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SEDIMENT ACCUMULATION ASSESSMENT DURING WET AND DRY SEASONS IN FISH CAGE CULTURE AREA: A CASE STUDY OF THE RANGSIT CANAL 13 IN THAILAND'S PATHUM THANI PROVINCE

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ABSTRACT: This research investigates the sedimentation rate for the assessment of sediment accumulation in the cage culture area, Rangsit canal 13 in Thailand's central province of Pathum Thani. Water and sediment qualitwasre conducted during September 2017 (rainy season) and March 2018 (dry season). The temperatures, dissolved oxygen, and pH ranged between 30.5-31.5 ^{O}C, 5.54-7.78 mg L^{-1}, and 7.7-8.1, respectively. The results revealed that the dissolved oxygen varied from season to season ($p \leq 0.05$). The results indicated that the water qualities varied in response to the seasonal variability and were alarmingly higher than Thailand's minimum threshold for aquaculture. In terms of sediment qualities, variations in water content, total organic matter, and sedimentation rate ranged between 37.4-62.4%, 67.6-97.6 mg g-dry $weight^{-1}$, and 438.8-3,768.8 g $m^{-2}day^{-1}$, respectively. The results revealed that water content and total organic matter had no different significance ($p > 0.05$) while sedimentation rates varied significantly ($p \leq 0.05$) with seasons. Such levels of total organic matter and sedimentation rate were high in the area, especially in the rainy season. The finding also showed that mass transfer and water inflow in the area, especially in the rainy season, influenced the sediment output in the water system, indicating the adequate sediment input-output balance. The water mass transfer will require consideration for the assessment of sediment accumulation and water resource management in the study area.

Keywords: Sedimentation rate, Accumulation, Fish cage culture, Water resource management

1. INTRODUCTION

The south Rangsit canal is located in Thailand's central province of *Pathum Thani*, about 50 km north of the capital Bangkok [1] . The canal is on the east of the *Chao Phraya River* and is approximately 54 km in length [2]. Land utilization along the canal is categorized into four main categories: urban areas, agriculture, aquaculture, and industry [3]. The Rangsit canal 13 is one of the main canal's branches. Water resources are used in more than 1,000 cages for fish farming, such as raising tilapia, catfish, and other freshwater fish throughout the year [4]. Aquaculture using natural systems saves the financial cost on water preparation and improvement [5]. By the way, in the event of a flood, this could have an impact on production risks. The sediment in the water, as well as pollution from human activities, causes cloudiness. and fish disease epidemics [6]. The canal's deteriorating biochemical composition, including excessive nutrient loadings, is a result of increased area utilization [7].

The environmental impact of cage culture is primarily due to the high input of high-quality artificial feeds into fish cages, of which only a small portion is consumed and assimilated by the culture. This results in significant organic and inorganic waste discharges into the surrounding environment [8]. The process of sedimentation from the surface water to the bottom. It can reflect the area's activity and physical condition and the effects of precipitation on the sediment's chemical quality. The occurrence of anaerobic conditions in the soil, as well as the continuous accumulation of sulfides, which are toxic to benthic organisms [9]. High nitrogen- and phosphorus-content organic waste discharged from cage farms have the potential to contaminate nearby waters and sediments, leading to eutrophication, increased turbidity, biodiversity loss, and other problems [8]. As a result, one of the most important factors affecting the quality of fishery products is the problem of sediment quality in the culture area.

Fish cage culture's impact on sediment quality. It's necessary to monitor and assess the sediment quality at a level that does not have an impact on water resources. Thus, this current research aims to comparatively investigate the effects of seasonal variability (the rainy and dry seasons), sediment quality, and sedimentation rate in the fish cage area. The findings are expected to avoid any negative impact on the ecosystems of water resources, which will be used for aquaculture and the production of fishery products for farmers in the future.

2. RESEARCH SIGNIFICANCE

The purpose of this study is to examine the particulate wastes generated by freshwater fish farming and to correlate the data with the Rangsit canal 13's impact. Significant water resources support a resident population as well as a variety of agricultural fields in this area. Indeed, water resources are used year-round in over 1,000 cages for fish farming. Correlations were made between fish farming waste and the physicochemical parameters and nutrients in the water and sediment accumulation. As a result of waste dispersion, fish farming may have an impact on the aquatic ecosystem. The entire set of results can be used to help maintain the area's natural ecosystem functions.

3. MATERIALS AND METHODS

3.1 Sampling Sites

In this research, eight localities along the Rangsit canal 13 were selected as the sampling stations (Fig.1) and were clustered in a 'fish cage area' (Stn. 1, 4, 7, and 8), and 'without fish cage' (Stn. 2, 3, 5, and 6) in sampling site. The water and sediment sampling were conducted in two separate periods to take account of the effects of seasonal variability: September 2017 (rainy season) and March 2018 (dry season).

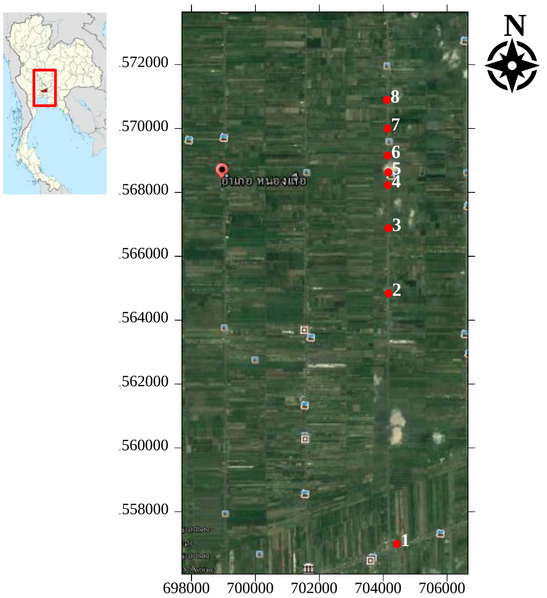


Fig.1 Sampling stations (UTM; 47P) from the satellite image of the Rangsit canal 13 with the eight sampling stations (Stn.1-8)

Under the influence of monsoon winds, Thailand has three seasons: rainy season (May-September), winter season (October-February), and dry season (March-April) [10]. In addition, the Rangsit canal 13 is under the jurisdiction of the North Rangsit Irrigation Office, which is responsible for the management and maintenance of the canal water for local demand [11]. Here, water management depends on the situation and agricultural activities. During the dry season, for example, the water discharge level was 64.8×10^6 m^3/month under normal conditions. When wastewater is present, the water discharge rate can be increased to 181.4×10^6 m^3/month.

3.2 Sample Collection and Analysis

The temperatures, dissolved oxygen (DO), and pH of the water samples were measured with a multi-parameter probe (YSI-6600 Sonde instrument) at the sampling sites (Stn.1-8). In the nutrient analysis, surface water samples (30 cm deep) were collected and pre-filtered using GF/F (Whatman) and retained at 4 ºC for further analysis. The ammonium (NH_4^+), nitrite and nitrate (NO_2^- +NO_3^-), and orthophosphate (PO_4^{3-}) concentrations were determined using a SKALAR segmented flow analyzer, given the corresponding detection limits of 0.70-57.14; 0.70-14.28 and 0.03-3.87 µmol L^{-1}. Samples to determine the levels of chlorophyll a and total suspended solids (TSS) were collected and placed in polyethylene bags that were kept away from direct light and heat. The samples were filtered through pre-weighed GF/F. Chlorophyll a and TSS measurements were analyzed according to a spectrophotometric method and a freeze-dried technique, respectively.

Two attached cylinders (30 cm in height and 10 cm in diameter) were used to measure the sedimentation rates. The traps were made up of two cylinders with an open top and a closed bottom, and the sedimentation rates were calculated. Each cylinder was placed at the bottom of the tank and removed after 24 hours of operation. To determine the amount of particulate matter generated during the investigation, samples were collected in sedimentation chambers installed below all of the net cages. During the sampling process, sedimentation trap samples were collected and placed in polyethylene bags, which were then frozen at -20 degrees Celsius (ºC) for no more than two months before being defrosted for analysis. The gravimetric method, which involves measuring the weight loss of components, was used to determine the sedimentation rates in this study. The sedimentation rate was given in g m^{-2} day^{-1}. The water content in the sample was determined by drying it in an oven at 110 ºC for 48 hours. The organic matter content of the dried sediment was determined by calculating the weight difference after it had been heated at 660 °C for three hours.

3.3 Data Analysis

Physicochemical properties of the water and sediment samples associated with both sampling periods September 2017 (rainy season) and March 2018 (dry season) were determined using descriptive statistics and presented as means ± standard deviations (SD). T-test was used to verify statistical differences between the two study periods, with $p \leq 0.05$. The Spearman rank correlation coefficient (rs) was used to analyze the relationships between nutrients (NH_4^+, NO_2^-+NO_3^- and PO_4^{3-}) and chlorophyll a. Additionally, Spearman rank correlation coefficients were used to analyze TSS, WC, TOM, and sedimentation rate. In this study, a confidence interval of more than 95% ($p \leq 0.05$) was considered to indicate a statistically significant impact.

4. RESULTS AND DISCUSSION

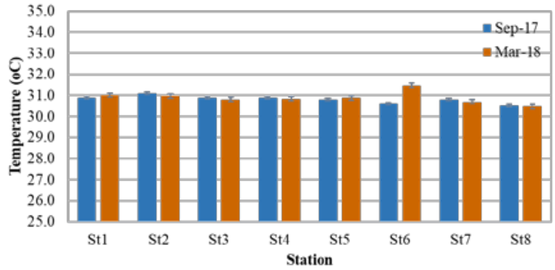
Table 1 shows the physicochemical characteristics of the water samples for both study periods (rainy and dry seasons). The results indicated that the water temperature (Fig.2a) and pH varied minimally between seasons, ranging from 30.5 to 31.5 of and 7.7 to 8.1, respectively ($p>0.05$). Sampling locations (st.1-12) and seasonal variability had no significant impact on pH levels which remained relatively constant throughout (Fig.2c). The results of the study revealed that the temperature of the canal water varied only slightly with the seasons, whereas the pH remained constant throughout the entire period. The findings revealed alarmingly higher than Thailand's minimum threshold of 4 mg L^{-1}, rendering it unfit for the aquatic animals [12].

Table 1 Physicochemical properties of water samples (mean±SD)

Parameters	Study period	
	September 2017 (rainy)	Match 2018 (dry)
Temp (°C)	30.8±0.2[a]	30.9±0.3[a]
DO (mg L^{-1})	4.9±0.4[a]	5.9±0.8[b]
pH	7.9±0.1[a]	7.8±0.1[a]
NH_4^+ (µmol L^{-1})	7.6±4.3[a]	4.0±1.7[b]
NO_2^-+NO_3^- (µmol L^{-1})	5.6±1.5[a]	6.5±0.6[a]
PO_4^{3-} (µmol L^{-1})	0.7±0.3[a]	1.0±0.1[b]
Chlorophyll a (µg L^{-1})	9.2±1.9[a]	20.2±5.7[b]
TSS (mg L^{-1})	59.0±15.7[a]	19.8±6.0[a]

Note: The values in the same row with different superscript letters are significantly different ($p \leq 0.05$).

Aquaculture requires dissolved oxygen (DO). It is required for respiration and other metabolic functions in fish [8]. During the rainy and dry seasons, the results revealed that DO varied from 4.5 to 5.6 mg L^{-1} and 5.1 to 7.8 mg L^{-1}, respectively, and that it varied in response to seasonal variability. ($p \leq 0.05$) at alarmingly higher than Thailand's minimum threshold of 4 mgL^{-1}.



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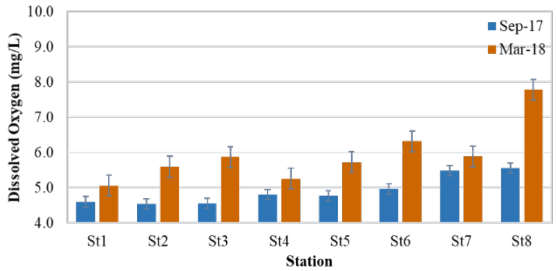

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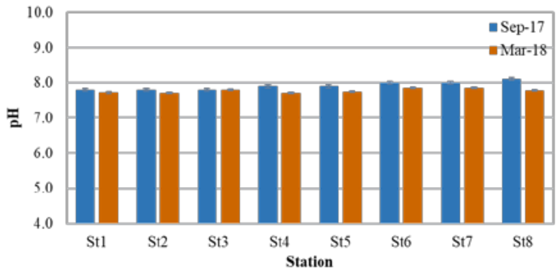


(c)

Fig.2 Distribution of (a) water temperature (°C) (b) dissolved oxygen (mgL^{-1}) and (c) pH in the Rangsit canal 13 surveyed during September 2017 and March 2018

Ammonium concentration ranged from 0.42 to 13.37 µmol L^{-1}. Maximum concentrations of NH_4^{+were} observed during the rainy season (Stn.1). Average levels of NH_4^+ varied from 0.42 to 13.37 (µmol L^{-1}) and had significantly ($p \leq 0.05$) with the season. The findings revealed that NH4+ levels increased as the stream moved downstream, with higher concentrations at the bottom. The NH_4^+ levels in water bodies should be below 1 mg L^{-1} (or 71.4 µmol L^{-1}) [13]. As a result of the findings, it was concluded that NH_4^+ could be a useful indicator of anthropogenic contaminants in the canal ecosystem. In water quality assessment, NH_4^+ is an important indicator of water quality [12]. The concentrations of NH_4^+ in the study site were not alarming throughout the study period, which could be attributed to water management reaching the area as a result of agricultural activities. [11].

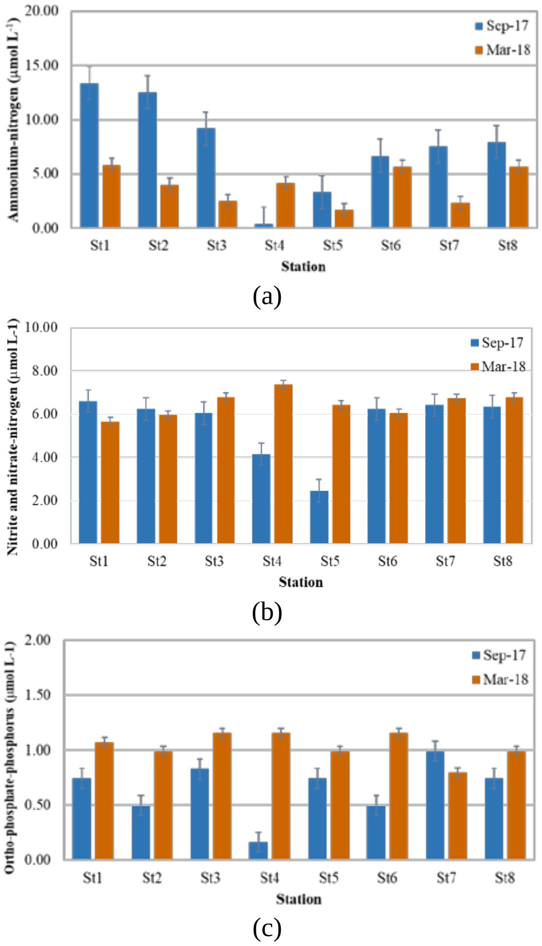


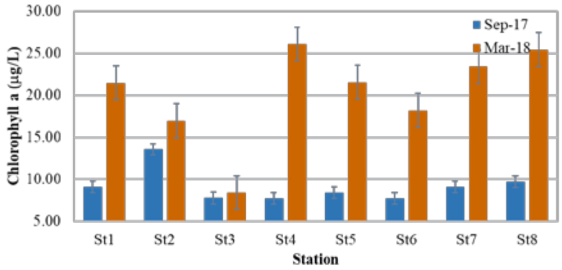
Fig.3 Distribution of (a) NH_4^+ (µmol L^{-1}) (b) NO_2^- $+NO_3^-$ (mgL^{-1}) and (c) PO_4^{3-} concentrations in the Rangsit canal 13 surveyed during September 2017 and March 2018

In addition, levels of NO_2^-+NO_3^- concentration were 5.6±1.5 and 6.5±0.6 µmol L^{-1} during the wet and dry seasons, respectively ($p>0.05$). It is possible that leaching from agricultural areas in this area, where chemical fertilizers containing nitrogenous compounds were used, was the primary source of nitrate. Moreover, the cultured organisms release nitrate and nitrite, which are produced as a result of the breakdown of waste and excess or uneaten feed, among other things [12].

During the period, PO_4^{3-} concentrations ranged from 2.46 to 7.37 µmol L^{-1} in the rainy season and 0.17 to 1.16 µmol L^{-1} in the dry season, respectively, and were higher in the dry season ($p \le 0.05$). The distribution of PO_4^{3-} was influenced by the effects of agricultural land use, domestic waste, and industrial contaminants. Such high levels of PO_4^{3-} necessitate more serious consideration in terms of effective management to prevent deterioration of water quality and related fishery resources PO_4^{3-} levels should be kept below 1 µmol L^{-1} to avoid eutrophication [14]. The PO43- levels in Rangsit canal 13 exceeded the allowable limit during the dry season. In addition, land use could contribute to nitrogen enrichment in the river [15], while phosphorus emission from wastewater is prevalent in highly populated areas [16]. Nutrients, particularly nitrogen and phosphorus, are directly related to the eutrophication of waters [17]. The wastes from fish farming can cause problems due to the high sedimentation load of total dissolved solids and nutrients such as nitrogen and phosphorus [18]. When the flow is less than $40x10^6$ m^3 $month^{-1}$, the water quality is poor [19].

The levels of chlorophyll-ion in the water reflected signs of plankton blooming, and the watercolor was visibly altered as a result. During the rainy and dry seasons, the concentrations of chlorophyll-a ranged from 7.8 to 13.6 µg L^{-1} and 8.4 to 25.4 µg L^{-1}, respectively. Seasonal variation in chlorophyll a ($p \le 0.05$) was significant (Fig.3a). During the rainy season, high levels were observed at St. 2 (>10 µg L^{-1}) which may have been because this sampling point is located close to urban development. During the dry season, the concentration was greater than 10 µgL^{-1}. Such occurrences should be assisted by the presence of inflow and rainfall, both of which have been shown to have an impact on nutrient levels. Additionally, fish excretion and excess fish feed are thought to be responsible for the increase in chlorophyll concentration at the cage station, as the nutrients from the excess feed and fish waste provided the necessary nutrients of nitrogen and phosphorus [8].

As an indicator of pollution in an urban area, total suspended solids (TSS) can be used. During the rainy season, TSS concentrations were found to range from 39.6 to 91.5 mg L^{-1} (Fig.3b). TSS concentrations in the Stn.3 area were higher than in the surrounding area because of higher anthropogenic particulate loads from canal dredging in the area. When sediment overloading occurs as a result of land and stream erosion, it has serious consequences for the surrounding environment. Higher TSS concentrations could be reflected in greater anthropogenic particulate loads in those areas [14] and freshwater inflow and precipitation-induced drainage influenced the TSS level. Fish cage culture and other activities such as agriculture, pond aquaculture, livestock, paddy fields, and household sewage discharge all contributed to changes in the canal's water quality [19]. Excessive release of this nutrient into the aquatic environment can cause eutrophication and a variety of conflicts related to the use of affected ecosystems [18].



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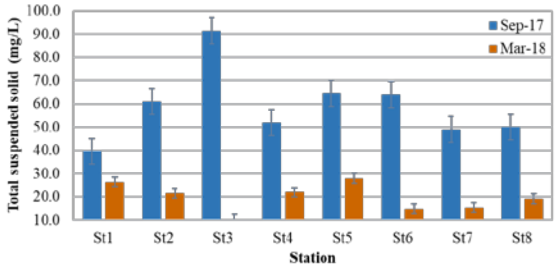

(b)

Fig.3 Distribution of (a) Chlorophyll a (μg L^{-1}) and (b) TSS (mg L^{-1}) in the Rangsit canal 13 surveyed during September 2017 and March 2018

The overall findings indicated that PO_4^{3-} had influenced the chlorophyll-a concentrations that had accumulated in the area, as shown in Table 2. According to a Spearman rank correlation coefficient (rs) analysis (Table 2), chlorophyll a high significantly (p<0.05) received PO_4^{3-} enhancement (rs = 0.55). PO_4^{3-} plays a role in phytoplankton blooming, according to these correlations [14]. The impact of anthropogenic activity was revealed by the nutrient loads from the major areas, and water flow characteristics influenced the water quality in those areas. The nutrient levels reported in this study were used to create nutrient criteria for long-term canal management.

Table 2 Correlation coefficients (rs) for Spearman's rank correlation and p-value between nutrients and chlorophyll-a at the Rangsit canal 13 surveyed during September 2017 and March 2018

Parameters	Chlorophyll a	
	rs	p-value
NH_4^+	-0.16	0.56
NO_2^-+NO_3^-	0.47	0.07
PO_4^{3-}	0.55	0.03*

*Note: * Correlation is significant at p<0.05.*

Table 3 shows the physical characteristics of the sediment samples for both study periods (rainy and dry season). Water content could be defined texture and structure of sediment, such as soil, rock, clay. During the rainy and dry seasons, respectively, the water content ranged from 37.4 to 59.8% and 41.7 to 62.4%, (p>0.05). Water content is primarily determined by the amount of organic matter and clay present in the soil. Water has an impact on the majority of soil's physical, chemical, and biological properties and processes, either directly or indirectly. Organic matter holds water and reduces soil surface crusting, allowing water to percolate into the soil [20].

Table 3 Physical properties of sediment samples (mean±SD)

Parameters	Study period	
	September 2017 (rainy)	Match 2018 (dry)
WC (%)	46.6±9.4^a	48.8±8.3^a
TOM (mg g^{-1} dry weight)	86.9±10.1^a	84.0±9.3^a
Sedimentation rate (g m^{-2} day^{-1})	2,719.6±1,068.1^a	1,133.6±469.5^b

Note: The values in the same row with different superscript letters are significantly different (p≤0.05).

Total organic matters (TOM) show high levels, varied from 70.2 to 97.6 and 67.6 to 97.0 mg g-dry $weight^{-1}$ in the rainy and dry season, respectively (p>0.05). High levels are visible during the rainy season near the station, which is located in an urban area. Solid waste, also known as particulate organic matter, is frequently composed of feces or uneaten food. Organic wastes are present in the recirculation system in three forms: settled solids, which accumulate on the tank's bottom; suspended solids, which float in the water column and will not settle out of water; and fine and dissolved solids, which float in the water column and can cause gill irritation and health damage to fish [21]. Fish farming contributes organic matter to the environment. The finding indicated the high level of total organic matter in the area. The tilapia cultivation in net cages increased the sedimentation rates of nutrients and particulate matter [18]. Resuspension, chemical transformations, and microbial breakdown of organic matter, as well as nutrients in sediment, could result in a partial release of nutrients into pond water. This is a continuous process that has an impact on primary productivity and, as a result, on the yield of fish. [20]. A major component of surface waters is sediment. At the higher levels of the food chain, this habitat serves as an important trophic resource for a variety of organisms [22].

Sedimentation rates varied from 1,031.3 to 3,768.8 and 438.8 to 1,699.4 g m^{-2} day^{-1} in the rainy and dry season, respectively (Fig.4). The potential for sedimentation rate may be greatly enhanced by the discharge of large pulses of water. During the dry season, the water discharge level can be increased to control wastewater and support agricultural areas [11]. Water current velocity may have been sufficient to disperse solid waste, thus reducing sedimentation rates in the dry season, according to a recent study. The homogeneity of the water could be due to the canal's shallowness (2.5-4.0 meters) and the water flow that flushed solid waste downstream through the sluice gate [19]. In reservoirs, accumulating water disrupts the hydro-morphodynamic continuity of the river, accumulating not only water but also sediment transported by the river [23].

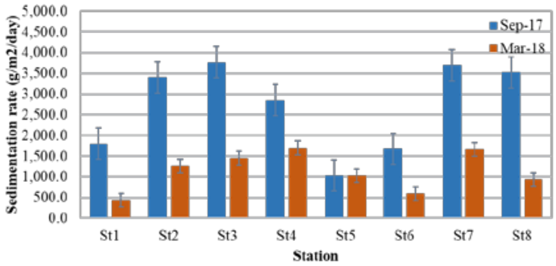

Fig.4 Distribution of Sedimentation rate in the Rangsit canal 13 surveyed during September 2017 and March 2018

Table 4 shows the findings indicated that total suspended solids had influenced the sedimentation rate. According to a Spearman rank correlation coefficient (rs) analysis, sedimentation rate high significantly ($p<0.05$) received TSS enhancement (rs = 0.57). As reported by Rossi [24], wet-weather pollution in urban areas, such as combined sewer overflows and stormwater discharges, is frequently evaluated using the parameter of total suspended solids (TSS). TSS can cause turbidity, which can have an impact on the various uses of receiving water, as well as on aquatic life, by limiting light penetration and reducing visibility. Furthermore, TSS can settle on the riverbed and have a significant impact on the environment. Settable materials can be used to cover the bottom of bodies of water.

Table 4 Correlation coefficients (rs) for Spearman's rank correlation and p-value between particulate factors (TSS, WC, and TOM) and sedimentation rate at the Rangsit canal 13 surveyed during September 2017 and March 2018

Parameters	Sedimentation rate	
	rs	p-value
TSS	0.57*	0.02
WC	-0.31	0.23
TOM	-0.09	0.72

*Note: * Correlation is significant at p<0.05.*

Sedimentation reduces the capacity of fishponds, posing a threat to the farmers who work in this industry. As a result, maintaining pond volume and environment through sediment removal is a beneficial practice for cost-effective fish production [20]. In some regions, fish cage farming has been banned entirely due to growing concern about the negative environmental consequences of cage culture practices [25]. As a result, the cage culture activities may have an impact on the water quality and sediment accumulation in the long term. Fish farming may have a significant impact on the environment due to the acceleration of the flow under the cages and the feed activities that cause the re-suspension of sediments and bio-deposits. To ensure that fish welfare is not negatively impacted by excessive excretion and metabolism-related products, the water flow, water exchange, and water treatment should ensure that the appropriate water quality and velocity for fish is maintained all the time, considering other factors such as temperature and stocking density [26].

6. CONCLUSION

Effects of seasonal variability (rainy and dry seasons) and sediment accumulation patterns on fish farming**,** the Rangsit canal 13 in Thailand were investigated. The DO showed in response to seasonal variability at alarmingly higher than Thailand's minimum threshold of 4 mg L^{-1}. Average levels of NH_4^+ varied significantly ($p\leq0.05$) with the season and were lower than the NH_4^+ limitation in water bodies. The PO_4^{3-} levels were more than the limit during the dry season.

The levels of total organic matter and sedimentation rate were high in the area. Sedimentation rates were high during the rainy season. The sediment accumulation was found to be season-dependent. The results revealed that the amount of water that flows through the system during the rainy season is higher than in the dry season. This increases the likelihood of water bodies sediment erosion. The water release level of the area is controlled compared to the dry season.

7. ACKNOWLEDGMENTS

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