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Correlation Between Algal Taxa and Physico-chemical Characters of the Protected Area of Wadi El-Rayan, Egypt

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ABSTRACT

The present investigation 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 physicochemical characteristics of the surveyed parts and monitor the associated algal community. The application of TWINSPAN classification technique led to the recognition of 8 algal groups, each group included a set of stands, which were similar in their habitat and characterized by indicator species. All TWINSPAN soil groups (four groups) were characterized by low content of organic carbon. Group I comprised two stands dominated by *Anabaena wisconsinense* and *Chlorella vulgaris.* Group II comprised 6 stands and *Anabaena wisconsinense* was the indicator species. Group III included 11 stands indicated by *Chroococcus limnneticus* and *Oscillatoria hamelii*. Group IV comprised 3 stands indicated by *Anabaena bornetiana.* Classification analysis by TWINSPAN successfully clarified that group V belongs to winter season and dominated by *Pinnularia gibba*. The five stands of group VI represent winter and summer seasons and indicated by *Gloeothece rupestris* and *Merismopedia elegans* var. *major*. Group VII comprised three stands belonging to the spring season dominated by *Ankistrodesmus falcatus* var. *tumidus* and *Oscillatoria tenuis* var. *tergestina*. Group VIII was represented by three stands belonging to autumn season with indicator species *Chroococcus limneticus* and *Nitzschia radicula*.

Key Words: Algae; Soil; Water; Protected area

INTRODUCTION

Wadi El-Rayan is located in the western desert of Egypt (approx. 125 Km to the southwest of Cairo & 40 Km southwest of El-Fayoum governorate). Linant de Bellefonds discovered Wadi El-Rayan in 1873 and described this area as a great depression. This depression is located between latitudes 28° 15` and 29° 17` N. The lowest point of the floor of the depression is at -60 m below sea level (22 Km^2), at the sea level, the contour is about 301 Km^2 and at +30 m above sea level its area is about 703 Km^2. Its maximum breadth is 25 Km at longitudes 30° 12` and 30° 32` E (Zahran, 1971). Wadi El-Rayan was once a barren, un-inhabited depression in Egypt's Western Desert and has the advantages of being near the Nile Valley. In the late 19^{th} century there was a debate as to whether to use Wadi El-Rayan as a reservoir for the Nile's flood water as it has a considerable depth 60 m below sea level at its lowest point. But this suggestion was shelved by building a dam at Aswan as the best solution (Kassas, 1984). In the late 1960s, the agricultural drainage of the Fayoum farmland into Lake Qarun (45 m below sea level) exceeded its capacity so Wadi El-Rayan depression was found suitable to divert part of this drainage water through canals and tunnels that built to transfer water from the Fayoum to Wadi El-Rayan. This drainage water eventually created two lakes, which added a significant feature to the Rayan landscape and provided a wetland habitat for a variety of resident and transient wildlife (Hewison, 1984). The upper lake reached its maximum level in 1978, covering approximately 5,100 hectares in the Wadi El Masakheet sub-depression and is being used to irrigate newly developed agricultural areas and aquaculture schemes. From here the water flows through a shallow swampy area and over a waterfall into the lower lake, which is not yet full but is estimated to cover approximately 7,700 hectares.

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 (Fig. 1). All of these springs provide drinking water for wildlife, (Saleh *et al*., 1988; Saleh *et al*., 2000), with all these developments taking place, the water management of Wadi El-Rayan is receiving renewed attention (Wadi El-Rayan protected area project, 2002). Wadi El-Rayan area has a typical hyper-arid desert climate (Ayyad & Ghabour, 1986), 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. The prevailing winds are north-west, north or north-east, resulting in the formation of extensive sand dunes (Saleh *et al*., 1988 & 2000).

Now, the main threat to the effective long-term protection of the Wadi El-Rayan protected area is seen to be the development of un-controlled economic activities within its boundaries. These activities include large-scale land reclamation schemes, major oil extraction operations, rapidly expanding aquaculture, commercial fishing and tourism, as well as human settlement in highly sensitive areas such as previously un-disturbed habitats used by gazelles and other key species (IUCN, 1998a & b). The aim of this study was to focus on the qualitative and quantitative assessment of the existing ecosystem conditions of the natural protectorate area of Wadi El-Rayan. This includes studying the physicochemical properties of the soil and water habitats and surveys the algal community, in order to establish data base information system for this area of Wadi El-Rayan, which will be monitored on regular basis for further studies. This could help to identify the potential risk hazards for possible early intervention.

MATERIALS AND METHODS

Sampling

Sampling locations. Three locations along the second lake of Wadi El-Rayan were chosen. The selection of these locations was based on the variability in the habitat features. Where, each location included three different habitats, which are water, wet soil and dry soil (i.e., the wet soil is continuously in contact with water body, while the dry soil is away from the contact with the water body). This means that nine stands were sampled every season. Overall, 36 stands (numbering from 1 - 36) represented all locations of the different habitats during the different seasons during the study period and the stands representing the different habitats are labeled as follows:

Water habitat (stands 1 - 12), wet soil habitat stands (13 - 24) and dry soil habitat, stands (25 - 36).

The stands are labeled according to the season of sampling as follows:

Winter season stands (1 - 3, 13 - 15 & 25 - 27); Spring season stands (4 - 6, 16 - 18 & 28 - 30); Summer season (stands 7 - 9, 19 - 21 & 31 - 33) and Autumn season stands (10 - 12, 22 - 24 & 34 - 36).

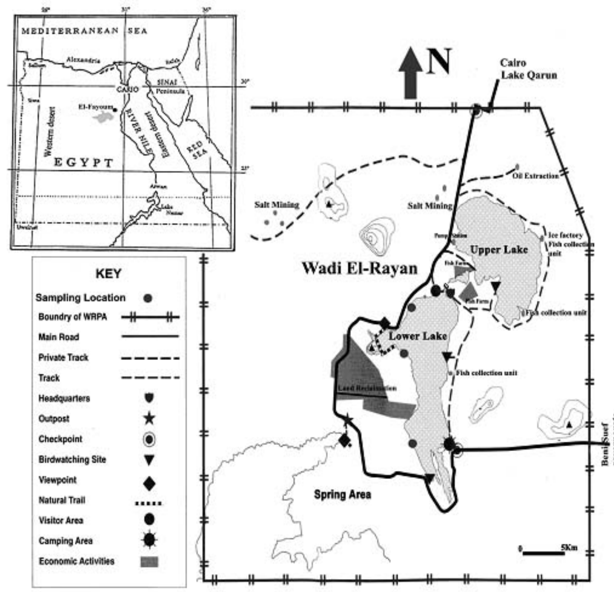
Sampling procedures. A water sampler was used to collect surface water (at 0 - 15 cm depth) in sterilized bottles from the different stands. The soil collection (wet & dry types) was carried out according to John (1942). The surface soil layers, normally to a depth of 2.0 cm were removed with a knife and were freed from gravels and debris and collected in sterile plastic bags.

Each water and soil sample represents a mixture of four random samples from each stand. The collected samples were kept in an ice box and transported to the laboratory for the sub-sequent studies.

Physicochemical Analysis

Soil analysis. Soil texture analysis was carried out using the sieving method to estimate the percentage of gravel, coarse and fine sand, silt and clay. The hygroscopic moisture

Fig. 1. Map of Wadi El-Rayan Protected Area showing the different activities in the study area (Design by Egyptian-Italian Environmental Programme)



content of the soil was estimated by oven drying soil samples. Total carbonates were estimated by titration according to Jackson (1962). The modified Walkely Black method was used for organic carbon estimation (Jackson, 1962).

Soil-water extracts of 1:5 were prepared and used for determination of electric conductivity (E.C.) by using electric conductivity meter (mmhos cm^{-1}) and the soil reaction (pH) was measured by a glass electrode pH meter.

Water analysis. Water pH was measured by a glass electrode pH meter and the electric conductivity (E.C.) was estimated by electric conductivity meter (mmhos cm^{-1}), then the water samples were subjected to the following chemical analyses: carbonate and bicarbonate estimation (Jackson, 1962), Chloride (Vogel, 1961), salinity, sulphate, phosphate, sodium, potassium, calcium hardness and total hardness were estimated according to Standard Methods for the examination of water and wastewater (1985). Magnesium (Mg^{2+}) ion concentration was calculated by subtracting the value of calcium hardness from the value of total hardness. Ammonia and nitrate were estimated according to Markus *et al.* (1982).

Isolation and Culturing of Algae

Soil algae. The moist plate technique recommended by Jurgensen and Davey (1968) was applied on air dry soil samples for cultivation of the algae that might be persisting in the form of spores, hormogonia, akinetes or any other perennating stages. One gram of each soil sample was added to 99 mL of a 0.7% sterile saline solution (as an osmotic protecting solution) then placed in a reciprocating shaker for 20 min. Three replicate Petri-dishes were inoculated each with 1 mL of the appropriate dilution and 25 mL of the molten medium were added. Different media were used for isolation and cultivation of the different algal genera. These media were Z-medium (Staub, 1961), Soil extract medium (Starr & Zeikus, 1993), Allen's medium (Allen, 1968) and Spirulina medium (Vonshak, 1984). The inoculated media were incubated in constant light intensity (4000 Lux) at 35°C for preferential isolation of the blue-green algae and at 25°C for the eukaryotic algae until good growth had been obtained (3 - 6 weeks). Then the number of colony-forming units on each plate was estimated on dry weight basis of the soil.

Monitoring of the phytoplankton population. The water samples were monitored qualitatively and quantitatively for the seasonal variation in their phytoplankton content. Parts of the water samples from each stand were preserved by using Lugol's iodine solution then the living and preserved cells were counted and identified according to the systems proposed by Pascher (1913); Fritsch (1935); Desikachary (1959); Chapman (1962); Palmer (1959); Baker and Bold (1970); Prescott (1962 & 1978) and Bourrelly (1966 & 1970), diatoms were cleared and identified according to Riley (1967); Al-Mausawi (1984) and Cox (1996). Centrifugation was carried out to concentrate the algal cells and the counting was conducted using an improved Neubauer Haemacytometer. Any filamentous or massed colonial forms were counted as one unit.

Multivariate and statistical analyses. TWINSPAN, Two Way Indicator Species Analysis (Hill, 1979) was applied for the classification of stands and species into groups based on the relative abundance of the species (reported as a percentage of the total count). The Detrended Correspondence Analysis (DCA) (Ter Braak, 1987) was used to ordinate stands and species in two-dimensional space using the relative abundance of species. The physicochemical analyses data of the TWINSPAN groups were compared using one-way ANOVA (SPSS package program, version 11, 2001).

RESULTS

Classification and ordination analyses. The classification and ordination techniques portray the algal vegetation groups of the different habitats in the study area.

TWINSPAN classification analysis of the algal isolates. The TWINSPAN classification analysis was done based on the relative abundance of the recorded identified species in the selected 36 stands. Obviously, 34 stands were the output of the TWINSPAN classification; this was due to the elimination of stands number 29 and 33 as both were devoid of any algal species. It was clear that the Dendrogram cluster analysis (Fig. 2) classified the investigated habitats into two major groups with different species composition at level number 2. The first one included soil habitat (22 stands) with the indicator species *Oscillatoria tenuis*. The second group comprised the remaining stands (12 stands), which represented the water habitat with three indicator species (*Synedra acus*, *Chlorella vulgaris* & *Phormidium* sp.).

The further classification led to the recognition of 8 algal vegetation groups at level number 4, where they are coinciding with their habitat types. These groups were labeled I, II, III, IV, V, VI, VII and VIII. Each group included a set of stands, which were characterized by indicator species.

Soil algal groups. Algal vegetation species at level number (4) were summarized in Table I for the groups I, II, III and IV, which represent the different soil types (wet & dry soil). Group I comprised two stands (22 & 26) with indicator species *Nostoc punctiforme* and dominated by *Anabaena wisconsinense* and *Chlorella vulgaris.* Group II comprised six stands (23, 27, 31, 32, 34 & 35) with *Anabaena wisconsinense* as the indicator and dominant species. Group III included 11 stands (13, 14, 16, 17, 18, 19, 21, 24, 28, 30 & 36), which were indicated by the *Chroococcus limnneticus* and *Oscillatoria Hamelii*. Group III was sharing the group IV in the same dominant species (*Oscillatoria tenuis*). Group IV comprised three stands (15, 25 & 20) with indicator species *Anabaena Bornetiana*.

Water algal groups. Algal groups representing the water habitat are separate at level 4 and they are labeled V, VI, VII and VIII (Table II). Group V was represented by only one stand (number 1) belonging to winter season. This group is devoid of the blue-greens and indicated by *Pinnularia gibba,* which is dominant species.

Five stands (2, 3, 7, 8 & 9) were representing group VI, which represented the winter and summer seasons. This group was indicated by the species *Gloeothece rupestris, Merismopedia elegans* var. *major* and *Phormidium* sp. The later is recorded as the most dominant species. Group VII comprised three stands (4, 5 & 6), which belonged to the spring season with *Chroococcus limneticus* var. *distans* as indicator species and dominated by *Ankistrodesmus falcatus* var. *tumidus* and *Oscillatoria tenuis* var. *tergestina*. Group VIII was represented by three stands (10, 11 & 12) belonging to autumn season with indicator species *Chroococcus limneticus* and *Nitzschia radicula* and dominated by *Ankistrodesmus falcatus* var. *tumidus* and *Chlorella vulgaris*.

Physico-chemical Characteristics of the TWINSPAN Groups

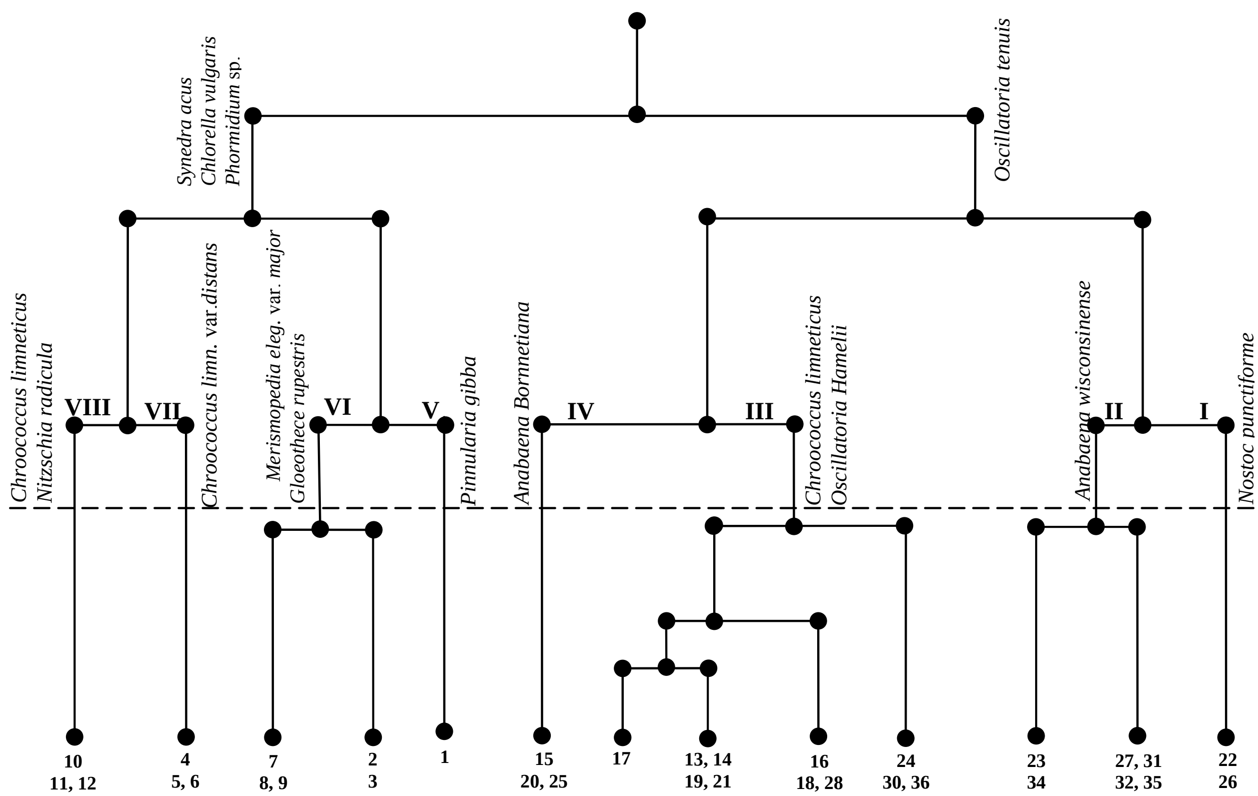
Soil habitat. Table III showed the results of the estimated physico-chemical characteristics of the TWINSPAN groups, which represent the soil habitat in the area of study. Soil pH ranged between 7.68 in group III to 7.98 in group IV, where no significant differences are observed between pH values among the soil habitat groups. Electrical conductivity (E.C.) recorded its maximum value in group IV (1.41 mmhos cm^{-1}) and minimum value in group II (1.07 mmhos cm^{-1}). Moisture content ranged between its maximum of 14.5% in group III to the minimal value of 3.92% in group II.

No significant differences were observed in soil

Table I. Relative abundance of the studied TWINSPAN groups which represent the soil habitats in the study area

Sampling site Algal sp	TWINSPAN Group																					
	I		II						III											IV		
	22	**26**	**23**	**27**	**31**	**32**	**34**	**35**	**13**	**14**	**16**	**17**	**18**	**19**	**21**	**24**	**28**	**30**	**36**	**15**	**20**	**25**
Cyanophyta																						
Anabaena bornetiana Collins	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	19.5	68.6	42.9
A. wisconsinense Prescott	37	75.9	22	76.8	100	100	37.5	100	-	-	-	-	-	-	-	3	-	-	-	-	-	-
Chroococcus limnneticus Lemmermann	-	-	21	-	-	-	-	-	8.1	8.1	-	7.69	-	11.2	25.9	-	-	-	-	11.7	-	42.9
Nostoc punctiforme (Kuetz.) Hariot	1	6.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Oscillatoria hamelii Frémy	31	-	-	-	-	-	-	-	56.4	56.4	50	7.69	56.6	59.4	35.6	21	50	-	-	35.2	11.4	-
O. tenuis C.A.Agardh, Algarum Decades	-	-	43	24.2	-	-	62.5	-	35.5	35.5	50	84.6	37.7	29.4	38.5	47	50	100	100	33.6	20	14.3
Species no.	3	2	3	2	1	1	2	1	3	3	2	3	2	3	3	3	2	1	1	4	3	3
Chlorophyta																						
Chlorella ellipsoidea Gerneck	31	17.2	14	-	-	-	-	-	-	-	-	-	-	-	-	29	-	-	-	-	-	-
C. vulgaris Bejerinck	-	-	-	-	-	-	-	-	-	-	-	-	5.66	-	-	-	-	-	-	-	-	-
Species no.	1	1	1	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-	-
Total number of species	4	3	4	2	1	1	2	1	3	3	2	3	3	3	3	4	2	1	1	4	3	3

Fig. 2. The Dendrogram resulting from the cluster analysis with 8 algal vegetation groups as derived from automatic classification



texture fractions during the investigation period among the different soil groups except the silt fraction, which was significantly different. Groups III and IV were characterized by a slightly higher gravel values (35.1%). Group IV recorded its maximum percentage of sand (36.2%) and followed by group III (32.5%) and declined to reach its minimum in group I (22.7%). The percentage of silt varied between 13.3% in group IV and 20.7% in group I. Clay fraction showed its maximum value in group II (23.3%) and recorded a minimum percentage of 15.3% in group IV. All TWINSPAN soil groups were characterized by low content of organic carbon and fluctuated between 0.3% in group I and 0.64% in group III. Apparently, carbonate ions were not detectable in the soil groups.

Bicarbonate level was detected in the range of 1.29 mg/100 g soil in group II to 2.21 mg/100 g soil in group IV. The highest percentage of the total soil carbonate was exhibited by group IV and recorded 5.43%, while the minimum value was estimated in group III (4.29%). Sulfate recorded its maximum value in group I (314 mg/100 g soil) and was reduced in the other groups to reach its minimum level in group III (161 mg/100 g soil). The chloride content of the soil groups showed its maximum in group I and recorded its minimum value in group IV (7.55 & 3.8 mg/100 g soil,

Table II. Relative abundance of the studied TWINSPAN groups which represent the water habitat in the study area

Algal species	TWINSPAN Group											
	V			VI			VII			VIII		
Sampling site	1	2	3	7	8	9	4	5	6	10	11	12
Cyanophyta												
Anacystis sp.	-	-	-	9.32	8.86	-	-	-	-	-	-	-
Chroococcus limneticus var. *distans* G.M.Smith	-	-	-	-	-	-	7.7	3.8	3.2	-	-	-
C. limnneticus Lemmermann	-	-	-	-	-	-	-	-	-	1.3	7.3	7.9
C. pallidus Naegeli	-	-	-	0.61	-	-	-	-	-	-	-	-
C. prescottii, Drouet&Daily in Drouet	-	-	-	-	-	-	-	9.09	2.04	-	-	-
C. turgidus (Kützing) Naegeli	-	-	-	-	-	4.55	-	-	-	-	-	-
Gloeothece rupestris (Lyngb.) Bornet in Wittrock & Nordstedt	-	22.2	52.2	-	-	-	-	-	-	-	-	-
Lyngbya birgei G.M. Smith	-	-	-	19.6	29.1	17.8	-	-	-	-	-	-
Merismopedia convoluta de Brébisson	-	-	-	-	-	-	5.61	-	2.8	-	-	-
M. elegans var. *major* G.M.Smith	-	33.3	19.4	4.28	1.36	5.8	2.04	-	-	-	-	-
M. glauca (Ehrenb.) Naegeli	-	-	-	1.22	0.91	-	-	-	-	-	-	-
M. punctata Meyen	-	-	-	4.58	2.5	2.28	3.06	6.66	5.57	-	-	-
M. tenuissima Lemmermann	-	-	-	-	-	-	-	-	-	-	1	-
Nostoc commune Vaucher	-	-	-	-	-	-	-	-	0.74	-	-	-
Oscillatoria hamelii Frémy	-	-	-	7.34	12.7	7.87	-	-	-	-	-	-
O.rubescens De Candolle	-	-	-	0.61	0.91	-	-	-	-	-	-	-
O. tenuis var.*tergestina* (Kützing) Rabenhorst	-	-	-	8.56	11.4	14.3	-	-	-	-	-	-
Phormidium sp.	-	11.1	16.4	13	14.3	23	9.7	30.3	29.9	-	-	-
Species no.	-	3	3	10	9	7	5	4	6	1	2	1
Chlorophyta												
Acanthosphaera zachariasi Lemmermann	-	-	-	0.76	-	-	-	-	-	-	-	-
Ankistrodesmus braunii (Naeg.) Brunnthaler	-	-	-	-	-	0.83	-	-	2.78	-	-	-
A. convolutus Corda	-	-	-	-	-	2.28	14.3	-	-	-	-	-
A. falcatus var. *acicularis* (A.Braun) G.S.West	1.92	-	-	-	-	-	3.06	0.51	1.3	-	-	-
A. falcatus var. *tumidus* (West&West) G.S. West after Smith	-	-	-	-	-	-	26.5	22.3	12.5	56	-	65
Chlorella vulgaris Beyerinck 1890	-	-	-	7.34	5.23	6.82	-	8.58	5.2	27	40	9.6
Dictyosphaerium pulchellum Wood	-	-	-	3.36	0.91	2.28	-	17.2	15.2	-	-	-
Dunaliella sp.	1.09	-	-	-	-	-	-	-	-	-	-	-
Franceia droescheri (Lemm.) G.M.Smith	-	-	-	0.61	-	0.83	-	-	-	-	-	-
Gomphosphaeria aponina var. *olelicatula* Virieux	-	-	-	-	-	-	2.04	-	-	1.3	-	-
Scenedesmus acuminatus (Lag.) Chodat (after Smith)	-	-	-	-	-	-	-	-	1.3	-	-	-
S. quadricauda (Turp.) de Brébisson in de Brébisson&Godey	-	-	-	-	-	-	-	-	1.3	-	-	-
Selenastrum westii G.M.Smith	-	-	-	-	-	-	5.61	-	-	-	-	-
Ulothrix sp.	-	-	-	-	-	-	-	-	0.74	-	-	-
Species no.	2	-	-	4	2	5	5	4	8	3	1	2
Bacillariophyta												
Amphora coffeaeformis (Agardh) Kützing	-	-	-	-	-	-	-	-	1.3	-	-	-
A. libyca Ehrenberg	-	-	-	-	-	-	-	-	0.74	-	-	-
A. ovalis Kützing	1.09	-	-	-	-	-	-	-	-	-	-	-
Caloneis silicula (Ehrenberg) Cleve	3.01	-	-	-	-	-	-	-	-	-	-	-
Cocconeis placentula Ehrenberg	7.12	-	-	-	-	-	-	-	-	-	-	-
Cyclotella meneghiniana Kützing	1.92	4.04	-	0.92	-	-	5.61	-	1.5	-	-	-
Cymbella affinis Kützing	-	-	-	-	-	-	-	-	0.74	-	-	-
C. ehrenbergii Kützing	1.09	-	-	-	-	-	-	-	-	-	-	-
C. silesiaca Bleisch	1.92	-	-	-	-	-	-	-	-	-	-	-
Diatoma mesodon (Ehrenberg) Kützing	-	-	-	2.6	-	-	-	-	-	-	-	-
D. vulgaris Bory	6.03	-	5.97	-	-	-	-	-	-	-	-	-
Diploneis elliptica (Kützing) Cleve	-	-	-	-	-	-	-	-	1.3	-	-	-
Fragilaria capucina Desmazières	-	-	-	-	-	-	-	-	1.3	-	-	-
Gomphonema angustatum (Kützing) Rabenhorst	-	4.04	-	-	-	-	-	-	-	-	-	-
G. gracile Ehrenberg	1.1	-	-	-	-	-	-	-	-	-	-	-
G. olivaceum (Hornemann) Brébisson	2.2	-	-	-	-	-	-	-	-	-	-	-
Navicula capitatoradiata Germain	-	-	-	-	-	-	2.04	0.51	0.75	-	-	-
N. cryptocephala Kützing	8.22	-	-	-	-	-	-	-	-	-	-	-
N. radiosa Kützing	-	-	-	-	-	-	-	-	-	-	5	-
Nitzschia alpina Hustedt	-	-	-	-	-	-	3.06	0.51	-	-	-	-
N. closterium (Ehrenberg) W.Smith	-	-	-	-	-	-	-	-	-	-	1.4	-
N. hungarica Grunow	-	-	-	-	-	-	-	-	-	-	1.4	-
N. palea (Kützing) W.Smith	-	-	-	0.92	-	-	3.06	-	0.75	-	-	-
N. radicula Hustedt	-	-	-	-	-	-	-	-	-	13	39.1	15
Pinnularia gibba Ehrenberg	43.6	-	-	-	-	-	-	-	-	-	-	-
P. viridis (Nitzsch) Ehrenberg	4.11	-	-	-	-	-	-	-	-	-	-	-

Table II. Continued

Stauroneis anceps Ehrenberg	-	-	-	-	-	-	-	-	0.75	-	-	-
S. kriegerii Patrick	-	-	-	-	-	-	-	-	-	-	1.4	-
Surirella oblonga Ehrenberg	-	-	-	-	-	-	-	-	0.75	-	-	-
Synedra acus (Kützing) Hustedt	2.2	7.07		12.6	11.8	11.4	-	-	0.75		1.4	-
S. berolinensis Lemmermann	12.33	7.07	-	-	-	-	-	-	-	-	-	-
S. ulna (Nitzsch) Ehrenberg	1.09	-	-	0.92	-	-	3.57	-	-	-	-	-
S. vaucheria (Kützing) Kützing	-	11.1	5.97	-	-	-	-	-	-	-	-	-
Tabellaria fenestrata var. *fenestrata* (Lyngbye) Kützing	-	-	-	-	-	-	3.06	-	-	-	-	-
Hantzschia amphioxys (Ehrenberg) Grunow	-	-	-	-	-	-	-	0.51	2.8	-	-	-
Species no.	15	5	2	5	1	1	6	3	12	1	6	1
Euglenophyta												
Euglena convoluta Korshikov	-	-	-	0.92	-	-	-	-	-	-	-	-
Phacus nordstedtii Lemmermann	-	-	-	-	-	-	-	-	2.04	1.3	1.4	2.3
Species no.	-	-	-	1	-	-	-	-	1	1	1	1
Total number of species	17	8	5	20	12	13	16	11	27	6	10	5

respectively). Phosphate content attained its maximum value in group III of 6.35 mg/100 g soil followed by group IV (3.25 mg/100 g soil) and the lowest value was detected in group I (2.08 mg/100 g soil). Significant differences were observed in nitrate content among the different soil groups. Nitrates reached its minimum in group II (0.05 mg/100 g soil), while the other groups exhibited a similar value of 0.01 mg/100 g soil. Total hardness recorded its highest measurement in group III (127 mg/100 g soil) and showed its minimum value in group IV (69.4 mg/100 g soil). Sodium content recorded the highest cation concentration, which ranged between 161 mg/100 g soil in group III to 325 mg/100 g soil in group I. Meanwhile, iron displayed low amount and reached its maximum concentration in group III (1.42 mg/100 g soil).

Water habitat. Table IV shows the estimated physico-chemical characteristics of the water TWINSPAN groups in the study area. The data revealed no Electric conductivity recorded a high value of 9.77 mmhos cm^{-1} in group VIII and a relatively lower measurement of 8.65 mmhos cm^{-1} in group V. The estimated sulfate recorded the highest anion concentration among the detected anions in the water samples, where it recorded 424.5 ppm in group V, followed by the chloride content, which was estimated as 98.3 ppm in the same group. This high chloride concentration was reflected on the salinity value that recorded 2% in group V. Carbonates recorded its lowest concentration in group V (0.32 ppm) and highest value in group VIII (2.47 ppm). Meanwhile, phosphates content displayed its lowest content of 0.71 ppm in group VI and its highest concentration in group V (1.3 ppm). Highly significant differences were observed in both carbonate and bicarbonate contents among the different water groups. Groups VIII and V recorded the highest bicarbonate concentration. Meanwhile, bicarbonate was significantly reduced in group VI (3.54 ppm).

No significant differences were observed in nitrate level of the different water groups, except for group VIII, which was devoid of nitrates. Groups V and VI recorded the maximum nitrate content (21 ppm). Sodium recorded high significant differences and was detected as the highest cation concentration among the water samples with a maximum in groups VII and VIII. Magnesium attains its highest values in groups V and VIII (1205 & 1052 ppm, respectively). The maximum calcium value was detected in group V (638 ppm). Potassium content showed its highest concentration in groups VIII and V. Highly significant differences were observed in sodium values, but significant difference was detected in the potassium and salinity values of the different water groups. Ammonia values were estimated in low levels among the detected parameters of the water samples with a maximum of 0.45 ppm in group V. Iron metal was not detectable among the water groups.

Ordination analysis. Ordination of algal vegetation groups of the 34 stands was given in Fig. 3, which indicated the segregation of the TWINSPAN groups, which represent the different habitat types. Soil habitat stands were arranged in the middle of the lower half of the diagram (groups I, II, III & IV), that represent the two soil types (wet & dry soil) along the different studied seasons. The distances between the soil stands were near to each other; this indicated the high relativeness between them. Meanwhile, water habitat stands were scattered along the upper half of the diagram from right to left side. Stands of group V are located independently far from the other stands in the right side of the diagram. On the opposite side (extreme left side) group VIII was located. Stands of group VII were located in the middle of the upper half of the diagram. Group VI stands were present in a scattered state from the lower to the upper level in the upper half of the diagram.

DISCUSSION

The area of Wadi El-Rayan is of special value in Egypt, as a protected area and more precisely for eco-tourism as the second most visited protected area after Sinai Peninsula (Hassan, 2005).

The investigated sites are located in the second lake of Wadi El-Rayan, which is considered an end point and retaining higher concentrations of pollutants. The data recorded the seasonal physico-chemical characteristics of the natural habitats as soil (wet & dry) and lake water and established a through survey of the algal community in the

Table III. Some physico-chemical characteristics of the TWINSPAN groups that represent the soil habitat in the study area. Values are the mean of four-independent samples, followed by standard deviation; F-value is the calculated value

Parameter	Group				F-value
	I	II	III	IV	
pH	7.95±0.21	7.9±0.52	7.68±0.27	7.98±0.33	ns
E.C. mmhos cm^{-1}	1.31±1.01	1.07±0.61	1.27±0.45	1.41±0.35	ns
Moisture content %	12±16.9	3.92±8.86	14.5±10.4	9.59±9.86	ns
Gravel %	34.3±0.81	33.2±2.09	35.1±3.28	35.1±3.04	ns
Sand %	22.7±14.3	25.9±5.41	32.5±8.03	36.2±1.88	ns
Silt %	20.7±6.24	17.7±2.24	14.6±3.03	13.3±1.64	3.9 *
Clay %	22.4±7.28	23.3±3.9	17.8±5.44	15.3±2.02	ns
Organic carbon %	0.3±0.09	0.38±0.05	0.64±0.31	0.42±0.08	ns
CO_3^{--} mg/100g soil	-	-	-	-	-
HCO_3^- mg/100g soil	2.02±0.54	1.29±0.55	2.15±0.92	2.21±1.28	ns
Total Carbonate %	4.8± 1.8	4.44±0.77	4.29±0.84	5.43±1.29	ns
SO_4^{--} mg/100g soil	314±124	233±90.4	161±36.2	199±154	ns
Cl^- mg/100g soil	7.55±1.48	3.88±4.93	5.75±3.12	3.8±1.97	ns
PO_4^{---} mg/100g soil	2.08±2.02	4.58±5.05	6.35±4.76	3.35±5.11	ns
NO_3^- mg/100g soil	0.01± 0.001	0.05± 0.034	0.01± 0.013	0.01± 0.009	3.45 *
Ca^{++} mg/100g soil	49.7±16.5	61.5±30.7	53.6±21.2	45±19.5	ns
Mg^{++} mg/100g soil	47.4±26.4	34.2±21.1	73.2±61.1	51.4± 20.5	ns
Total hardness mg/100g soil	97.1±9.9	95.7±44.2	127±69.4	69.4±2.62	ns
Na^+ mg/100g soil	325±247	246±123	161±38.3	244±164	ns
K^+ mg/100g soil	17.6±0.64	14.6±2.99	16.6±3.36	18.7±1.55	ns
NH_4^+ mg/100g soil	0.13±0.1	0.08±0.06	0.12±0.06	0.12±0.07	ns
Fe mg/100g soil	1.08±0.59	0.6±0.51	1.42±0.75	1.4±0.85	ns

*****$p \leq 0.05$; ns No significant difference; - Not detectable

Table IV. Some physico-chemical characteristics of the TWINSPAN groups that represent the water habitat in the study area. Values are the mean of four-independent samples, followed by standard deviation; F-value is the calculated value

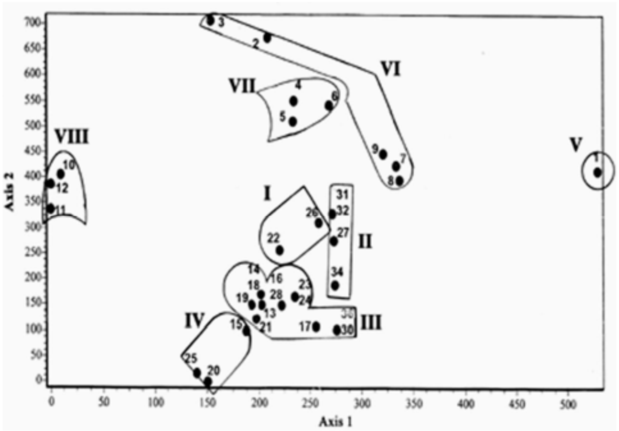
Parameter	Group				F-value
	V	VI	VII	VIII	
pH	7.95±0.07	8.66±0.45	8.22±0.19	8.22±0.19	ns
E.C. mmhos cm^{-1}	8.65±0.07	9.18±0.52	9.17±0.4	9.77±0.06	ns
CO_3^{--} ppm	0.32±0.01	1.31±0.2	1.63±0.32	2.47±0.12	34.5**
HCO_3^- ppm	8.2±0.28	3.54±0.48	5.8±1.9	8.3±0.44	15**
SO_4^{--} ppm	424.5±2.1	235±115.8	240.4±40.2	57±2.7	6.3*
Cl^- ppm	98.3±0.14	40.9±24	77±18.2	67.5±0.87	5*
PO_4^{---} ppm	1.3±0.14	0.71±0.66	0.72±0.24	0.15±0.06	ns
NO_3^- ppm	21±1.41	21±7.1	17.5±0.7	-	ns
Ca^{++} ppm	638±7.1	294.2±35.1	286±23.3	346.7±15.3	79.2**
Mg^{++} ppm	1205±4.24	870±71.3	917.7±76	1052±23.1	6.2*
Total hardness ppm	1843±11.3	1164 ±85.5	1204±98.5	1398.7±37	6.5*
Na^+ ppm	553.5±4.9	1556.8±76	1702±60.1	1698±1.73	175**
K^+ ppm	92±2.83	87.2±2.7	86.1±0.12	93.3±0.6	7.1*
NH_4^+ ppm	0.45±0.01	0.27±0.24	0.27±0.21	0.12±0.02	ns
Fe ppm	-	-	-	-	-
Salinity (g /L)	0.2±0.02	0.1±0.04	0.17±0.03	0.15±0.01	4.2*

*$p \leq 0.05$; **$p \leq 0.01$; ns No significant difference; - Not detectable

two habitats in correlation with their seasonal distribution. Obviously, the wet soil was dominated by Cyanophyta (96%) with *Oscillatoria Hamelii* (47%) and *Oscillatoria tenuis* (32.6%) as the most dominant species and Chlorophyta. A similar pattern was recorded in dry soil but with *Anabaena wisconsinense* as the most dominant species in winter and a generally very poor algal isolates in other seasons. On the other hand, water habitat harbored a relatively richer algal community belonging to the four algal phyla, Bacillariophyta (35 spp.), Cyanophyta (18 spp.), Chlorophyta (14 spp.) and Euglenophyta (2 spp.) with the spring as the richest season with algal flora and with the dominance of *Phormidium* sp. (28%) and *Ankistrodesmus falcatus* (20%).

Based on the results, the algal populations in the wet soil with high silt and clay fractions during autumn and spring were characterized by lower individual counts. Meanwhile, during summer and winter seasons they were characterized by lower silt and clay percentage and showed the maximum total isolates number. Also in the dry soil type

Fig. 3. Ordination on the axis 1 and axis 2 derived from the Detrended Correspondence Analysis (DCA)



winter season expose the minimum silt and clay fractions among the different seasons and showed the maximum individual number. This could be attributed to the finding that the winter season was characterized by high amount of HCO_3^-, SO_4^{2-}, Ca^{2+}, Mg^{2+}, Na^+, K^+ and NH_4^+. In contrast, most of the filamentous heterocystious blue-greens in desert soil have the ability to fix atmospheric nitrogen and carbon dioxide thereby increasing the organic carbon content of the soil and increasing the soil fertility and texture soil structure (El-Sheekh *et al*., 1998). The soil texture may also interfere in selecting and distributing soil algae. It takes its important effect from the fact that the presence of fine particles in one type of soil more than the other leads to the availability of more total exposed surface in such soil over that possessing coarse soil particles (Salama *et al*., 1971). It may be relevant to mention that when subsurface irrigation drainage water is discharged into a wet land, a variety of serious impacts can occur (Van Schilfgaarde, 1986; Zahm, 1986; Micklin, 1988; Lemly *et al*., 1993; Lemly, 1996). This led to conclude that the physicochemical characteristics of the lake are mainly due to the discharges of different drains into the lake and this conclusion may be in agreement with Mansour and Sidky (2003). The present study showed that the majority of algal isolates from wet-soil stands along all the studied seasons belong to Cyanophyta this might be in agreement with the observation of Kobbia and Shabana (1988), Ahmed (1994) and El-Sheekh *et al.* (1998). Most soil algae, however both in kind and number, are members of the Cyanophyceae and Chlorophyceae (Metting, 1981). Feher (1948) identified 685 taxa of soil algae reported from the literature and concluded that it was not possible to determine any geographic distribution or correlations with soil type. It appears that algae have the ability to prevent loss of soil ammonia and leaching out of nitrates by converting these forms to organic nitrogen (Shields & Durrell, 1964). The small amount of information on seasonal patterns in the diversity of soil algae suggests that seasonal succession such as those occurring in aquatic systems is not apparent in the soil (Broady, 1979; Hunt *et al*., 1979). The pH values in all stands in the present study recorded a minimum pH values more than 7 during summer and spring in both wet and dry soil types, so this might partially explain the wide distribution of blue-greens in the investigated soil types.

This highly numerous cyanophycean members as compared to other types of soil algae are a matter of tolerance and adaptability (Brock, 1973). These isolates were found to flourish under pH value more than 7 and they are intolerant to low pH conditions (Lund, 1962; Jurgensen & Davey, 1968; Bold, 1970; Brock, 1973; Dooley & Houghton, 1973).

The present study showed that the majority of algal isolates from water habitat during all the studied seasons are dominated by Bacillariophyta during winter and spring seasons with species number of 17 and 15, respectively. This could be related to the recorded mean temperature, which demonstrated the minimum values during winter and spring seasons. Meanwhile, blue-greens flourished and dominated during summer season with species number of 11, where the mean temperature reached its maximum (31.7°C). This high temperature stimulated the production of the cyanophytes. Chloropyhta recorded its highest species number during spring and summer (stands no. 11 & 6, respectively). The ability to withstand desiccation is quite common amongst the Cyanophyceae so it is not surprising that these are so abundant in such habitat (Round, 1981). Dawes (1981) 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. Both Frost (1980) and Sournia (1991) stressed that no size of class or group of algae should be considered immune from grazing and a large proportion of any phytoplankton biomass appears available to grazing though certain cyanophytes may be less palatable than other groups. Thus the determination of biomass of a phytoplankton community may not reflect the actual production, because the community may be under constant intense grazing (Arnold, 1971; Porter, 1973). Rousure (1973) pointed out that the production may not be correlated with temperature. Canale and Vogel (1974) reported that as temperature increased, the algal groups with the highest growth rate changed from diatoms to green algae to blue-greens. Kobbia (1982) pointed out that green phytoplankton dominated during summer accompanied by blue-green organisms, while diatoms flourished during autumn and winter.

TWINSPAN classification technique had classified the investigated 36 stands (two of which were devoid of vegetation) into two major groups representing two main habitats types. Those were the soil habitat (22 stands) with indicator species *Oscillatoria tenuis* and the water habitat (12 stands) with three indicator species as *Synedra acus, Chlorella vulgaris* and *Phormidium* sp. The classification successfully recognized eight algal vegetation groups, which coincided with two studied habitats; the soil (wet & dry) algal vegetation groups (I, II, III & IV) and the water algal vegetation groups (V, VI, VII & VIII) with their identified indicator species.

Bioregional studies tend to focus on landscapes and associated cultural and biological diversity (McGinnis, 2006). This investigation provides an establishment of data base information for the habitats as soil and water and the related algal vegetation with seasonal variations. Furthermore, information of the physicochemical characteristics of the TWINSPAN groups of the soil and water habitats provided more details. Based on the above, pH of the water habitat was obviously more alkaline as compared with the soil habitat value and iron was not detectable in the water groups. Although soil physicochemical characters has been considered important in determining soil algal distribution (Starks *et al*., 1981), correlations between taxa in desert soils and soil chemistry have not been made (Flechtner *et al*., 1998). To the author's knowledge this study was the first attempt to characterize the physicochemical properties of this area (lower lake) and establish a correlation with the identified algal communities.

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