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Using Macroinvertebrates Metrics in Assessing the Ecological Status of Ismailia Canal, Egypt

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ABSTRACT

Macroinvertebrate communities from a man-made canal called Ismailia Canal were analyzed seasonally in order to assess changes in their composition and structure over time as well as to study the canal's ecological status. The performance of the Biological Monitoring Working Party (BMWP) and Average Score Per Taxon (ASPT) indices, in the studied 10 stations, have been calculated and compared with the diversity index (H`) and the Intercalibration Common Metrics Index (ICMi) as well. Annelida, Insecta, Mollusca, and Crustacea composed the main groups of the benthic fauna in Ismailia Canal with an average density of 454 ind./m^2. Seasonally, winter exhibited the lowest population density and autumn revealed the highest density. Regarding Shannon Wiener diversity index, stations 1 and 2 represented the highest value (H`= 1.8) while the lowest biodiversity value was in station 5 (H`= 0.11). The BMWP scores revealed the first sector of the canal (stations 1 and 2) in moderate ecological status; however, stations 5 and 10 exhibited the poorest status. The Average Score Per Taxon (ASPT) divided the canal into two sections; the moderate ecological status (stations 1, 2, 3, 4, 7, and 8) and the poor ecological status (stations 5, 6, 9, and 10). Due to the presence and absence of some of the bioindicator groups, values of the STAR_ICM index varied from 0.20 to 1.64. However, the current investigation revealed long-term monitoring of ecology and diversity of macrobenthic assemblages is required for the sake of its conservation. Developing an index that suits the Egyptian hydromorphological status is a crucial issue.

INTRODUCTION

Due to the water scarcity, it is crucial managing the water resources clean. However, the process of chemical monitoring for any water stream is beneficial it could be expensive. Therefore it's crucial to find the most efficient, low-cost, and fast method to figure out the ecological status of the water stream under investigation. Indeed, benthic macroinvertebrates are the most widely used group for the biological monitoring of streams and rivers around the world **(Bonada *et al.* 2006)**. Tolerance values (TVs) are commonly used in the US, Europe, South Africa, and Australia. However, the scoring system of TVs differs from one region to another.

Benthic macroinvertebrates are significant bioindicators of the health of any water stream, and since some species are categorized based on how sensitive they are to pollution, their absence or presence can provide information about the level of pollution. They can have significant long-term effects due to their long life cycle and being almost sessile **(Hellawell, 1986).** Bio-indices have been accepted as appropriate standards for assessing the quality of the aquatic environment. They are numerical expressions that combine qualitative data on each taxon's ecological sensitivity with quantitative values of species diversity **(Czerniawska-Kusza, 2005)**. Concerning the Convention of Biodiversity (CBD), the biological criteria were the main elements in the assessments (**Fishar and Williams, 2008**). Furthermore, benthic macroinvertebrates are the recommended group used for assessing water quality according to the Water Framework Directive (WFD) as an obligatory examining tool in European countries. In the Italian legislation, the implementing decree no. 8 of 2010 November 260 introduced the calculation of the STAR multimetric intercalibration index. **Spitale (2017)** applied STAR_ICMi index to macroinvertebrates in Italian rivers. Because macroinvertebrates responses to the hydrological changes are still unclear, **Erba *et al.* (2020)** studied the STAR_ICMi index based on the macroinvertebrates ecological status in Italy.

The Biological Monitoring Working Party (BMWP) is a simple and reliable bio-assessment scoring system based on the family level developed in the UK and successfully applied in other countries. It was designed to give general information about the biological status of rivers in the UK **(Mason, 2002)**. In Egypt, the BMWP and BMWP-ASPT indices were applied to the River Nile by **Fishar and Williams (2008)**. In Nigeria, **Bawa *et al.* (2018)** examined the water quality using BMWP/ASPT at Kanye and Magaga Dams. **El Sayed *et al.* (2020)** approved the validity of using the BMWP to assess the River Nile water quality for aquatic life.

Because there are inadequate potential studies related to macrobenthic invertebrates bio-monitoring in Egypt, this study was devoted to introduce STAR_ICM index, to be used for the first time in Egypt, using macrobenthic invertebrates. In addition, it aimed to determine the ecological status of Ismailia Canal based on the biodiversity index and two different biotic indices (BMWP and ASPT).

MATERIALS AND METHODS

Study area

Ismailia Canal is considered as the main freshwater waterway in Egypt which used for fishing, irrigation, and drinking. It begins in the north Cairo (El-Mezalat station) moving towards governorates of Ismailia, Port Said and Suez (Fig. 1). **Abdo *et al.* (2010)** reported its average length of about 128 Km, and its depth and width are approximately 2.1m and 18 m, respectively.

Almost 40 kilometers have been chosen as a case study of the canal's benthic fauna health. Ten stations have been chosen and collected seasonally in 2019 and described as follows: Station 1 represents the reference site at the inlet of the canal and 3 stations at each company (1 km before the company, in front of the company, and 1 km after the company as shown in Fig. 1).

Station 1: El-Mezallat station (represents a reference site)
Station 2: Before the Electrical company

Station 3: Mixture station of the Electrical Company
Station 4: 1 Kilometer after the Electrical Company
Station 5: Before Petroleum Company
Station 6: Mixture station of Petroleum Company
Station 7: 1 kilometer after Petroleum Company
Station 8: Before Fertilizers Company
Station 9: Mixture of Fertilizers Company drainage water
Station 10: 1 Kilometer after Fertilizers Company

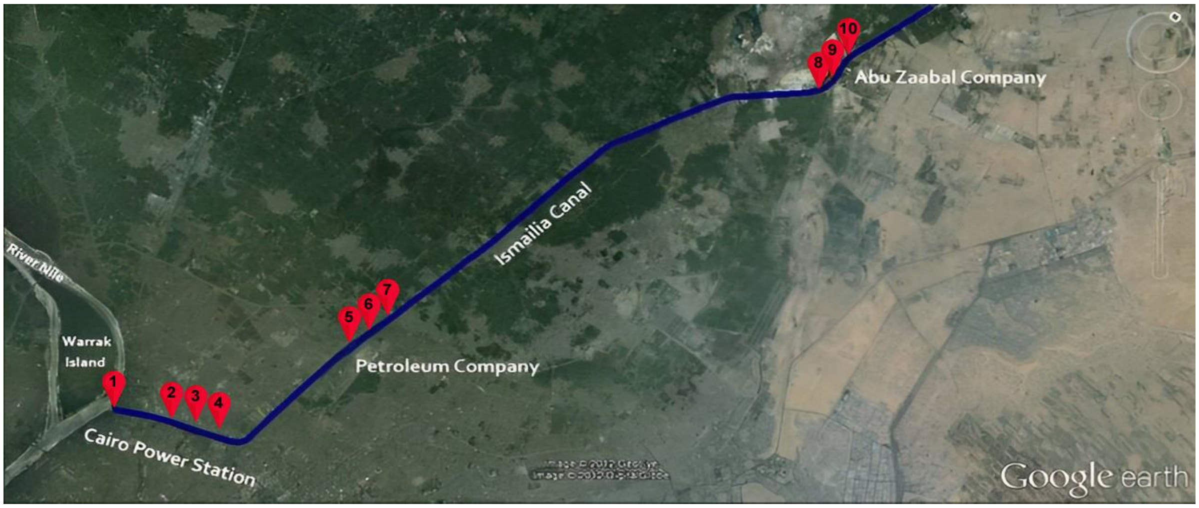

Figure 1. A map of Ismailia Canal showing the collecting stations

Macrobenthos Sampling:

The macrobenthic fauna was collected by square Ekman grab with 225 cm^2 surface area. Each sample was promptly sieved in the field via 500µm mesh net and stored in plastic containers with 7% formalin for preservation. The samples were washed and sieved another time through a 500µm mesh size net in the laboratory. Benthic animals were sorted to families, genera and species level (when possible) using a stereo microscope. The species were then identified according to **Bishai *et al.* (2000)**, and **Thorp and Covich (2009)**.

Shanon-Wiener diversity index (H`):

The macrobenthic fauna diversity index was calculated to assess the pollution consequences on the diversity and equitability at each station, and eventually on the ecosystem using the computer software Primer 5.

Biological Monitoring Working Party (BMWP):

It is a technique used to measure the quality of any water stream using the macroinvertebrates' families as biological indicators. The BMWP score was calculated as the sum of the tolerance scores of all macroinvertebrate families in each station according to Table 1.

Average Score Per Taxon (ASPT):

The average score per taxa (ASPT) was calculated for each station by dividing the BMWP score by the total number of the recorded families in the station.

Intercalibration Common Metrics and index easy calculation (ICMeasy 1.2):

The software was designed by **Buffagni and Belfiore (2006)** to calculate four sets of biological metrics and four ICM indices. It is an official method for the ecological status assessment in Europe. For the Mediterranean Geographical Intercalibration Groups (GIGs), the calculated metrics were as follows:

Total Number of Families, Number of Ephemeroptera- Plecoptera- Trichoptera (EPT) Families, Average Score per Taxon (ASPT), and Number of EPT/ Total Number of Families. The index was calculated by ICMeasy software version 1.2, August 2006.

Table 1. The Biological Monitoring Working Party (BMWP) scoring system (Alba-Tercedor, 1996).

Score	Families
10	Siphlonuridae, Heptageniidae, Leptophlebiidae, Ephemerellidae, Potamanthidae, Ephemeridae,Taeniopterygidae, Leuctridae, Capniidae, Perlodidae, Perlidae, Chloroperlidae Aphelocheiridae Phryganeidae, Molannidae, Beraeidae, Odontoceridae, Leptoceridae, Goeridae, Lepidostomatidae, Brachycentridae, Sericostomatidae
8	Astacidae Lestidae, Agriidae, Gomphidae, Cordulegasteridae, Aeshnidae, Corduliidae, Libellulidae, Psychomyiidae (Ecnomidae), Phylopotamidae
7	Caenidae Nemouridae Rhyacophilidae (Glossosomatidae), Polycentropodidae, Limnephilidae
6	Neritidae, Viviparidae, Ancylidae (Acroloxidae) Hydroptilidae Unionidae Corophiidae, Gammaridae (Crangonyctidae) Platycnemididae, Coenagriidae
5	Mesovelidae, Hydrometridae, Gerridae, Nepidae, Naucoridae, Notonectidae, Pleidae, Corixidae Haliplidae, Hygrobiidae, Dytiscidae (Noteridae), Gyrinidae, Hydrophilidae (Hydraenidae), Clambidae, Scirtidae, Dryopidae, Elmidae Hydropsychidae Tipulidae, Simuliidae Planariidae (Dogesiidae), Dendrocoelidae
4	Baetidae Sialidae Pisicolidae
3	Valvatidae, Hydrobiidae (Bithyniidae), Lymnaeidae, Physidae, Planorbidae, Sphaeriidae Glossiphoniidae, Hirudinidae, Erpobdellidae Asellidae
2	Chironomidae
1	Oligochaeta

RESULTS AND DISCUSSION

Community composition and population density of macrobenthic fauna:

During the current investigation, Annelida, Insecta, Mollusca, and Crustacea were the main groups that made up the macrobenthic fauna with percentages of 35.29%, 33.55%, 30.03%, and 1.13%, respectively (Fig. 2). The total recorded species were eighteen species with a total density of 454 ind./m^2. These findings are compatible with those recorded by **Khalil *et al.* (2012)**.

Fig. 3, illustrates that station 2 had the highest density with an average of 816 ind./m^2, while 116 ind./m^2 were the lowest benthic population density recorded in station 7. Evidently, the population densities were high in the first sector of the canal while it declined gradually downstream. Furthermore, there were two peaks in front of companies in stations 6 and 9. This phenomenon was due to the dominance of the organic matter bioindicator species *Limnodrilus* sp. and *Chironomus* larvae. Therefore, this result may reflect the adverse impact of the companies' wastewater on the benthic fauna community.

With an average density of 200 ind./m^2, winter had the least density. On contrary, autumn exhibited the highest density due to the dominance of *Limnodrilus* sp. with an average of 597 ind./m^2 (Fig. 4). **Khalil *et al.* (2012)** found comparable results in the same sector of the canal.

Limnodrilus sp. was the main constituent of annelids with an average population density of 154 ind./m^2. It was found in all the selected stations all the year round. Similar outcomes were recorded by **Nassif (2012)** who pointed out that 95% of the annelids were *Limnodrillus hoffmeisteri*. This result may be attributed to the presence of high content of nutrients and detritus in addition to the ability of *Limnodrillus* spp. to withstand high degrees of pollution **(Wissa, 2012)**. However, *Branchiura sowerbyi* and *Helobdella confera* were rarely and sporadically found. *Branchiura sowerbyi* was found in stations 1, 4, and 6 with an annual average of 5 ind./m^2 while *Helobdella confera* was found only in station 4 with an annual average of 1 ind./m^2. The same findings were recorded by **Nassif (2012)**. This could be attributed to, on one hand, the temperature preference by *Branchiura sowerbyi* as mentioned by **Wissa (2012)** and on the other hand, the dominance of *Helobdella confera* explicit that station 4 has the most favorable conditions for annelids diversity. Obviously, there were two peaks of the annelids population density in stations 4 and 9 (283 ind./m^2 and 248 ind./m^2, respectively). As illustrated in Fig. 5, stations 7, 8, and 10 had the least annelids density of population with an average of 55, 56, and 74 ind./m^2, respectively.

Insecta was represented by *Chironomus* larvae, Damselflies, and Caddis flies. According to Fig. 6, station 3 was the most populated station with Insecta (423 ind./m^2) while station 7 had the least population of Insecta (15 ind./m^2). *Chironomus* larvae composed 98.65% of the total insect density with an average annual of 150 ind./m^2. In 2010, **Nassif (2012)** revealed that *Chironomus* larvae composed 97% of the insects' population density. This means that *Chironomus* larvae become more dominant with time which may reflect the ecological status of the canal as *Chironomus* larvae prefer to live in oligotrophic and eutrophic lakes **(Wissa, 2002)**. Damsel flies, and Caddis flies were found sporadically and occasionally where the former were found in stations 2 and 10 while the later were found in station 3 only. These results revealed good water conditions in these stations because Order Odonata and Order Trichoptera are pollution-sensitive groups.

Ten mollusks species were recorded during the studied period. *Melanoides tuberculate* was the predominant and was found in all the studied stations with an annual average of 68 ind./m^2. *Lanistes carinatus*, *Physa acuta*, and *Succinea cleoptra* appeared rarely and randomly in stations. As shown in Fig. 7, stations 1 and 6 had the highest densities with mollusks (356 ind./m^2 and 273 ind./m^2, respectively) while the least mollusk density (22 ind./m^2) was found in station 5.

Crustacea composed of two species *Caridina nilotica* and *Potamonautes niloticus* where they seldom found with an annual average of 5 ind./m^2 and 1 ind./m^2, respectively. *Caridina nilotica* was found in stations 1, 2, and 4. *Potamonautes niloticus* was found in stations 1 and 4.

That means that stations 1 and 4 revealed somewhat clean water condition as they exhibited fauna diversity.

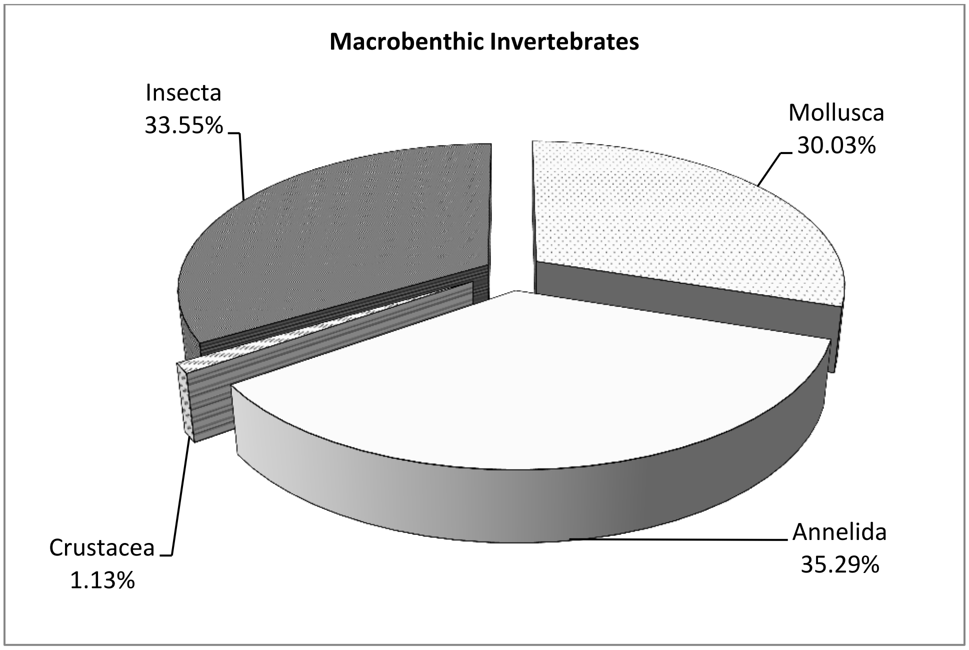

Fig. 2. Pie chart illustrates the community structure of macrobenthic invertebrates along the study area of Ismailia Canal.

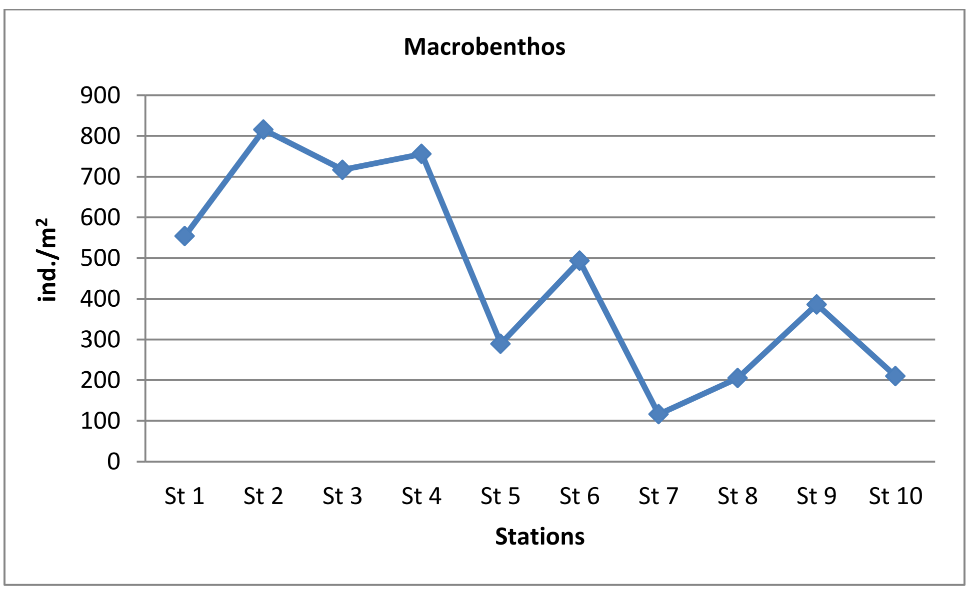

Fig. 3. The spatial distribution of macrobenthos in the study stations along Ismailia Canal.

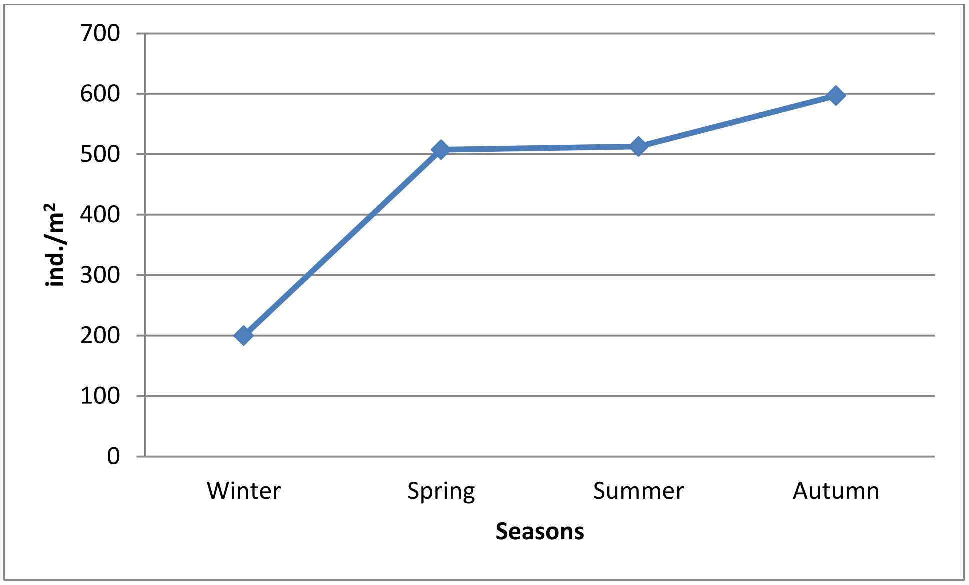

Fig. 4. The temporal distribution of macrobenthos in the study stations along Ismailia Canal.

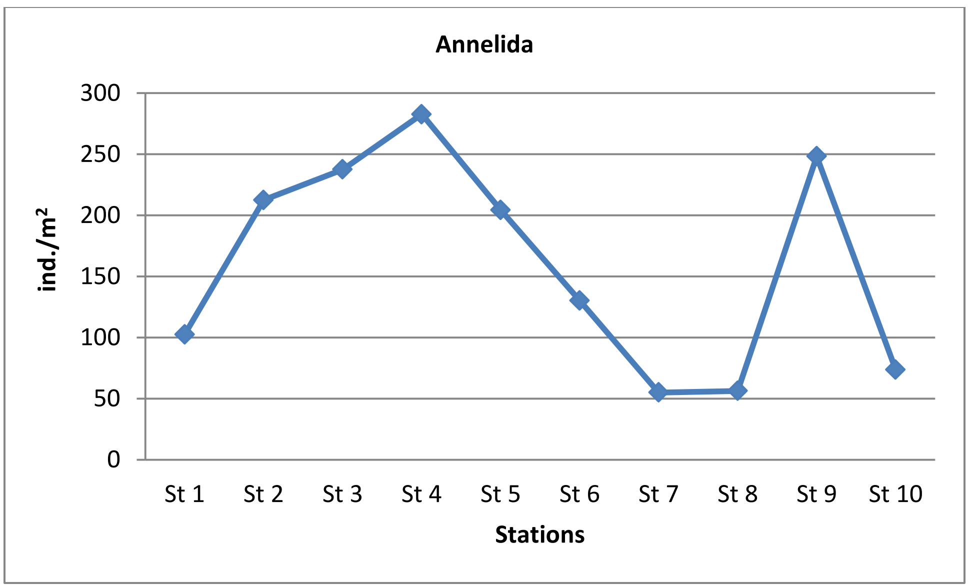

Fig. 5. The spatial distribution of Annelida in the study stations along Ismailia Canal.

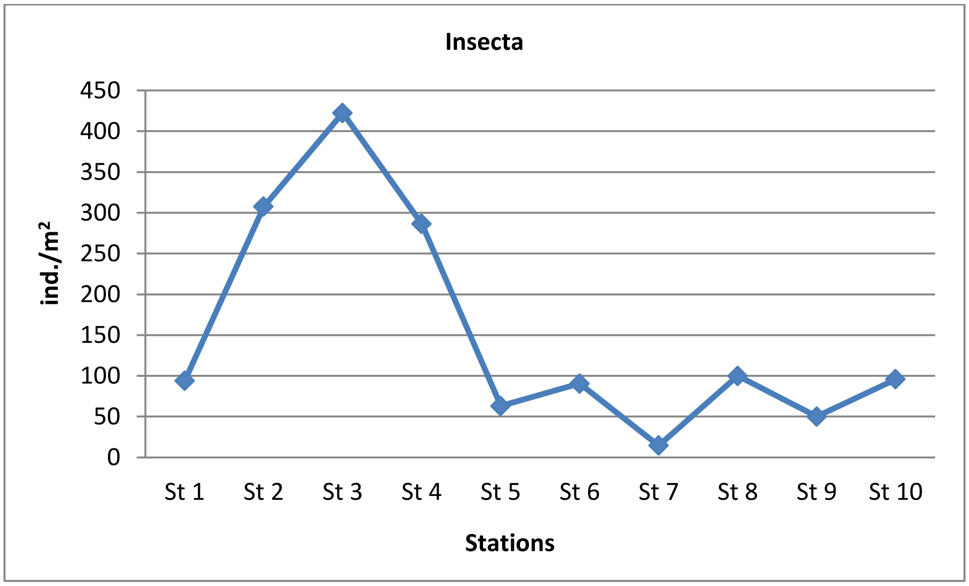

Fig. 6. The spatial distribution of Insecta in the study stations along Ismailia Canal.

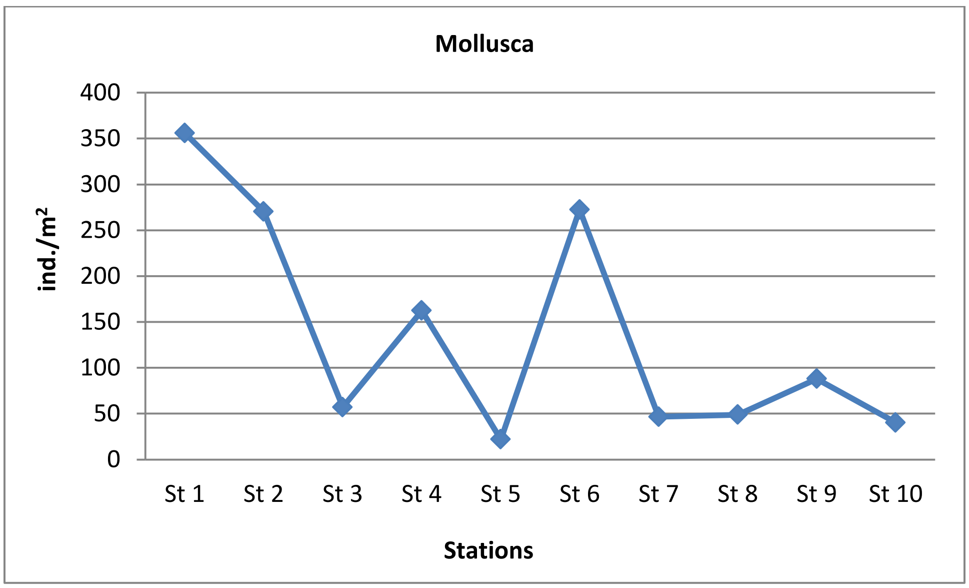

Fig. 7. The spatial distribution of Mollusca in the study stations along Ismailia Canal.

Macroinvertebrates biodiversity index:

Biodiversity provides important functions to the aquatic ecosystem due to the function done by different species in the community. Therefore, the decreased number of species is considered as loss of biodiversity in polluted ecosystems that leads to habitat destruction. Regarding the present investigation, the highest biodiversity value and number of species have seen in stations 1 and 2 (H`= 1.8 and N= 13). That means that these stations are to be considered as reference sites with no impacts of pollution. As shown in Table 2, station 5 exhibited the lowest diversity index and number of species (H`= 0.11 and N=4). This result explicit that either this is a source of pollution that affect on the benthic fauna or the substrate and living conditions are not suitable for the benthos in this sector.

Biological Monitoring Working Party (BMWP):

The Biological Monitoring Working Party (BMWP) was calculated for the average 10 stations to give general ecological status for the studied sector of the canal. The BMWP score was 65 which mean that the canal is moderately impacted by pollution according to the Table 3. Table 5, illustrated the scores of each station. It is obvious that the first sector of the canal (stations 1 and 2) revealed moderate ecological status while it seems that the canal's status dramatically declined downstream to reach its poorest status at stations 5 and 10. This result could explain the impacts of drainage wastewater from different kinds of industries.

Average Score Per Taxon (ASPT):

Stations 1, 2, 3, 4, 7 and 8 exhibited moderate ecological status according to ASPT values (Tables 4 and 5). However stations 5, 6, 9 and 10 revealed poor status for the benthic life.

Intercalibration Common Matrix Index (ICMi):

As shown in Fig. 8, STAR_ICMi values revealed stations 2, 3, 4, and 10 were higher than 0.95. Concerning Table 6, these stations are to be considered as elevated ecological quality. Station 1 (STAR_ICMi value = 0.92) exhibited good ecological status. Furthermore, the ICMi values of stations 6, 7, and 8 were 0.52, 0.65, and 0.64, respectively. Those three stations indicated sufficient ecological status. On contrary, stations 5 and 9 exhibited bad status with 0.20 index value for each of them.

BMWP, ASPT, and ICM indices compatibility study:

By comparing the BMWP, ASPT, and ICMi values, it's apparent that the three indices gave similar ecological view of each station with some exceptions. For instance, the three biological indices exhibited poor status in stations 5, and 9 and moderate status in station 1. ASPT and ICMeasy values figure out the same status for stations 1, 5, 7, 8, and 9. Furthermore, although ASPT and BMWP values in station 10 indicated poor ecological status, ICMi informed that station 10 is in elevated quality.

Table 2. Illustrates number of species, Shannon-Wiener index (H`), and Equitability of microbenthic invertebrates in different stations along Ismailia Canal.

Stations	No. of Species	H`	Equitability
St 1	13	1.82	0.71
St 2	13	1.8	0.7
St 3	8	1.01	0.48
St 4	12	1.53	0.61
St 5	4	0.11	0.079
St 6	7	1.44	0.74
St 7	4	1.16	0.84
St 8	7	1.41	0.72
St 9	6	1.12	0.62
St 10	5	1.25	0.78

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Table 3. Scheme illustrates the different ecological categories regarding BMWP scores

BMWP score	Category	Interpretation
0-10	Very poor	Heavily polluted
11-40	Poor	Polluted or impacted
41-70	Moderate	Moderately impacted
71-100	Good	Clean but slightly impacted
>100	Very good	Unpolluted, unimpacted

Table 4. Bioclassification according to the ASPT values by Friedrich *et al.* (1996)

ASPT value	Water quality assessment
>5	Excellent
4-5	Good
3-4	Moderate
2-3	Poor
1-2	Very poor

Table 5. Comparison between different biological indices (ASPT, BMWP, STAR_ICMi, and H`) in the studied stations along Ismailia Canal.

Station	ASPT	BMWP	STAR_ICMi	H`
1	3.53	46	0.92	1.82
2	3.69	48	1.64	1.8
3	3.13	25	1.05	1.01
4	3.08	37	0.99	1.53
5	2.25	9	0.2	0.11
6	2.71	19	0.52	1.44
7	3	12	0.65	0.16
8	3	21	0.64	1.41
9	2.5	15	0.2	1.12
10	2.25	9	1.08	1.25

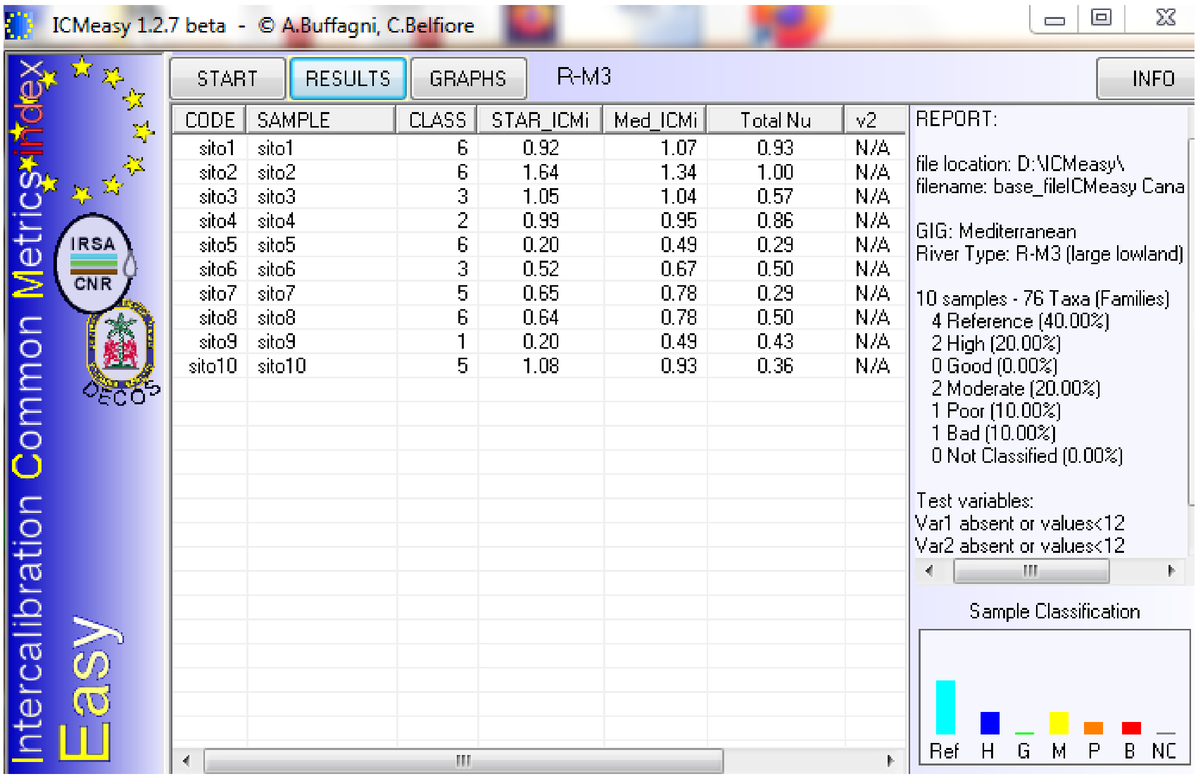

Fig. 8. ICMeasy results of the studied stations along Ismailia Canal.

Table 6. The ecological quality report (RQE values)

RQE values	STAR ICMi	Conventional color
RQE ≥ 0,95	elevated	
0,71 ≤ RQE < 0,95	good	
0,48 ≤ RQE < 0,71	sufficient	
0,24 ≤ RQE < 0,48	scarce	
RQE < 0,24	bad	

CONCLUSION

It could be concluded that the upstream sector of the canal is in a good ecological status that allows the benthic invertebrates to live and diverse, however, the canal's downstream exhibited moderate to poor status for the benthic fauna because of the industrial discharges.

To wrap up, the ASPT, BMWP, and STAR_ICMi indices are important and effective methods to figure out the real ecological status of any water stream, however, it is recommended to improve and develop a specific index that suits the hydromorphological status in Egypt.

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