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Remote Sensing Technique for Assessment of Zooplankton Community in Lake Mariout, Egypt.

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ABSTRACT

Lake Mariout is a shallow, brackish water basin located in the north of Egypt. Zooplankton samples were collected seasonally from 10 stations during the period from summer 2009 to autumn 2015 to evaluate the ecological status of Lake Mariout through variations in zooplankton community using time series analyses and remote sensing technique. Fifty zooplankton taxa belong to 36 genera were recorded all over the period of study. Rotifera was the most abundant and diversified group, followed by Copepoda and Ostracoda. The time series trending of the total zooplankton density was decreasing with time. Rotifers showed stability in abundance all over the study period. Copepod density tended to increase gradually with time while ostracod and cladoceran densities tended to decrease. *Brachionus urceolaris* and *Brachionus calyciflorus* were the most common species over the study period at all lake basins. The present results confirmed the continued deterioration of Lake Mariout situation, which threatens the breakdown of the Lake ecosystem that could have a negative impact on its fish production.

INTRODUCTION

Lake Mariout is a shallow water basin lies in the west of Alexandria city. It has no natural outlet to the Mediterranean Sea and water is pumped directly into the sea through El-Mex pumping station (Abd Allah, 2003).

It receives agricultural drainage water from the surrounding cultivated lands as well as industrial and domestic sewages from Alexandria city mainly through El-Umom drain and El- Qalaa drain.

Remote sensing data can provide accurate spatial distribution of Normalized Difference Chlorophyll Index (NDCI), also using GIS programs helps in the production of maps of zooplankton abundance. Previous studies on zooplankton community in Lake Mariout were mainly concerned with zooplankton abundance and distribution during certain limited periods (Samaan & Aleem, 1972; Abdel Aziz, 1987; Guerguess, 1988 and Abdel Aziz & AboulEzz, 2004).

For the first time, the present study examines the ecological status of Lake Mariout through variations in zooplankton community using time series analyses and remote sensing technique.

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MATERIALS AND METHODS

Lake Mariout lies between latitude 31° 01' 48", 31° 10' 30" N and longitudes 29° 49' 48", 29° 57' 00" E, extending about 25 km parallel to Alexandria coast. The lake has a maximum width of about 10 Km and one meter average depth. It consists of 4 basins; the Main Basin (MB), the Northwest Basin (NWB), the Fish Farm Basin (FFB) and the Southwest Basin (SWB). Samples were collected from ten stations, using standard plankton net of 55µm mesh size and a mouth diameter of 30 cm, throughout the period from 2009 to 2015 representing the four lake basins; St.1 and 2 in the Fish Basin (FFB), St. 3, 4, 5 and 6 in the Main Basin (MB), St. 7 and 8 in the Southwest Basin (SWB) and St. 9 and 10 in the Northwest Basin (NWB) as shown in Figure (1).

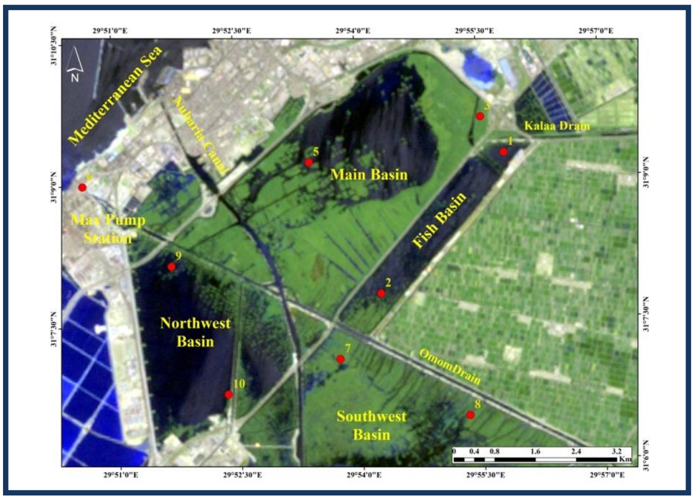

Fig. 1: Location of sampling stations in Lake Mariout

The collected samples were preserved in 4% neutral formalin solution and their volumes were concentrated to 100 ml. Quantitative and qualitative investigations were done by using a binocular research microscope. Zooplankton density was expressed as individual/m^3. Identification of species was done according to Edmondson *et al*. (1959), Berzins (1960), Harding & Smith (1960), Hutchinson (1967) and Dussart (1969). Time series analysis of Hydrographic conditions, total zooplankton and each zooplankton group was done using statistical analysis for windows ver. 7.0., MINITAB Release 16 computer program.

Chlorophyll-a (Chl-a) is commonly used as a representative for phytoplankton and remote sensing techniques can easily estimate Chl-a concentration through different satellite reflectance algorithms such as Normalized Difference Chlorophyll Index (NDCI) reflectance algorithms (Beck *et al.*, 2016).

Multispectral LANDSAT8/OLI sensor has shown the potential for applications in the estimation of Chl-a (Watanabe *et al*., 2015). For Remote Sensing application, Landsat-8/ OLI images at 2015 freely available from the United States Geological Survey was used for estimating Chl-a. The radiometric calibration was conducted to convert digital numbers into top-of-atmosphere radiance, using the metadata released with the images. The retrieval of the at-surface reflectance was accomplished using the Fast Line-of-sight Atmospheric Analysis of Spectral Hypercubes (FLAASH), an atmospheric correction module, implemented in the ENVI software. The two-band algorithm (Normalized Difference Chlorophyll Index, NDCI) was applied in which B and 4 (Red) and Band5 (near infrared (NIR)) were used as in the following equation:

NDCI = ((B5)-(B4)) / ((B5) + (B4)) **(Beck *et al*., 2016).**

RESULTS

Hydrographic conditions

The physico-chemical characteristics and chlorophyll-a of Lake Mariout were estimated at the sampling stations parallel to the collection of zooplankton samples. The time series analysis indicated that the water temperature trends to slight decrease with time (average ~23.4±5.5^{o}C) (Fig. 2). Water transparency exhibits a considerable increasing trend with an average of ~38.5±12.3cm; while salinity exhibits a considerable decreasing trend with an average of ~3.9±0.45‰. PH of the lake water lies in the alkaline side and shows a gradual increase.

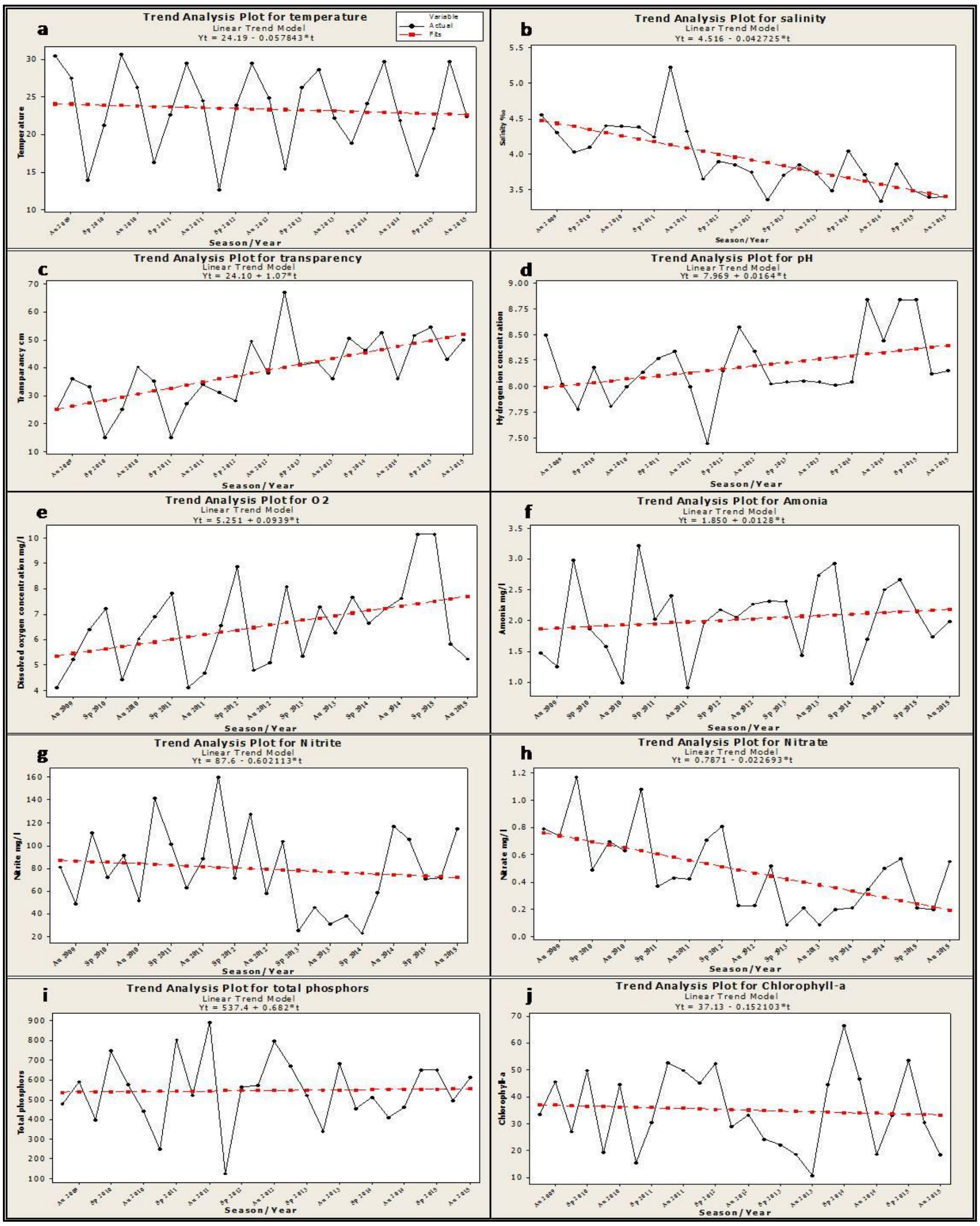

Fig. 2. Time series trend of Hydrographic conditions, a: Temperature, b: Salinity, c: Transparency, d: pH, e: Dissolved oxygen, f: Ammonia, g: Nitrite, h: Nitrate, i: Phosphors and j: Chlorophyll-a.

Regarding the dissolved oxygen concentration, the lake water was well oxygenated with an average of ~6.5±1.7mgl^{-1}. On the other hand, the nutrient trend shows a gradual increase in the concentration of ammonia, gradual decrease in nitrite concentration; sever breakdown in the nitrate concentration and stability in the total phosphors concentration (Fig. 2). The chlorophyll-a concentration tends to a gradual decrease all over the study period with an average of ~35.1±14.7mgl^{-1}.

Zooplankton abundance and community composition

Over 7-year study period, zooplankton community in Lake Mariout composes of 50 taxa belongs to 36 genera. Rotifers are the most diversified (27 species) followed by protozoans (12 species), copepods (7 species) and cladocerans (4 species). Nematodes, ostracods as well as the immature forms of copepods (copepod nauplii and copepodite stages) and mollusks (veligers of gastropods and lamellibranches) were also recorded. Rotifera is the most abundant zooplankton group (82246.15±48583.52 ind./m^3) representing 62.41% of the total zooplankton counts; followed by copepods (30650±16734.93 ind./m^3, 23.26%), ostracods (10688.46± 9782.2 ind./m^3, 8.11%) and protozoans (4776.9±13577.34 ind./m^3,3.63%). Nematods, cladocerans and molluscans are rare and represent 1.54%, 1.02% and 0.03% of the total zooplankton counts, respectively. NDCI algorithm for the available data during the study period (2009-2015) was applied and shown in (Fig. 3). Total zooplankton density at the sampling stations during the period of study was interpolated to show variations in the density (Fig. 4).

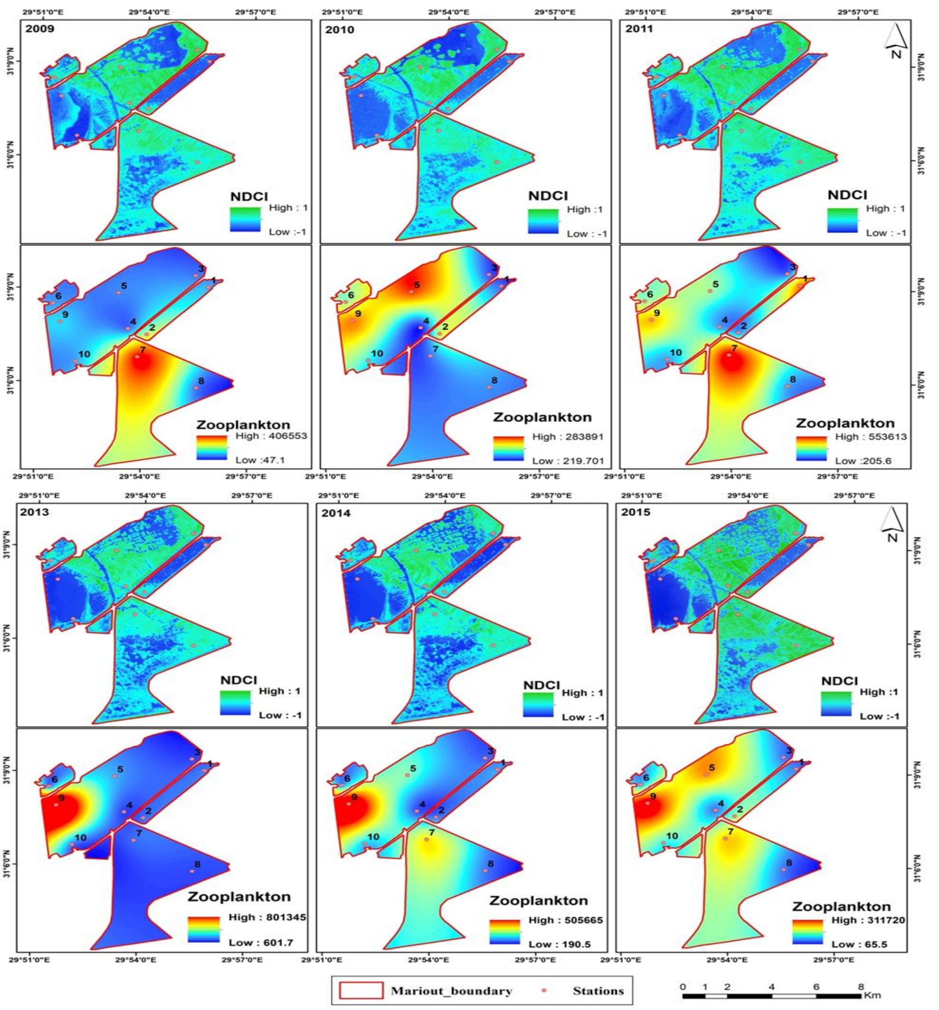

Fig. 3: NDCI algorithm

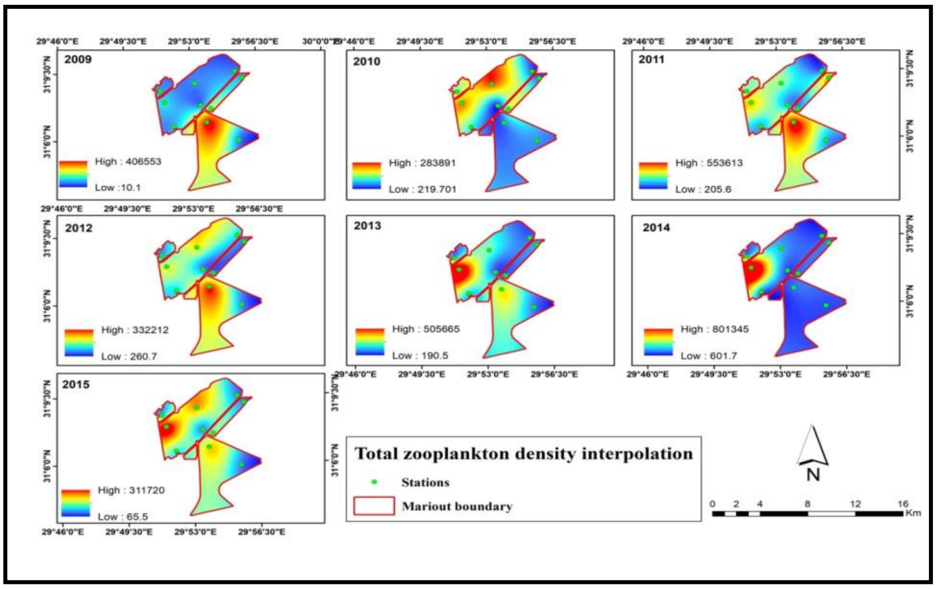

Fig. 4: Interpolation of zooplankton density at the sampling stations during the period 2009- 2015

The time series analysis of zooplankton density in Lake Mariout over the 7-year study period showed that, the total zooplankton density exhibits considerable decreasing trend with time, with high peak in spring 2014 (251800 ind./m^3) and low break in summer 2015 (53200 ind./m^3) (Fig 5).

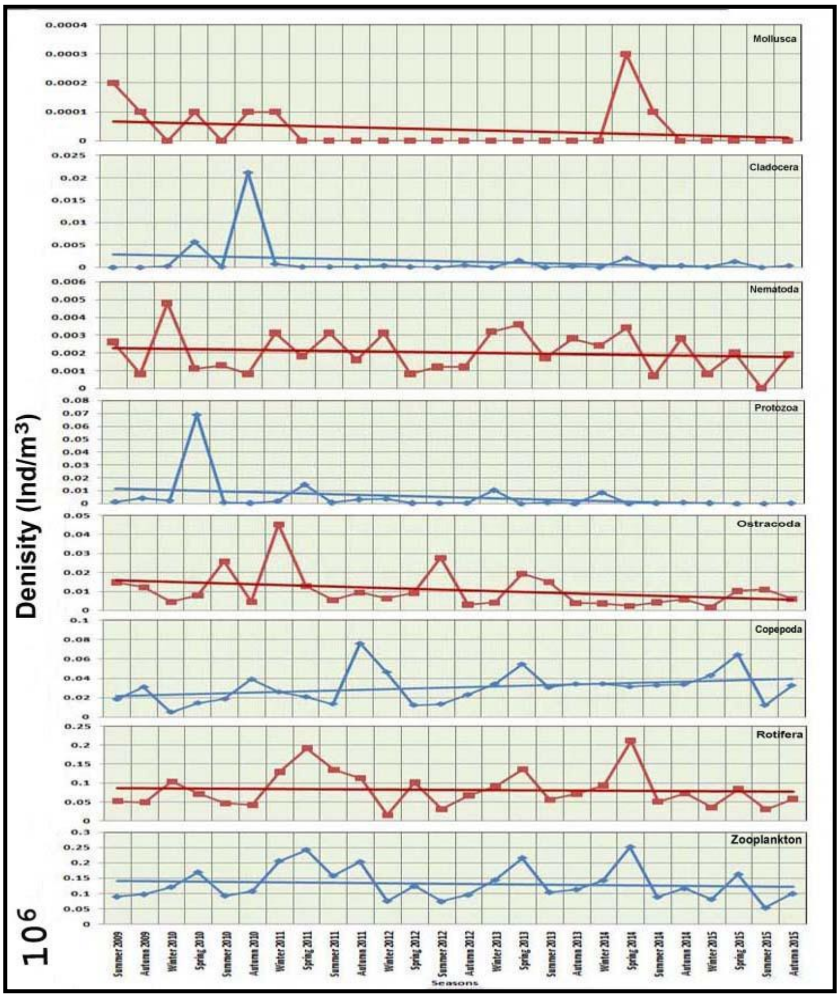

Fig. 5: Time series trend of total zooplankton density and the recorded groups.

Regarding the trending of the recorded zooplankton groups, rotifers show stability in their abundance all over the study period, their high peak in spring 2014 (212300 ind./m^3) and low break in winter 2012 (15100 ind./m^3). Copepods are trending to gradual increase with time and their high peak in autumn 2011 (76200 ind./m^3) and low break in winter 2010 (5000 ind./m^3). Ostracods trend to gradual decrease over the study period with high peak in winter 2011 (45300 ind./m^3) and low break in winter 2015 (1800 ind./m^3). As for protozoans which have decrease trending with high peak in spring 2010 (68900 ind./m^3). Nematodes are trending to slight decrease with time and their high peak was recorded in winter 2010. Cladocerans are gradually decreased all over the study period and their high peak in winter 2011 (21200 ind./m^3). Mollusks are rare and disappeared most of the study period (Figure 5).

Time series trending of the total zooplankton and the most common groups in the 4 lake basins during the study period were illustrated in Figures (6-9). Zooplankton density in the NWB exhibit a considerable increasing trend with time, with high peak in spring 2013 (536000 ind./m^3) and low break in winter 2010 (27000 ind./m^3) (Figure 6). On the other hand, zooplankton density at the SWB appeared stable with time. In the MB, there is a gradual decrease and the highest density was recorded in spring 2010 (344500 ind./m^3) and the lowest was recorded in winter 2010 (35500 ind./m^3). Zooplankton density at the FFB basin was also gradually decreased with time, with high value in autumn 2011 (244000 ind./m^3) and low in spring 2012 (10000 ind./m^3).

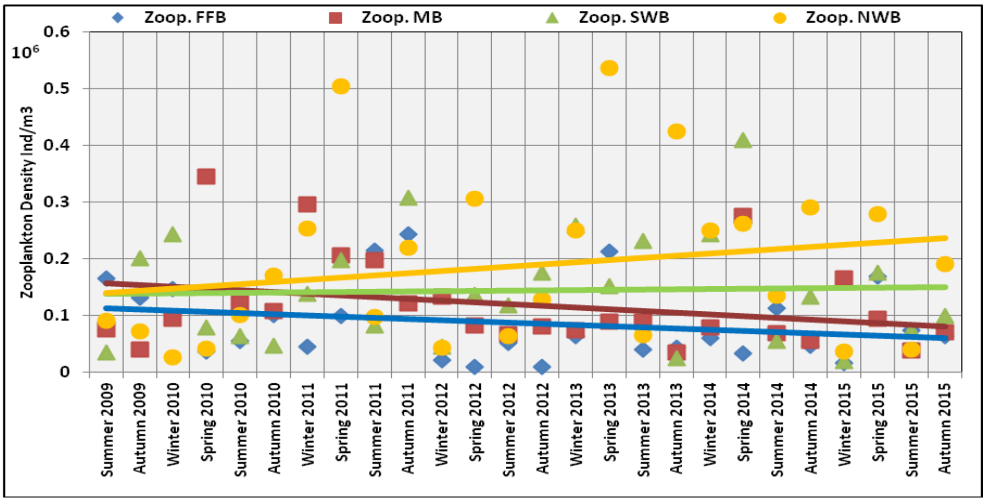

Fig. 6: Time series trend of total zooplankton density in the 4 lake basins during 2009-2015

Rotifera was the most dominant zooplankton group; its density attained the same trends as the total zooplankton at all lake basins (Figure 7). Rotifer density in the NWB exhibited gradual increasing with time, with high peak in spring 2011 (452500 ind./m^3) and low break in autumn 2009 (4500 ind./m^3). On the other side, the density appeared stable with time at the SWB. In the MB, there was a gradual decrease in density with time, with highest value in spring 2014 (240750 ind./m^3) and the lowest in summer 2012 (4750 ind./m^3). The rotifer density in FFB was also gradually decreased with time, with high value in spring 2013 (173500 ind./m^3) and low in spring 2012 (4000 ind./m^3). *Brachionus urceolaris* and *Brachionus calyciflorus* were the most abundant species over study period at all lake basins.

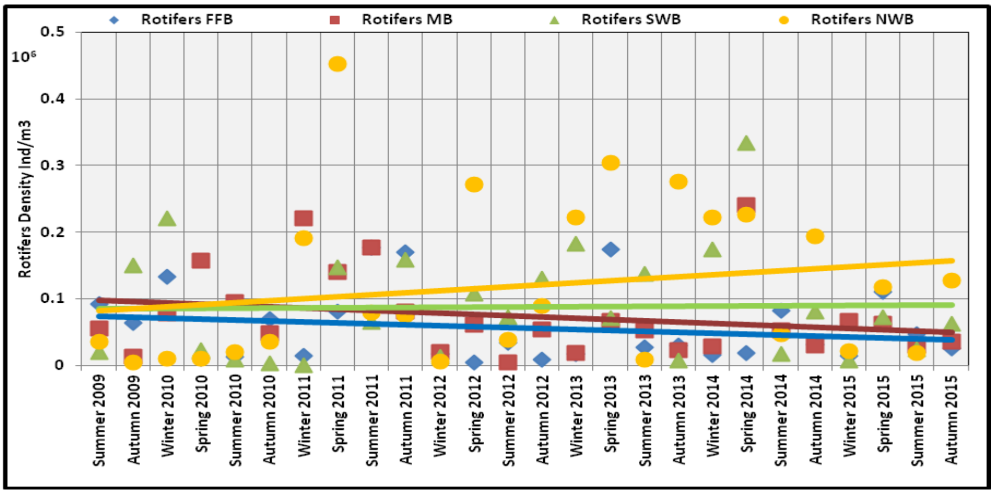

Fig. 7: Time series trend of rotifer density in the 4 lake basins during 2009-2015.

Copepod density at all 4 lake basins exhibited gradual increasing trend with time (Figure 8). In NWB, copepod density showed high peak in spring 2013 (222500 ind./m^3) and low break in winter 2010 (4500 ind./m^3). In SWB, the density showed high peak in summer 2013 (45500 ind./m^3) and low break in winter 2011 (1000 ind./m^3). In MB, copepod density attained high peak in winter 2015 (97250 ind./m^3) and low break in summer 2012 (2000 ind./m^3). While in FFB, the density attained high peak in winter 2015 (71500 ind./m^3) and low break in winter 2012 (500 ind./m^3). *Acanthocyclops americanus* and *Nitocera lacustris* were the most dominant species in NWB, SWB and FFB, while *Acanthocyclops americanus* and *Thermocyclops crassus* were dominant in the MB.

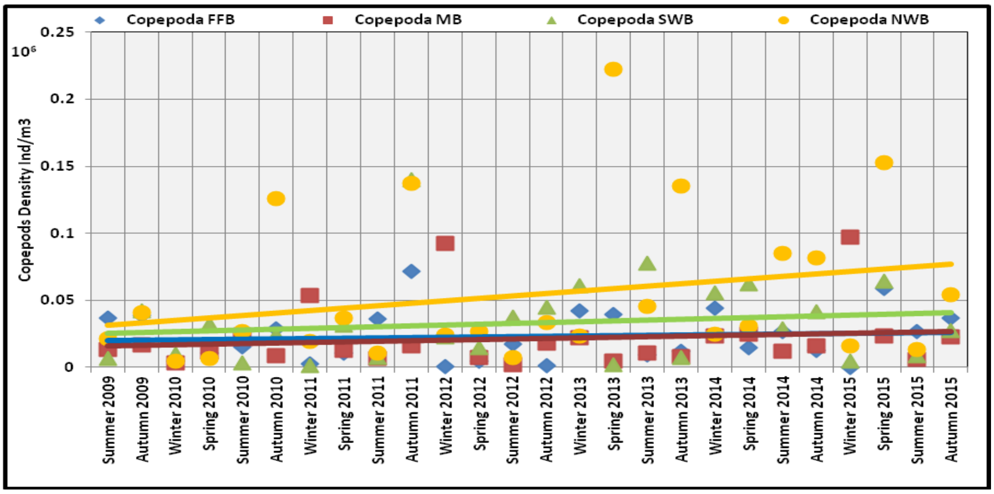

Fig. 8: Time series trend of copepod density in the 4 lake basins during 2009-2015

Ostracod density was trend to a gradual decrease with time at NWB, MB and FFB (Figure 9). In NWB, the density attained high peak in summer 2010 (52000 ind./m^3) and low break in spring 2014 (1500 ind./m^3). At SWB basin, ostracod density recorded its high peak in winter 2011 (135500 ind./m^3) and low break in autumn 2012 (500 ind./m^3). In the MB, the density attained high peak in summer 2012 (59250 ind./m^3) and low break in winter 2015 (250 ind./m^3). While in the FFB, ostracod density attained high peak in summer 2009 (36000 ind./m^3) and low break (500 ind./m^3) during spring 2012, summer 2012, autumn 2012 and autumn 2015. Protozoans, nematods, cladocerans and mollusks were poorly represented at all lake basins. Ciliated protozoans were represented by *Paramecium* spp at all the lake basins.

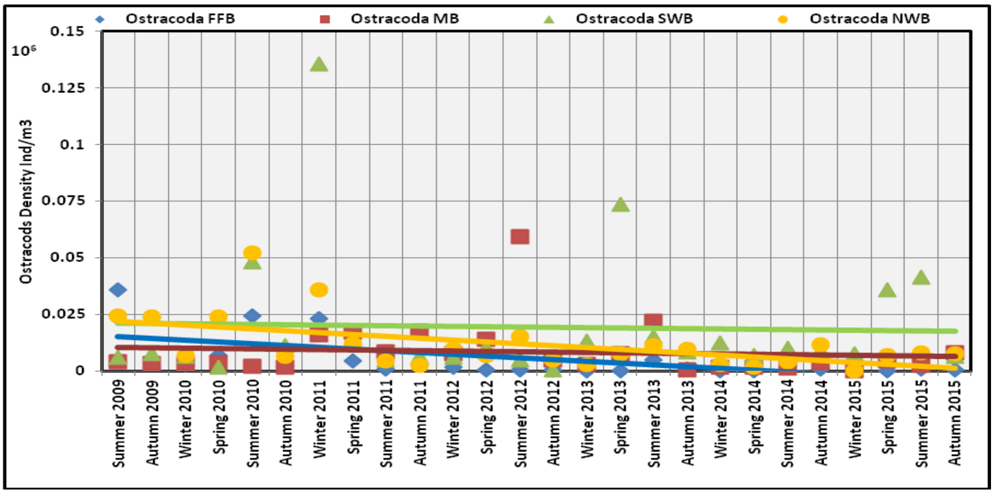

Fig. 9: Time series trend of ostracod density in the 4 lake basins during 2009-2015

DISCUSSION

The present study illustrates the changes in hydrographic conditions and zooplankton community over the course of time series in Lake Mariout. The environmental data obtained from time series trends of the hydrographic conditions indicated the deterioration in the Lake ecosystem. The present results revealed that the water temperature and salinity of the lake were trending to decrease with time. The lake was fairly turbid, the water transparency was very low (10 - 60 cm). Low transparency values were recorded near the sites of disposal of El-Kalaa Drain (Abdallah, 2003). The hydrogen ion concentration was trend to increase with time. The water of Lake Mariout had dissolved oxygen concentration values usually above the minimum of the WHO standard (5 mg DO/l) required for water quality assessment (Nkwo*et al.*, 2010). According to the present results, the concentration of ammonia was trend to gradual increase. The highest concentration of ammonia is principally attributed to the dumping of sewage and untreated wastes. Nitrite concentration in Lake Mariout was gradually decreased with time. The nitrite produced within the lake is principally from nitrification of ammonia. On the other hand, the present result recorded sever breakdown in the nitrate concentration with time. Sever decreasing of nitrate could be attributed to the reduction of nitrate to ammonia through the de-nitrification process (Scheffer 2004). The present results indicated the stability in phosphorus concentration. However, the present results indicate the low nutritional status of Lake Mariout. Further evidence of the low nutrient availability in the Lake is the gradual decrease of the chlorophyll-a concentration, which showed a steady decrease over the years parallel to the decrease in nutrient concentration. Monitoring chlorophyll levels is a direct way of tracking algal growth. There are many human activities that affect chlorophyll in water, such as sewage inputs and destruction of lake shorelines (Abdallah, 2003). The main aspect determining the distribution of zooplankton is the availability of nutrients that effect on phytoplankton abundance and as a consequence the survivability of zooplankton (Vrede, 1999).

The time series analysis of zooplankton density in Lake Mariout over 7-year study period showed that the total zooplankton density exhibited considerable decreasing trend with time. Previous studies (Samaan & Aleem, 1972; Abdel Aziz, 1987; Guerguess, 1988 and Abdel Aziz & AboulEzz, 2004) gave further evidence about a gradual degradation in zooplankton abundance. Zooplankton density dropped from about one million ind./m^3 in 1982-1983 and 360x10^3ind./m^3 in 1996 to 119635 ind./m^3 in 2009-15. As a result of heavy pollution coming from the discharge of industrial, agricultural and untreated domestic wastes into Lake Mariout, the water quality has severely deteriorated, and the Lake became highly eutrophic. Several studies concluded that Lake Mariout is considered the most heavily polluted of the northern delta lakes (Abdallah, 2003 and Saad & Safty, 2004) and the previous investigations on zooplankton assemblages confirmed this condition (Abdel Aziz, 1987; Guerguess, 1988, Abdel Aziz & AboulEzz, 2004 and El-Damhogy *et al*., 2016). In the present study, the dominance of Rotifera over other zooplankton groups indicated the polluted condition of the Lake. Although Rotifera is represented by 27 species, only 2 species appeared as dominant. Many rotifer species are considered as indicators of trophic status. *Rotaria* is among the poly saprobes organisms that inhabit highly polluted environments (Slideek, 1983). Meanwhile *Brachionus angularis*, *B. urceolaris*, *B. calycjfiorus*, *Filinia longiseta* and *Lecane* spp. indicated less-polluted water. The occurrence of some species in high abundance provides a good overview of the water quality (Gutkowska*et al*., 2013). Thus, the dominance of *Brachionus* spp. in Lake Mariout indicated the polluted nature of the lake. The occurrence of *Brachionus* spp. is important indicator of the status of aquatic ecosystem (Zakaria & El-Naggar, 2019). During 7 years of study period, seven *Brachionus* species were recorded in Lake Mariout. Previously, Samaan & Aleem (1972) recorded five species of *Brachionus*, Abdel Aziz (1987) listed six species, Guerguess (1988) recorded seven species, Abdel Aziz and AboulEzz (2004) identified six species and El-Damhougy (2016) mentioned that genus *Brachionus* was represented in the lake by ten species. Mageed (2008) and Uzma (2009) stated that the presence of more than five species of *Brachionus* refer to the eutrophic nature of an aquatic ecosystem.

Copepoda is considered as the second abundant zooplankton group in Lake Mariout. *Acanthocyclops americanus* was the most dominant copepod species. Copepod species are sensitive to water quality oscillations from natural or anthropogenic causes. Cladocerans are regarded among the most ubiquitous freshwater organisms. They are common in all types of fresh water, but they are more abundant in lakes and ponds than in rivers. *Moina micrura* constitute the main bulk of cladocerans in Lake Mariout and the other species were presented in low abundances. The limnetic region of many inland lakes has a cladoceran population high in the number of individuals and low in the number of species, as is the case with Cladocera in Lake Mariout. Ciliated protozoans are considered as a good indicator of organic pollution (Ferdous & Muktadir, 2009). The presence of ciliated protozoan species (*Paramecium* spp) in Lake Mariout also indicates the polluted and eutrophic condition of the Lake.

Comparison between zooplankton density at the sampling stations and NDCI showed that in 2009 there is a strong positive correlation between zooplankton density and NDCI at station 7, while there is a negative correlation at stations 3, 4, 5, 6 and 8. In 2010 there is a strong positive correlation between zooplankton density and NDCI at station 5, while there is a negative correlation at stations 3, 7, 8 and 9. In 2011 there is a strong positive correlation between zooplankton density and NDCI at station 7, while there is a negative correlation at station 1, 8 and 9. In 2013 there is a strong positive correlation between zooplankton density and NDCI at station 1, while there is a negative correlation at station 9. In 2014 and 2015 there is a strong positive correlation between zooplankton density and NDCI at stations 7 and 5, while there is a negative correlation at station 9. The results showed that station 9 had a negative correlation from 2010 till 2015. Remote sensing techniques provide the positive correlation between Chl-a and zooplankton at certain stations and negative correlation at the others which may be attributed to other factors that have adverse effect on zooplankton density.

CONCLUSION

Remote sensing data can provide accurate spatial distribution of NDCI, also using GIS programs help in the production of maps of zooplankton abundance in the study area that facilitates the comparison between these two factors yearly. Time series analyses are very helpful in the study of the past behavior of an aquatic ecosystem and predict its present. The data of time series analyses give a picture about pollution and eutrophic status of aquatic ecosystem. One promising approach to this broader ecosystem is via parallel analyses of time series of zooplankton. The present results confirmed the continued deterioration of Lake Mariout situation, which threatens the breakdown of the Lake ecosystem that could have a negative impact on its fish production.

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