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PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

OPEN ACCESS Pakistan Journal of Biological Sciences

ISSN 1028-8880
DOI: 10.3923/pjbs.2021.383.393

Research Article
Applicability of Using Biological Indices to Assess Water Quality of the Nile Branches, Egypt

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Abstract

Background and Objective: The Saprobity index (S) and the Wetland Zooplankton Index (WZI) are the most commonly used indices using zooplankton data to assess the water quality of many water bodies. However, these indices may be inadequate to assess the water quality of all freshwater bodies around the world. This study aims to evaluate the validity of these indices for assessing the water quality of the Nile branches (Damietta and Rosetta branches) as a case study. **Materials and Methods:** The validity of S and WZI is statistically tested against the Nile Chemical Pollution Index (NCPI) using linear regression analysis. The Physico-chemical parameters, zooplankton and Discriminant Analysis (DA) data show significant differences between the Damietta and Rosetta sites. **Results:** The results of both S and WZI do not coincide with those calculated with NCPI. The obtained S values show that all sites have poor water quality. On the other hand, the WZI values indicate that the Damietta branch sites in addition to the first two sites of the Rosetta branch (R_1 and R_2) have moderate water quality, while the other sites have poor water quality. **Conclusion:** Finally, the NCPI results show that the Rosetta branch sites are heavily polluted, while the Damietta sites are clean. This study concludes that S and WZI inaccurately describe the ecological status of the study area.

Key words: Zooplankton, saprobity index, wetland zooplankton index, environmental monitoring, aquatic invertebrates, Nile chemical pollution index, River Nile, Damietta, Rosetta branches

Citation: Hegab, M.H. and N. Khalifa, 2021. Applicability of using biological indices to assess water quality of the Nile branches, Egypt. Pak. J. Biol. Sci., 24: 383-393.

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

One of the most important worldwide problems today is the scarcity of freshwater resources, which are becoming insufficient to meet human demand[1]. Furthermore, freshwater bodies are increasingly polluted as the population grows due to human activities, forming a major environmental problem[2]. Water pollution has caused environmental degradation of many water bodies, disrupting their ecosystem balance, with significant implications for human health and economy[3]. Therefore, water quality assessment is the first step toward evaluating the ecological status of any water body, to conserve or restore its ecological status[4]. Several simple techniques (environmental indices) have been established for water quality assessment. These indices summarize all water quality parameters of a certain water body in one value and classified rank[5]. These indices mainly depend on the collected chemical, physical and biological data that give a full image of the ecological status of a certain water body[6].

Biotic indices are environmental tools for the evaluation of water quality and the entire ecosystem's health. One advantage of these indices is that they reflect the impact of environmental changes on living organisms, not only the physical and chemical properties of the water. They can be implemented quickly and at a low cost, because their application does not require chemicals, equipment and expensive devices. They are useful in emergency or accidental pollution cases since living organisms are very sensitive to toxic substances and respond quickly to environmental disturbances[7]. In this field, many biotic indices have been developed that are based on diatoms, phytoplankton, fishes, microorganisms, zooplankton and macroinvertebrates.

Zooplankton is a major component of the trophic web of any aquatic ecosystem[8]. Besides, zooplankton communities are characterized by high sensitivity to environmental changes, and, therefore, zooplankton composition reflects changes affecting the entire ecosystem. Indeed, it may be affected directly or indirectly by discharges of pollutants and may be useful in monitoring the presence of toxic substances for evaluating short or long-term changes in water quality[9]. Nevertheless, few trials have been implemented using zooplankton-based biotic indices to assess the quality of aquatic ecosystems[10].

The Saprobity index (S) is the most popular index for assessing water quality in terms of zooplankton species[11]. This index depends on the relationship between zooplankton species abundance and the values of specific environmental parameters. Consequently, each species is assigned an indicator value (s). The Saprobity index (S) has been applied in many studied to assess the water quality of different water bodies[11-15]. Also, the Wetland Zooplankton Index (WZI) is very commonly used for assessing water quality and it is based on the interaction between zooplankton species and the environmental conditions. For example, it was employed for evaluating the water quality of the Laurentian Great Lake by Lougheed and Chow-Fraser[10]. This index depends on three factors (relative abundance, tolerance and optimum environmental conditions) of each grouping taxonomic unit (taxon) that are used to describe the interaction between the zooplankton taxon and the environmental factors. This index has been widely applied in different water bodies[16-20].

The River Nile has been one of the most important rivers throughout history. It runs from Ethiopia in the south to Egypt in the north[21]. It is the only freshwater resource for about 100 million Egyptians. It is divided into two branches (the Damietta and Rosetta branches) at the Barrage Delta, north of Cairo, Egypt. Damietta branch supplies four Governorates (El-Qalubia, El-Gharbyia, El-Dakahlyia and Damietta) with fresh water for all human uses[22]. The Rosetta branch flows through the El-Giza, El-Menofyia, El-Gharbia, Kafr El-Sheikh and El-Beheira Governorates[4,23,24]. While several studies employed chemical indices to evaluate the water quality of the Nile River[4,22-26], few studies used biotic indices for this purpose[4,27-29]. Furthermore, there has been no attempt to evaluate the water quality of the river using zooplankton-based biotic indices. Although S and WZI are very common and applied to assess the water quality of many freshwater bodies, they may be inadequate to assess the water quality of all freshwater bodies around the world. Thus, the present study aims to evaluate the validity of two common zooplankton indices (S and WZI) for assessing the water quality of the Nile branches (Damietta and Rosetta) as a case study.

MATERIALS AND METHODS

Sampling area and sites: Approximately 20 km north of Cairo, the Nile River splits into two branches , Damietta and Rosetta (Fig. 1). The Damietta branch is about 242 km long and it has an average width of 200 m and an average depth of 12 m. Farskour Dam cuts its freshwater flow and it flows after the dam with brackish water to meet the Mediterranean Sea north of Egypt. Contrary to the Rosetta branch, it receives low discharges of different pollutants from industrial, domestic and agricultural sources[22]. On the other side, the Rosetta branch has a length of about 225 km, an average width of 180 m and its depth ranges from 2-4 m. Its freshwater flow ends at the Idfina Barrage and thereafter it flows with brackish water to the Mediterranean Sea. The Rosetta branch and its

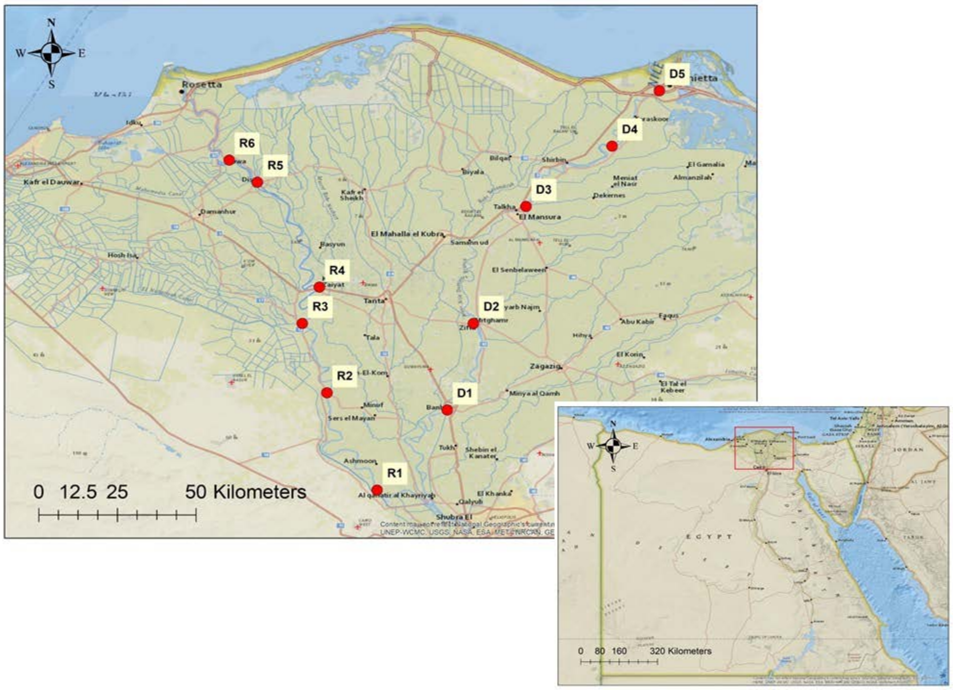

Fig. 1: Map of the two Nile branches (Damietta and Rosetta) showing the selected sampling sites
Map was created using ArcGIS 10.5 software using free base maps

extensions have received huge amounts of pollutants via several drains including the El-Rahawy Drain (a huge sewage drain), the Sabal Drain (agricultural drain), El-Tahreer (agricultural drain), Zaweit El-Bahr (agricultural drain), Tala (agricultural drain) and Kafr El-Zayat (industrial drain)[25].

Sampling for the present study was performed seasonally from the surface water of five sampling sites along the Damietta branch and six sites along the Rosetta branch (Table 1). The study was carried out at Hydrobiology Lab, Freshwater Division, National Institute of Oceanography and Fisheries, Egypt from October, 2016-September, 2017.

Measurement of abiotic parameters: Physico-chemical parameters, including water temperature, pH, Total Dissolved Solids (TDS) and Electrical Conductivity (EC) were measured in situ using a pH meter (Milwaukee, Mi-805). The transparency of the water column was determined by a Secchi disk with a diameter of 20 cm.

Nile Chemical Pollution Index (NCPI) calculation: To evaluate the water quality of the study area in terms of its chemical parameters, the Nile Chemical Pollution Index (NCPI) was calculated and the water quality was categorized according to Fishar and Williams[27] as modified from the saprobic system. The calculation of this index was based on the chemical data obtained by the chemistry lab of the Freshwater and Lakes Division, National Institute of Oceanography and Fisheries, which was published by El Sayed *et al*.[4]. The water samples used to obtain chemical parameter's measurements were collected from the same zooplankton sampling sites and at the same time as the other samples for the present study. This integrated work was included in the work program of the Freshwater and Lakes Division, National Institute of Oceanography and Fisheries, Egypt.

Nile Chemical Pollution Index depends on seven chemical parameters: Biological Oxygen Demand (BOD), Dissolved Oxygen (DO), Ammonia (NH_3), Nitrate (NO_3), Orthophosphorus (PO_4), Total Dissolved Solids (TDS) and Total Suspended Solids (TSS). Each parameter has a range of values for each pollution category. Each range of values is equivalent to a chemical pollution score (chem. score). The chemical pollution scores range from 1-10 for BOD, DO and NH_3 and from 1-5 for NO_3, PO_4, TDS and TSS, reflecting the different pollution levels as shown in Table 2. Each NCPI value equals the sum of the chemical pollution scores of the seven parameters at each sampling site. Water quality categories are listed in Table 3 according to the NCPI values, which ranged from a minimum of 16 (very clean water) to a maximum of 36-50 (grossly polluted water).

Table 1: Description of sampling sites of the study area (modified after El Sayed *et al.*[4])

Branch	Site	Coordinates	Site description and field observations
Damietta branch			
D_1	Benha City (50 Km from Nile split)	30° 27' 28.07" N 31° 10' 34.61" E	Distinguished by the presence of many clubs, restaurants, and small tourism boats on its banks
D_2	Zefta City (85 Km from Nile split)	30° 42' 53.07" N 31° 15' 04.58" E	There was no pollution source except for the presence of a river ferryboat for transport
D_3	Talkh City (145 Km from Nile split)	31° 03' 45.91" N 31° 24' 05.49" E	It lies 1 km downstream of the discharge point of the Talha electricity power station. Also, it is distinguished by the presence of a river ferryboat for transport
D_4	Serw City (187 Km El from Nile split)	31° 14' 30.31" N 31° 38' 50.41" E	There was no clear evidence on the presence of pollution except for a small number of primitive fishing boats
D_5	FarsKure City (222 Km from Nile split)	31° 24' 22.52" N 31° 46' 57.97" E	There was no clear evidence of the presence of pollution. It is distinguished by its standing water and the presence of agricultural fields on its western bank
There was no clear evidence of high-level pollution such as fish mortality, high water turbidity, or bad smell along the branch extension			
Rosetta branch			
R_1	El Qata City (16 Km from Nile split)	30° 13' 12.93" N 30° 58' 33.77" E	It lies at 6.8 km downstream of El Rahawy Drain. Water was very turbid with bad smell (ammonia smell). It is distinguished by the presence of agricultural fields on its banks
R_2	Tamalay City (66 Km from Nile split)	30° 30' 32.32" N 30° 49' 57.29" E	It lies at 50 km downstream of El Rahawy Drain. Water was turbid with a bad smell (ammonia smell). It distinguished by the presence of agricultural fields on its banks
R_3	Kom Hamada City (96 Km from Nile split)	30° 42' 52.91" N 30° 45' 44.28" E	There was a small island used as agricultural fields. There were small fishing boats. It was moderately turbid
R_4	Kafr El-Zayat City (117 Km from Nile split)	30° 49' 22.64" N 30° 48' 38.93" E	It lies at1 km downstream of Kafr El-Zyat industrial zone. It is distinguished by the presence of many clubs, fishing boats, tourism ships, and agricultural fields on its western bank
R_5	Desok City (167 Km from Nile split)	31° 08' 05.09" N 30° 38' 01.26" E	It is distinguished by the presence of many fishing boats and agricultural fields on its western bank
R_6	Fewa City (180 Km from Nile split)	31° 12' 00.67" N 30° 33' 11.18" E	It lies at 1 km upstream of Idfina barrage. It distinguished by its standing water, the presence of many clubs, and tourism boats

There was high turbidity and a bad smell especially at R_1 and R_2, in addition to high fish mortality during the winter season

Table 2: Pollution categories, chemical pollution scores, and range values of each chemical parameter of the Nile chemical pollution index (modified after Fishar and Williams[27])

Description	Chem. score	BOD (mg L^{-1})	DO (mg L^{-1})	NH_3 (mg L^{-1})	Description	Chem. score	NO_3 (mg L^{-1})	PO_4 (mg L^{-1})	TDS (mg L^{-1})	TSS (mg L^{-1})
Excellent	1	<1	>7	<0.25	Excellent	1	<0.1	<0.1	<200	<30
Very good	2	1-1.9	6-7	0.25-0.4						
Good	3	2-3.9	5-6.9	0.5-0.9	Good	5	0.1-0.4	0.1-0.4	200-299	30-49
Fair	5	4-5.9	3-4.9	1-2.4	Fair	3	0.5-0.9	0.5-0.9	300-499	50-99
Poor	7	6-9.9	1-2.9	2.5-4.9						
Very poor	9	10-15	0.1-0.9	5-10	Poor	4	1.0-1.4	1.0–2.0	500-800	100-300
Bad	10	>15	zero	>10	Bad	5	> 1.5	>2	>800	>300

BOD: Biological oxygen demand, DO: Dissolved oxygen, NH_3: Ammonia, NO_3: Nitrate, PO_4: Orthophosphorus, TDS: Total dissolved solids and TSS: Total suspended solids

Table 3: Water quality categories according the values of NCPI, S and WZI

NCPI		Saprobity index		WZI	
Categories	Value	Categories	Value	Categories	Value
Very clean	16	High	0.5	High	5
Good	16–20	Good	0.5-1.5	Good	4
Moderate	21-25	Moderate	1.6-2.5	Moderate	3
Heavily polluted	26-35	Poor	2.6-3.5	Poor	2
Grossly polluted	36-50	Bad	>3.5	Low	1

NCPI: Nile chemical pollution index, WZI: Zooplankton index

Measurement of biotic parameters: Zooplankton samples were collected seasonally by filtering 50 liters of surface water through a plankton net (20 μm). One ml of each sample in three replicates was investigated under a binocular microscope (10-100 X). The density of the zooplankton species was expressed as the number of individuals per cubic meter (Ind. m^{-3}). Zooplankton species were identified according to key references[30-34] and their densities were calculated according to the standard equation of APHA[35].

Calculation of the two biotic indices

Saprobity index (S): Saprobity index "S" was calculated using the following Eq.:

$$S = \frac{\sum(sh)}{\sum h}$$

as described by Khalifa *et al.*[20].

Where, S is the saprobic index, s is the saprobic indicator value of the zooplankton species and h is the species abundance. We used the list of Ottendorfer and Hofrat, which were taken from Dulić *et al.*[36] for the indicator values of the zooplankton species. According to the Pantle-Buck scale, h ranges from 1-5, where 1 means that only one individual was recorded in the whole sample (rare species), while 5 means that the species was recorded in high frequency (dominant species). The water quality categories based on the S values are listed in Table 3.

Wetland Zooplankton Index (WZI): WZI was calculated according to the weighted averages Eq.:

$$\text{WZI} = \frac{\sum_{i=1}^{n} \text{YiTiUi}}{\sum_{i=1}^{n} \text{YiTi}}$$

Where, Yi is the relative abundance of species i, Ti is its tolerance that ranges from 1-3 and Ui is the optimum that ranges between 1 and 5. We calculated WZI using the Ti and Ui list scores of Lougheed and Chow-Fraser[10]. The water quality categories based on the WZI values are listed in Table 3.

Statistical analysis: Discriminant Analysis (DA) was used to separate the study sites into different groups based on the chemical (seven parameters used in the calculation of NCPI) and zooplankton (abundance and diversity) data. The biotic indices (S and WZI) were statistically tested against the chemical index (NCPI) using linear regression analysis to estimate the validity of the S and WZI indices for assessing the water quality in the study area. All statistical analyses were performed with the XlStat software (version 2019).

RESULTS AND DISCUSSION

Physio-chemical parameters: The results of the physio-chemical parameters are shown in Table 4. The temperature varied in a narrow range between the sites, depending on the air temperature at the time of sampling. pH attained its lowest values (7.49 and 7.81) at R_1 and R_2, respectively. The TDS values were higher at the Rosetta branch compared to those at the Damietta branch, with the highest value (752.64 mg L^{-1}) recorded at R_1. The transparency readings were noticeably higher at the Damietta branch than at the Rosetta branch. The lowest value (40 cm) was recorded at R_1. The EC values were significantly high at the Rosetta sites with the highest value of 1176 µS cm^{-1} obtained at R_1. The DA results classified the study sites into two different groups, the first group included the Damietta sites, while the second group included the Rosetta sites. Furthermore, R_1 was different from all the other sites (Fig. 2).

The Physico-chemical parameters showed significant differences between the Rosetta sites and the Damietta sites. The Rosetta sites, especially R_1, were affected by pollution more than the Damietta sites, due to the direct discharge of several huge drains such as the El-Rahawy Drain. These findings are similar to those obtained by El Sayed *et al.*[4], Abdo[22], El Bouraie *et al.*[24], El Saadi[25], Mostafa and Peters[26].

Spatial composition and distribution of zooplankton: The zooplankton composition in the Rosetta branch sites revealed 57 species, including Rotifera (38 species), Protozoa (10), Cladocera (6) and Copepoda (3). On the other hand, zooplankton in the Damietta branch was represented by 52 species, including Rotifera (35 species), Protozoa (8 species), Cladocera (8) and Copepoda (one species). Rotifera is the dominant group in all studied sites, except R_1 and R_2, where protozoa are the dominant group. Cladocera and Copepoda are recorded rarely or in low densities in the study area (Table 5). The dominant species differs between the sites. The protozoan *Vorticella campanula* is the most dominant zooplankton species, with a seasonal average density of 40250 and 171500 Ind. m^{-3} at R_1 and R_2, respectively. The rotifer *Brachionus calyciflorus* is the dominant species at R_3, R_4, R_5 and R_6 with a seasonal average density of 48750, 164750, 384000 and 155750 Ind. m^{-3}, respectively. On the other hand, the rotifers *Keratella cochlearis*, *K. tropica* and *Polyarthera vulgaris* dominate the Damietta sites. The DA classified the study sites into two different groups based on the distribution of zooplankton species, the first group is represented by the Damietta sites and the second is represented by the Rosetta sites (Fig. 3). The dominance of the *Vorticella campanula* at R_1 and R_2 indicates heavy pollution at these sites. Although in general, the *Vorticella campanula* is an indicator species of pollution, it may occur in clean water as well but in low densities[37]. Moreover, the flourishing of *Brachionus calyciflorus* at the other Rosetta sites may indicate pollution in these sites. *Brachionus calyciflorus* is a pollution tolerant species[12,38-40]. On the other hand, the flourishing of some species (*Keratella cochlearis*, *K. tropica*, *Polyarthera vulgaris*, *Collotheca* sp., *Brachionus calyciflorus*) that are tolerant to pollution at the

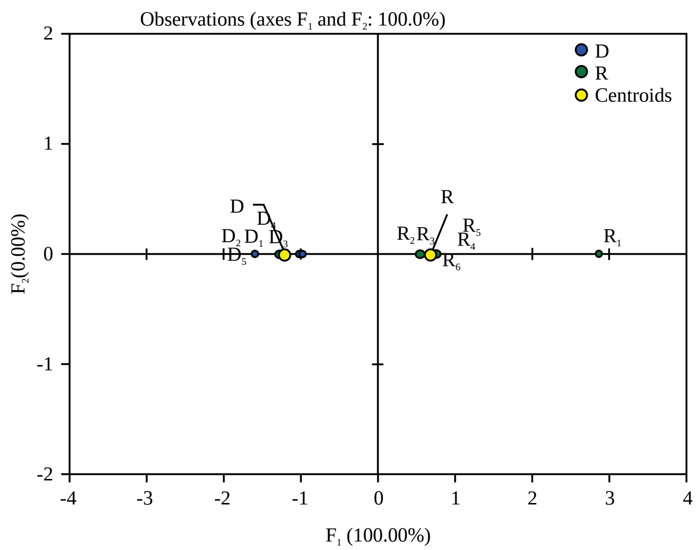

Fig. 2: Variance between the study sites according to the Discriminant Analysis (DA) based on the chemical data
D: Damietta branch sites, R: Rosetta branch sites

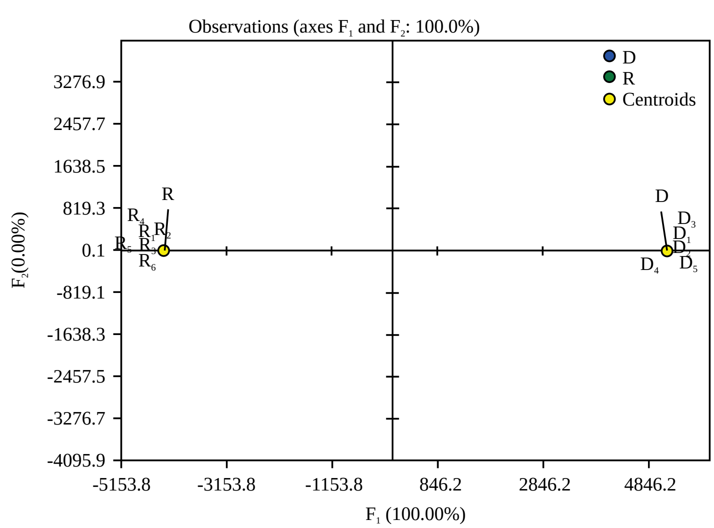

Fig. 3: Variance between the study sites according to the Discriminant Analysis (DA) based on zooplankton data
D: Damietta branch sites, R: Rosetta branch sites

Table 4: Average values of physico-chemical parameters at the different sites of the study area

Site	Temp. (°C)	pH	TDS (mg L^{-1})	Trans. (cm)	EC (µS cm^{-1})
D_1	30.20	8.54	284.16	140	444
D_2	30.80	8.36	292.48	200	457
D_3	30.70	8.24	320.64	130	501
D_4	31.40	8.20	328.96	150	514
D_5	30.80	8.30	330.24	200	516
R_1	28.00	7.49	752.64	40	1176
R_2	29.30	7.81	473.60	70	740
R_3	30.30	8.18	459.52	55	718
R_4	31.20	8.57	487.68	50	762
R_5	31.10	8.32	483.20	80	755
R_6	29.40	8.28	509.44	80	796

Trans: Transparency, TDS: Total dissolved solids and EC: Electrical conductivity

Table 5: Zooplankton composition and the seasonal average density (Ind. m^{-3}) at the different sites of the study area

Species	D_1	D_2	D_3	D_4	D_5	R_1	R_2	R_3	R_4	R_5	R_6
Sphenoderia sp.	5000	5500	0	5000	0	43500	34250	17000	500	5000	5000
Arcella vulgaris	0	1000	250	0	0	1750	1750	1000	0	0	500
A. discoid	500	250	0	0	0	0	0	0	500	500	0
Amoeba sp.	0	0	0	0	0	1250	500	0	0	0	0
Difflugia corona	750	0	500	0	0	1500	500	0	0	0	0
Centropyxis aculeata	1000	1000	500	0	0	0	500	250	500	0	500
Vorticella campanula	7750	500	0	0	250	40250	171500	9250	1500	1750	1250
Didinium nasutum	0	500	0	0	0	23250	9750	500	500	0	500
Acineta flava	0	0	0	0	0	0	1000	0	0	0	0
Paramecium sp.	0	750	250	0	0	0	250	0	2000	0	0
Total Protozoa	15000	9500	1500	5000	250	111500	220000	28000	5500	7250	7750
Percentage (%)	2.7	9.8	1.7	1.2	0.1	61.9	61.8	19.4	2.0	1.3	1.2
Keratella cochlearis	225000	26500	2000	5500	750	21500	48250	7000	7500	2500	85500
K. tropica	78250	15000	9250	5250	7500	5000	16250	3500	5000	8000	30750
Polyarthra vulgaris	29750	7000	20000	220250	83000	2500	1000	4500	16750	45250	106500
Collotheca sp.	78750	6250	3250	3000	5000	9500	5500	2000	4500	4500	50000
Conochilus unicornis	500	0	0	0	250	0	0	0	0	0	0
Brachionus calyciflorus	25250	7000	5500	69750	8000	4000	11000	48750	164750	384000	155750
B. bidentata	0	0	0	0	0	0	0	0	1000	0	0
B. angularis	14000	3000	8000	14000	38000	0	500	2500	13500	37000	72500
B. quadridentata	1000	750	500	500	0	0	1250	250	1000	1250	0
B. caudatus	10500	2000	2500	2500	2000	0	1000	0	500	9500	9000
B. patulus	0	0	0	0	0	0	500	0	0	0	500
B. falacatus	0	500	0	0	500	0	500	0	500	0	2000
B. quadricornis	0	500	0	0	0	0	0	250	0	0	0
B. urceolaris	500	0	4500	4250	10000	7000	9000	8500	16000	1500	500
B. zahniseri	0	0	0	0	0	0	0	0	0	500	0
B. budapestinensis	0	500	2500	4000	3500	0	0	0	0	11500	19500
Philodena sp.	6500	1750	1250	500	500	9750	30750	7000	19250	3500	3000
Trichocerca longiseta	2000	500	500	0	0	500	500	0	500	0	2500
T. cylindrica	0	0	0	0	500	0	0	0	0	0	0
T. porcellus	0	500	500	0	0	0	0	0	0	0	500
T. pusilla	3500	0	2000	500	0	500	500	1000	2000	500	0
Trichocerca sp.	40000	4000	7500	1000	0	0	2500	0	0	0	15000
T. elongata	0	0	0	0	0	500	0	0	0	0	0
Anuraeopsis fissa	8500	2000	1500	1500	8000	500	1000	2000	3500	1000	8000
Lecane leontina	0	0	0	0	0	0	0	0	0	0	500
L. elasma	500	0	0	0	0	0	0	0	500	0	0
L. depressa	0	0	1000	0	0	0	0	0	0	0	500
L. bulla	1000	1000	500	250	0	1000	1500	500	0	0	0
L. lunaris	500	0	0	0	0	0	0	0	0	0	0
L. closterocerca	0	0	0	0	0	0	1000	500	0	0	0
Tricotria tetractis	0	0	0	0	500	500	0	0	0	0	500
Ascomorpha ecaudis	0	0	0	750	2000	0	0	750	0	0	0
Synchaeta oblongata	0	0	500	60000	20250	0	0	0	4500	750	1250
Filinia longiseta	500	500	1000	750	20000	0	250	24500	2250	7000	1250
F. cornuta	0	0	0	0	0	0	0	0	0	250	0
F. brachiata	0	0	0	0	0	0	0	500	250	250	0
Lepadella ovalis	500	0	0	0	0	0	0	0	0	0	0
Mytilina ovalis	1000	500	0	0	0	0	0	0	500	0	0
M. mucronata	0	0	500	0	0	0	0	0	0	0	0
Hexarthra mira	0	0	500	500	500	0	0	0	0	2000	11500
Epiphanus clavulata	0	1000	1000	1000	0	0	0	500	0	12500	14500
Colurella adriatica	0	0	0	0	0	500	0	1500	0	0	0
Asplanchna girodi	500	0	0	0	6500	0	0	0	0	9000	7500
Conchloides sp.	1500	500	0	0	0	0	0	0	0	0	0
Total Rotifera	530003	81260	76252	395751	217250	63312	132812	116019	264252	542251	599001
Percentage (%)	93.7	83.8	87.9	94.7	89.5	35.2	37.3	80.6	97.1	97.1	94.1

Table 5: Continued

Species	D_1	D_2	D_3	D_4	D_5	R_1	R_2	R_3	R_4	R_5	R_6
Bosmina longirostris	10750	1750	5250	3500	250	1250	1000	0	0	0	2000
Ceriodaphnia reticulata	1500	0	0	0	1500	0	0	0	0	1000	2000
Alona affinis	500	0	250	0	0	0	0	0	0	0	0
Alona intermedia	750	500	0	0	0	0	0	0	0	0	0
Chydorus sphaericus	250	0	250	0	0	250	250	0	0	0	0
Macrothrix laticornis	1500	1000	0	500	0	0	0	0	250	1500	1500
Ilyocryptus spinifer	0	500	0	0	0	0	0	0	0	0	0
Alonella dadayi	0	0	0	0	0	250	250	0	0	0	0
Diaphanosoma mongolianum	1750	1250	750	2000	3250	750	500	0	250	0	2000
Total Cladocera	17094	5084	6588	6095	5089	2535	2037	81	597	2597	7594
Percentage (%)	3.0	5.2	7.6	1.5	2.1	1.4	0.6	0.1	0.2	0.5	1.2
Nauplius larvae	2000	1250	2000	10250	14750	250	0	0	1500	4000	16500
Copepodite of Cyclopoid	500	0	500	0	4500	500	0	0	500	2500	3000
Copepodite of Harpacticoid	0	0	0	0	0	0	500	0	0	0	0
Mesocyclops ogunnus	500	0	0	500	500	500	0	0	0	0	500
Thermocyclops neglectus	0	0	0	0	0	0	0	0	0	0	1000
Harpactus sp.	0	0	0	0	0	500	0	0	0	0	0
Total Copepoda	3003	1255	2508	10751	19752	1751	501	0	2000	6500	21001
Percentage (%)	0.5	1.3	2.9	2.6	8.1	1.0	0.1	0.0	0.7	1.2	3.3
Total zooplankton	565500	97000	86750	418000	242750	180000	355750	144000	272250	558500	636750

Damietta sites does not reflect pollution of the Damietta branch, because these species occur both in clean and in polluted water[41].

Validity of S and WZI compared to NCPI: The results of NCPI, S and WZI are shown in Table 6. We observe that the three indices produce different results. The calculated S values indicate that the sites of the two Nile branches are similar and both have poor water quality (S = 1.8-2.3). On the other hand, the WZI values indicate that the sites of the Damietta branch as well as sites R_1 and R_2 of the Rosetta branch, have moderate water quality (WZI = 3), whereas the other sites (R_3, R_4, R_5 and R_6) have poor water quality. In contrast, NCPI indicates that the sites of the Rosetta branch are heavily polluted and all Damietta sites are clean. The results of the Canadian WQI, that obtained by El- Sayed *et al.*[4] are coincide with those obtained with NCPI but not with S and WZI. Canadian WQI showed that all sites of the Damietta branch have fair (moderate) to good water quality, in contrast to the current results of S suggesting poor water quality, nevertheless, these results are nearly similar to those based on the calculated WZI (moderate water quality). Whereas the WZI values indicate that sites R_1 and R_2 have moderate water quality, the Canadian WQI indicated poor quality for these sites. Besides, El Bouraie *et al.*[24], Mostafa and Peters[26], mentioned that the water quality along the Rosetta branch is poor and that it is influenced by the direct discharge of El-Rahawy, Tala and Sabal drains. The Rosetta branch is affected by the direct discharge of domestic drainage (El-Rahawy Drain), agriculture drainage (Tala, Sabal, Tahrir and Zawyet El-Bahr drain) and industrial discharge (Kafr El-Zayat chemical company). On the other side, Abdo[22], Badr *et al.*[42] reported that the Damietta branch has moderate water quality in general, however, some of its parts are slightly polluted. Furthermore, Fishar and Williams[27] reported that the Damietta branch has moderate water quality, while the Rosetta branch is much polluted according to the results of two macroinvertebrates' indices [Biological Monitoring Working Party (BMWP) and Nile Biotic Pollution Index (NBPI)].

Based on the results presented above, S and WZI do not describe the ecological status of the Rosetta and Damietta branches accurately. This conclusion is further supported by the insignificant regression (p>0.0.795 and 0.117, r^2 = 0.008 and 0.250, respectively) between NCPI and the two biotic indices, the Saprobity index (Fig. 4a) and the Wetland Zooplankton Index (Fig. 4b). Similarly, Khalifa *et al.*[20] used S and WZI to evaluate the water quality of Lake Nasser and the study concluded that both indices were inaccurate. The same findings were recorded by Yermolaeva and Dvurechenskaya[11] in the application of S in some water bodies in Serbia. Also, Seilheimer *et al.*[17] recorded insignificant linear regression between WZI and WQI in the Laurentian Great Lakes in North America.

The inaccuracy of S and WZI for evaluating the water quality in the study area may be because such indices depend on the sensitivity of the indicator species to the environmental factors. Hence, any differences in these factors or the dominance of the species from one water body to another should lead to errors in the indicator values of the species and then errors in the calculation and the evaluation of water

Table 6: Water quality categories of the different sites of the study area according to NCPI, S and WZI values

	NCPI		S		WZI	
Site	Value	Water class	Value	Water class	Value	Water class
D_1	10	Clean	1.9	Poor	3	Moderate
D_2	10	Clean	1.9	Poor	3	Moderate
D_3	15	Clean	2.0	Poor	3	Moderate
D_4	14	Clean	2.2	Poor	3	Moderate
D_5	14	Clean	2.2	Poor	3	Moderate
R_1	30	Heavy polluted	1.8	Poor	3	Moderate
R_2	32	Heavy polluted	1.8	Poor	3	Moderate
R_3	28	Heavy polluted	1.4	Poor	2	Poor
R_4	30	Heavy polluted	2.3	Poor	2	Poor
R_5	25	Heavy polluted	2.4	Poor	2	Poor
R_6	25	Heavy polluted	2.2	Poor	3	Moderate

NCPI: Nile chemical pollution index, WZI: Zooplankton index, S: Saprobity index

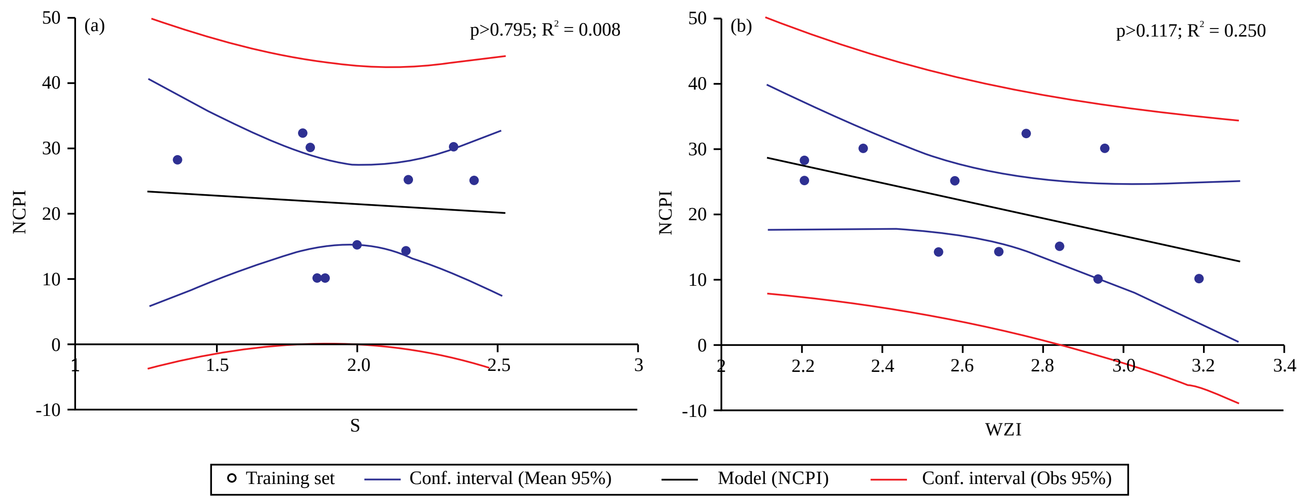

Fig. 4: Regression plots of the Saprobity index (S) and the Wetland Zooplankton Index (WZI) values against NCPI values
A: Regression between NCPI and S and B: Regression between NCPI and WZI

quality classes[11]. Furthermore, Khalifa *et al.*[20] attributed the inaccuracy of S and WZI to the differences in the ecological parameters and the dominance of the indicator species. Seilheimer *et al.*[17] attributed the weakness of WZI application in the Laurentian Great Lakes to the interaction between the zooplankton and environmental factors, vegetation and fish. The results of the present study do not provide a definitive answer to this question, it appears that the inaccuracy of such indices may be caused by other reasons such as food availability and predators (biotic factors). These biotic factors have a direct effect on the distribution and composition of zooplankton. However, this effect cannot be investigated from the calculations of the indicator values. Moreover, the Saprobity index is species-dependent and there are thousands of zooplankton species in the world's water bodies. Thus, the dominant indicator species vary from one water body to another. Therefore, our results suggest that we should aim to modify or develop indices that are specific to each zooplankton family, in a way similar to the most commonly applied biotic index (Biological Monitoring Working Party, BMWP), which is based on indicator families of macro invertebrates. The dependency on families rather than species may decrease the changes in the dominant species from one water body to another. Also, the dependency on families rather than species may decrease the misidentification of zooplankton species. Furthermore, this study suggests that pollution indicators should be specific to each zooplankton functional group instead of each taxonomic group (taxon) in WZI, similar to phytoplankton indices[43]. Species in the same zooplankton functional group have similar interaction with the environmental factors, regardless of whether or not they belong to the same taxonomic group. This study applied simple and advanced methods (chemical and biological indices) to assess the pollution of River Nile branches and its impact on the biotic components (zooplankton). The chemical index (NCPI) revealed that the Rosetta branch was much polluted. However, the biological indices (S and WZI) were not accurate in the assessment of the pollution in the study area. Therefore, the study recommends introducing some developments on the S and WZI indices to be more accurate for the description of the ecological status of the study area.

CONCLUSION

Water body degradation should be evaluated using both biotic and abiotic indices. Biotic indices reflect the direct impact of pollution on living organisms. In the present study, S and WZI inaccurately described the ecological status of the Rosetta and Damietta branches, Nile River, due to the changes in the ecological status and the dominant indicator species. Therefore, it is necessary to modify these indices based on the ecological status of the study area to improve their accuracy in water quality evaluation. Furthermore, the dependency on zooplankton functional groups instead of taxonomic groups may increase the accuracy of these indices for different water bodies.

SIGNIFICANCE STATEMENT

This study discovered that using of the biological indices, the Saprobity index and the Wetland Zooplankton Index, to assess the water quality of the River Nile branches inaccurately described its ecological status. The study will help researchers to develop different biological indices to be suitable for the freshwater Egyptian environment.

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