IMPACT OF WATER QUALITY PARAMETERS ON THE AVAILABILITY OF FISH LARVAE AT KUMIRA, CHATTOGRAM

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Roll No.: 0120/10

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A thesis submitted in the partial fulfillment of the requirements for the degree of Master of Science in Fisheries Resource Management

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LIST OF ABBREVIATIONS

ºC	Degree Celsius
ppt	Parts Per Thousand
g/L	Gram Per Liter
mg/L	Milligram Per Liter
BoB	Bay of Bengal
IUCN	International Union for Conservation of Nature
CZPo	Coastal Zone Policy
FAO	Food and Agricultural Organization
FRSS	Fisheries Resources Survey System
DoF	Department of Fisheries
DO	Dissolved Oxygen
TDS	Total Dissolved Solids
SPSS	Statistical Package for Social Sciences
gpg	Grains Per Gallon
$CaCO_3$	Calcium Carbonate
NH_3	Ammonia
NH_4^+	Ammonium Ion
SD	Standard Deviation
ECR	Environmental Conservation Rules
WHO	World Health Organization

ABSTRACT

The goal of the current experiment was to determine how fish larvae availability was impacted by water quality. Water and larvae samples were collected in this following time (January, 2021 to December, 2021) by per month sampling period from the coastal area of Kumira, Chattogram, Bangladesh. Surface water temperatures (ºC) varied from 22.5 to 31.8 whereas salinity values (ppt) varied from 2 to 16 and the pH ranged between 6.94 and 9.17. Total dissolved solids (g/L) content varied from 1.45 to 6.56. The ranges of ammonium ion (mg/L) and toxic ammonia (mg/L) content varied from 0.0224 to 1.0220 and 0.0009 to 0.0672 respectively. The amount of alkalinity (mg/L) and total hardness (mg/L) content varied from 51.3 to 369 and 320.8 to 906.3 respectively. The ranges of nitrite (mg/L) was found 0.023 to 1.320. Water quality parameters showed some significant relations among them in different seasons. The water quality parameters were collected by monthly basis during the sampling period. Larvae were categorized in two different types. Finfish and crustaceans showed some significant relationship among the different water quality parameters. The maximum and minimum number for finfish was 93 and 17 respectively; for crustaceans the amount of it was 571 and 44 respectively during the study period. The larvae samples were collected by using push net on monthly basis during the sampling period. Sudden fluctuation of water quality parameters, pollution, and food availability might be the reasons behind that. The findings of this study would help to know the overall condition of fish larvae on Kumira and the impact of water quality on them. It would be helpful for policymakers in improving management practices for maintaining water quality and conserving the fish larvae population.

Keywords: Water quality parameters, larvae, Kumira

CHAPTER ONE

INTRODUCTION

1.1 Background

The second-largest delta in the world, after the Amazon, is located in Bangladesh's coastal region (Department of Environment, IUCN, Bangladesh Center for Advanced Studies, 2006). Bangladesh has a 710-kilometer coastline (CZPo, 2005). People living along the shore have traditionally relied on the resources of the Bay of Bengal (BoB) since Bangladesh is a coastline rich nation (FAO, 2014). Bangladesh's coastal and marine zone is one of the world's most diverse ecosystems, with high biodiversity, increased production, and distinct mangrove characteristics (Islam, 2003). Fisheries support around 5, 08,830 individuals in the coastal region (FRSS, 2016). There are around 475 coastal and marine species, as well as 36 shrimps in the BoB (DoF, 2016). The coastal and marine environment is increasingly crucial in achieving the country's social, economic, development, and strategic goals. Over 30% of Bangladesh's cultivable lands are in the coastal region, which makes up about 20% of the country's overall land area (Minar et al., 2013). It contains a wide variety of ecosystems, the Sundarbans, the biggest tract of mangroves in the world, as well as beaches, coral reefs, dunes, and marshes. The inhabitants of Bangladesh can access a variety of goods and services because to its dynamic natural settings. A major environmental concern on a global and regional scale, coastal water quality is affected by both natural and man-made disturbances, including wastewater, runoff effluents, land reclamation, air deposition, and climate change (Bowen and Depledge, 2006) . The biological nature is briefly discussed in order to offer context for the primary habitats and their current state. The coastal resources are outlined, with a focus on living resources such as ecosystems and fisheries (Hossain, 2001).

Aquatic ecosystems are critical to the sustainability of water resources and the survival of all living beings. They provide a variety of vital environmental tasks, including nutrient recycling, water purification, flood mitigation, ground water recharge, and wildlife habitats. The physico-chemical properties of water, as well as the fact that all life processes are dependent on these factors, make it desirable to use water as an environment. For understanding the quality of coastal water is an important issue because it is the main factor determining its suitability for particular purposes. The spatiotemporal variability of all aquatic organisms, including larvae, is accounted for by these factors. In coastal ecosystems, interacting physical, chemical, and biological processes exist, resulting in greater diversity and richness (Meena and Chandrakala, 2017).

Tropical to subtropical climates are seen in Bangladesh. Here, physico-chemical parameters have changed on a monthly or seasonal basis. Different kinds of seasonal change take place in Bangladesh. (Mahmood et al., 1976). It is common to see seasonal fluctuation in salinity, dissolved oxygen, water temperature and suspended particle in Bangladesh (Akther et al., 2018).

Fish larvae assemblages were first discovered during late-nineteenth-century fisheries research and oceanographic explorations. Early larval research emphasized on the time and space of spawning, as well as the survival of the young of commercially significant species, while data from further oceanic expeditions offered a worldwide picture of larval diversity and distribution patterns (Moser and Smith, 1993). Because these environments provide shelter and food, fish larvae are most plentiful in estuaries and coastal habitats. The abiotic variables greatly impacted larvae. Salinity revealed to be the key environmental component determining the distribution and abundance of various larvae (Rezagholinejad et al., 2016).

Human activities in rivers, estuaries, and coastal areas have an impact on ecosystems, particularly in terms of pollution and habitat damage (Coleman et al., 2008; Diaz and Rosenberg, 2008). Because of the growth of additional industries, growing urbanization, and reclamation of land, the environment is under significant stress, leading to environmental degradation and an adverse habitat for aquatic species. Organisms in these environments are subjected to a mix of environmental stressors, including physical and chemical pollution, as well as additional stressors like pathogens and environmental impact (e.g. climate change or habitat loss). The people have been more alarmed about harmful and poisonous pollutants released into the aquatic environment during the last two decades. Toxic compounds may intensify the negative impacts on the sea organisms in question, either directly or indirectly (Filipuci, 2011).

Kumira is one of the most important coastal regions of Chattogram, which is in the southern part of Bangladesh, adjacent to Bay of Bengal (Mondal et al., 2018). Most of the fishers, of the fishing communities there, are dependent of larvae collection, and transport it to distant hatchery and fish farms. Many commercial shrimp hatchery and also other fish farm depends on this harvested fish larvae. Farmers earn a lot of revenue from this larvae collection process. Naturally produced fish larvae is an utmost need of many commercial fish farm. Bangladesh has studied fundamental characteristics to assess the productivity and ecological condition linked with phytoplankton in both inland and coastal waterways as a result of water quality monitoring programs in other countries. Because of both functional and biochemical characteristics, aquatic habitats provide food and shelter to a wide range of fish larvae. The aim of the current study is to determine the changes between water quality and larval availability, as no research was conducted regarding this in the area. Anthropogenic nutrient inputs to this coastal system have increased as a result of the notable increase in human population abundance along Chattogram's edges. The establishment of numerous shipbreaking companies there may damage the generation of fish larvae from this coastal area. It is crucial to determine the water quality in this ecologically rich coastal area as well as how it affects the fish larvae that live there. It will support the creation of new management strategies for ongoing larval production. Additionally, it will support future research or study objectives.

1.2 Significance of the study:

- The study will help to identify the seasonal variation of water quality parameters.
- It will help to identify the different larvae abundance in different season.
- The study will help to correlate the impact of water quality parameters in larvae.

1.3 Objectives of the study:

- To measure the water quality parameters of Kumira, coastal region of Chattogram.
- To determine how different water quality parameters affect larvae (Finfish and Crustaceans).

CHAPTER TWO

REVIEW OF LITERATURE

Water quality is an important factor for fish larvae production. It helps fish and other organisms to breed and maintain the natural production of different aquatic organisms. They also help to keep the ecological balance in aquatic ecosystem. Literature on water quality parameters and also the impact of water quality on fish larvae are reviewed below.

There are some notable research on coastal water quality of Bangladesh. Miah et al., (2015) conducted a research on assessment of the coastal area water quality in Noakhali, Bangladesh. They found pH value for surface water was 6.3 to 7.49; total hardness for surface water was 70 mg/L to 132 mg/L; alkalinity of the surface water was 68.5 mg/L to 112.5 mg/L. The DO value was found 4.05 mg/L to 4.95 mg/L for surface water. They identified the variation of water quality parameters for different sampling stations. They reported that hardness and alkalinity of surface water was not in a suitable condition. The assessment from different sources revealed that, pH of river was more acidic. Total dissolved solids and alkalinity of deep ground water was much higher than the acceptable limit. Sarwar et al., (2010) measured the water quality parameters of Karnaphully River. It involved the water quality Parameters of Karnaphully along with the Patenga estuary of Chittagong port. They found the value for water temperature, dissolved oxygen, pH and alkalinity were 23 ºC, 6.65 mg/L, 4.8, 247.47 mg/L respectively. They identified that the water quality was not in good condition for human consumption but still considerable for other useable purpose. It could affect aquatic health in near future if the pollution trends continued. A study was conducted to explore the physicochemical parameters of surface water from the Moheshkhali fishing zone at Cox's Bazar coastal area of Bangladesh. The result of the study showed that temperature, pH, TDS, salinity, DO were ranged from 27.5 to 29ºC, 7.1 to 8.5, 311 to 615 mg/L, 10 to 29‰, 6.2 to 6.9 mg/L, respectively. The result of the study concluded that most of the physicochemical parameters from marine surface water were found to be suitable for fish growth (Imran et al., 2020). The physico-chemical status of coastal seawater of the Saint Martin’s Island, Bangladesh was studied and coastal saltwater ranged from 25 to 30 °C in temperature, 30.8 to 33.4 ppt in salinity, 5.08 to 6.87 mg/L in DO, 8.05 to 8.38 mg/L in pH, and 29575 to 31980 mg/L in TDS. They found variation of different water quality parameters on different sampling sites. The ranges for the water quality parameters were suitable for fish breeding and that was the good production of fish from the ecologically important area of Bangladesh (Kashem et al, 2019). Aftabuddin et al., (2009) identified the physio-chemical parameters of water in Kolatoly coast and a shrimp hatchery. They found the variation of water quality parameters between Kolatoly coast and shrimp hatchery. The study suggested that the water quality of Kolatoly coast had impact on the shrimp hatchery. They reported that the value of dissolved oxygen, total dissolved solids, nitrate were fluctuating in different period of times. The fluctuation might happen due to the change of temperature, salinity, atmospheric pressure and other activities. According to Ahmed et al., (2010) the surface and ground water quality of the greater Chittagong. They identified the various physiochemical and microbiological parameters from the selected sampling sites. They found the water quality of different sampling site was critical and vulnerable for aquatic and human health. The effects of climate change on drinking water salinity and maternal health in coastal Bangladesh were studied by Khan et al. (2011). They identified the different salinity level in coastal region of Bangladesh. They also showed the salt intrusion due to the impact of climate change. Uddin et al., (2014) assisted the water quality parameters of Jamuna River. He identified different physical and chemical properties of water from different sampling sites. He showed the variation of different water quality parameters between dry and wet season. Almost all the water quality parameters were fluctuated in wide range due to domestic discharge in the river. In the main river systems of the Sundarbans Mangrove, Bir and Sumon, (2015) identified the effects of several water quality characteristics on zooplankton distribution. He showed the different water quality parameters on different river systems of Sundarbans Mangrove. The identified water quality was in suitable condition for the fish production. The study would be capable to identify the different fishing grounds in the river systems of Sundarbans Mangrove. Hossain, (2001) conducted a research on biological aspects of the coastal and marine environment of Bangladesh. In this study he showed the variation of water quality parameters from the coastal and marine area of Bangladesh. He interlinked the water quality and also some environmental factor with the fish production. Temperature, pH, dissolved oxygen, salinity was mainly identified from the selected sampling stations.

Along with this, there are some research along the coast of Indian coastal area about the water quality. Mazumder et al., (1997) carried out an experiment on water quality, plankton and periphyton assessment in different water body in west bengal. They found the value for water temperature, pH, alkalinity, nitrate and DO were 25-30ºC, 0.5 mg/L to 1.70 mg/L, 90 mg/L to 420 mg/L and 0.9 mg/L to 6.25 mg/L. The variation of different water quality parameters were identified and pH, alkalinity was fluctuated too much in different season. Hasan et al., (2021) tried to evaluate the seawater intrusion in the coastal aquifers of southern Bangladesh. They found the value for pH, TDS and salinity were 7.75 to 8.82, 182 mg/L to 2790 mg/L and 0.1 to 2.8 ppt respectively. The water quality of a tropical permanent estuary system called Tapi, on the west coast of India, was assessed spatially and temporally by Kumar and George (2009).They found the average value for temperature, salinity, DO, alkalinity and nitrate were 23.5°C to 33.5°C, 0.11 ppt to 32 ppt, 2.1 mg/L to 8.5 mg/L, 76 mg/L to 168 mg/L and 0.464 mg/L to 1.312 mg/L respectively. Satheesh and Khan, (2009) assisted a research on seasonal variation of physico-chemical parameters in Pondicherry mangroves, southeast coast of India. They reported that the atmospheric and surface water temperature varied from 17.9°C - 41.7°C and 16.66°C -37.91°C respectively. Seasonal variation of different parameters were found as follows; salinity 6.36 ppt-36.77ppt, dissolved oxygen 3.45 mg/L-5.49 mg/L and pH 7.11-8.52. Sekar et al., (2009) conducted an analysis of seawater samples which was collected from four different sampling stations in Thoothukudi coastal area for the study of physicochemical characteristics. They found the different physical and chemical parameters by using various analytical techniques. The studies showed that the physical and chemical parameters of all the samples depend on seasonal variations. Gupta and Gupta, (2003) assisted a comparison of water quality indices for coastal water. In his study he measured different water quality parameters from the coastal area. After six years, a different researcher used multivariate analysis techniques to examine changes in the water quality along the Mumbai shoreline (Gupta et al., 2009).The study showed the variation of different water quality parameters along the Mumbai coast. In this time, he used multivariate analysis. Temperature, pH, dissolved oxygen were identified from the collected water sample along the Mumbai coast. Kamble and Vijay, (2011) identified the water quality by using cluster analysis in coastal region of Mumbai, India. He measured the temperature, dissolved oxygen and other physico-chemical parameters along the coastal region of Mumbai, India. The study showed that the coastal water quality of Mumbai was deteriorating for several reasons. Due to the sewage and industrial effluents the water quality was deteriorating frequently in that region.

There are also some notable research works about the water quality of coastal area of different countries. A study on the evaluation of the water quality and pollution index in the coastal waters of Mimika, Indonesia, was advised by (Tanjung et al., 2019). This investigation demonstrated that the water's physio-chemical characteristics were suitable for that coastal area. They identified the difference in many water quality indices and demonstrated how aquatic biota was affected. Another researcher, Abbas et al., (2008) used multivariate statistical approaches to evaluate the surface water quality of a few Malaysian estuaries. This study served as an example of the value of multivariate statistical analysis in evaluating and interpreting large data sets in order to better understand the sources of pollution and how various characteristics affect water quality in order to manage river water quality effectively. Using multivariate statistical methods, Pejman et al., (2009) assessed the geographical and seasonal fluctuations in surface water of the Haraz River basin. From the acquired water sample, he was able to identify the various water quality characteristics. Temperature, dissolved oxygen, and pH were measured, and the water quality characteristics varied during the four distinct seasons.

There are a few notable research about the impact of water quality on fish larvae of Bangladesh. Many researchers focused on the availability of plankton in the water along with water quality of that area. Though few researcher worked about the impact of water quality on fish larvae in different countries of world. Hoq et al., (2005) determined the hydrographic status of the Sundarbans mangrove in Bangladesh, paying particular attention to the abundance of post-larval and juvenile fish and shrimp. He demonstrated how the quantity of fish larvae was connected with many environmental conditions, including water quality indices. Temperature and salinity had some substantial impact on the availability of fish larvae. Kannappan et al., (2013) conducted a research on diversity of fishes in connection to physcio-chemical features of Manakudy estuary, southwest coast of India. He measured different water quality parameters and those were suitable for fish larvae stocking. He also identified higher species diversity during the pre-monsoon and monsoon season. Brinda and Srinivasm, (2010) identified the diversity of fin fish larvae in vellar estuary, southeast coast of India. He measured the different water quality parameters and identified the diversity of fish larvae. He stated that the outbreak of rain and the changes in the environment act as a definite stimulant to spawning even in species. Selvam et al., (2013) found the impact of different physio chemical parameters on finfish egg diversity in south east coast of India. He identified in his study that temperature and salinity play a significant role in distribution of fin fish eggs. In coastal waters off the coast of Rekawa, Sri Lanka; Deepananda and Aresculαratne, (2013) determined the location and number of fish larvae. He emphasized the significance of the Rekawa Mangrove Forest as a shelter for young fish. A coastal marine reserve's variety of fish larvae was evaluated by Guyah and Webber, (2021). He discovered that the monsoon season had the highest concentration of fish larvae due to the best environmental conditions and water quality. In the mangrove estuarine area of Marudu Bay in Sabah, Malaysia, Rezagholinejad et al., (2016) demonstrated the impact of environmental factors on fish larval distribution and abundance. His research revealed a tenuous connection between environmental factors and fish larvae. He determined that the primary variable determining the distribution and abundance of fish larvae is salinity.

According to these reviewed research papers, there are a lot of information available on water quality in different coastal regions of Bangladesh. But there is no research conducted on Kumira about the water quality. Kumira is an important coastal area of Bangladesh because of the abundance of naturally produced fish larvae. In last few years, this is an important coastal area for naturally produced fish larvae. Many farmers are earning their livelihood by harvesting these fish larvae. Due to no research in this ecologically important coastal area, the production of fish larvae and the water quality of this area is still unknown. This study will help to identify the water quality of this ecologically important coastal area and also the impact of water quality on the availability of fish larvae.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Research Methodology

3.1.1 Sampling Area: The sampling area was near to the coastal area of Chattogram. Kumira which was highly abundance of fish larvae and many fishermen ensured their livelihood by harvesting fish larvae and finfish from there. Three stations were selected for collecting data (Figure No. 1).

Here is the name of those 3 stations with their geographical locations and the approximate distance among them was 1 km.

Station 1: (S1). 22°31´53´´ N 91°40´40´´ E

Station 2: (S2). 22°32´05´´ N 91°40´33´´ E

Station 3: (S3). 22°31´49´´ N 91°40´44´´ E

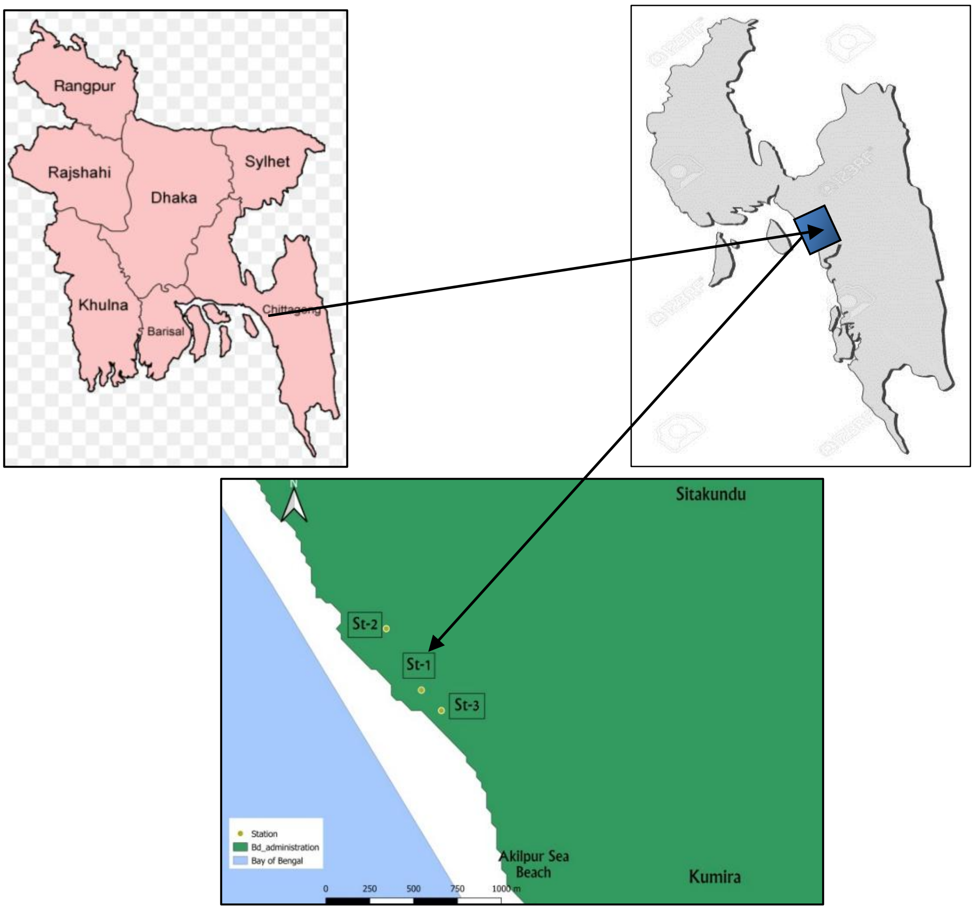

Figure No.1: Map of the sampling

3.1.2 Preparation for sampling:

Equipment were carried to the sampling stations for collecting the sample and further activities such as pH meter, DO meter, sampling jar, sampling bottle and ethanol etc. were used for measuring the water quality parameters on the spot and preserving the larvae sample.

3.1.3 Collection of sample:

Water sample was collected to measure the water quality. Shrimp and fish larvae was collected and preserved with ethanol to find the abundance of them in that coastal area and also for the determination of seasonal variation of them. The larvae sample were collected on monthly sampling period and the process was following for one year (January, 2021 – December, 2021).

3.1.4 Water quality determination

Water Temperature, pH were determined on the spot by using a Hannah pen pH meter (Model: pH100A). Dissoved oxygen, total dissolved solids, salinity were measured by utilizing DO meter (Model: DO200A), TDS meter (Model: sensION ECM), Refractometer (Model: ATC) respectively. Alkalinity, hardness, ammonia and nitrite were determined by using HACH (Model: FF-1A) test kit in the Aquatic ecology laboratory in Chattogram Veterinary and Animal Sciences University.

3.2 Laboratory Analysis

3.2.1 Alkalinity:

Alkalinity refers to the amount of titratable bases in water expressed as milligrams per liter of equivalent calcium carbonate. The presence of carbonates, bicarbonates and hydroxides is the most common cause of alkalinity in natural waters. Alkalinity is a crucial sign that water needs to be treated, as by adding time. The plastic tube initially had a full capacity of water sample. The mixing bottle was filled with the tube's contents. Phenolphthalein Indicator is added one drop at a time to the mixing bottle. Phenolphthalein Indicator was combined with the sample. Sulfuric Acid Standard Solution would be added one drop at a time if the sample turned pink. After each drop, the mixing bottle must be swirled and tallied. The procedure was carried out until the sample lost all color. The number of drops = Phenolphthalein alkalinity in grains per gallon calcium carbonate (gpg $CaCO_3$). The phenolphthalein indication was zero if the water stayed colorless. For that, the contents of Bromcresol Green-Methyl Red Indicator Powder Pillow and swirl to combine. Then, adding Sulfuric Acid Standard Solution one drop at a time, properly stirring after each addition. Drops would be applied until the sample turned pink rather than blue-green.

Calculation:

The total number of drops in both steps = Total alkalinity in gpg $CaCO_3$.

The following formula is used to determine alkalinity:

$$\text{gpg} \times 17.1 = \text{mg/L } (CaCO_3)$$

3.2.2 Ammonia:

Because of natural fish metabolism and microbial breakdown of organic waste, the presence of ammonia in fish waters is typical. Unionized ammonia (NH_3) and ammonium ion (NH_4^+) are the two forms of ammonia nitrogen that can coexist in water. Fish are poisonous to unionized ammonia, however the ammonium ion is not dangerous until it is present in extremely high concentrations. Deionized water reached the 5-mL mark in the observation tube. It served as the reagent's control. The material was poured into the second viewing tube to the 5-mL mark. It served as an organized sample. Each viewing tube received one drop of Rochelle Salt Solution, which was thoroughly mixed. Each viewing tube received three drops of Nessler Reagent, which were thoroughly mixed in. It kept 10 minutes for color development. The prepared sample goes into the right hand opening of the Color Comparator. The left-hand opening received the reagent blank. Comparator in front of a light source until the hues in the left and right windows are the same, the disc has been rotating. Read the ammonia nitrogen concentration in milligrams per liter (N) through the scale window.

Calculation:

The following equation used to express the test results as toxic ammonia (NH_3):

$$\frac{mg/L\ NH_3 as\ N\ \times value\ from\ Appendix\ III}{100} \times 1.2 = mg/L\ NH_3$$

To express result in ammonium ion (NH_4^+) the following formula is used:

$$\frac{mg/L\ NH_3 as\ N\ \times (100 - value\ from\ Appendix\ III)}{100} \times 1.3 = mg/L\ NH_3$$

3.2.3 Nitrite:

In the biological breakdown of substances containing organic nitrogen, nitrite nitrogen occurs as an intermediary stage. Because nitrates are easily converted to nitrites in aerobic environments, nitrates are rarely observed in surface waters. Fish can become highly poisonous when nitrite levels exceed their natural residual levels. The sample was washed via the viewing tube many times before being filled to the 5 mL line. One NitroVer 3 powder pillow's contents were put to a 5 mL sample. The stopper-sealed tube was shaken ferociously for exactly one minute. If nitrite was present, a pink color emerged. The prepared sample allowed to sit undisturbed for 10, but not more than 15 minutes. The tube inserted into the Color Comparator's right aperture. Using untreated sample, another tube was filled to the 5 mL point. It went into the opening on the left. Comparator was set in front of a light source. The color disc turned until the hues of the windows on the left and right were identical. The scale window's reading of mg/L nitrite-nitrogen (N).

Calculation:

The Following formula is used to determine Nitrite:

mg/L nitrite-nitrogen × 3.3 = mg/L nitrite (NO_2^-)

3.2.4 Total Hardness:

The most prevalent alkaline earth metals in natural waters are calcium and magnesium. Water's hardness is described as having a total calcium and magnesium concentration stated as their calcium carbonate equivalent. The sample completely filled the plastic measuring tube. The mixing bottle was filled with the tube's contents. Three hardness drops Buffer 1 Well-mixed after solution addition. 1-2 drops of Hardness added two test solutions and thoroughly combined. Hardness A drop of each titrant reagent was added three times. Only one drop of the solution was released every second. The side of the mixing bottle should not come into touch with the dropper. After each drop, the mixing bottle needs to be stirred. The technique was repeated until the solution's color changed from pink to blue and every drop was counted. Each drop contained as 1 grain per gallon (gpg) hardness as calcium carbonate.

Calculation:

Following formula is used to determine Hardness level:

$$gpg \times 17.1 = mg/L \text{ hardness}$$

3.2.5 Larvae Collection

The larvae were collected by using push net in the morning. After collecting larvae, they were separated in a pot by using small spoon. It was done for identifying the different finfish and crustaceans larvae. The collected larvae samples were categorized in two different types. Finfish and crustaceans larvae were counted and preserved with 90% ethanol.

3.3 Data analysis and interpretation

Finally collected data was analyzed by using SPSS (version-25) and Microsoft Excel (Version-16). Larvae availability was correlated with the water quality parameters.

CHAPTER FOUR

RESULTS

4.1 Water Quality Parameters

Water quality comprising temperature, pH, dissolved oxygen, total dissolved solids, salinity, alkalinity, ammonium ion, toxic ammonia, nitrite and total hardness were measured during the investigation of each site. The ranges of the values of water quality parameters and fish larvae are as following-

4.1.1 Temperature:

Temporal Variation: The highest temperature was recorded 30.97ºC in February and lowest temperature was recorded 23.53 ºC in January (Figure No. 2). The minimum and maximum value of temperature was 22.5 ºC and 31.8 ºC. The mean value for temperature was recorded 28.39 ºC.

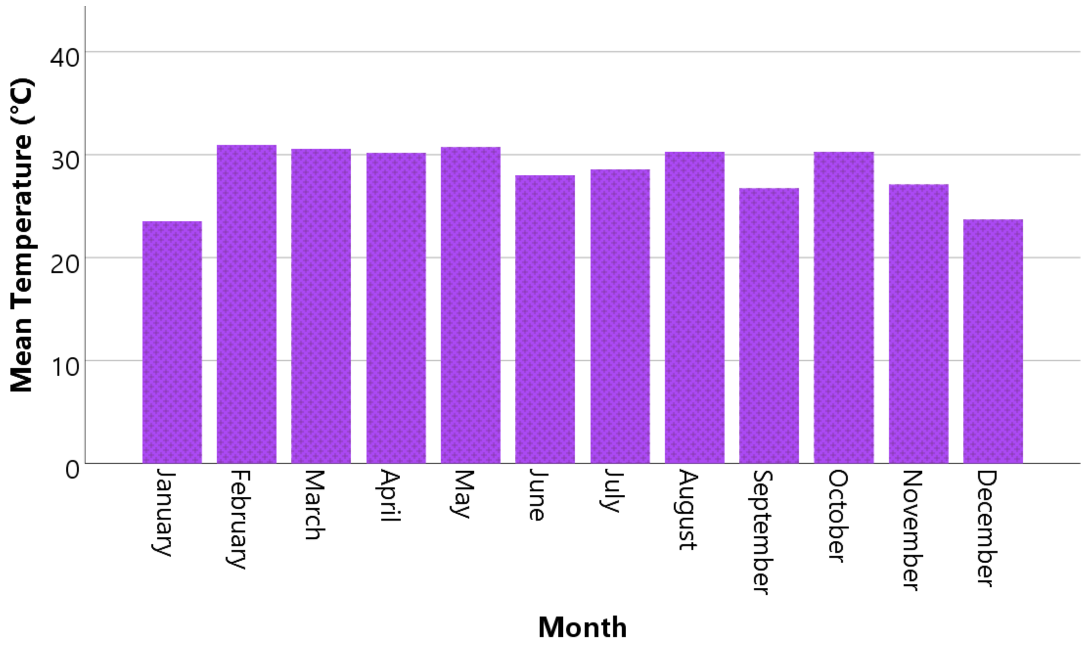

Figure No. 2: Monthly variation of temperature

Spatial Variation: The mean temperature ranged 28.408±2.8653 ºC, 28.258±2.6756 ºC, 28.492±2.6746 ºC in Station 1, Station 2, and Station 3 of Kumira respectively (Figure No. 3).

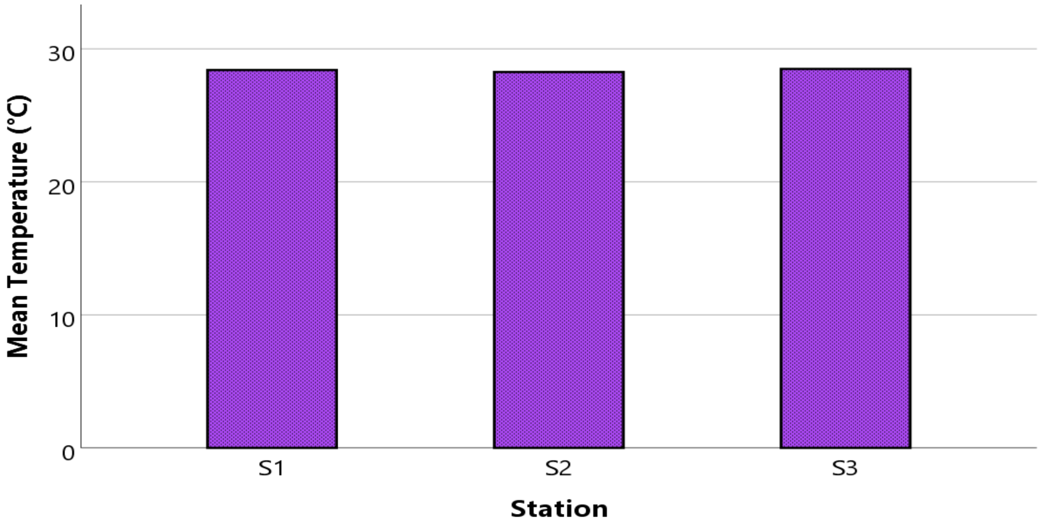

Figure No. 3: Spatial variation of temperature

4.1.2 pH:

Temporal Variation: The highest and lowest value of pH was recorded 8.707 in August and 6.977 in October respectively (Figure No. 4). The minimum and maximum value of pH was 6.94 and 9.17. The mean value of pH was 7.906.

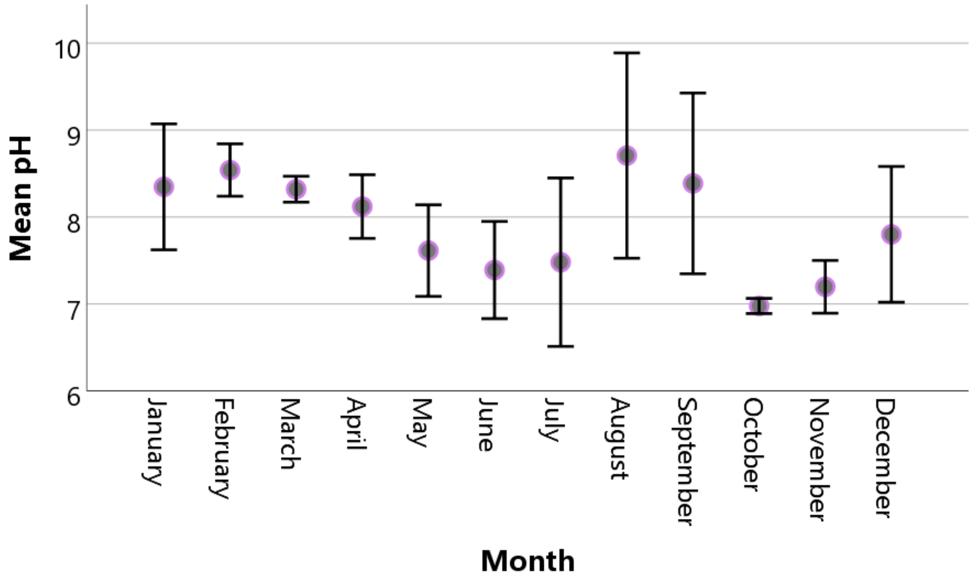

Figure No. 4: Monthly variation of pH

Spatial Variation: The mean value of pH was found 7.768±0.468, 7.911±0.651, 8.040±.678 in Station 1, Station 2 and Station 3 of Kumira respectively (Figure No. 5).

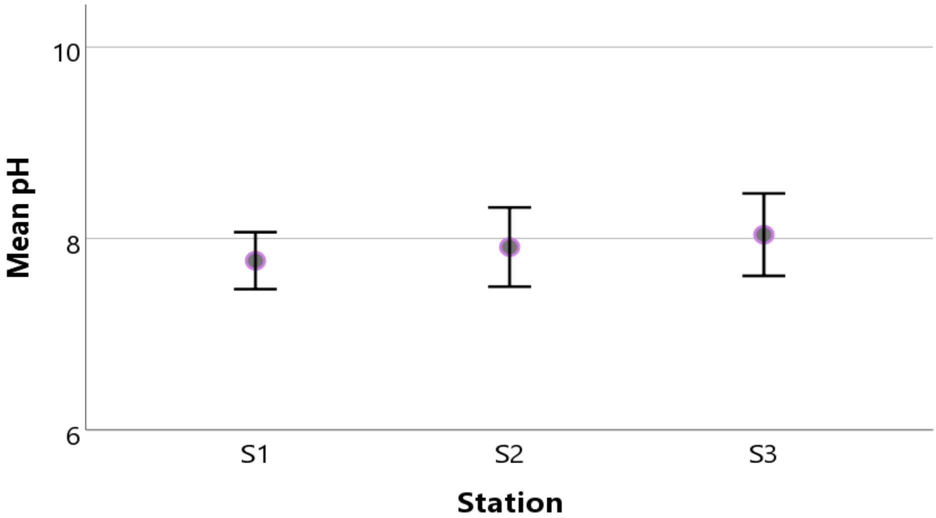

Figure No. 5: Spatial variation of pH

4.1.3 Dissolved Oxygen:

Temporal Variation: The highest and lowest value of dissolved oxygen was recorded 6.113 mg/L in June and 4.327 mg/L in December respectively (Figure No. 6). The minimum and maximum value of dissolved oxygen was 3.94 mg/L and 6.44 mg/L. The mean value of dissolve oxygen was 5.134 mg/L.

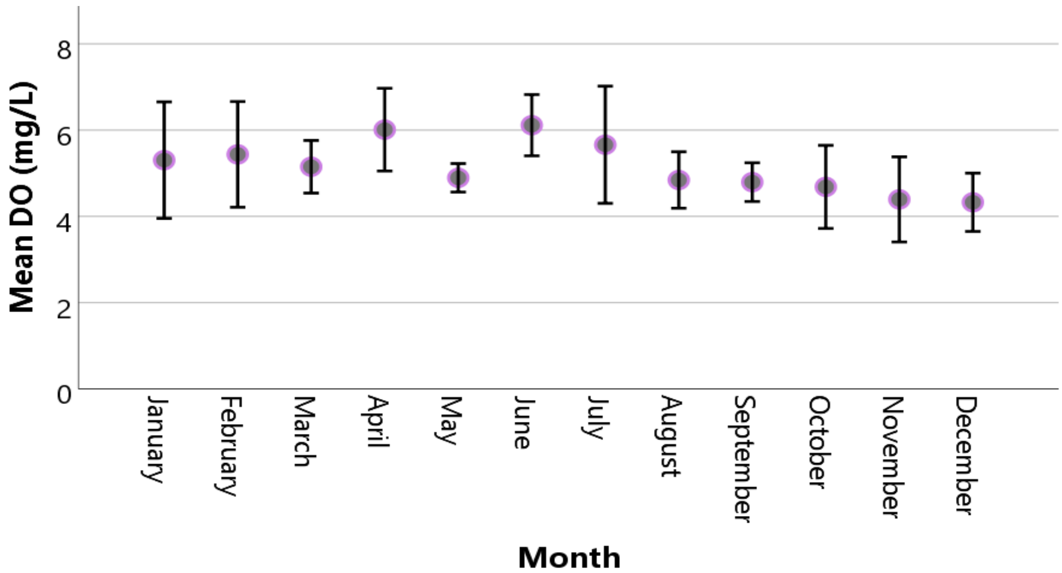

Figure No. 6: Monthly variation of dissolved oxygen

Spatial Variation: The mean value of dissolved oxygen was found 5.088±0.557 mg/L, 5.125±0.713 mg/L, and 5.189±0.711 mg/L in Station 1, Station 2, and Station 3 of Kumira respectively (Figure No. 7).

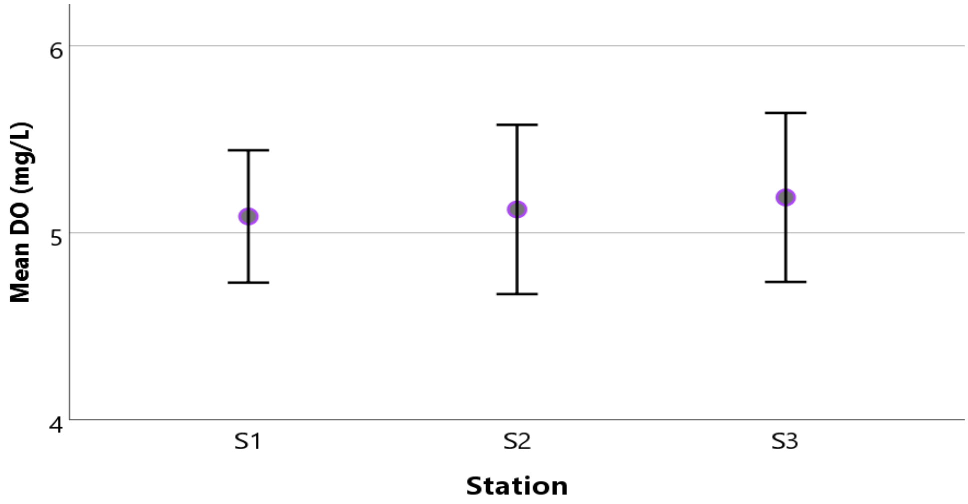

Figure No. 7: Spatial variation of dissolved oxygen

4.1.4 Total Dissolved Solids:

Temporal Variation: The highest and lowest value of total dissolved solids was recorded 5.243 g/L in May and 2.267g/L in October respectively (Figure No. 8). The minimum and maximum value of total dissolved solids was 1.45g/L and 6.56g/L. The mean value of total dissolved solids was 3.736g/L.

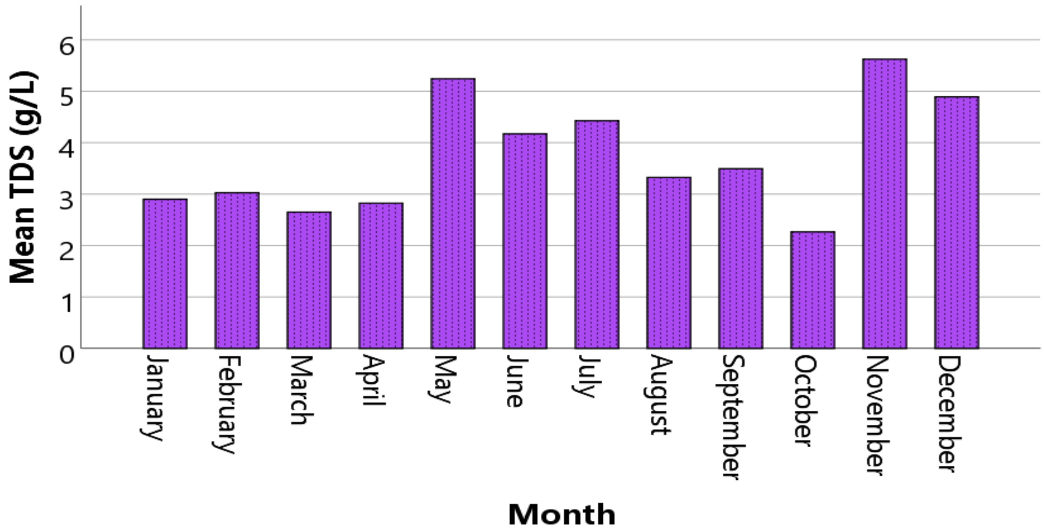

Figure No. 8: Monthly variation of total dissolved solids

Spatial Variation: The mean value of total dissolved solid was found 3.566±1.177 g/L, 4.006±1.454 g/L, and 3.638±1.364 g/L in Station 1, Station 2 and Station 3 of Kumira respectively (Figure No. 9).

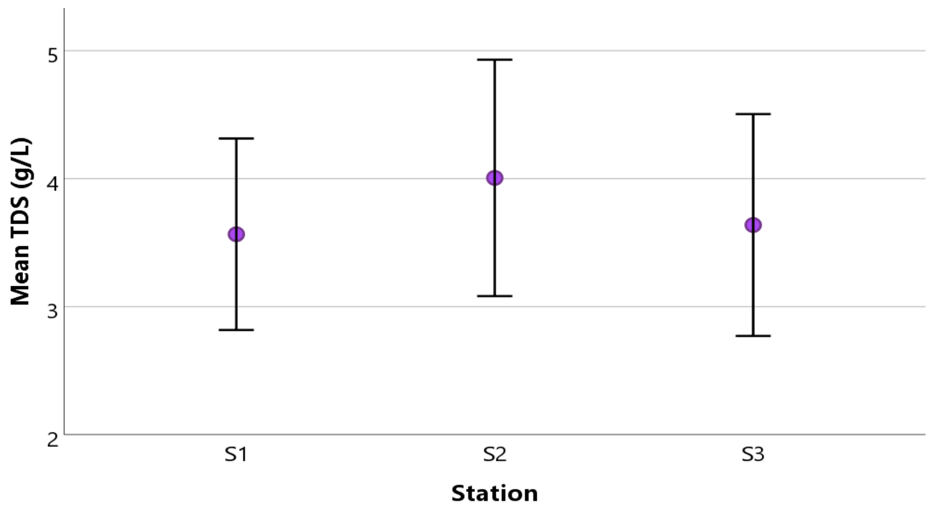

Figure No. 9: Spatial variation of total dissolved solids

4.1.5 Salinity:

Temporal Variation: The highest and lowest value of salinity was recorded 14.67 ppt in November and 6.33 ppt in June respectively (Figure No.10). The minimum and maximum value of salinity was 2 ppt and 16 ppt. The mean value of salinity was 11.81 ppt.

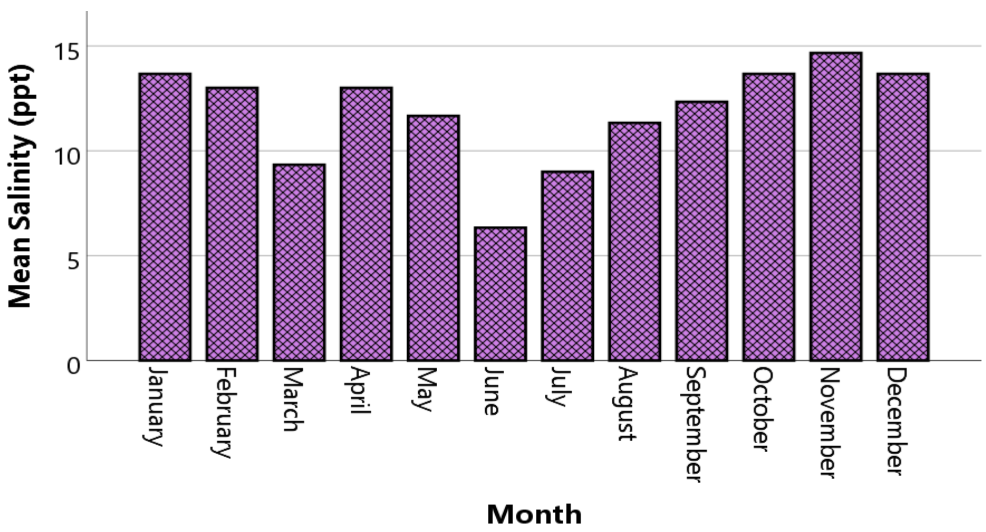

Figure No. 10: Monthly variation of Salinity

Spatial Variation: The mean value of salinity was found 12.17±4.108 ppt, 11.42±2.503 ppt, and 11.83±3.040 ppt in Station 1, Station 2 and Station 3 of Kumira respectively (Figure No.11).

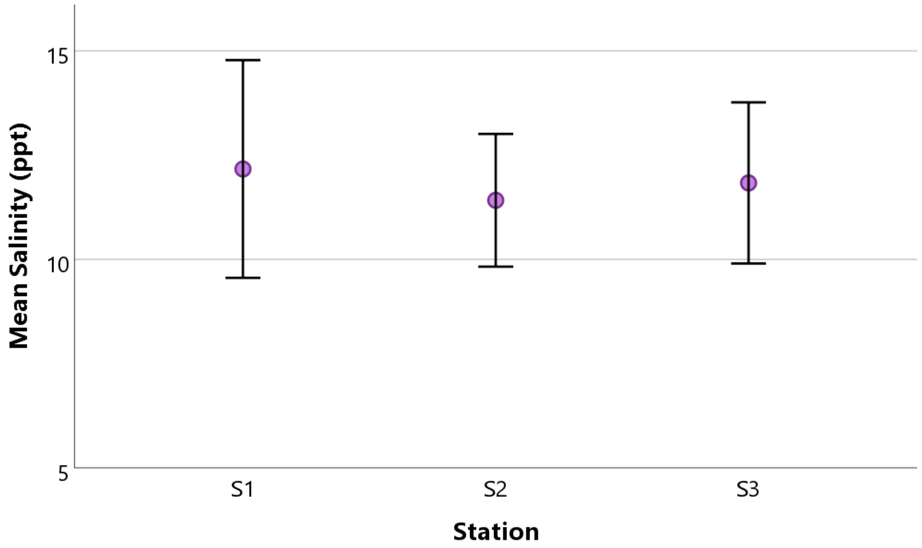

Figure No. 11: Spatial variation of Salinity

4.1.6 Alkalinity:

Temporal Variation: The highest and lowest value of alkalinity was recorded 325.767 mg/L in December and 73 mg/L in March respectively (Figure No.12). The minimum and maximum value of alkalinity was 51.3 mg/L and 369 mg/L. The mean value of alkalinity was 126.56 mg/L.

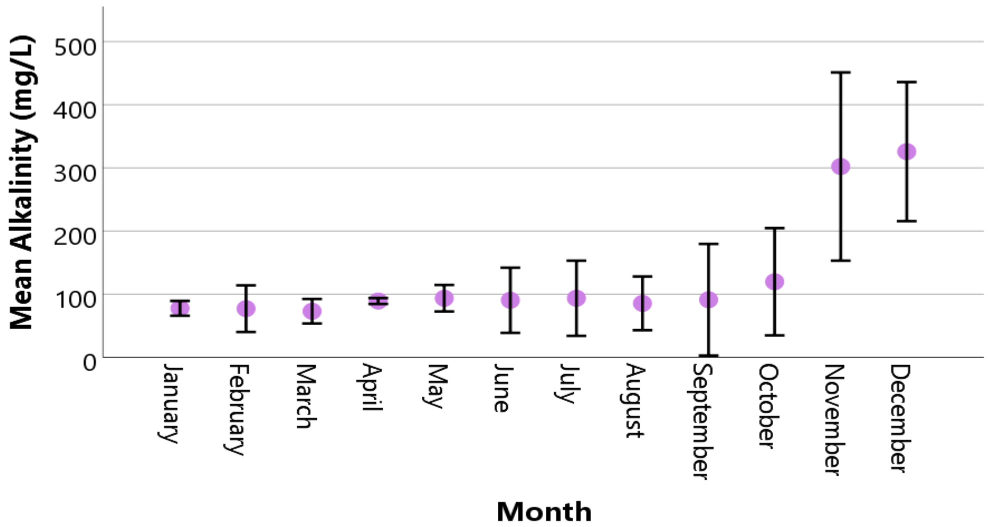

Figure No. 12: Monthly variation of alkalinity

Spatial Variation: The mean value of alkalinity was found 121.317±69.531mg/L, 123.658±92.168 mg/L, and 134.708±108.579 mg/L in Station 1, Station 2 and Station 3 of Kumira respectively (Figure No.13).

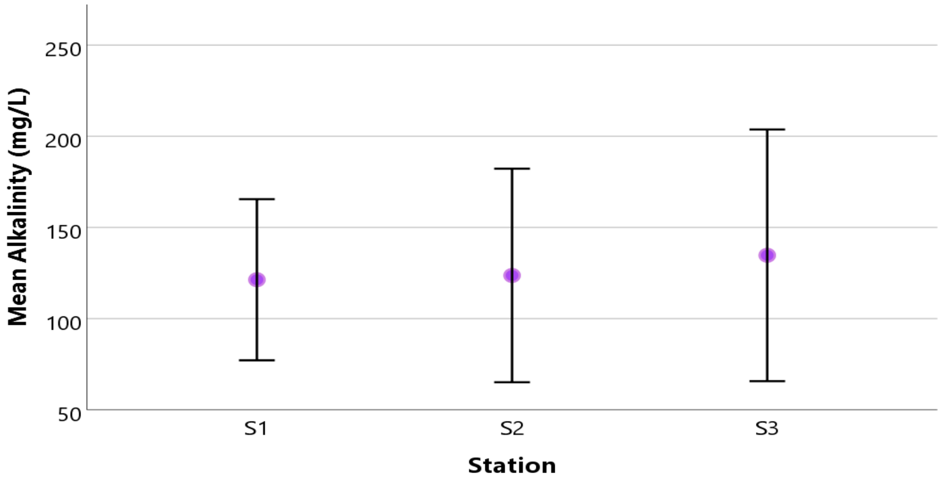

Figure No. 13: Spatial variation of alkalinity

4.1.7 Ammonium Ion:

Temporal Variation: The highest and lowest value of ammonium ion was recorded 0.770 mg/L in November and 0.0287 mg/L January respectively (Figure No.14). The minimum and maximum value of ammonium ion was 0.0224 mg/L and 1.0220 mg/L. The mean value of ammonium ion was 0.20064 mg/L.

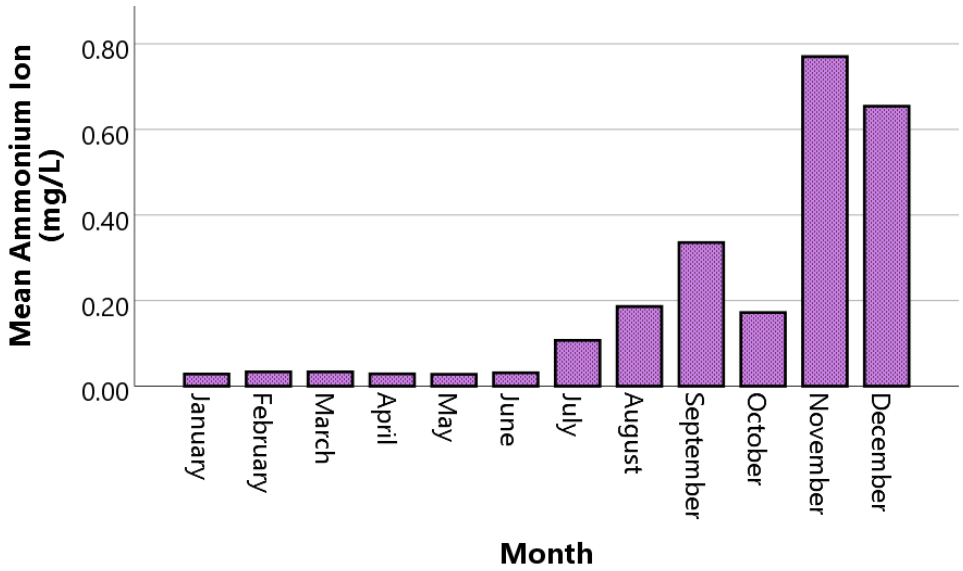

Figure No. 14: Monthly variation of ammonium ion

Spatial Variation: The mean value of ammonium ion was found 0.199±0.265, 0.187±0.204, 0.216±0.335 in Station 1, Station 2 and Station 3 of Kumira respectively (Figure No.15).

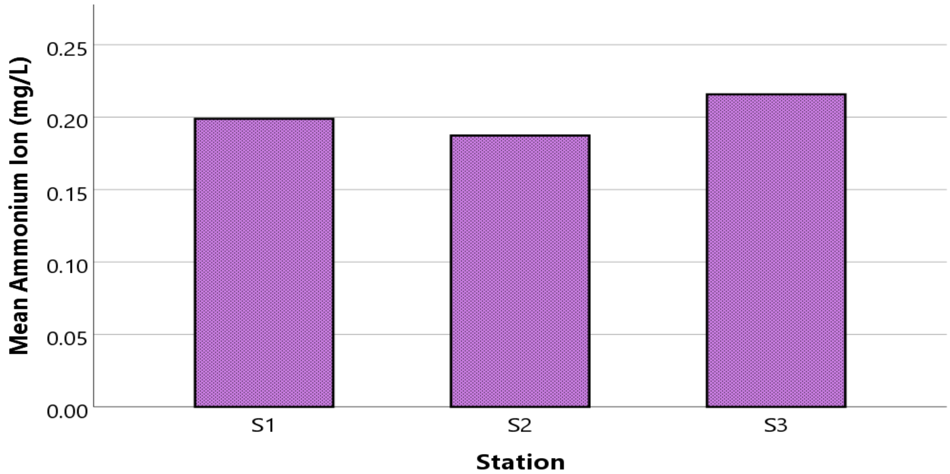

Figure No. 15: Spatial variation of ammonium ion

4.1.8 Toxic Ammonia:

Temporal Variation: The highest and lowest value of toxic ammonia was recorded 0.0351 mg/L in August and 0.00113 mg/L in October respectively (Figure No.16). The minimum and maximum value of toxic ammonia was 0.0009 mg/L and 0.0672 mg/L. The mean value of toxic ammonia was 0.01859 mg/L.

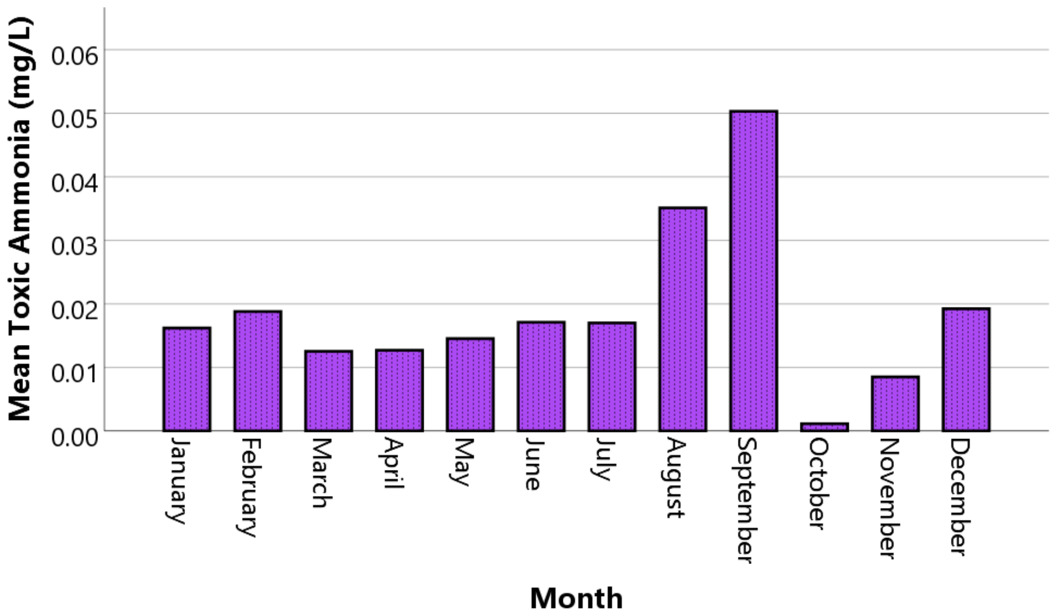

Figure No. 16: Monthly variation of toxic ammonia

Spatial Variation: The mean value of toxic ammonia was found 0.140±.007, 0.019±0.017, 0.022±0.216 in Station 1, Station 2 and Station 3 of Kumira respectively (Figure No.17).

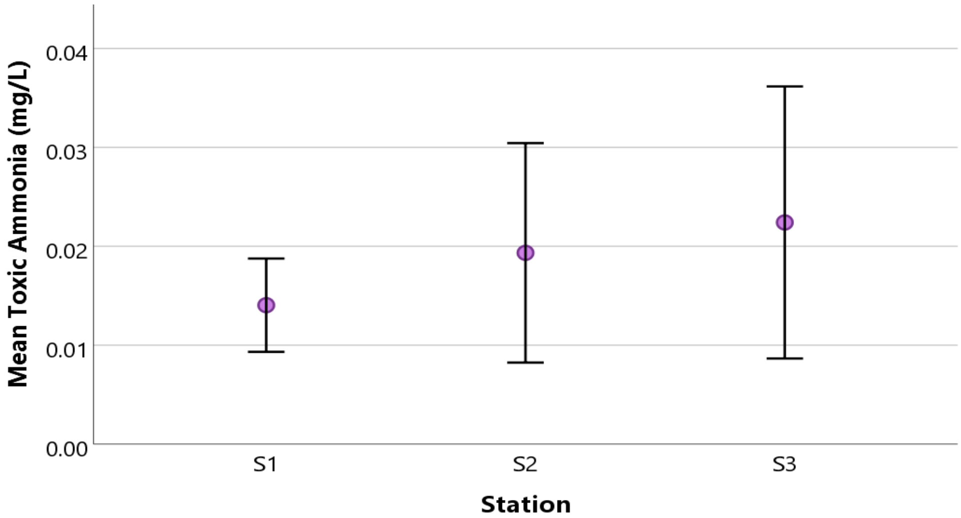

Figure No. 17: Spatial variation of toxic ammonia

4.1.9 Nitrite:

Temporal Variation: The highest and lowest value of nitrite was recorded 0.770 mg/L in November and 0.0677 mg/L in January respectively (Figure No.18). The minimum and maximum value of nitrite was 0.023 mg/L and 1.320 mg/L. The mean value of nitrite was 0.1967 mg/L.

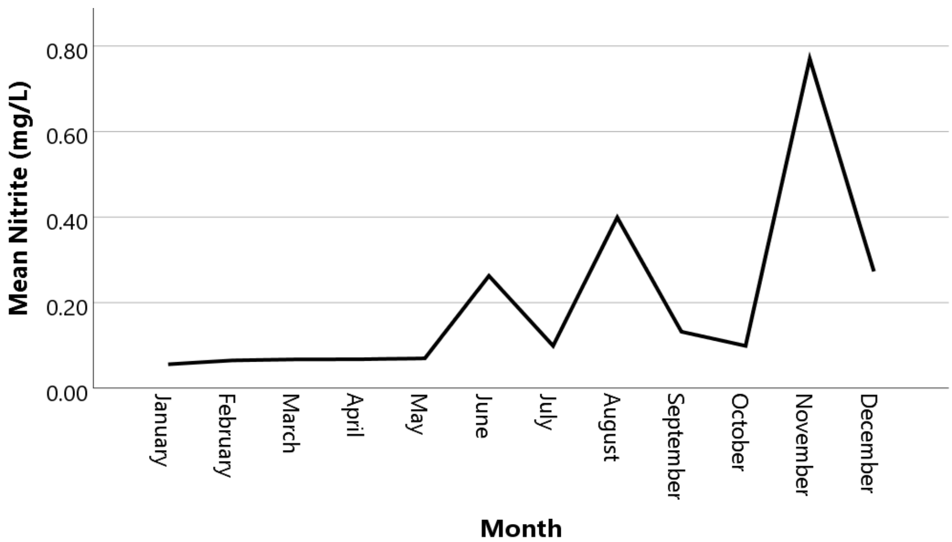

Figure No. 18: Monthly variation of nitrite

Spatial Variation: The mean value of nitrite was found 0.263±0.325, 0.189±0.388, 0.138±0.131 in Station 1, Station 2 and Station 3 of Kumira respectively (Figure No.19).

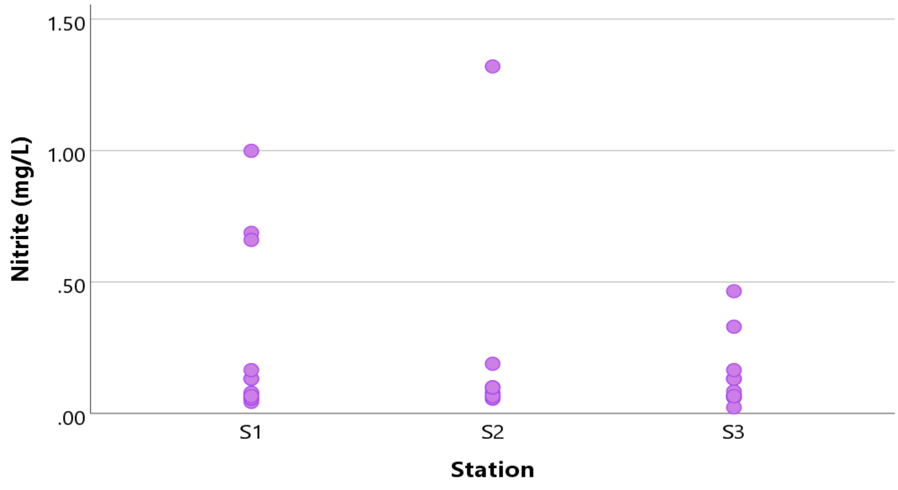

Figure No. 19: Spatial variation of nitrite

4.1.10 Total Hardness:

Temporal Variation: The highest and lowest value of total hardness was recorded 537.067 mg/L in November and 343.33 mg/L in January respectively (Figure No. 20). The minimum and maximum value of total hardness was 320.8 mg/L and 906.3 mg/L. The mean value of total hardness was 464.731 mg/L.

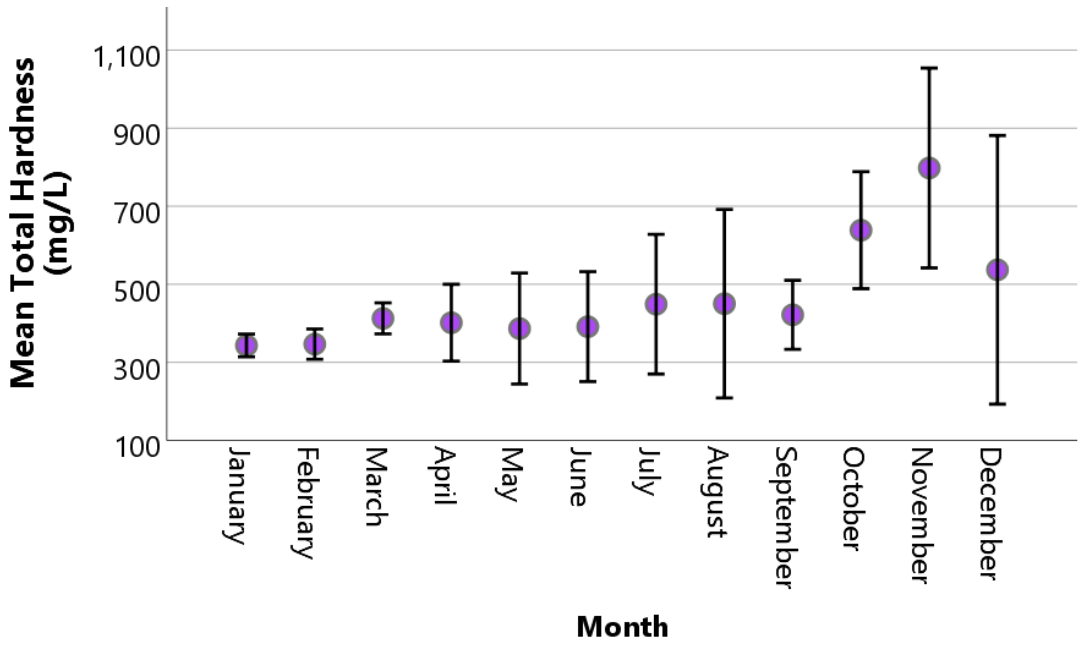

Figure No. 20: Monthly variation of total hardness

Spatial Variation: The mean value of total hardness was found 481.567±153.279 mg/L, 461.467±165.442mg/L and 451.158±112.026 mg/L in Station 1, Station 2 and Station 3 of Kumira respectively (Figure No.21).

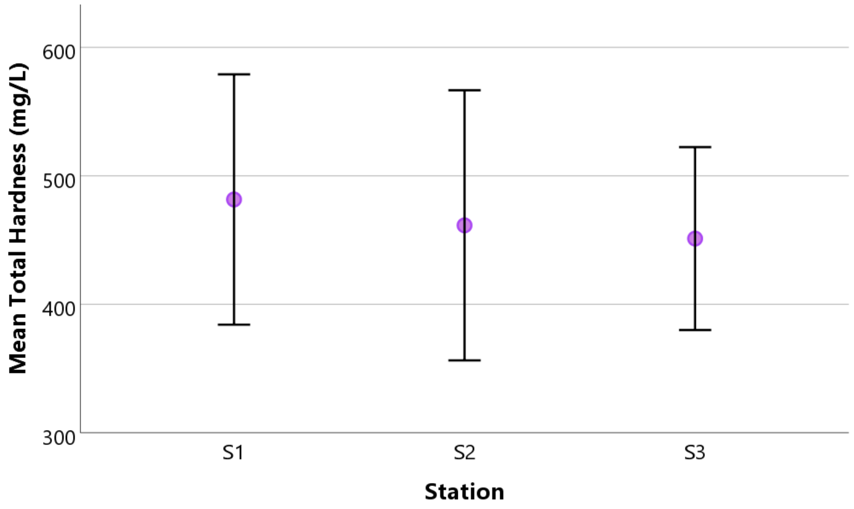

Figure No. 21: Spatial variation of total hardness

4.2 Fish larvae:

Temporal Variation: The highest amount of finfish larvae was recorded 220 in May and lowest amount is recorded 57 in December (Figure No.22). The mean value of finfish was 32.58±16.54. The highest amount of crustaceans was found 1068 in June and lowest amount is recorded 147 in January (Figure No.22). The mean value of crustaceans was 226.64±151.602.

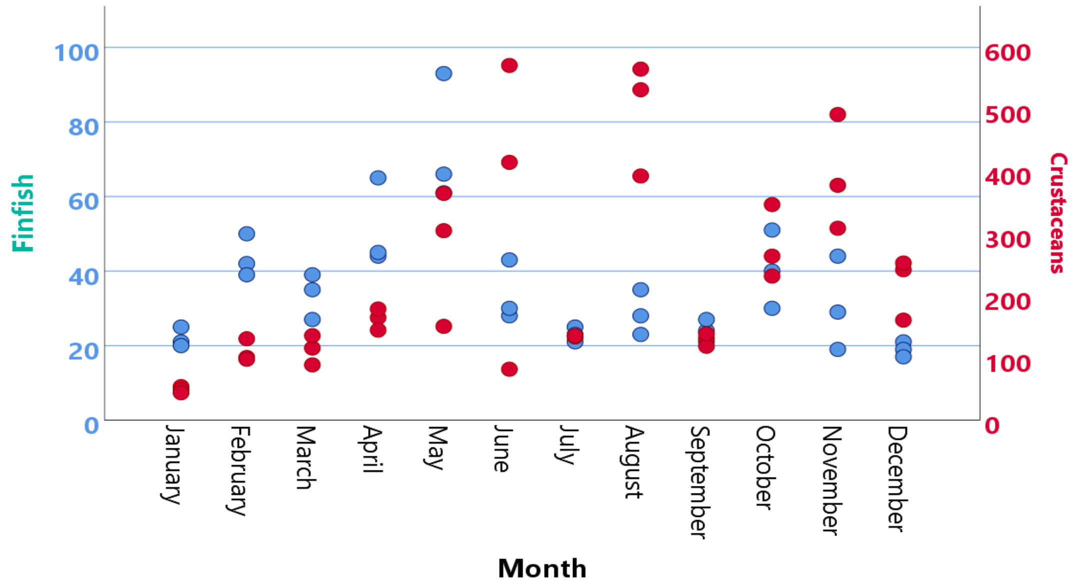

Figure. No. 22: Monthly variation of fish larvae

Spatial Variation: The highest amount of finfish and crustaceans larvae was recorded in station 2; lowest amount of finfish was found in station 1 and lowest amount of crustaceans was found in station 3 (Figure No.23).

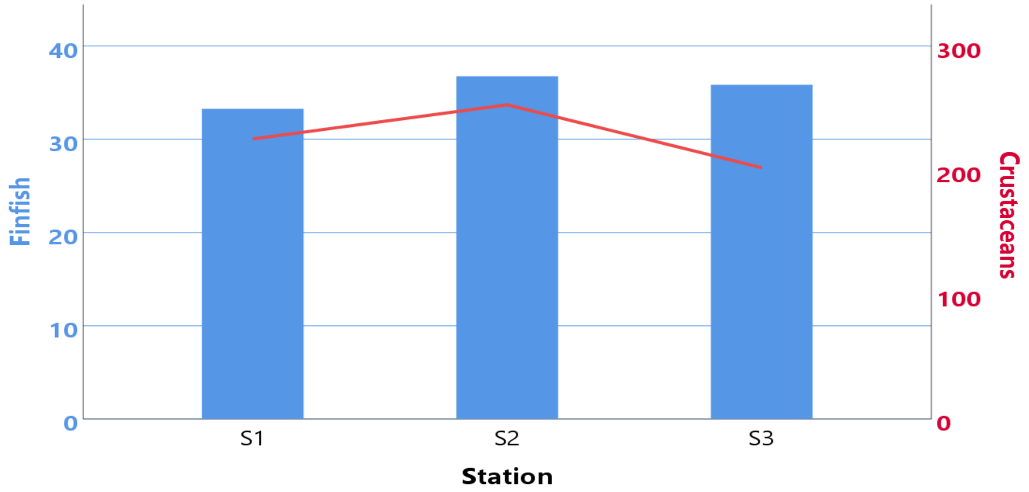

Figure. No. 23: Spatial variation of fish larvae

4.3 Relationship between different water quality parameters and fish larvae: Crustaceans showed positive relationship with finfish. Dissolved oxygen showed positive relationship with finfish and dissolved oxygen. Total dissolved solids showed positive relationship with finfish and crustaceans. Temperature showed positive relationship with crustaceans, pH, and dissolved oxygen. Toxic ammonia, ammonium ion, alkalinity and total hardness showed positive relationship with crustaceans. Temperature showed weak relationships with finfish larvae. Toxic ammonia showed positive relationships with pH. Ammonium ion showed strong positive relationship with TDS. Nitrite showed moderately positive relationship with crustaceans. Nitrite showed strong positive relationship with ammonium ion. Alkalinity showed strong positive relationship with TDS and ammonium ion. Alkalinity showed moderately positive relationship with nitrite. Total hardness and salinity showed positive relationship with total dissolved solids. Total hardness showed strong positive relationship with ammonium ion, nitrite and alkalinity. Salinity showed positive relationship with finfish, total hardness and nitrite. Salinity showed moderately positive relationship with ammonium ion and alkalinity. Finfish showed negative relationship with pH, toxic ammonia, ammonium ion, nitrite, alkalinity and total hardness. Crustaceans showed negative relationship with pH, dissolved oxygen and salinity.

Table No.1: Correlation between different water quality parameters with larvae

Parameters	Finfish	Crustaceans	pH	DO	TDS	Temperature	Toxic Ammonia	Ammonium Ion	Nitrite	Alkalinity	Total Hardness	Salinity
Finfish	1											
Crustaceans	.113	1										
pH	-.061	-0.199	1									
DO	.120	-.206	.120	1								
TDS	.030	.307	-.405*	-.157	1							
Temperature	.594**	.206	.032	.208	-.208	1						
Toxic Ammonia	-.173	.044	.578**	-.003	-.122	-.123	1					
Ammonium ion	-.340*	.306	-.263	-.663**	.499**	-.466**	-.015	1				
Nitrite	-.312	.367*	-.243	-.242	.336*	-.132	-.062	.456**	1			
Alkalinity	-.229	.302	-.349*	-.553**	.501**	-.463**	-.138	.844**	.446**	1		
Total Hardness	-.227	.329	-.550**	-.528**	.279	-.101	-.268	.669**	.570**	.622**	1	
Salinity	.023	-.013	-.001	-.279	.144	-.209	-.036	.343*	.002	.334*	.254	1

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

The relationship of finfish and crustaceans among the temperature, pH and salinity were shown in this figure below. Temerature showed strong positive relationship with finfish and salinity showed moderate correlation with finfish. In crustaceans, temperature showed moderate relation with temperature (Figure No.24). pH and salinity showed reverse relationship with finfish and crustaceans larvae. Temperature fluctuation showed some drastical change in the availability of finfish larvae.

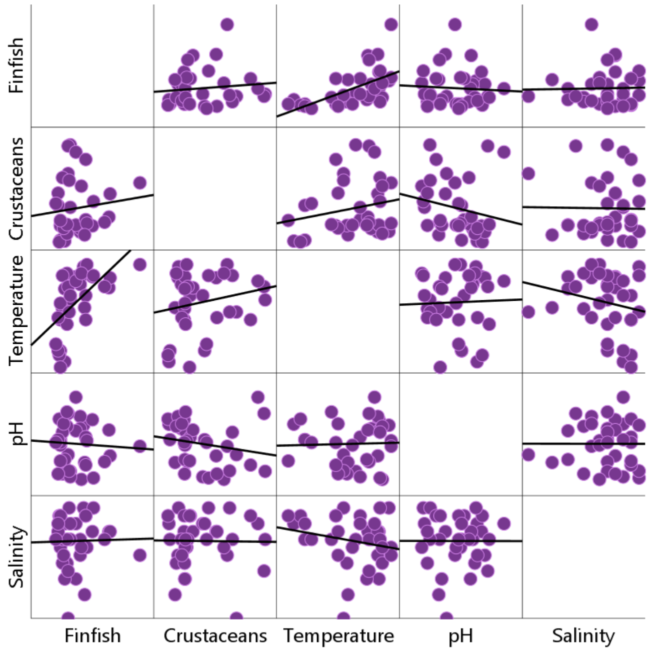

Figure. No. 24: Relationship between different water quality parameters (Temperature, pH, Salinity) with larvae (Finfish and Crustaceans)

Dissolved oxygen and total dissolved solids showed moderate relation with the finfish larvae. Nitrite showed strong positive relationship with crustaceans larvae; total dissolved solids showed moderate relation with crustaceans (Figure No.25). Nitrite showed reverse relation with finfish larvae that might happen due to the deterioration of water quality. Dissolved oxygen also showed negative impact on crustaceans.

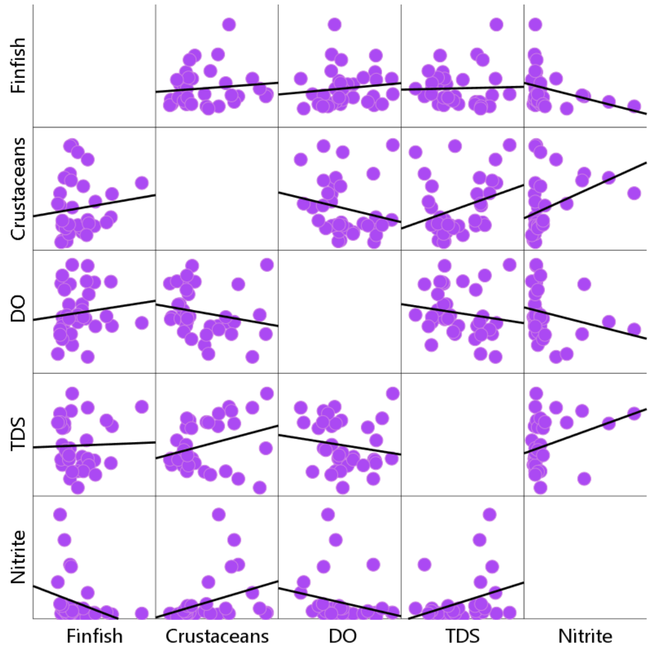

Figure. No. 25: Relationship between different water quality parameters (Dissolved oxygen, Total dissolved solids, Nitrite) with larvae (Finfish and Crustaceans)

Ammonium ion, toxic ammonia, alkalinity and total hardness showed moderate relationship with crustaceans (Figure No.26). But all of them showed weak relationship with finfish larvae.

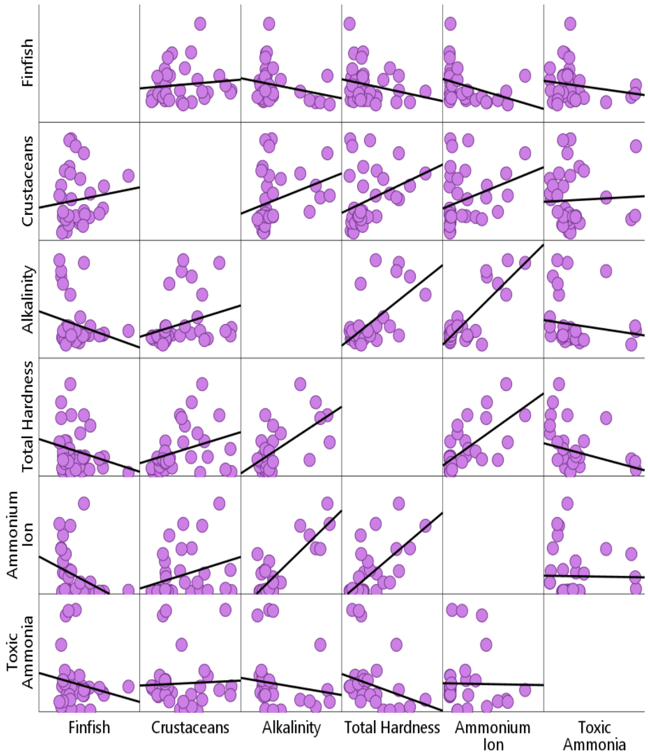

Figure. No. 26: Relationship between different water quality parameters (Alkalinity, Total hardness, Ammonium ion, Toxic ammonia) with larvae (Finfish and Crustaceans)

CHAPTER FIVE

DISCUSSION

Whether in a natural or artificial context, water quality is a key component in the formation of fish larvae. The overall generation of larvae in a given location may be impacted by changes in the various water quality criteria. There is a connection between fish larvae and the water quality measures. A comparative discussion of water quality parameters along with the collection of fish larvae from the coastal area of Kumira, Chattogram are given below.

5.1 Water quality parameters

5.1.1 Temperature

The location and quality of the habitat for aquatic life can be affected by water temperature, which has a significant impact on the aquatic system. The metabolic rates of fish and the rate of photosynthesis in aquatic plants can both be influenced by water temperature. The distribution and mixing of nutrients as well as ocean circulation patterns are both significantly influenced by water temperature. The mean temperature was found 28.41 ºC, 28.26 ºC, 28.49ºC in selected three locations of Kumira. The highest temperature was recorded in pre-monsoon (30.97ºC) and lowest in dry winter (23.53 ºC). The temperature of selected three sites of Kumira showed same variation with earlier reported works in Bangladesh coastal area conducted by Das et al., (2002). He reported temperature variation between 25-30^{0} C with a marked seasonal fluctuations. Temperature variations were significantly higher in the pre monsoon months due to the higher air temperature while lower recorded in winter due to lower air temperature and local climate condition.

5.1.2 pH

pH is a measurement of electrically charged particles in a substance. It is one of the most crucial water chemistry parameters and is expressed as the degree of acidity or alkalinity on a scale from 0 to 14. The mean value of pH was found 7.77, 7.91 and 8.04 in three different locations of Kumira. The highest value of pH was recorded in monsoon (8.707) and lowest in the end month of monsoon (6.977). The present study findings showed the pH range was in optimal condition. It showed the same pH range which was found by Miah et al., (2015) in the coastal region of Bangladesh.

Temperature, salinity, and biological activity variations cause the pH concentration to fluctuate over time. Due to the rain, the pH value is higher and lower during the monsoon.

5.1.3 Dissolved oxygen

The quantity of oxygen in water is known as dissolved oxygen. Water bodies acquire oxygen from the atmosphere and from aquatic plants. For marine life to exist, there must be dissolved oxygen. The mean value of dissolved oxygen was found 5.09 mg/L, 5.13 mg/L, and 5.20 mg/L in selected three stations of Kumira respectively. The highest value of dissolved oxygen was recorded in monsoon (6.113 mg/L) and lowest in winter (4.327 mg/L). In the present study the range of dissolved oxygen was similar to the findings of Kashem and Nahian (2019). He stated the standard for any purpose in terms of dissolved oxygen is 4.0 mg/L to 6.0 mg/L. For sustaining aquatic life the amount of dissolved oxygen should be 4 mg/L, Iqbal (2012) also stated that for drinking purpose it is 6 mg/L. Dissolved oxygen range could fluctuate due to the lower temperature and for the local climate condition.

5.1.4 Total dissolved solids

Total dissolved solids (TDS) is a measurement of the total amount of inorganic and organic compounds that have been dissolved and are suspended as molecular, ionized, or microgranular particles in a liquid. Higher concentrations of total dissolved solids frequently affect aquatic animals in water bodies like rivers. Numerous creatures depend on the mineral content of water, which is altered by TDS. The mean value of total dissolved solid was recorded 3.57 g/L, 4.00 g/L, and 3.64 g/L in three different selected stations of Kumira respectively. The highest value of total dissolved solids was recorded in pre monsoon (5.24 g/L) and lowest in the monsoon (2.267g/L). Kashem and Nahian (2019) stated that the value of total dissolved solids for coastal water should be ranged from 2.96 mg/L to 3.20 mg/L. In present study the value of total dissolved solids were in this range for three different selected stations. Due to agricultural runoff, soil pollutant leaching, and point source water pollution released by industrial or sewage treatment plants, it varies in some months.

5.1.5 Salinity

The saltiness or quantity of dissolved salt in a body of water is known as salinity. The mean value of salinity was recorded 12.17 ppt, 11.42 ppt, and 11.83 ppt in selected three stations of Kumira respectively. The highest value of salinity was recorded in winter (14.67 ppt) and lowest in monsoon (6.33 ppt). Rainfall, fresh water inflow, tidal flooding, evapotranspiration, soil type, and vegetation are some examples of the variables that affect how salty surface water is. (Vernberg, 1993). In present study, the value salinity is higher in winter due to the lower amount of rainfall and salinity is lower when the rainfall is higher in monsoon season.

5.1.6 Alkalinity

Alkalinity is a component of conductivity that is crucial for maintaining the ideal pH in the recirculating system and feeding bicarbonate ions to the nitrification operations. The mean value of alkalinity was found 121.32 mg/L, 123.66 mg/L, and 134.71 mg/L in selected three stations of Kumira respectively. The highest value of alkalinity was recorded in dry winter (325.767 mg/L) and lowest in pre-monsoon (73 mg/L). Alkalinity has positive correlation with with pH and salinity. pH value increase with salinity. The higher the pH of the water, the alkalinity amount is higher and it contains more lime (Wong, 1979). In present study, the alkalinity is higher in the dry winter and lower in the pre monsoon. It fluctuates due to the rainfall in pre monsoon and monsoon.

5.1.7 Ammonia

Ammonia is a poisonous substance that can harm fish health. The chemical composition of the ammonia, the pH and temperature of the water, the duration of exposure, and the life stage of the exposed fish are only a few of the variables that affect the type and level of toxicity. Ammonium ion and toxic ammonia have been analyzed. The mean value of ammonium ion was found 0.199 mg/L, 0.187 mg/L and 0.216 mg/Lin three selected stations of Kumira respectively. The highest value of ammonium ion was recorded in starting of winter (0.770 mg/L) and lowest in dry winter (0.0287 mg/L). The mean value of toxic ammonia was found 0.140 mg/L, 0.019 mg/L and 0.022 mg/L in selected three stations of Kumira respectively. The highest value of toxic ammonia was recorded in monsoon (0.0351 mg/L) and lowest in the ending of monsoon (0.00113 mg/L). Sharif et al. (2003) identified the ammonia content was 1.03 mg/L in the Bakkhali river water, which was higher than the present study. According to (Environmental Conservation Rules, 1997), the standard of ammonia is less than 0.5 mg/L for surface water, and the stated that ammonia contents of all the three stations of coastal surface water were lower than the standard level.

5.1.8 Nitrite

Nitrite is a chemical that nitrifying bacteria in soil and water use to convert ammonia nitrogen to nitrate. In anaerobic sediment or water, it can also be a byproduct of denitrifying bacteria. In the presence of dissolved oxygen, nitrite eventually undergoes oxidation to become nitrate. The mean value of nitrite was found 0.263 mg/L, 0.189 mg/L and 0.138 mg/L in three selected stations of Kumira respectively. The highest value of nitrite was recorded in the starting of dry winter season (0.770 mg/L) and lowest in dry winter (0.0677 mg/L). Shefat and Chowdhury (2020) stated that the nitrite range for coastal area is between 0.1 mg/L to 0.4 mg/L. In present study the value of nitrite range is similar and it fluctuates in different season. The fluctuations of nitrite may occur due to the fertilizers through run-off water, sewage, and mineral deposits.

5.1.9 Total hardness

Compounds of calcium and magnesium, as well as a number of other metals, contribute to hardness. When animals suddenly switch from hard to soft water, morbidity and mortality ensue. The mean value of total hardness was found 481.57mg/L, 461.47 mg/L and 451.16 mg/L in three different stations of Kumira respectively. The highest value of total hardness was recorded in the end of monsoon season (537.067 mg/L) and lowest in dry winter (343.33 mg/L). ECR (1997) and WHO (2006) suggested acceptable limit for hardness is 200mg/L to 500 mg/L and 500 mg/L respectively. In present study, the value of total hardness is in this limit.

5.2 Fish Larvae

The world's most productive ecosystems are shallow-water marine environments, which produce a variety of crucial ecological and economic services, including fisheries. Shallow-water habitats are frequently the dominant and crucial habitats for fish in tropical coastal seascapes, sustaining a high number and diversity of fish at various life stages. The maximum amount of finfish larvae was recorded in pre monsoon season (220); but the maximum amount of crustaceans was recorded in monsoon season (1068). Because of the climate change, the rainfall occurred before the monsoon season, which stimulated the finfish to spawn in pre monsoon season. Rainfall was also an important factor and the water quality parameters were in optimal condition in the pre monsoon and monsoon period, which help the fishes to spawn. In the salt marsh area of the Guadiana Estuary, Goncalves et al., (2015) discovered the peaks of fish larvae abundance on the pre-monsoon period. The minimum amount of finfish larvae was found in post monsoon (57); the minimum amount of crustaceans was found in pre monsoon (147) in our selected three stations of Kumira. The amount of larvae was reduced in post monsoon because of the water quality fluctuation and environmental changes. The sensitivity of first-feeding larvae to high pH and dissolved oxygen may present risks for the marine fish farmer, according to Brownell et al. (1980); low pH appears to be hazardous only at values below roughly pH 6.0. pH occasionally varied in this range during the length of our investigation. According to Stiff et al. (1992), fish and crustaceans are the most vulnerable to low dissolved oxygen levels, with young fish being especially vulnerable. They recommended a minimal dissolved oxygen requirement of 3–5 mg/L for estuary fish. Dissolved oxygen range also fluctuated in post monsoon period in our study. According to Frodge et al. (1990), sensitive species like fish and invertebrates suffer when dissolved oxygen levels drop below 5 mg/L. Most fish species suffered harm when dissolved oxygen levels fell below 2.5 mg/L. Depending on the species, temperature, and pH, ammonia is harmful for marine animals when its concentration is between 0.09 and 3.35 mg/L. When ammonia levels abruptly change, toxic effects can be difficult to foresee (Handy and Poxton, 1993). In our study, water quality parameters showed some gradual change in different season due to the several environmental factors.

CHAPTER SIX
CONCLUSIONS

Coastal area is important for fish larvae; it provides shelter, good environmental and water quality for them to live their early stages of life. The present investigation summarizes the fluctuations of different water quality parameters and their impact on fish larvae. In this study, collected information showed the water quality parameters from the coastal region of Kumira, Chattogram, including temperature, pH, dissolved oxygen, salinity, total dissolved solids, ammonia, nitrite, alkalinity, and total hardness. It is clearly evidenced that these water quality parameters fluctuated in different season. They also had impact on fish larvae. Water quality fluctuation showed several impact on fish larvae in different season. Fin fish and crustaceans larvae showed different correlation with the different water quality parameters.

Thus, the overall study gives a good outline of the water quality parameters in the coastal area of Kumira. This study also gives information about the fin fish and crustaceans larvae. This type of research work is time relevant and to know the overall larvae condition, the fluctuation of the water quality on that coastal whole area is needed. It will help to know the overall condition of that area and that will be helpful for bringing management policy. However, further analysis is needed to make a concrete comment on the impact of water quality on the availability of fish larvae at Kumira, coastal area of Chattogram.

CHAPTER SEVEN

RECOMMENDATIONS AND FUTURE PERSPECTIVES

The present investigation revealed data about the water quality parameters and their relation with fish larvae at coastal area of Kumira, Chattogram. However, this study had some limitations. Investigation of the resources in coastal water body is time consuming and cost intensive. The major limitations of the research work were the unpredictability of the weather, lack of time, transportation problem etc. If there were time and facilities the study could be more efficient. Therefore considering the limitations and importance of coastal waters following criterion are recommended.

- Proper transportation facilities and other support will help to conduct research more precisely and accurately.
- There should be more sampling area to gain the average condition of that area about the availability of larvae.
- The government could take management policy for maintaining the condition of that ecologically important area and for that reason this research will be helpful.

The result of the present study could be used as a guideline for further studies as seasonal variability in water quality parameters, assessment of pollution level, variation of availability in fish larvae, impact of environmental changes in fish larvae in the coastal area of Kumira, Chattogram.

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APPENDICES

Appendix I: Water Quality Parameters

(A)Temporal Variation of Water Quality Parameters:

Month		pH	DO (mg/L)	TDS (g/L)	Temperature (°C)	Toxic Ammonia (mg/L)	Ammonium Ion (mg/L)	Nitrite (mg/L)	Alkalinity (mg/L)	Total Hardness (mg/L)	Salinity (ppt)
January	Mean ±SD	8.35± 0.29	5.30± 0.54	2.90± 0.18	23.53± 0.50	0.0162± 0.0009	0.0284 ± 0.0039	0.0560 ± 0.0120	77.60 ± 4.73	343.33 ± 11.72	13.7 ± 1.5
February	Mean ±SD	8.54± 0.12	5.44± 0.49	3.03± 0.10	30.97± 0.55	0.0188± 0.0043	0.0334 ± 0.0040	0.0650 ± 0.0115	77.10 ± 14.87	346.63 ± 15.58	13.0 ± 3.0
March	Mean ±SD	8.32± 0.06	5.15± 0.25	2.65± 0.32	30.57± 0.51	0.0125± 0.0022	0.0334 ± 0.0060	0.0673 ± 0.0061	73.00 ± 7.81	412.57 ± 16.01	9.3 ± 2.5
April	Mean ±SD	8.12± 0.15	6.01± 0.39	2.82± 0.19	30.17± 1.46	0.0127± 0.0018	0.0287 ± 0.0061	0.0677 ± 0.0106	89.23 ± 1.89	401.50 ± 39.63	13.0 ± 2.0
May	Mean ±SD	7.61± 0.21	4.89± 0.13	5.24± 0.54	30.73± 1.01	0.0145± 0.0029	0.0278 ± 0.0068	0.0697 ± 0.0132	93.60 ± 8.44	386.57 ± 57.23	11.7 ± 1.5
June	Mean ±SD	7.39± 0.23	6.11± 0.29	4.17± 2.32	28.00± 0.56	0.0171± 0.0063	0.0313 ± 0.0050	0.2627 ± 0.3685	90.40 ± 20.78	391.40 ± 56.68	6.3 ± 5.1

July	Mean ±SD	7.48± 0.39	5.66± 0.55	4.43± 0.97	28.57± 0.93	0.0170± 0.0051	0.1070 ± 0.1167	0.0990 ± 0.0330	93.57 ± 23.97	449.00 ± 72.02	9.0 ± 2.0
August	Mean ±SD	8.71± 0.48	4.84± 0.26	3.32± 1.76	30.30± 0.50	0.0351± 0.0289	0.1861 ± 0.1134	0.3990 ± 0.5207	85.50 ± 17.10	450.30 ± 97.23	11.3 ± 3.1
September	Mean ±SD	8.39± 0.42	4.79± 0.18	3.49± 0.29	26.73± 0.31	0.0503± 0.0257	0.3355 ± 0.1345	0.1320 ± 0.0330	91.20 ± 35.60	421.80 ± 35.60	12.3 ± 2.5
October	Mean ±SD	6.98± 0.04	4.68± 0.39	2.27± 0.10	30.27± 1.10	0.0011± 0.0004	0.1720 ± 0.0747	0.0990 ± 0.0330	119.70± 34.20	638.60 ± 60.37	13.7 ± 2.5
November	Mean ±SD	7.20± 0.12	4.39± 0.40	5.62± 0.16	27.10± 0.36	0.0085± 0.0056	0.7700 ± 0.2527	0.7700 ± 0.5041	302.07± 60.01	798.00 ± 103.07	14.7 ± 1.5
December	Mean ±SD	7.80± 0.31	4.33± 0.27	4.89± 0.18	23.70± 1.08	0.0192± 0.0216	0.6541 ± 0.1425	0.2730 ± 0.1667	325.77± 44.34	537.07 ± 138.57	13.7 ± 1.5

(B)Spatial Variation of Water Quality Parameters:

Station	S1	S2	S3
	Mean±SD	Mean±SD	Mean±SD
pH	7.76±0.46	7.91±0.65	8.04±0.67
DO (mg/L)	5.08±0.56	5.12±0.71	5.18±0.71
TDS (g/L)	3.56±1.17	4.01±1.45	3.64±1.36
Temperature (°C)	28.41±2.87	28.26±2.68	28.49±2.67

Toxic Ammonia (mg/L)	0.0140±0.0074	0.0193±0.0174	0.0224±0.0216
Ammonium Ion (mg/L)	0.1988±0.2649	0.1873±0.2035	0.2157±0.3345
Nitrite (mg/L)	0.2626±0.3253	0.1896±0.3577	0.1378±0.1306
Alkalinity (mg/L)	121.32±69.53	123.66±92.16	134.71±108.58
Total Hardness (mg/L)	481.57±153.28	461.47±165.44	451.16±112.03
Salinity (ppt)	12.17±4.11	11.42±2.50	11.83±3.04

Appendix II: Larvae availability

	Minimum	Maximum	Sum	Mean	Std. Deviation
Month	1	12	234	6.50	3.501
Station	1	3	72	2.00	0.828
Finfish	17	93	1270	35.28	16.542
Crustaceans	44	571	8159	226.64	151.602

Appendix III: Value used for calculating the amount ammonium ion and toxic ammonia.

Table 2 Percentage Un-ionized Ammonia in Aqueous Solution by pH Value and Temperature Calculated from data in Emerson, et. al*

pH	Temperature (°C)														
	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32
7.0	0.11	0.13	0.16	0.18	0.22	0.25	0.29	0.34	0.39	0.46	0.52	0.60	0.69	0.80	0.91
7.2	0.18	0.21	0.25	0.29	0.34	0.40	0.46	0.54	0.62	0.82	0.83	0.96	1.10	1.26	1.44
7.4	0.29	0.34	0.40	0.46	0.54	0.63	0.73	0.85	0.98	1.14	1.31	1.50	1.73	1.98	2.26
7.6	0.45	0.53	0.63	0.73	0.86	1.00	1.16	1.34	1.55	1.79	2.06	2.36	2.71	3.10	3.53
7.8	0.72	0.84	0.99	1.16	1.35	1.57	1.82	2.11	2.44	2.81	3.22	3.70	4.23	4.82	5.48
8.0	1.13	1.33	1.56	1.82	2.12	2.47	2.86	3.30	3.81	4.38	5.02	5.74	6.54	7.43	8.42
8.2	1.79	2.10	2.45	2.86	3.32	3.85	4.45	5.14	5.90	6.76	7.72	8.80	9.98	11.29	12.72
8.4	2.80	3.28	3.83	4.45	5.17	5.97	6.88	7.90	9.04	10.31	11.71	13.26	14.95	16.78	18.77
8.6	4.37	5.10	5.93	6.88	7.95	9.14	10.48	11.97	13.61	15.41	17.37	19.50	21.78	24.22	26.80
8.8	6.75	7.85	9.09	10.48	12.04	13.76	15.66	17.73	19.98	22.41	25.00	27.74	30.62	33.62	36.72
9.0	10.30	11.90	13.68	15.65	17.82	20.18	22.73	25.46	28.36	31.40	34.56	37.83	41.16	44.53	47.91
9.2	15.39	17.63	20.08	22.73	25.58	28.61	31.80	35.12	38.55	42.04	45.57	49.09	52.58	55.99	59.31
9.4	22.38	25.33	28.47	31.80	35.26	38.84	42.49	46.18	49.85	53.48	57.02	60.45	63.73	66.85	69.79
9.6	31.36	34.96	38.38	42.49	46.33	50.16	53.94	57.62	61.17	64.56	67.77	70.78	73.58	76.17	78.55
9.8	42.00	46.00	50.00	53.94	57.78	61.47	64.99	68.31	71.40	74.28	76.92	79.33	81.53	83.51	85.30
10.0	53.44	57.45	61.31	64.98	68.44	71.66	74.63	77.35	79.83	82.07	84.08	85.88	87.49	88.92	90.19
10.2	64.53	68.15	71.52	74.63	77.46	80.03	82.34	84.41	86.25	87.88	89.33	90.60	91.73	92.71	93.58

* Emerson, K., R. C. Russo, R.E. Lund, and R.V. Thurston. 1975. Aqueous ammonia equilibrium calculations: effect of pH and temperature. *J. Fish. Res. Board Can.*, 32:2379-2383.

Appendix IV: Some pictures of research work

Plate No. 01: Water Quality Determination	
Plate No. 02 : Water Quality Determination	
Plate No. 03: Sample Collection	

Plate No. 04 : Sample Preservation	
Plate No. 05 : Laboratory Analysis	
Plate No. 06 : Laboratory Analysis	
Plate No. 07 : Laboratory Analysis	

Plate No. 08 : Laboratory Analysis	
Plate No. 09 : Laboratory Analysis	

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