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Spatial and temporal variations in physico-chemical characteristics of water in Gangavali and Aghanashini mangroves, Southwest coast, Karnataka

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Abstract
Mangrove is a unique ecological environment and forms the habitat for a wide variety of marine organisms. The present study was carried out to investigate the water quality and nutrient dynamics in the selected mangroves of the Uttara Kannada district, Karnataka. The physico-chemical parameters of water were analyzed by standard methods. The study was conducted during the period from October 2021-September 2022. The physico-chemical properties showed significant seasonal variations at all the selected stations. The water quality parameters namely temperature, pH, salinity, alkalinity, hardness, DO, BOD, NH_3-N, NO_2-N, NO_3-N, PO_4-P, SiO_3-Si were found to vary from 25 °C-34.5 °C, 7.1-8.5, 4-32 PSU, 40-162 mg/l, 468-11600 ppm, 4.48-8.96 mg/l, 0.4-6.11 mg/l, 0.63-23.68 µg-at./1, 0.06-3.28 µg-at./1, 0.13-10.55 µg-at./1, 0.11-20.5 µg-at./1 and 7.2-80.39 µg-at./1 respectively. The results showed that some parameters with slight deviations compared with optimal values. It was observed that the mangrove was provided with a diversified and rich fauna population and was shown to be significantly influenced by environmental variables. As a result, it is critical to monitor the health of the mangrove ecosystem in order to ensure more sustainable fisheries in the future.

Keywords: Mangrove, water quality, nutrients and southwest

Introduction

Mangrove flora (Kandla in Kannada) is a type of plant ecosystem that typically exists in the tropical and subtropical regions of the world's coastal zones. They play a pivotal role in ecological processes, fishing industry and effectively protect the shoreline by anchoring it and preventing soil erosion. They provide the cornerstone of a highly efficient and biodiverse environment that serves as a habitat and breeding site for a diverse range of organisms, most of which are threatened with extinction. These represent immensely valuable communities that provide a wide range of necessary commodities and services that are vital to coastal communities' livelihoods, well-being and security. People benefit from a variety of economic, societal and natural services offered by mangroves, which are known as ecosystem services. The mangrove ecosystems are home to a wide variety of living things and serve as a nursery and breeding ground for many species of fish, mollusks, crabs and other marine animals.

The world's mangroves comprise 1,50,000 square kilometers in total. The majority of the world's mangroves are found in Asia. 6.8% of the world's mangrove cover lies in South Asia. India contributes 45.8% of the region's total mangrove cover. According to India State of Forest Report 2019 [15], the mangrove coverage in India was 4,975 sq. km or 0.15% of the country's overall geographic region. Around 57% of the area in India covered by mangroves is on the East Coast, 23% is found on the West Coast and the residual 20% is in the Andaman and Nicobar Islands. The backwater-estuarine varieties of mangroves include those around the West Coast (Venkataraman, 2003) [45]. Mangrove vegetation may be seen all over India's 5,700 km of coastline. They are thought to cover roughly 7,00,000 ha of land worldwide or about 6% of the total area of mangroves (Chandran *et al*., 2012) [10].

The coastline of Karnataka stretches for more than 320 kilometers. The Arabian Sea is fed by fourteen rivers as well as a few minor rivulets that arise in the Western Ghats. Seawater surges reach several kilometers inland through riverbanks, affording an optimal environment for the mangrove ecosystem. The majority of mangroves are fringe types that grow in linear forms along the river or estuary banks. Despite mangrove ecosystems being few, they can be found across the river's margin (Mesta *et al*., 2013) [24]. The composition, abundance, association interaction, and distribution of fauna and flora in an ecosystem are significantly influenced by the physical and chemical characteristics of the water and sediments. The quality of the water as well as the variety and abundance of organisms are both significantly influenced by several physicochemical factors (Tijare and Kunghadkar, 2021) [42]. The biodiversity of aquatic systems depends largely on the habitat quality of the water, which varies with the season and temperature. In light of this, it is crucial to evaluate the water productivity over time and with the tide (Akhter *et al*., 2018) [1]. The alterations in the physical and chemical properties of the water body play a major role in determining the kind and distribution of flora and fauna in the aquatic system (Sundaramanickam *et al*., 2008) [39]. Due to instability, physico-chemical properties are crucial to water quality criteria to monitor since they have a substantial impact on the quality of water resources (Vaghela *et al*., 2010) [43]. Several studies on physicio-chemical parameters have been carried by many researchers on Indian mangroves (Prabu *et al.*, 2008; Saravana kumar *et al*., 2008; Kumara V and Vijaya Kumar, 2011; Ashok kumar *et al*.2011, Chandran *et al*., 2012; Kumar *et al*., 2013; Arumugam and Sugirtha P Kumar, 2014; Behera *et al*., 2014; Prakash *et al*., 2016, Dattatreya *et al*., 2018 and Chandrakant Lingadhal *et al*., 2020) [29, 37, 21, 4, 10, 20, 3, 7, 30, 14, 9]. The present work aim to study the seasonal and spatial variations in water quality and nutrient dynamics in Gangavali and Aghanashini mangroves, Southwest coast, Karnataka to create baseline data for the policy makers that would be valuable from the management point of view.

Materials and Methods
Study area
The present study was carried out in the mangroves of Gangavali and Aghanashini estuarine complex of Uttara Kannada District. The Gangavali stream is characterized by the constant churning of freshwater from the Khalghati in the Dharwad district and Aghanashini is from the central Western Ghats of Uttara Kannada with marine water. Six stations were selected for water quality parameters during the study period (Figure 1) with three stations selected in Gangavali mangrove area S1 (Latitude 14°35'37.38"N and Longitude 74°17'49.77"E), S2 (Latitude 14°35'25.87"N and Longitude 74°18'10.47"E), S3 (Latitude 14º35'48.35"N and Longitude 74º18'20.94"E) and three stations selected in Aghanashini mangrove area S4 (Latitude 14º32'06.11"N and Longitude 74º21'02.42"E), S5 (Latitude 14º32'42.51"N and Longitude 74º21'23.48"E), S6 (Latitude 14º32'59.58"N and Longitude 74º21'36.58"E).

Water sample collection and analysis
Surface water samples were collected at monthly interval from all stations of Gangavalli and Aghanashini mangroves for over a period of one year from October 2021 to September 2022 to analyse various physico- chemical parameters of water. At sampling sites, the water temperature, pH and salinity were measured using standard mercury thermometer, pocket pH meter (Hanna) and hand-held refractometer respectively. Water samples were collected from the site for the analysis of dissolved oxygen, ammonia-nitrogen and alkalinity were performed in the laboratory as per the standard methods (APHA, 2017) [2]. For dissolved oxygen analysis, water samples were collected in glass bottles of 125 ml capacity and fixed on the field using Winkler's reagents. For the estimation of ammonia-nitrogen, 50 ml of water sample was collected in clean amber-colored glass bottles (125ml capacity) and fixed in the field by following the phenol-hypochlorite method (Parsons *et al*., 1989) [28]. For the nutrients analysis, surface water samples were collected in clean polythene bottles and kept immediately in an icebox and transported to the laboratory and the water samples were filtered and analysed for nitrite-nitrogen, nitrate-nitrogen, phosphate-phosphorous and silicate-silicon by adopting standard procedures.

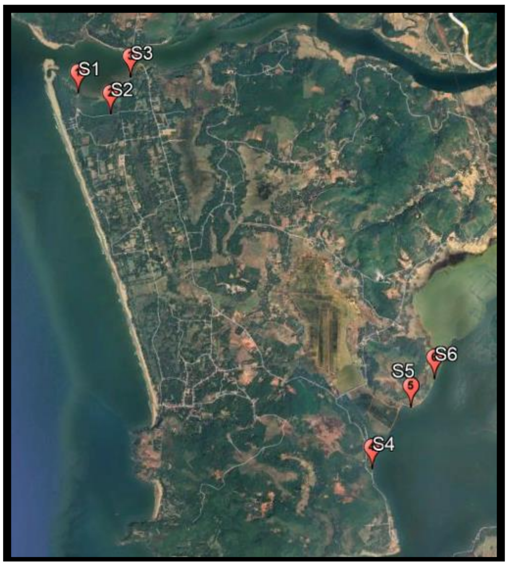

Fig 1: Satellite image showing location of sampling stations

Results
Meteorological parameters
Rainfall
The total rainfall received during the study period was 3883.44 mm from October 2021 to September 2022. The rainfall varied from 6.92 mm to 1371.30 mm. Maximum rainfall was received during the month of July (1371.30 mm), while the minimum rainfall was recorded during the month of March (6.92 mm).

Air temperature
The air temperature ranged from 26 to 34 °C in the Gangavali and Aghanashini mangrove areas (Figure 2). The minimum air temperature was recorded during the month of November (2021) at S5 and the maximum was in the month of April (2022) at S1 and S4. The high air temperature was recorded at the Gangavali mangrove area as compared to the Aghanshini mangrove area.

Hydrographical parameters
Water temperature
Water temperature during the sampling of different seasons was fluctuated between 25 °C (July 2022) at S4 and 34.5 °C (April 2022) at S1 and S6. Warm water conditions prevailed during the pre-monsoon period and the water temperature remained low during the monsoon period as compared to the other seasons. The water temperature varied from 26 to 34.5 °C and 25 to 34.5 °C at the Gangavali and Aghanashini

mangrove areas (Figure 3). Water temperature showed a significant positive correlation with air temperature, salinity, ammonia-nitrogen and negative correlation with nitrate-nitrogen.

Water pH

The pH of water in the present study ranged between 7.2 (S3) to 8.5 (S1) and 7.1 (S5) to 8.1 (S4) at Gangavali and Aghanashini mangrove areas respectively. The maximum (8.5) water pH was measured in March, while the lowest (7.1) was in July. Generally higher pH values were recorded in the Gangavali mangrove area compared to the Aghanashini mangrove area (Figure 4). Water pH showed a significant positive correlation with dissolved oxygen and negative correlation with nitrate-nitrogen.

Salinity

Monthly variations of water salinity recorded at different sampling stations during 2021-22 are presented in Figure 5. Salinity values during the study period fluctuated from a minimum of 4 PSU to a maximum of 32 PSU. The maximum was recorded in the month of April and May (32 PSU) While the minimum was in the month of August (4 PSU). In the Gangavali mangrove area salinity fluctuated from 4 (S2) to 32 PSU (S1) while in the Aghanashini mangroves, it was ranged from 6 (S6) to 32 PSU (S4). Generally higher salinity values were recorded in the Aghanashini mangrove area compared to the Gangavali mangrove area. Salinity showed a significant positive correlation with water temperature, alkalinity, hardness and ammonia-nitrogen.

Dissolved oxygen

The dissolved oxygen of water in the present study has fluctuated between 4.48 and 8.96 mg/l with a variation of 4.48 mg/l. The maximum (8.96 mg/l) dissolved oxygen of water was recorded in the month of July (S3) while the minimum (4.48 mg/l) was found in the month of March (S2). The dissolved oxygen varied from 4.48 to 8.96 mg/l in the Gangavali mangrove and 5.52 to 8.56 mg/l in the Aghanashini mangrove area, as compared to the above-obtained values Gangavali mangrove has higher dissolved oxygen compared to Aghanashini mangrove area (Figure 6).

Biological Oxygen Demand

The fluctuation in biological oxygen demand (BOD) of water at selected stations over the study period is depicted graphically in Figure 7. The biological oxygen demand of water in the present study ranged between 0.4 and 6.11 mg/l. The maximum biological oxygen demand of water was found in April (6.11 mg/l) at S6 while the minimum was reported in August at station S4 (0.4 mg/l). The Biological oxygen demand was varied from 0.48 to 4.08 mg/l in the Gangavali mangrove and 0.40 to 4.90 mg/l in the Aghanashini mangrove area, as compared to both mangrove areas Aghanashini mangrove has higher BOD values than Gangavali mangrove area.

Alkalinity

The alkalinity of water in the present study ranged between 40-162 mg/l. The maximum was recorded in the month of March at station S1 while the minimum was reported during the month of August at the same station. The alkalinity varied from 40 to 162 mg/l in the Gangavali mangrove and 54 to 132 mg/l in the Aghanashini mangrove (Figure 8). Generally, the Aghanashini mangrove has recorded the higher alkalinity values compared to the Gangavali mangrove areas. Alkalinity showed a significant positive correlation with salinity and negative correlation with nitrate-nitrogen.

Hardness

The fluctuation in the hardness of water at selected stations over the study period is depicted graphically in Figure 9. The hardness of water in the present study ranged between 468-11600 mg $CaCO_3$/l. The maximum was recorded in the month of March (11800 mg $CaCO_3$/l) at S6 while the minimum was reported during the month of November (468 mg $CaCO_3$/l) at S1. The hardness of water varied from 468 to 11600 mg $CaCO_3$/l in the Gangavali mangrove and 1700 to 11800 mg $CaCO_3$/l in the Aghanashini mangrove. Generally Aghanashini mangrove has the highest hardness of water compared to the Gangavali mangrove areas.

Nutrients

Ammonia-Nitrogen

The ammonia-nitrogen content of water in the current study ranged from 0.63 to 23.68 µg-at./1. The maximum value of ammonia-nitrogen in water was found in February (23.68 µg-at./1) at S3 while the lowest value was observed in August (0.63 µg-at./l) at S4. Two peaks were noticed with respect to ammonia-nitrogen the primary peak was recorded during the month of February whereas the secondary peak was documented during the months of April and May. The variation of ammonia-nitrogen in the Gangavali mangrove was from 1.64 to 23.68 µg-at./1 while in the Aghanashini mangrove area, it was ranged from 0.63 to 22.61 µg-at./1 (Figure 10). Generally higher ammonia-nitrogen values were recorded at Gangavali mangrove area compared to the Aghanashini mangrove area.

Nitrite-Nitrogen

The variation of nitrite-nitrogen concentration recorded in water at selected stations during the study period is graphically illustrated in Figure 11. The nitrite-nitrogen concentration of water in the present study ranged from 0.06 to 3.28 µg-at./1. The highest concentration of nitrite-nitrogen in water was found in July (3.28 µg-at./1) at S5 while the lowest concentration was recorded in March (0.06 µg-at./1) at S4 and S5 stations. This nutrient gave a bimodal pattern of oscillation with the primary peak in October and a secondary peak during the months of June and July. The variation of nitrite-nitrogen in the Gangavali mangrove was from 0.07 to 2.35 µg-at./1 while in the Aghanashini mangrove area, it ranged from 0.06 to 3.28 µg-at./1. Generally higher ammonia-nitrogen values were recorded at the Aghanashini mangrove area compared to the Gangavali mangrove area. Nitrite-Nitrogen showed a significant positive correlation with nitrate-nitrogen.

Nitrate-Nitrogen

The nitrate-nitrogen concentration of water in the present study ranged from 0.13 to 10.55 µg-at./1. The maximum concentration of nitrate-nitrogen in water was detected at S1 in July (10.55 µg-at./1) while the lowest concentration was observed at S1 in May (0.13 µg-at./1). The bimodal pattern of oscillation was observed with respect to nitrate-nitrogen. The peaks were during the months of November and July at all stations (Figure 12). The nitrate-nitrogen fluctuated from 0.13 to 10.55 µg-at./1 in the Gangavali mangrove and 0.18 to 8.19 µg-at./1 in the Aghanashini mangrove by comparing both mangroves, the Gangavali mangrove has recorded highest nitrate-nitrogen concentration than Aghanashini mangrove areas.

Phosphate-Phosphorus

The variation of phosphate-phosphorus concentrations in water found at selected stations of Gangavali and Aghanashini mangroves during the study period pictorially depicted in Figure 13. The phosphate-phosphorus content of water in the present study ranged from 0.05 to 20.5 µg-at./1. The highest concentration of phosphate-phosphorus in water was found at S3 in August (20.5 µg-at./1) while the lowest value was found at S6 in April (0.05 µg-at./1). The phosphate-phosphorus content of water varied from 0.05 to 20.5 µg-at./1 in the Gangavali mangrove and 0.11 to 12.84 µg-at./1 in the Aghanashini mangrove. Generally, the Gangavali mangrove has the highest phosphate-phosphorus content of water compared to the Aghanashini mangrove areas.

Silicate-Silicon

The silicate-silicon content of water in the present study ranged from 7.2 to 80.39 µg-at./1. The highest concentration of silicate-silicon in water was found at S1 in July (80.39 µg-at./1) while the lowest value was found at S6 in February (7.2 µg-at./1). The silicate-silicon content of water varied from 6.73 to 80.39 µg-at./1 in the Gangavali mangrove and 7.20 to 66.70 µg-at./1 in the Aghanashini mangrove (Figure 14). Generally, the Gangavali mangrove has recorded higher silicate-silicon values compared to the Aghanashini mangrove areas.

Discussion

Seasonal and spatial variations in physico-chemical parameters were observed in the present study and seasonal comparison was made between pre-monsoon, monsoon and post monsoon (Table 1). Monthly variations of the physico-chemical parameters of water in Gangavali and Aghanashini mangroves investigated were presented in Figs. 2 to 14. Correlation matrix for physico-chemical parameters of different stations are given in the Table 2. The most amount of rain fell in the month of July (1371.30 mm), while the least amount fell in the month of March (6.92 mm). According to Venkatesh and Jose (2007) [46], Ankola is classified as being in the coastal zone and receiving an average annual rainfall of 800 to 1000 mm. The most crucial element in the nutrition and well-being of animals is water. Water temperatures were recorded between 28.72 and 33.79ºC during the study of disturbance of mangrove forests causes alterations in estuarine phytoplankton community structure in Malaysian Matang mangrove forests (Hilaluddin *et al*., 2020) [17]. Similar observation was made during the present study where the water temperature between 25 °C (July 2022) and 34.5 °C (April 2022). Water temperature in the Mahanadi River Delta's mangrove habitat ranged from 24.2 °C to 30.9 °C (Behera *et al*., 2014) [7].

The biological and chemical properties of liquids are affected by pH, making it crucial to determine. It's one of the most crucial parameters in water chemistry. Due to variations in temperature, salinity, and biological activity, the pH concentration fluctuates throughout time (Balasubramanian and Kannan, 2005) [6]. The pH of water in the present study was observed to be ranged between 7.1 and 8.5, where maximum (8.5) water pH was measured in March, while the lowest (7.1) was in July. Das *et al*. (2019) [13] investigated the assessment of the natural regeneration of mangroves with respect to edaphic variables and water in the Southern Gulf of Kachchh, Gujarat, India and found that the pH of the water ranged from 7.87 to 8.04 and that the pH of the water was alkaline during the study period. Akther *et al*. (2018) [1] while investigating the assessment of water quality and seasonal variations based on the aquatic biodiversity of Sundarbans mangrove forest, Bangladesh reported that the pH values ranging from 7.0 to 9.2. In general, temporal changes in pH can be linked to factors such as CO_2 removal through photosynthesis, mixing of seawater by the freshwater input, poor primary production, salinity, and temperature, as well as organic matter breakdown (Rajasegar, 2003; Paramasivam and Kannan, 2005) [32, 27].

Salinity is an essential water parameter that affects water quality and determines the amount of gas dissolution, hydrogen ion concentration, and a variety of other brackish water properties. Salinity values during the current study period fluctuated from a minimum of 4 PSU in the month of August to a maximum of 32 PSU in the month of April and May. It could be because of the entry of fresh water from land runoff produced by monsoons or tidal changes (Prabhu *et al*., 2008; Swetha, 2009) [29, 40]. When examining the physico-chemical characteristics of the mangrove region in Keni creek, Ankola, Uttara Kannada district, Southwest coast of India, Chandrakant Lingadhal *et al.* (2020) [9] noted that salinity values ranging from 0 to 43 ppt. The salinity readings also showed a similar pattern from different regions in India's Southwest coast has been studied extensively (Saravanakumar *et al*., 2008; Kadam and Tiwari, 2011; Arumugam *et al.*, 2014; Naseema *et al*., 2017 and Thasneem *et al*., 2018) [37, 18, 3, 26, 41].

The dissolved oxygen of water in the present study showed a fluctuation between 4.48 and 8.96 mg/l. The maximum dissolved oxygen of water was recorded in the month of July while the minimum was found in the month of March. Nandini *et al*., 2021 [25] reported that at Adyar estuary, Tamil Nadu, the dissolved oxygen ranged from 3.24 to 4.91 mg/L, with the monsoon season recording the highest maximum value and the post-monsoon season the lowest minimum value. Gowda (1996) [16], Manjappa (1999) [23] and Ayyan Kumar (2007) [5] made comparable observations where they have noted that circumstances are well-oxygenated during the monsoon and are less DO during the pre-monsoon season. The biological oxygen demand of water in the present study ranged between 0.4 and 6.11 mg/l. The maximum biological oxygen demand of water was found in April month while the minimum was reported in the month of August. Pre-monsoon observed the least amount of BOD and monsoon recorded the highest amount of BOD. Similar outcomes were seen in trials carried out in the Muthupet estuary (Vasanthi and Sukumaran, 2017) [44]. This could be due to the influx of organic materials into the river, primarily from the deposition of faeces by the nearby urban area and human settlements. BOD values were measured between 2.1 and 9.6 mg/l while evaluating the water quality of several mangrove ecosystems in South Malang, East Java, Indonesia (Retnaningdyah *et al.*, 2021) [34].

The alkalinity of water in the current study ranged between 40-162 mg/l. The maximum was recorded in the month of March while the minimum was reported during the month of August in Gangavali mangrove. The existence of residential waste and the lack of regular tidal action, which would have had a flushing and diluting effect on dissolved components as well as bicarbonates, could have influenced the higher total alkalinity values found in summer regardless of the season (Dattatreya *et al*., 2018) [14]. The hardness of water in the present study ranged between 468-11800 mg/l. The maximum was recorded in the month of March (11800 mg/l) while the minimum was reported during the month of November (468 mg/l). At high temperatures, the rise in hardness could be related to a reduction in the volume of water and an increase in the speed of evaporation (Kaur and Sharma, 2001) [19]. Although the river water is rich in calcium, the amount of hardness it adds to coastal water during the monsoon is less than the amount added by magnesium during the summer Dattatreya *et al*. (2018) [13].

In the mangrove ecosystem, nutrients are thought to be the most crucial factors affecting the development, reproduction and metabolic processes of biotic components. The ammonia-nitrogen content of water in the present study ranged from 0.63 to 23.68 µg-at./1. The maximum value of ammonia-nitrogen in water was found in February (23.68 µg-at./1) while the lowest value was observed in August (0.63 µg-at./l). Similar findings was also made by Dattatreya *et al.* (2018) [13] assessment of the physico-chemical characteristics of the Krishnapatnam coast's mangrove region in India found that their research area had an ammonia concentration range of 3.9 µg/L to 19.8 µg/L. Ammonia concentrations in the Point Calimere and Muthupettai mangrove zones, varied from 0.698 to 0.120 µmol/L and 0.030 to 0.744 µmol/L, according to Srilatha *et al*. (2013) [38] observations. Nitrite is a useful form of nitrogen that is produced via oxidation-reduction processes in an environment like an estuary as it is the intermediate state of nitrogen in both the oxidation of ammonia to nitrate and the reduction of nitrate. The result obtain in the present study was compared with the study by Chandrakant Lingadhal *et al.* (2020) [9], where during investigating the physico-chemical characteristics of the mangrove region in Keni creek, Ankola, Uttara Kannada district, Southwest coast of India, recorded the nitrite values ranged from 0.19 to 3.14 µg-at/l. As per Boyd and Clay (1998) [8], nitrate is a nitrogenous compound that belongs to the nutrients present in saltwater and has a very little harmful effect on aquatic life even at high concentrations. In the present study the maximum concentration of nitrate-nitrogen in water was detected in July (10.55 µg-at./1) while the lowest concentration was observed in May (0.13 µg-at./1). Priya *et al*. (2019) [31] conducted research on the physico-chemical attributes of the Kodiakkarai coast and mangrove in Nagapattinam district, Tamil Nadu, India and recorded the nitrate levels ranging from 0.44 to 0.57 mg/l with the lowest during the summer and highest during the monsoon season. Prabhu *et al*. (2008), Damotharan *et al*. (2010), Manikannan *et al.* (2011), Arumugam and Sugirtha P Kumar, 2014, Dattatreya *et al*. (2018) and Chandrakant Lingadhal *et al.* (2020) [29, 12, 22, 3, 14, 9] made similar observations. Ravaniah *et al*. (2010) [33] stated that the impact of seasonal rainfall may be responsible for the highest concentration of nitrate during the rainy season, while the low value during the summer months may be brought on by limited freshwater influx and more salinity. During the current study, the monsoon seasons had high phosphate values. Due to the organism's use of phosphate, the phosphate levels in this area were lower during the pre-monsoon season. The high in August 2022 was noted and was linked to river runoff at that time. The accumulation of phosphate during the monsoon season that observed may be caused by the restoration and discharge of total phosphorus out from the bottom soil into the surrounding water via turbulence and blending (Chandran and Ramamoorthy, 1984) [11]. The silicate-silicon content of water in the present study ranged from 7.2 to 80.39 µg-at./1. The highest concentration of silicate-silicon in water was found in July (80.39 µg-at./1) while the lowest value was found in February (7.2 µg-at./1). similar to the current study Roopa and Gangadhar (2016) [35] recorded silicate concentrations ranging from 131.18 to 298.18 µg at/l while assessing the hydrological and nutrient status of the mangrove ecosystem of the Kali Estuary, Karwar, Karnataka, West coast of India. The range of the silicate concentration (µM) was observed to be between 21.35 to 316.84 µM such that the monsoon season observed the highest concentration of silicate, while the post-monsoon season recorded the lowest concentration (Santhanam *et al*., 2019) [36].

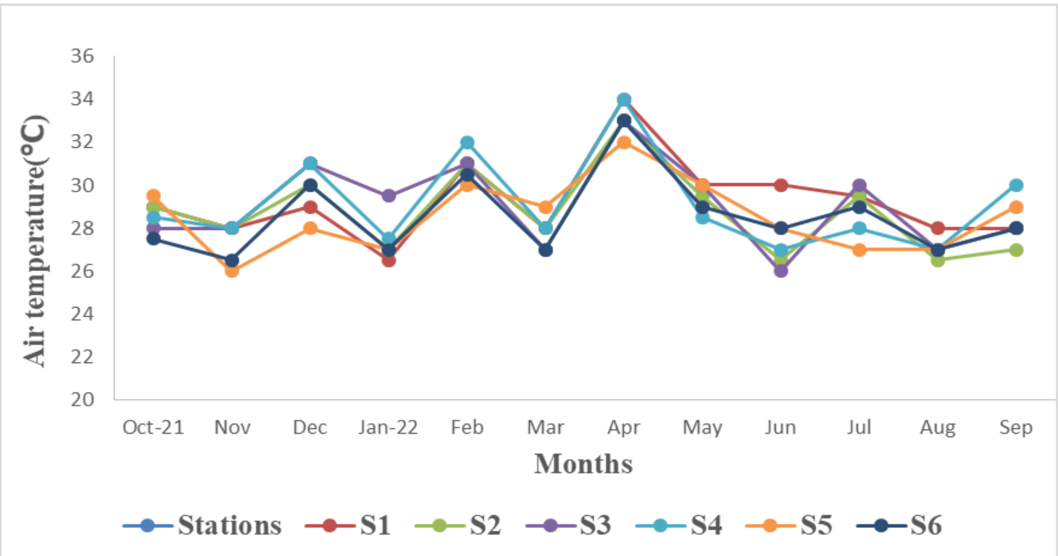

Fig 2: Monthly variation in Air temperature (°C) at selected stations of the Gangavali and Aghanashini mangroves.

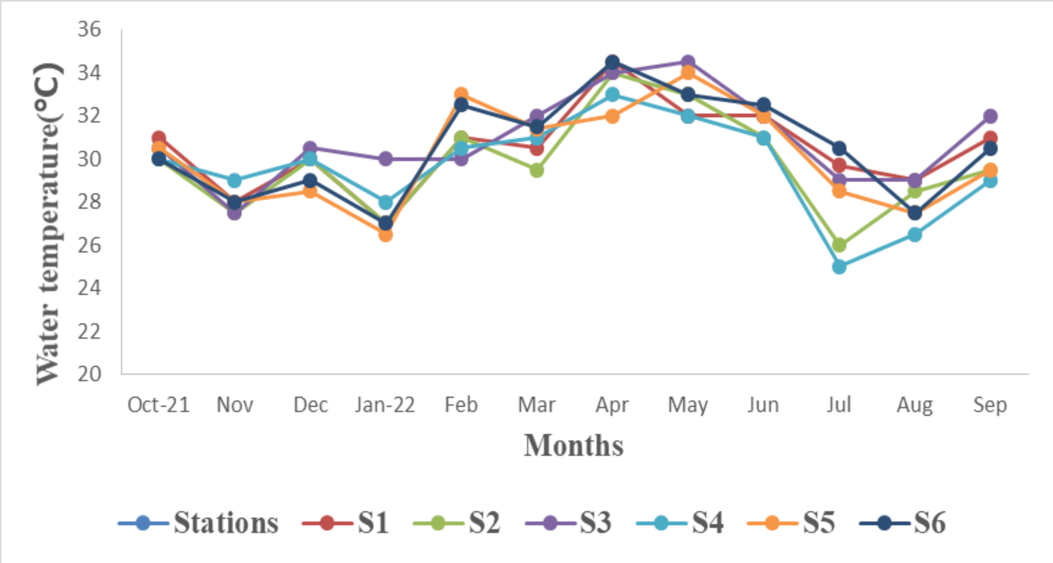

Fig 3: Monthly variation in Water temperature (°C) at selected stations of the Gangavali and Aghanashini mangroves.

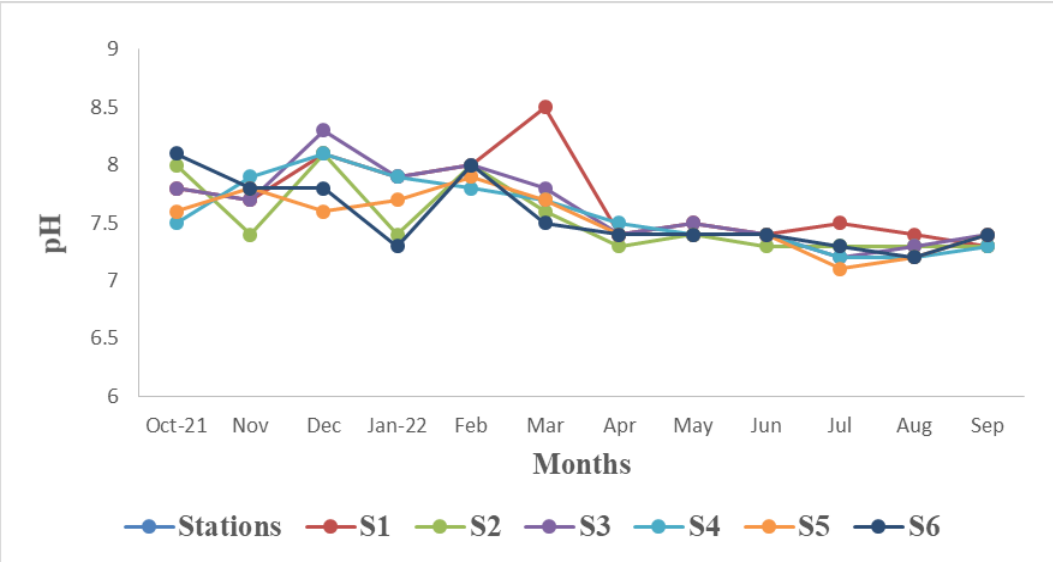

Fig 4: Monthly variation in pH at selected stations of the Gangavali and Aghanashini mangroves.

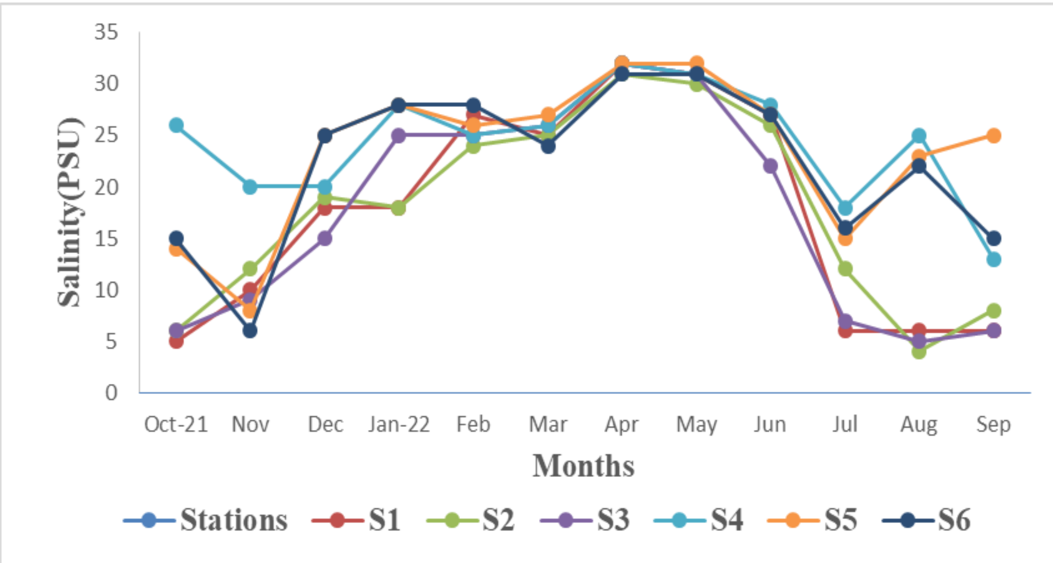

Fig 5: Monthly variation in Salinity (PSU) at selected stations of the Gangavali and Aghanashini mangroves.

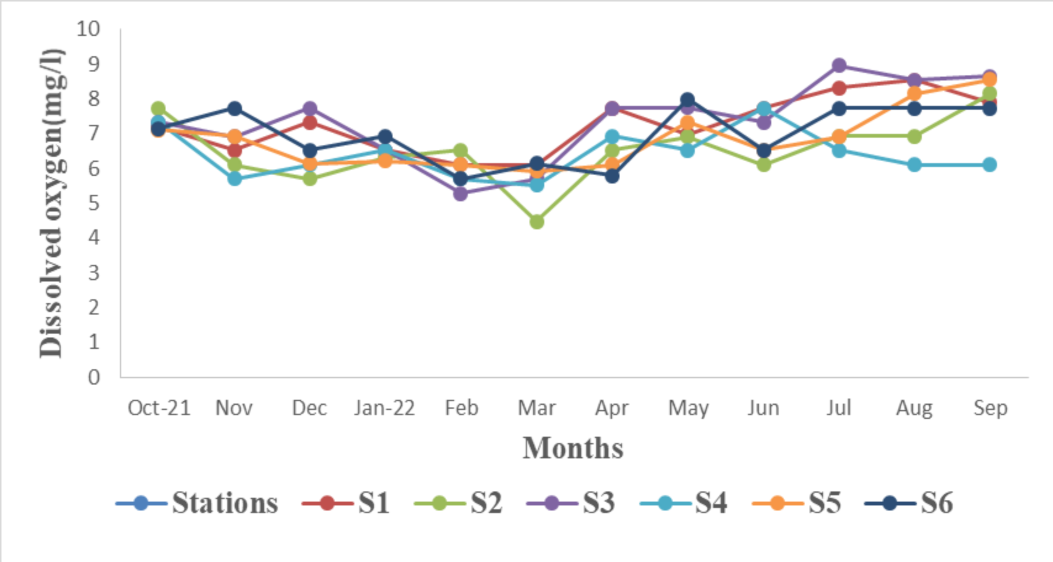

Fig 6: Monthly variation in Dissolved oxygen (mg/l) at selected stations of the Gangavali and Aghanashini mangroves.

Fig 7: Monthly variation in Biological Oxygen Demand (mg/l) at Gangavali and Aghanashini mangroves.

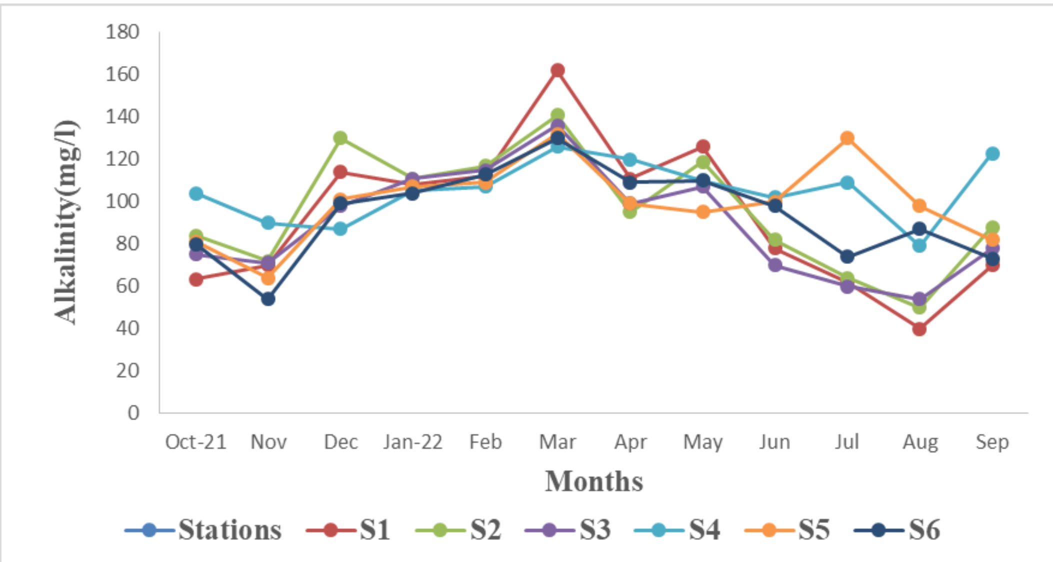

Fig 8: Monthly variation in Alkalinity (mg/l) at selected stations of the Gangavali and Aghanashini mangroves.

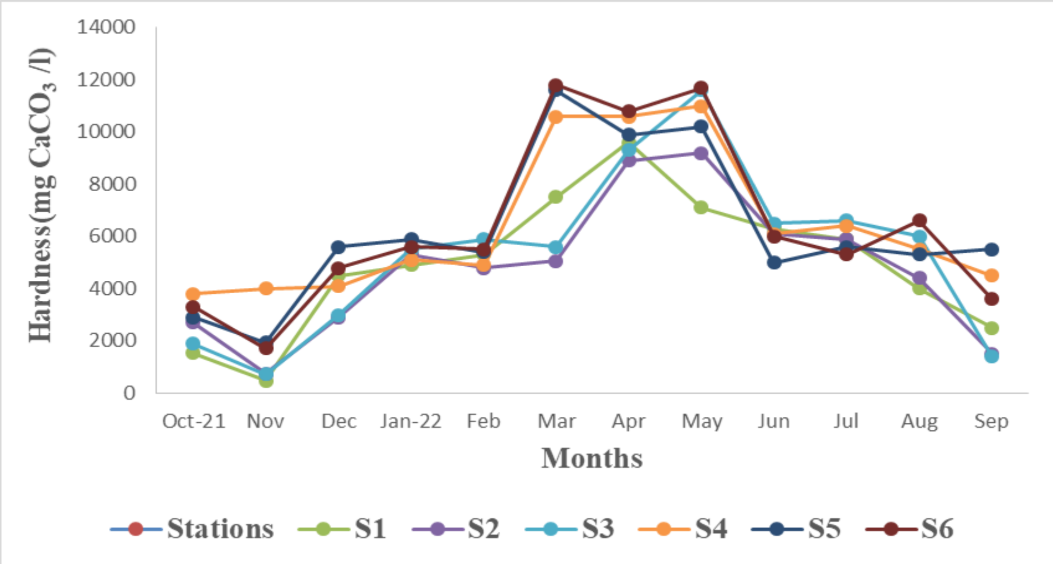

Fig 9: Monthly variation in Hardness (mg $CaCO_3$ /l) at selected stations of the Gangavali and Aghanashini mangroves.

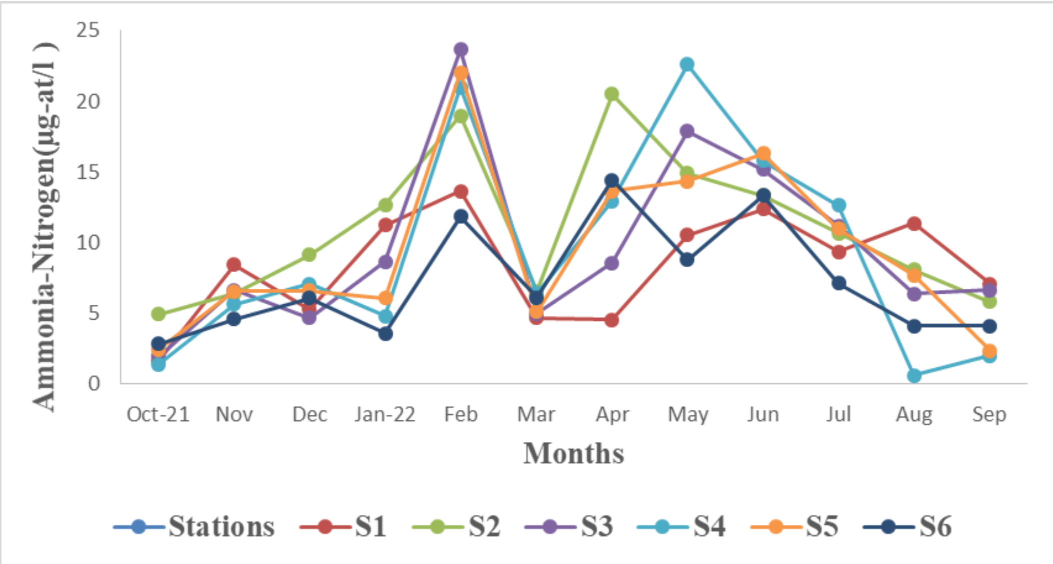

Fig 10: Monthly variation in Ammonia-Nitrogen (µg-at/l) at Gangavali and Aghanashini mangroves.

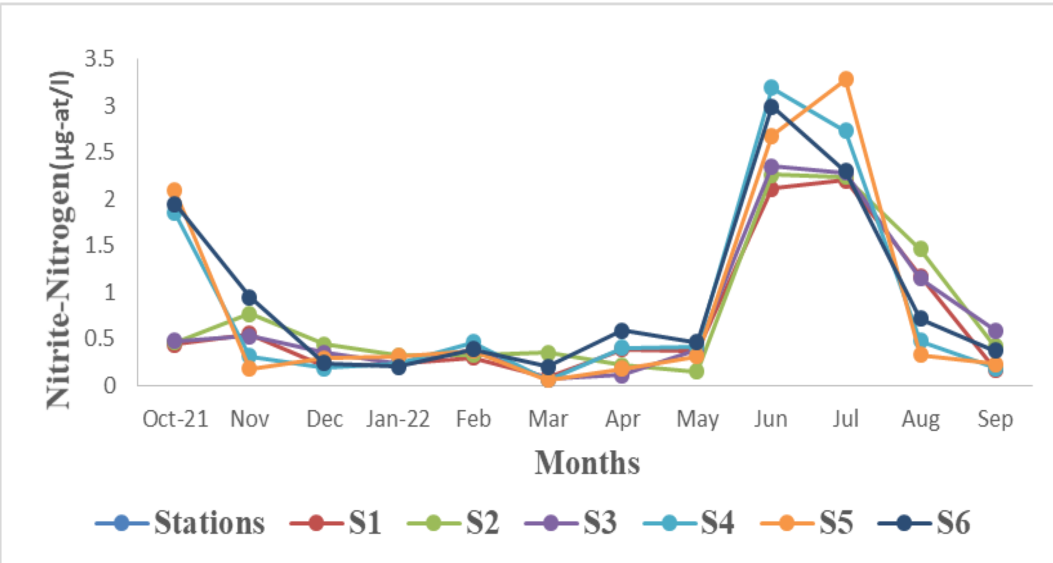

Fig 11: Monthly variation in Nitrite-Nitrogen (µg-at/l) at selected stations of the Gangavali and Aghanashini mangroves.

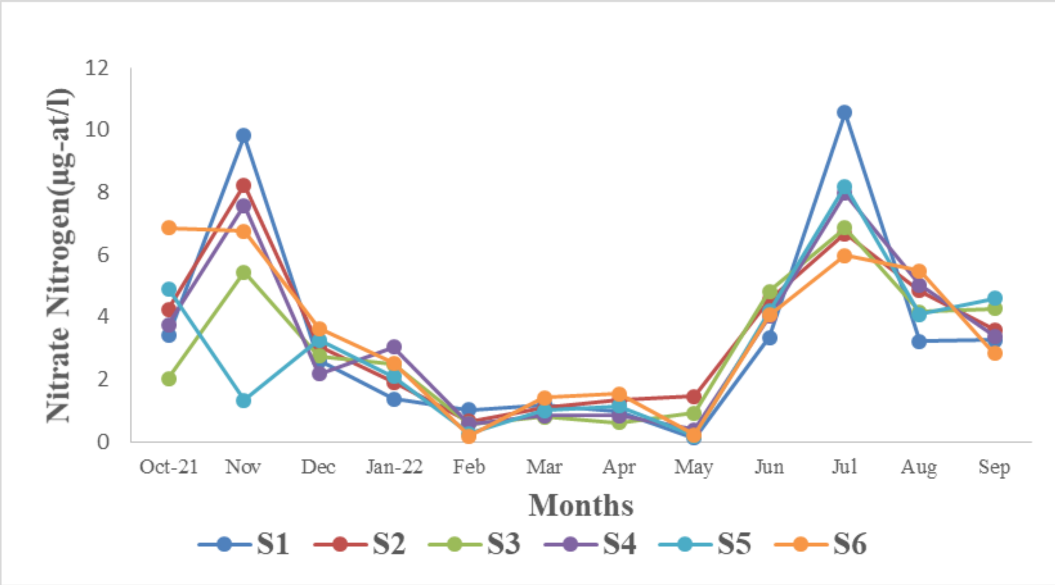

Fig 12: Monthly variation in Nitrate-Nitrogen (µg-at/l) at selected stations of the Gangavali and Aghanashini mangroves.

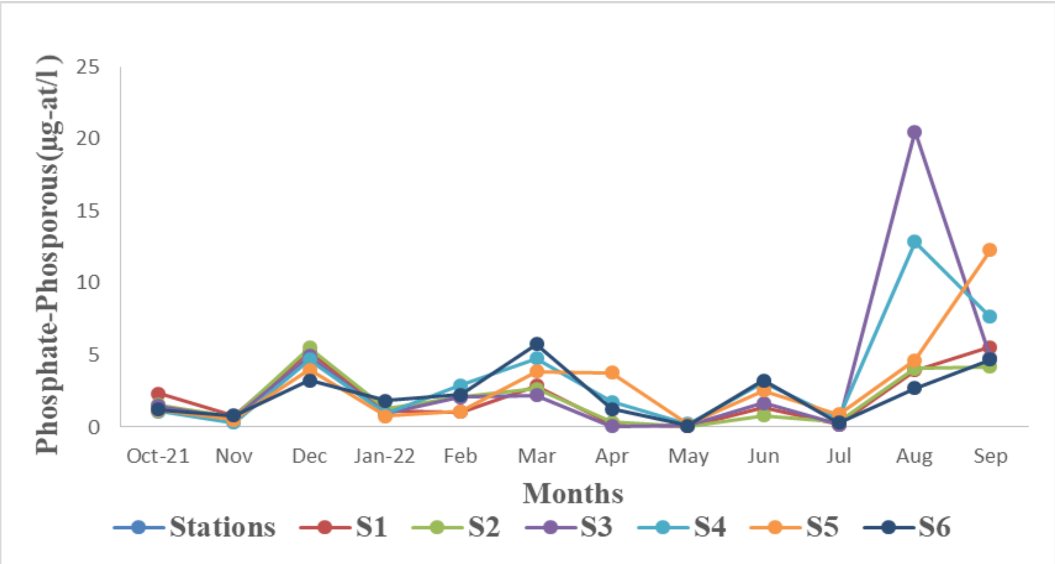

Fig 13: Monthly variation in Phosphate-Phosphorous (µg-at/l) at Gangavali and Aghanashini mangroves.

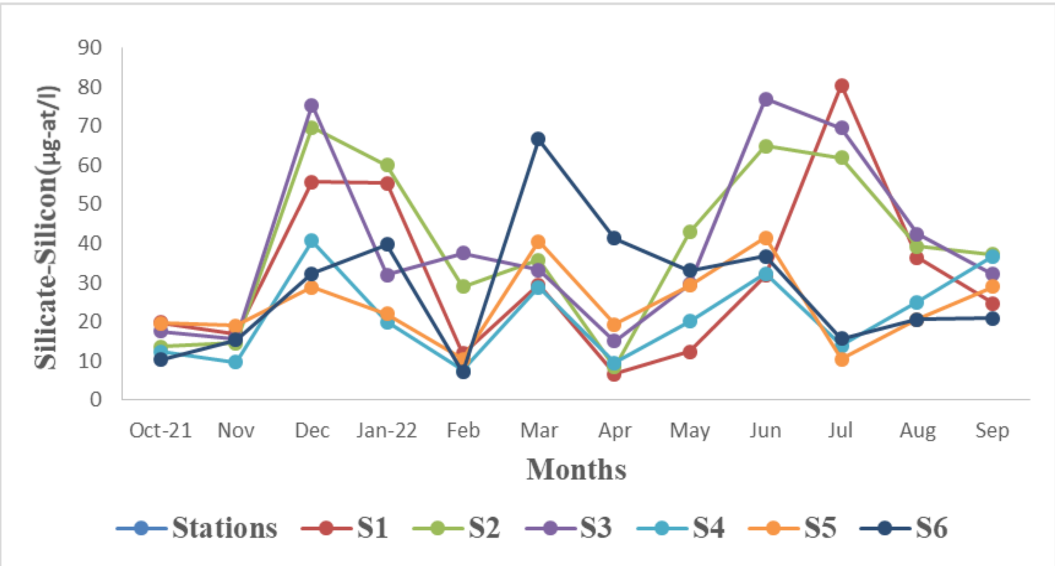

Fig 14: Monthly variation in Silicate-Silicon (µg-at/l) at selected stations of the Gangavali and Aghanashini mangroves.

Table 1: Seasonal mean values of various hydrograghical parameters at selected staions of Gangavalli and Aghanashini Mangroves.

Seasons	Place	Stations	Air temp (°C)	Water temp (°C)	pH	Salinity (PSU)	DO (mg/l)	BOD (mg/l)	Alkalinity (mg/l)	Hardness (mg $Caco_3$/l)	Ammonia-N (µg-at./l)	Nitrite-N (µg.at./l)	Nitrate-N (µg-at./l)	Phosphate-P (µg-at./l)	Silicate-Si (µg-at./l)
Pre - monsoon	Gangavalli	S1	30.75	32.00	7.85	28.75	6.74	2.37	127.75	7375	8.35	0.29	0.83	1.05	15.11
		S2	30.38	31.88	7.58	27.50	6.11	2.55	118.00	6990	15.25	0.26	1.14	1.30	29.07
		S3	30.25	32.63	7.68	28.50	6.62	2.78	114.25	8100	13.78	0.24	0.73	1.12	28.89
	Aghanashini	S4	30.63	31.63	7.60	28.50	6.17	3.57	115.75	9275	15.74	0.34	0.67	2.41	16.51
		S5	30.25	32.60	7.60	29.25	6.37	3.06	108.75	9275	13.78	0.23	0.65	2.23	24.94
		S6	29.88	32.88	7.57	28.50	6.41	4.07	115.50	9950	10.29	0.41	0.84	2.35	37.09
Monsoon	Gangavalli	S1	28.88	30.43	7.40	11.25	8.13	2.96	62.50	4675	10.04	1.41	5.10	2.77	43.36
		S2	27.38	28.75	7.30	12.50	7.03	2.20	71.00	4475	9.47	1.60	4.92	2.35	50.81
		S3	27.75	30.50	7.33	10.00	8.38	1.81	65.50	5125	9.84	1.60	5.04	6.79	55.25
	Aghanashini	S4	28.00	27.88	7.28	21.00	6.62	1.63	103.25	5625	7.77	1.65	5.11	6.05	27.06
		S5	27.75	29.38	7.28	22.50	7.54	4.18	102.50	5350	9.33	1.63	5.27	5.08	25.38
		S6	28.00	30.25	7.33	20.00	7.44	2.65	83.00	5375	7.18	1.60	4.59	2.74	23.49
Post-Monsson	Gangavalli	S1	28.13	29.65	7.88	12.75	6.89	2.45	88.88	2852	6.66	0.36	4.31	2.35	37.00
		S2	28.50	28.06	7.73	13.75	6.47	2.76	99.25	2912	8.29	0.50	4.36	2.26	39.44
		S3	29.13	29.13	7.93	13.75	7.13	2.03	88.75	2775	5.48	0.40	3.18	1.99	35.18
	Aghanashini	S4	28.75	27.94	7.85	23.50	6.42	2.85	96.50	4250	4.72	0.65	4.14	1.76	20.69
		S5	27.63	28.56	7.68	18.75	6.60	2.96	88.25	4085	5.42	0.72	2.90	1.61	22.36
		S6	27.75	29.13	7.75	18.50	7.09	3.47	84.25	3850	4.28	0.84	4.95	1.78	24.46

Table 2: Significant correlation coefficient between different parameters at selected stations of Gangavalli and Aghanashini Mangrove waters.

Parameters	Air Temp.	Water Temp.	pH	Salinity	Dissolved Oxygen	Alkalinity	Hardness	Nitrite- N
Air Temp.		0.86**(S1) 0.78**(S5) 0.69*(S6)						
Salinity	0.58*(S1) 0.64*(S5)	0.68*(S2) 0.67*(S3) 0.67*(S4)						
Dissolved Oxygen			-0.75**(S1) -0.63**(S3)					
BOD		0.78**(S3)	-0.67*(S5)	0.77**(S3)	0.68*(S1) -0.74**(S3)			
Alkalinity			0.68*(S1)	0.76**(S1) 0.64*(S2) 0.77**(S3) 0.64*(S4) 0.86**(S6)	0.69*(S1) -0.74**(S3) -0.67*(S6)			
Hardness	0.61*(S1)	0.59*(S1) 0.63*(S3)		0.78**(S1) 0.73**(S2) 0.71**(S3) 0.73**(S4) 0.76**(S5) 0.72**(S6)		0.59*(S1)		
Ammonia- N	0.63*(S4) 0.73**(S6)	0.58*(S2) 0.58*(S4) 0.62*(S5) 0.83**(S6)		0.75**(S2) 0.75**(S4) 0.63*(S6)			0.75**(S4)	
Nitrite- N						-0.65*(S2) -0.65*(S4)		
Nitrate - N		-0.60*(S3) -0.61*(S4) -0.58*(S6)	-0.61*(S2) -0.66*(S5)	0.63*(S1) -0.63*(S2) -072**(S3) -0.63*(S4) -0.78**(S6)	0.59*(S3)	0.77**(S2) -0.81**(S3) -0.77**(S4) -0.81**(S6)	-0.68*(S6)	0.63*(S2) 0.63*(S4) 0.77**(S5)
Silicate - Si						0.68*(S6)	0.72**(S6)	

**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).

Conclusion

The physico-chemical characteristics of the water fluctuates as the season changes, this will be due to ebb and flow, change in the temperature and salinity as season changes. The present water quality of Gangavali and Aghanashini mangrove ecosystem reveals that salinity plays a dominant role in controlling the water quality. In addition, intense pollution from agricultural inputs deteriorates the water quality of mangrove ecosystem. The present information of the physico-chemical characteristics of water would form a useful tool for further ecological assessment, monitoring and to evaluate the health of the coastal sensitive mangrove ecosystems.

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Conflicts of Interest
The authors declare no conflict of interest.

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