Water quality monitoring and analysis biology essay

Science, Biology

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CHAPTER 4

4. 1Introduction

This chapter discusses the water quality obtained from Bukit Merah that will be presented in graph. The variation of the water quality will be discussed in terms of different parameters and Water Quality Index (WQI) along the Bukit Merah on a 15 different dates. The water quality monitoring trends were divided into 2 graphs which are during the spawning peak season and during the non peak season. August to October is the spawning peak season and therefore February to July was made as a comparison to see whether there is difference between those seasons. The water quality was then being justified using an error bar graph to give information in describing the data. Finally, graph presenting the water quality parameter and Arowana production on each pond will be present to define the relationship between the water quality parameter and Arowana production. Pearson correlation statistics were used to define the correlation between each water quality parameter and the Arowana production.

4. 2Water Quality Monitoring and Analysis

A preliminary water quality monitoring was done 3 times previously on February, April and June 2011. Water quality at Bukit Merah was monitored from 10th July to 1st October 2011 on a weekly basis. The variations of water quality at Bukit Merah were showed in the graph with 9 different parameters and Water Quality Index (WQI) on 15 different dates for each parameter. The water quality parameter are temperature, conductivity, total dissolved solids (TDS), dissolved oxygen (DO), pH, ammonia nitrogen (NH3N), suspended solids (SS), Biological Oxygen Demand (BOD5) and Chemical Oxygen Demand (COD).

4. 2. 1Temperature

The water temperature is a measure of the heat content of the water mass and influences the growth rate and survivability of aquatic life (Davis and McCuen, 2005). Temperature is an important variable because there are critical temperatures for many aquatic species (Said et al., 2004). Different species of fish have different needs for an optimum temperature and tolerances of extreme temperatures (Davis and McCuen, 2005). Most waterborne animal and plant life survives within certain range of water temperatures, and few of them can tolerate extreme changes in temperature (DID, 2009). Temperature at Bukit Merah from upstream to downstream were compared with the guidelines given by the Department of Fisheries (DOF) for Arowana water quality. Arowana can live healthily with temperature in a range of 29°C - 31°C. The minimum temperature obtained was 27. 1°C at pond 27 on 11th September while the maximum temperature was 31°C at pond 39 on 1st October and at Bukit Merah dam on 2nd June. The difference in temperature was probably due to the solar radiations that differ during early morning to afternoon since the sampling was conducted on the same day from upstream to downstream. Higher temperatures in ponds can be explained by standing water exposed to the sun. The water level at upstream which is from the Bukit Merah dam also played an important role since large volume of water inputs and higher flow rate were the other factors that lowering the water temperature. Figure 4. 1:

Temperature on non peak season February to JulyFigure 4. 1 shows the variations of temperature on non peak season from 26 February to 31 July 2011 while Figure 4. 2 shows the variations of temperature on the peak season from 6 August to 1 October 2011. On the non peak season, the lowest temperature was 28. 3°C at Pond 29 and Pond 37 on 26 February. The highest temperature was 31°C at Bukit Merah Dam on 6 June. This is due to dry season occurring on June to July causing by the south-west monsoon. Mostly, all of the temperatures were within the guidelines given except on 26 February where 4 out of 10 sampling points were not within the range given. However, the differences were too little and will not affect the water quality. Figure 4. 2: Temperature on peak season August to OctoberOn the peak season (Figure 4. 2), the lowest temperature was 27. 1°C at Pond 27 on 11 September while the highest was 31°C at Pond 39 on 1 October. On 21 August and 11 September, the temperature was all below the guidelines. This low temperature happened most probably because the effect of overnight rain that occur during the night before the sampling day. Based on both graph (Figure 4. 1 and 4. 2), there is not much different between both peak season and the non peak season on temperature. Figure 4. 3: Error bar for TemperatureError bar in Figure 4. 3 indicates that the mean for all sampling point were in the range of the guidelines except for Pond 50. This low temperature happened most probably because the absence of the fish at that pond since Pond 50 is an empty pond which acts as a control pond. In this study the values of observed temperature indicate that the water quality would not be affected by this parameter (Mishra et al., 2008). 4. 2. 2Conductivity and Total dissolved solids (TDS)The minimum conductivity and

TDS obtained from the monitoring were 28 µs/cm and 16mg/L respectively at the upstream while the maximum were 225 µs/cm and 135mg/L respectively at pond 28 on 10th July. According to INWQS, the range of this both parameters obtained were classified as class I. Conductivity is a measure of the ability of water to conduct an electric current and it is highly dependent on the amount of dissolved solids in the water (Bakan et al., 2010). On the other hand, TDS are a measure of the solid fraction of a sample able to pass through a filter. The amount of dissolved solids gives a general indication of the suitability of the water as a drinking source and for certain agricultural and industrial uses (Avvannavar and Shrihari, 2007). The high conductivity may be due to high organic residue in the water body. As high temperature favors degradation of organic pollutants thus it also increases the conductivity value in water bodies. Conductivity and TDS also represents the salinity of water. The values of these parameter obtained are unusually low as compared to INWQS values where the maximum conductivity and TDS for INWQS Class I is 1000 µs/cm and 500 mg/L respectively. However, the conductivity of the water was in a same range with study by Al-Shami et al (2010) at Bukit Merah Rice Field with 15 to 250 µs/cm of conductivity. A study by Shuhaimi-Othman et al (2010) at Bukit Merah Lake shows a conductivity and TDS values that much lower than the result obtained with 17. 7 to 22. 2µs/cm for conductivity and 11 to 14 mg/L for TDS. Figure 4. 4: Conductivity on non peak season February to JulyFigure 4. 5: TDS on non peak season February to JulyFigure 4. 4 and Figure 4. 5 shows the variations of conductivity and TDS on a non peak season. The lowest conductivity obtained is 28 µs/cm at upstream point on 23 April and 2 June. The lowest

TDS obtained were 16 mg/L at upstream point and Pond 50 on 2 June. The graph shows that the conductivity and TDS at upstream had constantly uniform lower concentration compare to Arowana farm and downstream. It shows that the concentrations of organic residue at upstream were lower compare to the other points. The highest conductivity and TDS obtained were 225 µs/cm and 135mg/L respectively at Pond 28 on 10 July. Figure 4. 6: Conductivity on peak season August to OctoberFigure 4. 7: TDS on peak season August to OctoberFigure 4. 6 and Figure 4. 7 shows the variations of conductivity and TDS on the peak season. The lowest conductivity and TDS obtained were 30 µs/cm and 18mg/L respectively at Pond 50 on 1 October. Pond 50 shows the lowest range of conductivity and TDS and in the range exactly as the upstream. Other than that, pond 39 which is filled with other species of fish that found in the Terusan Besar were also had a range of conductivity and TDS of 35 to 65 µs/cm and 21 to 38 mg/L which is also significantly lower compare to other point. This shows that with the absence of Arowana fish, the conductivity and TDS were lower. The highest conductivity and TDS obtained were 206 µs/cm and 127mg/L respectively at Pond 45 on 11 September. Based on (Figure 4. 4 and 4. 5), the non peak season had a value of conductivity and TDS value that alternately fluctuate high and low at Arowana farm followed by apparently static for some ponds and gradual increased value for others. On the other hand, the peak season (Figure 4. 6 and 4. 7) had a more uniform gradual increased and it can be seen at Pond 29, 45 and at the drainage canal. At downstream, the TDS and conductivity shows a gradual increased towards the end of Sungai Kurau. Figure 4. 8: Error bar for ConductivityFigure 4. 9: Error bar for Total dissolved solids (TDS)Error bar in Figure 4. 8 and Figure 4. 9 indicates that the conductivity and TDS at the upstream and Pond 50 had a lower range of concentration. At the Arowana farm, the conductivity and TDS were higher especially for Pond 28, 29, 37 and the highest Pond 45 where these pond were the actively producer for Arowana fry. The high conductivity and TDS at downstream indicates the mixing of pollutants in river from anthropogenic activities by nearby populated area at Bukit Merah, such as the mixing of sewerage, clothes washing and garbage dumping, which are some common activities at the drainage canal in this area. Higher TDS in water system increases the chemical and biological oxygen demand and ultimately depletes the dissolved oxygen level in water (Zeb et al., 2011). 4. 2. 3Dissolved oxygen (DO)Oxygen is the single most important gas for most aquatic organisms. DO is a measure of the amount of oxygen freely available in water. It is commonly expressed as a concentration in terms of milligrams per liter, or as a percent saturation, which is temperature dependent. The colder the water, the more oxygen it can hold (Said et al., 2004). The DO concentrations at Bukit Merah were in the range of 1. 78 to 8. 27 mg/L. The lowest was during the peak season at Terusan Besar on 3 September while the highest was during the non peak season at pond 45 on 23 April. The guidelines given by the DOF highlighted that the DO should be more than 5 mg/L for the Arowana to live healthily. The quality of the water in terms of DO content is always of primary importance because as the waste is discharge, the DO is required for aerobic oxidation of the wastes. Other than that, DO levels are important in the natural self-purification capacity. A good level of DO in sampling sites indicated a high re-aeration rate and rapid aerobic oxidation of biological substances (Zeb et al., 2011). Important factors that affect DO in water were water temperature, aquatic plant photosynthetic activity, wind and wave mixing, organic contents of the water and sediment oxygen demand. Oxygen is lost to the atmosphere more rapidly in warm water than cold water. The biodegradable organic substances are decomposed by bacteria which use oxygen from the water for this process. The availability of dissolved oxygen in a flowing stream is highly variable due to several factors. For instance, the diurnal variations in DO are primarily induced by algal productivity and the seasonal variations are attributable to changes in temperature that affect DO saturation values (Shun and Lee, 2007). Figure 4. 10: Dissolve Oxygen during non peak season February to JulyFigure 4. 10 shows the trend of DO during non peak season with the lowest DO was 3. 84mg/L at Pond 28 on 31 July while the highest was 8. 27mg/L at pond 45 on 23 April. Based on the graph, the DO for all the points are within the range except on 26 February and 31 July where all of the points were below the range. This can be explained by the level of water at the dam. On the 31 July, where the DO was the lowest the water level were 12. 2 ft while on 23 April where the DO was the highest, the water level was 16 ft. The difference with the water level at the dam are most probably the factor for the difference in DO concentration since the ability of a stream to absorb or reabsorb oxygen from the atmosphere is affected by flow factors such as water depth and turbulence (Shun and Lee, 2007). D: ATIQAHATIQAH MASTERsmpling pictureApril24 aprilDSC00268. JPG D: ATIQAHATIQAH MASTERsmpling pictureApril24 aprilDSC00265. JPGPlate 4. 1: Water level at Bukit Merah Dam on 24 April 2011 (16ft)D: ATIQAHATIQAH

MASTERsmpling pictureSeptember4 septDSC01048. JPG D: ATIQAHATIQAH MASTERsmpling pictureSeptember4 septDSC01052. JPGPlate 4. 2: Water level at Bukit Merah Dam on 3 September (13ft)Plate 4. 1 and Plate 4. 2 above shows the difference in water level at Bukit Merah dam on 24 April and 3 September. On the high water level day, the water surface seems to have a strong turbulence compare to the lower water level where the water surface seems to be calmer. Oxygen diffuses into the water from the air especially where the surface is turbulent and also from the photosynthesis of aquatic plants (Svobodova, 1993). Figure 4. 11: Dissolve Oxygen during peak season August to October. Figure 4. 11 shows the trend of DO during peak season. The lowest concentration of DO was 1. 78mg/L at Terusan Besar on 3 September while the highest was 6. 32mg/L at Pond 37 on 11 September. The DO were all below the guidelines on 6 August, 13 August, 21 August and 3 September with a low water level at dam of 12. 5ft, 12. 3ft, 12. 3ft and 13 ft respectively. Based on both figure (4. 10 and 4. 11), the variations of DO on non peak season shows a better water quality with only two dates that were below the guidelines as compared to the peak season with 4 dates that are below the guidelines. The difference among sampling dates for DO was probably related directly to the turbulences and flow rate of water at the Bukit Merah dam since the water level were different for each time of sampling. Figure 4. 12: Error bar for Dissolved oxygenAnalysis using an error bar in Figure 4. 12 shows that the median for all points are within the minimum guidelines suggested except for Sungai Kurau where it is slightly lower than the minimum guidelines. The lower DO values at the downstream indicate the level of pollution due to anthropogenic activities as mentioned above with the conductivity and TDS parameter. Higher TDS in water system increases the chemical and biological oxygen demand and ultimately depletes the dissolved oxygen level in water (Zeb et al., 2011). In summary, the oxygen levels in water depend on the balance between the inputs from the air and plants, and the consumption by all forms of life. Inputs from the air depend on the turbulence of the air-water interface, and the oxygen deficiency of the water. Inputs from plants depend on photosynthetic activity which increases with temperature where excess oxygen can be lost to the atmosphere. Oxygen consumption depends on the respiration of aquatic organisms, including plants, and the aerobic decomposition of organic material by bacteria where these rates also increase with temperature (Svobodova, 1993). However, from the error bar, it shows that from upstream to downstream, the concentration of DO had not much different from each point4. 2. 4pHThe pH value of water is a measure of the acid strength in the water. The pH directly measures the activity of the hydrogen ion, H+. The lower the pH, the higher the H+ activity and the more acidic is the water (Davis and McCuen, 2005). In simplest terms, pH can be divided into three categories which is acid, neutral, and basic. The range of pH values fits on a scale of 1 to 14. Values below 7. 0 represent acidic water, values between 7. 0 and 7. 9 are neutral, and values above 8. 0 are basic (Svobodova, 1993). Fishes live the best in waters with a pH in a range of 6. 5 to 8. 4 (Raman et al., 2009). Fish are harmed if pH becomes too acidic when it falls below 4. 8 or too alkaline when it goes above 9. 2 (Babaei et al., 2011). The ranges of pH obtained from the result are 6. 49 to 8. 71 where the lowest acquired at Bukit Merah dam on 26 February and the highest at

Sungai Kurau on 10 July. The guidelines suggested by DOF for Arowana is in a range of 6. 5 to 8. 5. Figure 4. 13: pH during non peak season February to JulyFigure 4. 13 shows the pH variations during the non peak season. The lowest pH is 6. 49 at Bukit Merah dam on 26 February while the highest is 8. 71 at Sungai Kurau on 10 July. The pH obtains on 10 July shows that the value for all points were nearly at the maximum borderline with 3 points had slightly exceeded the guidelines. The exceeded point was at Bukit Merah Dam with 8. 68, at Terusan Besar with 8. 60 and at Sungai Kurau with 8. 71. Figure 4. 14: pH during peak season August to OctoberFigure 4. 14 shows the variations of pH during the peak season. The lowest pH was 7. 95 at Bukit Merah dam on 21 August while the highest was 8. 32 at Sungai Kurau on 18 September. The pH obtained were within the guidelines with most of the points were nearly the maximum borderline. The results obtained were also higher compared to the previous study done by Shuhaimi et al (2010) at Bukit Merah Lake and Al Shami et al (2010) where the range of pH were between 5. 92 to 6. 67 and 5. 15 to 7. 7. Based on both figure (4. 13 and 4. 14), the peak season shows a higher alkaline level and the trend of pH were quite stagnant and uniform. In comparison with the peak season, the non peak season has a pH that was varies on each date. Figure 4. 15: Error bar for pHAnalysis using an error bar in Figure 4. 15 shows that the pH were closer to the maximum guidelines. The higher alkaline value in most sites is due to the limestone additives applied to the land previously since the Arowana farm was formerly a paddy field. The limestone was applied to regulate the soil pH for an objective of better production since paddy prefers an alkaline condition. Other than that, Arowana farmers also did apply the limestone at the farm to regulate the soil pH from acidic to alkaline and to kill bacteria. High alkaline pH usually occurs in eutrophic reservoirs and ponds where the green plants take up considerable amounts of CO2 during the day for intensive photosynthetic activity. This affects the buffering capacity of the water and the pH can rise to 9. 0–10. 0 or even higher if bicarbonate is adsorbed from waters of medium alkalinity (Svobodova, 1993)4. 2. 5Ammonia nitrogen (NH3N)Ammonia is produced as a major end product of the metabolism of protein catabolism and is excreted as un-ionized ammonia across the gills of aquatic organisms. Ammonia, nitrite, and nitrate are all highly soluble in water. In water, ammonia exists in two forms: un-ionized ammonia, NH3, and ionized ammonium, NH4+. The relative concentration of each of these forms is primarily a function of pH, temperature, and salinity (Anthonisen et al., 1976). The sum of the two (NH4+ + NH3) is usually referred to as total ammonia–nitrogen (TAN) or simply ammonia. It is common in aquatic chemistry to express inorganic nitrogen compounds in terms of the nitrogen they contain, i. e., NH4+–N (ionized ammonia–nitrogen, NH3–N (un-ionized ammonia–nitrogen). This allows for easier computation of total ammonia–nitrogen (TAN = NH4+–N + NH3–N) and a mass balances between the various stages of nitrification (Timmons et al., 2002 M. B. Timmons, J. M. Ebeling, F. W. Wheaton, S. T. Summerfelt and B. J. Vinci, Recirculating previous termAquaculturenext term Systems (2nd Edition), Cayuga Aqua Ventures, New York (2002) 769 pgs.. Timmons et al., 2002). There are major environmental problems caused by the high levels of this nitrogenous compound. Firstly it results in the acidification of the ecological systems due to the increasing concentration of hydrogen ions in freshwater ecosystems without much acid-neutralizing capacity. Secondly, it stimulates or enhances the development, maintenance and proliferation of primary producers, resulting in eutrophication of fresh water, estuaries, and coastal marine ecosystems. In some case, these can also induce the occurrence of toxic algae. Third, they can impair the ability of aquatic animals to grow, survive and reproduce as a result of direct toxicity of inorganic nitrogen compounds. Other consequences are gill ventilation, hyperexcitability, loss of equilibrium and convulsions as the fish is subjected to a high concentration of ammonia even at a short term period (Camargo and Alonso, 2006). Ammonia nitrogen level suggested by DOF was 1 mg/L. The obtained ammonia nitrogen from February to October is in a range of 0. 04 mg/L to 1. 84 mg/L where the lowest acquired at pond 50 on 26 February while the highest acquired at pond 39 on 10 July. Pond 39 is filled with various species of fish such as tilapia, gouramies and catfish while Pond 50 is an empty pond that acts as a control pond. Figure 4. 16: Ammonia nitrogen during non peak season February to JulyFigure 4. 16 shows the variations of ammonia nitrogen during the non peak season. The lowest concentration is 0. 04mg/L at Pond 50 on 26 February while the highest is 1. 84mg/L at Pond 39 on 10 July. The graph shows that the concentration at upstream were uniformly lower than the guidelines but as it enter the Arowana farm, the value of ammonia nitrogen start to fluctuate with pond 39 have the frequent time of exceeded ammonia nitrogen followed by Pond 29 on 26 February with 1. 12mg/L, Pond 37 on 2 June with 1. 11mg/L and discharge on 31 July with 1. 12mg/L. The sudden fluctuated that happen at the Arowana farm was due to the feeding technique and the waste from the fish excreta. Figure 4.

17: Ammonia nitrogen during peak season August to OctoberFigure 4. 17 shows the variations of ammonia nitrogen during the peak season. The lowest was 0. 26mg/L at Terusan Besar on 18 September while the highest was 1. 80mg/L at Pond 27 on 18 September. The graph also shows that when entering the Arowana farm, the ammonia nitrogen start to fluctuate with pond 27, 39 and 45 have the highest concentration. Both Figure 4. 16 and 4. 17 shows that starting from upstream, the ammonia nitrogen were uniformly lower and started to fluctuate when entering the Arowana farm where most of the pond had exceeded the guidelines. However, as it goes down the downstream, the concentration starts to fall back below the guidelines. The higher concentration at the Arowana farm was expected because these ponds were actively managed, with fertilization and daily feeding carried out. Figure 4. 18: Error bar for Ammonia Nitrogen (NH3N)Analysis using an error bar in Figure 4. 18 above indicates that the mean for all points were within the maximum guidelines except for Pond 39. The high concentration of ammonia nitrogen at Pond 39 was most probably because of the overstocking of various fish species in that pond. Overstocking an aquarium can overburden the biologic filter and therefore, ammonia levels can rise higher. In summary, it shows that the level of ammonia nitrogen at the Bukit Merah especially at the Arowana farm were in a good condition where the mean concentration of ammonia nitrogen do not exceed 1 mg/L and therefore suitable for the aquatic species. 4. 2. 6Suspended solids (SS)Total suspended solids (TSS) are usually referred to the particles in water which is usually larger than 0. 45 µm. Solid content is one of the most important physical characteristic of water. Too high solid content will cause turbidity in water and too low will cause the water to have corrosive effect. Many pollutants especially toxic heavy metals can be attached to TSS, which is not good for the aquatic habitat and lives. High suspended solids also prevent sunlight to penetrate into water and increase heat absorption (Avvannavar and Shrihari, 2007). In biological water treatment, solid content represent the nutrient and the support for bacterial growth. Suspended solids are the solids that are retained on a filter after a water sample has been filtered. Suspended solids include a wide variety of material such as silt and living or decaying organic matter. Total suspended solids (TSS) may increase in surface waters due to increases in flow rate, as higher velocities increase water’s capacity to suspend solids. Runoff from heavy rains can simultaneously introduce large amounts of solids into surface waters and provide the capacity for their suspension. Therefore, suspended solids concentrations can vary significantly over relatively short time periods. The result shows the suspended solids (SS) obtained from the study were in a range of 2 mg/L to 106. 7 mg/L. The highest acquired at discharge on 2 June while the lowest acquired at Sungai Kurau on 10th July. Suspended solids for Arowana suggested by DOF was 30 mg/L. Apparently, SS can threatened fish community in aquatic system where the death rate of fish were observed at SS level higher than 200 mg/L. Fish may suffer clogging and abrasive damage to gills and other respiratory surfaces. Accumulation of silt particles in the gill and possible flocculation of iron salts affected the gills causing amphyxiation and high mortality. The fish community usually avoids areas with higher SS by moving away from the sources of SS. Thus, degree of injury and the actual effects observed to fish fauna in a given level of SS may be less due to the avoidance behavior (Othman et al., 2002). The high amounts of SS will block the light penetration into the water column and increase heat absorption. Figure 4. 19: Suspended solids during non peak season February to JulyFigure 4. 19 shows the variations of suspended solids during the non peak season. The lowest was 2mg/L at Sungai Kurau on 10 July while the highest was 106. 7mg/L at discharge point on 2 June. The SS at the upstream were below the guidelines but as it enter the Arowana farm the SS reading start to fluctuate with Pond 27, 39, 45 and discharge have the obvious reading that is more than other points with some of the time exceeded the guidelines. Figure 4. 20: Suspended solids during peak season August to OctoberFigure 4. 20 shows the variations of suspended solids during the peak season. The lowest was 6. 3 mg/L at Terusan Besar on 6 August while the highest was also at Terusan Besar with 93. 7mg/L on 11 September. The SS at upstream and downstream were relatively low compare with the Arowana farm where the entire pond had a SS reading that exceeded the guidelines. By comparing Figure 4. 19 and 4. 20, the SS shows a relatively same concentration at the upstream and downstream which is within the guidelines given. However the SS start to show a fluctuate trend when entering the Arowana farm. The SS during the peak season shows a high concentration for all the ponds while during the non peak season the SS only fluctuate higher over a certain period. This happened most probably because the runoff from heavy rains that can simultaneously introduce large amounts of solids into surface waters and provide the capacity for their suspension. Therefore, suspended solids concentrations can vary significantly over relatively short time periods. SS also may increase in surface waters due to increases in flow rate, as higher velocities increase water's capacity to suspend solids. Figure 4. 21: Error bar for Suspended SolidsAnalysis using an error bar in Figure 4. 21 above indicates that the median for SS at the Arowana farm had exceeded the maximum guidelines except for Pond 28, 29 and 50. All of the points at upstream and downstream were also within the maximum guidelines except for discharge point. Higher SS at the Arowana farm was due to the harvesting activities that occur every 50 days at each pond. This happen when the bottom sediment were re-suspended by their agitating actions. The activity of fish in ponds would also be expected to keep solids suspended even in the absence of harvesting activities. 4. 2. 7Biological Oxygen Demand (BOD5)The values of BOD5 obtained were used to deputize the organic content in the aquatic system. It measures the amount of food for bacteria found in water. The BOD test provides a rough idea of how much biodegradable waste is present in the water (DID, 2009). The ranges of BOD5 obtained from the result were 0. 12 mg/L to 6. 18 mg/L. The highest acquired during the non peak season at pond 45 on 23 April while the lowest acquired during the peak season at Terusan Besar on 25 September. BOD5 that is acceptable for sensitive fish and classified by INWQS as class II should be less than 3 mg/L. BOD5 is one of the most concern water quality variables for aquaculture other than nutrients and TSS (Xinglong & Boyd 2005). It determines the strength of pollutants in terms of oxygen required to stabilize domestic and industrial wastes. For the degradation of oxidizable organic matter to take place minimum of 2 to 7 mg/L of DO level is to be maintained at laboratory experimentation or should be available in the natural waters (Avvannavar and Shrihari, 2007). BOD also measures the amount of food (mainly organic) for bacteria found in water. The BOD test provides a rough idea of how much biodegradable waste is present in the water (DID, 2009). Dissolved oxygen levels, water temperature, water flow, chlorophyll a and nutrient levels (ammonia, nitrite, nitrate) are among the most critical factors for biochemical oxygen demand (BOD) in the rivers. Figure 4. 22: BOD5 during non peak season February to JulyFigure 4. 22 shows the variations of BOD5 during non peak season with the lowest acquired at Pond 28 on 2 June with 0. 12mg/L while the highest at Pond 45 on 23 April with 6. 18mg/L. The value of BOD5 were varies from upstream to downstream and for each dates. However, most of the BOD5 were in a range that within the guidelines with slightly fluctuated on certain date. Figure 4. 23: BOD5 during peak season August to OctoberFigure 4. 23 shows the variations of BOD5 during peak season with the lowest acquired at Terusan Besar and Pond 37 on 25 September and 1 October with 0. 12mg/L. The highest were 5. 52mg/L at Terusan Besar and Sungai Kurau on 21 August. The BOD5 were within the guidelines from upstream to downstream for all the date except on 21 August where none of the sampling point did comply with the INWQS Class II with BOD5 in a range of 5. 22mg/L to 5. 52mg/L. However, the BOD5 values were still in a range of INWQS Class III. Class III is suitable for water supply with extensive treatment required. It is also suitable for fishery, common economic value, and tolerant species livestock drinking. Comparing both Figure 4. 22 and 4. 23, the peak season shows a better quality of water since most of the point has a lower BOD5. Figure 4. 24: Error bar for Biological Oxygen Demand (BOD5)Analysis using an error bar in Figure 4. 24 indicates the mean for all the sampling points were within the maximum guidelines for INWQS Class II. It shows that the water were in a good quality since BOD is an important parameter for surface waters. Excessive BOD loads will cause damage to the quality of surface water. 4. 2. 8Chemical Oxygen Demand (COD)Chemical oxygen demand (COD) is an important parameter of water indicating the health scenario of freshwater bodies. The permissible level of COD for sensitive aquatic species according to INWQS which is also at Class II should be less than 25 mg/L where else for Class I is less than 10 mg/L. COD is often used as measurement of pollutants in natural and waste waters and to assess the strength of waste, such as sewage. The ranges of COD obtained were 0. 31mg/L to 15. 26 mg/L. The highest acquired at Pond 37 on 21 August while the lowest at Terusan Besar on 25 September.

Various compounds of organic matter containing materials can be measured in two simple parameters, i. e. biochemical oxygen demand (BOD) and chemical oxygen demand (COD). It is well known that BOD is a standard test for assaying the oxygen-demanding concentration of microbes to degrade organic matter over a given time period, usually 5 days but can be extended to 30 days. COD is a standard test for water to consume oxygen in the form of potassium dichromate during the degradation of organic matter and inorganic chemicals such as ammonia and nitrite for few hours. The potassium dichromate is not specific to oxygen-consuming chemicals either organic or inorganic and therefore, both chemicals are included in COD. As a results, the BOD/COD ratio should be equal or less than 1. 0 (Samudro and Mangkoedihardjo, 2010).

COD test is commonly used to measure the amount of organic and inorganic oxydizable compounds in water. COD is a useful measure of water quality since most applications of COD determine the amount of total oxidizable pollutants found in surface water. It is expressed in milligrams per liter (mg/L), which indicates the mass of oxygen consumed per liter of solution (DID, 2009). High value of COD indicates water pollution, which is linked to sewage effluents discharged from town, industrial or agricultural practice. The input of anthropogenic contaminants (from point discharges mixing with urban and agricultural runoff) causes distinct, but variable COD concentration peaks which responsible for increasing the concentrations in nutrients and organic carbon in the fresh surface waters of the river (Bakan et al., 2010). Figure 4. 25: COD during non peak season February to JulyFigure 4. 25 shows the variations of COD during the non peak season.

The lowest reading was 0. 40mg/L at Pond 28 on 2 June while the highest was 11. 24mg/L at Pond 45 on 23 April. The water possessed a good water quality since the COD readings were all in a range of INWQS Class I. Figure 4. 26: COD during peak season August to OctoberFigure 4. 26 shows the variation of COD during peak season. The lowest concentration were 0. 31 mg/L at Terusan Besar on 25 September while the highest were 15. 26mg/L at Pond 37 on 21 August. The COD during peak season also shows that the variations of COD were all within the permissible limit of INWQS Class II. Based on both Figure 4. 19 and 4. 20, the reading of COD for both peak season and non peak season were in a same range which most of it is classified by WQI as class I. Figure 4. 27: Error bar for Chemical Oxygen Demand (COD)Analysis using an error bar in Figure 4. 27 indicates that the mean for all the sampling points were within the maximum guidelines for INWQS Class I. It shows that COD level at Bukit Merah contribute an important roles for a good water quality at Bukit Merah. This was expected since there is no chemical activity or industry near the Bukit Merah area. 4. 2. 9Water Quality Index (WQI)Water quality index provide information on a rating scale from zero to hundred. Higher value of WQI indicates better quality of water and lower value shows poor water quality (Alam and Pathak, 2010). WQI obtained from the result were in a range of 64. 9 -91. 3. The lowest acquired during peak season at Pond 39 on 3 September while the highest acquired during non peak season at Pond 50 on 23 April. Figure 4. 28: WQI during non peak season February to JulyFigure 4. 28 shows the variations of WQI during non peak season with the lowest obtain at Pond 39 on 31 July with 68 and the highest obtain at Pond 50 on 23 April with 91. 3.

Most of the WQI were within the class II except on 23 April where Pond 40 and discharge fall into class III and on 31 July where Terusan Besar, Pond 27, 37, 39, 40 and discharge fall into class III. Other than that, Pond 39 shows the poorest water quality since most of the time, the WQI were nearly at the borderline of Class II. Figure 4. 29: WQI during peak season August to OctoberFigure 4. 29 shows the variations of WQI during the peak season. The lowest WQI were 64. 9 at Pond 39 on 3 September while the highest were 88. 9 at inflow on 1 October. The WQI from upstream to downstream on 21 August and 3 September were both fall to Class III. Other than that, Pond 37, 39 and 45 on 6 August and 13 August also fall to Class IIIFigure 4. 30: Error bar for Water Quality Index (WQI)Analysis using an error bar in Figure 4. 30 indicates that mean for WQI for all the sampling points were within the INWQS Class II except for Pond 39 that was slightly below the guidelines. This shows that water quality from upstream to downstream do not deteriorate with the presence of Arowana farm aquaculture activity. Table 4. 1: Mean water quality parameter and WQI (max-min) for 14 sampling points at Bukit Merah (February - October 2011). UnitWater qualityMinMaxTemperature(ºC)29. 327. 131Conductivity(µs/cm)40. 428225Total Dissolved Solids (TDS)(mg/L)24. 216135Dissolved Oxygen (DO)(mg/L)5. 11. 788. 27pH8. 16. 498. 71Ammonia nitrogen (NH3N)(mg/L)0. 60. 041. 84Suspended Solids (SS)(mg/L)27. 82. 0106. 7Biological Oxygen Demand (BOD5)(mg/L)2. 00. 126. 18Chemical Oxygen Demand (COD)(mg/L)4. 30. 415. 26Water Quality Index (WQI)80. 864. 991. 3In summary, the water quality at Bukit Merah was in a good quality. According to Table 4. 1, the mean for water quality index (WQI) and all the water parameter were in Class II where it shows that the water quality at Bukit Merah were suitable for water supply and for fishery of sensitive aquatic species. 4. 3Production of ArowanaData for the production of Arowana were taken from the recorded file by the farm owner. Arowana spawn throughout the year with breeding cycle around 1-2 times per year. The peak seasons for the fish spawning occur between August and October. Data for Arowana production were taken from February 2011 until October 2011 for each six ponds which is Pond 27, 28, 29, 37, 40 and 45. All of the ponds had a production along the monitoring period except for Pond 27. The production and the water quality for each pond were plotted in a graph. Pearson correlation statistical analysis was conducted in order to determine the relationship between the 9 water quality parameter with the Arowana productivity. 4. 3. 1Arowana Productivity at Pond 28Pond 28 consists of Arowana fish with age of 3 years old. Figure 4. 23 shows the water quality variations at Pond 28 and the production of Arowana. Along the monitoring period, the Arowana had spawn once which is on 1 October 2011 with 21 fry had been produced. The water quality parameter had a quite uniform trend starting 2 weeks before the production day. Pearson correlation analysis shows that production were correlated with the ammonia nitrogen ($r = 0.585$, $p < 0.05$). The value of NH_3N during the day of production was 1. 14mg/L which is the highest and had exceed the guidelines suggested by DOF which is below 1 mg/L. According to Othman et al (2002), the acute lethal concentrations of NH_3N for a variety of fish species lie in the range of 0. 2 -2. 0 mg/L. The increased concentration of NH_3N in aquatic systems can heightened the toxic effect to fish community where the toxicity of NH_3N can be affected by the temperature, pH, and low DO concentrations. The water qualities for all parameter on the day of production were also within the suggested guidelines except for SS with 39. 7 mg/L which exceeded the guidelines of 30mg/L. According to Figure 4. 23, the water quality parameter from February to October was all in a uniform trend except for conductivity and TDS. Those both parameters fluctuate higher on 10 July and then show a decreasing trend until 21 August. However, as it reaches near the production day, the conductivity shows an increasing trend. The WQI classified the water quality on 1st October as Class II which is suitable for water supply and conventional treatments are required. It is also suitable for fishery of sensitive aquatic species. Figure 4. 23: Arowana production at Pond 284. 3. 2 Arowana Productivity at Pond 29Pond 29 consists of Arowana fish with age of 6 years old. Figure 4. 24 shows the water quality trend and the production of Arowana. During the monitoring period, the Arowana had spawn twice, which is on 18 September and 1 October with 27 fry and 5 fry had been produced respectively. Pearson correlation analysis shows that the production were correlated with suspended solid ($r = 0.699$, $p < 0.01$). The SS value on the day of production was 38. 3mg/L and 22mg/L respectively. The high value of SS on the day of production was probably because of the harvesting activity. On the 18 September the SS had exceed the guidelines of 30mg/L which were also the highest value on that pond. Other than that, BOD5, NH3N and COD were higher on the production day comparing to the week before and after. However, these parameters were still within the guidelines. The WQI at the pond during the production day were also classified as Class II. Figure 4. 24 shows that conductivity had fluctuate higher on 31 July and 3 September and it shows a decreasing trend as it reaches the day of productions for both days. Figure 4. 24 : Arowana production at Pond 294. 3. 3Arowana Productivity at Pond 37Pond 37 consists of Arowana fish with age of 4 years 3month old. Figure 4. 25 shows the water quality variations with the Arowana production. During the monitoring period, the Arowana had spawn 5 times with a total of fry produce were 263 fry. The production of Arowana were obtained on 23 April with 48 fry, 2 June with 66 fry, 10 July with 21 fry, 31 July with 23 fry, 3 September with 79 fry, 18 September with 40 fry and on 1 October with 34 fry. Pond 37 shows the most frequent time of Arowana spawning compare to the other ponds. Pearson correlation analysis shows that ammonia nitrogen were correlated with the production ($r = 0.620$, $p < 0.05$) and COD were anti correlated with production ($r = -0.539$, $p < 0.05$). Based on Figure 4. 25, SS seem to be higher on each day of production compare to the other day without the fry production. The spawning also occurs twice during the non peak season which is on 2 June and 10 July where the highest production was on the 2 June. On that day, the TDS, conductivity and SS were fluctuating higher, in contrast with BOD_5 and COD where the parameter were lower. However, these parameters were still within the guidelines except for NH_3N with 1. 11 mg/L and SS with 34 mg/L that slightly exceeded the guidelines suggested. Figure 4. 25 : Arowana production at Pond 374. 3. 4 Arowana Productivity at Pond 40Pond 40 consists of Arowana fish with age of 4 years 8 months old. Figure 4. 26, shows the water quality trend and the production of Arowana fry. During the monitoring period, Arowana had spawn once which is on 2 June with 30 fry's were produce. These spawning occur during the non peak season. The water quality variations were also in a range that is quite lower comparing with other ponds. Based on Pearson correlation analysis, conductivity and TDS were correlated with the production with (r = 0. 602, p <0. 05) and (r= 0. 608, p <0. 05) respectively. On the day of production, TDS, conductivity and SS were higher compare to rest of the day without the spawning activity. However the water quality parameters were all within the guidelines. Figure 4. 26: Arowana production at Pond 404. 3. 5Arowana Productivity at Pond 45Pond 45 consists of Arowana fish with age of 5 years 3 month old. Figure 4. 27 shows the water quality variations at Pond 45 and the production of Arowana. Along the sampling period, the Arowana had spawn 3 times with a total of fry produce were 87 fry. The spawning occur on 3 September with 30 fry, 18 September with 31 fry and lastly on 1 October with 26 fry. Pearson correlation analysis shows that the suspended solid and ammonia nitrogen were correlated with the production with (r = 0. 631, p <0. 05) and (r= 0. 663, p <0. 01) respectively. During the 3 production day, the SS were all exceeded the guidelines and the same goes for NH3N except on 3 September. The conductivity and TDS were also shows a fluctuate trend like the other ponds. It starts to fluctuate higher on 18 July and then shows decreasing trends until it reaches the day of production on 3 September and then fluctuates back on the next week and shows a decreasing trend until 1 October. The BOD5 and COD were also lower during the period of production. Figure 4. 27: Arowana production at Pond 45