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Assessing The Valaichchenai Lagoon Healthiness: Implication For Aquaculture Suitability

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Abstract-The present study assessed the healthiness of Valaichchenai Lagoon, Batticaloa, regarding water quality and the implications of aquaculture. The objective of this study is to determine the spatial variation of physiochemical water quality parameters in the lagoon and to find out the existing threats. Sampling was conducted fortnightly at predefined selected ten sites on a replicate basis, and physicochemical water quality parameters were measured between January and May 2023. Results revealed that there is a significant spatial variation in salinity (0.29 ± 0.18 to 12.57 ± 0.84 ppt), Electrical conductivity (222 ± 28.01 to 28361.4 ± 2025.72 µS/cm), Total dissolved solids (123.14 ± 12.82 to 13760.9 ± 950.56 mg/L), cadmium (0.0025 ± 0.0006 to 0.04 ± 0.01 mg/L), magnesium (10.52 ± 2.80 to 95.99 ± 18.37 mg/L), phosphate (0.05 ± 0.01 to 1.07 ± 0.07 mg/L), and nitrate (0.24 ± 0.06 to 2.1 ± 0.09 mg/L) ($p < 0.05$, ANOVA). Phosphate and cadmium levels exceeded the threshold level for the aquaculture implications in the L2 (Murakattanchenai) and L4 (Kiran) regions, where fish consumption is unsuitable for humans. As per the findings, L1 (Sittandy), L2, L3 (Santhively), and L4 sites are suitable for freshwater species culturing, such as Tilapia and Carp in cages and pens, along with fry rearing. Furthermore, L5 (Kinnayadi), L6 (Meeravodai), L8 (Oddamavadi), and L9 (Valaichchenai) regions suit Seabass and Mullet culture in cages. The L10 (Nasuvantheevu) region can be utilized for seaweed culture on rafts and crab fattening.

Keywords: Aquaculture, Valaichchenai Lagoon, Water quality parameters

Suggested Citation

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1. Introduction

Coastal lagoons are shallow brackish separated from the ocean by a barrier island, spit, reef, or sand bank. Depending on the extent of the barriers, they may be partially or enclosed, although most are connected intermittently to the open ocean by one or more restricted tidal inlets (Kennish, 2016).

Lagoon healthiness (along with water quality) is essential for aquaculture production as it is the main factor controlling aquaculture production in lagoons. In addition, it affects the production in the lagoons, which affects food productivity and the health of people (Cardia & Lovatelli, 2007). Aquaculture production in Sri Lanka has shown an upward trend since 1999, with production increasing from 31,450 to 116,890 MT in 2022. Rs. 13,174 million was added to the GDP of the country by exporting aquaculture products (NAQDA, 2022). Coastal land scarcity and growing population make land a major limiting factor for developmental activities. Globally, water bodies such as seas and lakes have contributed to fish production. Aquaculture is not constant but varies with the time of the day, season, weather conditions, water source, soil type, temperature, stocking density, feeding rate, and culture systems (Simpi *et al.*, 2011). For a successful aquaculture venture, it is essential to maintain suitable water quality for both the survival and optimum growth of cultured fish (Odino, 2013).

The coastal lagoon system is an ecosystem that continuously fluctuates due to periodic and seasonal environmental alterations. Regular monitoring of the lagoon through proper scientific studies with frequent assessment is essential to get the current status and knowledge about a particular aquatic body. However, health-related studies in the Valaichchenai Lagoon are limited. This study was conducted to find suitable sites on the lagoon for aquaculture implications. Furthermore, we can fulfil the consumer demand for fish protein, ensure food security within their region, and ensure the continuous supply of aquaculture products.

2. Materials and Methods

2.1 Study site

The present study was conducted in the Valaichchenai Lagoon, located in Batticaloa District on the east coast of Sri Lanka (Figure 1). The lagoon started from Sittandy in the south (about 20 km away from urban), extending up to Nasuvantheevu in the north between the geographical coordinates of 7^0 48' 26" N, 81^0 33' 03" E and 7^0 56' 22" N, 81^0 33' 03" E. Lagoon has single narrow bar mouth connection (about 300 m length) that opens to the Indian Ocean at the Nasuvantheevu. The total area of the lagoon extends approximately 13.21 km^2 and 84.4 km in perimeter. Valaichchenai Lagoon is comparatively the smallest and narrowest among the three lagoons of Batticaloa, and the width of the lagoon ranges from 0.2 to 1.2 km. Freshwater inflow prominently occurs in the lagoon through the connection of three rivers. These are Maduru Oya, Miyangolla Ela and Mundeni Aru.

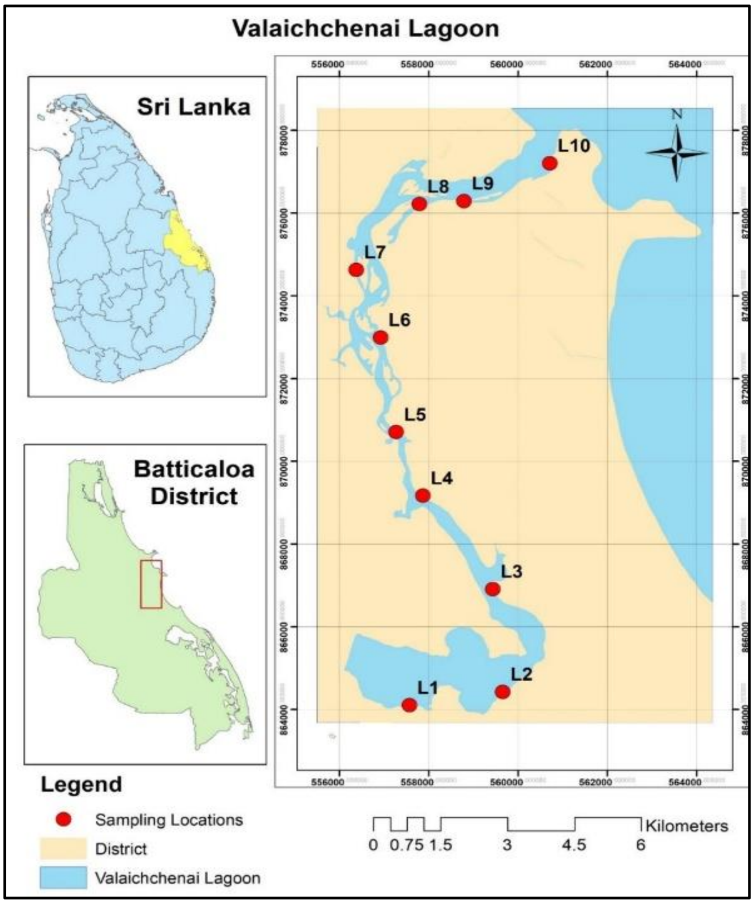

Figure 1. *Study area with sampling locations*

2.2 Water sample collection

The survey was conducted from January 2023 to May 2023. Samples were collected fortnightly at each sampling location. A total of 07 sampling surveys were recorded throughout the study period at each sampling location from L1 to L10 (Table 1). All sampling were done within the daylight period.

Water samples were collected in replicates by dipping a labelled, pre-cleaned 500 ml plastic bottle into a Lagoon about 50 cm below the surface layer, filling it with lagoon water, and closing it with a lid. For the Heavy metal analysis, water samples were immediately acidified with Concentrated-HNO_3 to reduce the pH of the water sample to less than 2 at the time of sample collection to prevent the absorption of heavy metal ions and minimize microbiological degradation. All sample bottles were kept in a Styrofoam box and transported immediately to the laboratory for further analysis.

Table 1

Geographical coordinates of sampling locations

Sampling Location	Name of location	Geographical Coordinates
L1	Sittandy	7 49’ 57.21” N 81 33’ 2.97” E
L2	Murakattanchenai	7 82’ 65.50” N 81 55’ 05.69” E
L3	Santhively	7 84’ 17.01” N 81 54’ 12.19” E
L4	Kiran	7 86’ 49.28” N 81 52’ 52.56” E
L5	Kinnayadi	7 53’ 16.96” N 81 31’ 19.09” E
L6	Meeravodai	7 54’ 10.66” N 81 31’ 5.32” E
L7	Kavaththamunai	7 54’ 52.29” N 81 30’ 45.76” E
L8	Oddamavadi	7 55’ 16.60” N 81 30’ 56.25” E
L9	Valaichchenai	7 55’ 38.15” N 81 31’ 50.68” E
L10	Nasuvantheevu	7 56’ 5.44” N 81 32’ 31.12” E

2.3 Analysis of Water Quality parameter

A total of twelve physiochemical parameters were analyzed for the lagoon water. Temperature, Electrical Conductivity (EC), Total Dissolved Solid (TDS), Turbidity, Salinity, pH, Nitrate, Phosphate, Dissolved oxygen (DO), and Heavy metals (Cr, Cd, and Mg) were measured. All water quality parameters were measured *in situ* with the help of portable devices and *ex-situ* measurements in the laboratory. All laboratory analyses were done at the Laboratories of the Department of Chemistry and Department of Zoology, Faculty of Science, Eastern University, Sri Lanka.

2.4 Data analysis

All statistical analyses were performed by using the Minitab 17.0 Geo statistical version. One-way unstacked ANOVA was used to compare the statistical significance among sampling sites for each parameter, employing a 0.05 significance level. This level of significance was consistently applied to all statistical tests. The graphs relevant to the analyses were plotted using Microsoft Excel 2019.

3. Results

3.1. Physicochemical water quality parameters

3.1.1. Salinity

The mean salinity of Valaichchenai Lagoon ranged from 0.29 ± 0.18 ppt (L1) to 12.57 ± 0.84 ppt (L10) throughout the study period. The spatial variation of salinity across the locations exhibited a significant difference ($p < 0.05$, alpha 5%, ANOVA).

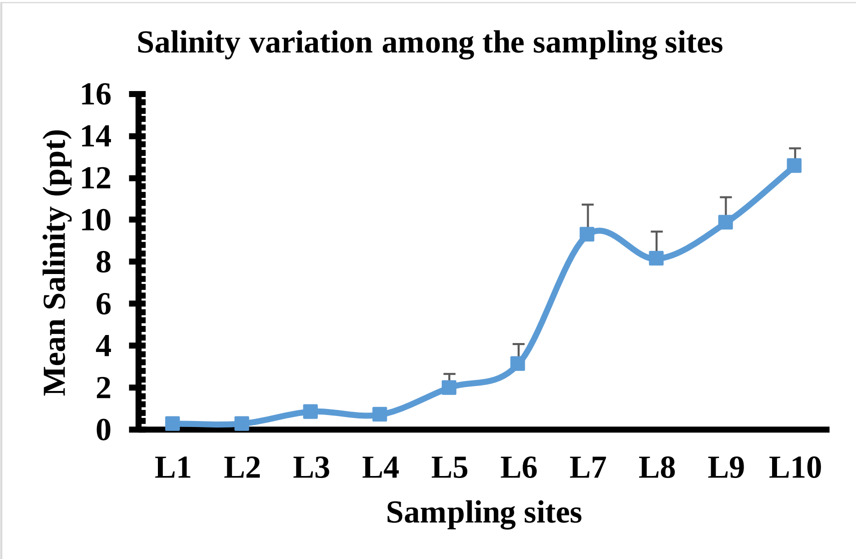

Figure 2. *Spatial variation of mean salinity (ppt)*

3.1.2. Temperature

The mean surface water temperature of Valaichchenai Lagoon ranged from 29.42 ± 0.48 (L1) to 30.61 ± 0.33 ˚C (L6) during the study period.

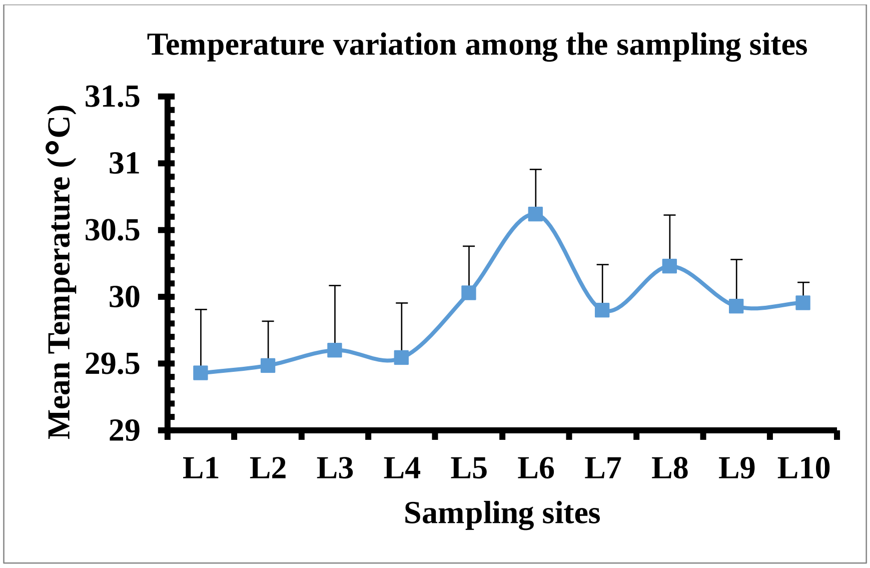

Figure 3. *Spatial variation of mean temperature (°C)*

3.1.3. Turbidity

The mean turbidity level of Valaichchenai Lagoon ranged from 3.63 ± 0.78 (L9) to 8.61 ± 0.44 NTU (L1) throughout the study period.

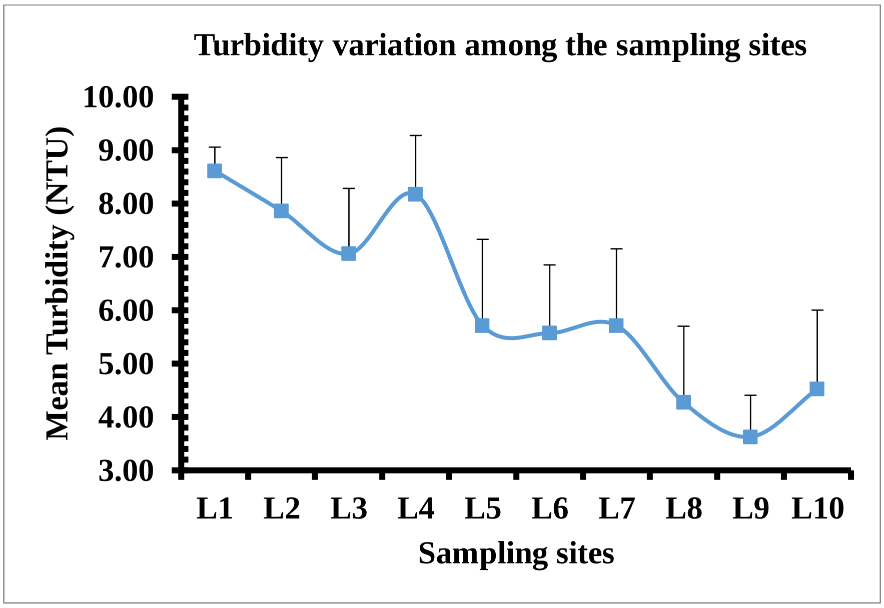

Figure 4. *Spatial variation of mean turbidity (NTU)*

3.1.4. Electrical conductivity

The mean electrical conductivity (EC) of Valaichchenai Lagoon ranged from 222 ± 28.01 µS/cm (L1) to 28,361.4 ± 2025.72 µS/cm (L10). There was a statistically significant difference in EC among the sampling locations ($p < 0.05$, alpha 5%, ANOVA) strongly suggesting spatial variability in EC within the lagoon.

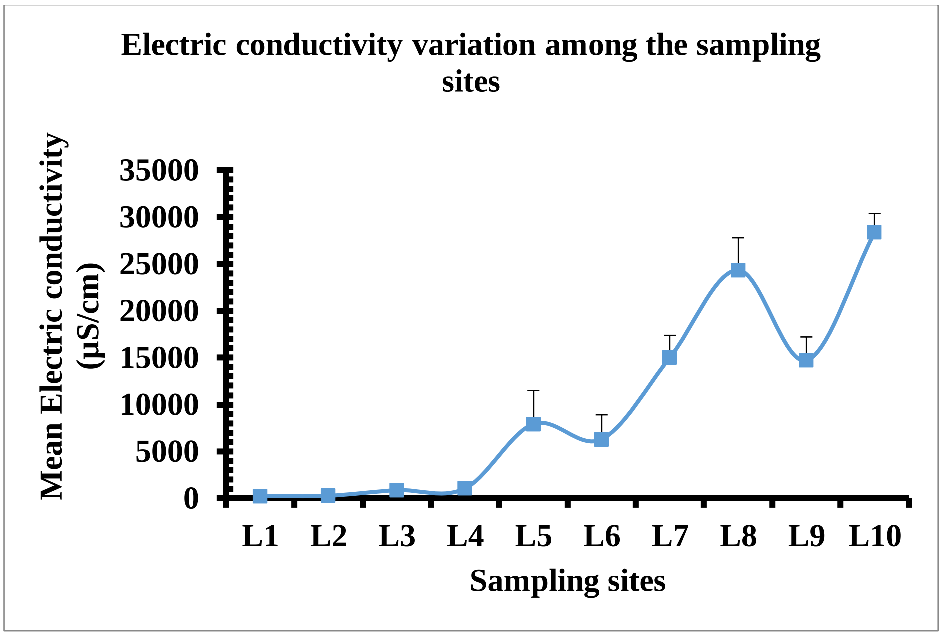

Figure 5. *Spatial variation of mean electric conductivity (EC)*

3.1.5. Total dissolved solids

The mean total dissolved solids (TDS) level of Valaichchenai Lagoon ranged from 123.14 ± 12.82 mg/l (L1) to 13,760.9 ± 950.56 mg/l (L10). There was a statistically significant difference in TDS levels among the sampling locations ($p < 0.05$, alpha 5%, ANOVA) indicating substantial spatial variation in TDS across the lagoon.

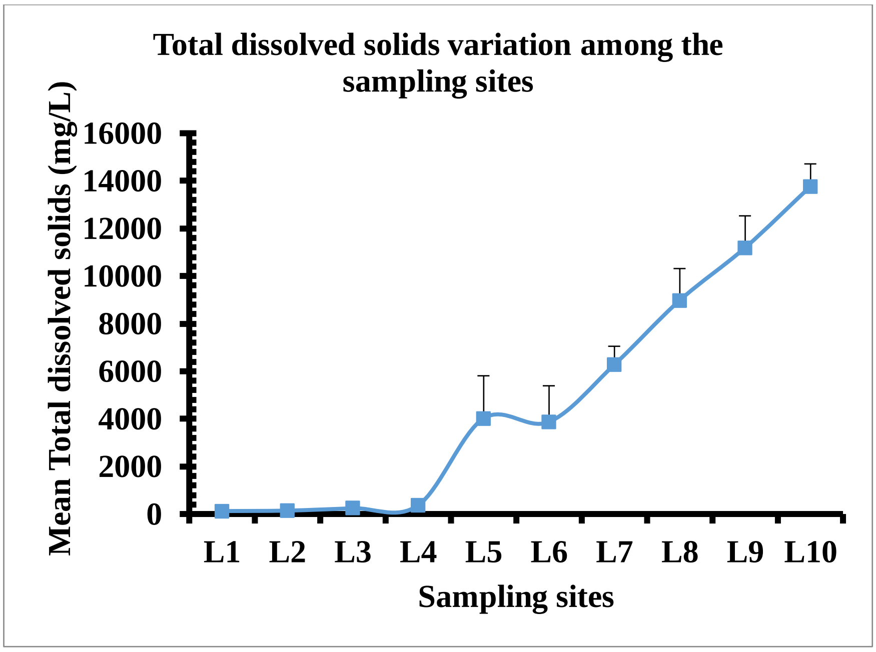

Figure 6. *Spatial variation of mean total dissolved solids (TDS)*

3.1.6. pH

The mean pH value of Valaichchenai Lagoon ranged from 7.07 ± 0.03 (L2) to 7.54 ± 0.17 (L10) throughout the study period.

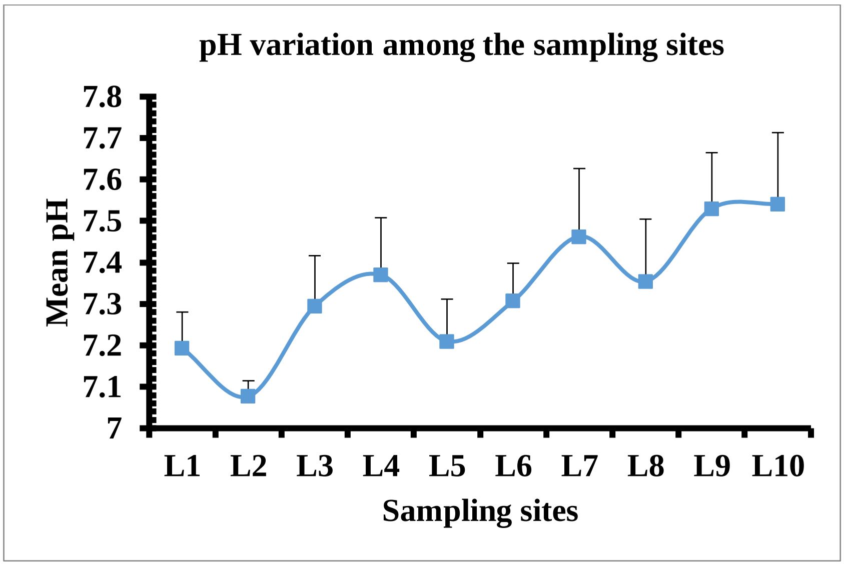

Figure 7. *Spatial variation of mean pH*

3.1.7. Dissolved oxygen

The mean Dissolved Oxygen level of Valaichchenai Lagoon ranged from 5.28 ± 0.13 (L2) to 6.45 ± 0.55 mg/L (L4) throughout the study period.

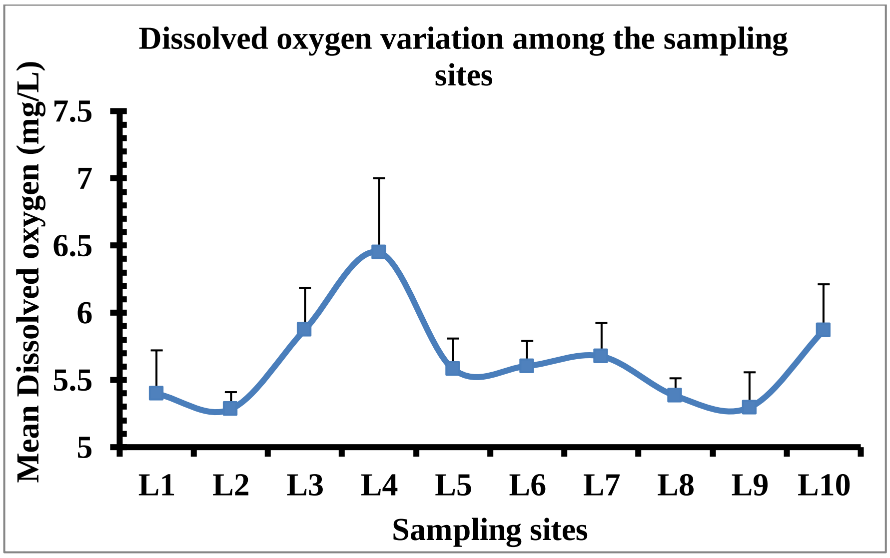

Figure 8. *Spatial variation of mean dissolved oxygen (DO)*

3.1.8. Phosphate

The mean phosphate level of Valaichchenai Lagoon ranged from 0.05 ± 0.01 (L9) to 1.07 ± 0.07 mg/L (L2) throughout the study period. There was a statistically significant difference in the spatial variation of phosphate among the sampling locations ($p < 0.05$, alpha 5%, ANOVA).

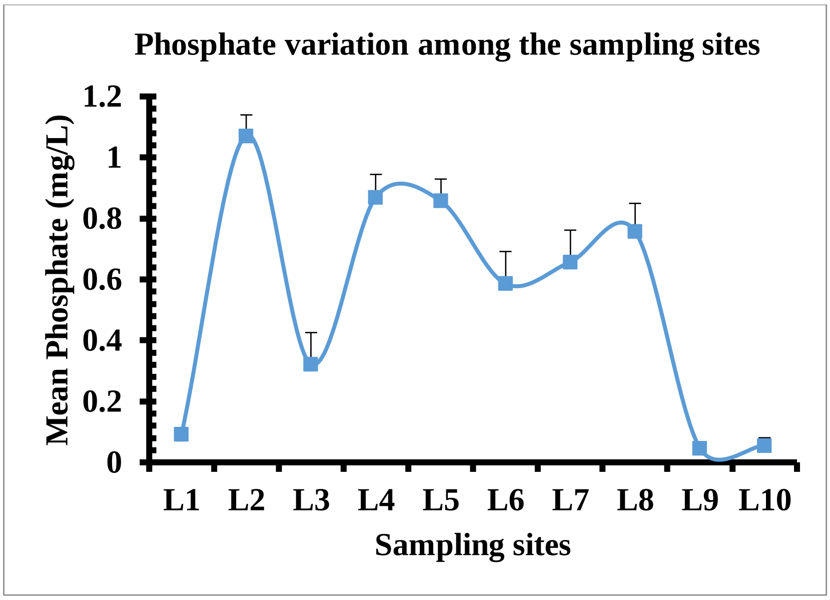

Figure 9. *Spatial variation of mean phosphate*

3.1.9. Nitrate

The mean nitrate level of Valaichchenai Lagoon ranged from 0.24 ± 0.06 (L10) to 2.1 ± 0.09 mg/L (L4) throughout the study period. There was a statistically significant difference in nitrate levels among the sampling locations ($p < 0.05$, alpha 5%, ANOVA), indicating substantial spatial variation in nitrate across the lagoon.

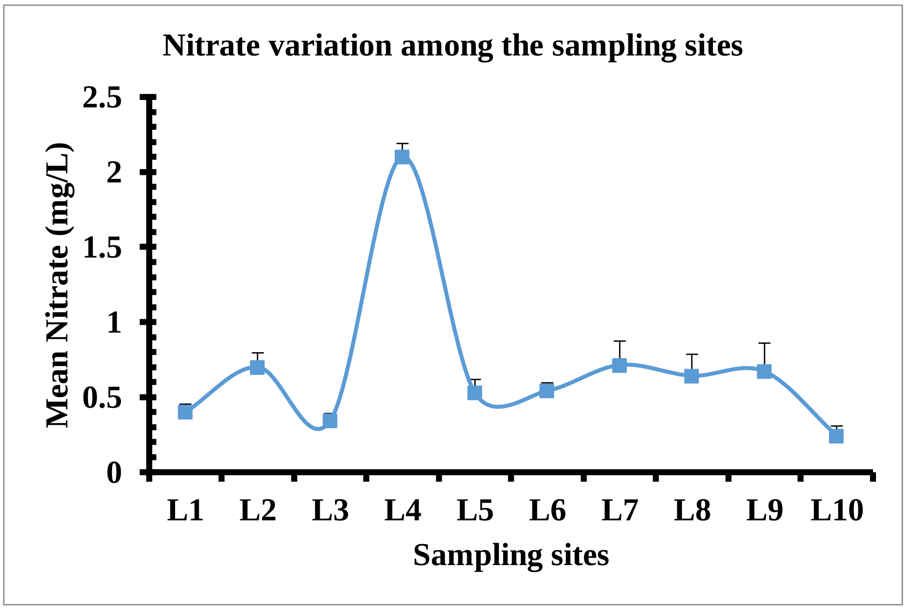

Figure 10. *Spatial variation of mean nitrate*

3.1.10. Heavy metals

3.1.10.1. Magnesium

The mean magnesium level ranged from 10.52 ± 2.80 (L3) to 95.99 ± 18.37 mg/L (L10) throughout the study period. There was a statistically significant variation in Mg concentration among the sampling locations ($p < 0.05$, alpha 5%, ANOVA) across the lagoon.

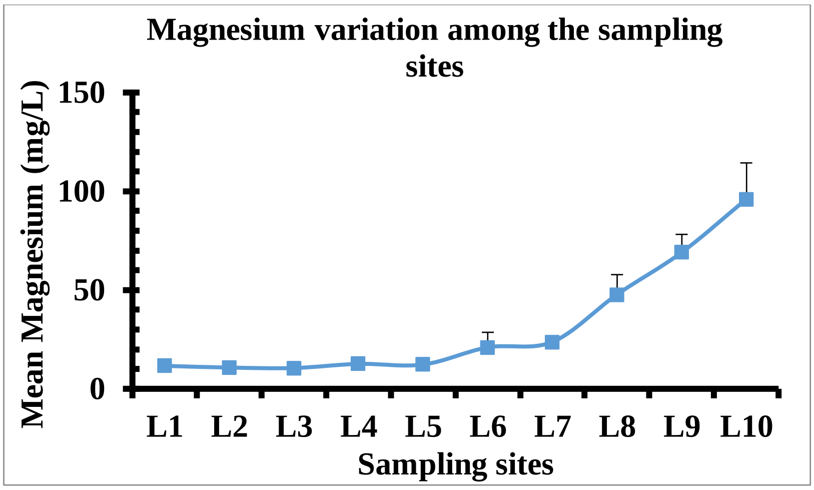

Figure 11. *Spatial variation of mean magnesium*

3.1.10.2. Chromium

The mean chromium level ranged from 0.0001 ± 0.0000001 (L4) to 0.00039 ± 0.00014869 mg/L (L7) throughout the study period.

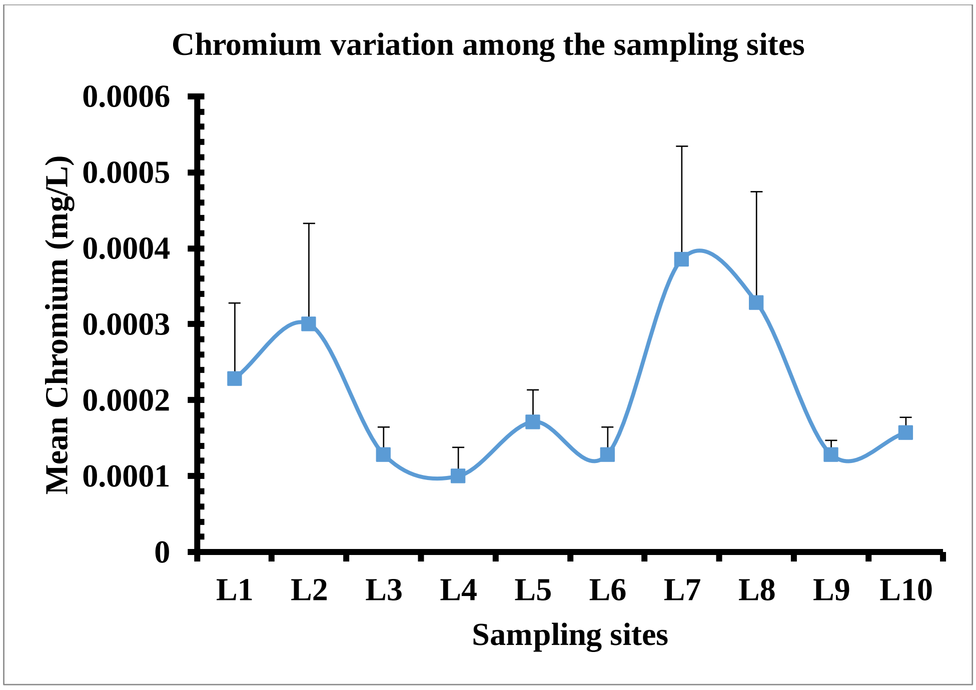

Figure 12. *Spatial variation of mean chromium*

3.1.10.3. Cadmium

The mean cadmium level ranged from 0.0025 ± 0.0006 (L6) to 0.04 ± 0.01 mg/L (L1) throughout the study period. There was a statistically significant difference in the Cd concentration among the sampling locations ($p < 0.05$, alpha 5%, ANOVA) across the lagoon.

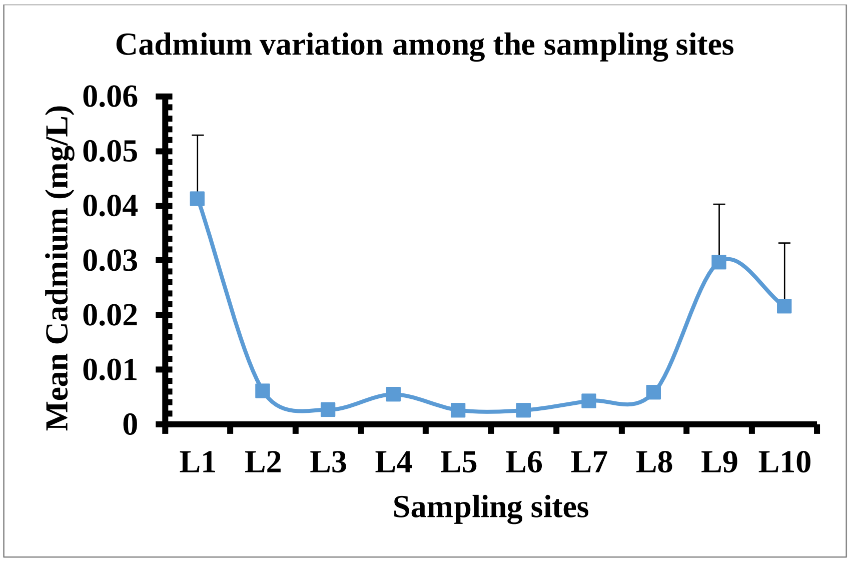

Figure 13. *Spatial variation of mean cadmium*

4. Discussion

This study recorded the mean higher salinity value in Nasuvantheevu (L10), where sea and lagoon water exchange occurs. The increased mixing rate of seawater inside the lagoon paves the path to reach high salinity. Low salinity was recorded at the farthest points from the bar mouth. Lack of seawater mixing and high freshwater inflow by river connection lowers the salinity (Loitzenbauer & Mendes, 2012). This variation in salinity was observed under the two diverse categories, oligohaline (0.5 ≤ 5.0 ppt) and mesohaline (5.0 ≤ 18.0 ppt), which highly influence the species composition (Harris & Vinobaba, 2013).

The suitable recommended temperature for the aquaculture is 28 to 32 °C (FAO, 2006). So, the Valaichchenai Lagoon temperature range is within the recommended level. The highest mean turbidity value (8.61 ± 0.44 NTU) was recorded in Sittandy (L1), which is due to a high level of river connection in this region—other regions L2, L3, and L4 comparatively have a higher turbidity nature than other areas. Most of the runoffs from upstream and adjacent agricultural lands with high amounts of suspended particles and river connections were laid in these regions, and flooding conditions occurred during the study periods, which influenced the turbidity level. Dissolved suspended solids will also clog filters and injure fish gills (Carballo *et al.*, 2008).

The lowest turbidity values were recorded in Valaichchenai, which is nearest to the sea, and the water flow rate is also high in this region, which influences the turbidity level in this region. According to the statement of EL-Shafei (2016), the maximum threshold limit of turbidity for aquatic life is 22 NTU. So, the turbidity range of Valaichchenai Lagoon lies within the acceptable level for the aquaculture implication.

The sampling location Nasuvanthhevu (L10) has the highest mean EC value (28,361.4 ± 2,025.72 µS/cm) due to the seawater mixing. When seawater is mixed with lagoon water at the site of the connection point, the EC level increases due to the existence of the ions at a high level. Water EC is depending on ionic concentrations (Ca^{2+}, Mg^{2+}, HCO_3^-, CO_3^{2-}, NO_3^- and PO_4^{3-}), temperature and dissolved solids fluctuations. The region of L1 to L4 was recorded with lower-level EC, and L1 had the lowest value. Because of freshwater inflow, low levels of dissolved particles and salt content of this region influence the EC value.

The highest mean TDS concentration, 13,760.9 ± 950.56 mg/L, was observed in the region of the bar mouth (L10) of Lagoon. According to Lawson (2011), the TDS level was raised by the presence of potassium, chlorides, and sodium-like ions. TDS was also progressively reduced from L4 to L1 due to increased distance from the bar mouth. According to the statement of EL-Shafei (2016), the acceptable range of TDS for aquatic life is 450 - 2,000 mg/L. However, the findings show that the mean value of TDS of some locations on the Lagoon exceeds the permissible level.

The mean high pH value of sampling site L10 (Nasuvantheevu) was recorded as 7.54 ± 0.17 due to the mixing of seawater with the lagoon. It could also be attributed to the high amount of nutrients. L2 (Murakkadanchenai) recorded the lowest mean value (7.07 ± 0.03), a neutral condition attributed to the natural environment of that region, which is also influenced by the type of soil of that region and heavy rain. The recorded range of mean pH from the present study shows which is suitable for aquaculture implications.

The highest DO level of 6.45 ± 0.55 mg/L was reported in Kiran (L4). The river connection and runoff rate of high and continuous input of river water with lagoon water allow the dissolution of more atmospheric oxygen in water, which maintains the peak DO level in this region. The lowest mean value of DO (5.28 ± 0.13 mg/L) was recorded in Murakkadanchenai (L2). In this region, agricultural runoffs mixed with the Lagoon may reduce the ability of oxygen to dissolve in water and deplete existing DO through decomposition. Howell & Simpson (1994) stated that a DO level above 5 mg/L in aquatic systems is ideal and favourable for aquatic life. According to these statements, the mean DO value of the studied site of Valaichchenai Lagoon ranges within the suitable level for the implication of aquaculture.

The highest mean phosphate level, 1.07 ± 0.07 mg/L reported in Murakkaanchenai (L2). The primary sources of high concentrations of phosphates in the Lagoon are sewage, animal wastes, disturbed land, and fertilizers. According to Makori *et al.* (2017), the maximum allowable level of phosphate concentration for aquatic life is 0.4 mg/L, and the potential level for avoiding augmented eutrophication is 0.1 mg/L. However, the Valaichchenai Lagoon has some potential sites to imply aquaculture with a suitable range of phosphate levels (L1, L3, L9, and L10).

The highest mean nitrate level, 2.1 ± 0.09 mg/L recorded in Kiran (L4). Agricultural lands, rice mills, animal farms, and the compost-making industry surround L4. Their waste material is directly and highly mixed with the Lagoon during flooding. Agricultural runoff has been identified as one of a water body's most significant nitrate loadings (Smith, 2003). Apart from that, the graph shows that the sampling sites L7, L8, and L9 expressed elevated patterns of nitrate levels. In the L9 (Valaichchenai fishing harbour), drainage effluent and most fish trash were directly discharged into the lagoon water, which is the source of increasing nitrate levels. Near the L7 (Kavaththamunai), shrimp farm practices were carried out, the reason for the elevation of nitrate owing to the direct discharge of effluents from the farming site. FAO (2012) limits the concentration of nitrate fish culture to be 0.1- 4.5 mg/L; thus, the Valaichchenai Lagoon water in the study locations was within limits. So, the lagoon sites are suitable for the implication of aquaculture.

The mean higher magnesium, 95.99 ± 18.37 mg/L, was recorded in Nasuvantheevu (L10), where sea and lagoon water exchange occurred. The increased mixing rate of seawater inside the Lagoon paves the path to reaching high magnesium levels. The recommended standard of Mg in water used for growing fish should be 80 to 500 mg/L; therefore, the Valaichchenai Lagoon is suitable for aquaculture.

The mean higher chromium < 0.01 mg/L was recorded in Oddamavadi (L7) near the Oddamavadi bridge and paper factory. The recommended standard of Cr in water used for growing fish should be less than 0.05 mg/L; therefore, the Valaichchenai Lagoon is suitable for aquaculture.

The mean higher cadmium concentration of 0.04 ± 0.01 mg/L was recorded in Sittandy (L1), with exceptionally high cadmium concentration at the river connect region of lagoons compared to another area of the Lagoon. Cadmium is one of the severe pollutants in the natural environment due to its toxicity, persistence, and bioaccumulation problems (Ridgway & Shimmield, 2002). Next to the L1, the highest mean cadmium concentration was recorded in Valaichchenai harbor (L9) due to fuel leakage discharge and the repair of vessels and boats in the Lagoon, where oil spillage occurred. According to Chandrasekara *et al*. (2014), the inland water standard for Cd is < 0.005 ppm, recorded in L3, L5, L6, and L7.

5. Conclusion

Valaichchenai Lagoon has suitable conditions for aquaculture implications. Salinity, electrical conductivity, total dissolved solids, cadmium, magnesium, phosphate, and nitrate showed distinct spatial variation ($p < 0.05$, ANOVA) along sampling locations. Among the measured physicochemical parameters, phosphate, and cadmium levels exceeded the standard limits in L2 and L4. The aquaculture systems that suit Valaichchenai Lagoon include cages or pens for fish and shrimp and systems for rearing mollusks or seaweed on artificial substrates. Fixed units are best suited to the Valaichchenai Lagoon. Economically, cage or pen cultures of high protein value fishes, e.g., Sea bass, *Mossambique tilapia*, Groupers, and Snappers, are suitable to culture in the Valaichchenai Lagoon.

L1, L2, L3, and L4 regions are suitable to culture tilapia and mullet in cages, while L5, L6, L8, and L9 regions are suitable to culture sea bass in cages. Moreover, the L10 region suits the seaweed culture on the raft and crab culture. Proper management and strategies are needed to protect the environmental conditions of the Lagoon before planning the aquaculture. So, this study will provide information to expand brackish water aquaculture in the Valaichchenai Lagoon, which could be a livelihood for coastal communities.

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