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The Effect of Water Quality on Aquaculture Productivity in Estuaries of Ampara District, Sri Lanka

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Abstract-The coastal region of the Ampara district of Sri Lanka has a considerable number of perineal and seasonal estuaries which are poorly used for aquaculture. The reason they are not being used in aquaculture is the lack of awareness and inadequate information on the water quality parameters of these estuaries. Thus, the research has focused on investigating the water quality parameters of brackish waters in the Ampara district of Sri Lanka, with particular emphasis on their suitability for aquaculture. Water temperature, dissolved oxygen (DO), water and soil pH, salinity, conductivity, and total dissolved solids of the available estuaries or coastal wetlands in the Ampara district were investigated to assess the sites suitable for aquaculture for a full year from January to December 2018. Ambient temperature and precipitation were also recorded over the course of the year. The annual differences between the maximum and minimum level of water temperature, salinity, pH, specific conductivity, total dissolved solids, DO, and soil pH were 24.2 - 36.2°C, 0.9- 38.2 ppt, 6.2 - 8.9, 55.5 - 62870 µs/cm, 35.5 - 37800 mg/L, 3.2 - 13.4 mg/L, and 4.0 - 7.2 respectively for the whole year of 2018. The water quality parameters investigated in the full year indicate that the culture of brackish water shrimps would be suitable in Arugam lagoon (salinity, 17.1±3.3ppt) and Komari river mouth area (salinity, 21.4±8.4ppt), and culture of freshwater fish would be better in Oluvil (5.3±3.5ppt), Addalaichenai- Konawatte and River mouth (4.1±1.2ppt), Periyamuhathuwaram (3.2±1.2ppt), and Urani lagoon (5.1±3.0ppt) in all year long. As the seasonal lagoon of Sainthamaruthu (9.8±2.6) is unpredictable and recorded with highly variable water quality parameters, it would be very risky to culture the shrimps and may be suitable for euryhaline fish culture. The Sinnamuhathuwaram lagoon (9.3±3.9 ppt) is suitable for euryhaline fish farming during the period between November and March, while it is suitable for shrimp cultivation from April to October. Pottuvil Lagoon in Kottukkal would be suitable for freshwater fish farming from November to April, and for shrimp farming from April to October. Our study concluded that the lagoons of Komari- II and Arugambay are the ideal sites for culturing shrimp in all year long.

Key words: *Water quality parameters, shrimp aquaculture, estuaries, temperature, salinity, Ampara district of Sri Lanka*

I. INTRODUCTION

Estuaries have unique animal groups and vegetation, such as mangroves, that serve as nursery grounds for many aquatic creatures. Hence estuaries are some of the most productive ecosystems in the world (Daborn and Redden, 2018). Therefore, monitoring and understanding their water quality is essential. The recent review on estuarine ecosystem services shows that estuaries provide benefits to humans and help them maintain their livelihoods, however estuaries face significant threats and challenges, the majority of which are caused by human activities, while others are caused by climate change (Booi et al, 2022). When estuary water quality deteriorates, vulnerable aquatic plants and animals may cease to exist and thrive. In severe deterioration of estuary water quality, leads to contaminants and high ammonia content and they are toxic sources to aquatic organisms. Moreover, presence of more microbes depletes dissolved oxygen (DO) which is required by aquatic organisms to survive. Nuisance and harmful algal

blooms can also thrive when there are excessive levels of plant nutrients. Poor water quality can also limit usage of coastal waters for recreation or shellfish-gathering by the people (Boyd, 2017).

Temperature, depth, salinity, DO, turbidity, specific conductivity and pH of estuary waters are the key indicators of water quality and environmental conditions for the plants and animals that live in or use the estuary (Daborn and Redden, 2018). The water temperature is probably the most important environmental variable as it affects metabolic activities, growth, feeding, reproduction, distribution and migratory behaviours of aquatic organisms (Mugwanya *et al*, 2022; Crillet and Quetin, 2006; Suski *et al*, 2006). When the water temperature increases, the amount of oxygen that can dissolve in the water will decrease (Danladi Bello *et al*, 2017). Hydrogen ion concentration or pH of water as one of the vital environmental characteristics decides the survival, metabolism, physiology and growth of aquatic organisms (Lawson, 2011). Ramanathan *et al* (2005) recommended optimum range of pH as 6.8 to 8.7 for maximum growth and production of shrimp and carps. Water pH ranged from 7 to 8.5 according to Abowei (2010) is ideal for biological productivity, but pH less than 4 is detrimental to aquatic life (Lawson, 2011). Salinity determines the distribution of organisms in aquatic environments. The salinity of the water within the estuary indicates how much fresh water has mixed with sea water. Oxygen solubility decreases slightly as salinity increases, but oxygen solubility decreases more as temperature goes up regardless of salinity (Lawson, 2011). Estuarine organisms have different tolerances and responses to salinity changes. Many bottom-dwelling animals, like oysters and crabs, can tolerate some change in salinity, but salinity levels outside the acceptable range will negatively affect their growth and reproduction, and ultimately their survival (Daborn and Redden, 2018). Dissolved oxygen (DO) affects the solubility of and availability of nutrients (Lawson, 2011). Dissolved carbon dioxide in aquatic environment increases with decreased DO which is important parameter in primary production and phytoplankton biomass. Water acidity increases with dissolved carbon dioxide. High rate of dissolved carbon dioxide is detrimental to survival, physiological and metabolic activities of aquatic animals including fish (Lawson, 2012). Total dissolved solids (TDS) affect metabolism and physiology of fish and other aquatic organisms. They are products of run offs during the rainfall and have adverse effects on DO and carbon dioxide. Dissolved solids could directly influence water conductivity, the higher the dissolved solids the higher the conductivity (Lawson, 2011). Rainfall is an important factor in aquatic environment (Lawson, 2011). Substances present in the air such as, dust and natural gases (such as carbon dioxide, oxygen, sulphur dioxide and nitrogen) are dissolved or entrapped in rainwater. Toxic chemicals or lead in the air get mixed in the rain and fall to the ground. Rain reaches the earth's surface and, as runoff, flows over and through the soil and rocks, dissolving the substances in the rainwater and picking up other substances from the ground (Lawson, 2012).

There are about 45 estuaries and 42 lagoons in Sri Lanka (IUCN, 2002). Estuary is defined as a semi-enclosed body of water connected to the sea as far as the tidal limit or the salt intrusion limit and receiving freshwater runoff; however, the freshwater inflow may not be perennial, the connection to the sea may be closed for part of the year and tidal influence may be negligible (Wolanski, 2007). The pattern of dilution of sea water varies between different estuaries and depends on the volume of fresh water, the tidal range, and the extent of evaporation of the water in the estuary (McLusky and Elliott, 2004). Southeastern region of Sri Lanka has a moderate number of small freshwater wetlands, commonly referred to as 'lagoons'. The term lagoon is often applied to what is, from an ecological perspective, an estuary (NECCDEP, 2009). There are no true lagoons in Eastern province including Ampara district according to the definition of 'lagoon' in the Sri Lankan coastal zone Management plan 2004 (GoSL, 2006). Therefore, the use of the term lagoon is synonymous with estuary in Eastern Province (NECCDEP, 2009). Estuaries are shallow areas separated from the sea by a sand bar of variable width that may be permanently (Batticaloa lagoon) or occasionally (Palvaki lagoon) breached by one or more bar mouths. They are natural systems that transition between rivers/streams and the open sea. Salinity ranges from freshwater to seawater depending on the proximity to the bar mouth and extent of freshwater river discharges which vary according to whether it is the wet or dry season. Estuaries are significant natural assets in all three districts in Eastern Province (NECCDEP, 2009).

Estuaries in this region can be viewed as wetlands. These are places, which are temporarily or permanently covered with water (NECCDEP, 2009). The Convention on Wetlands of International Importance especially as waterfowl habitat (The Ramsar Convention) defines wetland as "Areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters" (UNESCO, 1994).
According to the Wetland Atlas of Sri Lanka, (1999), Coast Conservation Department (CCD) information classifications and IP NGO (Implementing Partner – Non-Governmental Organizations) surveys, over 35 estuaries have been identified in Southeastern region of Sri Lanka. However, no detailed studies have been done on these estuaries. Therefore, the current study was initially aimed to measure the physical parameters of 12 selected estuaries. Physical parameters such as Salinity, pH, Conductivity, Temperature, DO, TDS, and Soil pH of 12 estuaries were monitored in different climatic conditions between January and December 2018.

The objectives of the study were to provide baseline information on physical and chemical parameters of estuarine waters in the Ampara sistrict, Southeastern region of Sri Lanka, and to assess the suitability of different estuaries in Southeastern region for best aquaculture practices.

II. MATERIALS AND METHOD

A. Study area

Present study was carried out in 12 subset of water bodies which were previously identified in an inventory of lagoons or estuaries in the Southeastern region of Sri Lanka (Figure 1). Two of the water bodies were covered by trees and are referred as 'tree swamps', rather than lagoons (Figure 2) in this document. 12 Estuaries (L1 to L12) were monitored at monthly intervals between January 2018 and December 2018 for physical and chemical parameters (Figure 1).

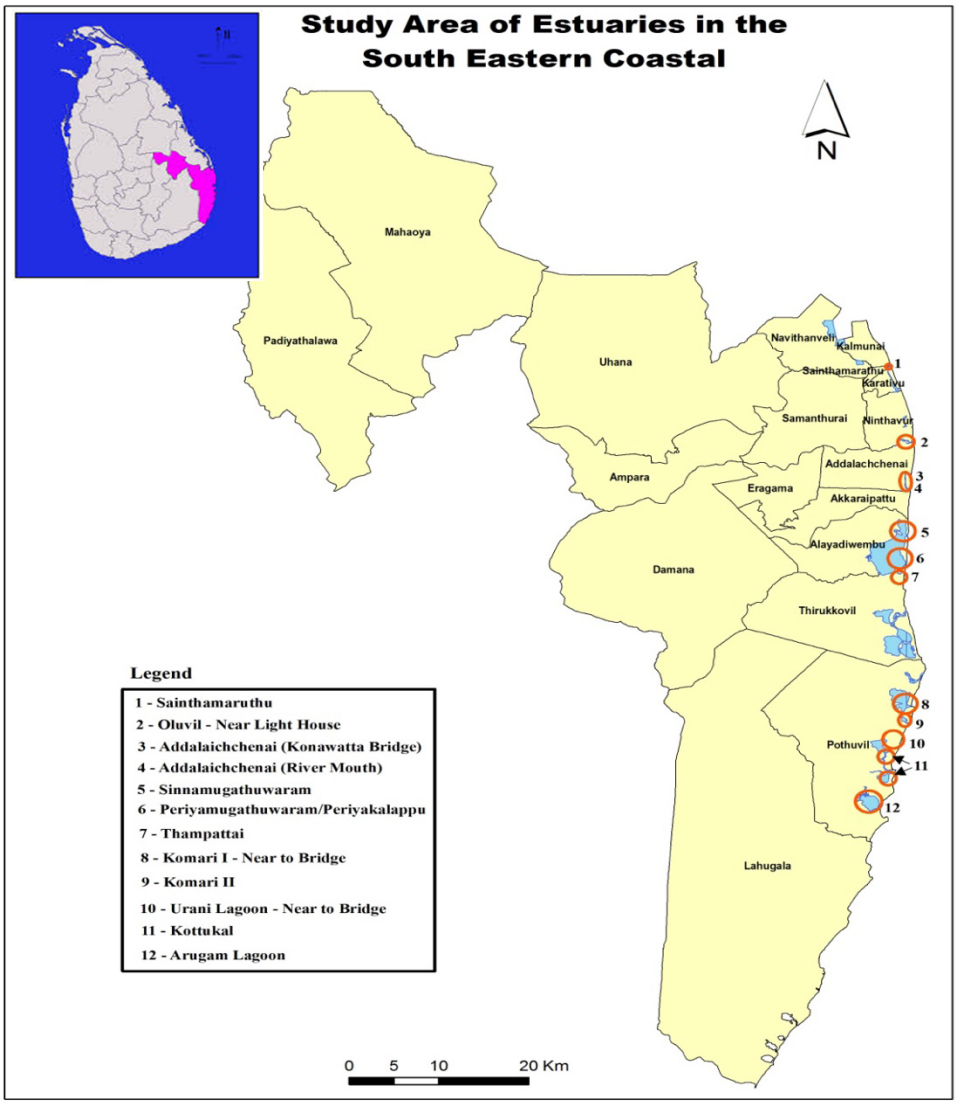

Figure 1: GIS map of estuaries in Southeastern region of Sri Lanka

Figure 2: Estuaries with a cover of mangrove trees (Urani Lagoon -Left) and open lagoon (Komari-i Lagoon – right).

B. Data Collection

Field measurements and water samples for analysis were collected over 12 months period from January to December 2018. Three water samples per lagoon were collected at each sampling time and further analysis was also done. Water samples were collected from the sampling sites using cleaned high density 1.5 l plastic bottles. At the sampling points, the bottles were lowered into the lagoon at a depth of about 30 cm below the water surface. The physical parameters were also measured at the sampling location. Physical parameters such as salinity, specific conductivity, pH and total dissolved solids (TDS) were measured using Portable multi parameter (Hach, sension^{TM}156, U.S.A) which has the specific conductivity (± 0.5% of range), salinity (0.1 ppt accuracy), and total dissolved solid (± 0.5%). DO meter (Hach, sension^{TM}156, U.S.A) was used to determine the DO level and the temperature (±0.3ºC accuracy). Finally, Model 3510 pH/mV/Temperature meter with an accuracy ± 0.003 pH and ± 0.5ºC was used to record the pH and temperature of the soil in different points at each estuary. Each instrument was calibrated before the analysis of each physical parameter. DO meter was calibrated using sodium sulfite solution and air bubbled water. Sodium chloride solution was used to calibrate the salinity meter. Multiparameter was calibrated before the testing and the electrode was immersed about 25 to 30 cm into the water. Care was taken to avoid the deposition of the soil particles into the electrode surface. After the measurement, the electrode was washed with de-ionized water and air dried, prior to capping the electrode. The reading of the specific conductivity and the TDS were taken using the above same probe and the meter.

III. RESULTS

Current study showed that there were significant variations of water quality parameters in 12 estuaries of Southeastern region. The following water quality parameters were studied in all 12 locations; temperature, dissolved oxygen (DO), water pH, specific conductivity, total dissolved solids and soil pH. It was observed that some of the water quality parameters showed a relationship with the rainfall.

A. Water temperature

Mean day water temperature of selected estuaries varied from 24.7^{0}C to 35.3^{0}C (Table 1 and Figure 3). The highest mean temperature of 35.3 ^{0}C and the lowest mean temperature of 24.7^{0}C was observed in Saintamaruthu wetland. On other hand, the highest mean temperature was observed in the months of April, May and June 2018, whereas the lowest mean temperature was observed in in the month of December 2018.

Figure 3 illustrates the fluctuation of temperature at each sampling location at different months. The mean temperature in most locations was high during the months between March to September, whereas, it was low from October to February. However, this range was within the range of temperature taken by Pottuvil metrological department during the period of study. Figure 3 further illustrates fluctuation of water temperature in all locations, which was observed within the range of air temperature variations of each month. It is interesting to note that there were significant ($P<0.05$) differences in temperature in all locations at each month.

B. Dissolved Oxygen (DO)

The mean DO concentrations of the surface water of the estuaries ranging from 4.0 to 14.0 mg/L (Table 1 and Figure 3). The highest mean value of 14.0 mg/L was observed in location 11-Kottukkal, whereas the lowest mean value of 4.0 mg/L was observed in location 10-Urani lagoon and location 5- Thambattai. Temperature and DO were also significantly ($P<0.05$) different in all locations at each month and were inversely related (Figure 3).

Table 1: Ranges of the water quality parameters in the estuaries of Southeastern region of Sri Lanka

Name of Estuaries	Temperature (°C)	DO (mg/l)	Water pH	Soil pH	Salinity	Conductivity (µs/cm)	TDS (mg/L)
Sainthamaruthu	24.7-35.3	4.4 -9.1	7.2 - 8.4	5.5 - 6.3	7.5 - 15.3	9167 - 9850	5392 - 5794
Oluvil	26.5-32.2	4.9 - 10.9	6.5 - 7.7	5.3 - 6.5	2.7 - 15.5	3150 - 4400	1853 - 2588
Addalaichennai-Konawatte	26.2 - 32.4	4.3 - 9.0	7.2 - 8.4	5.6 - 6.7	2.3 - 6.2	6200 - 7317	3647 - 4304
Addalaichenai-Rivermouth	26.6 - 32.8	4.5 - 9.5	7.2 - 8.5	5.4 - 7.3	2.6 - 7.3	67`17 - 9000	3951 - 5294
Thambattai	26.0 - 31.9	4.0 - 10.6	6.5 - 7.3	6.0 - 6.8	2.7 - 10.7	3300 - 4533	1941 - 2725
Sinnamuhathuvaram	25.5 - 32.1	4.2 - 10.2	7.4 - 8.8	5.0 - 6.7	2.7 - 14.4	6200 - 8100	3647 - 4765
Periyamuhathuvaram	26.6 - 32.2	4.9 - 11.0	6.8 -7.9	5.3 - 6.6	1.3 - 5.2	3433 - 4400	2020 - 2569
Komari lagoon- i	26.6 - 32.6	5.0 - 10.8	7.0 - 8.5	4.1 - 6.8	6.5 - 13.6	3150 - 4400	1853-2588
Komari lagoon- ii	26.3 - 32.4	4.7 - 10.9	7.1 - 8.5	4.0 - 6.9	10.2 - 36.6	15667 -64000	9216 - 37647
Urani lagoon	26.1 - 31.9	4.0 - 8.4	7.1 - 8.4	5.5 - 6.6	1.2 - 9.4	7200 -20333	4255 - 11961
Kottukkal lagoon	26.1 - 31.9	6.8 - 14.0	7.4 - 8.9	4.9 - 6.7	1.7 - 10.2	783 - 11000	461- 6569
Arugam lagoon	25.9 - 32.3	4.5 - 11.5	7.3 - 8.4	5.5 - 6.6	11.2 - 22.1	1183 -22167	6961- 13039

C. Water pH

The mean water pH of estuaries ranged from 6.5 to 8.9 (Table 1 and Figure 3). The highest mean water pH of 8.9 was observed in location 11-Kottukkal lagoon, whereas the lowest mean pH of 6.5 was observed in location 05-Thambattai. There was significant variation in water pH also across the location and month ($P<0.05$). It was also noted that the water temperature has a influence on the water pH.

D. Soil pH

The mean soil pH of estuaries ranged from 4.0 to 7.3 (Table 1 and Figure 3). The highest mean value of 7.3 was observed in location 4- Addalaichenai Rivermouth, whereas the lowest mean value of 4.0 was observed in location 9-Komari- ii. According to the statistical analysis of the data there were some outliers. Temperature, DO and water pH, soil pH was also significantly ($P<0.05$) different in all locations in each month.

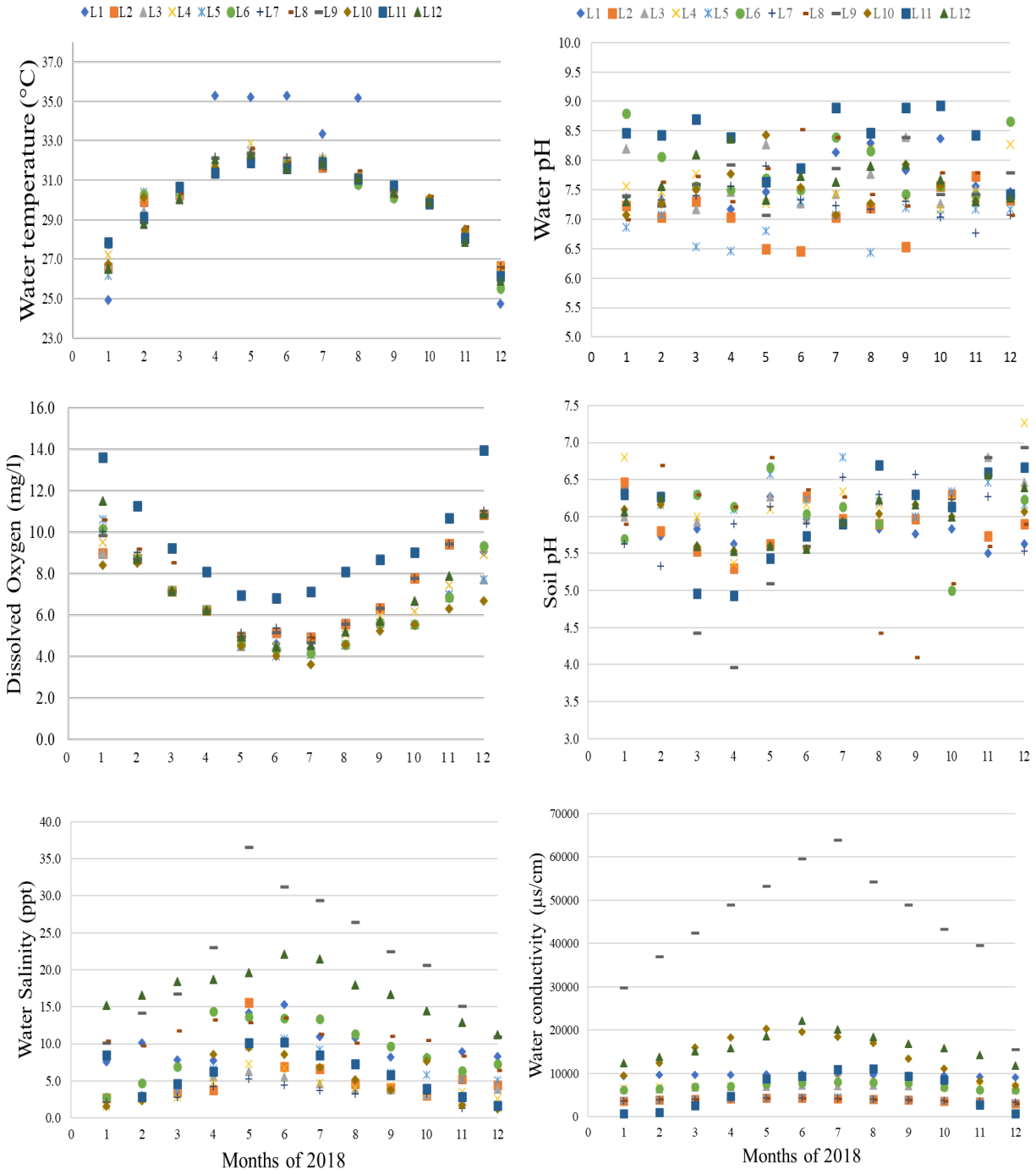

Figure 3: Monthly variation of physico-chemical parameters of estuaries of Ampara district of Sri Lanka from January to December 2018. Esturaiers were numbered from L1- L12; L1 -Sainthamaruthu, L2- Oluvil, L3- Addalaichennai-Konawatte, L4 -Addalaichenai-Rivermouth, L5-Thambattai, L6- Sinnamuhathuvaram, L7-Periyamuhathuvaram, L8 -Komari lagoon- i, L9 -Komari lagoon- ii, L10 -Urani lagoon, L11-Kottukkal lagoon, and L12 - Arugam lagoon.

E. Salinity

The mean salinity of the estuaries ranged from 1.2 to 36.6 ppt (Table 1 and Figure 3). The lower salinity was observed in all locations from October to March. The highest mean salinity of 36.6 ppt was observed in location 9- Komari- ii, whereas the lowest mean value of 1.2 was observed in Urani lagoon. However, the lowest salinity (1.3-5.2 ppt) in all around the year was observed in the location 7 Periyamuhaththuwaram. The mean salinity of the Arugam lagoon was 17.1±3.3 ppt.

The fluctuation of salinity values was observed during different months at different sampling locations (Figure 3). Lowest value of 1.2 ppt was observed in January 2018 in Urani lagoon, whereas the highest value of 36.6±1.6 ppt was observed in May 2018 in location 9- Komari-ii. Salinity also showed the variation in across the location and month ($P<0.05$).

F. Specific Conductivity

The mean conductivity values of estuaries falls in between 783 and 64000 µs/cm (Table 1 nad Figure 3). The highest mean conductivity of 64000 µs/cm was observed in location 9- Komari-ii, whereas the lowest mean conductivity of 783 µs/cm was observed in location 11- Kottukal lagoon.

In this study the lowest mean conductivity value was observed in December in location 11- Kottukkal, whereas the highest value was observed in July in location 9- Komari ii. It is also interesting to note that there were significant ($P<0.05$) differences in conductivity in all locations at each month.

G. Total Dissolved Solids

The mean TDS values of estuaries in Ampara distric were observed in between 461 and 37647 mg/L (Table 1 and Figure 4). The highest mean TDS of 37647 mg/L was observed in location 9- Komari-ii in the month of July, whereas the lowest mean TDS of 461mg/L was observed in location 11- Kottukkal in the month of December. There was significant variation in TDS also across the location and month ($P<0.05$), according to statistical analysis. TDS was pssitively correlated with conductivity.

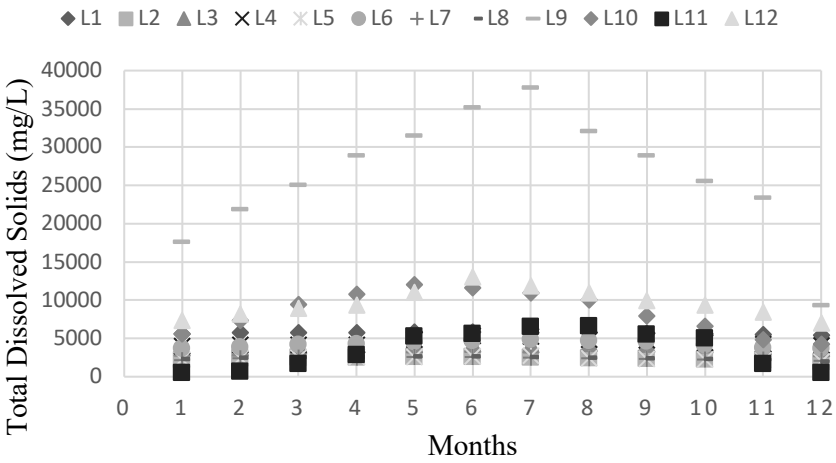

Figure 4: Mean TDS in estuaries in Southeastern region of Sri Lanka from January to December 2018

H. Seasonal variation

Most of the physical parameters of estuaries were influenced by the rainfall and ambient temperature. Water temperature, salinity, conductivity, and total dissolved solids were high when the rainfall was low during the period between March and September 2018 (Figure 5). It is also observed that the DO content in the water was low when the water temperature and salinity were high (Figure 3).

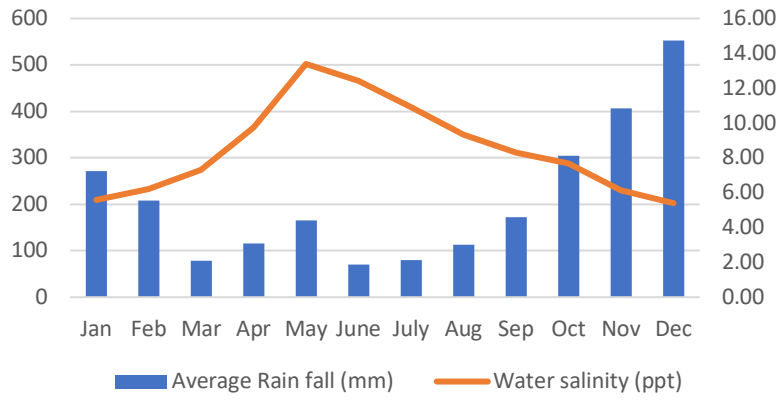

Figure 5: Relationship between rainfall and the water salinity in the estuaries in Ampara district of Sri Lanka (Rainfall data Sources: The Global Historical Weather and Climate Data-2023)

IV. DISCUSSION

Addressing the water quality parameters in a water source is very important to use the water quality for various agro-industrial projects such as selecting a site for aquaculture. Many studies have attempted to address such issues of water quality in lagoons and estuaries in the world (Kara *et al*, 2004, Lawson, 2011). In the present study, air temperature varied between 26.2-30.97^{0C} and daytime water temperature of estuaries ranged from 26.11 and 32.5^{0}C. These values were acceptable levels for survival, metabolism and physiology of aquatic organisms (Lawson, 2011). The optimum temperature for shrimp culture is about 25-30^{0}C (Margabandu and Ramamurthy, 2015). In this study, water temperature in all locations during the study period was suitable to establish a best shrimp culture although water temperature during November to February 2018 was influenced by the rainfall. During November to February 2018, it was observed that there was high rainfall and low water temperature in all locations.

The DO values of 4.5 to 11.5 (7.0±2.4) mg/L in this study were similar to those reported from the study of Water Quality Assessment in Arugam Lagoon (2.24 to 11.21 mg/L) by GreenTech (2010). According to their findings, the DO level is closer to 4.0 mg/L which is considered as low value under which the organisms may be stressed. GreenTech (2010) concluded that, the low DO levels were the reason for death of fish in Arugam Lagoon time to time in 2010. Further, they have mentioned that if DO levels drop below 3.9 mg/L some fish and other aquatic organism can be stressed and if levels drop below 2 mg/L many species can die off. High organic content from human feces, decayed plant material, and domestic and sawmill wastes that found their ways into the lagoon may be responsible for low DO (Lawson, 2011). Frequent deaths of fish in water in fact do not come from toxicity of matters, but from deficit of consumed oxygen from biological decomposition of pollutants (Lawson, 2011). Sufficient levels of DO in the water is essential for the survival of fish, crabs, oysters and other aquatic animals (Daborn and Redden, 2018). The amount of DO in an estuary's water is the major factor that determine the type and abundance of organisms that live there (Daborn and Redden, 2018). Many channel catfish and *Penaeid* shrimps need minimum daily concentration of DO above 3 mg/L for better feed consumption and growth. Tilapia can tolerate lower DO levels than catfish and shrimp, but concentrations should not fall below 1 mg/L (Boyd, 2000). DO levels are influenced by temperature and salinity. The solubility of oxygen or its ability to dissolve water decreases as the water temperature and salinity increase (Daborn and Redden, 2018). In this study the range of DO in estuaries is within the recommended range for best aquaculture practices. However, tropical aquatic organisms are able to adapt to lower oxygen concentration than their temperature counterparts (Margabandu and Ramamurthy, 2015). The pH values between 6.5 and 8.9 (8.2±0.04) recorded in the study also similar to the pH the ranges reported previously in Arugam Lagoon (GreenTech, 2010). The pH of seawater is usually between 7.8 and 8.4 (GreenTech, 2010). The range of mean pH values in this study was from 7.2±0.07 to 8.2±0.04. Water with pH ranging from 6.8 to 8.7 is generally regarded as suitable for shrimp production (Margabandu and Ramamurthy, 2015). The pH of the water is indicative of its fertility or potential productivity. The growth of shrimps is retarded if pH falls below 5.0 (Margabandu and Ramamurthy, 2015; Rahman *et al*, 2015). So, in this study, the pH range in estuaries is also suitable for the best aquaculture practices. The present study revealed the soil pH varied between 4.0-7.3 (6.42±0.05) in estuaries of southeastern region of Sri Lanka. The optimum conditions of shrimp culture, the soil pH should be within 5-7 (Hoque *et al*, 1997). According to this study, in all estuaries, the soil pH is most suitable for the shrimp culture. There was a big range of salinity recorded in the present study for the whole one-year period; 1.2- 36.6 (8.46±6.66) ppt. However, salinity is a key factor affecting the physical make-up of the estuary (GreenTech, 2010). The salinity levels within the estuary also may vary, depending on the volume of fresh water that flows into the estuary (GreenTech, 2010). According to the two-way analysis of ANOVA there was significant variation in salinity across the locations and months ($P<0.05$). Lowest values were observed during November to February 2018, when the rainfall was high. This may be due to dilution of the estuarine water by the increase freshwater inflow during the

rainy season (Lawson, 2011). Higher salinity levels were recorded across the locations during the dry seasons (April-September). This was similar to the findings of Edokpayi *et al* (2010). Furthermore, compare to all the estuaries, the location 9- komari- ii had higher salinity ranges because this site is a river mouth area of Komari, where there is more inflow of the sea water compare to other estuaries. salinity. Younger shrimps appear to tolerate a wider fluctuation of salinity than the adults. The post-larvae of many *Penaeid* species can tolerate wide salinity fluctuation which has little effect on their survival or growth. *Penaeus monodon* can tolerate a wide range of salinity from as low as 5 ppt to a high of 40 ppt (Rahman *et al*, 2015). The lower salinity changes were recorded in the lagoons/wetlands of Thambattai, Oluvil, Addalaichenai, and Urani during whole study period which are considered as not suitable places for shrimp culture. However these estuaries may be suitable for euryhaline or freshwater fish culture. Based on the data, water quality parameters may favour the culture of brackish water shrimps in Arugam lagoon (salinity, 17.3±3.32ppt) and Komari river mouth area (salinity, 21.42±8.19ppt), and culture of freshwater fish in Oluvil (4.29± 1.53ppt), Addalaichenai- Konawatte (4.03±1.7ppt), Thambattai (3.23±1.18ppt), and Urani lagoon (5.11±3.81ppt) in all year long. As the seasonal lagoon of Sainthamaruthu (9.83±3.09) is unpredictable and recorded with highly variable water quality parameters, it would be very risky to culture the shrimps, may be suitable for euryhaline fish culture. Sinnamuhathuwaram lagoon (6.18±2.72ppt) is suitable for euryhaline fish culture during the period between November and March, whereas it is suitable for shrimp culture from April to October. Periyamuhathuwaram lagoon (9.33±3.83ppt) may be suitable for culturing freshwater fish from December to March, whereas it would be suitable for shrimp culture from April to October. Pottuvl lagoon, Kottukkal would be suitable for freshwater fish culture from November to April, and it may be suitable for shrimp farming from May to October. Therefore, ranges of salinity recorded for lagoons of Arugam and Komari II in this study was suitable for shrimp culture in all year long.

Lawson (2011) described dissolved solids could directly influence the water conductivity and conductivity increases with increase of salinity. Similar patterns between salinity, TDS, and conductivity were also found in the present study. Interestingly, in location 9- Komari- ii, we found comparatively higher salinity with high conductivity and TDS was noted. At the same time it was found that conductivity ranged between 55.5 to 62870 (39030±3919) µs/cm, whereas TDS ranged between 35.5 to 37800 (21992±2222) mg/L with direct relationship between conductivity and TDS in all locations in the study. Water can be classified according to Ela (2007) by the amount of TDS per liter: fresh water (<1500 mg/L TDS), brackish water (1500 to 5000 mg/L) and saline water (>5000 mg/L TDS). This is an indication that water in the estuaries can switch between fresh and brackish waters. Spawning fishes and juveniles appear to be more sensitive to high TDS levels (Lawson, 2011). According to Boyd (2000), most aquatic ecosystems involving mixed fish fauna can tolerate TDS levels of 1000mg/L. In all locations fluctuate between freshwater and brackish water during all year round period of time except Komari- ii, (21992±2222) mg/L, and Arugam lagoon, (9929±485) mg/L which were slightly brackish and more saline water.

V. CONCLUSION

The water quality parameters investigated in the full year indicated that the culture of brackish water shrimps would be suitable in Arugam lagoon (salinity, 17.1±3.3ppt) and Komari river mouth area (salinity,21.4±8.4ppt), and culture of freshwater fish would be better in Oluvil (5.3±3.5ppt), Addalaichenai- Konawatte and River mouth (4.1±1.2ppt), Periyamuhathuwaram (3.2±1.2ppt), and Urani lagoon (5.1±3.0ppt) in all year long. The Sinnamuhathuwaram lagoon (9.3±3.9ppt) is suitable for euryhaline fish farming during the period between November and March, while it is suitable for shrimp cultivation from April to October. Pottuvl Lagoon in Kottukkal would be suitable for freshwater fish farming from November to March, and for shrimp farming from April to October. Our study concluded that the lagoons of Komari- II and Arugambay are the ideal sites for culturing shrimp all year long.

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