MONITORING WATER QUALITY CHEMICAL PHYSICAL PARAMETERS AROUND UMS HATCHERY

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DECLARATION

I declare that this dissertation is the result of my own independent work, except where otherwise stated.

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ABSTRACT

University Malaysia Sabah Hatchery (UMS Hatchery) is an important place for practice and study in aquaculture field in University Malaysia Sabah. UMS hatchery located near the coastal water at Sepanggar Bay and the water from this coastal is the source of seawater for this hatchery. This hatchery often faces the threat of severe water quality problem like low salinity, high concentration of turbidity, red tides. On other hand, hatchery activities maybe also contribute to pollutant. The effects of hatchery discharging water on the adjacent water bodies over a crop cycle period were evaluated by studying the water quality of inlet and outlet of the hatchery. The characterization of the water consisted of the evaluation of the variation of 10 parameters along the inlet and outlet creeks and during the period of 10th January 2006 until 22nd February 2006. These parameters were pH, temperature, dissolved oxygen, turbidity, total dissolve solid nutrients (ammonium, nitrite, nitrate total nitrogen and total phosphorus). Average concentrations of total nitrogen (20.12 µg/l), total phosphorus (18.50 µg/l), nitrate (0.95 mg/l), nitrite (0.03 mg/l), ammonia (0.12 mg/l), dissolve oxygen (6.60 mg/l), temperature (29.88 °C) and turbidity (28.38 NTU) at the discharge site in the outlet were higher than in the inlet ((19.75 mg/l, 18.05 mg/l, 0.71mg/l, 0.021, 5.88 mg/l, 28.00 °C and 19.98 NTU). The other parameters show that reading at inlet is higher than at outlet.

ABSTRAK

Hatcheri Universiti Malaysia Sabah (Hatceri UMS) adalah tempat yang penting untuk pembelajaran dan latihan dalam bidang akuakultur di Universiti Malaysia Sabah. Hatceri UMS terletak di pinggir pantai Teluk Sepanggar and air laut dari pantai ini adalah sumber utama bagi hatceri. Hatceri ini kerap kali menghadapi masalah berkaitan kualiti air yang terjejas seperti saliniti rendah, kekeruhan yang tinggi, dan masalah *red tides*. Dalam pada itu, aktiviti hatceri juga mungkin menyumbang kepada pencemaran. Kesan pembuangan air yang tidak terawat berdekatan sumber air ini dikaji dengan menganalisis kualiti air dibahagian air keluar dan air masuk oleh hatceri. Sifat-sifat air yang dikaji terdiri dari 10 parameter di kawasan air masuk dan air keluar bermula pada 10 Januari 2006 sehingga 22 Februari 2006. Parameter-parameter itu adalah pH, suhu, keterlarutan oksigen, kekeruhan, jumlah pepejal terlarut, nutrient-nutrient (ammonia, nitrit, nitrate, nitrogen keseluruhan, dan fosforus keseluruhan). Purata kepekatan nitrogen keseluruhan ialah (20.12 mg/l), fosforus keseluruhan (18.50 mg/l), nitrat (0.95 mg/l), nitrit (0.03 mg/l), ammonia (0.12 mg/l), oksigen keseluruhan (6.60 mg/l), suhu (29.88 °C) dan kekeruhan (28.38 NTU) di bahagian air keluar adalah lebih tinggi berbanding di kawasan air masuk iaitu (19.75 mg/l, 18.05 mg/l, 0.71mg/l, 0.021, 5.88 mg/l, 28.00 °C dan 19.98 NTU). Lain-lain parameter menunjukkan bacaan di kawasan air masuk adalah lebih tinggi berbanding kawasan air keluar.

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LIST OF ABBREVIATIONS

°C	degree centigrade
%	percentage
cm	centimeter
DO	dissolved oxygen
g	gram
mg/l	milligrams per liter
H	hour
m	meter
km	kilometer
l	liter
ml	milliliter
mm	millimeter
mt	metric ton
ppt	part per thousand
Sig.	Significance
SPSS	Statistical Package for Social Science
UMS	Universiti Malaysia Sabah

CHAPTER 1

INTRODUCTION

1.1. Importance of water quality monitoring

The need to define the quality of water has developed with the increasing demand for water which is suitable for specific uses and conforms to a desired quality. Water quality is very importance for fishing and the aquaculture industry, especially shellfish and high value fish like tiger grouper, giant grouper, mouse grouper, and sea bass. Increasing development and its associated industrialization have, in addition, introduced the need for water quality with specific physical, chemical, or biological characteristics. At the same time, however, water bodies offer a convenient option for the disposal of domestic, agricultural, and industrial effluents and wastewaters, all of which can significantly affect the natural physical, chemical, and biological characteristics of receiving waters. Sea water from Sepanggar Bay area is the main seawater resources for University Malaysia Sabah Hatchery (UMS Hatchery). In many world regions water resources serving as a waste-disposal facility for one activity are resource of water for another activity, necessitating even more through and complex monitoring and assessment activities.

Accurate assessment of water quality, whenever in relation to the requirements of intended water uses or in order to determine the impacts of an activity on the water resource such as waste disposal or abstraction), depends on the results generated by specific monitoring activities which define the physical, chemical, and or biological condition of the resources. Consequently, the quality of the data generated during a monitoring program is crucial to the resultant assessment and the eventual effectiveness of any recommendations for management action.

The terms 'monitoring' is often used very loosely to encompass all aspects of the collection and evaluation of information relating to water quality. For the purposes of this discussion, a distinction is made between monitoring and the evaluation of the resultant data. Monitoring is defined as being the actual collection of information at set location and at regular intervals in order to provide the data which may be used to define current conditions, establish trend, etc. The complete process of monitoring, data evaluation, and reporting the result of the monitoring, can be defined as an assessment. The regular collection of water quality information is an important component of monitoring and distinguishes monitoring activities from surveys, which may be conducted only once or for a specific time period and for a specific purpose such as during research projects or to obtain preliminary information prior to the detailed design of a monitoring program.

Monitoring programs can range from those using the simplest techniques for a few sites and analyzing the result with a pocket calculator and hand drawn graph, those using advanced laboratory facilities and techniques capable of measuring low concentrations of any variable in large numbers of samples, and processing the results in a powerful computer. Monitoring the quality of seawater can be carried out in a variety of way; by making quantitative measurements of physical, chemical, and biological characteristics and by qualitative descriptions of some features such as odor, transparency, and vegetative changes. All monitoring activities can generate enormous amounts of information. The time, effort, financial resources spent to collect the information and of the information thus collected. This can be achieved only by carefully defining the objectives of a monitoring program and including the anticipated outcome, in terms of the assessments achieved, in these objectives. Monitoring without clear purpose and without a final assessment of the generated data is a very wasteful activity. A properly conducted program with fully assessed data should be able to make recommendations for the improvement of the monitoring program itself.

1.2 Objective of Study

The time and effort devoted to the setting of objectives can be repaid by more focused and cost-effective monitoring program which results from them. In the past, monitoring was frequently carried out without a clear impression of the purpose of the exercise and of how the data obtained might be interpreted. The setting of clear objectives before designing a monitoring program is essential to the overall success of the program and has been emphasized for all types of monitoring programs, in all types of water bodies. The objectives are state the reason for the monitoring program and the anticipated information to gained from it. The anticipated outputs must be clearly described in order to aid those involved in the design and implementation of the program to choose the appropriate methods and media to sample (physical, chemical, or biological), suitable sampling location, number of samples, and data-analysis techniques. Inappropriate choices resulting from poorly defined objectives can lead wasted effort, time, and resources. So this monitoring program was generated clearly its objectives to make sure this activity will able to give benefit to university and aquaculture site. The objectives of this study are;

1. To See the effect of water quality discharge by UMS hatchery
2. To know the changes in water quality parameters in and out of UMS hatchery
3. To get the general information on water quality in Sepanggar Bay areas for the potential of aquaculture.

1.3 Hypothesis

1. H_0 : No nutrient concentration changes (nitrate, nitrite, ammonia, Total Nitrogen, Total Phosphorous) in UMS Hatchery inlet and outlet.

   H_a : The nutrient concentration changes (nitrate, nitrite, ammonia, Total Nitrogen, Total Phosphorous) in UMS Hatchery inlet and outlet.

2. H_0 : The value of water parameter *in-situ* inlet and outlet (UMS hatchery) is not changes.

   H_a : The value of water parameter *n-situ* inlet and outlet (UMS hatchery) is changes.

CHAPTER 2

LITERATURE REVIEW

2.1 Nutrient

The term "nutrients" refers broadly to those chemical elements essential to life on earth, but more specifically to nitrogen and phosphorus in a water pollution context. Plants and animals are made up mostly of compounds of carbon (C), hydrogen (H), oxygen (O), nitrogen (N), and phosphorus (P), and lesser amounts of sulfur (S), potassium (K), magnesium (Mg), and calcium (Ca). These are the macronutrients. Many other elements are necessary for growth, yet because these are needed in very small amounts they are classified as micronutrients.

Animals get nutrients (that is, the chemicals they need to grow and reproduce) from eating plants or other animals; the air (or water in aquatic systems) provides animals only with oxygen (Liken 1972). Plants, however, obtain carbon, hydrogen, and oxygen from the air and water, where all three elements are very abundant (as water and carbon dioxide).

So the term "nutrients" in a water quality sense really deals with those elements that are necessary for plant growth, but are likely to be limiting -- that is, where used up or absent, plant growth stops. Of the nine macronutrients (C, H, O, N, P, S, K, Mg, and Ca), nitrogen and phosphorus are most likely to become limiting in aquatic environments (Liken 1972).

Farmers apply fertilizer nutrients in the form of nitrogen, phosphorus, and potassium (N, P, & K with perhaps micronutrients) to prevent these elements from becoming limiting in the soil. These elements are concentrated in wastewaters from animal pens and septic systems. And these elements (especially N & P) in runoff or wastewater discharges reaching streams, lakes, or seas will promote aquatic plant growth (Morton 1972). Abundant plant growth itself is a concern in assessing water quality. The most abundant "plants" in most aquatic environments are algae. When essential nutrients are plentiful, algae multiply. If these algae are microscopic phytoplankton, their growth increases the turbidity of the water. The water then becomes cloudy and colored a shade of green, yellow, or brown (sometimes red). The abundance in an aquatic system of any algae, or of higher plants, can signal excessive inputs of nutrients (Morton 1972).

2.2 Salinity

Conductivity and salinity are essentially measures of the salts dissolved in a sample. Generally, this is close to the TDS. Conductivity measures how well the water sample conducts an electrical current, a property that is proportional to the concentration of ions in solution (Row and Abdel-Majid, 1995). The advantage of using conductivity over TDS is the ease with which measurements can be made. Conductivity or specific conductance (in units of microsiemens/cm or the older micromhos/cm) is the usual measure of "salts" in fresh and slightly brackish waters. However, some instruments will, by changing scales, permit conductivity measurements in saline waters (Hasan and Ibrahim 1994).

2.3 Temperature

Water temperature helps determines which species may or not be present in the system. Temperature affects feeding, reproduction, immunity, and the metabolism of aquatic animals (Parker, 2002). Drastic temperature changes can be fatal to aquatic animals. Not only do different species have different requirements, but optimum temperatures can change or have a narrower range for each stage of life (Parker, 2002). All species tolerate slow seasonal changes better than rapid changes. Thermal stress or shock can occur when temperatures changes more than 2° to 3°F (1° to 2°C) in 24 hours. The heat capacity of water is very high, making it resistant to changes in temperature (Parker, 2002). This moderates daily and seasonal climatic changes in temperature. But cooling is often impractical, and heating is possible but costly.

Water temperature is an important variable in many biological chemical processes. Spawning is triggered by temperature. Temperature differences between the surface and bottom waters help produce vertical currents moving nutrients and oxygen throughout the water column. The temperature influences the solubility of oxygen and the percentage of un-ionized ammonia in water (Parker, 2002).

Temperature would seem to have less importance in tropical and subtropical aquatic environments than it does at higher latitudes. Yet even in Hawaii where air temperature at lower elevations seldom falls below 16 °C (60 °F) , the physical effects of thermal stratification and the influences of temperature on water chemistry and biological activity cannot be ignored. Shallow water and a high sun angle combine to create situations where temperature becomes damaging to biota at the high end. Water has a considerable capacity to hold heat, much more than air. Consequently, a water body will be slower to heat and slower to cool than the surrounding air.

With respect to water quality monitoring, one important aspect of water temperature is the influence it has on dissolved oxygen, the weight or volume of oxygen dissolved in water. The solubility of a gas in water decreases as the water temperature increases -- so warmer water simply holds less oxygen. Temperature is also important in other chemical reactions, such as those involving water (Raw and Abdel-Majid, 1995).

2.4 pH

The pH-one of the most common water tests- is a measure of hydrogen ions in the water. The pH scale spans a number range of 0 to 14 with the number 7 being neutral. The pH scale is logarithmic, so every one-unit change in pH represents a ten-fold change in acidity. Measurements above 7 are basic and below 7 are acidic. The farther a measurement is from 7, the more basic or acidic is the water. Acid and alkaline (basic) death points for fish are approximately pH 4 and 11 (Tebbute, 1983).

Growth and reproduction can be affected between pH 4 and 6 and pH 9 and 10 for some fishes. Also, pH affects the toxicity of other substances, such as ammonia and nitrite. The pH of some pond may change during the course of a day and is often between 9 and 10 for short periods of afternoons. Fish can usually tolerate such rises that result when carbon dioxide, an acidic substance, is used up by plant in photosynthesis (Kamarudin *et al.*, 1990). The most common pH problem for pond fish is when water is constantly acidic. The nature of the bottom and watershed soils is usually responsible. Water with a stable and low pH is only correctable with liming (Kamarudin *et al.*, 1990).

2.5 Dissolved Oxygen

Aquatic life requires dissolved oxygen (DO). It varies greatly in natural surface water and is characteristically absent in ground waters. Most aquatic animals need more than a 1-ppm concentration for survival. Depending on culture circumstances, aquatic animals need 4 to 5 ppm to avoid stress. Concentrations considered typical for surface water are influenced by temperature but usually exceed 7 to 8 mg/l (ppm) (Parker, 2002). In ponds, dissolve oxygen fluctuates greatly due to photosynthetic oxygen production by algae during the day and the continuous consumption of oxygen due to respiration (Alabaster *et al.* 1980). Dissolve oxygen typically reaches a maximum during the late afternoon and a minimum around sunrise. Cloudy weather, rain, plankton die-offs, and heavy stocking and feeding rates result in low level of dissolve oxygen, which can stress or kill fish (Parker, 2002).

Oxygen is only slight soluble in water. Water may be frequently supersaturated with oxygen in ponds with algae blooms. For example, at sea level at a temperature 77°F (25°C), pure water contains about 8 ppm of oxygen when 100 percent saturated,but during the afternoon hours, levels of 10 to 14 ppm in pond with healthy algae blooms are not uncommon (Parker, 2002).

As water warms, is raised to higher altitudes, or becomes more saline, its oxygen holding capacity declines. Water saturated with oxygen at 59 °F (15 °C) contains about 9.8 ppm, whereas water at 86 ° (30°C) is saturated at about 7.5 ppm (Parker, 2002).

Aquaculturist measure dissolve oxygen with oxygen meter or chemical test kits, which result in mg/l. Guidelines for oxygen management usually report that oxygen levels should be maintained above 4 mg/l (ppm) to avoid stress. Most warmwater fish experience significant oxygen stress at levels of 2 mg/l, and that levels of less than 1 mg/l (ppm) may result in fish kills (Parker, 2002). While the guidelines are accurate, fish actually respond to the percent saturation of oxygen rather than the oxygen content in water. A reading of 1 mg/l at 30° (13.3 percent saturated) and represents more available oxygen.

If dissolve oxygen reach low levels, fish will shoe signs including (Parker, 2002);

1. Not eating and acting sluggish
2. Gasping for air at the surface
3. Grouped near water inflow pipe
4. Slow growth
5. Outbreaks of disease and parasites.

Proper water management prevents the problems form depletion of dissolve oxygen. Management techniques include (Parker, 2002);

1. Monitoring dissolve oxygen at critical times
2. Avoid overfeeding
3. Proper stocking level
4. Avoiding over fertilization
5. Controlled plant growth
6. Some form of aeration
7. Keeping water circulating

2.6 Ammonia

Ammonia is present in slight amount in some well, pond waters and tank culture in hatchery. As fishes become more intensively cultured or confined, ammonia can reach harmful levels. Any amount is considered undesirable, but stress and some death loss occur at more than 2 mg/l (2 ppm), and at more than 7 mg/l (7 ppm) fish loss increase sharply (Parker, 2002). Ammonia is a waste product of their protein metabolism by aquatic animals. In water, ammonia occurs either in the ionized (NH4+) or un-ionized (NH3) form, depending upon pH. Un-ionized ammonia is considerably more toxic to fish and occurs greater proportion at high pH and warmer temperatures (Parker 2002). Unionized ammonia is successful to warmwater fish at concentrations grater than 0.1 mg/l and lethal at concentrations approaching 0.5 mg/l. Concentrations of 0.0125 ppm cause reduced growth and gill damage in trout (Parker, 2002).

Test kit for determining ammonia in water measure total ammonia. To determine a large percentage of the ammonia is in un-ionized form, pH is also measured. A pH above 8 in the percentage of ammonia concentrations above 0.5 mg/l is cause for concern. Algae use ammonia as a nitrogen source for making proteins. Concentrations usually remain low in pond or tank cultures with phytoplankton blooms. The greatest concentration of ammonia often occurs after plankton die-off, at which time pH is low due high level of carbon dioxide, and the majority of ammonia is present in the relatively nontoxic ionized form (Parker, 2002).

Heath (2000) said that un-ionized ammonia in the water caused trout to increase their urine production. The effect on urine production was dose-dependent but acclimation to ammonia for only 24 hour reduced the diuretic response. Heath explained the enhanced urine flow as due to increased inflow of water that was then excreted. Heath found that renin activity in the blood was elevated by exposure to ammonia at concentrations and times of exposure that are comparable to those used in the foreign study. Renin is released by the kidney and catalyzes the conversion of angiotensinogen to angiotensin in the plasma. This later protein is a powerful vasoconstrictor that causes an increase in the blood pressure (Heath, 2000).

Parker proposed that management is the key to preventing problems from ammonia. The management techniques are similar to those for preventing oxygen depletion (Parker, 2002)-

1. Avoid overcrowding
2. Avoid overfeeding
3. Add freshwater

REFERENCES

Abentin, E., 1999. *Kajian Nutrien dan Kesannya Terhadap Peningkatan Populasi Pyrodinium Bahamense Var Compressum (RED TIDE) di Perairan Marin Sabah*, Disetasi Sarjana Sains, Sekolah Sains Dan Teknologi, Universiti Malaysia Sabah, Sabah.

Alabaster, J.S. and Lyrord, R., 1980. *Water Quality Criteria for Freshwater Fish.* Butterworths, London.

American Public Health Association, 1990. *Standard Method for The Examination Of Water and Waste Water*. 19th Edition. APHA, Washington D.C.

Deudoroff, P. and Shumway, D.L., 1970. *Dissolve Oxygen Requirements of Freshwater Fishes*. FAO, United Nation.

Erneysarina, M., 2003. *Analisis Kandungan Nutrien di Sungai Likas*. Disertasi Sarjana Muda Sains, UMS, Sabah.

Hargreaves, V.B., 2003. *The Complete Book of the Marine Aquarium*, Greenwich Edition, London.

Hasan, A. and Ibrahim, A.B., 1994. *Ekologi Samudera*. Dewan Bahasa dan Pustaka, Kuala Lumpur.

Heath, A.G., 2000. *Water Pollution and Fish Physiology*. Department of Biology Virginia Polytechnic Institute and State University Blacksburg, Virginia.

Ismail, A. and Mohammad, A.B., 1992. *Ekologi Air Tawar*. Perpustakaan Negara Malaysia, Dewan Bahasa dan Pustaka, Kuala Lumpur.

Kamaruddin, M.S, Siraj, S.S. and Shazili, N.A., 1990. *Mutu Air Kolam Di Kawasan Beriklim Panas*. Dewan Bahasa dan Pustaka, Kuala Lumpur

Kilmer, V.J., J.W. Gilliam, J.F Lutz, R.T. Joyce and C.D. Eklund.,1970. *Nutrient Losses from Fertilized Grasses Watersheds in Western North Carolina*. J. Environmental Quality, Carolina.

Liken, G.E., 1972. *Nutrient and Eutrophication: The Limiting-Nutrient Controversy*. Volume I. Limnol, Oceanogr..

Morton, S.D., R. Sernan and P.H. Derse., 1972. *Natural Carbon Sources, Rates of Replenishment, and Algal Growth*, Limnol, Oceanorg.

Nathanson, J.A., 2000. *Basic Environmental Technology: Water Supply, Water Management of Diffuse Pollution*, International Thomson Publishing, USA.

Parker, R., 2002. *Aquaculture Science*. Second Edition. Delmar Thomson Learning, New York.

Risely, R.A., 1971. *Tropical Marine Aquaria The Natural System*. Times Roman by Cox and Wyman, Fakenham, Great Britain.

Rows, D.R. and Abdel-Majid I.M., 1995. *Handbook of Wastewater Declamation and Reuse*. Lewis Publisher, London.

Tebutte, T.H.Y., 1983. *Principal of Water Quality Control*. Pergamon Press, England.

Trudgill, T., 2000. *Water Quality Processes and Policy*. John Wiley and Sons, Baffins Lane Chichester, England.

Waite, T.D., 1984. *Principles of Water Quality, An International Series of Books*. Harcourt Brace Jovanovich Publishers, United Kingdom.