. Fry requirement for all area was 1,221,000 per cycle. Cages used in cage cultures activities in Batang Ai Dam are made up of wooden or HDPE materials with general size of 3m x 3m x 1.5m. Fish are feed with pellets twice a day. The stocking density is 500 fries of 300g/cage and mortality rate is 15-20% (DOA Sarawak, 2006).

2.3 Impact of cage cultures activities on water quality

Sustainable cage fish culture is dependent on both long-term environmental and economic viability. Environmental viability is dependent on maintaining water quality at or above a minimum standard. In turn, maintenance of a water quality standard is dependent on the management system and collective amount of wastes introduced into the water, resulting from the quantity and quality of feed and other nutrient used to culture the fish and from all other sources (Wang *et al*., 2005). Cage culture eventually causes an increase of nutrient in sediments and water pollutants (Gooley *et al*., 2000). A cage culture inevitably enriches the surrounding water environment with metabolized feed waste as

would organic fertilization where nutrient enrichment of waters may lead to increase algal growth and downstream impacts (Liao and Lin, 2000). Other influencing factors include water surface area, water depth, seasonal fluctuations, amount and seasonality flow-through, and other uses of the environment. Impacts from cage culture are largely from uneaten feed and fish excreta. All these factors can alter water and sediment chemistry of the wastes accumulated near to or under the cages (Chellappa *et al*., 2009).

Besides that, sediment accumulation can lead to deterioration in sediment and water quality and the water quality will affect the wild fish population. Apart from increased in phytoplankton production, eutrophication can cause many other effects which may be more sensitive and relevant indicators such as changes in energy and nutrient fluxes, pelagic and benthic biomass and community structures, fish stocks, sedimentation, nutrient cycling, and oxygen depletion (Gregory and Zabel, 1990; Fang *et al*., 2004). Water deterioration may bring low productivity and disease may break out. Furthermore, it may cause serious consequences for human health, environment and economic development (Enelld and Lof, 1983).

2.4 Water Quality Monitoring in Malaysia

Pollution status of freshwater river in Malaysia caused by agrobase activity occurred in 22 rivers that are categorized as severely polluted, 28 rivers basins as slightly polluted and 96 river basins as clean (Annual Report Department of Environment, 2006). High BOD was contributed by untreated or partially treated sewage and discharges from agro-based and manufacturing industries.

River Water Quality Monitoring has been started by Natural Resource and Environment Board (NREB), Sarawak since 1998. As rapid population growth, land development along river basin, urbanization, agricultures, aquacultures and

industrialization have subjected the rivers in Sarawak to increasing stress and giving rise to water pollution. The State Government has directed NREB to ensure that the water qualities in all rivers in Sarawak are maintained at least at Class II B of INWQS of Malaysia (Sumok, 2001).

2.5 Phytoplankton as indicator of water quality

Biological analyses are important as it can detect possible alteration in water quality, and the tendencies over the time that reflected in natural habitat or the nature of aquatic organisms (Chellappa *et al*., 2009). All impacts from the cage culture can be quantified by evaluating the effects of the practice on the phytoplankton community as they are sensitive to the environmental changes and respond to various types of impacts by altering the quantity of organisms or their composition in diversity, due to their rapid response changes in the environment. Hence, they are considered good indicators of pollution and water quality (Starling, 1993; Menezes and Beyruth, 2003; Sampaio and Braga, 2005).

Among all phytoplankton communities, algae are recommended for water quality assessment as they have diverse spatial and productivity (Schoeman and Haworth, 1986; Coste *et al*., 1991; Prygiel, 1991; Round, 1991). Phytoplankton consists of large variety of algae with different forms and life history strategies to maximize their productivity. Among those planktonic genera are *Microcystis, Anabaena, Nodularia, Planktothrix, Aphazomenon, Cylindrospermopsis* and *Trichodesmium* (Codd, 2005). Members of dinoflagellates and euglenophyceae migrated freely in water column (Reynolds, 1984). When water bodies become eutrophicated, the diversity of phytoplankton composition will gradually decrease and lead to cyanobacteria dominance and toxin production. This will

affect human health especially for rural area as they consume the water directly from the dam without any proper treatment (Chellapa, 1990; Anderson, 1997).

2.6 Phytoplankton biomass

Chlorophyll *a* is a green pigment in plant that captures energy from the sun during photosynthesis. It is also an essential photosynthetic pigment for phytoplankton to absorb sun light energy during photosynthesis. Phytoplankton lives in well-lit surface layer or euphotic zone as there require sun light energy for photosynthesis (Thurman, 1997). Phytoplankton primary productivity in lakes and reservoir plays an essential role in element cycling, water quality and food supply to heterotrophs (Cloern, 1996).

Chlorophyll *a* concentration is an indicator of phytoplankton abundance and biomass in lakes. They can effectively measure for trophic status. Water bodies that contain high level of chlorophyll *a* indicate a poor water quality (Wellman *et al*., 2002). The determination of phytoplankton biomass can vary in terms of cell counting, chlorophyll *a*, in-vivo fluorescence, adenylates, nucleic acids, elements and nutritive value. (Sakshaug, 1980).

Cell direct counting is the oldest method used to determine the algal biomass. Phytoplankton species must be identified and counted to assess the biomass (Charpy and Blanchot, 1998). The common method used to determine phytoplankton biomass is chlorophyll *a*. The method used to determine chlorophyll *a* concentrations is by collecting phytoplankton with fine filters and the chlorophyll *a* is extracted by means of solvent (acetone) and the fluorescence of the extract is measured (Parsons *et al*., 1984). Phytoplankton decreased in biomass with an increment of pollution (Bunyat *et al.*, 1998). Thus, it is important to obtain phytoplankton biomass value in order to assess the cage culture impact on water quality in Batang Ai Dam.

3.0 Materials and Methods

3.1 Study Site

This study was carried out in Batang Ai Hydroelectric Dam located at Lubok Antu area (Figure 1). Cage culture activities in this impounded reservoir cover an area of 655 ha with eleven cage culture farms in operation during sampling. Freshwater is supplied to the reservoir via two major upstream river of Batang Ai and Sungai Engkari. All cage culture farms in Batang Ai Dam were located at corner of bays surrounding the reservoir and the main fish species cultured is red tilapia. The water sampling was done on 14 September 2009. Three cage culture sites and one site at upstream of Engkalili River and Batang Ai River that connected to dam were selected as sampling sites (Table 1).

Table 1 : Sampling sites selected for this study

Sampling Sites	GPS reading
Station 1	N 01° 09’ 20.8’’ & E 111° 50’ 45.9’’
Station 2	N 01° 10’ 45.6’’ & E 111° 52’ 3.7’’
Station 3	N 01° 10’ 39’’ & E 111° 53’ 9.4’’
Station 4	N 00° 11’ 37.8’’ & E 111° 55’ 28.8’’

3.1 Sample Collection and Storage

At each sampling site, sampling was done at three different sampling points with distances of 0m, 20m and 100m from the cage culture site. At each point, water samples were collected for vertical water column at three levels of depth that were at 0.2m, 10m and 20m. Each level of depth was determined by total depth of water column divided by three (Figure 2). For each station, three replicates of water samples were taken using Van-Dorn sampler and kept in a two little opaque polyethylene bottle. All water samples were stored in cooler box filled with ice cubes for further analysis of other parameters in the laboratory.

The collection of phytoplankton was carried out using 20µm mesh horizontal plankton drag nets. Dragging type net was used to collect the phytoplankton on the water surface and vertical type of phytoplankton net was used for deep water column. Phytoplankton was preserved in Lugol solution. Investigation on the operation system for every selected cage cultures was done by interviewing the culturist in term of culture period, feed type, feed quality, cultured species, feeding time and cage managing system.

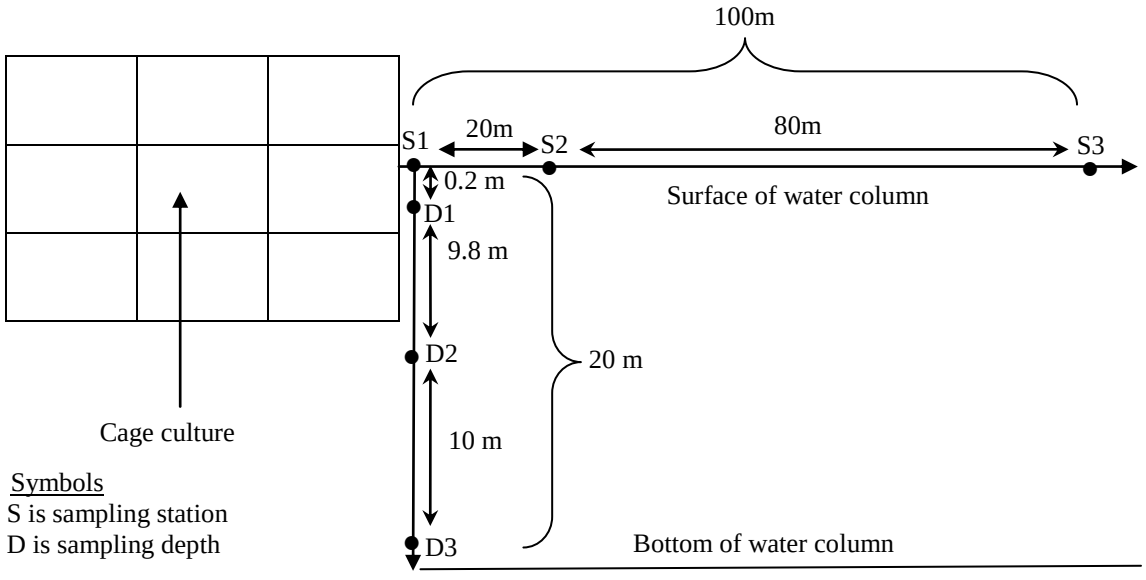

Figure 2: The sampling stations and depths at each cage culture site

3.2 *In-situ* measurement of water quality

In-situ water quality parameters for each station had been determined whereby physical parameters such as pH, salinity, conductivity, turbidity and dissolved oxygen were measured using YSI. Coordinates of sampling sites were measured using GPS readers. Depth of water column at sampling sites was determined using depth finder. For each sampling point the water transparency was determined by using WildcoÂ® secchi disc.

3.3 *Ex-situ* measurement of water quality

3.3.1 Total suspended solids (TSS)

Total suspended solids concentration of water samples were determined by filtering about 1L of well-mixed water samples through a pre-weighted 0.45 µm pore size membrane filter. The filter paper was then wrapped with a piece aluminium foil and dried in the oven at 103 ºC overnight. The dry weight of the residue was measured until getting a constant measurement. The formula is shown below (APHA, 1998).

$$\text{TSS (mg/L)} = \frac{(A - B) \times 1000}{C}$$

A= Weight after filtration (mg)

B= Weight before filtration (mg)

C= Volume of water sample which had been filtered (L)

3.3.2 Biochemical oxygen demand (BOD_5)

Water samples was collected and diluted with oxygenated distilled water in ratio 1:1 during sampling. And biochemical oxygen demand was measured by measuring the differences between the initial dissolved oxygen (DO) and DO reading obtained after five days. Three hundred ml BOD bottles was wrapped with aluminium foil and kept at 25 ºC

in a cooler box. After five days, DO reading was measured again to obtain the BOD_5 value. The formula is shown below (APHA, 1998) :

$$BOD_5\ (mg/L^2) = \frac{D_1 - D_5}{P}$$

D_1 = Intial DO in the sample mg/L (before incubation)

D_5 = Final DO after 5 days mg/L (after incubation)

P = Dilution ratio(L)

3.3.3 Chlorophyll *a* content

At each station, triplicate water samples were taken using Van Dorn water sampler at three different depths (subsurface, middle and bottom). The depth determination was decided by dividing the total depth by three. The water samples were stored in opaque polyethylene bottles and kept at 25 ºC in cooler box. The water samples were kept in as dark condition as possible to minimize the metabolic activity of phytoplankton in the water samples.

Phytoplankton chlorophyll *a* was extracted using APHA (1998). Before the water samples were taken out from the bottle, bottles were shaken first to make sure the water mixed equally as its original form (in the nature water body). Then, 1L water sample was measured and filtered with 0.45 µm membrane filter under 0.5 atmosphere pressure vacuum to avoid rupture as well as deformation of small and delicate phytoplankton cells. The 0.5L of water samples from bottom water column was fixed as it appeared with high turbidity (aspect of huge amount of suspended solid) for minimizing the time for filtering process. A few drop of magnesium carbonate (MgO_3) were added during the filtration to prevent acidity on the membrane filter and degradation of chlorophyll *a*.

The membrane filters that contained phytoplankton samples were immersed in 15ml acetone 90% solution and grinded into smaller size before they were transferred in to

a separate screw-cap tubes for chlorophyll *a* extraction. These tubes were covered with an aluminium foil and then stored in the refrigerator at 2 ºC for 24 hours. The chlorophyll extracts were centrifuged at 3000 r.p.m. at room temperature for ten minutes.

The supernatant was then decanted into a 1cm path length quartz cuvette and the absorbance of the chlorophyll *a* extract was measured spectrophotometrically at 750nm, 644 nm, 647 nm, and 630 nm wavelength using a spectrophotometer (Hach 700/2010). The concentration of chlorophyll *a* pigment of each sample was then determined according to the equation by Parson *et al.* (1984).

(*Ca*) Chlorophyll *a* = 11.85_{E664}-1.54_{E647}-$0.08_{E636.}$

(*Ca*) = amount of chlorophyll *a* in µg/ml if a 1cm light path cuvette is used.

E = absorbance at different wavelength.

$$\text{mg Chlorophyll/m}^3 = \frac{Ca \times v}{V \times 1}$$

v = volume of acetone in ml (10ml)

V = volume of sample in Liters

1 = the length of cuvette path used (cm)

3.3.4 Identification of phytoplankton

Phytoplankton collected during field trip was preserved in neutral Lugol's iodine solution. Species identification up to genus level for phytoplankton was done with a Tamin TM800 inverted light microscope using 40X magnification aided with phytoplankton identification key such as Smith (1950), Desikachary (1959), Prescott (1970), Baber and Haworth (1981) and Wehr and Sheath (2003).