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Applying Diversity and Pollution Biotic Indices Based on Macroinvertebrates to Assess Water Quality of the Ismailia Canal, Egypt

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ABSTRACT

The Ismailia Canal is one of Egypt's most crucial irrigation and drinking water sources. However, it suffers from many sources of pollution that can damage and impair the canal's water quality. The development and use of biotic indices represent an integrative water quality assessment technique, complementing chemical indices that facilitate the reading of environmental changes. In this study, macroinvertebrates were collected from 13 sampling sites, covering all habitats along the canal. The Biological Monitoring Working Party (BMWP-ASPT) and the Nile Biotic Pollution Index (NBPI-ASPT) were used to evaluate water quality, and diversity indices were also applied. Twenty-seven taxa belonging to three major groups—i.e., Mollusca, Annelida, and Arthropoda were identified in the Ismailia Canal. The most abundant taxon was *Bellamya unicolor*, with 37.3% of the whole community in summer and 41% in winter. The results of BMWP-ASPT and NBPI-ASPT indicated a poor class (≤ 4.9 scores) in the winter season at all canal sites. The same results were obtained in summer, except at sites M11 and M12, where the water quality was good (≥ 6). The richness index in the study area was 1, while the evenness index was closer to 1 in the Ismailia Canal, which indicated good water quality. The canonical correspondence analysis (CCA) showed that K significantly impacted the distribution of macrobenthic organisms (*P*-value = 0.03 and F-ratio = 1.75). K, BOD, and TDS established strong relations with the distribution of *Theodoxus niloticus* and *Bulinus truncates*. *Dytiscidae* larvae, *Baetis* nymph, and *Limnodrilus udekedmianus* were closely associated with COD. According to the results of BMWP-ASPT and NBPI-ASPT, it was concluded that the Ismailia Canal generally suffers from pollution and is categorized as having a bad water quality class.

INTRODUCTION

The Ismailia Canal is one of Egypt’s most incredible and crucial drinking and irrigation water resources; it was built in 1862 to provide drinking water to settlements along the Suez Canal zones and employees excavating the Suez Canal navigation route **(Geriesh *et al.*, 2004)**. Nowadays, its water is utilized for irrigation and domestic and industrial purposes, given that the canal is the primary source of drinking water for approximately 12 million Egyptian people. The Ismailia Canal suffers from several sources of pollution that can damage and impair water quality **(Girish *et al.*, 2008)**. The first source is the largest industrial zone at the beginning of the canal from Cairo to Abu Zaabal on the western side; it includes many industrial activities such as that of oil, petrol gas, iron, and steel companies in addition to Abu Zaabal fertilizer company, aluminum sulfate company, detergent industries, and power plants. The second source is water treatment plants, which have considerably changed water quality by eliminating aluminum, iron, and manganese wastewater. The leading pollution causes include community waste leakage, septic tanks near the canal road, and agricultural effluents **(Goher *et al*., 2014)**.

Macrobenthic invertebrates are essential to freshwater ecosystems and are important components of the food web **(Lu, 2005)**. Furthermore, benthic invertebrates play a crucial role in ecological processes such as dispersion and burial, pollutant metabolism, nutrient cycling, and secondary production **(Snelgrove, 1998)**. As a result, they can be used as ecological indicators to convey holistic data on ecosystem conditions and assist in improvement planning and decision-making actions. Aquatic organisms are subject to anthropogenic instabilities and natural variations in their environments, and accordingly, they react in various behaviors **(Nouri *et al*., 2008; Saghali *et al*., 2013)**.

Biotic indices for freshwater pollution monitoring were developed in Europe and later in the United States. Several groups of species, including Protozoa **(Jiang & Shen, 2003)**, benthic invertebrates **(Fishar & Williams, 2008)**, and diatoms, macrophytes, fish **(Lainé *et al*., 2014)** have been used to produce these indices. Using these groups in the biotic index makes it easier to interpret a large amount of data obtained from the biological investigation of freshwater quality **(Hellawell, 1986)**. Developing and using biotic indices is an integrative water quality assessment technique with chemical indices that facilitates reading environmental changes **(Zeybek *et al*., 2014)**. Moreover, living organisms reflect the negative influence of pollution on aquatic life as they react in diverse ways to natural fluctuations **(Roozbahani *et al*., 2010)**. Macrobenthic invertebrates appear to be the best and preferred biological indicators of the condition of aquatic ecosystems **(Mahler & Barber, 2017)**. Therefore, this study aimed to determine the accessibility of macroinvertebrates to assess water quality in the Ismailia Canal by using some diversity and biotic indices.

MATERIALS AND METHODS

1. Study area and sampling sites

The Ismailia Canal is originated from the Nile River in Cairo and extends eastward to the Ismailia Governorate, fleeting through the governorates of Cairo, Qalyubia, and Sharqia **(Stahl & Ramadan, 2008)**. It splits near Ismailia Governorate into two branches, i.e., one to the North with 90km long to feed Port Said Governorate and the other to the South with approximately 80km long to supply the Suez Governorate **(Abdo, 1998)**. Thirteen sampling sites were selected to give comprehensive geographical coverage of the Ismailia Canal during winter and summer of 2022 (Fig. 1 & Table 1).

Two sites, M1 and M2, were selected before the industrial zone, seven sites (from M3 to M9) within the industrial zone, and four sites (from M10 to M13) were chosen after the industrial zone.

Table 1. Sampling sites in the Ismailia Canal with latitudes, longitudes, and site locations

Sample code		Site location	Latitude	Longitude
Before the industrial zone	M1	El Mazalate (Mouth of Ismailia Canal)	30° 06' 628"	31° 15' 365"
	M2	Near the Al-Amiria Water Treatment Plant	30° 06' 672"	31° 16' 744"
The industrial zone	M3	Mostourd (Izbat El Rayse) (In front of Al Delta company for Iron, Electro Cable Egypt Company (ECE))	30° 07' 097"	31° 17' 165"
	M4	Downstream of Petroleum Company (Drain)	30° 08' 315"	31° 17' 398"
	M5	Upstream of Abu Za'baal Fertilizer Company	30° 16' 094"	31° 22' 043"
	M6	In front of Abu Za'baal Fertilizer Company	30° 16' 466"	31° 22' 887"
	M7	Downstream of Za'baal Fertilizer Company (Drain)	30° 16' 471"	31° 22 741"
	M8	Near Aluminum Sulfate Company (Drain)	30° 16' 843"	31° 23' 165"
	M9	Downstream of Aluminum Sulfate Company	30° 17' 050"	31° 23 443"
After the industrial zone	M10	Bilbeis	30° 24' 840"	31° 34' 225"
	M11	Al Abbas	30° 31' 984"	31° 42' 576"
	M12	El-Tal El-Kabee	30° 33' 690"	31° 47' 068"
	M13	El-Ismailia (before bifurcation)	30° 34' 057"	32° 14' 178"

2. Macroinvertebrates sampling

Macroinvertebrate samples were collected by an Ekman grab with a 250cm^2 cross-section. The samples were sieved through 0.425-mm mesh, and the remaining was fixed and preserved in 97% ethanol and transferred to the laboratory for further analysis. Organisms were stained with rose bengal and recognized to the feasible lowermost taxonomic level.

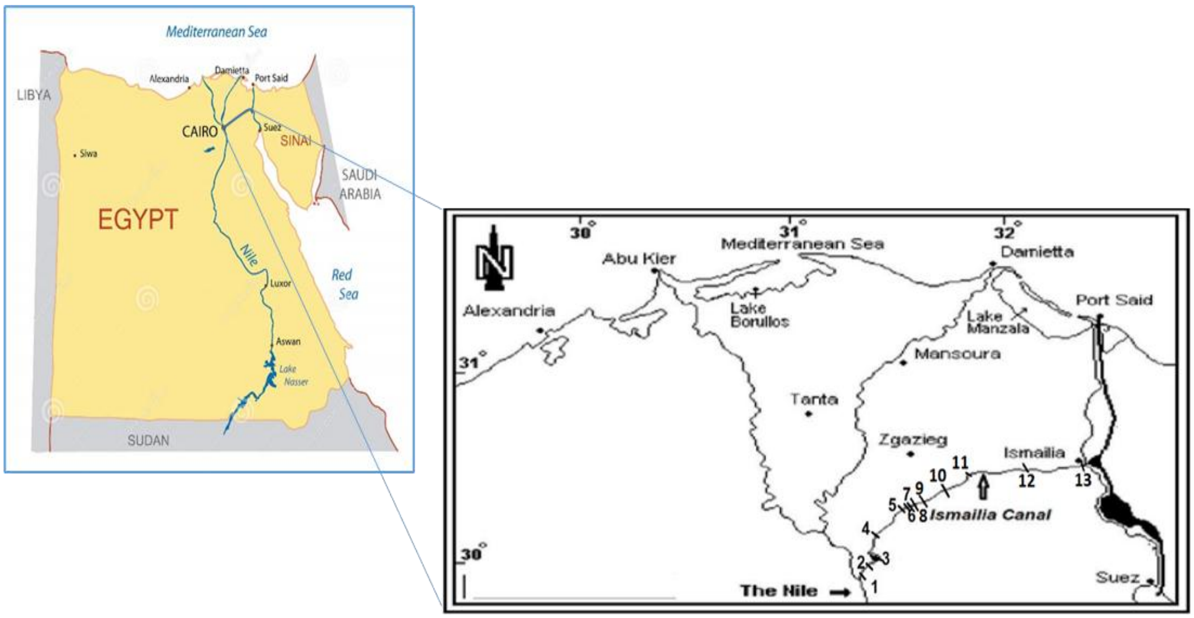

Fig. 1. A map of the Ismailia Canal showing the location of sampling sites

3. Diversity indices

The index of species richness (SR) was calculated according to the equation outlined by **Margalef (1958)**, and the diversity index (H) and evenness index (E) were also assessed, which is consistent with **Shannon and Wiener (1963)**. The Primer 5 program conducted the diversity indices.

4. Biotic indices

The biological monitoring working party (BMWP-ASPT) and the Nile biotic pollution index (NBPI-ASPT) were used to assess water quality. The BMWP and NBPI scores for families range between 1 and 10; this score reflects the family's ability to tolerate pollution and indicates the pollution level at each lake site. Families with a score 1 are tolerant of pollution, while families with a score of 10 are susceptible to corrosion. The values of BMWP and NBPI were obtained by summing the BMWP and NBPI scores of all families, respectively, that were recorded in the sample. The average of BMWP (BMWP-ASPT) and NBPI (NBPI-ASPT) was calculated by dividing the BMWP and NBPI values by the number of families **(Fishar & Williams, 2008)**. In their study, **Ochieng *et al.* (2020)** elucidated that, the values of BMWP-ASPT and NBPI-ASPT for more than 5.4 indicate excellent water quality, 5.4– 4.8 suggest good water quality, 4.7– 4.4 mean moderate water quality, 4.3– 3.7 mean bad quality (contaminated water), and less than 3.7 refer to bad quality (very contaminated water).

5. The relation between the macroinvertebrates and abiotic parameters

The canonical correspondence analysis (CCA) was conducted to find the relationship between the dominant species of macroinvertebrates and the abiotic parameters using the CANOCO 4.5 program **(Ter Braack & Smilauer, 2002)**.

The abiotic results were obtained from the Chemistry Laboratory, Freshwater Division, National Institute of Oceanography and Fisheries (NIOF), Egypt. These parameters were measured from the exact locations and time as invertebrate sampling within a project: Radioactivity sources and water quality in the Ismailia Canal: Assessment and treatment using nanotechnology and eco-friendly natural materials (2022). This project was funded by the Freshwater Division (NIOF).

RESULTS

1. Community composition of benthic macroinvertebrates

Twenty-seven taxa belonging to three main groups, Mollusca, Annelida, and Arthropoda were identified in the Ismailia Canal. The overall average of 6123ind./ m^2, with 4240ind./ m^2 in summer and 1892ind./ m^2 in winter, was collected from the Ismailia Canal. Mollusca constituted the highest density of 1523ind./ m^2 and a diversity of 11 species belonging to nine families. Arthropoda formed the second-highest density, 997ind./ m^2, and a diversity of 11 species belonging to eight families. Annelida comprised the lowest density of 546ind./ m^2 and a variety of five species belonging to three families (Table 2). The most frequent taxa were *Chironomus* larvae and *Bellamya unicolor*. The most abundant taxon was *Bellamya unicolor*, with 37.3% of the whole community in summer and 41% in winter. Among nineteen families recorded during the study, Chironomidae and Viviparidae comprised 57.3% of the macrobenthic invertebrate families. All identified families were used in the applied biotic indices, except Ampullariidae, Paludomidae, Cyrenidae, and Tabanidae since they were not listed in BMWP and NBPI indicator family scores.

2. Diversity indices

In summer, sites M7 and M9 recorded the broadest diversity of species, with 11 and 13 species, respectively. Site M1 revealed the highest density of 20,200ind./ m^2, while site M7 recorded the highest species richness (SR = 1.22) and diversity index (H' = 2.04). On the other hand, sites M8 and M10 recorded the lowest density, with 175 and 525ind./ m^2, respectively, and the lowest species number (3 species). Site M8 showed the highest evenness (E = 0.98), while site M10 had the lowest species richness (SR = 0.32). The lowest diversity index (H' = 0.3) and evenness (E = 0.22) were recorded at site M11 (Table 3).

Table 2. Community of macrobenthic invertebrates (ind./ m^2) at different sites in the Ismailia Canal

Species	Sites	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	Avg.
Mollusca	**Family**														
Theodoxus niloticus	**Neritidae**	2688	250	500	25	63	625	25	63	0	113	0	375	275	**385**
Lanistes carinatus	**Ampullariidae**	0	0	0	0	0	0	0	0	0	0	0	63	25	**7**
Bellamya unicolor	**Viviparidae**	3125	125	2188	250	25	0	50	113	2500	213	2000	1500	375	**959**
Melanoides tuberculata	**Thiaridae**	125	0	163	0	25	0	250	0	125	0	38	125	188	**80**
Cleopatra bulimoides	**Paludomidae**	0	0	88	63	0	0	0	0	0	0	63	250	63	**40**
Corbicula fluminalis	**Cyrenidae**	0	0	50	0	0	0	125	0	0	0	50	0	75	**23**
Coelatura aegyptiaca	**Unionidae**	0	0	0	0	13	0	0	0	0	0	0	25	13	**4**
Coelatura prasidens	**Unionidae**	0	0	0	0	0	0	0	0	25	25	0	0	0	**4**
Mutela rostrata	**Unionidae**	0	0	0	0	13	0	50	0	25	0	0	0	0	**7**
Bulinus truncatus	**Planorbidae**	0	0	0	0	0	63	0	25	0	38	0	25	25	**13**
lymnaea natalensis	**Lymnaeidae**	0	0	0	0	0	0	25	0	0	0	0	0	0	**2**
subtotal		**5938**	**375**	**2988**	**338**	**138**	**688**	**525**	**200**	**2675**	**388**	**2150**	**2363**	**1038**	**1523**
Annelida															
Helobdella conifera	**Glossiphoniidae**	0	0	88	0	0	0	0	0	0	25	0	313	250	**52**
Limnatis nilotica	**Hirudinidae**	0	0	25	0	0	0	0	0	0	0	63	63	0	**12**
Branchiura sowerbyi	**Naididae**	4250	875	50	188	38	0	125	38	88	250	0	0	38	**457**
Limnodrilus udekemianus	**Naididae**	0	63	0	50	25	0	0	25	0	125	0	0	0	**22**
Tubifex tubifex	**Naididae**	0	0	0	0	0	0	0	0	50	0	0	0	0	**4**
subtotal		**4250**	**938**	**163**	**238**	**63**	**0**	**125**	**63**	**138**	**400**	**63**	**375**	**288**	**546**
Arhropoda															
Chironomus pupa	**Chironomidae**	38	0	0	63	0	0	88	0	313	0	0	0	0	**38**
Chironomus larvae	**Chironomidae**	500	3250	375	125	125	375	150	250	125	188	38	88	125	**439**
Pentaneura larvae	**Chironomidae**	625	250	500	0	250	938	375	0	375	188	25	0	0	**271**
Spaniotoma larvae	**Chironomidae**	0	0	125	0	250	125	0	63	0	63	0	0	0	**48**
Coenagrionidae larvae	**Coenagrionidae**	150	125	63	0	25	88	250	0	125	25	38	125	0	**78**
Dytiscidae larvae	**Dytiscidae**	0	0	0	0	0	50	0	0	0	25	0	0	0	**6**
Baetis nymph	**Baetidae**	0	125	0	0	0	0	0	0	0	0	0	0	0	**10**
Caenis nymph	**Caenidae**	0	0	0	0	0	0	0	0	0	0	25	0	0	**2**
Oxyethira larvae	**Hydroptilidae**	0	0	0	0	38	0	500	0	250	0	0	0	0	**61**
Tabanidae larvae	**Tabanidae**	125	0	0	0	0	0	0	0	0	0	0	25	0	**12**
Caridina nilotica	**Atyidae**	125	0	88	0	0	63	0	0	0	0	63	0	88	**33**
subtotal		**1563**	**3750**	**1150**	**188**	**688**	**1638**	**1363**	**313**	**1188**	**488**	**188**	**238**	**213**	**997**
Total no.of Ind.		**11750**	**5063**	**4300**	**763**	**888**	**2325**	**2013**	**575**	**4000**	**1275**	**2400**	**2975**	**1538**	**3066**
Total no. of species		**10**	**8**	**13**	**7**	**12**	**8**	**12**	**7**	**11**	**12**	**10**	**12**	**12**	

In winter, sites M10 and M3 showed the highest diversity, with 12 and 11 species, respectively. Site M10 recorded the highest species richness (SR = 1.44) and diversity index (H' = 2.18), while site M3 manifested the highest density (4575ind./ m^2). Site M2 showed the lowest diversity (2 species), density (150ind./ m^2), species richness (SR =

0.2), and diversity index (H' = 0.64). The highest evenness (E = 0.94) was recorded at sites M11 and M5, while the lowest (E= 0.69) was at site M8 (Table 4).

Table 3. Species number, population density, species richness (SR), diversity index (H), and evenness (E) of macrobenthic invertebrates during summer in the selected sites

	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13
Species number (sp. no.)	7	6	5	3	9	6	11	3	10	3	4	4	5
Population density (Ind./m2)	20200	9000	4025	275	1525	1050	3750	175	7850	525	4000	2175	575
Species richness (SR)	0.61	0.55	0.48	0.36	1.09	0.72	1.22	0.39	1.00	0.32	0.36	0.39	0.63
Diversity index (H')	1.27	1.01	0.34	1.04	1.65	1.43	2.04	1.08	1.35	0.98	0.30	1.04	1.46
Evenness (E)	0.65	0.56	0.21	0.94	0.75	0.80	0.85	0.98	0.59	0.89	0.22	0.75	0.91

Table ٤. Species number, population density, species richness (SR), diversity index (H), and evenness (E) of macrobenthic invertebrates during the winter in the selected sites

	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13
Species number (sp. no.)	8	4	11	4	3	8	4	6	2	12	7	9	10
Population density (Ind./m2)	3300	1125	4575	1250	250	3600	275	975	150	2025	800	3775	2500
Species richness (SR)	0.86	0.43	1.19	0.42	0.36	0.85	0.53	0.73	0.20	1.44	0.90	0.97	1.15
Diversity index (H')	1.77	1.27	2.08	1.28	1.03	1.43	1.29	1.42	0.64	2.18	1.82	1.58	1.93
Evenness (E)	0.85	0.92	0.87	0.92	0.94	0.69	0.93	0.79	0.92	0.88	0.94	0.72	0.84

3. Pollution indices

3.1. BMWP and BMWP-ASPT

The results of BMWP-ASPT indicated a bad class in the winter season at all canal sites. Table (٥) shows that the highest score of BMWP-ASPT was calculated at site M13 (4.3), followed by site M3 (3.9) and site M12 (3.8), whereas the lowest score (1) was observed at site M9. In summer, the results of BMWP-ASPT indicated a very contaminated bad class along the canal sites. Nevertheless, the results of BMWP-ASPT showed good and excellent water at sites M11 and M12, with scores of 9 and 6.3, respectively, in summer.

3.2. NBPI and NBPI-ASPT

The results of NBPI-ASPT indicated a bad (contaminated water quality) to a very contaminated bad water quality class in the winter season at all canal sites. The calculated scores ranged between 4.1 at sites M13 and 1 at site M9. In summer, the highest score of 6, an indicator of good water quality, was estimated at sites M12 and M11. Furthermore, site M10 was categorized as a moderate water class, with a score of 4.7. Otherwise, the other sites ranged between 3 and 4.3 indicators of very bad and bad water quality class, as shown in Table (5).

Table 5. The applied BMWP-ASPT and NBPI-ASPT indices in the Ismailia Canal during the winter and summer of 2022

	Winter		Summer	
	BMWP/ASPT	NBPI/ASPT	BMWP/ASPT	NBPI/ASPT
M1	3.4	3.6	3.8	4.0
M2	1.5	1.5	4.2	4.2
M3	3.9	3.9	3.3	3.3
M4	3.0	3.0	3.0	3.0
M5	2.7	2.7	4.5	4.3
M6	3.7	3.9	4.2	4.3
M7	3.0	3.0	4.1	4.0
M8	3.3	3.3	4.3	4.3
M9	1.0	1.0	4.1	4.0
M10	3.6	3.6	4.7	4.7
M11	3.3	3.2	6.3	6.0
M12	3.8	3.7	9.0	6.0
M13	4.3	4.1	3.5	3.8

4. Macrobenthos relation to the physicochemical parameters of water

The canonical correspondence analysis (CCA) showed that potassium (K) significantly impacts the distribution of macrobenthic organisms (*P*-value = 0.03, F-ratio = 1.75). K, biochemical oxygen demand (BOD) and total dissolved solids (TDS) established strong relations with *Theodoxus niloticus* and *Bulinus truncates* distributions. *Dytiscidae* larvae, *Baetis* nymph, and *Limnodrilus udekedmianus* were closely associated with chemical oxygen demand (COD). The individuals of *Chironomus* pupa, *Mutela rostrate*, and *Oxyethira* larvae were exposed to a strong relationship with pH. However, *Caridina nilotica*, *tabanidae* larvae, and *Corbicula fluminalis* revealed a vibrant relationship with dissolved oxygen (DO) and carbonate (CO_3) (Fig. 2).

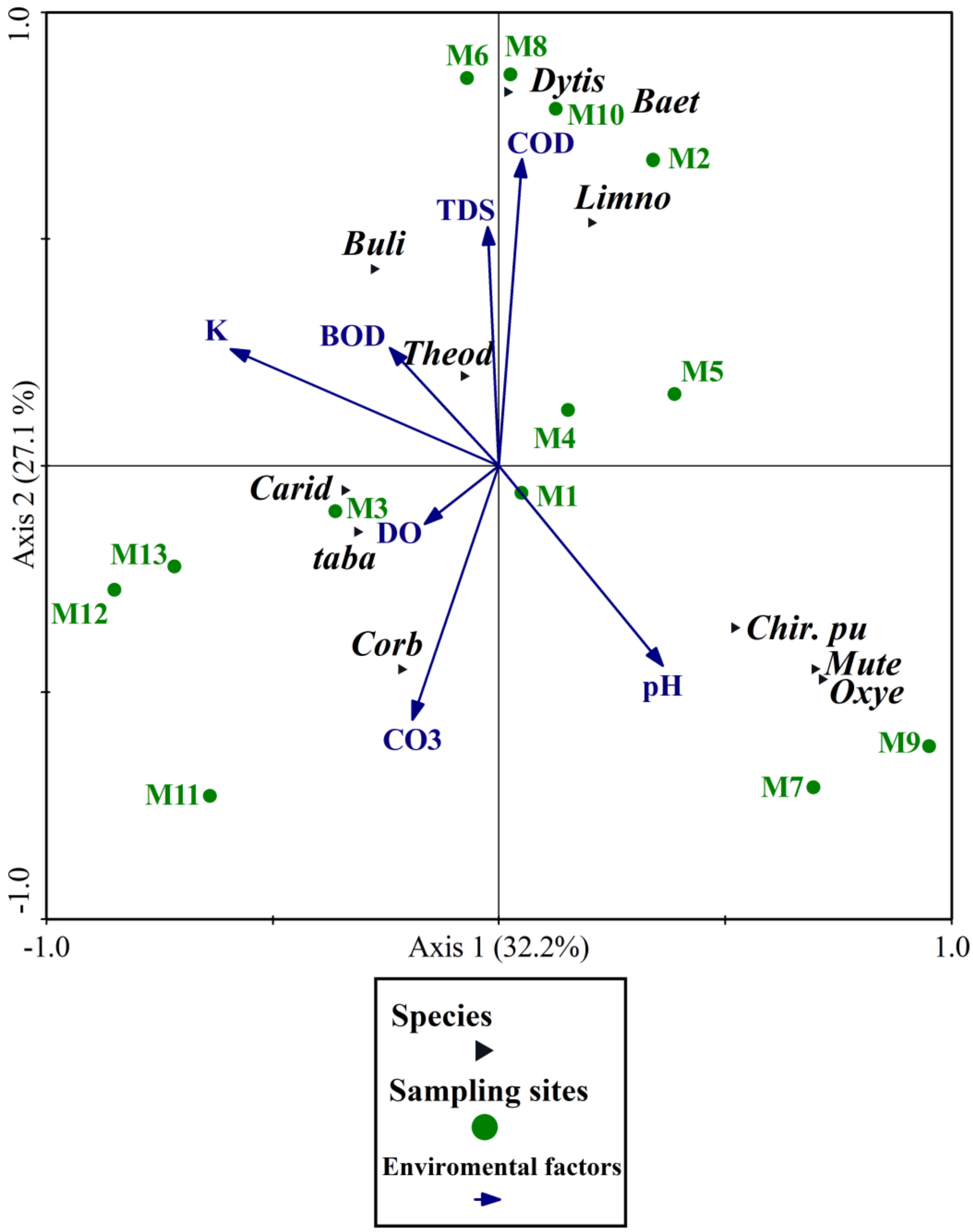

Fig. 2. Biplot of canonical correspondence analysis (CCA) showing the relationships between the dominant benthic species and environmental factors of water

DISCUSSION

Macroinvertebrates provide excellent biological water quality indicators for their relatively long lifespan, particularly sessile, and entire communities respond to environmental variations. Therefore, macroinvertebrates can specify the overall state of water quality for numerous months **(Hellawell, 1986)**. Since macroinvertebrates are bioindicators, several biotic indices have been developed to evaluate water quality. The most common macroinvertebrate bioindicators used for freshwater quality evaluation are the biological monitoring working party (BMWP, BMWP-ASPT) **(Barton & Metcalfe-Smith, 1992; Capítulo *et al.*, 2001; Czerniawska-Kusza, 2005)** in addition to the Nile biotic pollution index (NBPI; NBPI-ASPT). The latter was modified from BMWP to be more suitable for assessing the water quality of the Nile River course **(Fishar & Williams, 2008)**.

In this study, the results of both BMWP-ASPT and NBPI-ASPT indicated that water quality ranged from bad (contaminated water) to very contaminated bad water quality in the winter at all sites of the Ismailia Canal and the same at most sites in the summer. However, at sites and M12, the water quality ranged from excellent to good in the summer. Based on the results, the bad water quality at most sites of the Ismailia Canal in winter and summer can be confirmed by the high abundance of pollution indicator families such as Thiaridae, Naididae, and Chironomidae. According to **ISO (1980)** and **Fishar and Williams (2008)**, all these families have low scores (≤ 4) in the BMWP and NBPI indices. This indicates that their occurrence and abundance reflect bad water quality and high contamination.

Branchiura sowerbyi and *Limnodrilus udekemianus* were the most abundant species in the Naididae family. According to prior studies, *B. sowerbyi*, which feeds on organic waste such as sewage sludge, has shown good survival, growth, and reproduction rates in areas of high organic pollution **(Aston & Milner, 1981)**. Their flourishing at any site indicates organic pollution. Therefore, based on the results of this study, there is pollution in the Ismailia Canal. In addition, **Naqvi (1973)** tested 23 commercial insecticides on *B. sowerbyi*, collected from the Mississippi Delta region, where extreme concentrations of 15 insecticides failed to cause mortality at 72-hour exposure. This means the ability of this species to withstand and survive in difficult pollution conditions. Regarding *Limnodrilus* spp., they are known to be resistant to pollution and can live in ecosystems with poor water quality **(Yap *et al.*, 2006)**. According to **Aston (1973)**, *Limnodrilus* spp. was dominated in polluted water bodies by sewage and deficient in dissolved oxygen. This means that the high abundance of these species is an indicator of pollution. Therefore, their flourishing proves the presence of pollution in the Ismailia Canal. **Al-Shami *et al*. (2010)** also found *Chironomus* spp. with high densities in some polluted rivers in Malaysia, demonstrating that the high density of these species is considered an evidence of pollution.

On the other hand, the good to excellent water quality at sites M11 and M12 in summer can be attributed to the presence of families such as Neritidae, Viviparidae, Unionidae, Caenidae, and Atyidae in summer. They are considered indicators of good water quality. Given that their scores were high (≥ 5) in BMWP and NBPI indices, the water quality in these sites is good, with low concentrations of pollution. *Theodoxus* *niloticus* was the only species to represent the Neritidae family. The mortality rate of this species was experimentally increased with high values of metals **(Abdel Gawad, 2018)**. Therefore, this species can be used as a bioindicator of pollution with heavy metals, and the flourishing of this species means low metal contamination. *Bellamya unicolor* was recorded at an extremely low density in Lake Timsah, Egypt, an extremely polluted lake. Therefore, the high abundance of this species indicates a good water quality and a lack of pollutants **(Saad El-Din & El-HaK, 2017)**. The presence of Unionidae in an area means that pollution is low. These species are declining in the Canal due to the industrial and human activities causing an environmental pollution **(El-Assal *et al*., 2014)**. However, the presence of pollution indicator species, such as *Limnodrilus* spp. and *Chironomus* sp. at sites M11 and M12 of good water quality during summer can be attributed to the fact that these species, resistant to pollutants, can also survive in good water quality.

According to **Patra (2011)**, the water quality of the Ismailia Canal is bad and contaminated. Since the richness index is a diversity index reflecting the ecological state of a water body, it usually ranges between 1 and 5, with a higher value indicating that the water body is healthy. However, pollution increases when it tends toward 1 **(Patra, 2011)**. In this study, the values of the richness index tended to be 1, including sites M11 and M12, but these results do not completely coincide with those of BMWP-ASPT and NBPI-ASPT.

The evenness index values were closer to 1 in the Ismailia Canal, meaning a good water quality **(Herawati *et al*. 2020)**. However, the evenness results are inconsistent with those of BMWP-ASPT and NBPI-ASPT. Such a difference can be explained by the diversity indices being more concerned with species diversity and distribution. This does not necessarily give a clear reflection on water quality and pollution compared to BMWP-ASPT and NBPI-ASPT, which were mainly designed for this purpose. Furthermore, the BMWP index was applied and valid for evaluating water quality in many freshwater bodies worldwide, such as the United Kingdom, Portugal, Egypt, Turkey, Latin America, Poland, and others **(Ruiz-Picos *et al*., 2017)**. The NBPI also accurately described the Nile River's water quality and its branches in Egypt **(Fishar & Williams, 2008; El Sayed *et al*., 2020)**.

In addition, the previous studies on the physicochemical parameters are another variable taken into consideration to estimate the water quality of the Ismailia Canal. In this respect, the values of the water quality index (WQI) of the Ismailia Canal are considered poor in some areas but good in others in terms of drinking and aquatic life. Furthermore, the metal index (MI) and pollution index (PI) values indicated severe contamination at utmost sites along the canal, particularly for drinking and fisheries uses **(Goher *et al*., 2014)**. These outcomes agree with the results of the indexes used in this study.

CONCLUSION

In this study, bioindicators based on macroinvertebrates BMWP-ASPT and NBPI-ASPT were used to assess the water quality of the Ismailia Canal and its diversity indices. Based on the findings, it was evident that BMWP-ASPT and NBPI-ASPT were more accurate than diversity indices in describing the water quality class at different canal locations. Their results indicated that water quality was bad at all canals in winter and most sites in summer. Hence, it can be concluded that the Ismailia Canal generally suffers from pollution, and it is categorized as a bad water quality in general.

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