Heliyon 8 (2022) e10935

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Vertical profile of dissolved oxygen and associated water variables in the Pasur-Rupsha estuary of Bangladesh

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ARTICLE INFO

Keywords:
Stratification
Water parameters
Plankton
Mixing
Bangladesh Estuary

ABSTRACT

Vertical profile of dissolved oxygen (DO) and associated water variables were measured in the head of the Pasur-Rupsha estuary of Bangladesh. Water samples were collected from two stations at 0.60 m depth intervals during high and low tides from July, 2016 to January, 2017. DO concentration was ranged from 6.0 to 8.6 mg/l with maximum two units of variation in the profiles of the stations and demonstrated an inconsistent stratification pattern. The observed stratification pattern was remarkably triggered by a relatively high concentration of DO in the bottom layer than that of the surface layer during both the high and low tides in most of the study periods. High rate of freshwater flow at the surface; existence of estuarine gravitational circulation with 5–15 m depth profile; and lack of consumers in the bottom due to the high deposition of sediment particles were found responsible for the relatively high concentration of DO at bottom and low in surface layer of the estuary. Water temperature, salinity, pH, phytoplankton density and transparency were ranged from 22 to 32 °C, 0–6 ppt, 7.0 to 8.5, 1000–23000 ind/l and 13–17 cm respectively considering the depth profiles in the study periods. Temperature and plankton density were found significantly ($P < 0.000$) correlated with DO while the pH and salinity did not show any significant ($P > 0.3$) correlation. The ecosystem process associated with the vertical profile of DO explained in this study will provide considerable advances in understanding the ecosystem dynamics of the Pasur-Rupsha Estuary of Bangladesh.

1. Introduction

Coastal rivers in the southwest coastal region of Bangladesh are comprised of a unique ecosystem and significantly contribute to the activities like open and closed water fisheries. Quality of the water is obviously an important consideration to sustain both the open (capture) and closed (culture) water fisheries resources. Such as disease occurrence or low production of shrimp culture in the region is due to the unsuitability of the source (river) water [1]. Among the considerable water variables, dissolved oxygen (DO) is one of the key attributes that indicates the suitability of the habitat for aquatic biota and can reflects the healthiness of a river water ecosystem. DO is required for respiration by most aquatic biota. Natural stream purification processes therefore, require adequate oxygen levels in order to provide aerobic life forms. As dissolved oxygen levels in water drop below 5.0 mg/l, aquatic life is put under physiological stress. Oxygen levels that remain below 1–2 mg/l for a few hours can adversely affect the growth and survivability of aquatic organism. DO is, therefore, an indispensable element to all forms of aquatic life [2].

Dissolved oxygen used to change horizontally along the course of the waterway in shallow-river but most likely to vary vertically in the water column in deep-river. A theoretical deduction shows that vertical stratification of DO concentration can be explained by the extended Hansen and Rattray's central region theory, which suggest that vertical DO profiles are mainly controlled by biological factors such as photosynthesis, biochemical oxygen demand (BOD), sediment oxygen demand (SOD) as well as physical factors such as surface re-aeration, river flow and estuarine gravitational circulation [3]. Freshwater from upland and saline water from sea can generate a stratified layer and limit the DO in the epilimnion (near the surface) and the hypolimnion (near the bottom) region. Alternately, a deep river can also generate an un-stratified water column due to well mixing of the water. Depth of the coastal rivers in the

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https://doi.org/10.1016/j.heliyon.2022.e10935
Received 11 May 2022; Received in revised form 20 August 2022; Accepted 29 September 2022
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southwest region ranges from 5 to 15 m and the presence of stratification is unknown [4].

The stratification pattern following vertical profile of DO in estuaries is considered as a highly informative variable for obtaining the ecosystem's functionality and behaviors. Stratification of DO have been reported from various estuaries of the world in recent years [3, 5, 6, 7, 8, 9, 10, 34]. It appears that vertical distributions of DO concentrations in estuaries are affected by different variables in different systems. The dominant variables in a system are often unknown a priori. Most of the studies regarding estuaries in Bangladesh are focused on pollution [11, 12, 13], fish diversity [14, 15], water quality variables [16, 17], plankton communities [18, 19], and land cover land use change [20]. However, vertical profile of DO and thereby stratification have not been studied in the estuaries of Bangladesh.

Several studies have reported the DO of southwest coastal rivers or estuaries in Bangladesh. Shah et al. [21] studied the three major river systems (Pasur, Sibsa and Malancha) of Sundarbans. The observation considered only the surface layer of the water columns and the DO was ranged 2.95–5.06 mg/l at the Pasur, 3.18–6.08 at the Sibsa and 2.92–5.10 at the Malancha rivers. Rahaman et al. [22], Rouf [1] and Rouf and Jensen [23] observed the DO of several rivers in the southwest coastal region. These studies were also based on the surface layer observations and addressed the DO ranged from 3.90 to 7.03 mg/l, 2.80–7.50 mg/l and 2.19–8.10 mg/l respectively. All these studies were based on surface layer observation instead of considering the observations from the vertical profile of the rivers. The understanding of the river ecosystem is therefore not sufficient enough to the estuarine ecologists and coastal managers.

The Pasur-Rupsha estuary adjacent land is intensively used for agriculture, settlements, forests, aquaculture, industries, and tourism [24]. According to the Word Bank [25], this estuary receives approximately 10 million gallons of effluents from the adjacent industries per day. Besides the heavy metals (Cd, Ni, As, Pb and Cr) in water from Rupsha River are higher than permissible value and 85% of the samples pose moderate ecological risk [26, 27, 28]. In addition, extensive agricultural runoff, the effluents from aquaculture farms and households urge us to choose the site as a significant research area [26].

Considering the importance of the estuaries in the southwest coastal region of Bangladesh and the survival of its biota, a comprehensive field investigation was carried out for the first time to explore the vertical profile of DO in the head of the Pasur-Rupsha estuary from July, 2016 to January, 2017 and its association with temperature, salinity, pH, transparency and phytoplankton density. It is anticipated that the results of the present study will provide clues to assess the variability and suitability of the aquatic habitat and thereby broaden the information and provide considerable advances in understanding the ecosystem dynamics of the Pasur-Rupsha Estuary.

2. Materials and methods

2.1. Study area

The study was focused on the head of the Pasur-Rupsha estuary located in the southwest coastal region of Bangladesh. Two stations (St.1 and St.2) were selected to investigate the stratification pattern of dissolved oxygen and its association with relevant variables like temperature, salinity, pH, transparency and phytoplankton density. Location of the study area including selected stations is shown in Figure 1. Both stations are characterized by semidiurnal tides and strong currents.

Station-St.1 is located near the Chalna launch terminal in Dakope upazilla of Khulna district and adjacent to the Rampal Power Plant, Mongla Port and the Sundarbans. This station is in the Pasur River which originates from the Rupsha River and travels around 65 km before emptying directly into the Bay of Bengal. The width, depth and mean

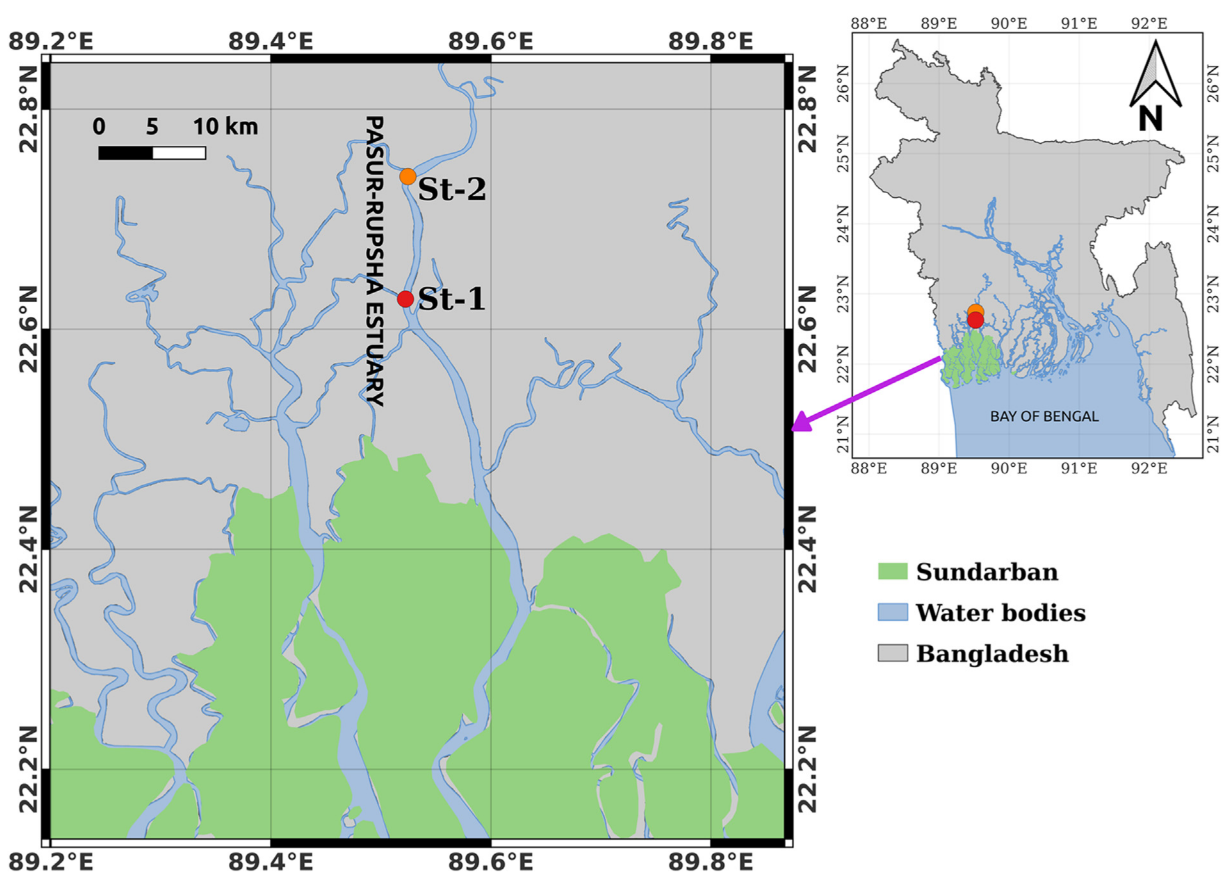

Figure 1. Location of two stations (St.1 and St.2) in the Pasur-Rupsha Estuary in Southwest coastal region of Bangladesh.

tidal range of the river surrounding the station ranges from 0.8 to 1.0 km, 7.0–8.6 m and around 1.5 m respectively. Station-St.2 is located near Batiaghata bridge in Botiaghata upazilla of Khulna district and lies in the Rupsha River, which empties directly into the Pasur River. The width, depth and mean tidal range of this station surrounding river ranges from 0.4 to 0.5 km, 6.0–7.5 m and around 1.8 m respectively. This station is located around 10 km upstream from the St.1.

2.2. Sample collection and preparation

Water samples were collected monthly from the stations between July, 2016 and January, 2017 for in-situ measurements and laboratory analysis. Sampling was conducted during the slack period of both high tide and low tide. Water sampling date, time of respective tidal level, moon phase, weather and atmospheric temperature are shown in Table 1. Water samples were collected by using a bottom water sampler following 0.60 m of depth intervals. During in-situ measurements, water temperature was measured by digital thermometer (with stainless steel sensor probe), while salinity and pH were measured by refractometer (Model: Cat No. 2493, MASTER-S/MillM, ATAGO, Japan, Range: 0–50‰; Accuracy: ±2‰) and digital pH meter (Model: pH 5011, E2DO, Range: 0–14.0, Resolution: 0.1, Accuracy: ±0.2) respectively. For phytoplankton, water samples were immediately fixed with Lugol's solution (3 ml/l) upon collection and stored in the dark until returned to the laboratory.

Table 1. Station wise water sampling dates with their respective moon phase, tidal level, sampling time, weather and atmospheric temperature.

Stations	Sampling date	Phases of the moon	Tidal level and sampling time	Weather and atmospheric temperature
St. 1	2nd July, 2016	Between new moon and first quarter	High tide	Cloudy
			(3.45 pm)	29.9 °C
			Low tide	Cloudy
			(11.30 am)	30.9 °C
	8th September, 2016	Between first quarter and full moon	High tide	Sunny
			(10.45 am)	28.5 °C
			Low tide	…….
			________	________
	29th November, 2016	Between new moon and first quarter	High tide	Sunny
			(4.15 pm)	30.3 °C
			Low tide	Sunny
			(11.55 am)	37.0 °C
	6th January, 2017	Between full moon and last quarter	High tide	Cloudy
			(2.00 pm)	25.3 °C
			Low tide	Cloudy
			(9.30 am)	23.9 °C
St. 2	19th July, 2016	Exactly last quarter	High tide	Cloudy
			(6.00 pm)	29.9 °C
			Low tide	Cloudy
			(2.15 pm)	33.1 °C
	15th September, 2016	Between full moon and last quarter	High tide	Sunny
			(4.15 pm)	32.8 °C
			Low tide	Sunny
			(11.50 am)	33.3 °C
	16th November, 2016	Exactly last quarter	High tide	Sunny
			(4.30 pm)	33.0 °C
			Low tide	Sunny
			(12.15 pm)	34.5 °C
	15th January, 2017	Between last quarter and new moon	High tide	Sunny
			(11.00 am)	26.1 °C
			Low tide	Sunny
			(3.45 pm)	28.1 °C

The processed water samples were taken to the water quality laboratory of Fisheries and Marine Resource Technology (FMRT) Discipline of Khulna University for analysis. Winkler's method [29] was followed during the measurements of dissolved oxygen. An accuracy of 0.1 % was observed while comparing with the standard based dissolving known quantities of O_2 in O_2 free water. Mann-Whitney test was conducted at 5 % significance level in order to determine the statistical difference between the surface (records observed within 2 m below the surface) and bottom (records observed within 2 m above the bottom) layers DO of each depth profile. To calculate the percentage saturation of DO, a monogram was used to get quick approximate oxygen saturation values [30]. Phytoplankton densities were measured by direct cell counting method using Sedgwick-Rafter (S-R) chamber and optical Microscope (Carl Zeisis Microimaging, ZEISIS Primo Star, GmbH 37081 GoHingen, Germany).

3. Results and discussion

3.1. Vertical profile of dissolved oxygen (DO)

Dissolved oxygen with the depth profiles in two stations during high and low tide from July to January are shown in Figure 2. Dissolved oxygen was not possible to be recorded at St.1 during low tide in the month of September due to extreme water current. Dissolved oxygen concentration ranged from 6.0-8.6 mg/l in the stations at both tides during the sampling months throughout the depth profiles. The range of DO found in the stations indicates a healthy water mass for estuarine biota throughout the profiles. Coastal waters require a minimum of 4.0–5.0 mg/l of DO to provide optimum ecosystem function with the highest carrying capacity [31]. Rahman et al. [32] recorded the DO as 6.0–7.3 mg/l at around 0.3 m depth for the samples obtained from the lower stream of the Pasur-Rupsha estuary. Upstream location with lower water salinity in the present study may be responsible for the higher range of DO than the range mentioned in Rahman et al. [32]. Relatively high DO was found in the low tide than that of the high tide in most of the profiles due to the large intensity of tidal fluctuation in the estuary, with cold incoming seawater and warm outgoing freshwater. It was noticed during the sampling that the water current was relatively strong during the low tide than that of the high tide. It is suspected that this phenomenon influences on the DO variation in the study areas. Supporting this, Pereira et al. [33] also reported that intense water-atmosphere interactions and photosynthetic activity dominated the concentration of DO in the Amazon Coast. Small depth may also be responsible for mixing or little stratification in the study area. DO was found relatively higher in January than in the other months due to the winter season.

Maximum two units (mg/l) of variation in DO were noticed in the depth profiles of the stations. It is noticeable that the DO concentration was relatively high in the bottom layer and low in the surface layer during both the high and low tides in most of the months except September and January for St.1. The obtained results from Mann-Whitney test suggest that both significant difference ($P < 0.05$) and no difference ($P > 0.05$) between the surface and bottom layer DO of the profiles were evident in the study area (Table 2). Therefore, it can be said that the stratification of DO was inconsistent in the depth profiles of study area. Lin et al. [3] found similar stratification pattern in the Cape Fear River Estuary of North Carolina due to higher estuarine gravitational circulation. In contrast, Liblik et al. [34] reported strong stratification of DO due to wind forcing circulation patterns, upwelling and downwelling in the Changjiang (Yangtze) Estuary, China.

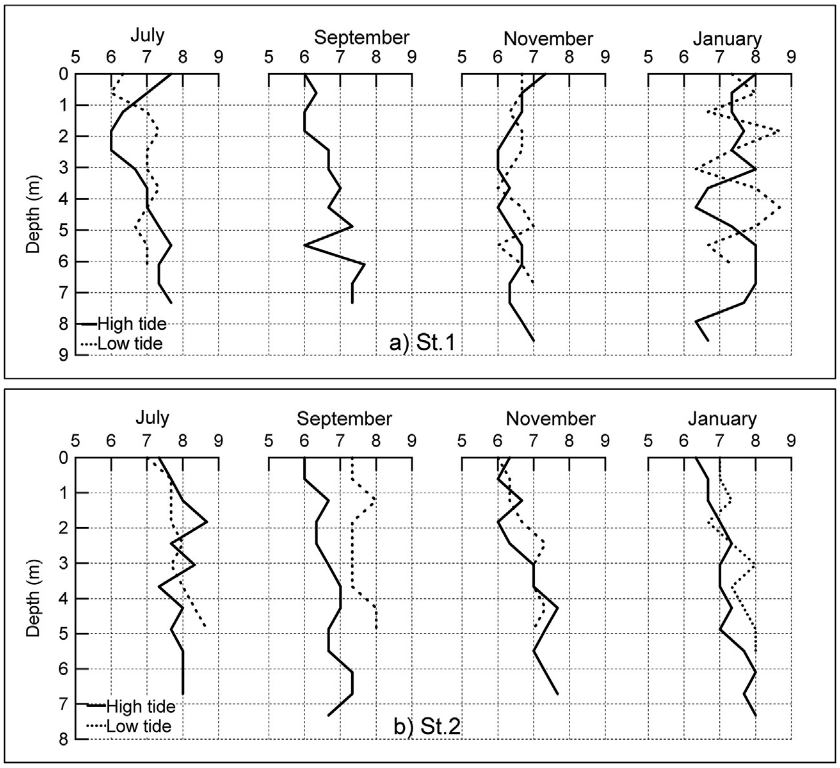

Figure 2. DO profiles during high and low tide in four months at St.1 and St.2.

Table 2. Statistical difference between the surface and bottom layers DO in the Pasur-Rupsha estuary.

Station	Tide	Asymptotic significance level (*P*)			
		July	September	November	January
St.1	High	0.04*	0.64	0.48	0.37
	Low	0.82	-	0.82	0.50
St.2	High	0.90	0.07	0.04*	0.04*
	Low	0.04*	0.47	0.04*	0.04*

Note: * indicates significant difference between the surface and bottom layers DO [Significance level = 0.05].

3.2. Association of DO profiles with temperature, salinity, pH, plankton density and transparency

Dissolved oxygen, temperature, salinity, pH and phytoplankton density with depth profiles during the high and low tides in four sampling months in the study areas are shown in Figures 3a and 3b. The vertical profiles of DO, temperature, salinity and pH showed inconsistent stratification pattern throughout the study period.

Temperature controls the lives of aquatic organisms [35]. The temperature of a particular water system usually affects the solubility of substances on it. Certain substances dissolved significantly in water at high temperatures, while others do so at low temperatures [36]. Temperature has direct relation with sedimentation and filtration rate as well as with the metabolism rate of aquatic organisms. Water temperature was 30–32 °C from July to November and 22–25 °C in January in the vertical profiles of the stations. One or less than one unit (°C) variation in temperature was noticed from July to November and nearly two unit variations were noticed during January in the profiles. Less variation (<2 units) of temperature within the profiles indicates a weak stratification, which addresses a level of water mixing. This mixing is suspected to be regulated mostly by the water movement following ebb and flood tides in the estuary. The relation between the temperature and DO was found inversely correlated (−0.252) with high significance level ($P < 0.000$). Some temperature profiles showed inverse relation (Figure 3a iii, iv low tide) with DO profiles while others showed opposite or no relation (Figure 3a iii, iv high tide). Seasonal variation of temperature within the temperature profile was found responsible factor for that minimum level of inverse correlation coefficient.

As the temperature is associated with the solubility of oxygen in water, the saturation point indicates the level at which water generally holds any more oxygen at a given temperature. The percentage saturation level ranged from 72% to 110% in the Pasur-Rupsha estuary considering the obtained temperature range from 22 to 32 °C and DO range from 6 to 8 mg/l.

Water salinity in the stations were ranged from 0 to 6 ppt during the study period. Maximum four units (ppt) variations in salinity were noticed in the profiles of St.1 and nearly two unit variations in St.2. Relatively large variations were observed in St.1 as the station is located in more downstream (around 10 km) than the St.2. The study results addressed that the downstream station (St.1) experienced two times more saline water than the upstream station (St.2). It is also noticeable that salinity in the stations showed variability in the profiles. Some profiles showed relatively low salinity in surface and high in bottom and others showed opposite scenario. The salinity profiles however, indicate a weak stratified profile in the stations. Variation in salinity profiles from high tide to low tide, shown in Figures 3a and 3b, addressed that the water movement is regulated by ebb and flood tides along with the differences in the density of water. The movement of water due to the density differences in turn expresses the existence of estuarine gravitational circulation. These regulatory mechanisms may be responsible for the weak stratification in the estuary. Rahaman et al. [22] accorded that a large amount of freshwater inputs from upstream areas and semidiurnal tidal variations are highly responsible for salinity variations in the Pasur-Rupsha estuary. The relation between salinity and DO in this study was not found significant ($P > 0.3$) in the profiles. Some salinity profiles showed inverse relation (Figure 3a i, 3b ii, iii, iv low tide; 3a iii high tide) with DO profiles while others showed opposite or no relation (Figure 3a i,

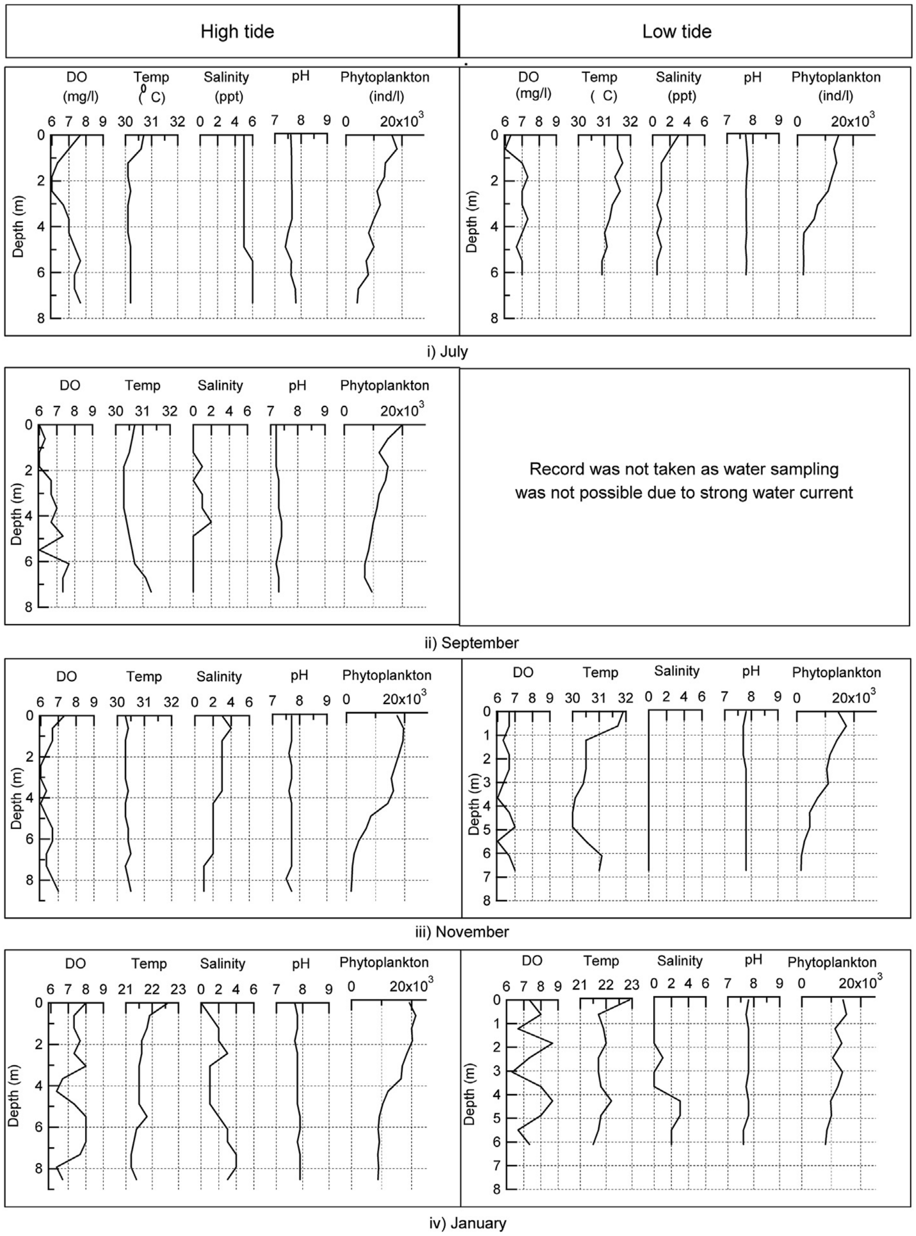

Figure 3a. DO, temperature, salinity, pH and phytoplankton density with depth profiles during high (left) and low tides (right) in four sampling months in St.1.

iv 3b iv high tide). In few cases (Figure 3b low tide), DO stratification was observed even under conditions of a similar salinity profile. Water sampling area i.e., the head of the estuary may be responsible for the insignificant relation.

pH determines the acidity or alkalinity of a water system. It regulates the chemical and biological states of nature water. The changes in pH bring the dissociation of weak acids and bases that affects the toxicity of most compounds in water. Hence the ability of water to support life is a function of pH [37]. Water pH was found between 7.0 and 8.5 in the profiles during the study period in both stations. The range is within the preferred pH of 6.5–9.0 recommended for the survivability of fish [38] and 6.0 to 8.5 recommended for the Environmental Quality Standard (EQS) of Bangladesh [39]. Hoq et al. [40] and Rahaman et al. [22] reported the pH range of estuarine water as 7.08–8.10, which is slightly alkaline and remains neutral to alkaline throughout the year. Maximum half unit variation was noticed in the pH profiles of the stations. The pH profiles rarely showed any major stratification in the stations. The relation between pH and DO in the estuary was not found significant ($P >$ 0.05) in the profiles. Dissolved oxygen and pH would increase when photosynthesis by aquatic plants removes carbon dioxide (CO_2) from the medium and decline when respiration by aquatic organisms and decomposition by decomposers release CO_2 into the medium [41]. The observed pH range (7.1–8.4) in the surface layer of the stations suggests a reasonable extent of photosynthesis by aquatic plants in the surface of the estuary. While nearly similar pH range (7.1–8.0) in the bottom layer suggests insufficient respiration and decomposition in the bottom of the estuary. In addition, water mixing is also responsible for similar pH in the profiles [42].

Phytoplankton density was 1000–23000 ind/l during the study period in the stations. Downstream station (St.1) exhibited higher phytoplankton density than the upstream station (St.2). A relatively high density of phytoplankton was also noticed in the high tide while low densities were recorded in the low tide at both stations. These density variations suggest that the water from downstream carries more phytoplankton than the water from upstream. Phytoplankton density was 10000–23000 ind/l and 1000–10000 ind/l in the surface and bottom

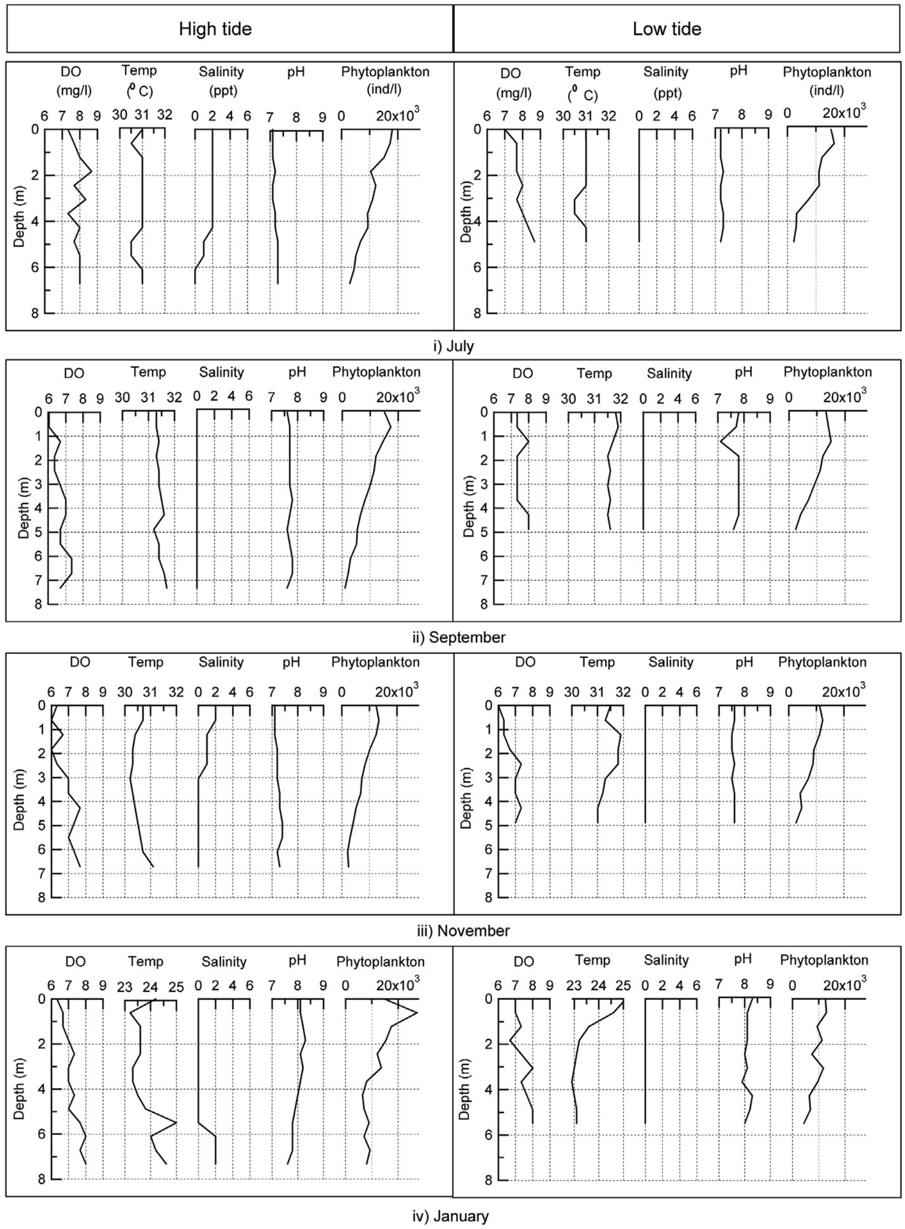

Figure 3b. Vertical profile of DO, temperature, salinity, pH and phytoplankton density during high (left) and low tides (right) in four sampling months in St.2.

layers respectively. Rahaman et al. (2013) reported the average phytoplankton density in the surface as 22800 ind/l in the Pasur-Rupsha estuary. A significant ($P < 0.05$) negative correlation (r = -0.144) was found between the phytoplankton density and DO in the profiles. This negative correlation was mostly derived by the gradual decrease of phytoplankton density and increase of DO concentrations with depth in bottom layers. Considering the observations shown in Figures 3a and 3b, it is anticipated that phytoplankton has little or no influence on higher DO in the bottom layer. A large variation of phytoplankton density however, was noticed in the profiles and it was supposed to be due to the nutrient availability and light intensity. Similar observation was reported by Pereira et al [33].

Transparency of the Pasur-Rupsha Estuary was also observed during the study period and the records are shown in Table 3. The values ranged from 13 to 17 cm. Rahaman et al. [22] found the transparency between 8 and 36 cm in the Pasur-Rupsha estuary. The range of transparency observed in the estuary was noticeably low and represents (in general) extensive turbid water.

Turbidity of water is caused by plankton, dissolved organic matter, and suspended sediments. Range of plankton density as well as the color of water observed in the present study suggests no plankton bloom, which represents minimum influence of plankton on the high turbidity. Biochemical oxygen demand (BOD) indicates the amount of dissolved oxygen used up during the oxidation of oxygen demanding wastes to produce carbon dioxide and water. Rouf et al. [1] recorded BOD from 2.0 to 3.0 mg/l in the surface of the estuary. Rahaman et al. [22] reported

Table 3. Transparency of water in the head of Pasur-Rupsha estuary.

Station	Tide	Transparency (cm)			
		July	September	November	January
St.1	High	14	13	15	16
	Low	13	-	15	16
St.2	High	14	15	13	17
	Low	13	15	13	16

that mean BOD in the surface of the Pasur-Rupsha estuary (around 5 km downstream from the St.1) ranged between 0.3 and 4.1 mg/l with an average of 2.04 mg/l. The BOD indicates a small quantity of biodegradable organic matter in the estuary and thereby has less contribution to the high turbidity. Rahman et al. [32] reported yearly average of total dissolved solids (TDS) and total suspended solids (TSS) in the Pasur River as 28,400 mg/l and 4760 mg/l respectively, which were comparatively higher than the recommended level of TDS (1000 mg/l) and TSS (150 mg/l) in Bangladesh. Among the TDS, inorganic solids were around 85% and organic solids were only 15%. A high amount of suspended sediment (fine and coarse) particles was also noticed during the water sampling of this study. Therefore, the inorganic suspended particles played a major role for the high turbidity of the study areas water. These particles supposed to reduce the abundance of biota particularly the microorganisms responsible for degrading organic matter at the bottom layer following the course of sedimentation process.

In general, it is expected that the upper portion of the water column would be dominated by photosynthetic oxygen-producing activities and euphotic zone would be dominated by oxygen consuming respiratory processes. Apart from atmospheric oxygen re-aeration fluxes, phytoplankton density of surface layer observed in the present study can be considered as a major source of DO in the water column of the stations. The newly added oxygen is mixed toward deeper waters due to strong water movement. The DO is also supposed to be consumed by consumers along its way. As mentioned earlier, the mean BOD in the surface of the Pasur-Rupsha estuary is only 2.04 mg O_2/l. The BOD in the bottom layer is suspected to be less than the surface layer due to the high amount of suspended particles accumulated following the sedimentation process. Lower BOD reflects lower microbial growth and less utilization of oxygen. The similar range of pH throughout the depth profile in the study area supports the phenomena. Hence, it is anticipated that the DO in the bottom layer is not sufficiently utilized like the surface layer and become responsible for relatively high DO near the bottom in comparison to the surface. Tidal records from Mongla, nearby tidal station from the study area, indicate that ebb tide takes longer time (around 7–8 h) than the flood tide (4–5 h) in the estuary [43]. Therefore, the river water flow is stronger than the sea water flow in this head of the estuary. This higher freshwater flow velocity near the surface (hence larger negative horizontal oxygen fluxes) and lower in the deeper waters (hence smaller negative horizontal oxygen fluxes) may also be responsible for lower DO near the surface and higher near the bottom. Lin et al. [3] also addressed the strong river flow and estuarine gravitational circulation for the lower DO near surface and higher near the bottom in the Cape Fear River Estuary of North Carolina. In addition, heat generated by sunlight may reduce the DO in the surface [3]. Hence, in the vertical direction it appears that both biological and physical factors contribute markedly to the vertical DO distributions in the Pasur-Rupsha estuary.

This study considered only two locations in the head of the estuary. Consideration of multiple locations in head, middle and mouth of the estuary may enrich a complete dynamic of the estuary including a detailed trend of vertical DO stratification. Moreover, Biological Oxygen Demand (BOD), Sediment Oxygen Demand (SOD), surface re-aeration, river flow, gravitational circulation and decomposer are also considered as important factors for influencing the vertical stratification of DO in an estuary which is deemed beyond the scope of the paper.

4. Conclusion

The Pasur-Rupsha estuary has significant ecological importance in the southwest coastal region of Bangladesh. Understanding of the ecosystem of this estuary is not sufficient enough due to lack of scientific information. This study explores the stratification pattern of DO and its association with temperature, salinity, pH, transparency, and phytoplankton density following a comprehensive field investigation with vertical profile of the mentioned water parameters from July, 2016 to January, 2017. DO concentration was ranged from 6.0 to 8.6 mg/l with maximum two units of variation in the depth profiles and demonstrated an inconsistent stratification pattern. Relatively low DO concentration near the surface layers and high near the bottom layers were remarkably noticed in most of the sampling periods. Temperature and phytoplankton density showed their significant ($P < 0.000$) association with DO profiles while pH and salinity recorded no significant ($P > 0.3$) association. Strong freshwater flow in the surface layer, existence of estuarine gravitational circulation, and lack of oxygen user in the bottom layer due to high sediment particles ameliorated the pattern of higher DO concentration in bottom and lower in surface layer of the estuary. The results explained in this study will provide considerable advances in understanding the ecosystem dynamics related to DO profile in the Pasur-Rupsha Estuary of Bangladesh.

Declarations

Author contribution statement

Muhammad Abdur Rouf: Conceived and design the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Md. Jahidul Islam; Md. Roknuzzaman: Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Md. Noman Siddiqui; Md Rony Golder: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Funding statement

Dr Muhammad Abdur Rouf was supported by Ministry of Science and Technology, Bangladesh [BS-219/2013–14].

Data availability statement

Data included in article/supp. material/referenced in article.

Declaration of interest's statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

Acknowledgement

The auhors acknowledge the Ministry of Science and Technology (MOST) for their support to accomplish the study. Assistance in the field provided by Mr. Md. Monirul Islam Faisal is highly appreciated. The authors would like to acknowledge the necessary approval and cooperation received from the Fisheries and Marine Resource Technology Discipline of Khulna University authority for the successful implementation of this study.

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