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Study on the Water Quality Parameters in Semi-Intensive Coastal Shrimp Culture System in Mafia Island, Tanzania

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Abstract

This study was conducted to understand the effect of coastal shrimp farming on water quality properties in the surrounding area of a semi-intensive culture system in Mafia Island, Tanzania. Monthly water samples were collected from six stations located within culture ponds, inlet creek and outlet/effluent creek, from June, 2008 to May, 2009, and November, 2009 to March, 2010. The samples were used for the analysis of the selected water quality parameters following the standard procedures. The data obtained was analyzed using one way ANOVA and significant differences accepted at $p \leq 0.05$. Post Hoc Turkeys' test was used to determine the specific stations which were sources of differences. Correlation co-efficient (r) was performed to establish the relation between independent and dependent parameters. Results showed that DO, salinity, NH_4-N, NO_2-N and PO_4-P were significantly ($p<0.05$) higher in sampling stations inside culture ponds. NO_3-N had significantly ($p<0.05$) higher mean values at the stations along the effluent creek. No significant differences ($p>0.05$) were recorded between the stations in terms of temperature, EC and chlorophyll-*a*. High positive correlations ($r = 0.646–0.927$) between EC and dissolved nutrients is an indication of common origin of these parameters that is, mineralization of organic materials. In general, concentrations of all analysed parameters were within the desirable and acceptable limits for marine ecosystems. To sustain the present conditions it is being recommended to adopt better farm husbandry as well as treating effluent materials before discharging them to the marine water medium. The study would provide essential information on which further studies can be carried out to evaluate the environmental impacts of marine aquaculture and, supports protection and decision making for sustainable development in the coastal areas.

Keywords: Semi-intensive shrimp culture, Water quality, inorganic nutrients, environmental impacts, Mafia Island.

1.0 Introduction

As the world human population continues to expand, the demand for high protein foods also rises. This demand is not likely to be covered by livestock production and with capture fisheries which are being exploited to their sustainable limit and beyond. Aquaculture is therefore expected to be the major means of promoting production to meet the increasing demand for quality protein for human consumption (Boyd, 2003; Pulatsü *et al*., 2004). The farming of marine organisms (mariculture) is also recognized as one of the most important instrument for promotion of economic growth, provision of food, employment as well as foreign exchange earnings in most coastal areas worldwide. Ecologically, marine aquaculture could play an important role in restocking over-exploited wild stocks and saving threatened species (Pulatsü *et al*., 2004).

Nevertheless, the negative environmental impact associated with coastal aquaculture is a very big threat to the surrounding environment and marine ecosystems in general and thus, the industry is receiving increasing criticism. Supplementary feeds, fertilizers and metabolic wastes are the main source of inorganic nutrients input and particulate loads in semi-intensive and intensive aquaculture systems and the surrounding environments (Pulatsu *et al*., 2004). These materials may contribute significantly to nutrient enrichment (eutrophication), increased suspended solids, build-up of anoxic sediments and changes in benthic community structure of receiving coastal waters (Boyd and Green, 2002).

Although the adverse environmental impact of marine fish farming has been a subject of increasing attention worldwide, there have been very few such studies conducted in Tanzania on this subject (e.g. Mmochi and Mwandya, 2003). In the same way, large body of existing information from temperate countries (e.g. Samocha *et al*., 2004) cannot be used to predict with certainty the adverse environmental effects of coastal aquaculture in tropical countries. Furthermore, severe environmental effects of aquaculture systems tend to be site-specific as they are influenced by production characteristics at each farm-site and environmental conditions in the surrounding areas (Wu *et al*., 1994). Thus, each coastal area influenced by aquaculture activities requires its own specific study since data collected from other areas may not be correctly applicable to it. This study, therefore sought to determine the physicochemical properties of water in relation to the coastal shrimp culture operated in a semi-intensive system in the Mafia Island, Tanzania. A particular focus was given to relative changes in water temperature, dissolved oxygen (DO), pH, salinity, electrical conductivity (EC), turbidity, ammonium-N, nitrite-N, nitrate-N, phosphate-P and chlorophyll–*a* among sampling stations. It is expected that the study will be of significance in environmental research and for protection of the coastal ecosystems. Its data would provide essential information on which further studies can be carried out to assess the environmental impacts of marine aquaculture. In addition, it would contribute essential information for environmental protection, management and sustainable marine aquaculture development in Tanzania and probably in the whole region of East African coast.

2.0 Materials and Methods

2.1 Study Area

The study was carried out in the Mafia Island (07°45′S and 39°50′ E); the island is in the shore of the Indian Ocean (Figure 1). The Mafia semi-intensive coastal shrimp culture system is situated about 25 km northeast of the Mafia district administrative township, Kilindoni. The system is developed in the wetland area that was previously covered with mangrove forest and inundated with sea water during high tides. The area had a narrow creek (about 3.5 km) draining its water into the nearby Kirongwe bay. Thus; with the development of shrimp farm, upper section of the creek (inlet creek) has become the water source for the culture ponds, while the lower section (outlet/effluent creek) carries aquaculture effluents to the sea. At the beginning of this study, the farm was operating sixteen earthen shrimp culture ponds while during the last sampling session the number had risen to thirty ponds but operating in alternation. Each culture pond has an average water surface area of 1.5 ha and depth of 1.7 m, and stocking density of averages 15-20 post-larvae/m^2 in a production cycle of 140-180 days. The ponds are treated with agricultural lime ($CaCO_3$), and fertilized with urea (30-45kg/production cycle) and triple super-phosphate (10-15kg/production cycle). The shrimps are also fed directly with commercial feeds containing 36-40% crude protein.

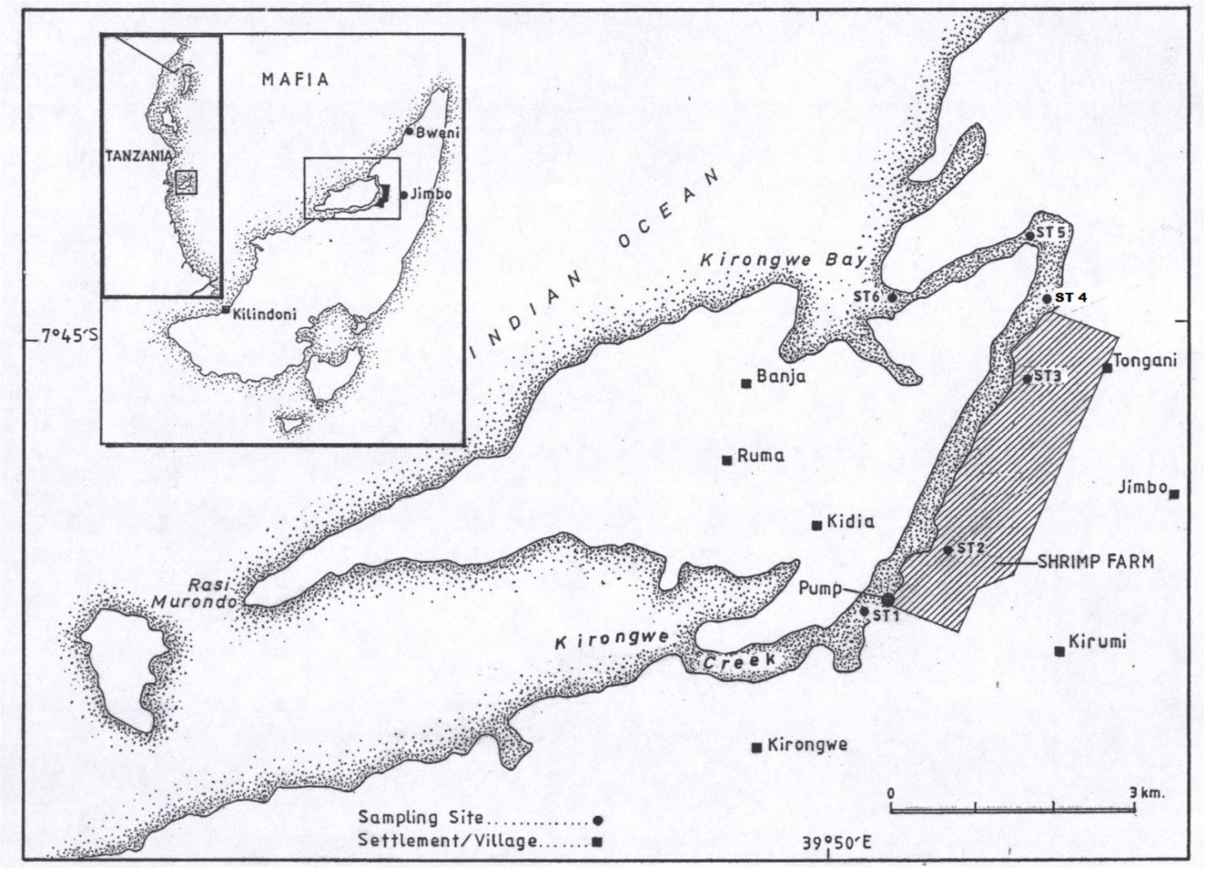

Figure 17: ***The map of Mafia Island showing the location of sampling stations in the shrimp farm.***

2.2 Sampling Stations

Six sampling stations: ST 1, ST 2, ST 3, ST 4, ST 5 and ST 6 were established at three key sections of the culture system; inlet creek, the culture ponds and outlet/effluent creek (Figure 1). The ST 1 was located along the inlet/influent creek approximately 50 m to the pump house, a point at which ambient sea water is pumped into the culture ponds. The ST 2 and ST 3 were situated within culture ponds, whereas ST 4, ST 5 and ST 6 were located along the effluent creek. The ST 4 was situated at the confluence point for all outlet canals from the culture ponds, ST 5 was about 450 m downstream of ST 4, and ST 6 was at the point where effluent creek and sea water meet during high tides, about 700 m downstream of the ST 5.

2.3 Sampling Strategy

Surface water samples were collected at monthly intervals from June, 2008 to May, 2009 and, then from November, 2009 to March, 2010. Measurements of temperature (^{o}C), DO (mg/l) pH, salinity, EC (mS/cm) and turbidity (NTU) were done *in situ* using a multimeter water quality checker (HORIBA-U10). For the determination of dissolved nutrients and chlorophyll-*a*, three replicates of water samples were collected from different locations of the same sampling station and mixed together into one composite-sample. The samples were preserved in 500 cm^3 acid-washed polyethylene sampling bottles. The bottles were also rinsed several times with distilled water followed by thorough rinsing with water from the respective sampling station before being filled with samples. The appropriately labeled sample bottles were immediately kept in ice-filled cooler box, transported to the laboratory within 36-48 hours and stored into a deep freezer at -20^{o}C until analysis.

2.4 Laboratory Analysis

Prior to analysis, refrigerated water samples were thawed to reach room temperature. Then, the samples were filtered using GF/C Whatman® filter papers (0.45 µm pore size) and the filtrates were analyzed for the concentrations of inorganic nutrients: ammonium-nitrogen (NH_4-N), nitrite-nitrogen (NO_2-N), nitrate-nitrogen (NO_3-N) and phosphate-phosphorus (PO_4-P), while filter papers were used for the analysis of chlorophyll-*a* concentration. Concentrations of inorganic nutrients (µm/l) and chlorophyll-*a* (mg/m^3) were determined following the standard analytical procedures (Parsons *et al*., 1984; APHA/AWWA/WEF, 2005) using a JENWAY 6505 UV/VIS spectrophotometer.

2.5 Data Analysis

Calculation of range, mean and standard error for each parameter and stations were made and presented using tables and graphs. The data obtained were subjected to one way analysis of variance (ANOVA) and significant differences accepted at $p \leq 0.05$. In case of significance, the mean values were separated using *post-hoc* Tukey's 'Honest Significant Difference' (HSD) tests to ascertain the stations which were sources of differences. Correlation co-efficient (r) was performed to establish the relationship between parameters. Data analyses were carried out using the statistical software GraphPad Instant tm version 2.04 and Microsoft office Excel 2007.

3.0 Results and Discussion

Mean values and range of water quality parameters (mean ± SE) from the six sampling stations in the coastal shrimp culture system in Mafia Island are given in Figures 2-4 and correlation coefficients among water quality parameters are shown in Table 1.

3.1 Temperature

In the present study, there was no significant variation in temperature between stations ($p>0.05$). Its values ranged between 29.67 ± 0.56^{o}C and 30.95 ± 0.48^{o}C recorded at ST 1 and ST 6, respectively with an overall mean value of 30.28 ± 0.21^{o}C (Figure 2). This temperature range, although small and insignificant, followed closely the changes in diurnal air temperatures on the shallow waters. The small range in water temperature could be explained by the statement made by Nkwoji *et al.* (2010) that temperature is not a major factor in tropical aquatic ecosystems. The values of water temperature in this study were within the desired range of 25-32°C for normal growth and survival of aquatic organisms in tropical aquatic environments as well as favorable conditions for tropical aquaculture activities (Boyd and Pillai, 1984).

3.2 Electrical Conductivity

There was no significant variation in EC values between sampling stations ($p>0.05$). The highest mean EC values were recorded at ST 2 and ST 3 (48.67±0.89 mS/cm) and, the lowest value at ST 1 (41.77±2.77 mS/cm) while the overall mean value was 45.92±1.04 mS/cm (Figure 2). The relatively high EC values recorded in the culture ponds might imply that the applied agrochemicals, food additives and shrimp excreta were the major sources of ionic substances in the water column of the culture system. This corroborates with the findings of Mishra *et al*. (2008), and Bhadja and Kundu (2012). The overall mean EC for the present study is slightly higher than the EC range of 17.17-17.58 mS/cm obtained by Bhadja and Kundu (2012) and 20.0-36.1 mS/cm reported by Ideriah *et al.* (2010) in the industrially impacted coasts of the tropical ecosystems. Furthermore, EC had strong positive significant relationships with DO ($r=0.917$), PO_4-P ($r=0.871$), NH_4-N ($r=0.905$) and NO_2-N ($r=0.927$) (Table 1). Such relationships might imply that increased DO levels could have favoured the biological decomposition of organic matter and consequently release of ionic substances mainly nutrients to the water column. From their studies in the aquaculture settings, Mishra *et al*. (2008), and Bhadja and Kundu (2012) reported similar relationships between EC and dissolved inorganic nutrients concentration.

3.3 Salinity

In the present study, salinity of water sample varied significantly at the different sampling stations ($p<0.05$). Respectively, the lowest and highest values of 30.12±0.09 and 34.4±0.1 were recorded at ST 6 and ST 2, while the overall mean value was 32.33±0.10 (Figure 2). Factors such as high rates of evaporation of the confined ponds' water and the elevated concentration of dissolved solids from the aquaculture inputs such as fertilizers could be considered for the high salinity in culture ponds. This is consistent to the findings of Guerrero-Galvan *et al.* (1999), Kumar *et al.* (2012) and Barraza-Guardado *et al.* (2013) who studied the water quality parameters of the coastal shrimp farms. The strong significant positive correlation between salinity and PO_4-P (r=0.869) as well as excellent positive relationships with NH_4-N (r=0.774), NO_2-N (r=0.779) and EC (r=0.646) (Table 1) favours the idea that agrochemicals and shrimp excreta are the major factors for the elevated ionic content of the water column of the culture systems. This corroborated with the findings of Chagas and Suzuki (2005) and, Carvalho *et al.* (2010).

3.4 Dissolved Oxygen

The mean DO concentration was highest (6.77±0.35 mg/l) at ST 2 and lowest (4.63±0.23 mg/l) at ST 1 with the overall mean value of 5.77±0.28 mg/l. Other peaks were 6.04±0.49 mg/l and 5.91±0.24 mg/l recorded at ST 4 and ST 3, respectively. Results showed a significant variation amongst the stations ($p<0.05$). A post-hoc test revealed that ST 1 had significantly lower mean DO concentrations than both ST 2 ($p<0.001$) and ST 4 ($p<0.05$) (Figure 2). Decomposition of the vegetal matter from the surrounding mangrove forests could probably be related to the depletion of DO in the inlet creek (ST 1). This biodegradable material is more oxygen demanding during its bacterial decomposition. This was similar to results of Boyd and Pillai (1984) and Barraza-Guardado *et al.* (2013) during their study in the tropical aquatic ecosystem. High DO concentrations in the culture ponds (ST 2 and ST 3) could be related to the mechanical aeration and high phytoplankton biomass with a resultant increase in photosynthetic activities as confirmed by the high chlorophyll-*a* concentrations within production ponds. Comparable observations were also made by Maia *et al.* (2011) from their studies in aquaculture settings elsewhere. The minimum limit of DO concentrations suitable for aquatic organisms recommended by Global Aquaculture Alliance (GAA) standards is 4 mg/l (Boyd and Gautier, 2000 *in*: Boyd, 2003) and 3 mg/l for marine shrimp farming (Ferreira *et al.*, 2011). When compared to all these standards, the mean DO value (4.63±0.23 mg/l) with a range of 4.63±0.23 to 6.77±0.35 mg/l observed during the present study was within the safe limits.

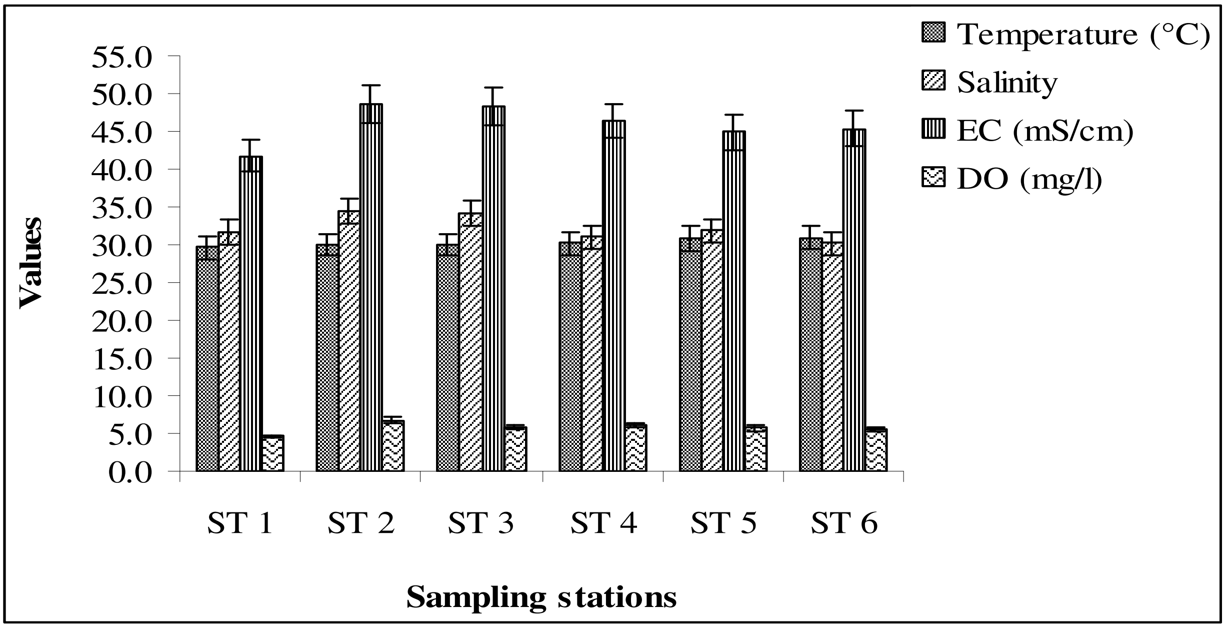

Figure 2: ***Mean variations (±SE) of the water quality parameters recorded in the Mafia shrimp farm during the study period.***

3.5 pH

The pH values recorded in this study were not significantly different across the sampling stations ($p>0.05$). Mean pH values ranged between 7.15±0.24 and 7.41±0.15 recorded at ST 1 and ST 2, respectively (Figure 3). This high value at ST 2 may be attributed to the influence of liming treatments and high rates of photosynthesis by phytoplankton in the culture ponds (ST 2 and ST 3). This corroborates with the finding of Guerrero-Galvan *et al.*, (1999) and Manna *et al.*, (2003) in the tropical aquaculture systems. Pond liming is a common procedure used to neutralize sediment acidity, increase temporarily total alkalinity and total hardness of pond waters (Johnston *et al.*, 2002; Sipauba-Tavares *et al.*, 2003; Nyanti *et al.*, 2011). The overall mean pH value (7.27±0.05) obtained in the study area shows that the water is slightly alkaline and the value is within the permissible limit of 6.0-9.0 for estuarine and marine ecosystems (Boyd and Green, 2002).

Moreover, pH showed strong significant positive relationship with EC (0.936), PO_4-P (0.905), NH_4-N (r=0.868) and NO_2-N (r=0.912). Again, pH is strongly correlated with DO value (r=0.796) (Table 1). This relationship might be an indication that the pH variation in the study area was rather controlled by the involvement of these variables in the processes of photosynthesis and decomposition of organic materials. According to Guerrero-Galvan *et al.* (1999), photosynthesis increases oxygen and pH of water, and accelerates decomposition of organic materials resulting in a higher concentration of ionic substances such as nutrients which further accelerate the phytoplankton productivity.

3.6 Turbidity

Results showed that the mean turbidity values of water samples fluctuated between 11.14±2.09 and 25.71±6.60 NTU. The lowest and highest values for the study were recorded at ST 1 and ST 5, respectively (Figure 3). There was no significant variation across sampling stations (p>0.05). Poor renovation with a resultant long retention time of turbid water from the shrimp culture ponds could be related to the high turbidity values recorded in the effluent creek. This assertion concurs with previous findings (Rajasegar, 2003; Pulatsu *et al.*, 2004; Bui *et al.*, 2012) from the tropical aquaculture systems. The overall mean turbidity value (17.47±3.82 NTU) obtained in this study was below the upper limit (42.5 NTU) recommended for marine shrimp culture (Ferreira *et al.*, 2011).

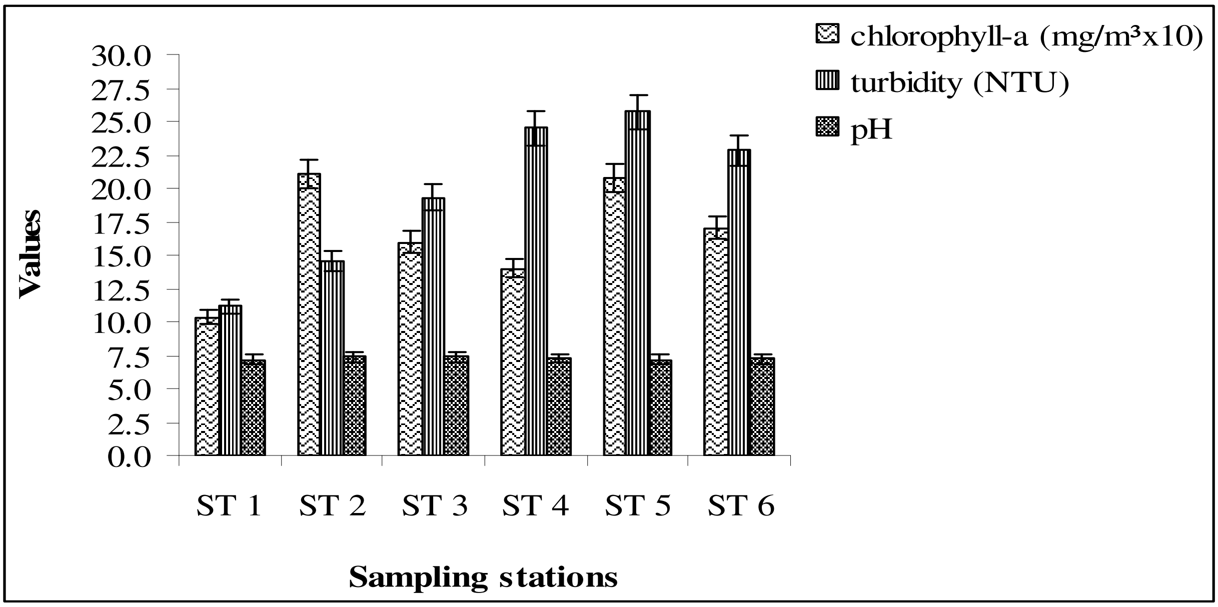

Figure 3: ***Mean variations (±SE) of the water quality parameters recorded in the Mafia shrimp farm during the study period.***

3.7 Chlorophyll-a

Chlorophyll-a concentration for the present study fluctuated between 103.20±32.06 mg/m3 (ST 1) to 210.99±60.97 mg/m3 (ST 2). ANOVA showed non-significant variation among the sampling stations (p>0.05) (Figure 3). When compared with the recommended guidelines by Boyd and Green (2002) (>10 µg L-1), mean values for this study (165.26±16.82 mg/m3) showed preliminary signs of eutrophication development. However, chlorophyll-a concentrations found in this study are generally lower than those reported by Setiarto and Suradi (1999) in the coastal waters adjacent to shrimp ponds in Indonesia. Seemingly, the higher chlorophyll-a concentrations in the culture ponds may in part be related to the nutrient supply through supplementary fish feeds and fertilizer input that stimulated the growth of phytoplankton. This corroborates with several previous reports in the fish culture systems (Guerrero-Galvan et al., 1999; Ferreira et al., 2011; Kumar et al., 2012). High positive correlations between chlorophyll-a with DO and NO3-N (Table 1) could imply that photosynthesis by phytoplankton raises oxygen of water and accelerates the rate of nitrification. Similar relationship was reported by Samocha et al. (2004) from their studies in intensive and semi-intensive shrimp culture systems.

3.8 Ammonium-Nitrogen

The NH_4-N concentration varied significantly across the sampling stations (p<0.05); and fluctuated between

2.98±0.20 µm/l and 7.96±1.03 µm/l recorded at ST 1 and ST 2, respectively. Moreover, there was a slight decrease in NH_4-N concentration downstream the effluent creek with increasing distance from the culture ponds (Figure 4). The overall mean concentration of NH_4-N in this study (5.54±0.84 µm/l) was lower than the allowable concentration of (<3 mg/l ≈ <54.12 µm/l) for protecting aquatic ecosystems (Boyd and Green, 2002). Similarly, this result was slightly lower than those observed in the Integrated Mariculture Pond Systems (IMPS) by Mmochi *et al.* (2002) and, Mmochi and Mwandya (2003). This variation might be attributed to the applied commercial feeds and inorganic fertilizers such as urea in Mafia shrimp farm in comparison to locally produced fish feeds (rich in organic content) used at IMPS, Zanzibar. High concentrations of NH_4-N in culture ponds could be ascribed to the addition to the system of inorganic nitrogenous fertilizers as well as the accumulation and microbial decomposition of organic materials from unconsumed food materials and waste products excreted by fish. This can be verified by the work of Boyd *et al.* (2002), and Mmochi and Mwandya (2003) who noted that organic materials from the fish feed as well as fish excretion and secretion to be the dominant sources of organic carbon and nutrients input into the culture system.

Self-purification mechanisms of the running water and tidal dilution of effluent water may have accounted for a gradual decreasing trend of NH_4-N concentration with increasing distance from the effluent discharge point (ST 4). Cancemi *et al.* (2003) and Biao *et al.* (2004) observed similar fluctuations pattern in NH_4-N concentrations in the fish culture systems. Alternatively, low concentration of NH_4-N in the inlet creek (ST 1) could be attributed to the presence of higher plant organic matter that are quite resistant to decomposition by microorganisms and nutrients release as previously reported by Strömberg *et al.* (1998) and Boyd *et al.* (2002).

3.9 Nitrite-Nitrogen

In the present study, the average NO_2-N concentration (0.31±0.04 µm/l ≈ 0.01 mg/l) was below the upper limits of <0.2 mg/l and 0.3 mg/l for marine shrimp culture systems recommended by Ferreira *et al.* (2011) and Maia *et al.* (2011), respectively. Likewise, these values were lower than those reported by several studies in marine shrimp aquaculture elsewhere (Guerrero-Galvan *et al.*, 1999; Bui *et al.*, 2012). This low concentration could be related to its short residence time in the environment under optimum conditions such as water temperature and high concentrations of DO. According to Samocha *et al.* (2004), increase in water temperature and DO concentration causes an increase in the rate of nitrification while reducing the concentration of NO_2-N of the water column.

As shown by Figure 4, concentration of NO_2-N varied between 0.18±0.03 µm/l and 0.44±0.06 µm/l recorded at ST and ST 2, respectively; and it varied significantly across the sampling stations ($p<0.05$). The high NO_2-N concentrations in the shrimp culture ponds may be attributed to the influence of the applied nitrogen fertilizers such as urea as well as oxidation of ammonia. According to Maia *et al.* (2011) and Devi *et al.* (2012), there is a close association between levels of NO_x with oxidized nitrogen inputs originating from terrestrial run-off or intensive N-fertilizers use. The strong positive correlation between NO_2-N and NH_4-N concentrations ($r=0.995$; $p=0.00$) (Table 1) could suggests the production of nitrites through nitrification process of ammonium as previously reported by Manna *et al.* (2003) and Bui *et al.* (2012).

3.10 Nitrate-Nitrogen

Results showed that NO_3-N concentrations of water sample varied significantly between sampling stations ($p<0.05$); with the highest value of 1.98±0.39 µm/l and lowest of 0.32±0.07 µm/l recorded at ST 5 and ST 1, respectively (Figure 4). The high concentrations recorded at ST 4 and ST 5 may be attributed to the inadequate management of the effluent creek with a resultant build-up of organic materials in the sediments from the preceding production cycles. According to Gross *et al.* (2000), concentration of nutrients of the nitrogen species is mainly associated with organic compounds because about 90% of nitrogen in sediment exists in organic form. Thus, sediment drying, tilling and removal are among the regular and important aquaculture farm management practices for removing all the accumulated organic materials in the pond floors. The overall mean concentration of NO_3-N (1.08 µm/l ≈ 0.02 mg/l) determined during the present study was below the range (0.4–0.8 mg/l) proposed by Nunes (2001) *in*: Maia *et al.* (2011) for protecting aquatic ecosystems. Moreover, NO_3-N concentrations obtained in this study were lower than those found by several studies from the tropical mariculture systems (Guerrero-Galvan *et al.*, 1999; Mmochi *et al.*, 2002; Ferreira *et al.*, 2011; Bui *et al.*, 2012).

3.11 Phosphate-Phosphorus

Results showed that there was a significant variation in PO_4-P concentrations between sampling stations ($p<0.05$). As presented in Figure 4, the highest mean concentration of PO_4-P recorded was 1.36±0.19 µm/l at ST 2, while ST 6 had the lowest value of 0.54 ± 0.07 µm/l. Relatively high PO_4-P concentrations obtained at ST 2 and ST 3 as well as at ST 4 may probably be attributed to the application of phosphorus-containing fertilizers such as triple superphosphate (TSP) as well as shrimp excreta. Kumar *et al.* (2012) attributed that nearly all fertilizers used in aquaculture systems contain phosphates which stimulate the growth of plankton and water plants that provide food for fish. Application of liming materials to increase pH of bottom sediments could also be associated with elevated PO_4-P concentrations in the culture ponds as it makes phosphorus accumulated in sediments more available in the water column (Boyd *et al.*, 2002). This statement could be substantiated by a strong significant positive correlation between PO_4-P and pH (r=0.905) of the water column (Table 1).

The general tendency of running water to undergo self purification would have caused the stations in the effluent creek to record lower PO_4-P concentrations. These results may be supported by the work of Wu *et al.* (1994) who found that the impact of shrimp farm effluent usually concentrates within 1-1.5 km from the discharge point. The average PO_4-P concentration (0.92±0.14 µm/l ≈ 0.0.01 mg/l) obtained in this study was lower than levels set as guidelines for protecting aquatic life in estuaries (<0.045 mg/l) and coastal waters (<0.015 mg/l) (Biao *et al.*, 2004). Moreover, these values were lower than those reported by Guerrero-Galvan *et al.* (1999), Mmochi *et al.* (2002) and Bui *et al.* (2012) from the related studies in the marine aquaculture systems.

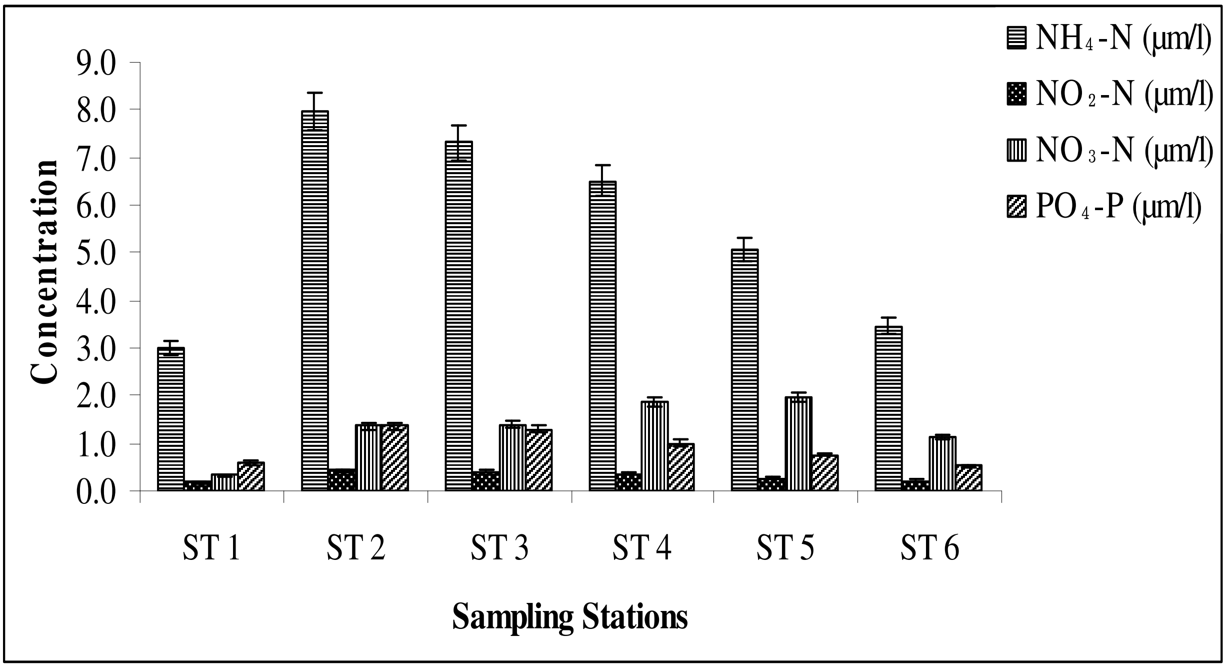

Figure 4: ***Mean variations (±SE) in concentrations of inorganic nutrients recorded in the Mafia shrimp farm during the study period.***

Table 1: Pearson correlation coefficient (r) for the water quality parameters determined during the study period in the Mafia shrimp farm.

Parameter	Chl-*a*	Turbidity	Salinity	EC	DO	pH	Temp	PO_4-P	NH_4-N	NO_3-N	NO_2-N
Chl-*a*	1										
Turbidity	0.376	1									
Salinity	0.363	-0.427	1								
EC	0.590	0.202	0.646	1							
DO	0.730	0.239	0.538	**0.917**	1						
pH	0.359	-0.122	0.748	**0.936**	0.796	1					
Temp	0.510	0.824	-0.555	0.016	0.113	-0.284	1				
PO_4-P	0.377	-0.127	**0.869**	**0.871**	0.793	**0.905**	-0.423	1			
NH_4-N	0.481	0.065	0.774	**0.905**	**0.875**	**0.868**	-0.256	**0.976**	1		
NO_3-N	0.621	0.824	0.065	0.542	0.638	0.234	0.522	0.375	0.558	1	
NO_2-N	0.456	0.022	0.779	**0.927**	**0.879**	**0.912**	-0.276	**0.983**	**0.995**	0.500	1

*Significant (p<0.05) correlation coefficient is presented in bold.

4.0 Conclusion and Recommendations

The health of the aquatic environment could easily be assessed by considering its water quality characteristics. Thus, when taking into account the results of this study, it is clearly showing that activities in the Mafia shrimp farm did not cause any significant and irreversible changes in the environment. This is an indication that the level of farming has not gone beyond the carrying capacity of the coastal area under shrimp production. Overall, findings of this study are consistent with a number of other studies in the tropical ecosystems (Wu *et al*., 1994; Rajasegar 2003) that have reached similar conclusion concerning changes in water quality parameters in the vicinity of the shrimp farm. However, fairly high concentration of nutrients observed in the culture ponds and along the effluent creek could imply that the area is starting to experience environmental degradation. Thus, with increasing production and age of the farm, significant environmental deteriorations of the surrounding environment are expected. This study therefore, suggests that environment impacts could be avoided or reduced through better culture husbandry, mixed culture as well as implementing regulatory, control and monitoring measures It is also expected that this study could provide essential information on which further studies can be carried out to assess the environmental impacts of commercial marine aquaculture development in Tanzania and the whole of East African coast.

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