Current Applied Science and Technology e-ISSN: 2586-9396

Curr. Appl. Sci. Technol. 2025, Vol. 25 (No. 3), e0262154

Research article

Plankton Assemblages and Water Quality in Kirulapone, Wellawatte, and Dehiwala Canals, Colombo, Sri Lanka

Madhavi Kolambage, Inoka Batugedara, Chalani Perera and Indunil Senanayake*

Department of Zoology, Faculty of Applied Sciences, University of Sri Jayewardenepura, Gangodawila, Nugegoda, Sri Lanka

Received: 10 February 2024, Revised: 20 July 2024, Accepted: 7 November 2024, Published: 9 December 2024

Abstract

Plankton are significant bioindicators that can be employed in water quality assessments. However, there is a notable scarcity of plankton-based water quality studies in the Colombo South canal system. The present study was carried out to assess water quality in three selected canals belonging to the Colombo South canal system with special reference to the plankton community. Plankton and water samples were collected from November 2022 to February 2023 from twelve locations along the three canals of the Colombo South canal system. During the study, nine physiochemical parameters were measured and the biotic indices were calculated. Pollution status and the suitability of the canals for aquatic life were assessed using the water pollution index (WPI) and the weighted arithmetic water quality index (WAWQI), respectively. Overall, forty-six phytoplankton species and seventeen zooplankton species were recorded during the study. Chlorophyceae (48%) and Rotifera (59%) were the dominant plankton groups. More than 50% of the total recorded plankton species were pollution indicators. According to Principal Component Analysis (PCA), plankton abundance showed a weak positive correlation with nitrate, phosphate, TDS, BOD_5, salinity, electrical conductivity, and temperature while negatively correlated with dissolved oxygen. The Shannon-Weiner diversity index and WPI revealed a moderate pollution level in the canals. WAWQI indicated that the canals were unsuitable for aquatic life. Moreover, moderate and high pollution-tolerant organisms were more dominant in the canals. Hence, the proper measures must be taken to restore the canal ecosystem. This study could significantly guide future research and highlight the importance of plankton in water quality assessments.

Keywords: Colombo South canal system; Dehiwala canal; Kirulapone canal; plankton; water quality; Wellawatte canal

*Corresponding author: E-mail: indunil@sci.sjp.ac.lk
https://doi.org/10.55003/cast.2024.262154

1. Introduction

Plankton are a diverse group of macro and microscopic life forms that are free-floating in water (D'Alelio et al., 2016; Roy et al., 2016; Suthers et al., 2019). Plankton distribution as well as their community structure are influenced by interactions among the physical, chemical, and biological factors in a water body (Hoang et al., 2018). Some plankton species are highly sensitive to environmental changes and they prefer special environmental conditions (Warusawithana & Yatigammana, 2019). Therefore, the absence of sensitive forms and the thriving of tolerant forms can be considered as indicators of higher pollution levels (Thakur et al., 2013). Plankton indicates a comprehensive understanding of aquatic habitats when integrating information on previous disturbances and various stress factors (Thakur et al., 2013). Furthermore, acting as an early warning system, plankton can predict pollutant contamination in a water body before it becomes apparent. Therefore, plankton are considered a reliable and cost-effective tool in water quality assessment.

One of the most prevalent environmental issues associated with the canal ecosystems in Sri Lanka is the deterioration of water quality, which is mainly caused by human population growth, rapid urbanization, and industrialization (Hettige et al., 2014; Munasinghe, 2014). Nowadays, urban canals in Sri Lanka are mainly utilized to remove excess floodwater, sewage, and industrial wastewater from urban areas to the sea and nearby rivers, lakes, and marshlands (Madhushan & Dharmasena, 2021). Colombo is the commercial capital of Sri Lanka. The Colombo drainage system consists of a network of open drainage canals, smaller tributary canals, and low-lying marshes (Dharmasoma & Piyadasa, 2014; Jayaweera & Samarakoon, 2020). The Colombo canal system is divided into two parts, the Colombo South system and the Colombo North system. The Colombo South canal system has been subjected to development projects including several attempts to launch a passenger boat service along the Kirulapone and Wellawatte canals. Moreover, the Urban Development Authority of Sri Lanka has outlined plans to establish a canal-based development area within the South canal system, focusing on the Dehiwala and Wellawatte canals, under the Colombo City Development Plan 2019-2030. Hence, it has become imperative to evaluate the aquatic ecosystem status of the Colombo South canal system before the commencement of the proposed development activities. However, according to the literature, the Colombo South canal system is in an environmentally deteriorated condition (Eriyagama & Ratnayake, 2008).

Plankton, a critical biological indicator of water quality remains explored in a limited number of studies in Sri Lankan urban canals (Idroos & Manage, 2012; Perera, 2015; Pieris et al., 2021). Although physiochemical parameters have been used in a number of studies to assess the water quality in the Colombo South canal system, there is a notable dearth of plankton-based research. Therefore, the present study was carried out to assess water quality in three selected canals belonging to the Colombo South canal system with special reference to the plankton community. This research included the assessment of plankton composition in the canals using biotic indices, identification of indicator species for pollution tolerance, assessment of pollution status in the study area using the water pollution index (WPI), and also the development of the weighted arithmetic water quality index (WAWQI) for aquatic life. The present study reveals the current ecosystem status of the Colombo South canal system which can be incorporated into future restoration measures.

2. Materials and Methods

2.1 Study area and sampling locations

The present study was focused on three canals: Kirulapone (6.8835°N and 79.8915° E), Wellawatte (6.8852°N and 79.8709°E), and Dehiwala (6.8851°N, 79.8712° E), which belong to the Colombo South canal system. Kirulapone canal starts near the Nawala Urban Wetland Park and divides into two branches called Wellawatte and Dehiwala canals. These canals flow directly to the Indian Ocean through the Dehiwala and Wellawatte canal outfalls. The Dehiwala canal is 3.8 km in length whereas the distance from the start point of the Kirulapone canal to the Wellawatte canal outfall is 4.5 km. For the present study, twelve sampling locations were selected along the three canals, including four from the Kirulapone canal (K1, K2, K3, K4), three from the Wellawatte canal (W1, W2, W3), and five from the Dehiwala canal (D1, D2, D3, D4, D5). These locations were selected based on the stratified random sampling technique considering spatial intervals and accessibility (Figure 1).

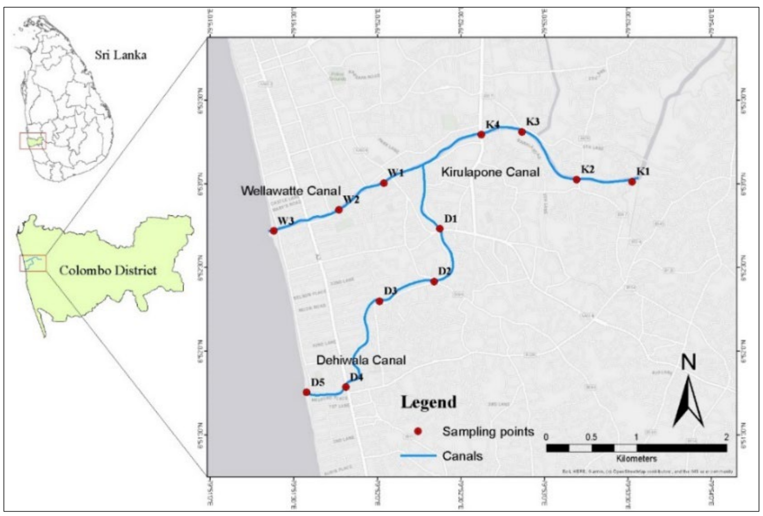

Figure 1. Sampling locations of Kirulapone, Wellawatte, and Dehiwala canals

2.2 Sample collection and analysis

Sample collection was carried out monthly from November 2022 to February 2023. To avoid the sampling time influence on plankton community composition that occurs due to the vertical migration of plankton, samples were collected at approximately the same time on each sampling day. Therefore, throughout the study period, plankton samples were collected from each location from 7.00 am to 10.00 am using a plankton net (HYDRO-BIOS, KIEL plankton net: 55 µm mesh size). At each location, 20L of surface water was filtered through the plankton net (55 µm) and transferred to a labeled 100mL opaque plastic bottle. Each filtered sample was immediately fixed using acidified Lugol's solution and transported to the laboratory. In addition to the plankton samples, water samples were collected for laboratory analysis and nine physiochemical parameters were measured for each location. At each location, pH and water temperature were measured using a pH meter (APERA PH400S), whereas salinity, electrical conductivity (EC), and total dissolved solids (TDS) were measured using a conductivity meter (HACH HQ14D) onsite. In the laboratory, dissolved oxygen (DO), phosphate, nitrate, and biological oxygen demand (BOD_5) were analyzed according to the American Public Health Association's standards (APHA, 2017). At the laboratory, preserved plankton samples were concentrated to 10mL, and 1mL from each concentrated sample was added to a Sedgewick-rafter counting chamber after being vigorously shaken to ensure homogeneity. Samples were observed under a light microscope (OPTIKA B-159) for plankton identification and enumeration. Observed phytoplankton and zooplankton were identified to the lowest possible taxonomic level using the standard identification keys (Prescott, 1970; Doan et al., 2015).

2.3 Calculation of plankton abundance and biotic indices

2.3.1 Plankton abundance

Plankton abundance was estimated as individuals per liter using the equation given below (modified from APHA, 1998).

$$Total\ number\ of\ plankton\ in\ 1\ L = \frac{1}{Vd} \times \frac{B}{C} \times n \times \frac{Vt}{Vs} \quad (1)$$

Where n = the total number of plankton counted, Vt = the concentrated volume of the water (mL), Vs = the water volume in the Sedgwick rafter counting cell (mL), B = the number of squares in the counting chamber, C = the number of squares counted and Vd = Total volume of the filtered water sample (L)

2.3.2 Biotic indices

The plankton community in the study area was assessed using four biotic indices, as summarized in Table 1.

2.4 Development of WPI and WAWQI

WPI and WAWQI were calculated using five water quality parameters (pH, phosphate, nitrate, BOD_5, and DO) based on the standards of the Central Environmental Authority (CEA), Sri Lanka under category C; ambient water quality standards suitable for aquatic life.

2.4.1 Water pollution index (WPI)

As the first step, the pollution load (PL_i) of the i^{th} parameter was calculated using the following equation (Hossain & Patra, 2020).

$$PL_i = 1 + \left(\frac{C_i - S_i}{S_i}\right) \quad (6)$$

S_i = the standard value for the respective parameter
C_i= Observed concentration of the i^{th} parameter

Table 1. Selected biotic indices and formulas

Name of the index	Formula	Abbreviation	Reference	Equation Number
Shannon-Wiener diversity index (H)	$H = -\sum_{i=1}^{S} pi\ lnpi$	Pi = fraction of the entire population made up of species i S = number of species encountered Σ = sum from species 1 to species S	Shannon & Weaver, 1949	(2)
Pielou's evenness index (E)	$E = \frac{H}{ln(S)}$	H= Shannon-Wiener diversity index S = number of species encountered	Pielou, 1966	(3)
Simpson index of diversity (SID)	$SID = 1 - \frac{\Sigma\, n(n-1)}{N\,(N-1)}$	n = number of individuals of each species N = Total number of individuals of all species	Simpson, 1949	(4)
Margalef's richness index (D_{Mg})	$D_{Mg} = \frac{(S-1)}{ln(N)}$	S = the number of species N= the total number of individuals in the sample	Margalef, 1968	(5)

Since a standard pH range has been given, in the case of pH, the following equations were used to calculate PL_i as recommended by Hossain & Patra, (2020).
When the pH is less than 7,

$$PL_i = \frac{C_i - 7}{Si_a - 7}$$

C_i = observed pH value
Si_a = minimum acceptable pH value (6.0)

When pH is greater than 7,

$$PL_i = \frac{C_i - 7}{Si_b - 7}$$

Ci= observed pH value
Si_b = the maximum acceptable pH value (8.5)

Finally, WPI values were calculated using the following formula (Hossain & Patra, 2020).

$$WPI = \frac{1}{n}\sum_{i=1}^{n} PL_i \quad (7)$$

WPI can be categorized as given in the following (Hossain & Patra, 2020).

WPI < 0.5 - excellent quality
0.5 > WPI < 0.75 - good quality
0.75 > WPI < 1 - moderately polluted
WPI > 1 - highly polluted

2.4.2 Weighted arithmetic water quality index (WAWQI)

As the first step, unit weight factors (Wi) for each water quality parameter were calculated using the following formula (Hyarat & Al Kuisi, 2021; Nishanthi et al., 2021).

$$Wi = \frac{K}{Si} \quad (8)$$

K = proportionality constant
Si = the recommended standard value of the i^{th} parameter

The proportionality constant was calculated using the formula given below (Hyarat & Al Kuisi, 2021).

$$K = \frac{1}{\Sigma(\frac{1}{Si})} \quad (9)$$

The quality rating (Qi) for each water quality parameter was calculated using the equation given below (Hyarat & Al Kuisi, 2021; Nishanthi et al., 2021).

$$Qi = 100 \times \frac{(Vi - Vo)}{(Si - Vo)} \quad (10)$$

Vi = actual value of the i^{th} parameter
Si = standard desirable value of the i^{th} parameter
Vo = ideal value of the i^{th} parameter in pure water
(Vo = 0 for most of the water parameters except pH = 7.0 and DO = 14.6 mg/L)

Finally, the overall water quality index values for each location were obtained by using the following equation (Hyarat & Al Kuisi, 2021; Nishanthi et al., 2021).

$$Overall\ WQI = \frac{\Sigma QiWi}{\Sigma Wi} \quad (11)$$

According to the WAWQI, water quality is categorized into five classes, as shown below (Nishanthi & Dushanan, 2022).

0-25 - Excellent 26-50 - Good
51-75 - Poor 76 -100 - very poor
Above 100 - unsuitable

The study area map was generated using ArcGIS 10.8 version. All the statistical analyses including Principal Component Analysis (PCA) were conducted using Minitab 17 statistical software package and Microsoft Excel 2013 version.

3. Results and Discussion

3.1 Plankton identification

A total of forty-six phytoplankton species belonging to five groups were recorded from the study area. Chlorophyceae was the dominant phytoplankton group (48%). This is possible because Chlorophyceae remains the most diverse algal group, exhibiting higher reproductive capacities in comparison to other groups (Adesalu, 2016). The percentage composition of phytoplankton recorded from the study area is given in Figure 2.

The percentage composition of zooplankton recorded from the study area is given in Figure 3. A total of seventeen zooplankton species belonging to seven groups were identified from the three canals. Rotifera, which constituted ten species, was the dominant zooplankton group representing 59 % of the total recorded zooplankton. This can be attributed to their high reproductive rates, frequent asexual reproduction, wide tolerance to environmental conditions, and capacity to consume diverse food particles (Villaruel & Camacho, 2024).

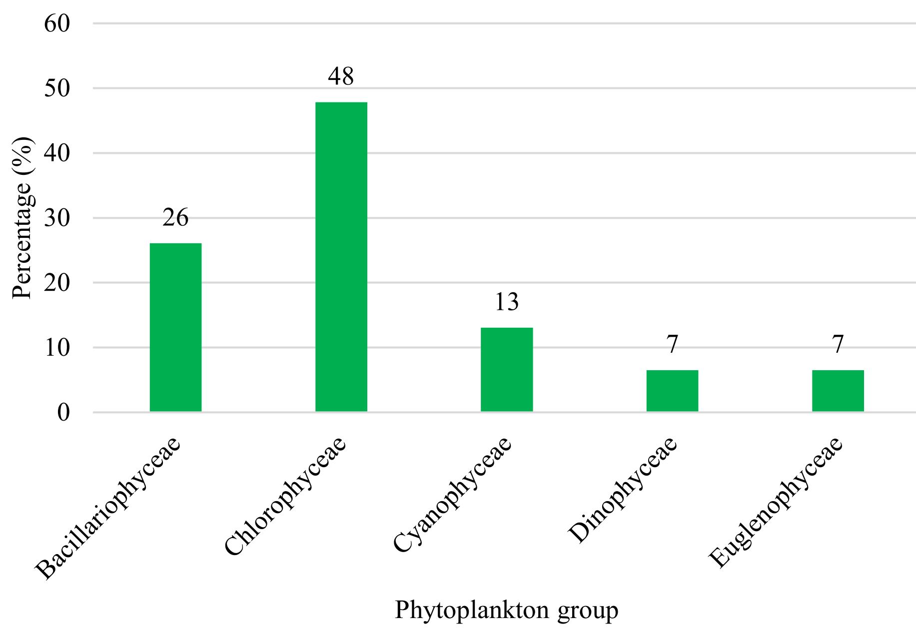

Figure 2. Percentage composition of the phytoplankton recorded from the study area

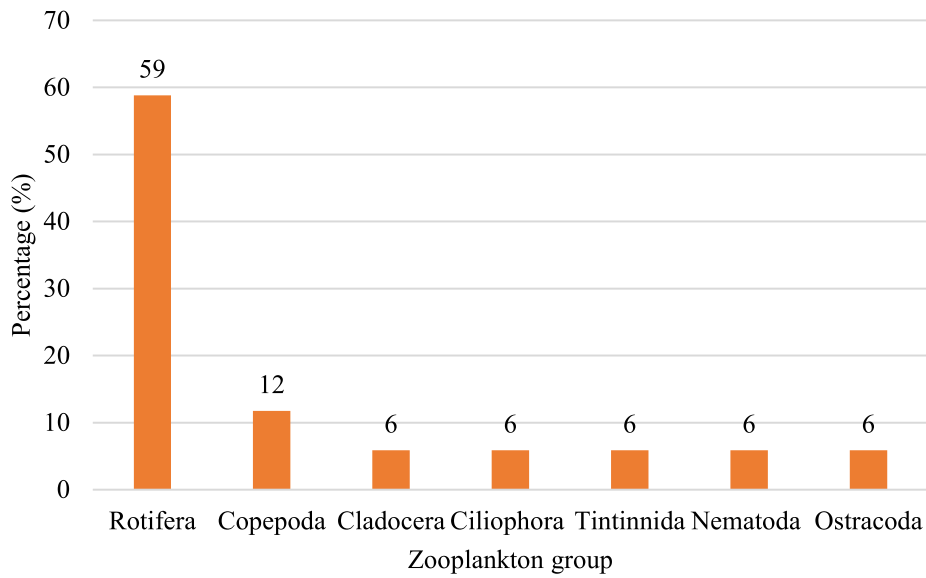

Figure 3. Percentage composition of the zooplankton recorded from the study area

The distribution of plankton species in the three canals during the study period is summarized in Table 2. According to Table 2, some plankton species were restricted to the Kirulapone canal while some species were absent. It has been reported that *Brachionus calyciflorus* was restricted to areas with low salinities in the West Naubaria canal, Egypt (Aziz, 2005). Similarly, during the present study, four out of five recorded *Brachionus* spp., including *B. calyciflorus*, were found only in the Kirulapone canal which is the farthest canal from the sea and where the lowest salinities were recorded (2.75±1.06 ppt). The impact of the salinity variations that occurred due to the saltwater intrusion might be the reason behind this plankton distribution pattern. Further, nutrient input and other environmental conditions could have altered the plankton distribution in the study area. During the present study, the impact of saltwater intrusion was observed up to location K2. Most of the time, water in these three canals varies between brackish and saline water ranges (Nandaseela & Piyadasa, 2015). Salinity can be considered a significant factor influencing plankton diversity in a water body (Larson & Belovsky, 2013). During the study period, the occurrence of a marine dinoflagellate *Noctiluca* sp. was reported from the Kirulapone canal. In addition, *Mesodinium rubrum*, a marine ciliate was recorded from both Wellawatte and Kirulapone canals. Therefore, it can be assumed that due to saltwater intrusion, marine, and brackish water plankton species existed in these canals together with freshwater species. Some of the microscopic photographs of phytoplankton and zooplankton species observed during the study are shown in Figure 4 and Figure 5 respectively.

Table 2. Distribution of plankton species in Kirulapone, Dehiwala, and Wellawatte canals during the study period

Plankton Group	**Species Name**	**Kirulapone Canal**	**Dehiwala Canal**	**Wellawatte Canal**
Phytoplankton				
Bacillariophyceae	*Aulacoseira* sp.	++	++	++
	Cyclotella sp.	+	+	+
	Pinnularia sp.	+	+	-
	Melosira moniliformis	-	-	+
	Melosira sp.	+++	+++	+++
	Pseudonitzschia sp.	-	-	+
	Nitszchia sp.	++	++	++
	Synedra sp.	+	+	++
	Navicula sp.	+	+	+
	Amphora sp.	-	-	+
	Skeletonema sp.	+	-	-
	Leptocylindrus sp.	-	+	+
Chlorophyceae	*Pediastrum duplex*	+	+	+
	P. simplex	+	+	+
	P. tetras	-	+	+
	Pandorina sp.	+	+	+
	Scenedesmus acuminatus	+	+	+
	Scenedesmus sp.	++	+	++
	Staurodesmus sp.	+	-	-
	Staurastrum sp.	+	+	+
	Zygnema sp.	+++	++	++
	Eudorina sp.	+	+	+
	Actinastrum sp.	+	+	+
	Ankistrodesmus sp.	+	+	+
	Coelastrum sp.	++	+	++
	Tetrastrum sp.	++	++	+++
	Tetraedron sp.	-	-	+
	Closterium sp.	+	+	++
	Crucigenia sp.	+	+	+
	Cruciginiella sp.	+	+	+
	Desmodesmus sp.	+	+	+
	Microspora sp.	+++	++	++
	Mougeotia sp.	++	+	++
	Mucidosphaerium sp.	+	+	+
Cyanophyceae	*Oscillatoria* sp.	+	+++	++
	Phormidium sp.	-	+	-
	Microcystis sp.	+	+	+
	Spirulina sp.	+	+	++
	Coelosphaerium sp.	-	+	+
	Chroococcus sp.	+	-	-

Table 2. Distribution of plankton species in Kirulapone, Dehiwala, and Wellawatte canals during the study period (continued)

Plankton Group	**Species Name**	**Kirulapone Canal**	**Dehiwala Canal**	**Wellawatte Canal**
Dinophyceae	*Noctiluca* sp.	+	-	-
	Dinophyceae species 1	+	-	-
	Dinophyceae species 2	-	+	+
Euglenophyceae	*Euglena acus*	+	++	+
	Phacus sp.	+	+	+
	Euglena sp.	+	+	+
Zooplankton				
Copepoda	Nauplius larvae	+	-	+
	Cyclops sp.	+	-	-
Cladocera	*Daphnia* sp.	+	-	-
Ciliophora	*Mesodinium rubrum*	+	-	+
Ostracoda	*Cypridopsis* sp.	+	+	-
Rotifera	*Keratella cochlearis*	+	+	+
	K. tecta	+	-	-
	Lecane sp.	+	-	-
	Brachionus havanaensis	+	-	-
	B. falcatus	+	-	-
	B. calyciflorus	+	-	-
	B. angularis	+	-	-
	B. forcifula	+	+	-
	Filinia longiseta	+	-	-
	F. camascela	-	+	-
Tintinnida	*Favella* sp.	+	-	-
Nematoda	Nematode species	-	+	-
+++ = abundant (25% -15%)	++ = some (15% -5%)	+ = little(≤5%)	- = absent	

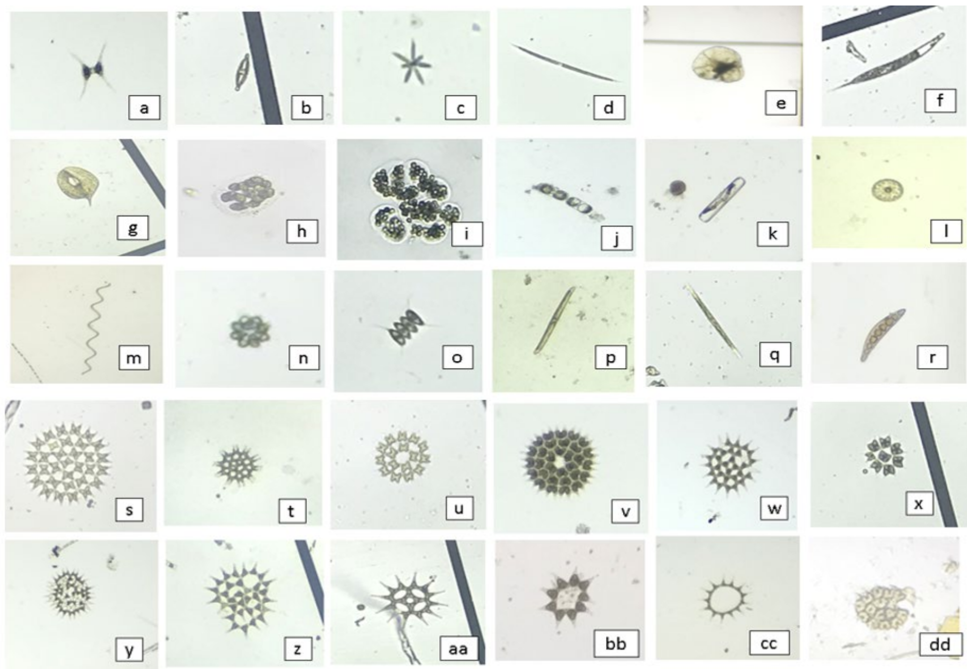

Figure 4. Phytoplankton species observed during the study: (a) *Staurastrum* sp., (b) *Navicula* sp., (c) *Actinastrum* sp., (d) *Closterium* sp., (e) *Noctiluca* sp., (f) *Euglena acus*, (g) *Phacus* sp., (h) *Pandorina* sp., (i) *Microcystis* sp., (j) *Melosira* sp., (k) *Pinnularia* sp., (l) *Cyclotella* sp., (m) *Spirulina* sp., (n) *Coelastrum* sp., (o) *Scenedesmus* sp., (p) *Nitzschia* sp., (q) *Synedra* sp., (r) Unknown species, (s)-(z) *Pediastrum duplex* variants, (aa)-(cc) *P. simplex* variants and (dd) *P. tetras*

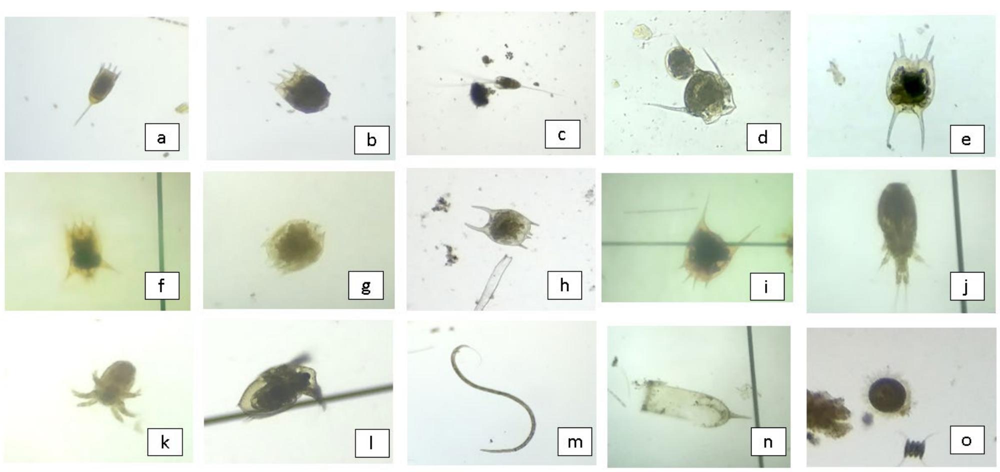

Figure 5. Zooplankton species observed during the study: (a) *Keratella cochlearis*, (b) *K. tecta*, (c) *Filinia longiseta*, (d) *F. camascela*, (e) *Brachionus falcatus*, (f) *B. calyciflorus*, (g) *B. angularis*, (h) *B. forficula*, (i) *B. havanaensis*, (j) *Cyclop*s sp., (k) Nauplius larvae, (l) *Daphnia* sp., (m) Nematoda species, (n) *Favella* sp. and (o) *Mesodinium rubrum*

3.2 Plankton abundance and biotic indices

3.2.1 Plankton abundance

Plankton abundance is shaped by a diverse range of abiotic factors including temperature, salinity, pH, and nutrient concentration along with biotic factors such as predators and parasites (Harris & Vinobaba, 2013). The mean plankton abundance values recorded from the Kirulapone, Dehiwala, and Wellawatte canals were 1027.0±261, 1350.0±283.0, and 670.3±96.2 individuals/L, respectively. The plankton abundance values of the Dehiwala and Wellawatte canals were significantly different (P=0.013). However, there was no significant difference between the plankton abundance of the Kirulapone canal and the other two canals separately (P>0.05). The variation of the recorded plankton abundance along the three canals is given in Figure 6. During the present study, the highest plankton abundance was recorded from location D3, followed by D4, whereas the lowest was recorded from location W1.

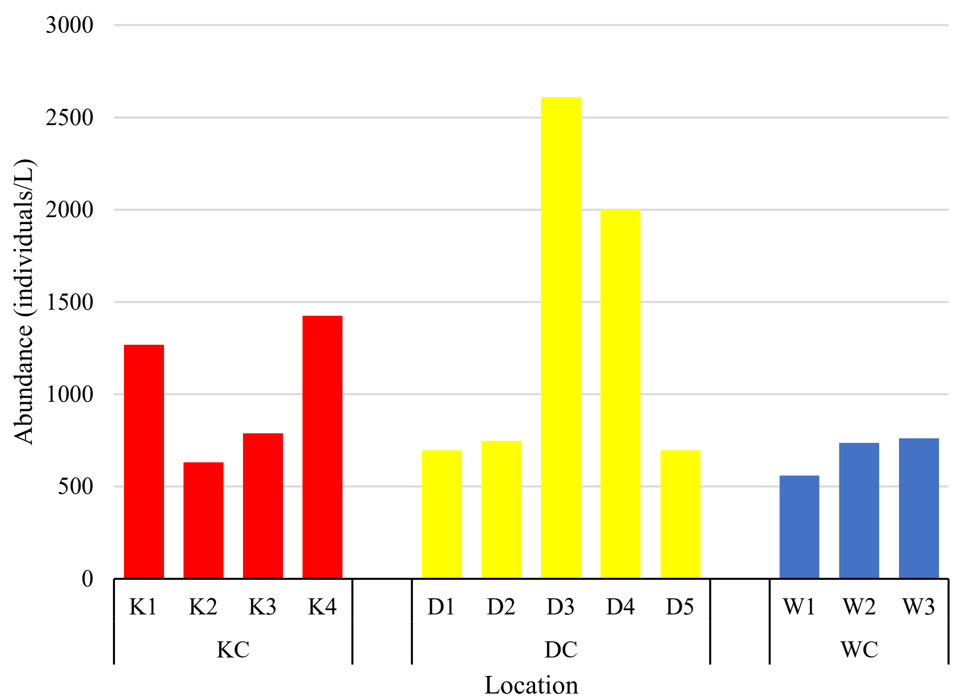

Figure 6. Variation of plankton abundance in the sampling locations

The Kinda canal connects with the Kirulapone canal at a point between K2 and K3. Perera et al., (2018) noticed a relatively high phosphate concentration close to the above-mentioned point. Hence, it can be assumed that the Kinda canal contributed to the increase in the nutrient input of the Kirulapone canal. A high phytoplankton density can be observed in nutrient-enriched canal waters (Perera et al., 2018). Thus, the high nutrient load obtained from the Kinda canal might be a reason behind the recorded high plankton abundance in K3 and K4 when compared to K2. Similarly, the Nadimala canal connects with the Dehiwala canal at a point close to location D3, potentially carrying a higher nutrient load into the Dehiwala canal. It can be attributed to the high plankton abundance values recorded from locations D3 and D4. In the present study, *Melosira* sp., *Oscillatoria* sp., and *Tetrastrum* sp. were the most abundant plankton species in Kirulapone (KC), Dehiwala (DC), and Wellawatte (WC) canals, respectively. The high abundance of these three pollution-tolerant plankton species can be considered an indication of pollution in the canal waters.

3.2.2 Biotic indices

The calculated biotic index values and the classifications are given in Table 3. It is generally accepted that the Shannon-Wiener diversity index is a good indicator of water quality. There is a negative correlation between the Shannon-Wiener diversity index and pollution status (Shanthala et al., 2009). This has been proved by many authors (Shekhar et al., 2008; Idroos & Manage, 2012). According to the Shannon-Wiener diversity index, the three canals were moderately diverse and moderately polluted. Plankton communities in the three canals were more evenly distributed according to Pielou's evenness index (E-values ranged from 0.76 to 0.82). The Simpson's Index of Diversity gives more weight to dominant species. According to SID, there was a higher degree of diversity in the study area. It can be supported by the reported high evenness values (close to 1) of the study area. The recorded medium to high species richness (D_{Mg}-value ranged from 3.84 to 5.93) could be attributed to the ability of freshwater, brackish water, and marine plankton to exist in the canals due to the saltwater intrusion. Further, favorable environmental conditions for pollution-tolerant species to thrive in the study area might be the reason behind the reported medium (H-values ranged from 2.49 to 2.97) to high (SID-values ranged from 0.89 to 0.92) plankton diversity levels.

3.2.3 Pollution-tolerant species

More than 50% of the plankton species (34 out of 63) recorded during the study period were pollution-tolerant (Table 4). The presence of these pollution-tolerant species indicated the deteriorated water quality condition of the canals. In the literature, twenty algal genera that were most tolerant to organic pollution were documented (Palmer, 1969). Of them, fourteen genera *(Ankistrodesmus, Closterium, Phormidium, Pandorina, Cyclotella, Phacus, Euglena, Melosira, Navicula, Nitzschia, Oscillatoria, Scenedesmus, Lepocinclis*, and *Synedra)* were recorded from the three canals during the research period. The presence of phytoplankton species such as *Oscillatoria* sp., and *Microcystis* sp. is an excellent indication of water pollution (Harris & Vinobaba, 2013). Further, euglenoids indicate organic contamination in water (Harris & Vinobaba, 2013). Thus, the presence of species such as *Phacus* sp. and *Euglena acus* indicated organic pollutant contamination of the canal waters. In addition, *Nitzschia* sp. is considered an organism with a higher pollution tolerance (Setyono & Himawan, 2018). Furthermore, *Aulacoseira* sp. and *Navicula* sp. are known as pollution indicators (Nwonumara, 2018), and both of these species were observed in each canal. Pollution indicator species such as *Oscillatoria* sp., *Nitzschia* sp., *Melosira* sp., *Microcystis* sp., and *Pediastrum duplex* were common to almost all the sampling locations. Rotifers such as *Brachionus* spp., *K. cochlearis*, and *F. longiseta* are good indicators of eutrophic conditions (Tasevska et al., 2010).

Table 3. Mean (± Standard Deviation) values and classification of the calculated Biotic Indices of Kirulapone (KC), Wellawatte (WC) and Dehiwala (DC) canals

Biotic Index	Calculated Index value	Index Value Classification Range	Remarks	References
Shannon-Wiener Diversity Index (H)	2.69±0.10 (KC)	2.0-3.0	Moderate plankton diversity and moderately polluted canal water	Shanthala et al., 2009
	2.97±0.28 (WC)			
	2.49±0.37 (DC)			Trivedi, 1981
Pielou's Evenness Index (E)	0.76±0.01 (KC)	E' value is closer to 1.	More evenly distributed plankton community	Latumahina et al., 2020
	0.82±0.05 (WC)			
	0.76±0.08 (DC)			
Simpson's Index of Diversity (SID)	0.89±0.01 (KC)	0.81-0.99	A higher degree of diversity/ heterogeneity	Guajardo, 2015
	0.92±0.05 (WC)			
	0.91±0.08 (DC)			
Margalef's Richness Index (D_{Mg})	5.00±0.45 (KC)	D_{Mg}>4	High species richness	Latumahina et al.,2009
	5.93±1.45 (WC)			
	3.84±0.04 (DC)	2.5<D_{Mg}<4	Medium species richness	

During the present study, five *Brachionus* spp. were recorded. In addition, *K. cochlearis* was recorded in each canal, indicating eutrophic conditions. Due to the presence of these pollution-tolerant plankton species, it can be assumed that the canal waters were experiencing pollution pressure along with organic contamination and eutrophic conditions during the research period.

During a previous study, Perera, (2015) reported the occurrence of *Lecane* sp. and *B. calyciflorus* at several locations along the Kirulapone and Wellawatte canals. Further, the same author recorded the presence of *Monia micrura* in the same locations, highlighting its role as a potential indicator of organic pollution (Perera, 2015). In contrast, *M. micrura* was not reported during the present study. In addition, several previous studies reported the presence of some pollution-tolerant plankton species in Sri Lankan urban canals. The occurrence of pollution-tolerant phytoplankton species such as *Spiriluna* sp., *Pediastrum duplex, Actinastrum* sp., *Phacus caudatus*, *Microcystis aeraginosa*, and *Scenedesmus armatus* was reported in the Bolgoda canal, Colombo, Sri Lanka (Idroos &

Table 4. Pollution indicator species recorded from of Kirulapone, Wellawatte, and Dehiwala canals during the study period

Plankton Group	Indicator Species	References
Phytoplankton	*Ankistrodesmus* sp., *Closterium* sp., *Phormidium* sp., *Pandorina* sp., *Cyclotella* sp., *Phacus* sp., *Euglena* sp., *Melosira* spp., *Navicula* sp., *Nitzschia* sp., *Oscillatoria* sp., *Scenedesmus* spp., *Synedra* sp., *Aulacoseira* sp., *Microcystis* sp., *Coelastrum* sp., *Spiriluna* sp., *Euglena acus*, *Pinnularia* sp., *Pediastrum duplex,Crucigenia* sp., *Eudorina* sp., *Tetrastrum* sp., *Tetraedron* sp., *Actinastrum* sp.	Harris & Vinobaba, 2013; Idroos & Manage, 2012; Palmer, 1969; Mahadevaswamy, 2020;Nwonumara, 2018; Thakur et al., 2013
Zooplankton	*B. angularis, B. calyciflorus.*, *B.havanaensis, B. forcifula*, *K. cochlearis*, *F. longiseta* , *Lecane* sp.	Setyono & Himawan, 2018;Thakur et al., 2013; Villaruel & Camacho, 2024

Manage, 2012). Furthermore, a study documented that *Nitzschia reversa* dominated the phytoplankton community in the Hamilton canal, Sri Lanka (Pieris et al., 2021). According to Pethiyagoda et al., (2021), plankton species such as *Closterium* sp., *Melosira* sp., *Phacus* sp., *Euglena* sp., *Oscillatoria* sp., *Lecane* sp., and *Brachionus* sp. were reported in several sampling locations within the Colombo canal system. However, more detailed previous records related to the plankton assemblages present in the study area (Kirulapone, Wellawatte, and Dehiwala canals) are absent in the literature.

3.3 Physiochemical parameters

Physiochemical parameters significantly affect the biological components of a water body (Idroos & Manage, 2012). During the present study, physiochemical parameters were compared with the Sri Lankan ambient water quality standards for aquatic life. However, CEA has not proposed standard values for temperature, salinity, TDS, and EC in terms of aquatic life. The water temperature of the three canals ranged between 29.44±0.25°C to 29.93±0.03°C during the research period. Temperature affects photosynthesis and other metabolic activities of phytoplankton species. Reproductive activity, the rate of molting, and the rate of egg development in zooplankton can be influenced by the temperature (Villaruel & Camacho, 2024). The mean pH values varied between 6.85±0.06 to 6.90±0.03 in the study area. During the research period, the mean salinity levels of Kirulapone, Dehiwala, and Wellawatte canals were 2.75±1.06, 7.95±0.89 and 8.42±2.13 ppt, respectively. The lowest salinity concentration, 0 ppt, was recorded from location K1 throughout the whole research period. The highest average salinity level was recorded from location D5 followed by location W3. These two locations were the nearest locations to the sea. The salinity of the Kirulapone canal was significantly lower than that of the other two canals because it is the farthest canal from the sea ($P=0.000$). However, no significant salinity difference was recorded between the Dehiwala and Wellawatte canals ($P>0.05$). A similar pattern was recorded for the measured TDS and EC values of the three canals. Accordingly, both TDS and EC values of the Kirulapone canal were significantly different from the other two canals. Hence, the lowest average salinity, EC, and TDS values were recorded from the Kirulapone canal since it is the farthest canal from the sea.

A declining trend in the salinity levels of the Wellawatte and Kirulapone canals between January and February was reported by Nandaseela & Piyadasa, (2015). Similarly, during the present study, there was a drastic decline in the salinity levels between January and February. Even though the salinity level of location K1 was 0 ppt in January, salinity levels of all the other locations varied between 11-26 ppt while it declined to a range of 0-5 ppt in February. The measured salinity values might change depending on the time of sample collection, sampling location, and the rainfall of the sampling day (Nandaseela & Piyadasa, 2015; Perera et al., 2018).

Phosphate and nitrate are critical nutrients that are required for the growth and reproduction of phytoplankton. The phosphate level of the study area ranged between 0.50±0.10 to 0.64±0.03 mg/L during the research period. Mean phosphate levels recorded from all the sampling locations except location K1 were not within the acceptable limit (0.4 mg/L, maximum) for aquatic life. Discharging untreated domestic and industrial wastewater into the canals could be the reason for the observed high phosphate values exceeding the permissible limit. The recorded phosphate value of the Dehiwala canal significantly differed from that of the Kirulapone canal (P=0.025). However, nitrate levels recorded from all the sampling locations were found to be within acceptable limits (10mg/L, maximum).

Further, the recorded average DO values for all the sampling locations were within acceptable limits (5 mg/L, minimum), except in locations D4 and W1. According to the findings of Hemachandra et al., (2019), the average DO values of the Kirulapone canal ranged from 0.8 to 1.7 mg/L indicating the inability of the canal water to support aerobic life. However, in contrast with the findings of the aforementioned study, the average DO values of the Kirulapone canal ranged from 5.64 to 6.32 mg/L during the present study. The DO level of the canal water varies with the time of the day due to the impact of photosynthesis (Perera et al., 2018). Hence, the phytoplankton abundance significantly contributes to the DO concentration of the canal water. Further, it was stated that the flow rate of the canal may have an impact on the DO concentration of the canal water (Perera et al., 2018).

A higher rate of decomposition of organic matter increases BOD_5 in a water body (Sanap et al., 2006). Therefore, high BOD_5 values indicate the presence of a high amount of organic matter. The BOD_5 values recorded from the four sampling locations of the Kirulapone canal were found to be within acceptable limit (4mg/L, maximum). However, the BOD_5 values of all the other sampling locations were higher than the permissible limits. Hence, the Dehiwala and Wellawatte canals were unsuitable for aquatic life in terms of BOD_5. A significant difference was recorded between the BOD_5 values of the Kirulapone and Wellawatte canals (P=0.001). Similarly, there was a significant difference between the BOD_5 values of the Kirulapone and Dehiwala canals (P=0.000). Further, no significant difference was recorded between the Dehiwala and Wellawatte canals (P>0.05). The lowest BOD_5 values were reported for the Kirulapone canal, and therefore, the input of the pollution load into the Kirulapone canal might be lower than the other two canals. It can be further confirmed because two out of four locations of the Kirulapone canal were categorized as ‘good’ according to WPI.

The relationship between the physiochemical parameters and the plankton abundance in the study area was determined using PCA. In addition, PCA was used to identify the most prominent physiochemical parameters contributing to water quality in the study area. PCA loadings can be categorized as strong (>0.75), moderate (0.75-0.5), and weak (0.5-0.3) (Barakat et al., 2016; Liu et al., 2003). However, none of the parameters, except for pH, showed a strong or moderate loading on principal components. Hence, parameters with loading values greater than 0.3 were considered contributing factors for principal components. Salinity, EC, TDS, BOD_5, temperature, and phosphate contributed to PC1, while nitrate and pH contributed to PC2 (Figure 7). Thus, salinity, EC, TDS, BOD_5, temperature, and phosphate were identified as the most important factors that contributed to most water quality variations in the study area.

The first two PCA components (PC1=52.4% and PC2=18.2%) cumulatively accounted for 70.6% of the total variance observed in the study area. The PCA revealed a weak positive correlation between plankton abundance, pH, EC, TDS, salinity, BOD_5, temperature, nitrate, and phosphate (Figure 7). It proved that increasing trends of these physiochemical parameters favored the plankton growth in the study area. Moreover, a negative correlation was observed between DO and plankton abundance (Figure 7). This indicated that the plankton community in the study area increased in numbers with decreasing DO levels. Several authors have reported negative relationships between DO and the abundance of several plankton groups encountered in different aquatic systems. In a study conducted in eutrophic freshwater lakes in India (Himachal Pradesh), rotifers and cyanophytes were reported to have an inverse relationship with DO (Thakur et al., 2013). Similarly, Hussain et al., (2016) documented a negative correlation between rotifer density and DO. In addition, Okechukwu & Ugwumbav, (2019) reported a negative relationship between the abundance of cyanophytes and DO in the Mid-Cross River, Nigeria. Shekar et al., (2015) also noticed an inverse relationship between DO and zooplankton density in Gidadakonenahalli Lake, India. Furthermore, Sharma & Sharma, (2019) observed negative correlations between DO and the abundance of several zooplankton groups including rotifers and copepods. Moreover, the abundance of *Filinia longiseta* in the Kotmale Reservoir, Sri Lanka, and *Lecane subtilis* in Lake Tadlac, Philippines, exhibited inverse relationships with DO (Villaruel & Camacho, 2024, Warusawithana & Yatigammana, 2019). Further, the findings of Yusuf, (2020) revealed a negative correlation between euglenoids and DO. Rotifers such as *Brachionus* spp., cyanophytes such as *Microcystis* sp. and *Oscillatoria* sp., as well as euglenoids, have been documented as pollution indicators (Harris & Vinobaba, 2013; Thakur et al., 2013; Warusawithana & Yatigammana, 2019). Some plankton species can withstand harsh environmental conditions and thrive in polluted waters, reflecting a high level of pollution tolerance (Jakhar, 2013). Thus, it can be said that these pollution indicator species may have the ability to thrive even under low DO levels. For instance, rotifers have a wide tolerance to various physical and chemical factors including DO (Lazo et al., 2009). In addition, Hujare, (2008) noted that low DO levels in the water favor the abundance of euglenoids. Further, it has been documented that cyanophytes are capable of tolerating low oxygen conditions (Mercurio et al., 2016). Therefore, the observed inverse relationship between DO and plankton abundance may be attributed to the predominance of pollution-tolerant plankton species (more than 50%) in the canal waters. However, more future studies must be conducted to clarify the underlying factors contributing to this inverse relationship.

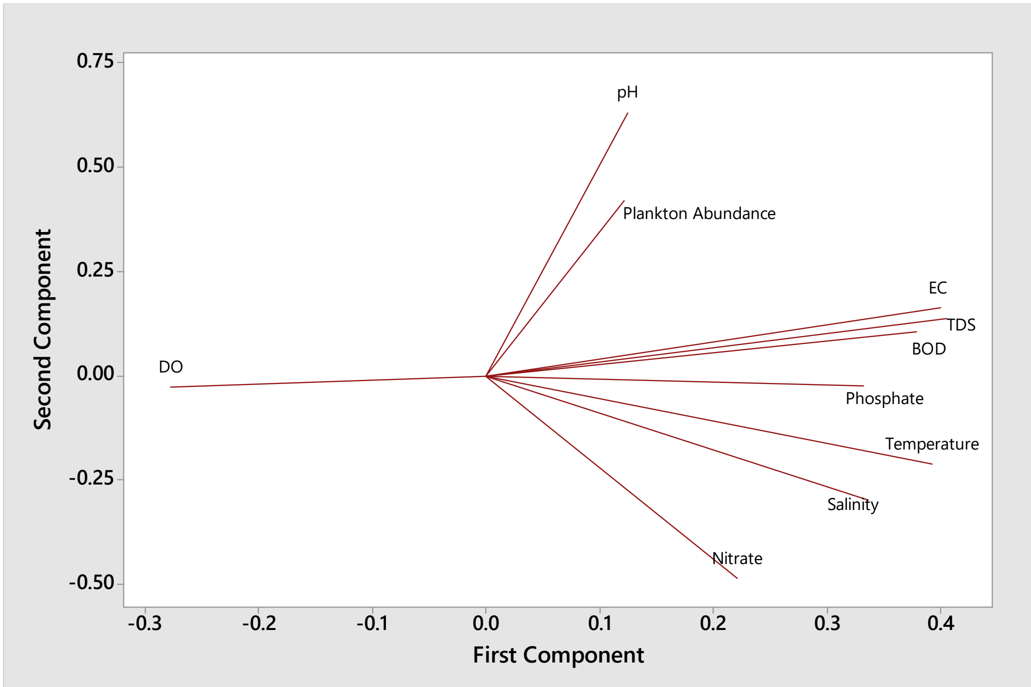

Figure 7. Loading plot of the PCA

3.4 WPI and WAWQI

WPI is an integrated approach that converts all the input parameters into a single value index (Hossain & Patra, 2020). Even a slight change in the concentration of any input parameter can change the WPI class of water quality (Hossain & Patra, 2020). It provides an overall idea about the water quality status of an aquatic system in terms of pollution. Plankton are considered excellent indicators of water pollution. The greater impact of pollution may lead to a lesser diversity of plankton in a water body. Based on the calculated WPI values, four locations (K2, K3, W1, D4) out of twelve were categorized as 'good' in terms of pollution while other locations were moderately polluted. However, there were no significant differences among the WPI values of the three canals (P>0.05). The calculated mean WPI values of the Kirulapone, Wellawatte, and Dehiwala canals were 0.76±0.05, 0.76±0.04, and 0.82±0.06, respectively. This suggested that the canal waters were moderately polluted. This was consistent with the results obtained from the Shannon-Wiener diversity index which sorted out three canals as moderately polluted. Moreover, plankton species present in the study area also confirmed the polluted condition of the canals. In the present study, WPI was calculated using five selected water quality parameters. Therefore, the calculated WPI values of the present study might be changed if WPI was calculated considering heavy metals and organic pollutants such as oil and grease along with more physiochemical parameters.

During the present study, WAWQI was used to evaluate the suitability of the study area to maintain a healthy aquatic life. According to the calculated WAWQI values, all the sampling locations except K1 were in conditions that were not suitable for aquatic life. Location K1 was poor in water quality according to WPI. The mean WAWQI values of the

Kirulapone, Wellawatte, and Dehiwala canals were 109.07± 18.60, 125.41±3.50, and 136.11±9.02, respectively. A significant difference was recorded between the WAWQI values of Kirulapone and Dehiwala canals (P=0.025). However, according to the mean WAWQI values, the study area was unsuitable for aquatic life. The results indicated that the water quality of the three canals was not up to the standard level to sustain sensitive organisms. Hence, it is reasonable to assume that sensitive plankton species had been eliminated from the study area allowing the thriving of pollution-tolerant plankton species. It can be further supported by the pollution indicator species encountered in the study area. As concluded by Hemachandra et al., (2019) the Kirulapone canal was unable to support aquatic life. In addition, Nishanthi & Dushanan, (2022) stated that the Kirulapone canal was unsuitable for aquatic species considering the increase of ammonia concentration in the canal water from 2015 to 2020. Thus, the present study's findings based on the WAWQI are confirmed.

The Colombo South canal system connects with large water bodies such as Parliament Lake and marshes like Kotte Marsh and Heen Marsh. This connection promotes the dilution of pollutants before entering the canal water (Eriyagama & Ratnayake, 2008). Thus, it is clear that these water bodies and wetlands act as natural buffers of pollution. The Kirulapone canal starts near the Nawala Urban Wetland Park. However, even the nearest sampling location to the start point of the canal (K1) was moderately polluted according to WPI. Further, according to the WAWQI, location K1 had very poor water quality. Hence, it can be assumed that the proper functioning of the wetlands might have been altered, reducing the capacity of pollution buffering.

As per the observations of the present study, wastewater disposal and urban surface runoffs can be identified as the major causes of the above pollution status. Further, it was noted that the direct discharge of effluents and disposal of various pollutants was a widespread practice associated with the three canals. The dark, gloomy appearance of the canal water observed during the present study further provided evidence to confirm the deteriorated water quality condition of the canals. These observations can be supported by the results of the present study which revealed the presence of pollution indicators species, moderate pollution levels, and the unsuitability of the canal waters for aquatic life.

4. Conclusions

The water quality in the Kirulapone, Wellawatte, and Dehiwala canals was assessed during the present study with special reference to the plankton community. Chlorophyceae was the dominant phytoplankton group in the study area, whereas rotifers comprised most of the zooplankton. The plankton communities in the canals were moderately diverse and more evenly distributed. Further, the study area had medium to high species richness. The presence of pollution indicator species including *Nitzschia* sp., *Oscillatoria* sp., *Melosira* spp., *Aulacoseira* sp., *Cyclotella* sp., *Coelastrum* sp., *Pinnularia* sp., *Synedra* sp., *Navicula* sp., *Pandorina* sp., *Eudorina* sp., *Scenedesmus* spp., *Actinastrum* sp., *Ankistrodesmus* sp., *Tetrastrum* sp., *Tetraedron* sp., *Closterium* sp., *Crucigenia* sp., *Pediastrum duplex*, *Microcystis* sp., *Spirulina* sp., *Phacus* sp., *Euglena* sp., *Lecane* sp., *Keratella cochlearis*, *Filinia longiseta, Brachionus angularis*, *B. calyciflorus, B. forcifula* and *B.havanaensis* indicated the polluted condition of the canal waters. Two marine plankton species were recorded in the canals at a considerable distance from the sea. There was a suitable condition for freshwater, brackish water, and marine species to live in the three canals due to the impact of saltwater intrusion. Thus, plankton encountered in the study area were capable of tolerating various salinity levels. The measured pH and nitrate values were within the acceptable limits for aquatic life. The observed phosphate, DO, and BOD_5 values exceeded the Sri Lankan ambient water quality standards for aquatic life at several sampling locations. PCA revealed a negative correlation between plankton abundance and DO whereas the plankton abundance positively correlated with the other physiochemical parameters. Based on PCA, salinity, EC, TDS, BOD_5, temperature, and phosphate were the most prominent physiochemical parameters contributing to water quality variations in the study area. Based on WPI and WAWQI, the three canals were moderately polluted and unsuitable for aquatic life. Hence, it can be inferred that, during the research period, canal waters were more suitable for pollution tolerance plankton species. Thus, it is necessary to implement proper measures to restore the aquatic ecosystem status of the canals. The present study provides baseline information for future research in the study area while emphasizing the importance of incorporating plankton into water quality assessments. It is highly recommended to conduct future research to determine long-term temporal and spatial variations of plankton communities in the study area.

5. Conflicts of Interest

The authors declare no conflicts of interest related to this manuscript.

ORCID

Madhavi Kolambage https://orcid.org/0009-0008-8554-2680
Inoka Batugedara https://orcid.org/0009-0000-0225-1418
Chalani Perera https://orcid.org/0009-0006-6639-1392
Indunil Senanayake https://orcid.org/0000-0003-1525-5092

References

Adesalu, T. A. (2016). Diversity of green microalgae in South-Western lagoon, Nigeria. *Journal of Scientific Research and Development*, 15(2), 14-19.

APHA. (1998). *Standard Methods for the Examination of Water and Wastewater* (20th ed.). American Public Health Association.

APHA. (2017). *Standard Methods for the Examination of Water and Wastewater*. (23rd ed.). American Public Health Association.

Aziz, N. E. A. (2005). Short term variations of zooplankton community in the West Naubaria Canal, Alexandria, Egypt. *Egyptian Journal of Aquatic Research*, 31(1), 119-131.

Barakat, A., El Baghdadi, M., Rais, J., Aghezzaf, B., & Slassi, M. (2016). Assessment of spatial and seasonal water quality variation of Oum Er Rbia River (Morocco) using multivariate statistical techniques. *International Soil and Water Conservation Research*, 4(4), 284-292. https://doi.org/10.1016/j.iswcr.2016.11.002

D'Alelio, D., Libralato, S., Wyatt, T., & d'Alcalà, M. R. (2016). Ecological-network models link diversity, structure, and function in the plankton food-web. *Scientific Reports,* 6(1), Article 21806. https://doi.org/10.1038/srep21806

Dharmasoma, U. Y. I. L., & Piyadasa, R. U. K. (2014). An assessment of seasonal water quality variations in the inlets of Diyawanna Lake, Sri Lanka. *Proceedings of the 4th SAITM Research Symposium on Engineering Advancements* (pp. 110-112). South Asian Institute of Technology and Medicine.

Doan, D. P., Van, K.N., Nguyet, N. L. T., Thanh, D. N., & Ho, T. H. (2015). *Identification handbook of freshwater zooplankton of the Mekong River and its tributaries*. Mekong River Commission.

Eriyagama, N., & Ratnayake, N. (2008). Decision support tool for Colombo canal system water quality monitoring. *Engineer: Journal of the Institution of Engineers, Sri Lanka,* 41(1), 24-33. https://doi.org/10.4038/engineer.v41i1.7081

Guajardo, S. A. (2015). Measuring diversity in police agencies. *Journal of Ethnicity in Criminal Justice,* 13(1), 1-15.

Harris, J. M., & Vinobaba, P. (2013). Assessment the present status of Batticaloa Lagoon, Sri Lanka by means of water quality, fish diversity indices, and pollution indicating planktons. *Journal of Biodiversity and Endangered Species*, 1(2), Article 105. https://doi.org/10.4172/2332-2543.1000105

Hemachandra, I. V. D., Hettiarachchi, G. K., Mudalige, K. E. H., Premasiri, V. P. N. A., Karunathilaka, M. D. S. I., & Halwatura, D. (2019). Freshwater pollution: A study on Kirulapone canal. In *Proceedings of the 2nd National Undergraduate Research Symposium* (p. 2). National Science and Technology Commission.

Hettige, N., Weerasekara, S., Azmy, S., & Jinadasa, K. B. S. N. (2014). Water pollution in selected coastal areas in Western Province, Sri Lanka: A baseline survey. *Journal of Environmental Professionals Sri Lanka*, 3(2), 12-24.

Hoang, H. T. T., Duong, T. T., Nguyen, K. T., Le, Q. T. P., Luu, M. T. N., Trinh, D. A., Le, A. H., Ho, C. T., Dang, K. D., Némery, J., Orange, D., & Klein, J. (2018). Impact of anthropogenic activities on water quality and plankton communities in the Day River (Red River Delta, Vietnam). *Environmental Monitoring and Assessment,* 190(2), Article 67. https://doi.org/10.1007/s10661-017-6435-z

Hossain, M., & Patra, P. K. (2020). Water pollution index - a new integrated approach to rank water quality. *Ecological Indicators*, 117, Article 106668. https://doi.org/10.1016/j.ecolind.2020.106668

Hujare, M. S. (2008). Seasonal variations of phytoplankton in the freshwater tank of Talsande, Maharashtra. *Nature, Environment and Ecology*, 7(2), 253-256.

Hussain, A., Sulehria, A. Q. K., Ejaz, M., & Maqbool, A. (2016). Population dynamics of rotifers in the floodplain of River Ravi, Pakistan. *Pakistan Journal of Zoology*, 48(1), 215-225.

Hyarat, T., & Al Kuisi, M. (2021). Comparison between weighted arithmetic and Canadian council of ministers of the environment water quality indices performance in Amman-Zarqa area, Jordan. *Jordan Journal of Earth and Environmental Sciences,* 12(4), 295-305.

Idroos, F. S., & Manage, P. M. (2012). Aquatic life health quality assessment of the Bolgoda canal and Waga stream with respect to selected physicochemical parameters and bioindicators. *Journal of Tropical Forestry and Environment*, 2, 13-26.

Jakhar, P. (2013). Role of phytoplankton and zooplankton as health indicators of aquatic ecosystem: A review. *International Journal of Innovation Research Study*, 2(12), 489-500.

Jayaweera, J. A. C. K., & Samarakoon, M. B. (2020). Effect on water quality due to residential development - A case study on Kolonnawa canal. *13th International Research Conference* (pp. 27-35). General Sir John Kotelawala Defence University.

Larson, C. A., & Belovsky, G. E. (2013). Salinity and nutrients influence species richness and evenness of phytoplankton communities in microcosm experiments from Great Salt Lake, Utah, USA. *Journal of Plankton Research*, 35(5), 1154-1166.

Latumahina, F. S., Mardiatmoko, G., & Sahusilawane, J. (2020). Richness, diversity and evenness of birds in Small Island. *Journal of Physics: Conference Series,* 1463(1), Article 012023. https://doi.org/10.1088/1742-6596/1463/1/012023

Lazo, M. A. V. A., Nielo, K. K. P., Rayel, M. F. S., Domingo, D. M. S., Vergara, M. A. M., & Papa, R. D. S. (2009). Composition, abundance, and distribution of rotifers in the Pasig River, Philippines. *The Philippine Scientist*, 46, 47-64.

Liu, C. W., Lin, K. H., & Kuo, Y. M. (2003). Application of factor analysis in the assessment of groundwater quality in a blackfoot disease area in Taiwan. *Science of the Total Environment*, 313(1-3), 77-89.

Madhushan, A. M. L., & Dharmasena, J. (2021). A study on quality of life of middle-income group along urban canal waterfronts with special reference to Greater Colombo region. In *FARU Proceedings 2021* (pp.139-149). University of Moratuwa.

Mahadevaswamy, M. (2020). A study on diversity and abundance of microphytoplankton in River Cauvery and its four upstream tributaries in South Karnataka, India. *Indian Journal of Pure and Applied Biosciences*, 8(3), 477-486.

Margalef, R. (1956). Information and diversity specifies the communities of organisms. *Invest Pesg,* 3, 99-106.

Mercurio, A. L., Querijero, B. L., & Ching, J. A. (2016). Phytoplankton community in aquaculture and non-aquaculture sites of Taal Lake, Batangas, Philippines. *Journal of Experimental Biology and Agricultural Sciences*, 4(1), 66-73.

Munasinghe, H. K. (2014). *Spatial model for water quality changes of urban canals and associated land use pattern in Colombo City.* [M.Sc. dissertation, University of Sri Jayewardenepura]. Library, University of Sri Jayewardenepura. http://dr.lib.sjp.ac.lk/handle/123456789/5425

Nandaseela, S. M. A. T. D. S., & Piyadasa, R. U. K. (2015). Variations of water quality in Dehiwala, Wellawatte and Kirulapone canals. In 5th *International Research Symposium on Engineering Advancement* (pp. 76-81). South Asian Institute of Technology and Medicine (SAITM).

Nishanthi, K., & Dushanan, R. (2022). Water quality estimation in Kirulapone canal: application of weighted arithmetic water quality index method. In *Proceedings of the 10th YSF Symposium* (pp.202-206). National Science and Technology Commission.

Nishanthi, K., Dushanan, R., Mathanraj, S., & Priyadharshini, C. (2021). An assessment of water quality temporal variation in Sri Jayewardenapura Kotte canal, Sri Lanka. *World News of Natural Sciences,* 38, 139-157.

Nwonumara, G. N. (2018). Water quality and phytoplankton as indicators of pollution in a tropical river. In *Proceedings of 6th NSCB Biodiversity Conference* (pp. 83-89). Uniuyo.

Okechukwu, I. O., & Ugwumba, O. A. (2009). Cyanobacteria abundance and its relationship to water quality in the mid-cross river floodplain, Nigeria. *Revista de Biología Tropical*, 57(1-2), 33-43.

Palmer, C. M. (1969). A composite rating of algae tolerating organic pollution. *Journal of Phycology*, 5(1), 78-82.

Peiris, B. A. D., Maddumage, M. D. S. R., Manage, P. M., Jayawardhane, J. K. P. C., Weerasekara, K. A. W. S., & Mahagamage, M. G. Y. L. (2021). Species diversity and abundance of phytoplankton and zooplankton along the Hamilton Canal. In *Proceedings of the 8th International Symposium on Water Quality and Human Health: Challenges Ahead* (p. 44)*.* Postgraduate Institute of Science, University of Peradeniya.

Perera, G. L. E. P., Dayarathne, G. C. R., Perera, H. K. M., & Athapattu, B. C. L. (2018). Modelling stratification ascendancy of Kirulapone canal at Wellawatte outfall. In *Annual sessions of IESL* (pp.145-154). The Institution of Engineers, Sri Lanka.

Perera, L. G. R. Y. (2015). A preliminary study on the variation of zooplankton diversity, abundance and density in a selected branch of Diyawanna Oya Canal System. *OUSL Journal,* 9, 61-81. https://doi.org/10.4038/ouslj.v9i0.7327

Pethiyagoda, P. D. R. S., De Alwis, S. M. D. A. U., & De Silva, B. G. D. N. K. (2021). Food and feeding habits of wild guppy (*Poecilia reticulata*), in natural water bodies of Sri Jayewardenepura canal system, Sri Lanka. *KDU Journal of Multidisciplinary Studies*, 3(2), 56-63.

Pielou, E. C. (1966). The measurement of diversity in different types of biological collections. *Journal of Theoretical Biology*, 13, 131-144.

Prescott, G. W. (1962). *Algae of the Western Great Lakes Area.* Cranbrook Institute of Science.

Roy, K., Gupta, S., & Nandy, S. (2016). Checklist of commonly occurring phytoplankton and zooplankton genera of urban and rural ponds of Raipur, Chhattisgarh. *International Journal of Research in Biological Sciences*, 6(1), 1-6.

Sanap, R. R., Mohite, A. K., Pingle, S. D., & Gunale, V. R. (2006). Evaluation of water qualities of Godawari river with reference to physicochemical parameters, Dist. Nasik (M.S.), India. *Pollution Research*, 25(4), 775-778.

Setyono, P., & Himawan, W. (2018). Analyses of bioindicators and physicochemical parameters of water of Lake Tondano, North Sulawesi Province, Indonesia. *Biodiversitas Journal of Biological Diversity*, 19(3), 867-874.

Shannon, C. E. & Weaver, W. (1949). *The mathematical theory of communication*. The University of Illinois Press.

Shanthala, M., Hosmani, S. P., & Hosetti, B. B. (2009). Diversity of phytoplanktons in a waste stabilization pond at Shimoga Town, Karnataka State, India. *Environmental Monitoring and Assessment*, 151, 437-443.

Sharma, A., & Sharma, M. (2019). Zooplankton diversity in relation to physico-chemical parameters in subtropical pond of Jammu, Jammu, and Kashmir, India. *Biosciences Biotechnology Research Asia*, 16(2), 425-439.

Shekar, G., Narayan, L., & Muniyellappa, R. M. (2015). Impact of urbanization and study of water quality index on Gidadakonenahalli Lake, Bangalore urban district, Karnataka, India. *Advances in Forestry Science,* 2(1), 7-12.

Shekhar, T. R., Kiran, B. R., Puttaiah, E. T., Shivaraj, Y., & Mahadevan, K. M. (2008). Phytoplankton as index of water quality with reference to industrial pollution. *Journal of Environmental Biology*, 29(2), 233-236.

Simpson, E. H. (1949). Measurement of diversity. *Nature*, 163, Article 688. https://doi.org/10.1038/163688a0

Suthers, I. M., Rissik, D., & Richardson, A. J. (2019). *Plankton: A Guide to Their Ecology and Monitoring for Water Quality*. (2nd ed.). CSIRO Publishing.

Tasevska, O., Kostoski, G., & Guseka, D. (2010). Rotifers based assessment of the Lake Dojran water quality. In *BALWOIS 2010. The 4th International Scientific Conference on water observation and information system for decision support* (pp. 1-8). Ohrid, Republic of Macedonia.

Thakur, R. K., Jindal, R., Singh, U. B., & Ahluwalia, A. S. (2013). Plankton diversity and water quality assessment of three freshwater lakes of Mandi (Himachal Pradesh, India) with special reference to planktonic indicators*. Environmental Monitoring and Assessment*, 185, 8355-8373.

Trivedi, R. C. (1981). *Use of Diversity Index in Evaluation of Water Quality*. Central Board for the Prevention and Control of Water Pollution.

Villaruel, M. J. S., & Camacho, M. V. D. C. (2024). Zooplankton community as indicator of trophic status of Lake Tadlac in Los Baños, Laguna, Philippines. *Current Applied*

Science and Technology, 24(3), Article e0258364. https://doi.org/10.55003/cast.2023.258364
Warusawithana, A. L., & Yatigammana, S. K. (2019). Ecology and diversity of plankton in Kotmale Reservoir, Sri Lanka. *Sri Lanka Journal of Aquatic Sciences*, 24(1), 25-40.
Yusuf, Z. H. (2020). Phytoplankton as bioindicators of water quality in Nasarawa reservoir, Katsina State Nigeria. *Acta Limnologica Brasiliensia*, 32, Article e4. https://doi.org/10.1590/S2179-975X3319