BIODIVERSITAS
Volume 24, Number 9, September 2023
Pages: 5179-5188

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d240962

Deterministic assessment of the ecological vulnerability of coastal freshwater canals: A perspective on social awareness and conservation

NAJMUS SAKIB KHAN[1,♥], MD. SAIFUL ISLAM[1], JABER BIN ABDUL BARI[1], MAEEN UDDIN[1], IRINA MASHKOVA[2,♥♥], ANASTASIYA KOSTRYUKOVA[2], VIKTOR TROFIMENKO[3]

[1]Department of Oceanography, Noakhali Science and Technology University. Sonapur Road, Noakhali-3814, Bangladesh. Tel.: +8802334496522, Fax.: +8802334496523, ♥email: nsakib.iium@gmail.com, nsakib.ocn@nstu.edu.bd

[2]Department of Chemistry, Institute of Natural Sciences and Mathematics, South Ural State University. 76 Lenin Prospect, 454080 Chelyabinsk, Russia. Tel./fax.: +7-351-2679517, ♥♥email: mashkovaiv@susu.ru

[3]Department of Philosophy and Culturology, South Ural State Humanitarian Pedagogical University. 69 Lenin Prospect, 454080 Chelyabinsk, Russia

Manuscript received: 17 July 2023. Revision accepted: 30 September 2023.

Abstract. *Khan NS, Islam MS, Bari JBA, Uddin M, Mashkova I, Kostryukova A, Trofimenko V. 2023. Deterministic assessment of the ecological vulnerability of coastal freshwater canals: A perspective on social awareness and conservation. Biodiversitas 24: 5179-5188.* Inland freshwater canals are formed by geomorphological evolutions or artificially for communal welfare. The freshwater canal ecology differs mainly from rivers, estuaries, and the ocean for salinity variables, nutrient concentrations, morphological structure, and unique flora and fauna distribution. These canals and their aquatic organisms are very sensitive to surface runoff and direct sewage pollution. Thus, these freshwater canals become threats to society in case of contamination. The current study focused on the water quality, microalgae, and zooplankton communities in two renowned canals: Basurhat (BH) canal and Dotterhat (DH) canal in coastal Noakhali, Bangladesh. The study attempted to demonstrate these canals' aquatic and ecological status by evaluating plankton distribution and some important water quality parameters. Furthermore, a classic Palmer's algal organic pollution Index and wetland zooplankton Index were applied to determine the water quality according to species assemblages of freshwater algae and zooplankton, respectively. The present study identified 27 phytoplankton genera from Bashurhat Canal and 21 from Datterhat Canal. At the same time, 16 genera of zooplankton were observed with 2,269.09±52.12 ind/L and 4,588.54±40.79 ind/L from Bashurhat Canal and Datterhat Canal, respectively. The water quality differed from Bashurhat Canal and Datterhat Canal, where the highest temperature was found at Bashurhat Canal at 23.55±0.15°C and the lowest was 22.6±0.1°C. Moreover, the highest and lowest temperature was found from Datterhat Canal as 29.8±0.9°C and 29.67±0.78°C respectively. The highest transparency (cm), Dissolve Oxygen (mg/L), alkalinity (mg/L), free carbon dioxide (mg/L), ammonia (mg/L) and TSS (mg/L) were found as 29±1.0, 1.25±0.25, 58.76±0.26, 59.25±0.66, 8.25±0.25, 2.25±0.05 and the lowest were found 20.5± 0.5, 0.75±0.25, 27.73±0.49, 11.28±0.69, 8.15±0.15, 2.2±0.1 in Bashurhat Canal. Additionally, the highest transparency (cm), Dissolve oxygen (mg/L), alkalinity (mg/L), free carbon dioxide (mg/L), ammonia (mg/L), and TSS (mg/L) were found as 15.75±0.25, 1.85±0.50, 53.96±0.5, 55.09±0.8, 8.1±0.1, 4.0±0.1 and the lowest were identified 14.5± 0.5, 1.25±0.25, 23.1±0.4, 49.23±0.38, 7.65±0.50, 2.54±0.75 in Datterhat Canal. The study results indicate the deterioration of water quality in urbanized canals and that aquatic ecosystems face many long-term anthropogenic pressures. The current canal state requires measures to restore them. In addition, there is a need for strict control over the discharge of waste and pollutants from residential areas, fish markets, and hospitals.

Keywords: Anthropogenic pollution, freshwater canal, phytoplankton, social concern, zooplankton

INTRODUCTION

Canals are the narrow waterways created by the river's protrusion or coastal water invasion towards land. Natural or artificial canals have been used from ancient times to the present day. Today, canals are used for hydraulic power generators in many countries (Palanisamy and Chui 2015; Zaman et al. 2019). Also, canals support the local economy through fisheries, irrigation for agricultural fields, and industrial uses. Canals facilitate local communication and transportation. But most importantly, they mitigate floods during monsoons or other natural disasters (e.g., cyclones, typhoons, etc). Bangladesh is considered one of the most disaster-prone countries in the world (Hossain et al. 2020), where coastal districts are most vulnerable to natural disasters. Monsoon precipitation initiates flooding and results in the loss of human life, natural resources and economic development's downfall (Hossain et al. 2016). Noakhali is one of the southeastern districts of Bangladesh, which is crisscrossed with many natural and artificial canals. It lies between 22°07′ and 23°08′ north latitude and between 90°53′ and 91°27′ east latitudes and comprises an area of 3,685.87 km^2. The annual average rainfall is 3,302 mm (BBS 2013). Noakhali has suffered greatly from natural disasters like tornadoes, floods, cyclones, etc (BBS 2013). However, the canals located here may alleviate flooding and other disasters in the future. The contaminated water may cause adverse effects on human and animal health, such as hypertension, kidney failure, carcinogenic diseases, skin diseases, heart failure, and other water-borne diseases, and reduce agriculture production (Miah et al. 2015). Being a coastal district, Noakhali is no exception and faces a similar problem of salinization and groundwater contamination with heavy metals (Miah et al.

2015; Prosun et al. 2018). The Noakhali canals can be used as additional freshwater sources, reducing dependence on polluted groundwater. Nevertheless, their water quality must be regularly monitored and managed properly. Many water bodies in Noakhali are very aged, and some are over a hundred years old; the endemic aquatic plants and micro or macro-organisms habitats living there (Khan et al. 2020). Anthropogenic activities have increased tremendously, which has caused ecological and economic damages to the canals and their ecosystems. The canal area is decreasing daily; local people have infringed on the canal and built numerous illegal structures. Although an initiative was taken by the authority to demolish these structures, the remaining of these structures are left as a sign of destructive activities. The local people became so careless about canal water quality and ecology that they started to use canals as dumping sites for organic and inorganic wastes. Moreover, domestic pollutants and sewage are discharged into the canals without treatment. Some canals are contaminated by industrial pollutants and agrochemical waste, which may lead to heavy metal pollution and deteriorate the water quality (Zaman et al. 2019). The ecological diversity of canals in Noakhali is much ignored; the lack of awareness, carelessness, and negligence towards the canals has disrupted its aquatic ecosystem. Many canals dry up and cause the death of fish and other aquatic organisms during dry seasons, resulting in biodiversity loss. Some of the canals almost disappeared; only monsoons create a potential opportunity for their self-recruiting. The assessment of the water bodies' health is determined as a result of chemical analysis or assessing bio-indicators (Poulíčková et al. 2004). Bioindicators are used to detect changes in the environment. Their presence, absence, frequency, and abundance at a given location can provide important information about water ecosystems (Singh et al. 2013; Uddin et al. 2022).

Plankton is a widely used bioindicator that generates quickly and has a higher reproduction rate (Thakur et al. 2013; Parmar et al. 2016). Plankton is a vital component and forms the basis of the aquatic food chain. In addition, these tiny organisms greatly influence the primary productivity of an aquatic ecosystem (Bassey et al. 2019). Micro-communities can provide significant information about the ecological condition of water bodies (Khan and Islam 2019; Khan et al. 2020). Therefore, this study aimed to evaluate the status of two freshwater canals (Datterhat and Basurhat) in Noakhali (Bangladesh) by examining the algae and zooplankton distribution and their role. The canal's micro-communities must be monitored to understand its ecological state.

MATERIALS AND METHODS

Study area

The two most critical polluted canals were selected during present studies from the Noakhali region based on their special location and vulnerability. The studies were carried out from June 2020 to September 2020. Water and plankton sampling was carried out weekly. There are two replicas in both water parameters and collected plankton samples. A total of six sampling stations from two different freshwater canals such as the Basurhat (BH) canal and the Datterhat (DH) canal of the Noakhali District, Bangladesh were selected for the experiment (Figure 1, Table 1).

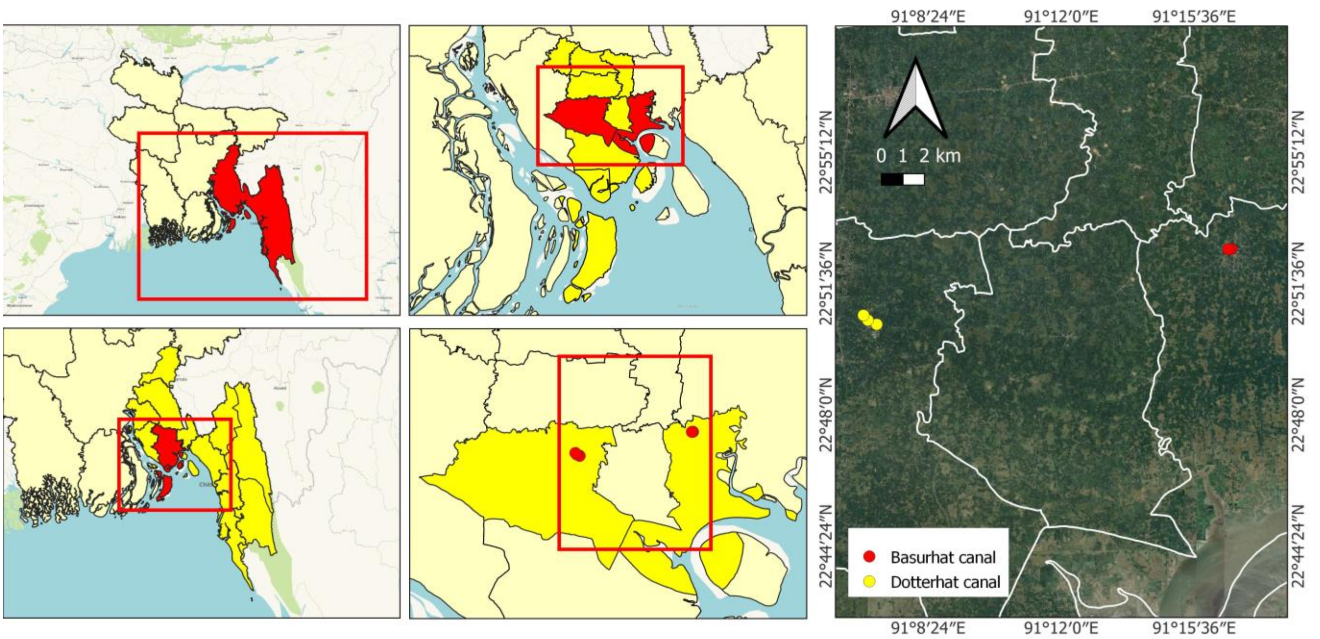

Figure 1. Location of Basurhat (BH) canal and Dotterhat (DH) canal of Noakhali District, Bangladesh indicating the sampling sites

Figure 2. Sampling sites: A. BH 01, B. BH 02, C. BH 03, D. DH 01, E. DH 02, F. DH 03

The Basurhat canal stations are denoted by BH 01, BH 02, and BH 03; the Datterhat canal stations are denoted by DH 01, DH 02, and DH 03, respectively. Both canals are situated near developing cities and are extremely eutrophic by excessive untreated sewage disposal from nearby residential areas, hospitals, and grocery markets. Canals are ignored by social inattentiveness but used for one-way daily purposes without any intensive management. The canals are seriously polluted for this reason by many organic and inorganic toxic compounds discharged from numerous point source and non-point sources of pollutants (Figure 2).

Water quality analysis

Water temperature (°C) and transparency (cm) were recorded on the spot, and additionally, 250 mL sample bottles were used for collecting water for further laboratory analysis to measure the water quality. APHA and WEF (1998) was followed to determine dissolved oxygen (mg/L), the concentration of hydrogen ion (pH), total alkalinity (mg/L), free carbon dioxide (mg/L), total suspended solids, and ammonium (mg/L) in the collected water samples.

Plankton collection and analysis

Plankton samples were collected from each station by filtering 48 liters of water on the spot using a plankton net (mesh size: 25 µm). Then, the samples were preserved with 5% formalin in a 250 mL bottle for further analysis. The abundance of phytoplankton and zooplankton was identified using a light binocular microscope (Labomed, model: CXL-181085030) at 16×10 and 16×40 magnification levels. The estimated phytoplankton was recorded to determine the organic pollution level of canals using phytoplankton pollution index values (Palmer 1969).

The calculation of the abundance of zooplankton was done using a Sedgwick-Rafter cell, and the abundance was expressed as cells L^{-1}. One (1) mL sample was put in the Sedgwick-Rafter (S-R) cell and left for 5 min to allow plankton to settle down. The plankton in 10 randomly selected fields in the S-R cell was counted, and plankton density was calculated as cells L^{-1} using the formula (Stirling 1985):

$$Yi = \frac{(P \times C \times 1000)}{(L \times V \times F)}$$

Where:

Yi : Total number of plankton per sample water liter
P : Total number of counted plankton in sample water
C : Volume of the concentrated sample water (250 mL)
L : Total volume of the filtered sample water (48 L)
V : Volume of mm^3 of a small square field (1 mm^3)
F : Number of fields counted (10)

Table 1. Geographical location of study areas

Sites	Stations	Latitude (N)	Longitude (E)
Dotterhatt Canal (DH)	DH 01	22°50'55.47"	91° 6'9.09"
	DH 02	22°50'22.73"	91° 7'3.00"
	DH 03	22°49'46.39"	91° 6'36.41"
Bashurhatt Canal (BH)	BH 01	22°52'32.90"	91°16'36.98"
	BH 02	22°52'24.36"	91°16'39.13"
	BH 03	22°52'18.63"	91°16'48.70"

The zooplankton density and diversity were determined by the following (Al-Yamani et al. 2011a,b). Wetland Zooplankton Index (WZI) values are used for ranking water quality using zooplankton.

$$WZI = \frac{\sum Y_i \cdot T_i \cdot U_i}{\sum Y_i \cdot T_i}$$

Where:
Y_i : The abundance (individual/liter) of species *i*
Ti : Its tolerance (values 1-3)
Ui : Its optimum (values 1-5) (Lougheed and Chow-Fraser 2002).

Data analysis

The non-metric multidimensional scaling was carried out for these results of water quality analysis at different sites in a special comparative floristic program GRAPHS (Nowakowski 2004).

We chose the cluster analysis method to study the species similarity of the zooplankton communities of the studied lakes. The data were analyzed using the Sorensen-Chekanowski coefficient of species similarity:

$$Is = \frac{2c}{(a + b)}$$

Where:
a : Number of species in one community
b : Number of species in another community
c : Number of species common to the two communities

The limits of this coefficient are from 0 to 100%, where 100% is a complete similarity of communities (the absolute coincidence of lists), and 0% means that they have no common species.

The results are presented in a dendrogram, used to compare the taxonomic composition of plankton in different water bodies or areas of the same water body (Komulaynen 2018; Barinova and Smith 2019). The dendrogram was calculated using a special comparative floristic program GRAPHS (Nowakowski 2004).

RESULTS AND DISCUSSION

Environmental characteristics of the study canals

The two most critical polluted canals were selected from the Noakhali region for study based on their special location and vulnerability. There were three different stations in each canal. A description of the environmental state and water pollution sources in canals is presented in Table 2.

Some important parameters of the aquatic environment have been investigated. The primary producers are directly and indirectly correlated with the range of environmental variables. Temperature, water transparency, dissolved oxygen), alkalinity, free carbon dioxide, ammonium, and Total Suspended Solids (TSS) are the major physico-chemical variables determined from both two canals (Table 3).

Water transparency is one of the important aquatic parameters for phytoplankton growth. The water transparency is 14-16 cm in the Datterhat canal, which is 1.3-1.5 times lower than in the Basurhat (20-30 cm). Transparency determines the sunlight's ability to pass through the water and thus affects the phytoplankton community's prosperity. The sunlight penetration intensity at Basurhat station was higher than at the Datterhat station importation. Low water transparency values often relate to high suspended solids concentrations (Kostryukova et al. 2020). However, TSS is almost the same (2-3 mg/L) at all stations except for DH 01. It seems transparency is lower in the Datterhat Canal due to more intensive phytoplankton blooms.

A significant deficiency of dissolved oxygen (less than 2 mg/L) was observed in both canals (Figure 3). Usually, mass death of the water bodies fauna is observed with a decrease in the oxygen concentration below 2 mg/L. Such low values indicate a high pollution level with organic waste and the unsuitability of using such water for drinking. The main physical factor affecting the dissolved oxygen concentration is temperature. The water temperature in the Basurhat canal was lower than in the Datterhat; the dissolved oxygen in the Basurhat was also lower, although the oxygen solubility should increase with decreasing temperature.

This study recorded High ammonium concentrations in both canal's water (Table 3). The content of it in water is much higher than environmental standards. According to Drinking Water Directive (EU) 2020/2184 drinking water standard for ammonium is 0.5 mg/L (Directive (EU) 2020/2184 2020). Water with a high ammonium amount is unusable and hazardous to human and animal health. The increased ammonium content is most likely associated with sewage ingress from agricultural land and sewerage.

Phytoplankton and zooplankton structure

A total of 27 genera of algae belonging to 5 phyla were recorded in this study (Table 4). A large genera diversity is observed for the Basurhat canal water.

Cyanobacteria can grow and expand when Chlorophyta has bloomed and thick scum on the water surface due to eutrophication. Chlorophyta is not toxic like Cyanobacteria and Euglenophyta; more diatoms toxicities are not so notable in freshwater environments (Khan and Tisha 2020). However, green algal blooms initiate oxygen scarcity for living micro- and macroorganisms and are affected by gills or filtering organs injury and even death by clogging them (El-Kassas and Gharib 2016).

The Palmer's Algal Pollution Index is employed to assess the severity of the organic pollution; the results are given in Table 4. According to Palmer's Algal Pollution Index, values 20 and above as confirmed high organic water pollution. The algal genera such as *Oscillatoria*, *Euglena*, *Scenedesmus*, *Navicula*, and *Ankistrodesmus* are among the pollution-tolerant genera found in organically polluted aquatic bodies, according to Khan and Islam (2020). There were 10 pollution-tolerant taxa identified across all sample sites in this research, with Chlorophyta accounting for one, Cyanobacteria for two, Bacillariophyta for four, Euglenozoa for two, and Charophyta for one. Both canals had a high pollution score (25) and indicated confirmed high organic pollution.

Table 2. Results assessment of canals and their water quality state from sampling stations

Observations	**Dotterhatt Canal**	**Bashurhatt Canal**
Chemical pollutants in surface runoff	Dotterhatt was named after a local weekly market name, "Hatt." A weekly cattle market has also occurred here. And it's one of the busiest and most people-concentrated areas in Noakhali Sadar Upazila. Dotterhatt is oriented with a large portion of a residential area. Many chemical pollutants (nitrogen, phosphorus, heavy metals, etc.) enter the canal with surface runoff.	Basurhatt Pourashava was found as another busiest place in Companigonj Upazila, Noakhali. The canal across the Bashurhatt Pourashava was named as Bashurhatt Canal. The chemical pollutants end up in the canal from roads, commercial areas (e.g., local grocery and fish markets, hospitals), and agriculture fields.
Roadside pollutants	Roadside pollutants deeply hamper the canal.	The sources of silts and harmful heavy metals were construction activities and transport.
Household activities pollutants	Pollutant discharges from households were observed in residential areas.	Restaurant chore pollutants ended up in the canal.
Domestic and industrial sewage	The discharge of wastewater was observed from residential areas.	The discharge of wastewater from residences and markets was observed, besides house chore pollutants.
Organic waste, inorganic pesticides, and fertilizers	The weekly temporal cattle market built up a large amount of organic waste.	Inorganic pesticides and fertilizers were discharged from nearby agriculture fields.
Heavy metal pollution sources	No specific heavy metal pollution sources were observed. Some shops selling expired cars' iron and silver parts were identified as point heavy metal pollution sources.	Many markets, houses, and small businesses along the canal have been noted. These could pollute the water with heavy metals.
Plastic pollution sources	Local residents dumped plastics into the canal.	The specific plastic pollution sources weren't observed in the canal-associated locality but as local people dumped plastics.
Aquatic weeds	There are five groups of aquatic weeds in both channels such as floating weeds (Eichornia, Pistia, Azolla, Lenpa, etc.), marginal weeds (Colocasia, Typha, Cyperus, Marsilia, etc.), emergent weeds (Nymphae, Myriophyllum, Nelumbo, etc.), submerged weed (Hydrilla, Valisnaria, Chara, Ceretophyllum, etc.), algal weeds (Spirogyra, Microcystis, Oscillatoria, Dinoflagellates, etc.).	
Algal scum	Thick algal and probable bacterial blackish scums were observed on the canal's surface.	Algal scums were also observed in this canal's surface water but not so thick compared to the Dotterhatt canal.
Fish culture	There weren't fish culture activities.	The canal had the potential for fish culture, such as cage culture. However, there weren't fish culture activities.
Fishing strategy	During the monsoon, local people attempted to fish with traditional fishing gear. Several indigenous fish and crustaceans were found in this canal, and dominant species such as fishes *Anabas testudineus, Channa punctata, Clarias batrachus, Heteropneustes fossilis*, and crustaceans (mud crabs, freshwater prawn). Most important to notice, in early monsoon, local people cruelly sieved prawn larvae to sell.	Seasonal fishing was observed in rainy monsoons. Local people set several types of traditional fish traps across the canal. More or less similar types of indigenous fishes and crustaceans were found in this canal, like the DH canal. Moreover, no management was observed in eco-friendly fisheries.
Feeding ducks and other aquatic birds	No aquatic birds, such as ducks or other winter birds, were observed in this canal for food foraging.	Local people used the canal to feed their ducks during winter. Also, some aquatic birds, such as *Ardeidae* sp. and *Alcedinidae* sp., were observed in the canal.
Integrated agriculture	Integrated agriculture wasn't observed on the rows.	Some agricultural activities like vegetable culture were observed on the canal banks.
Off-flavor in water	The water had a bad odor, like a "rotten egg," and the entire environment was aerosolized with this bad odor, especially in the dry season.	Local people do not note severe odor except during any algal bloom.
Drinking water	Local residents did not use the water from the canal for drinking or social or ritual activities.	Local residents usually did not use the water from the canal as drinking water. However, some social or ritual programs used the water for bathing, washing, and sometimes drinking. All actions depended on the water's taste and color.
Monitoring and management	Social monitoring and management activities weren't observed in this canal. This canal was almost dead and had many garbage blockages, and the water flow was very poor.	The anthropogenic impact was less on the canal. As a result, it remained alive and flowing throughout the entire study period.

Table 3. Water quality parameters of Basurhat Canal and Datterhat Canal

Water Quality Parameters	Basurhat Canal			Datterhat Canal		
	BH 01	**BH 02**	**BH 03**	**DH 01**	**DH 02**	**DH 03**
Temperature (°C)	23.25±0.25	22.6±0.1	23.55±0.15	29.55±1.55	29.8±0.9	29.67±0.78
Water transparency (cm)	29±1	23.5±1.5	20.5±0.5	14.5±0.5	15.75±0.25	15.43±0.45
Dissolved oxygen (mg/L)	1.25±0.25	0.75±0.25	0.75±0.25	1.75±0.25	1.25±0.25	1.85±0.50
Alkalinity (mg/L)	44.95±0.45	58.76±0.26	27.73±0.49	23.1±0.4	53.96±0.5	42.65±.15
Free carbon dioxide (mg/L)	11.28±0.69	59.25±0.66	12.11±0.13	52.075±0.14	55.09±0.8	49.23±0.38
Ammonium (mg/L)	8.2±0.2	8.15±0.15	8.25±0.25	8.1±0.1	7.95±0.05	7.65±0.50
Total Suspended Solids (mg/L)	2.2±0.1	2.23±0.115	2.25±0.05	4±0.1	2.62±0.12	2.54±0.75

Table 4. Phytoplankton distribution of Basurhat Canal and Datterhat Canal and pollution index of Algal genera according to Palmer (1969)

Phytoplankton Genus	Basurhat Canal	Datterhat Canal
Chlorophyta		
Botryococcus	+	+
Chlorogonium	+	+
Chlorella	+ (3)	+ (3)
Characium	+	-
Oocystis	+	+
Sphaerocystis	+	-
Tetraedron	+	+
Ulothrix	+	-
Cyanobacteria		
Aphanocapsa	+	+
Aphanothece	+	-
Gomphosphaeria	+	-
Merismopedia	+	+
Microcystis	+ (1)	+ (1)
Oscillatoria	+ (5)	+ (5)
Bachillariophyta		
Amphora	+	+
Cyclotella	+ (1)	+ (1)
Cymatopleura	+	+
Fragilaria	+	+
Melosira	+ (1)	+ (1)
Navicula	+ (3)	+ (3)
Synedra	+ (3)	+ (3)
Euglenozoa		
Euglena	+ (5)	+ (5)
Phacus	+ (2)	+ (2)
Trachelomonas	+	-
Charophyta		
Closterium	+ (1)	+ (1)
Cosmarium	+	+
Zygnema	+	+
Total Palmer Index Value	25	25

Note: + = present,- = absent, *Closterium, Melosira, Microcystis*-1, *Phacus*-2, *Chlorella, Navicula, Synedra*-3, *Euglena, Oscillatoria*-5 (Palmer 1969)

According to the laboratory analysis, *Euglena, Oscillatoria, Navicula, Synedra, Chlorella,* and *Phacus* were the most prevalent pollution-tolerant taxa found in both canals. The most active participant in all sites was *Cyclotella*, which could be an excellent predictor of pollution tolerance; a similar observation is recorded by Venkatachalapathy and Karthikeyan (2013). Filamentous and non-nitrogen-fixing *Oscillatoria* can live in the metalimnion means the intermediate layer in any thermally graded aquatic body, where environmental conditions (light intensity, water temperature, and nutrient distribution) are not as favorable for the species' growth as in the epilimnion. Blooms of these algae are observed in eutrophic (rich in nitrogen and phosphorus) water bodies. Moreover, *Oscillatoria* can predominantly adapt to comparatively low light environments, allowing this genus to coexist with another non-nitrogen fixing surface dwelling genus, *Microcystis*. These two cyanobacteria release toxic compounds with an unpleasant odor and taste, making the water undrinkable. At the same time, harmful toxins produced by *Microcystis* and *Oscillatoria* are strongly inhibited in most phosphorus-enriched, nitrogen-limited environments.

The zooplankton has typically lagged behind the other bioindicators because it has been underutilized in biomonitoring programs. Zooplankton indicators have, however, become more developed, coordinated, and used systematically in recent years (Caroppo et al. 2013; Wasmund et al. 2016). The most convincing scientific justifications for using zooplankton as bio-monitors are their intermediary roles in the aquatic food chain, connecting primary producers with higher trophic levels, driving biogeochemical cycling, contributing to energy transfer in pelagic food webs, and ultimately affecting fish recruitment and other ecosystem services (Caroppo et al. 2013; McQuatters-Gollop et al. 2019). One of the zooplankton groups, copepods, can survive by feeding very selectively and avoiding toxic, filamentous, and comparatively large and colonial algae (Bari et al. 2021). Usually, the copepods are found coexisting with rotifers in freshwater bodies, but not so dominantly (Singh et al. 2013). Another zooplankton group, cladocerans, is the most environmentally sensitive (Mashkova et al. 2020). They are not adapting to avoid harmful algae because of their filter-feeding strategies, but some species, like Daphnia, show feeding inhibition on toxic *Microcystis* to protect themselves (Parmar et al. 2016; Bassey et al. 2019). However, they can't escape from predators and avoid harmful algae for foraging like rotifers and copepods because of their larger sizes, non-selective feedings, disability to hide quickly except for very slow diurnal migration, and very vulnerable to oxygen shortage in the water column (Jakhar 2013; Krupa et al. 2020). The accumulation of these living strategies cladocerans proves their dominant distribution in water bodies. Their sensitive living in aquatic bodies marks them as promising biological indicators of environmental instabilities; even very slight aquatic chemical changes are also noticed by their species distribution.

Table 5. Zooplankton in study canals with a specific number of Plankton per Litre (Yi), Optimum (Ui), and Tolerance (Ti) values (Lougheed and Chow-Fraser 2002)

Zooplankton Genus	Optimum (*Ui*)	Tolerance (*Ti*)	DH 01	DH 02	DH 03	BH 01	BH 02	BH 03
Rotifera (Yi = cells L^{-1})								
Lecane	5	2	0	0	291.66	453.12	265.62	447.91
Trichocerca	4	2	322.91	421.87	406.25	348.95	453.12	406.25
Notholca	3	1	406.25	0	0	276.04	0	447.91
Polyarthra	3	1	0	0	0	458.33	453.12	447.91
Cephalodella	3	1	0	0	0	453.12	338.54	411.45
Anuraepsis	3	1	348.95	411.45	421.87	406.25	453.12	437.5
Lepadella	4	2	0	406.25	0	468.75	291.66	348.95
Ascomorpha	1	1	307.29	359.37	411.45	380.20	510.41	395.83
Testudinella	4	2	0	0	0	0	338.54	0
Euchlanis	4	2	406.25	0	0	473.95	0	406.25
Mytllina	5	3	0	333.33		296.87	328.12	453.12
Platyios	4	2	0	0	354.16	0	453.12	395.83
Sub-total/Station			1791.65	1932.27	1885.39	4015.58	3885.37	4598.91
Average±Standard Error)				1869.77±23.67			4166.62±126.33	
Cladocera (Yi = cells L^{-1})								
Chydorus	4	2	0	0	0	0	296.87	0
Macrothrix	5	3	328.12	0	0	0	0	0
Sub-total/Station			328.12	0	0	0	296.87	0
Average±Standard Error				109.33±63.12			98.96±57.13	
Copepoda (Yi = cells L^{-1})								
Neodiaptomus	-	-	0	0	0	0	348.95	0
Mesocyclops	-	-	0	416.66	0	0	0	0
Heliodiaptomus	-	-	0	0	453.12	0	0	281.25
Thermocyclops	-	-	0	0	291.66	338.54	265.62	0
Sub-total/Station			416.66	744.78	338.54	614.57	281.25	416.66
Average±Standard Error				387.15±124.33			411.45±59.33	
Sub-total Zooplankton/Station (Average ± SE)			2119.79 ±23.54	2348.95 ±66.61	2338.54 ±66.21	4354.16 ±44.78	4531.25 ±43.34	4880.20 ±34.25
Total Zooplankton (Average ± SE)				2269.09±52.12			4588.54±40.79	
WZI			2.5	3.4	2.6	3.5	3.4	3.4
Water Quality				Worse than moderate			Moderate	

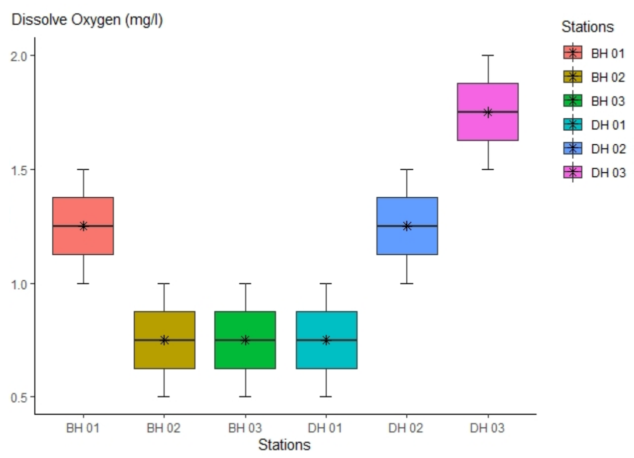

Figure 3. The boxplot shows Dissolve Oxygen (mg/L) with standard error (±SE) in different stations

Zooplankton are an excellent health indicator of any aquatic ecosystem. Three major zooplankton groups (Rotifera, Cladocera, and Copepoda) dominated both polluted canals (Table 5). The same three zooplankton groups were recorded in wild ponds in a similar study conducted in a rain-fed lake (Khan et al. 2020). Rotifera was dominated in phylum number in both water bodies. The study identified twelve different genera of Rotifera in the Basurhat Canal and nine genera in the Datterhat Canal (Table 5).

The total zooplankton abundance (4,588.54±40.79 ind/L) in the Basurhat Canal was higher than in the Datterhat Canal (2,269.09±52.12 ind/L) in the present study. The Rotifera abundance (1,869.77± 23.67 and 4,166.62± 126.33 ind/L) was found dominated followed by Copepoda (387.15± 124.33 and 411.45± 59.33 ind/L) and Cladocera (109.33±63.12 and 98.96±57.13 ind/L) in Datterhat and Basurhat canals, respectively. It has already been mentioned that the sunlight penetration intensity in Basurhat Canal was higher than in Datterhat Canal because of its high water transparency. This high-water transparency probably supports the abundance and distribution of rotifer, copepod, and cladoceran (Khan and Bari 2019) positively. Datterhat and Basurhat canals are oriented with single cladoceran species like *Chydorus* and

Microthrix. However, the single species dominating indicates the unfavorable conditions for other species of Cladocera in both canals.

Zooplankton are very sensitive to different water pollutants (microplastics, heavy metals, pesticides, oil, petroleum products, etc). The zooplankton internal apparatuses are clogged by plastic particles and cause death (Baliarsingh et al. 2010; Cole et al. 2013; Botterell et al. 2019; Islam et al. 2022). Cladocerans are more sensitive to heavy metal concentrations than rotifers and copepods (Gagneten and Pagi 2009). It is also demonstrated that cladocerans may successfully recover from their diapause egg bank during lethal heavy metal concentrations (Oskina et al. 2018). The pesticide residues affect several behavioral zooplankton characteristics, such as swimming and vertical migration. Moreover, their reproduction, egg production, and fitness of neonates are also hampered by pesticide toxicity (Hanazato 2001). An algal bloom is exerting capable allelopathic actions on zooplankton. The habitual cyanobacterial blooms produce the most infectious toxin in freshwater zooplankton, especially filter-feeder cladocerans (e.g., *Daphnia*). They are much more affected by cyanotoxins through their egg damage and unfit nauplii (Bednarska and Slusarczyk 2013). Cladocerans are very underprivileged in studied canals for such organic and inorganic pollutions.

Freshwater canals are reservoirs of endemic and indigenous aquatic plant and animal species and are a potential source of drinkable water and aquaculture opportunities for the people. Furthermore, freshwater canals are reservoirs of many filter-feeding crustaceans and shellfish like clams, oysters, mud crabs, mussels, and scallops, which feed on algae and zooplankton. The toxic algal accumulation (e.g., *Microcystis*, *Dolichospermom*, *Planktothrix*) by them causes toxin entrance into the higher food chain (Stewart et al. 2008). As a result, fishes, aquatic birds, cattle, and even human beings might suffer or be killed by absorbing and assimilating these algal toxins directly or indirectly. The euglenoid algae are found to be directly responsible for massive fish killing by their ichthyotoxin, euglenophycin (Khan and Tisha 2020).

Another unpleasant consequence of algal blooms is the aquatic off-flavor associated with their natural massive mortalities and release from hydrogen sulfate (H_2S). The H_2S production is determined by oxygen availability, as algal sulfur converts into sulfates in an aerobic environment. In contrast, algae produce H_2S, nitrogen, methane, and carbon dioxide in anaerobic conditions. Despite H_2S, other sulfur gasses are also emitted from algae like DMS (Dimethyl Sulfide) and DMDS (dimethyldisulfide) in aquatic bodies and dominate especially in a lentic ecosystem (e.g., ponds, lakes, wetlands, and sometimes in flowless canals). *Anabaena* and *Nostoc* generate more DMS and DMDS than other cyanobacterial groups. The present study found filamentous cyanobacteria as Oscillatoria, also observed in excreting DMS and DMDS. Thus, the water in Basurhat Canal and Datterhat Canal is smelly like a "rotten egg," which might be due to H_2S from dead algal cell decomposition.

The abundance ratio of different zooplankton species is shown in Figure 4. *Trichocerca, Anuraepsis, Lepadella,* and *Ascomorpha* are the most widespread species. Apparently, they are best adapted to aquatic pollution. Therefore, the presence of these unpretentious species cannot be considered a water quality indicator. As bioindicators, we can consider the species *Testudinella, Chydorus, Macrothrix, Neodiaptomus*, and *Mesocyclops* (Figure 4), found in moderately polluted water.

Moreover, by tracking zooplankton dispersion, the Wetland Zooplankton Index (WZI) was used to assess water quality (Lougheed and Chow-Fraser 2002). The WZI score was 2.83 for Datterhat Canal and about 3.4 for Basurhat Canal, indicating moderate water quality for both water bodies.

The non-metric multidimensional scaling was carried out for these results of water quality analysis at different sites. Two groups of sites can be distinguished that differ significantly in environmental conditions (Figure 5) and zooplankton biodiversity (Figure 6). The conditions of BH 01 and BH 03 sites are very similar; these sites form a cluster completely different from the cluster in which the rest are combined (Figure 5). The main indicators distinguishing BH 01 and BH 03 stations from the rest are Free carbon dioxide and alkalinity. The zooplankton biodiversity of BH 01 and BH 03 sites is also highly similar (70%) (Figure 6). This biodiversity is due precisely to Free carbon dioxide and alkalinity.

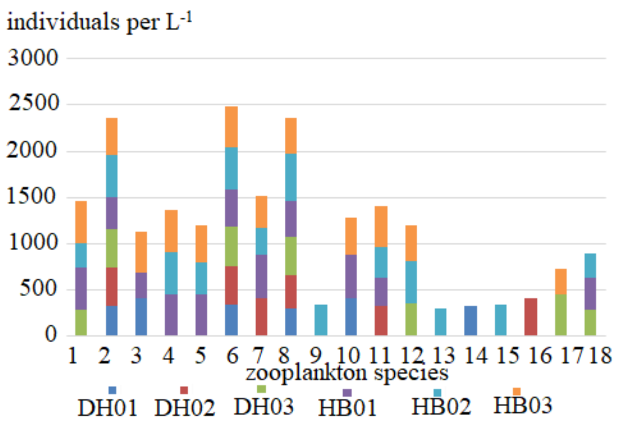

Figure 4. The abundance ratio of different zooplankton species at the studied sites: *Lecane* (1), *Trichocerca* (2), *Notholca* (3), *Polyarthra* (4), *Cephalodella* (5), *Anuraepsis* (6), *Lepadella* (7), *Ascomorpha* (8), *Testudinella* (9), *Euchlanis* (10), *Mytllina* (11), *Platyios* (12), *Chydorus* (13), *Macrothrix* (14), *Neodiaptomus* (15), *Mesocyclops* (16), *Heliodiaptomus* (17), *Thermocyclops* (18)

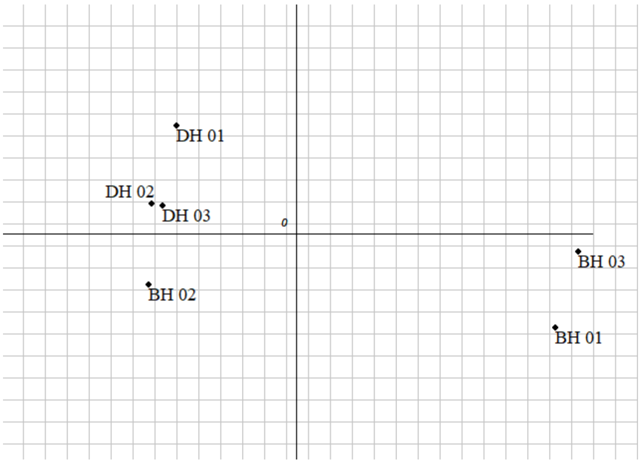

Figure 5. Non-metric multidimensional-scaling (stress = 0.01%) of sites showing two sites' groups

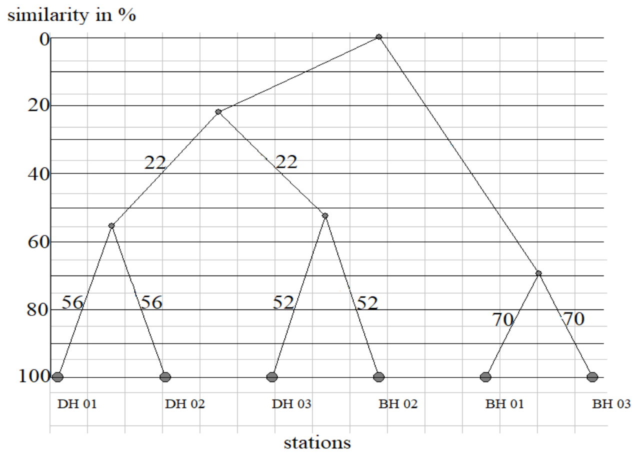

Figure 6. Dendrogram of the similarity of zooplankton composition in the studied sites (Sorensen-Czekanowski coefficient)

In conclusion, the variabilities of physico-chemical parameters, the taxonomic structure of plankton, pollution index, and pollution strategies were explored in this study's Datterhat Canal and Basurhat Canal. The study findings exhibit a decline in water quality in these urbanized canals and aquatic ecosystems, which face many long-term anthropogenic stresses. According to current studies, the tendency to decrease dissolved oxygen concentrations (i.e., hypoxia) in the canal and nutrient load from the surroundings leads to toxic algal bloom (i.e., cyanobacteria bloom). Eutrophication can deteriorate the water quality and become unsafe for social usage (e.g., drinkable water, agricultural irrigation, small-scale fisheries). Freshwater canals might be used dynamically for cage aquaculture, game fishing, recreational cruises, short-distance communication channels, transportation of groceries, and agricultural irrigation.Our study shows that the canal water in the Noakhali region is gradually deteriorating thus creating critical consequences for the future. Hence, massive actions are required to restore these canals from their shabby conditions. Besides, the encroachment on the canals must be stopped, and an excavation attempt should be carried out to recover these canals. Proper steps need to be taken by the authorities to control the dumping of waste and discharge of pollutants from industries. This study aimed to realize the present status of two ancient freshwater canals by monitoring water quality by implementing specific pollution indices. It's a preliminary approach for recommending further insight research on restoring and protecting freshwater canals.

ACKNOWLEDGMENTS

The authors greatly appreciate the scientific professionals during the analysis of plankton samples from canal water in the Coastal Plankton Laboratory, established in the Department of Oceanography, Noakhali Science and Technology University, Bangladesh.

REFERENCES

Al-Yamani FY, Skryabin V, Gubanova A, Khvorov S, Prusova I. 2011a. Marine Zooplankton Practical Guide for the Northwestern Arabian Gulf. Vol (1). 1st Edition. Kuwait Institute for Scientific Research, Kuwait.

Al-Yamani FY, Skryabin V, Gubanova A, Khvorov S, Prusova I. 2011b. Marine Zooplankton Practical Guide for the Northwestern Arabian Gulf. Vol (2). 1st edition. Kuwait Institute for Scientific Research, Kuwait.

American Public Health Association (APHA) and Water Environment Federation (WEF). 1998. Standard Methods for the Examination of Water and Wastewater. American Water Works Association and Water Environmental Federation, Washington DC.

Baliarsingh SK, Srichandan S, Padmavati T, Naik S, Sahu KC. 2010. Accumulation of heavy metals by freshwater zooplankton-A toxicological study. In: Recent Advances in Space Technology Services and Climate Change 2010 (RSTS & CC-2010). Chennai, India. DOI: 10.1109/RSTSCC.2010.5712789.

Bari JBA, Islam MS, Nisa SA, Tisha NA, Mashkova I, Khan NS. 2021. Responses of freshwater zooplankton as biological indicators to the aquatic chemical properties. Curr Environ 1 (1): 9-14. DOI: 10.54479/ce.v1i01.6659.

Barinova S, Smith T. 2019. Algae diversity and ecology during a summer assessment of water quality in the Abraham Lincoln Birthplace National Historical Park, USA. Diversity 11 (11): 206. DOI: 10.3390/d11110206.

Bassey A, Odey CO, Imeh E, Inimfon I. 2019. Ecological approach of plankton responses to water quality variables of a tropical river, Southeastern Nigeria: A bio-indicator-based community assessment of Idundu River. Asian J Fish Aquat Res 3 (1): 1-17. DOI: 10.9734/AJFAR/2019/v3i130027.

BBS. 2013. District Statistics 2011 Noakhali. December: 119. Bangladesh.

Bednarska A, Slusarczyk M. 2013. Effect of non-toxic, filamentous cyanobacteria on egg abortion in Daphnia under various thermal conditions. Hydrobiologia 715: 151-157. DOI: 10.1007/s10750-012-1424-2.

Botterell ZLR, Beaumont N, Dorrington T, Steinke M, Thompson RC, Lindeque PK. 2019. Bioavailability and effects of microplastics on marine zooplankton: A review. Environ Pollut 245: 98-110. DOI: 10.1016/j.envpol.2018.10.065.

Caroppo C, Buttino I, Camatti E, Caruso G, De Angelis R, Facca C, Giovanardi F, Lazzara L, Mangoni O. Magaletti E. 2013. State of the art and perspectives on the use of planktonic communities as indicators of environmental status in relation to the EU Marine Strategy Framework Directive. Biol Mar Mediterr 20 (1): 65-73.

Cole M, Lindeque P, Fileman E, Halsband C, Goodhead R, Moger J, Galloway TS. 2013. Microplastic ingestion by zooplankton. Environ Sci Technol 47 (12): 6646-6655. DOI: 10.1021/es400663f.

Directive (EU) 2020/2184 of the European Parliament and of the Council of 16 December 2020 on the quality of water intended for human consumption (recast) (Text with EEA relevance). OJL 435: 23.12.2020. https://eur-lex.europa.eu/eli/dir/2020/2184/oj.

El-Kassas HY, Gharib SM. 2016. Phytoplankton abundance and structure as an indicator of water quality in the drainage system of the Burullus Lagoon, southern Mediterranean coast, Egypt. Environ Monit Assess 188: 530. DOI: 10.1007/s10661-016-5525-7.

Gagneten AM, Paggi JC. 2009. Effects of heavy metal contamination (Cr, Cu, Pb, Cd) and eutrophication on zooplankton in the lower basin of the Salado River (Argentina). Water Air Soil Pollut 198: 317-334. DOI: 10.1007/s11270-008-9848-z.

Hanazato T. 2001. Pesticide effects on freshwater zooplankton: An ecological perspective. Environ Pollut 112 (1): 1-10. DOI: 10.1016/S0269-7491(00)00110-x.

Hossain B, Sohel MS, Ryakitimbo CM. 2020. Climate change induced extreme flood disaster in Bangladesh: Implications on people's livelihoods in the Char Village and their coping mechanisms. Prog Disaster Sci 6: 100079. DOI: 10.1016/j.pdisas.2020.100079.

Hossain MN, Rahman MM, Islam K. 2016. Vulnerability of agricultural production due to natural disaster at Mongla Upazila (sub district) in Bangladesh. Br J Appl Sci Technol 16 (1): 1-13. DOI: 10.9734/BJAST/2016/26007.

Islam MS, Uddin M, Jaman A, Bhowmik S, Rifa TJ, Mashkova I, Khan NS. 2022. Freshwater zooplankton in Rain-fed wild ponds: A perspective on species diversity and water quality. Curr Environ 2: 28-32. DOI: 10.54479/ce.02.2022.0106.

Jakhar P. 2013. Role of phytoplankton and zooplankton as health indicators of aquatic ecosystem: A review. Intl J Innov Res Stud 2 (12): 490-500.

Khan NS, Bari JBA 2019. The effects of Physico-chemical parameters on plankton distribution in poultry manure and artificial formulated feed treated fish ponds, Noakhali, Bangladesh. International Journal of Fisheries and Aquatic Studies 7 (5): 1-7.

Khan NS, Islam MS, Bari JBA, Tisha NA. 2020. Water quality evaluation by monitoring zooplankton distribution in wild ponds, Noakhali, Bangladesh. Nat Environ Pollut Technol 19 (4): 1767-1770. DOI: 10.46488/NEPT.2020.v19i04.050.

Khan NS, Islam S. 2019. State the organic pollution level in rain fed ponds, Noakhali, Bangladesh. Intl J Fish Aquat Stud 7 (5): 438-441.

Khan NS, Tisha NA. 2020. Freshwater algal tolerance to organic pollution : A review. Pollut Res 39 (4): 1297-1301

Komulaynen SF. 2018. Phytoperiphyton of water bodies and water courses of the State Nature Reserve «Kivach» (Republic of Karelia, Russia). Nat Conserv Res 3 (3): 46-60. DOI: 10.24189/ncr.2018.029. [Russian]

Kostryukova A, Mashkova I, Shchelkanova E, Trofimenko V, Kornilova A. 2020. Analysis of water quality of rivers and reservoirs in Chelyabinsk region, South Ural. Intl J Geomate 18 (67): 120-127 DOI: 10.21660/2020.67.9163.

Krupa E, Romanova S, Berkinbaev G, Yakovleva N, Sadvakasov E. 2020. Zooplankton as an indicator of the ecological state of protected aquatic ecosystems (Lake Borovoe, Burabay national nature park, Northern Kazakhstan). Water 12 (9): 2580. DOI: 10.3390/w12092580.

Lougheed VL, Chow-Fraser P. 2002. Development and use of zooplankton index of wetland quality in the Laurentian Great Lakes Basin. Ecol Appl 12 (2): 474-486. DOI: 10.2307/3060956.

Mashkova IV, Kostriykova AM, Shchelkanova E, Trofimenko V, Slavnaya A. 2020. Study of the zooplankton community as an indicator of the trophic status of reservoirs. Intl J Geomate 19 (73): 57-63 DOI: 10.21660/2020.73.5337a.

McQuatters-Gollop A, Atkinson A, Aubert A, Bedford J, Best M, Bresnan E, Cook K, Devlin M, Gowen R, Johns DG, Machairopoulou M, McKinney A, Mellor A, Ostle C, Scherer C, Tett P. 2019. Plankton lifeforms as a biodiversity indicator for regional-scale assessment of pelagic habitats for policy. Ecol Indic 101: 913-925. DOI: 10.1016/j.ecolind.2019.02.010.

Miah MY, Robel FN, Bhowmik S, Bhattacharjee S, Paul SC, Hossain MJ, Hossain MZ. 2015. Assessment of the coastal area water quality in Noakhali, Bangladesh. Intl J Sci Eng Res 6 (2): 1116-1123.

Nowakowski AB. 2004. Possibilities and principles of operation of the software module "Graphs". Autom Sci Res 27: 2-29. [Russian]

Oskina N, Lopatina T, Anishchenko O, Zadereev E. 2018. High resistance of resting eggs of Cladoceran Moina macrocopa to the effect of heavy metals. Bull Environ Contam Toxicol 102 (3): 335-340. DOI: 10.1007/s00128-018-2473-7.

Palanisamy B, Chui TFM. 2015. Rehabilitation of concrete canals in urban catchments using low-impact development techniques. J Hydrol 523: 309-319. DOI: 10.1016/j.jhydrol.2015.01.034.

Palmer CM. 1969. A composite rating of algae tolerating organic pollution. J Phycol 5 (1): 78-82. DOI: 10.1111/j.1529-8817.1969.tb02581.x.

Parmar TK, Rawtani D, Agrawal YK. 2016. Bioindicators: The natural indicator of environmental pollution. Front Life Sci 9 (2): 110-118. DOI: 10.1080/21553769.2016.1162753.

Poulíčková A, Duchoslav M, Dokulil M. 2004. Littoral diatom assemblages as bioindicators of lake trophic status: A case study from perialpine lakes in Austria. Eur J Phycol 39 (2): 143-152. DOI: 10.1080/0967026042000201876.

Prosun TA, Rahaman MS, Rikta SY, Rahman MA. 2018. Drinking water quality assessment from groundwater sources in Noakhali. Intl J Dev Sustain 7 (5): 1676-1687.

Singh UB, Ahluwalia AS, Sharma C, Jindal R, Thakur RK. 2013. Planktonic indicators: A promising tool for monitoring water quality (early-warning signals). Ecol Environ Conserv 19 (3): 793-800.

Stewart I, Seawright AA, Shaw GR. 2008. Cyanobacterial poisoning in livestock, wild mammals and birds-an overview. Adv Exp Med Biol 619: 613-637. DOI: 10.1007/978-0-387-75865-7_28.

Thakur RK, Jindal R, Singh UB, Ahluwalia AS. 2013. Plankton diversity and water quality assessment of three freshwater lakes of Mandi (Himachal Pradesh, India) with special reference to planktonic indicators. Environ Monit Assess 185 (10): 8355-8373. DOI: 10.1007/s10661-013-3178-3.

Uddin M, Sultana T, Nisa SA, Bari JBA, Mashkova I, Khan NS. 2022. Freshwater algal assemblages in seasonal ponds: An opportunity in coastal agriculture and aquaculture. Curr Environ 2: 22-27. DOI: DOI: 10.54479/ce.02.2022.0105.

Venkatachalapathy R, Karthikeyan P. 2013. Physical, chemical and environmental studies on the Cauvery River in parts of Tamil Nadu (Mettur and Bhavani). Univers J Environ Res Technol 3 (3): 415-422.

Wasmund N, Dutz J, Pollehne F, Siegel H, Zettler ML. 2016. Biological assessment of the Baltic Sea 2015. Meereswiss Ber 102: 10.12754. DOI: 10.12754/msr-2016-0102.

Zaman S, Hasan MK, Khanom S, Choudhury TR, Kabir MM. 2019. Assessment of water and sediment quality of Noakhali Canal, Noakhali, Bangladesh. Intl J Environ Sci Nat Resour 17 (3): 93-102. DOI: 10.19080/IJESNR.2019.17.555963.