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Some Investigations on Zooplankton and Biochemical Contents of Phytoplanktons inWadi El-Rayan Lakes, Egypt

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Abstract: Wadi El-Rayan is a natural protected area in Egypt. Wadi El-Rayan depression consists of two man-made lakes in the Western Desert of Egypt which receive the wastewater drainage of El Fayoum province. In the present study, seasonal variations in both phytoplankton biochemical contents and zooplankton density in Wadi El-Rayan Lakes were studied. Six stations along the two lakes were selected representing different habitats of the lakes. The major Chlorophyll *a* peak occurred in winter and the minimum values occurred in summer. The average levels of protein were higher at the stations of the first lake than that of the second. Spring was the optimum season for total lipid content of phytoplankton, while total carbohydrate increased in autumn in both lakes. Zooplankton communities were represented mainly by crustacean zooplankton (Copepoda and Cladocera) in the first lake of Wadi El-Rayan. While, Rotifera was the most dominant zooplankton group in the second lake. The statistical analysis of the studied stations according to zooplankton results showed the lowest diversity between stations of the first and second lakes confirmed the variation characteristics between the two lakes. It was concluded that the changes in biochemical content of phytoplankton, as well as changes in zooplankton abundance and diversity depend mainly on physico-chemical and biological conditions of lakes water.

Key words: Zooplankton diversity · Chlorophyll *a* · Wadi El-Rayan Depression

INTRODUCTION

Lakes and reservoirs are key components of the world's water resources, providing water for drinking, irrigation, power generation and habitat for innumerable species of plants and animals. These important resources are now under serious threat. Disturbances in the watersheds, pollution, overfishing, introduction of exotic species and excessive water withdrawals, diversions and lake reclamation are all taking a toll. Action must be taken now to protect and manage them so that they may provide their immense and varied benefits to the world's people in the future [1].

Wadi El-Raiyan Depression, El-Fayoum Governorate, is located in the Western Desert of Egypt, about 140 km southwest of Cairo. This depression was connected to the agricultural drainage system of El-Fayoum Governorate in an effort to decrease the accumulation of excess drainage water in Lake Qarun and to protect the nearby agricultural land from inundation. The project depended on the discharge of drainage water of 4,800 hectares to Wadi El-Rayan Depression. The flow of the drainage water to the Northern Wadi El-Rayan Lake (First Lake) began in April 1973. In 1983 the water flowed through an open canal about 5 km long and a vertical drop of 2.5 m over the falls located in the Southern Wadi El-Rayan Lake (Second Lake) [2]. Many changes have occurred in the Wadi El-Rayan area since the lakes were formed in 1973. Significant effects started to be seen in 1988, as the human activities with the most impact include agricultural land reclamation, digging and exploration for crude oil, fish farming, building of cafeterias and the creation of tourist visiting areas [3].

Wadi El-Rayan area has a typical hyper-arid desert climate [4], hot and dry with bright sunshine throughout the year. The potential evapotranspiration rate is extremely high, throughout the year; coupled with low precipitation, this makes the area one of the most arid places in the world. Plankton dynamics or the time dependent changes in plankton biomass are the result of a complex interplay of physical, chemical and biological processes. The seasonal cycles of biological parameters are usually driven by factors referred to as physical biological [5]. Therefore, plankton diversity in relation to

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water quality is a well practiced protocol, accepted all over the world, which help to describe an ecological system and is a measure of community pattern [6,7]. Plankton diversity is controlled by seasonal changes as well as by the rate at which plant nutrients are supplied. Primary production has performed by chlorophyll bearing plants ranging from the tiny phytoplankton to the giant kelps through the process of photosynthesis. Zooplankton plays an important role as secondary producers and together with phytoplankton; they support the vast assemblages of food chain with all their diversity and complexity. Data on chlorophyll pigments, phytoplankton and zooplankton has regarded as a sound basis for environmental appraisal of ecosystems [8].

The present investigation was concerned with Wadi El-Rayan as a natural protected area in Egypt. The study was mainly initiated to establish data base information on the seasonal biochemical characteristics of algal community at the surveyed parts and the associated zooplankton. This study might be helpful for regulating the ecosystem and maintaining the aquatic fauna and flora.

Fig. 1: Map of Wadi El-Rayan Lakes showing the selected stations. (After [36]).

MATERIALS AND METHODS

Sampling Locations: The two Wadi-El Rayan Lakes lie between 30° 20´- 30° 25´ E and 29°05´- 29°20´ N. Three locations along each of the first and second lakes of Wadi El-Rayan were chosen (Fig.1). The selection of these locations was based on the variability in the habitat features. Seasonal sampling programme takes place during the period from February (winter) to November (autumn) 2006.

Physico-chemical Characteristics: Temperature, pH, transperancy, dissolved oxygen and salinity were measured at each location. Water temperature was measured by an ordinary thermometer, pH by Orion Research Ion Analyzer 399A pH meter and transparency by Secchi disc. Dissolved oxygen (DO) was determined by azide modification method as specified [9].

Phytoplankton Sampling and Biochemical Analysis: The water samples were collected by plastic bottles, then sieved and filtered through zooplankton net (100 µm pore diameter) to separate macrozooplankton. Then the filtered water was refiltered on Whatman GF/F (0.7 µm pore diameter) fiber circles and the samples were transferred to the laboratory in ice tanks to determine the biochemical parameters of the separated phytoplankton.

Chlorophyll *a* values were measured according to standard method [9]. The total protein content was determined by Biuret method [10], while, total carbohydrate content was determined by phenol sulphuric acid method [11]. The total lipid content was recorded by the Sulphophosphovanillin procedure (SPV) [12].

Monitoring of the Zooplankton Population: The water samples were monitored qualitatively and quantitatively for the seasonal variation in their zooplankton content. Zooplankton samples were collected by using a plankton net of 55 µm mesh size and a mouth diameter of 30 cm. the net was vertically hauled from 2m depth to the surface. Collected samples were kept in plastic bottles with some lake water to which 4% formalin was added as a preservative. The filtered volume of water was calculated according to the standard method [9]. Samples were studied under the compound microscope and specimens were identified to the species level when possible. Zooplankton density was expressed as number of organisms per cubic meter. Many publications and taxonomic references were used for identification [13-21]. The statistical analysis was performed using Primer 5 (2001).

RESULTS AND DISCUSSION

It is well known that, the physical and chemical characteristics controlling life in aquatic habitats, either saline or brackish water, lead to the appearance of special types of biota [22]. The average water temperature of Wadi El-Rayan Lakes was subjected to seasonal variations. The water temperature reached its minimum in winter (14.2°C), while the maximum of 28.8°C was recorded in summer samples. High water temperature recorded in summer period was mainly due to the high intensity of solar radiation and low water level. While low temperature recorded in winter were probably due to the prevailing weather experienced in the area during this season. Transparency is always higher in the second Lake, it varied from 60-300 cm and from 65-175 cm in the first Lake. El-Shabrawy and Dumont [23] mentioned that, the vegetation in the connecting channel reduces the suspended material and consequently increases transparency in the second Lake. The pH values were always in the alkaline side with small differences without seasonal variations, it ranges between 8.1-8.53 in the first Lake and in the second Lake ranged between 7.98 and 8.42.. This general tendency to the alkaline side may be due to the increased photosynthetic activity of planktonic algae, or to the chemicals nature of water [24].

Salinity in the second lake (11.69-12.94‰) is much higher than the first lake (1.53-1.73‰), Abd Ellah [25] explained that as a result of the dilution effect of drainage water in the north. Also, El-Shabrawy [26] explained that the continuous inflowing of brackish water (gained salt) from El-Wadi Drain to the first lake and out flowing to the second lake through connected channel (loss salt), leads to fairly constant of first lake salinity levels. Since the second lake is considered as closed basin, so the rate of salinity undergoes progressive increase.

The biochemical compositions determine the nutritive quality of phytoplankton as natural food grazers such as zooplankton [27]. The chlorophyll *a* values give an idea of phytoplankton biomass. Figure (2A) showed that the major chlorophyll *a* peak occurred in winter (242.1 µg/l in the first lake and 17.83 µg/l in the second lake). Table 2 revealed their abundance in stations 2 and 3 (485.95 and 226.5 µg/l), while the minimum values occurred in summer (7.53 µg/l in the first lake and 4.9 µg/l in the second lake). These results were confirmed by Konsowa [28] who studied the phytoplankton community during the same period of study which found that the maximum total algal counts were recorded in winter (1120 X 10^4 unit/l), while the minor peak (167 X 10^4 unit/l) was recorded in summer. This finding is mainly due to outburst of blue green algae in mid area of the first lake during winter and declined in

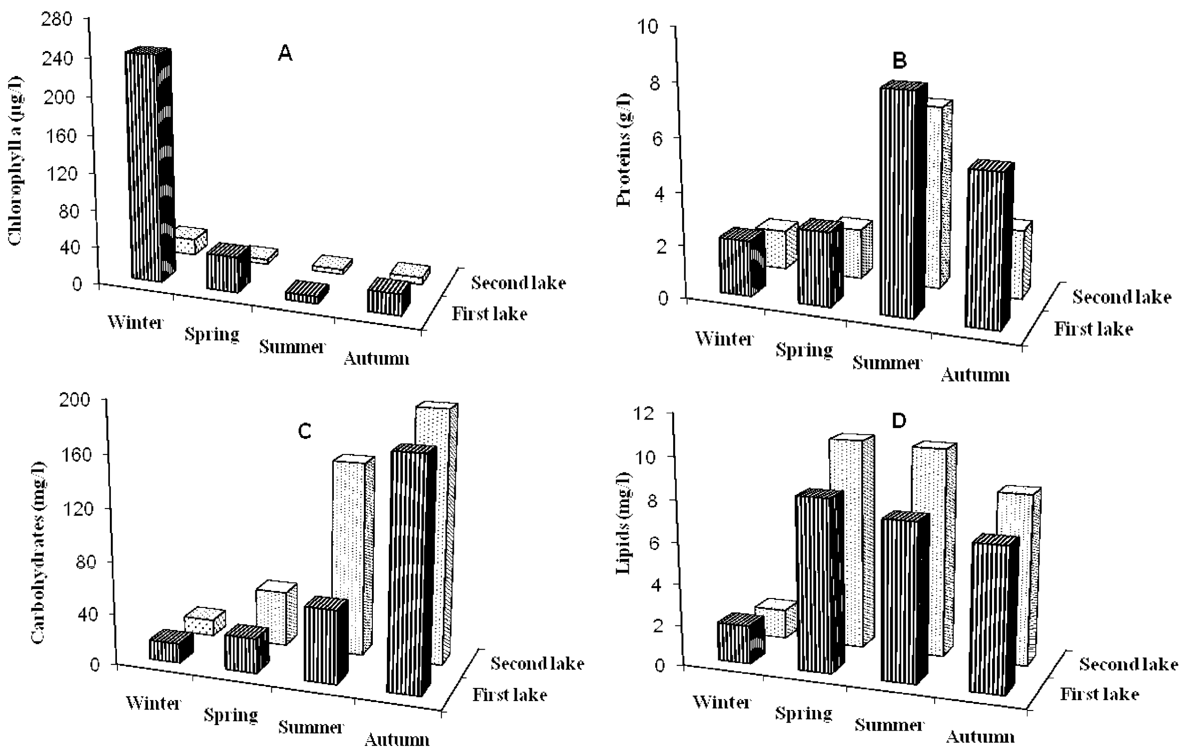

Fig. 2: Seasonal variations in total biochemical content of phytoplankton in Wadi El-Rayan Lakes during the study.

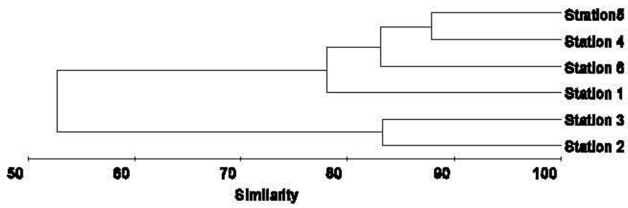

Fig. 3: Cluster analysis of the studied station according to chlorophyll *a* data.

summer. Cyanophyceae were the most dominant (68% of the total phytoplankton) and represented with 16 species. The winter bloom was visible to the naked eye which formed of the colonial *Microcystis aeruginosa* and *Microcystis flos-aquae* triggered markedly in autumn and extended to spring. This event was accompanied by a rapid decline in the green algae and diatoms during summer [28,29]. Abd El-Karim [30] recorded these blue greens among the periphytic algae in Wadi El-Rayan Lakes. Also, Konsowa and Abd Ellah [31] indicated that *Microcysitis* blooming arise when the Lake is being highly eutrophic, particularly in January. On the other side, zooplankton grazing was declined to the lower extent in winter [32,33]. Dawes [34] indicated that the sharp drop in phytoplankton in the summer in temperate zones may not be caused by a depletion of nutrients; instead the decline in phytoplankton biomass may be due to a rapid rise in zooplankton.

Also, the decline in chlorophyll *a* in the second lake was attributed to phytoplankton density in the lower one which decreased southwards from 127 X 10^4 unit/l to 47 X 10^4 unit/l, due to decrease nutrients (N and P) and increase in salinity levels southwards which decreased freshwater algae and induced some marine algal species depending on the total weight of living algae phosphorus and inorganic nitrogen are the most limiting nutrient to primary production in water where phosphorus deficiency affects algal metabolism, growth and photosynthetic activity [35]. On the contrary, Chlorophyll concentration in the second lake was always much higher than in the first lake. The highest values of chlorophyll *a* in both lakes were observed during the winter mixing, these high values were attributed to the release of the nutrients that accumulated during the spring and summer stratification [2]. During the present study the average concentrations of ortho-P, nitrite, nitrate in the first lake sites showed slight increase compared with the second lake [36].

Cluster analysis of Chlorophyll *a* measures revealed two main groups, stations 2 and 3 and stations 4, 5 and 6. The discharging area of El-Wadi drain into the first lake (Station 1) is forever loaded with high nutrient concentrations (N and P) and may be explain why station 1 revealed the lowest similarity with the rest of sites (Fig. 3). The highest similarity (87.9%) was recorded within the 2nd group (stations 4 and 5).

According to Carlson's trophic index depending on the total weight of living algae, the first reservoir is classified as mesotrophic or eutrophic water, while the second lake oligotrophic or eutrophic [28].

The results of this study revealed that the maximum contents of total protein in phytoplankton (Fig. 2B) was found in summer in both lakes with an average of 8.16 and 6.91 g/l for first and second lake, respectively. Maxwell *et al.* [37] suggested that an early light-inducible protein (ELIP) of some green algae serve as light harvesting protein increased in summer season of high light intensity. Summer was the optimum season for Chlorophyceae which occupied the dominant class in the first lake and the second one in the second lake where *Binuclaria tenuis*, *Planktonema lauterbornii*, *Oocystis* spp., *Cosmarium* spp., *Stigeoclonium* sp. and *Closteriopsis* spp. were the abundant species[3,28].

The average levels of protein were higher at stations of first lake than that of the second (Table 1). Konsowa [28] mentioned that the phytoplankton densities in the upper Wadi El-Rayan Lake were much higher than the lower lake (4.8 folds). This may be due to the high nutrient concentrations loaded with drainage water via El-Wadi Drain. The maximum water turbidity values at Wadi El-Rayan Lakes with more suspended matter (in the form of phytoplanktonic organisms) were found in the first lake [36].

The maximum levels of total carbohydrate concentration was found in autumn reached 173.3 and 193.3 mg/l for first and second lakes, respectively (Figure 2C and Table 1). Carbohydrates constituted the major part of the biochemical contents of the epiphytic microalgae in Lake Bardawil [38]. Brouwer *et al.* [39] showed that the diatoms of Lake Manzala had the ability to produce copious amounts of extracellular polymeric substances (EPS), mainly consist of carbohydrates, thus responsible of the input of high-quantity organic carbon into the sediment which used as a food source for heterotrophic consumer [40].

Table 1: The values of total biochemical composition of phytoplankton in the studied stations at Wadi El-Rayan Lakes during the study

	First lake				Second lake			
	St. 1	St. 2	St. 3	Avg.	St. 4	St. 5	St.6	Avg.
Chlorophyll *a* (µg/L).								
Winter	13.70 ±0.55	485.95 ±5.4	226.5 ±1.3	242.1	12.8 ±0.45	24.5 ±0.98	16.2 ±0.34	17.83
Spring	16.74 ±0.76	56.5 ±1.2	40.8 ±1.5	38.01	8.2 ±0.32	5.2 ±0.22	2.2 ±0.23	5.2
Summer	3.3 ±0.15	7.5 ±0.35	11.8 ±0.88	7.53	3.35 ±0.65	2.85 ±o.24	8.5 ±0.38	4.9
Autumn	32.4 ±1.5	8.8 ±0.43	25.5 ±1.3	22.23	11.3 ±0.56	7.0 ±0.37	4.7 ±o.29	7.67
Avg.	16.54	139.69	76.15		8.91	9.89	7.9	
Total protein contents (g/L).								
Winter	4.02 ±o.7	1.43 ±0.03	0.91 ±0.07	2.12	0.88 ±0.09	2.49 ±0.4	1.17 ±0.02	1.51
Spring	1.79 ±0.008	5.3 ±o.81	1.35 ±0.01	2.81	1.22 ±0.05	2.52 ±0.06	2.01 ±0.08	1.92
Summer	8.91 ±0.54	8.12 ±0.62	7.45 ±0.84	8.16	7.64 ±o.81	7.67 ±o.33	5.43 ±1.00	6.91
Autumn	6.03 ±0.57	6.38 ±1.01	4.47 ±o.78	5.63	2.68 ±0.23	3.05 ±0.73	2.07 ±o.19	2.6
Avg.	5.19	5.31	3.55		3.11	3.93	2.67	
Total carbohydrate contents (mg/L).								
Winter	10.67 ±0.85	26 ±0.99	8 ±0.66	14.89	13.33 ±0.45	10.67 ±0.32	14.67±0.77	12.89
Spring	32 ±1.22	20 ±1.05	28 ±0.87	26.67	20 ±0.98	52 ±1.65	56 ±1.87	42.67
Summer	80 ±1.88	12 ±0.75	76 ±2.33	56.0	80 ±2.87	280 ±5.76	88 ±2.55	149.33
Autumn	140 ±2.55	200 ±5.32	180 ±4.09	173.3	250 ±5.85	140 ±2.06	190 ±3.98	193.33
Avg.	65.67	64.5	73		90.83	120.67	87.17	
Total lipid contents (mg/L).								
Winter	1.8 ±0.09	0.73 ±0.05	3.07 ±1.02	1.87	1.67 ±0.76	1.13 ±0.78	1.53 ±0.45	1.44
Spring	6 ±1.03	9.6 ±1.65	9.4 ±1.08	8.33	15.2 ±1.08	11.2 ±1.86	4.4 ±1.04	10.27
Summer	13.6 ±1.54	5.2 ±0.98	4 ±0.55	7.6	10.6 ±2.05	9 ±1.56	10.8 ±2.03	10.13
Autumn	3.8 ±0.34	4.2 ±0.67	12.6 ±2.05	6.87	18.4 ±1.99	3.2 ±0.98	3.2 ±1.02	8.27
Avg.	6.3	4.93	7.27		11.47	6.13	4.98	

Table 2: Seasonal changes in total zooplankton density (Organisms/m^3) in Wadi El-Rayan Lakes during the study

	First Lake			Second Lake		
	St.1	St. 2	St.3	St.4	St.5	St.6
winter	43359	38605	53664	8558	5516	3111
spring	32045	52266	36315	25393	162890	145317
summer	11517	7973	23223	21129	43189	90367
autumn	55014	45116	34872	16317	41275	15311
Avg.	35484	35990	37019	17849	63218	63527

Table 3: Species number, population density, richness, evenness and shanno diversity index of zooplankton in the samples localities during the study

	First lake			Second Lake		
Parameter	St.1	St. 2	St.3	St.4	St.5	St.6
Population Density (Organisms.m^{-3})	35484	35990	37019	17849	63218	63527
No. of species	38	32	35	49	24	32
Diversity Index [H')	3.270	3.317	3.582	2.936	1.888	1.779
Evenness [E)	0.623	0.663	0.698	0.523	0.412	0.356
Species Richness [SR)	3.53	2.95	3.23	4.90	2.08	2.80

Figure (2D) illustrated that spring was the optimum season for total lipid contents of phytoplankton in Wadi El-Rayan Lakes with an average of 8.33 and 10.27 mg/l for first and second lakes, respectively. The optimum value of total lipids was recorded in spring in Lake Qarun and at Milwaukee River [41,42]. Thus the results indicated that the phytoplankton biochemical compositions of Wadi El-Rayan Lakes are variable in the four seasons according to changes in environmental conditions.

Many factors can affect the distribution of plankton in an ecosystem, which has a detrimental effect on the rest of the ecosystem. Regarding to seasonal changes, total zooplankton community showed consistently high abundance at all studied sites of the first Lake in winter and autumn compared with that of the second Lake, while summer was the least productive season for zooplankton in the first lake (Table 2). Low population density of zooplankton registered coincided with the decline in phytoplankton (as indicated by chlorophyll *a*) in summer suggest that the decrease in zooplankton production may be attributed to unavailability of food in form of phytoplankton.

The sharply declined of zooplankton at all sites of second lake during winter (Table 2) where diatoms dominated the phytoplankton groups in the number of species and individuals [28]. Most of the abundant species such as: *Cyclotella meneghiniana, Synedra ulna*, *Nitzschia* spp. and *Navicula* spp. which dominated mainly in the study area, were reported as indicator species of high productive and/or waste water polluted water body [43-45]. Also, *Cyclotella* was reported among the governing organisms of the eutrophic lakes and reservoir worldwide [46].

The highest population density of zooplankton was recorded at stations 5, 6 in the second Wadi El-Rayan Lake with highest average of about 63000 Organisms.m^{-3}. The lowest density was attained at northern station 4 (17849 Organisms.m^{-3}) of the same lake, which attained at the same time, the maximum number of zooplankton species (49) as well as the highest value of species richness (4.9) as shown in table (3). Mageed [47] reported that zooplankton was poor at the northern part of the second lake due to the filtration of its water through the macrophytes of the connecting canal between the two lakes in addition to oxidation of the organic matter through the water-fall at this site. Station 5 attained the lowest number of species (24) and consequently the lowest richness (2.08). The evenness and diversity index showed its lower values at station 6, while their highest values were detected at station 3 (Table, 3).

The statistical analysis showed a highly similarity index (93%) between stations 1 and 2 and with them and station 3 (1st group), followed by stations 5 and 6 (87.8%) which considered 2nd group. Station 4 revealed the lowest similarity with the rest of sites (Fig.4). On the other side, the lowest diversity values between the first and second groups confirmed the variation characteristics between the two lakes. Mansour and Sidky [48] reported that the second water lake was more contaminated by trace metals and pesticides than the first.

Zooplankton abundance varied from 3111 Organisms.m^{-3} at station 6 in winter to 162890 Organisms.m^{-3} at site 5 in spring (Table 2). Average zooplankton densities in the first Lake (36.164 Organisms.m^{-3}) was lower than that of the second lake (48.198 Organisms.m^{-3}), the increase in population density in second Wadi El-Rayan Lake mainly due to due to the sharp increase of zooplankton standing crop at stations 5 and 6 in spring and summer (Table, 2). Also the decrease of average zooplankton densities in the first Lake may be due to the blue green algal bloom [28], it is known that Cyanobacteria are low quality food for zooplankton, due to their filamentous or colonial structure, low digestibility and toxin production, inducing limitations to the growth and reproduction of zooplanktonic organisms [49]. On the contrary, the average numbers of the zooplankton organisms in the Upper Lake was 131.057 org/m^3 and the Lower Lake was less productive than the Upper Lake (37.4681 org/m^3)[2]. Also, Mageed [47] found that the annual average number of zooplankton in the first lake was more than four folds of the second lake (106.746 and 22.924 Organisms. m^{-3}, respectively). It is appeared that the total zooplankton in the first lake sharply decreased in number compared with the previous studies and this may be attributed to the continuous discharge of agricultural drainage water and the outflow of water used in land reclamation and aquaculture activities. While the slight increase of zooplankton in the second lake may be as a result of appearance of some marine species started to appear concurrent with the rise in salinity.

Zooplankton communities during the present study were represented mainly by crustacean zooplankton (Copepoda and Cladocera) in stations of the First Wadi El-Rayan Lake forming about 69% of the total zooplankton (Table 4). Copepeda attained an average of 16510 Organisms.m^{-3}, constituting 45.6% of total zooplankton. Larval forms of copepods constituted about 76 % of the total group, the cyclopoid *Thermocyclopes* sp., *Megacyclops* sp. and the calanoid *Thermodiaptomus galebi* were abundant. Crustacean zooplankton were the main dominant group in the first Wadi El- Rayan Lake [32,50]. While Copepoda during the present study dropped to 25 % of total zooplankton count in the second Lake, it flourished in station 4 as it formed 48% of total zooplankton and gradually decreased until reached about 13% in station 6 (Table 4). In Second Wadi El-Rayan Lake juvenile copepods reached 92% of the total group. The adult stage was dominated by the cyclopoid *Thermocyclops* sp., Scattered specimens of the harpacticoide *Nitocra lacustris* were detected mainly in spring and summer (Table 5). In addition to the appearance of marine calanoid *Paracartia latisetosa* which were considered with its nauplii and copepodides as the most important copepods in Lake Qarun [51]. *Paracartia latisetosa* has been found in many sites of the Ponto Mediterranean Province [52] where it prefers confined environments independently from the salinity (from 10 ‰ in the Azov Sea up to 50‰ salinity in Bitter lakes of Suez Canal). The maximum peaks of Copepoda occurred at stations 1 and 5 in autumn which corresponding minimum values of total carbohydrates contents of phytoplankton. The grazing impact of Copepods can remove daily up to 9% of phytoplankton biomass on the Galician shelf [27].

Cladocera was less abundant, contributed about 23% of the total zooplankton count in the first lake, with an average of 8358 Organisms.m^{-3}. The cladoceran *Diaphanosoma excisum* was perennially appeared in upper lake during the study (Table 5), the maximum occurrence of this genus was in spring in addition to flourishing of *Ceriodaphnia reticulate* and *Chydrous sphericus* in winter. Mageed [47] reported that *D. excisum* was the main dominant cladoceran species in the first Wadi El-Rayan Lake. As shown in tables (4 and 5), Cladocera were nearly disappeared in the second lake except scattered specimens of the marine form *Podon polyphemoides* newly appeared in winter and spring. In Wadi El-Rayan Lakes it is clear that salinity changes control Cladocera community. El-Shabrawy [33] mentioned the presence of four cladoceran species in the second Wadi El-Rayan Lake and also added that chorosity showed a strong negative relation with Cladocera.

The population density of rotifers in the First Wadi-El- Rayan Lakes attained an average of 10881 Organisms.m^{-3}. The maximum average of 15202 Organisms.m^{-3} detected in winter, while the minimum average of 4100 Organisms.m^{-3} was noticed in summer. In Wadi-El Rayan temperature plays a major role in rotifer abundance [53]. During the study *Keratella quadrata* was the most dominant rotiferan species in first Lake, it formed about 56% of the total rotifer and it dominated the rotifers in winter and spring. The species was completely disappeared from the lake in summer and scarcely occurred in autumn. In the second lake *K. quadrata* was noticed in winter and rarely recorded in spring. Winter is regarded as the most productive season for *K. quadrata* in Wadi EL-Rayan and it considered from rotifer genera prefer cold water [53]. *Colotheca cornata* was the second predominant rotifer in first lake, forming about 14.7 % by number of the total rotifer and it became abundant during autumn and totally disappeared in winter. Scattered specimens of this species only recoded in station 4 in the second lake in summer and autumn (Table 5).

Rotifera appeared as the most dominant zooplankton group in the second lake (Table 4), their average standing crop was 35793 Organisms.m^{-3}, constituting about 74 % of total zooplankton. This was confirmed El-Shabrawy [33,53] who mentioned that the maximal flourishment of Rotifera occurred in the second lake of Wadi El-Rayan. On the contrary, Rotifera constituted the third important group in terms of abundance after Copepoda and Cladocera comprising about 17.2 and 38.9% of the total zooplankton count in the first and second lake respectively [47]. The dominance of rotifera in the second lake during the present study mainly due to the outstanding peaks of *Hexarthra oxyuris* in spring especially in stations 5 and 6 (which attained high salinity levels) and *Brachionus pliatilis* in summer which formed about 63.2 and 34.3 % of the total group during the study, respectively. *Brachionus pliatilis* is a cosmopolitan, eurohaline, warm water rotifer [54]. *Brachionus pliatilis* and *Hexarthra oxyuris* revealed a high density in the tail of the second lake, where highest chlorosity values were recorded [53]. The other rotifer species detected in the second lake were rarely appeared in one station or more during the study (Table 5). The maximum abundance of Rotifera found at stations 5 and 6 in spring which may be produced at the expenses of the lowest chlorophyll *a* concentration at this season. In Lake Aydat, the rotifers community could play an important role in the regulation of seasonal succession of phytoplankton and bacteria [55]. During this study water temperature and salinity seem to be the most important factors controlling succession of rotifers in Wadi-El Rayan lakes.

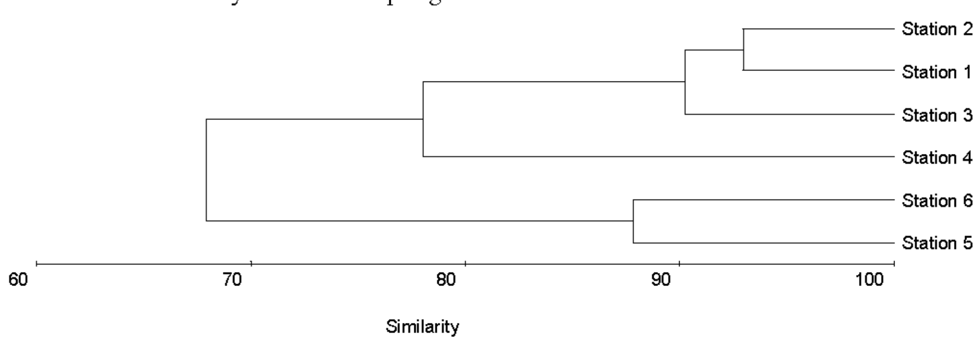

Fig. 4: Cluster analysis of the studied station according to zooplankton data.

Table 4: Variations in groups composition of zooplankton (Organisms/m^3) and its percentage abundance to the total density in Wadi El-Rayan Lakes during the study

	First Lake						Second Lake					
	St. 1		St. 2		St. 3		St. 4		St. 5		St. 6	
	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%
Rotifera	11539	32.5	10717	29.8	10387	28.0	7618	42.7	45454	71.9	54306	85.5
Copepoda	18280	51.5	15595	43.3	15656	42.2	8566	48.0	17025	26.9	8354	13.2
Cladocera	5298	14.9	9607	26.7	10168	27.4	64	0.4	159	0.3	64	0.1
Protozoa	244	0.7	53	0.1	69	0.2	578	3.2	216	0.3	272	0.4
Others	124	0.3	18	0.05	789	2.1	1024	5.7	364	0.6	532	0.8

Table 5: Seasonal distribution of zooplanktonic fauna in water of Wadi-El Rayan Lakes over the study period

	First Lake			Second Lake		
	St.1	St. 2	St.3	St.4	St.5	St.6
Protozoa						
Arcella vulgaris	A			W,Su		
Carchesium sp.				W		A
Centropyxis oculeata	A			W,Su,A		
Epistylis sp.				A		
Euglypha sp.				Su		
Vorticella sp.	W	Su				
other ciliates	Su	Su	Su	S,Su		A
Helicostomella sp.				Su,A		
Tintinopsis sp.	A	A	A	Su,A	A	A
Rotalaria sp.	A	Su	A	A	Su	A
Testularia sp.		A		W	W,S	S
Other Forminefera				A	S	S,A
Rotifera						
Asplanchna priodonta	S		W	Su		
Anuraeopsis fissa				W		
Brachionus angularis	A			W,S,A		S
Brachionus calyciflorus	A	A	A	Su		
Brachionus quadridentatatus		W				
Brachionus plicatlis	Su,A	Su,A	Su,A	S,Su	S,Su	S,Su
Brachionus urceolaris				S,A		
Cephalodella sp.			W	Su		
Colltheca cornata	S,Su,A	S,Su,A	S,Su,A	Su,A		
Colurella adriatica	A			W,S,Su,A		Su,A
Filinia longiseta				Su		
Hexarthra oxyuris.	Su	Su		S,Su	S,Su,A	S,Su,A
Keratella cochlearis	A	Su	Su		S,Su	
Keratella quadrata	W,S,A	W,S,A	W,S,A	W	W	W,S
Keratella tropica	S,Su,A	W,S,Su,A	S,Su,A	W,A	A	A
Lecane luna			W			A
Lecane sp.				Su		A
Macrochaetus sp.				S		
Monostyla bulla	A	A	A	S,Su,A		A
Monostyla closterocerca				W,Su,A	A	Su,A
Monostyla hamata.				W,Su		
Monostyla lunaris				Su		
Monostyla sp.		Su	A	Su		A
Philodina roseola	S,A	A	A	W,S,Su,A		W,A
Polyarthra vulgaris	A	S,A	W,S,A			
Rotaria sp.	S			Su,A		A
Synchaeta sp.			W			
Trichocerca sp.	A	Su		S,Su	S	
Other Rotifera	A		Su	Su		Su,A

Table 5: Seasonal distribution of zooplanktonic fauna in water of Wadi-El Rayan Lakes over the study period

	First Lake			Second Lake		
	St.1	St. 2	St.3	St.4	St.5	St.6
Copepoda						
Nuplius larvae	W,S,Su,A	W,S,Su,A	W,S,Su,A	W,S,Su,A	W,S,Su,A	W,S,Su,A
Copopodit	W,S,Su,A	W,S,Su,A	W,S,Su,A	W,S,Su,A	W,S,Su,A	W,S,Su,A
Thermodiaptomus galebi	W,S,A	W,S,A	W,S,Su,A			
Paracartia latisetosa				Su	Su	Su,A
Thermocyclops sp.	W,S,Su,A	W,S,Su,A	W,S,Su,A	W,S,Su,A	W,Su,A	W,S,Su,A
Megacyclops sp.	S,Su	S,Su	S,Su,A	Su	Su	S,Su
Mesocyclops sp.	A					
Nitocra lacustris				W,S,Su	S	S,Su,A
Cladocera						
Alona intermedia	W,S,A	W,S				
Bosmina coregoni	S		A			
Bosmina longirostris	S,A		A			
Ceriodaphnia reticuata	S	S	W,S			
Chydorus sphaericus	W,S	W,S	W			
Dadaya sp.			W			
Diaphnia longispina	W,S	W	W		W	
Diaphanosoma brachyurum	W,S	W,S	W,S			
Diaphanosoma excisum	W,S,Su,A	W,S,Su,A	W,S,Su,A			
Podon polyphemoides				S	W,S	W,S
Moina sp.				Su		
Others						
Ostracoda	Su,A	Su	W,S	Su,A	S,Su	A
Mollusca larvae			W	Su	A	S,Su,A
Free Living Nematoda		W	W	S		A
Polychaeta larvae				S,A	S,A	S,Su,A
Nauplius larvae of Balanus				Su	Su	A
Insect larvae				W	W	

W: winter Sp:Spring Su:Summer A:Autumn

During the study, the other components, which comprised members of Protozoa, Ostracoda,, nauplius larvae of *Balanus*, Mollusca larvae, Polychaeta larvae and others (Table 5), were rarely encountered and they contributed collectively ~1.7 % of the total zooplankton.

Zooplankton can consume a substantial portion of the phytoplankton, but zooplankton-phytoplankton relationships within Wadi-El Rayan lakes were variable seasonally and among sites. The present study indicated that in the first lake there was no clear relation between zooplankton density and chlorophyll *a* content of phytoplankton, while in the second lake, zooplankton seems to fallow chlorophyll *a* content in winter, summer and autumn seasons. The maximum count of zooplankton in stations 5 and 6 in spring associated with decreasing in chlorophyll *a* concentration (Fig. 5). The abundance of phytoplankton is the result of the balance of reproduction, selective grazing, mortality and sedimentation [56]. Bleiwas and Stokes [57] found grazing rates increasing with chlorophyll concentration, but their data were limited to oligotrophic lakes (0.3-3 μg chlorophyll. l^{-1}). In a study performed in the shallow lakes located in northern and central Florida, it was mentioned that in subtropical and tropical lakes grazing by zooplankton is of little importance for controlling the phytoplankton community structure and biomass [58].

The influence of flow of drainage effluent in the first lake and the amount of water released to the second lake will enhance great changes in phytoplankton community structure and its biochemical content, as well as changes in zooplankton abundance and diversity. The salinity of the second lake is likewise increasing and this is likely to diminish its importance. The greatest threat to the area comes from a land-claim project (in progress) which aims at cultivating 15,000 feddan of desert, right in the centre of Wadi El Rayan Protected Area. Fish-farming taking place in and around the lakes, is a potential source of water-pollution. In addition there is a possibility that

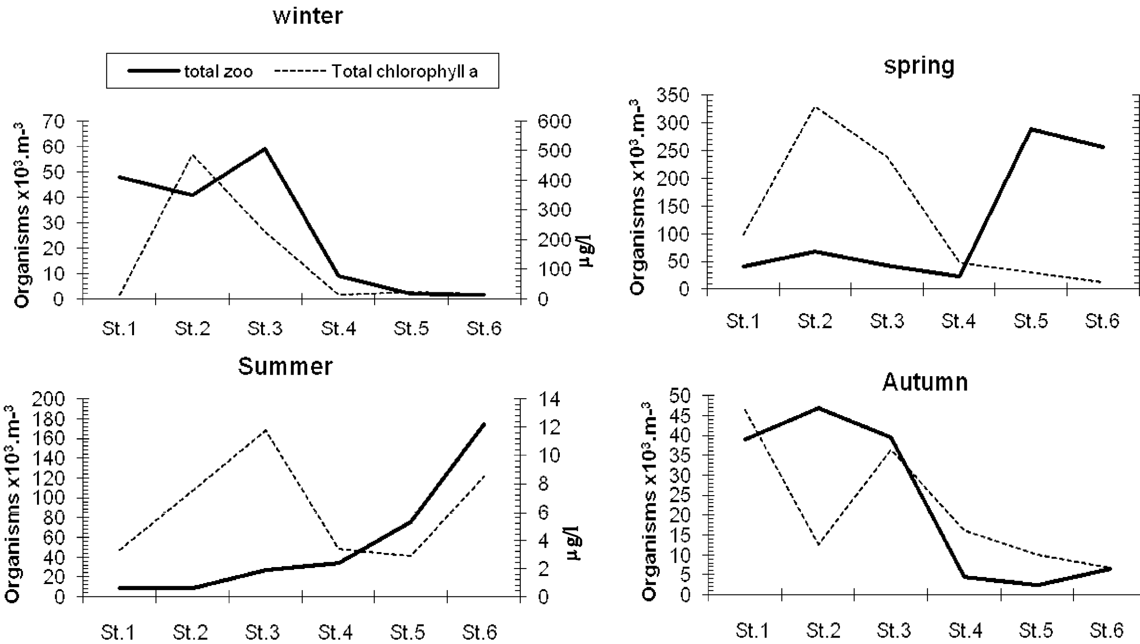

Fig. 5: Seasonal variations in total zooplankton and chlorophyll *a* in Wadi El-Rayan Lakes during the study.

water flow to the lakes will be severely reduced in the future as part of the drainage-water recycling policy the government is applying to conserve water. This would lead to a great reduction in the size of the second lake or its complete disappearance which consequently affect the biota in Wadi El Rayan. Declaring Wadi Al-Rayan as a protected area has required reaching some objectives related to: natural resources management, sustainable tourism and environmental awareness and biodiversity conservation.

In conclusion, the biochemical constitutes of phytoplankton and population densities and species composition of zooplankton communities in Wadi El-Rayan Lakes depends mainly on physico-chemical and biological conditions of the water.

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