Fayoum University
Faculty of Science
Zoology Department

Evaluation of aquatic invertebrate organisms as bioindicators of pollution in Lake Qarun, Egypt.

A Dissertation Submitted to

Zoology Department, Faculty of Science, Fayoum University

in partial fulfillment of the requirements for
the degree of Doctor of Philosophy in Zoology

By

MARWA ESSAM ABD ALLA ABDELATIF

B.Sc. in Zoology, Cairo University (Fayoum Branch)
M.Sc. in Zoology, Fayoum University

Egypt

2023

Evaluation of aquatic invertebrate organisms as bioindicators of pollution in Lake Qarun, Egypt.

By

MARWA ESSAM ABD ALLA ABDELATIF

B.Sc. in Zoology, Cairo University (Fayoum Branch)

M.Sc. in Zoology, Fayoum University

Supervision committee:

Prof. Dr. Afaf Mohammed Mostafa El-Gindy
Professor, Zoology Department, Faculty of Science, Fayoum University.

Prof. Dr. Jurek Kolasa
Professor, Department of Biology, Faculty of Science, McMaster University.

Dr. Ragaa Taha Mohammed Ahmed Abd Alla
Assistant Professor, Zoology Department, Faculty of Science, Fayoum University.

Dr. Lamiaa Ismail Khalil Ismail Mohamedein
Associate Professor, National Institute of Oceanography and Fishereries (NIOF), Suez Branch.

Summary & Coclusion

The aim of this study is to estimate spatial and seasonal changes of seven heavy metals (Fe, Pb, Cd, Cu, Mn, Ni, and Zn) in water and sediment, and the tissues of five invertebrate species (*Cerastoderma glaucum*, *Venerupis aurea*, *Peneaus. semiculactus*, *cymothoid isopods*, and *portunid crabs*) collected from six different sites in Lake Qarun during the winter and summer of 2018. The heavy metals concentration was analyzed using Atomic Absorption Spectrophotometer (AAS). The interspecific and inter-site differences of the heavy metal concentrations in the studied invertebrate species were analyzed using one-way ANOVA and post-hoc tukey's test. A Pearson correlation matrix was used to measure the strength of the linear association relationship between metals in water, sediments, and biota. Furthermore, we assessed population changes of the cockle *C. glaucum* from the Winters of 2008 and 2018 samples as it showed a high mortality rate during the last period. Ultimately, insights into the population size structure and growth will help improve our understanding of heavy metal pollution in the lake. The statistical analysis was performed using Minitab software (version 17) and Statistica (StatSoft, version 10), with levels of statistical significance set at $p < 0.05$.

The body size (length-frequency) distributions of the cockle *C. glaucum* considerably varied among the collections. A single peak at 14 mm was present in 2008, and two peaks appeared ten years later (one at 13mm and another at 19 mm). the condition index (CI) suggests a significant deterioration ($P = 0.000$) in the growth conditions of the cockle in the recent decade. The growth of *C. glaucum* indicated a decadal decline, based on the conditions index of 28.81 in 2018. Our

findings suggest that *C. glaucum* has differential sensitivity to metal accumulation, with larger individuals less resistant to environmental pollution and pathogens, which may translate the low representation (2.2%, 10.1%) of large cockles (>19 mm SL) of all samples collected during the two sampling years (2008 and 2018), respectively and seeing a high percentage of large cockles dead on the shore of the lake.

The annual levels of the examined heavy metals (µg/l) in water samples ranged as follows; Fe (8.11 - 25.93), Pb (0.40 – 0.88), Cd (0.18 – 0.32), Cu (0.28 – 0.69), Mn (0.28 – 1.21), Ni (0.82 – 1.35), and Zn (4.06 – 11.55) and lies in the following hierarchy order: Fe > Zn > Mn > Ni > Pb > Cu > Cd, while the annual metal concentrations (mg/kg) in surface sediment samples were ranged as follow; Fe (1549.5 – 2438.5), Pb (3.72 – 8.67), Cd (0.32 – 0.62), Cu (1.79 – 7.17), Mn (142.67 – 320.15), Ni (4.52 – 14.24), and Zn (13.40 – 29.39) and could be arrayed in the following order: Fe > Mn > Zn > Pb > Cd > Cu > Ni.

Generally, there were negligible differences in heavy metal levels between Winter and Summer. The concentrations of metals in sediments exceed that calculated in water samples for the same site and the highest levels were obtained at sites 1, 2, and 4, which receive a massive amount of aquacultural, industrial, agricultural, and untreated sewage drainage water. The annual concentrations of heavy metals in water and sediment samples were lower than the permissible limits stated by CCME (2007) for aquatic life and USEPA, 1986 and sediments quality guidelines (SQGs). The results of the single factor pollution index (SPI) and metal index (MI) were lower than 1 for all studied sites. The results of CF and I_{geo}showed considerable contamination of the lake's sediment with Cd, while the enrichment factor (EF) evaluation confirmed levels of high anthropogenic pollution. The EF data indicated that the eastern (site 1)

and southern (sites 2, 3, 4) areas of the lake showed moderate enrichment for Cu and Ni and moderately severe enrichment of Pb, Mn, and Zn, while the Cd showed extremely severe enrichment in all studied sites. Moreover, the results of SQG-Q at sites 2 and 4 could be classified as a tall negative effect on biota (SQG-Q ≥ 1).

Most studies carried out on heavy metals accumulation in biota of Lake Qarun focused on fish and scarce studies have been performed on bivalves and crustaceans. The levels of contamination found in the studied invertebrate species indicated an origin of anthropogenic inputs. The results of the annual means revealed higher concentrations of Fe, Mn, and Zn in the bivalves *C. glaucum* and *V. aurea* whereas Ni, Pb, Cu, and Cd were the lowest ones. The estimated annual averages (mg/kg dry weight) of Fe, Pb, Cd, Cu, Mn, Ni, and Zn levels in *C. glaucum* were as follows; 449.09, 4.58, 0.58, 4.81, 36.77, 18.61, 67.12, respectively and in *V. aurea* were as follows; 944.28, 24.92, 2.81, 11.71, 93.86, 46.11, and 129.22, respectively. The order of the examined trace metals in *P. semisulactus* is Fe (67.27) > Zn (53.27) > Cu (17.77) > Mn (7.29) > Ni (4.73) > Pb (3.38) > Cd (0.44), while in *cymothoid isopods* is Fe (1820.44) > Zn (140.14) > Ni (94.76) > Mn (87.88) > Pb (47.62) > Cu (52.28) > Cd (6.14), and in *portunid crabs* is Zn (83.91) > Fe (8.30) > Mn (2.09) > Cu (1.78) > Ni (0.055) > Pb (0.035) > Cd (0.002).

The international official regulatory agencies have set permissible limits for the levels of heavy metals above which the animals are considered inappropriate for human use. Our study concluded that all examined metals in *V. aurea* exceed the acceptable limits proposed by WHO, 1989 and FAO, 1983 except for Cu, while in *C. glaucum* Fe, Pb, Mn, and Ni exceed the permissible limits. All metals in the studied isopods exceed the acceptable limits stated by WHO, 1989 and FAO,

1983, while the levels of the heavy metal in *P.semisulactus* and *portunid crabs* remain within the acceptable limits for consumption except for Mn in both species and Ni in shrimp. Pb and Cd in shrimps were above the accepted limits proposed by JCEFA, 2003.

Generally, the obtained data revealed non-significant differences for heavy metal concentrations in water, sediment, and biota between sites in front of the drains (sites 1, 2, 3, and 4) and the middle of the lake (site 5), and site 6 (away from pollution sources).

The Fe element showed a significant positive correlation with the rest of the metals in water and sediments. Correlation coefficient results indicated that Fe, Pb, Cd, Cu, Mn, and Ni in the bivalve *V. aurea* had a significant positive correlation ($p < 0.05$) with the same metal in the lake water and sediment, while *C. glaucum* showed a significant positive correlation with Fe, Cd, Cu, Ni, Zn in sediment. On the other hand, contamination of crabs, shrimps, and isopods was generally not correlated with that of water and sediment, suggesting that the bioaccumulation of heavy metals in the crustacean species was related more to the biochemical and physiological processes of crustaceans themselves.

The present study reported that the studied species were found to vary significantly ($p < 0.05$) in trace element loads and reflect the levels of pollution from Lake Qarun. *Cymothoid isopods*, *V. aurea*, *C. glaucum*, and *P. semisulactus* are considered appropriate candidates for bioindication of Fe, Pb, Mn, Ni, Zn, Cu, and Cd in lake Qarun (BAF > 1000), while crabs show a tendency for accumulation of Zn, Mn, and Cu and they could be arranged as follow *cymothoid isopods* > *V. aurea* > *C. glaucum* > *P. semisulactus* > *portunid crabs* according to the bioaccumulation values. Moreover, this study can provide a guideline for

the consumption of cockles, shrimps, and crabs as food by the local community.

It is evident from the results of metal indices that the lake suffers from a serious pollution problem that may affect negatively aquatic life, fishing, and recreational activities because of the adjacent harm to the environment and human health. As a result, decision-makers should pay attention to protecting this Lake by regulating the discharge of industrial, agricultural and sewage inputs, treating it before discharging, and continuously monitoring the lake water quality and sediment.