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Application of some biological indices to benthic macroinvertebrates related to water quality index of Lake Burullus, Egypt

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ABSTRACT

Seven chemical variables; Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Total Dissolved Solids (TDS), Ammonia (NH_3), Nitrate (NO_3^-), Orthophosphate (PO_4^{3-}) and Total Suspended Solids (TSS) were measured at twelve stations covering all area of Lake Burullus during winter and summer seasons (2018). These parameters were used to estimate Nile Chemical Pollution Index (NCPI) at each station. From the same stations, Macrobenthic invertebrates were collected, sorted, identified and counted. Twenty-three families were recorded during this study, seven of them are bioindicatory families: Viviparidae, Planorbidae, Thiaridae, Physidae, Neritidae Tubificidae and Chironomidae. Biological Monitoring Working Party (BMWP) and Biological Monitoring Working Party Average Score Per Taxon BMWP-ASPT) were applied to biological data. Regression values between the chemical index and BMWP, BMWP-ASPT indices showed nonsignificant values (P value more than 0.05) during winter and summer. BMWP and BMWP-ASPT indices were not similar with chemical indices. It was concluded that these indices can not used to assess water quality of Lake Burullus,so BMWP and BMWP-ASPT need more developments according to bioindicators organisms of Lake Burullus and its nature.

INTRODUCTION

Lake Burullus is one of the most significant coastline lagoons in the Mediterranean basin. It is the second largest lake of the northern Egyptian lakes. It lies in the Nile Delta, between Longitude 30° 30-E and 31° 10-E and latitude 31° 21-N and 31° 35-N. The lake is separated from the Mediterranean Sea by a narrow sandbar. The area of Burullus Lake is about 420 km^2 of which 370 km^2 is open water (Younes, 2012). On the other side, the lake area was 588 km^2 in 1956 while it was 462 km^2 in 1974 and this reduction is owing to projects of reclamation along the eastern and southern sides of the lake and processes of fish farming (Younes, 2012). Lake Burullus is linked to the sea through the Burullus inlet (width 250 m and depth 5 m) at its northeastern edge. The lake is very shallow, with a depth ranged from 40 cm and 200 cm (El-Zeiny & El-Kafrawy, 2017). Eight drains (Burullus, El Gharbia, Nasser, Baltim, and drains 7, 8, 9, and 11) and only one canal (Brimbal Canal) discharge agricultural drainage water into the lake (El Baz, 2015). Domestic wastes, industrial and agricultural discharges have increased the pollutants in the lake. The increasing pollution of water resources in Lake Burullus makes the lake under severe environmental stress and the consequent effects on aquatic environment and human health is an issue of great concern (Al- Afify *et al*., 2019).

According to the European Union Water Framework Directive (EU WFD), the abundance and composition of benthic invertebrate constitute one of the quality elements for the classification of the ecological status of rivers. Physico-chemical conditions of water support the biological data. However, because Member States establish monitoring system for determining the values of the biological elements. According to the requirements of the Water Framework Directive, macroinvertebrate groups are largely used for evaluating quality of water (Zeybek *et al*., 2014, Lewin *et al*., 2013, Fishar *et al*., 2015, Abdel Gawad, 2019). Benthic macroinvertebrates reflect types of stream degradation as anthropogenic perturbation, acidification, organic pollution and etc (Mykra *et al*., 2012). The biological indices are commonly recommended and appear to be a valuable tool in observing macroinvertebrate response to both reference conditions and anthropogenic disturbances in rivers throughout the European ecoregions (Sporka *et al.*, 2009, Torrisi *et al.*, 2010).

Benthic fauna composition has mainly been considered as a good indicator of water quality (Abubakar and Yakasai, 2015). Their composition, abundance and distribution pattern act as an ecosystem index, thus indicating trophic construction, water quality (Mehdi *et al*., 2005). Benthic invertebrates cannot avoid Pollution because they are limited in their movement or sessile on the sediment so they have been favoured in monitoring of environmental effects (Gaufin, 1973).

The aim of this work is to evaluate biological assessment of Lake Burullus using BMWP and BMWP-ASPT indices based on the macrobenthic invertebrate communities diversity and the BMWP, BMWP-ASPT were compared with the chemical index at each sampling site to show how these indices reflect chemical water quality.

MATERIALS AND METHODS

Sampling

Water samples and bottom fauna were collected from twelve sites at Lake Burullus during winter (February, 2018) and summer (August, 2018). The locations and names of sampling sites represented in Table (1) and Fig. (1). Samples of bottom fauna were taken using Ekman Grab Bottom Sampler (area 625 cm^2). The samples were washed to remove any adhering mud or sediments in a sieve with screen of 500 micro meter mesh size.

Table 1: Location and feature of sampling sites.

Stations	Features of stations
1	In front of mouth of the East Bank of Burullus Lake
2	In front of Boughaz El-Burullus
3	Al-Bolaq
4	In front of the bank mouth 7
5	Al-Zanka (middle of Lake; farthest from pollution sources)
6	Al-Taweelah (middle of Lake; north of bank mouth 8 and 9)
7	Al-Shakhlawya (middle of Lake; Banking Est. 8 and 9)
8	Mastrou (North of the Lake)
9	Abu Amer (Northwest of the Lake)
10	Al-Perka (middle of Western Sector of the Lake)
11	Al-Hoksa (in front of bank mouth 11)
12	In front of mouth of Brimbal Canal (mouth of Nile River (Rosetta Branch) in the Lake)

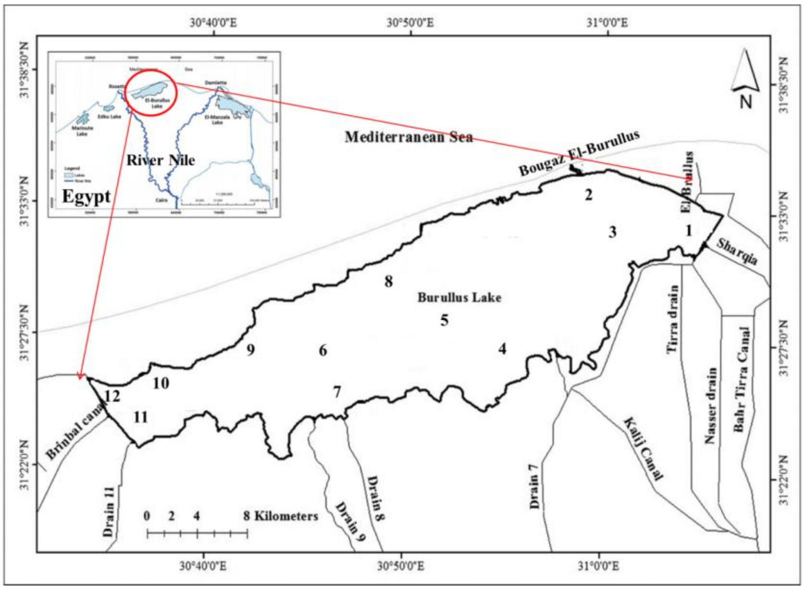

Fig. 1: A map of Lake Burullus showing sampling stations.

The samples were kept in plastic jars with 7% formalin solution. In the laboratory, the samples were examined and identified to its genera or species level by using a dissecting binocular microscope.

Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Nitrate (NO_3^-), Ammonia (NH_3), Orthophosphate (PO_4^{3-}), Total Dissolved Solids (TDS), Total Suspended Solids (TSS) for each station were measured according to APHA (2005), in Chemistry Lab at National Institute of Oceanography and Fisheries-El-Qanater El-Khairia.

Analysis of data

Pollution significance was assigned to a selection of chemical parameters to adapt Chemical Pollution Index depending on the Nile Chemical Pollution Index (NCPI). Score of NCPI determined the pollution of lake water by given a distinct number for each selected chemical parameters for each station. There are two score types, primary significance was given to DO, NH_3 and BOD each has a maximum score in the index of (10), where 1 was equated with clean water and 10 with gross pollution. Secondary status was given to NO_3^-, PO_4^{3-}, TSS and TDS with a maximum index of (5) indicating highly significant inputs and one to clean water. Table (2) A and B show the value for each score for the previous chemical parameters. The scoring groups have been selected on the basis of known levels in grossly polluted and clean sites from the literature (Armitage *et al*., 1983; Fishar and Williams, 2008 and Fishar *et al*., 2015). The NCPI scoring system means that a grossly polluted station could theoretically have a score of 50 and a pristine (very clean) stations a score of 7. Sites with scoring 36–50 will be as gross pollution, 26–35 heavy pollution, 21–25 moderate pollution, 16–20 slight pollution, less than 15 clean.

Biological data were analyzed using Biological Monitoring Working Party (BMWP) established in the United Kingdom in 1976 (Chester, 1980) to develop a biotic system to evaluate the quality of rivers and canals. Invertebrate families should be owed a score from 1 to 10 on the basis of their tolerances to pollution and the highest tolerant families are given the lowest scores. For each station, BMWP families scores was calculated by summation scores of all families according to BMWP scoring system and BMWP-ASPT was calculated by division the BMWP to the number families**.** As the score increased the better the quality of water increased.

Classes of water quality according to BMWP indices were: more than 8 high water quality, 6-8 good, 5-5.9 moderate, 3.5-4.9 poor, less than 3.5 bad.

Table 2: Groups for the Nile Chemical Pollution Index
A) Ammonia (NH_3), Dissolved Oxygen (DO) and Biological Oxygen Demand (BOD).

	Index	NH_3 (mg/l)	DO (mg/l)	BOD (mg/l)
Excellent	1	0 < 0.25	+7	0 < 1
Very Good	2	0.25 < 0.5	6 < 7	1 < 2
Good	3	0.5 < 1	5 < 6	2 < 4
Fair	5	1 < 2.5	3 < 5	4 < 6
Poor	7	2.5 < 5	1 < 3	6 < 10
Very Poor	9	5 < 10	0 < 1	10 < 15
Bad	10	10+	0	15+

B) Total Orthophosphate (Orth-PO_4^{3-}), Nitrate (NO_3^-), Total Suspended Solids (TSS) and Total Dissolved Solids (TDS).

Description	Index	O-PO_4^{---}(mg/l)	NO_3^- (mg/l)	TSS (mg/l)	TDS (mg/l)
Excellent	1	< 0.1 0	0 < 0.1	0 < 30	0 < 200
Good	2	0.1 < 0.5	0.1 < 0.5	30 < 50	200 < 300
Fair	3	0.5 < 1.0	0.5 < 1.0	50 < 100	300 < 500
Poor	4	1.0 < 2.0	1.0 < 1.5	100 < 300	500 < 800
Bad	5	2.0+	1.5+	300+	800+

RESULTS AND DISCUSSION

Chemical characteristic

Table (3) shows results of chemical parameters in the area under investigation during winter and summer (2018). The highest values of ammonia were recorded during winter being 7.01 and 6.68 mg/l at station 7 and station 11 respectively and 6.75 mg/l at station 11 during summer. The lowest values 1.3 and 1.4 mg/l were measured at station 3 during winter and station 4 during summer respectively. The highest nitrate value was observed during winter being 0.84 at station10 and 0.25 mg/l during summer at station 12 while the lowest value of nitrate (0.04 mg/l) were recorded at station 9 during winter and station 5 during summer. Ortho-phosphate recorded the highest values at station 7 being 1.51 mg/l during winter and at station 11 being o.86 mg/l during summer while the lowest value was detected at station 10 during summer. The highest values of Dissolved Oxygen (DO) were recorded at station 9 during winter being 10 mg/l and station 10 during summer being 15.2 mg/l while the lowest recorded at station 3 being 2.9 and 4.28 mg/l during winter and summer respectively. Biological Oxygen Demand (BOD) recorded the highest values (9.58 and 14.96 mg/l) at station 10 during winter and summer respectively, while the lowest values (2.30 and 3.96 mg/l) were recorded at station 3 in winter and summer, respectively. Station 2 recorded the highest values of Total Dissolved Solids during winter and summer (20130 and 17260 mg/l respectively), where station 11 has the lowest TDS values 1012 and 1131mg/l during winter and summer respectively. Station 2 showed the highest values of Total Suspended Solids (TSS) during two seasons while station 6 and station 8 showed the lowest (TSS) during winter and summer seasons respectively. The previous results representing that the highest values of all measured physico-chemical parameters except Dissolved Oxygen were recorded at stations receiving different pollutants via drains and the lowest values were recorded at far stations from these drains (Abu El-Gheit *et al*., 2012)..

Table 3: Some chemical parameters of Lake Burullus during winter and summer 2018.

	NH_3 (mg/l)		NO_3^- (mg/l)		PO_4^{3-} (mg/l)		DO (mg/l)		BOD (mg/l)		TDS (mg/l)		TSS (mg/l)	
	W	S	W	S	W	S	W	S	W	S	W	S	W	S
1	1.80	0.17	0.32	0.21	0.25	0.40	5.1	5.64	4.70	4.20	3321.00	2800.00	1599.00	702.00
2	0.23	0.22	0.08	0.05	0.13	0.23	7.1	6.32	6.60	5.96	20130.00	17260.00	10014.00	9702.00
3	0.13	0.16	0.05	0.07	0.12	0.19	2.9	4.28	2.30	3.96	16540.00	14370.00	6948.00	5466.00
4	0.40	0.14	0.19	0.05	0.20	0.21	5.9	5.96	5.60	5.72	10240.00	11580.00	3540.00	3946.00
5	0.22	0.23	0.08	0.04	0.18	0.30	5.6	4.80	4.60	4.60	9190.00	7190.00	4654.00	7212.00
6	0.16	0.29	0.11	0.07	0.17	0.47	8.5	10.00	7.86	9.68	3120.00	4380.00	220.00	490.00
7	7.01	1.58	0.17	0.18	1.51	0.68	4.5	6.60	4.38	6.36	2020.00	2430.00	248.00	290.00
8	0.50	0.26	0.07	0.05	0.15	0.16	9.4	11.40	9.30	11.20	3420.00	3680.00	420.00	180.00
9	0.16	0.48	0.04	0.17	0.15	0.07	10	12.80	8.04	12.60	3450.00	1327.00	1046.00	629.00
10	3.36	0.29	0.84	0.05	0.79	0.06	9.7	15.20	9.58	14.96	3640.00	1334.00	740.00	728.00
11	6.68	6.75	0.24	0.20	0.85	0.86	8.2	8	8.10	8.20	1012.00	1131.00	752.00	719.00
12	0.63	0.65	0.23	0.25	0.23	0.25	8	8.25	7.90	8.00	4230.00	4350.00	826.00	630.00

W: winter, S: summer, DO: Dissolved Oxygen, BOD: Biological Oxygen Demand, TDS: Total Dissolved Solids, NH_3: Ammonia, $NO3^-$: Nitrate, $PO4^{3-}$: Orthophosphate, TSS: Total Suspended Solids.

Benthic Community

This study declared that the benthic macrofauna at Lake Burullus, it contained twenty seven species belonging to twenty three families within eight classes and three phyla; Mollusca, Annelida and Arthropoda. Mollusca recorded the highest number of species (19 species) while Annelida and Arthropoda recoded 4 species for each. At all the studied stations, station 10 recorded the highest species number (10 species) during winter while station 6 recorded the highest one (13 species) during summer. The lowest species number was observed at station 1 when 2 species only were found during winter and summer (Tables 4 & 5). Some of the recorded families are bioindicatory families as Viviparidae, Planorbidae, Thiaridae, Physidae, Neritidae, Tubificidae and Chironomidae which used in the applied biotic indices.

Table 4: Macrobenthic invertebrates at Lake Burullus during winter, 2018.

families	Species recorded	1	2	3	4	5	6	7	8	9	10	11	12
Mollusca													
Viviparidae	*Bellamya unicolor*						+		+				
Planorbidae	*Biomphlaria alexandrina*			+	+	+					+	+	+
	Bulinus truncates												
	Gyraulus sp.												
Hydrobiidae	*Hydrobia ventrosa*												
Bithyniidae	*Gabbiella senaariensis*										+	+	
Ampullariidae	*Lanistes carinatus*												+
Thiaridae	*Melanoides tuberculata*	+	+	+	+	+	+	+	+		+	+	+
	Cleopatra bulimoides												
Physidae	*Physa acuta*				+		+					+	
Succineidae	*Succineac leopatra*						+						
Potamididae	*Pirenella conica*				+								
Neritidae	*Theodoxus niloticus*				+		+	+			+	+	
Valvatidae	*Valvata nilotica*				+								
Cardiidae	*Cerastoderma glaucum*		+	+	+	+				+		+	
Semelidae	*Abra ovata*				+		+						
Tellinidae	*Macoma* sp.												
Corbiculidae	*Corbicula fluminalis*					+			+				
	Corbicula consobrina												
Annelida													
Naididae	*Chaetogaster lamnaei*	+				+					+		
Tubificidae	*Limnodrilus udekemianus*		+			+	+	+	+	+	+	+	
	Limnodrilus hoffmeisteri												
Nereididae	*Neris diversicolor*		+	+							+		
Arthropoda													
Balanidae	*Balanus amphitrite*		+	+									
Corophiidae	*Corophium volutator*			+		+			+	+	+		
Gammariidae	*Gammarus lacustrus*		+										
Ostracoda						+		+		+	+		+
Chironomidae	Chironomidae larvae		+			+	+		+		+		
Number of families		2	7	6	8	9	8	4	6	4	10	7	4

Table 5: Macrobenthic invertebrates at Lake Burullus during summer, 2018.

fmilies	Species recorded	1	2	3	4	5	6	7	8	9	10	11	12
Mollusca													
Viviparidae	*Bellamya unicolor*						+		+	+	+		
Planorbidae	*Biomphlaria alexandrina*			+	+	+	+	+	+	+	+	+	+
	Bulinus truncates												
	Gyraulus sp.												
Hydrobiidae	*Hydrobia ventrosa*	+											
Bithyniidae	*Gabbiella senaariensis*							+				+	
Ampullariidae	*Lanistescarinatus*												
Thiaridae	*Melanoides tuberculata*	+	+	+	+	+	+	+	+	+	+	+	+
	Cleopatra bulimoides												
Physidae	*Physa acuta*						+	+			+		
Succineidae	*Succinea cleopatra*												
Potamididae	*Pirenella conica*								+				+
Neritidae	*Theodoxus niloticus*			+				+	+				
Valvatidae	*Valvata nilotica*									+			
Cardiidae	*Cerastoderma glaucum*		+	+	+		+	+		+		+	
Semelidae	*Abra ovata*				+	+	+	+					
Tellinidae	*Macoma* sp.						+	+			+		
Corbiculidae	*Corbicula fluminalis*					+	+		+				
	Corbicula consobrina												
Annelida													
Naididae	*Chaetogaster lamnaei*		+										
Tubificidae	*Limnodrilus udekemianus*				+	+	+		+			+	
	Limnodrilus hoffmeisteri												
Nereididae	*Nerisdiversi color*		+	+	+			+					
Arthropoda													
Balanidae	*Balanus amphitrite*		+	+					+				
Corophiidae	*Corophium volutator*		+	+	+		+		+				
Gammariidae	*Gammarus lacustrus*						+						
Ostracoda							+	+	+		+		+
Chironomidae	Chironomidae larvae		+		+	+	+	+	+		+		
Number of families		2	7	7	8	6	13	11	11	5	7	5	4

Common species

Limnodrilus spp.were the most abundant annelid in the area this agree with Khalil *et al*. (2004). They are good bioindicator of polluted area since they are abundant in the poor water quality because of their resistance and tolerance to pollution (Yap *et al*., 2006). *Corophium vulutator* was the most dominant arthropod. It was found in eastern and middle sectors where the bottom is sandy silt and this bottom is devoid of hydrophytes. This agrees with Aboul-Ezz (1984) who stated that *Corophium vulutator* was abundant in bare area and browses on detritus. The maximum abundance of this species was found in winter when the temperature ranged between 17 and 23^{0}C. This species can live optimum in range of 19.2^{o}C to 24^{o}C so its appearance in summer was poor (few density) due to high temperature during this season when the temperature reached 34^{o}C. Meadows and Ruagh (1981) stated that this animal is found in a wide range of salinity and wide range of temperature but prefers temperature around 25^{o}C. *Melanoides tuberculata* was the most abundant mollusc and widely distributed in Lake Burullus during this study, this result observed by Aboul-Ezz (1984) and Khalil *et al*. (2004) at the same lake. It appeared in the whole Lake during winter and summer.

Indices

Three indices; Nile Chemical Pollution Index (NCPI), (BMWP) and (BMWP-ASPT) were shown in table 6. NCPI reflects the chemical quality of water in the Lake according to the data from some parameters e.g. Dissolved Oxygen, Total Dissolved Solids, Total Suspended Solids, Biological Oxygen Demand, Ammonia, Nitrate and Phosphate.

Lake Burullus has been contaminated by trace elements mainly from industrial waste and by agricultural effluent. In recent years, wastewaters are being directly released into the Lake via drains without treatment. Furthermore, the increase of petro-refineries and fertilizer industries are noted, representing sources of pollution (Ameen *et al*., 2013 & El Baz, 2015). During winter NCPI was applied on the Lake stations to find that the highest scores (34, 32, 31 and 27) were calculated at stations 7 &11, 10 and 1 respectively indicating heavy polluted stations. Scores of stations 2, 3, 4, 5, 6, 8, 9, and 12 ranged from 22 to 25 indicating moderate pollution. During summer, stations 11 and 7 have the highest NCPI score 32 and 28 respectively indicating heavy pollution while the remaining stations scores ranged from 25 to 21 indicating moderate pollution (Table 6).

This means that pollution level of Lake Burullus ranged from heavy to moderate pollution during winter and summer. The southern and eastern parts of the Lake receive agriculture and sewage drainage water from eight drains and one brackish water canal (Nafea and Zyada, 2015). The present study showed that, the average values of NCPI reached 26 during winter and 24.4 during summer in the whole area of investigation**.**

Table 6: The applied NCPI, BMWP, BMWP-ASPT indices at Lake Burullus during the period of study.

	Winter				Summer			
Stations	NCPI	No of family	BMWP	BMWP-ASPT	NCPI	No of family	BMWP	BMWP-ASPT
1	27	2	7	3.5	23.0	2	12	6.0
2	22	7	30	4.3	21.0	7	30	4.3
3	24	6	30	5.0	22.0	7	36	5.1
4	24	8	30	3.7	22.0	8	30	3.8
5	22	9	31	3.4	24.0	6	18	3.1
6	22	8	30	3.7	23.0	13	51	3.9
7	34	4	19	4.8	28.0	11	47	4.3
8	24	6	24	4.0	24.0	11	51	4.6
9	22	4	16	4.0	25.0	5	21	4.2
10	31	10	43	4.3	24.0	7	29	4.1
11	32	7	28	4.0	32.0	5	19	3.8
12	25	4	18	4.5	25.0	4	21	5.3
average	25.8		25.5	4.1	24.4		30. 4	4.4

The application of the BMWP to the data of Burullus Lake

During winter, the results showed that the highest values of BMWP-ASPT were recorded at station 3 (score5 moderate pollution) and the remaining stations score less than 4.9. This means that this biological index (BMWP-ASPT) less than five (poor and bad pollution level) and this reflects the pollution state of the lake.

During summer, the highest score was calculated at station 1 (score 6) good water quality while stations 3 and 12 have score5.1 and 5.25 respectively indicating moderate pollution. Stations 2, 4, 5, 6, 7, 8, 9, 10, 11 have score ranged from 4.6 to 3.1 (Table 6) indicating poor and bad water quality. The influence of pollution is observed along the whole lake.

The Lake receives about four thousand million m^3 of drainage water annually from agricultural lands of the Nile Delta (El-Shinnawy, 2002), which accounts for 97% of the water entry (Eid, 2012; Eid *et al*., 2012). Macrobenthic fauna affected by contaminants which accumulate in the sediment, exposure to low dissolved oxygen that often occur near the bottom due to degradation of organic matter, they can not avoid adverse conditions because limited mobility that restricts their ability; taxonomic and functional diversity that make them suitable for detection of different levels and types of stress (Tagliapietra and Sigovini, 2010).

The most dominant oligochaets recorded during study was *Limnodrilus s*sp.which have high tolerance to organic and metal pollution. This agrees with Abdel Gawad & Mola, (2014) and Mola & Abdel Gawad (2014).

Among 23 families recorded in the Lake during this study, seven families; Viviparidae, Planorbidae, Thiaridae, Physidae, Neritidae, Tubificidae and Chironomidae are used as bioindicators of pollution and used in the application of biotic indices. This results agree with Fishar *et al*. (2015).

Regression analysis

Regression between the chemical (NCBI) and BMWP indices showed non significant values during winter and summer (P-value more than 0.05). The highest value of P was recorded between NCPI and BMWP (P about 1, R^2 = 0.00) during winter while during summer the highest value (P=0.7, R^2=0.01) was recorded between NCPI and BMWP (Table 7). The R^2 values for the BMWP-ASPT were higher than that of BMWP.

These results showed that BMWP and BMWP-ASPT are not similar with NCPI (P-value more than 0.05) so BMWP and BMWP-ASPT indices are not give good indication to evaluate water quality in Lake Burullus. This agree with the result of Fishar *et al*. (2015) who stated that the same indices not give good indication to assess the water quality of Manzala Lake and need to develop according to the nature of the lake and its macrobenthic fauna.

Our results disagree with Fishar and Williams (2008) who mentioned that these indices give indication to assess water quality of the whole River Nile in Egypt.

Table 7: Regression between chemical index (NCPI) and biological index (BMWP).

	winter		summer	
Output of regression	R^2	P-value	R^2	P-value
NCPI *BMWP	0.00	0.97	0.01	0.70
NCPI *BMWP-ASPT	0.12	0.27	0.04	0.51

CONCLUSION

The present study showed that, the average values of NCPI reached 25.75 during winter and 24.4 during summer in the whole area of investigation. This reflected the Burullus Lake water ranged from heavy to moderate pollution. In this study, the biotic indices BMWP and BMWP-ASPT results are not matching with NCPI results. Regression analysis between the chemical (NCPI) and BMWP indices showed non significant values during winter and summer (P-value more than 0.05) so BMWP and BMWP-ASPT indices are not give good indication to assess water quality in Lake Burullus.

The use of biological evaluation of water quality in Lake Burullus in Egypt was the first attempt and the index require testing in different sites along years and in case of pollution instances. The biotic index have strong impact and can indicate the occurrence of unrecorded chemical pollution incidents. We hope this attempt will encourage more studies to develop these biotic index according to nature of the Lake and its macrobenthic organisms.

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