Journal of Applied Sciences Research, 3(6): 495-506, 2007

Floristic Survey of Blue-Green Algae / Cyanobacteria in Saline-Alkaline Lakes of Wadi El- Natrun (Egypt) by Remote Sensing Application

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Abstract: Floristic survey of blue-green algae / cyanobacteria was carried out in saline alkaline lakes of Wadi El-Natrun region by using the tool of remote sensing during the period of January 2003 and February 2004. The locations of the collected samples were determined geographically in longitude / latitude by using the Global Position System (GPS). A total of 86 cyanobacterial taxa, among species and varieties were identified for the study area. Analysis of ANOVA indicated that each lake had distinguished species type. The technology of remote sensing provided spatial information about the whole study area. Particularly, Landsat image gave preliminary surveillance about the blooming of *Spirulina platensis* and this was confirmed by the ground reference studies.

Key words: Cyanobacteria, alkaline lakes, remote sensing.

INTRODUCTION

Blue-green algae / cyanobacteria are the most common inhabitants of saline-alkaline lakes in different parts of the world[17] as in saline lake of Saskatchewan, Canada[22], in South Africa[20], in Cuba[30], in Italy[1], in Great Salt Lake, USA[36], in East Africa[40], in Bulgaria[37], in Slovakia[24], in Kenya[34] and in China[39].

Although Wadi El-Natrun has a fair number of saline alkaline lakes with wetland surroundings, few randomly records have been published on cyanobacteria[29,2]. This leading to carryout this study which present floristic surveys of blue green algae / cyanobacteria in some of the saline-alkaline lakes of Wadi El-Natrun region, using the information acquired by the earth observing satellites (remote sensing tool).

The technology of remote sensing is providing the determination of the geographical distribution of samples through using the Global Positioning System and is also observing the blooming of phytoplankton through its characteristic spectral signatures[31].

Study Area: Wadi El-Natrun is an elongate, narrow sandy depression, about 50 km long, with an average width of 8km, oriented from south-east to north-west in a NW-SE direction between the latitudes 30° 17` and 30° 33` N and between longitudes 30° 02` and 30° 30` E, situated west of the Nile Delta (Fig. 1). It comprises a number of major shallow lakes and wetlands extending from north west to south east as follows: 1- El-Gaar Lake; 2- El-Sabkha Lake; 3- El-Khadra Lake; 4- El-Zaagig Lake; 5- El-Karnak wetland; 6- El-Hamra Lake; 7- Um El-Risha Lake; 8- El-Fasda Lake.

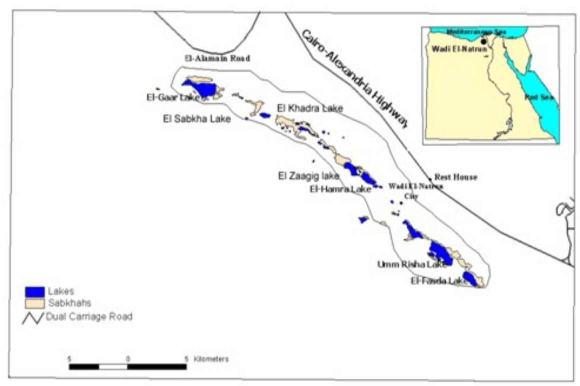

Fig. 1: The location of Wadi El Natrun in Egypt

Water of the lakes originates from the underground water through springs like the one found in Lake El-Hamra or from seepage of the Nile water, where Wadi El-Natrun is a depression which is hydrostatically linked with the delta[32,25]. The climate of Wadi – El Natrun is arid resulting in a continuous evaporation of the lakes water, which generates the formation of vast crusts of salt[7]. Limnologically, El-Gaar, El-Sabkha and El-Hamra Lakes, it's water are permanent, while the rest of the investigated lakes are dried up during certain seasons.

MATERIALS AND METHODS

Materials:

Cyanobacterial Samples: Generally all cyanobacterial samples were collected seasonally during the period of January 2003 to February 2004. In particular,

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Table 1: Geographical distribution of samples collected & the number designed for each sample
(P) = Isolated as Plankton, (B) = Isolated as Benthic

Location	Date	Sample	Position
El - Gaar lake	18 / 1 / 2003	1 , 2 (B)	N= 30? 27`211`` E= 030? 10` 829``
El - Hamra lake	18 / 1 / 2003	1-10(B)	N= 30? 23` 784`` E= 030? 19` 252``
El – Zaagig lake	18 / 1 / 2003	1- 4 (B)	N= 30? 24` 507`` E= 030? 17` 781``
El – Khadra lake	18 / 1 / 2003	1 , 2(P)	N= 30? 26` 504`` E= 030? 13` 546``
El – Sabkha lake	18 / 1 / 2003	1- 5 (B)	N= 30? 26` 309`` E= 030? 13` 231``
El – Gaar lake	24 / 4 / 2003	1- 3 (P) 1- 4 (B)	N= 30? 27` 243`` E= 030? 10` 771``
El – Hamra lake	24 / 4 / 2003	1 , 2 (P) 1- 8 (B)	N= 30? 23` 781`` E= 030? 19` 248``
Um El – Risha lake	24 / 4 / 2003	1 (B) 2- 5 (B)	N= 30? 20` 906`` E= 030? 22` 346`` N= 30? 20` 860`` E= 030? 22` 462``
El – Fasda lake	24 / 4 / 2003	1 , 2 (P) 3 (P) 1- 3 (B) 4- 6 (B)	N= 30? 19` 232`` E= 030? 24` 56`` N= 30? 19` 165`` E= 030? 24` 386`` N= 30? 19` 229`` E= 030? 24` 030`` N= 30? 19` 220`` E= 030? 24` 207``
El – Khadra lake	24 / 4 / 2003	1 (P) 1- 5 (B)	N= 30? 27` 047`` E= 030? 12` 864``
El – Sabkha lake	24 / 4 / 2003	1- 5 (B)	N= 30? 26` 569`` E= 030? 13` 080``
El – Zaagig lake	24 / 4 / 2003	1 , 2 (B) 3 , 4 (B)	N= 30? 25` 335`` E= 030? 16` 548`` N= 30? 25` 257`` E= 030? 16` 731``
El- Karnak wetland	24 / 4 / 2003	1- 4 (B)	N= 30? 24` 497`` E= 030? 17` 415``
Um El – Risha lake	14 / 8 / 2003	1- 3 (B)	N= 30? 20` 850`` E= 030? 22` 471``
El – Fasda lake	14 / 8 / 2003	1 (P) 1- 5 (B)	N= 30? 19` 238`` E= 030? 24` 047``
El – Gaar lake	14 / 8 / 2003	1- 5 (B)	N= 30? 27` 283`` E= 030? 10` 848``
El – Khadra lake	14 / 8 / 2003	1- 4 (B)	N= 30? 27` 071`` E= 030? 12` 826``
El – Sabkha lake	14 / 8 / 2003	1 (P) 1- 2 (B)	N= 30? 26` 600`` E= 030? 12` 802``
El – Hamra lake	14 / 8 / 2003	1 (P) 1 (B)	N= 30? 23` 780`` E= 030? 19` 242``
El- Karnak wetland	14 / 8 / 2003	1- 3 (B)	N= 30? 24` 620`` E= 030? 17` 465``

Table 1: Continued

El – Gaar lake	19 /10/ 2003	1- 9 (B)	N= 30? 27` 336`` E= 030? 10` 851``
El – Sabkha lake	19 /10/ 2003	1- 2 (P) 1- 3 (B)	N= 30? 26` 630`` E= 030? 12` 739``
		4- 6 (B)	N= 30? 26` 456`` E= 030? 13` 438``
El- Karnak wetland	19 /10/ 2003	1- 6 (B)	N= 30? 24` 438`` E= 030? 17` 434``
El – Hamra lake	19 /10/ 2003	1 (P) 1- 4 (B)	N= 30? 23` 780`` E= 030? 19` 242``
Um El – Risha lake	19 /10/ 2003	1- 4 (B)	N= 30? 20` 330`` E= 030? 22` 488``
El – Fasda lake	19 /10/ 2003	1- 5 (B)	N= 30? 19` 267`` E= 030? 24` 992``
El – Gaar lake	19 / 2 / 2004	1- 7 (B)	N= 30? 27` 222`` E= 030? 10` 831``
El – Sabkha lake	19 / 2 / 2004	1- 5 (B)	N= 30? 26` 598`` E= 030? 12` 793``
El – Khadra lake	19 / 2 / 2004	1 (P) 1- 2 (B)	N= 30? 26` 447`` E= 030? 13` 569`` N= 30? 26` 566`` E= 030? 13` 133``
El – Hamra lake	19 / 2 / 2004	1 (P) 1- 8 (B)	N= 30? 23` 798`` E= 030? 29` 237``
El – Fasda lake	19 / 2 / 2004	1- 5 (B)	N= 30? 19` 225`` E= 030? 24` 065``
El- Karnak wetland	19 / 2 / 2004	1- 4(B)	N= 30? 27` 532`` E= 030? 10` 402``

phytoplanktonic samples were collected by filtering of water through 15 µm mesh of phytoplankton net to fill cleaned plastic bottles of 1 liter volume and then preserved by few drops of 4% formalin. Ecotones (Littoral zones) of the lakes were shown some benthic growths in the form of mats and scums which were easily removed by hand using a sharp blade shovel. The geographical localities of the collected samples were determined in longitudes/latitudes readings by using Global Positioning System (GPS) (GARMIN 12XL) (Table 1).

Water Samples: Surface water samples were collected from the investigated lakes in plastic bottles of 1 liter volume for chemical analysis.

Remote Sensing: In this study, two multispectral satellite images of Landsat and SPOT were used to give a preliminary spatial and quick surveillance upon the study area. The acquisition dates of the two images were 25/7/1997 for SPOT and 23/12/2001 for Landsat.

Methods:

Cyanobacteria: Microscopic identification of cyanobacteria were performed, based on morphological characteristics, using the keys of Geitler[13], Gollerbach *et al.*,[14], Desikachary,[10], Anagnostidis and Komarek[3,4], Komarek and Anagnostidis[30]. Counts were performed by using a counter chamber. The colonial or filamentous species was counted as one individual. Statistical analysis was carried out by applying the analysis of Variance (ANOVA)[35].

The data set analyzed was based on quantitative samples using the percentages of the identified taxa and the corresponding environmental variables (seasons, localities).

Water Samples: The temperature of water and its pH were measured in *situ* using a thermometer of 20 degrees up to 100°C and by digital pH meter respectively. Major cations and anions of water were quantitatively determined according to Jackson[26].

Table 2: Mean, minimum and maximum values of the physical and chemical variables for the investigated lakes.

	El- Gaar	El-Sabkha	El-Khadra	El-Zaagig	El-Hamra	El-Fasda
Temp.(^{0} C)	25.2	25.2	23	25	24.9	26.7
	14- 33	16-33	15-33	22-28	17-34	24-29
pH	9.9	9.6	9.2	9.7	9.9	9
	9.6-10	9-10.4	9-9.4	9.4-10	9.8-10	8.5-10
T.D.S.(ppm)	306650	14867	31102	264926	2239667	21503
	13573-665230	9402-17408	21581-43852	58315-471537	203862-301806	6631-38733
Ca^{+2} (ppm)	48	45.7	50.6	32	24.8	309
	22-104	36.1-58.1	30.1-60.1	26.1-38.1	20-32.1	72.1-729
Mg^{+2} (ppm)	104.6	34	243.3	431.8	187.3	283.8
	73-134	24.3-60.8	109.5-316.3	158-705.6	170.3-206.8	60.8-596.1
Na^{+} (ppm)	93264	4703	10057	93264	84662	6506
	4230-229241	2851-5471	6575-14460	18988-167540	72598-106115	1609-13540
K^{+} (ppm)	2288	345	463	1545	559	342
	352-6223	316.4-379	363-711	477-2613	292.9-668	332-355
CO_3^{--} (ppm)	2781	222	533	6201	5418	150
	90-8198	150-300	180-1051	450-11952	4595-6607	30-360
HCO_3^{-} (ppm)	2024	829	1493	2408	2927	488
	366-4878	366-1098	729.7-1768.3	1158.5-3658	1463.4-3902.4	182.9-975.6
Cl^{-} (ppm)	95071	2269	6693	72694	60922	5177
	3546-161879	1773-2660	2660-10638	14184-131205	48404-72872	1418-12518
SO_4^{--} (ppm)	95662	6418	11568	88348	84968	8247
	4289-265173	2870-8173	10274-14889	22313-154384	63087-113562	2586-11303
PO^{4---} (ppm)	2.5	3.4	4.6	1.66	2.9	1.88
	2.01-3.36	2.61-4.6	2.24-7.75	0.6-2.73	0.88-5.9	0.49-4.1
NO_3^{-} (ppm)	21	19.6	30.5	20.4	13	5.6
	10.54-49.6	11.2-34.7	13.6-47.1	19.8-21.1	8.68-18.6	4.34-7.44

Remote Sensing: Collected cyanobaterial samples were allocated precisely on SPOT image with reference to its GPS readings (Table 1). Image preprocessing, processing and classification were performed with the uses of ERDAS/IMAGINE Version 8.4. The spectral signatures of the features of the study area were enhanced through an unsupervised classification procedure[11].

Supervised classification was then performed on the image using the maximum likelihood classification algorithms. With the aid of ArcView GIS software[5] a layout of the study area will be obtained.

Results:

Physical and Chemical Variables: Table 2 summarizes physical and chemical variables of the sampling sites. Some of these variables presented marked differences between the investigated lakes.

Physically, minimum surface water temperature was measured in El-Kadra lake of 24 ºC, while maximum value of 27 ºC was achieved in El-Fasda lake (Fig. 2a). Waters showed alkaline tendency where pH ranged from 9 to 9.9 (Fig. 2b). Minimum total dissolved salts (T.D.S) of 18000 mg $^{-1}$ was recorded for El-Sabkha lake, while maximum value of T.D.S was recorded in El-Gaar lake of 300500 mg $^{-1}$ (Fig. 2c). The lowest mean calcium concentration was measured in El-Hamra lake of 20 mg $^{-1}$; while the highest value was recorded in El-Fasda lake of 310 mg $^{-1}$ (Fig. 2d). In particular, the chemical variables (Mg^{+2}, Na^{+}, K^{+}, CO_3^{--}, Cl^{-}, SO_4^{--}) exhibited the lowest concentrations determined in El-Sabkha lake (Fig. 2e, 2f, 2g, 2h, 2j, 2k). In El-Gaar lake, sodium, potassium, chloride and sulphate concentrations with an order of higher magnitude were recorded (Fig. 2f, 2g, 2j, 2k).

Phosphate and nitrate concentrations were higher in El-Kadra lake (Fig. 2l, 2m).

It was apparent from (Fig. 2f, 2g, 2j, 2k) that, there was a gradual decreasing in the concentrations of Na^{+}, K^{+}, Cl^{-}, SO_4^{--} along El-Gaar, El-Zaagig and El-Hamra lakes. This means that the mean value of Na^{+} concentration in El-Gaar lake > the mean value of Na^{+} concentration in El-Zaggig lake > the mean value of Na^{+} concentration in El-Hamra lake. The same observation was obtained for K^{+}, Cl^{-}, SO_4^{--}.

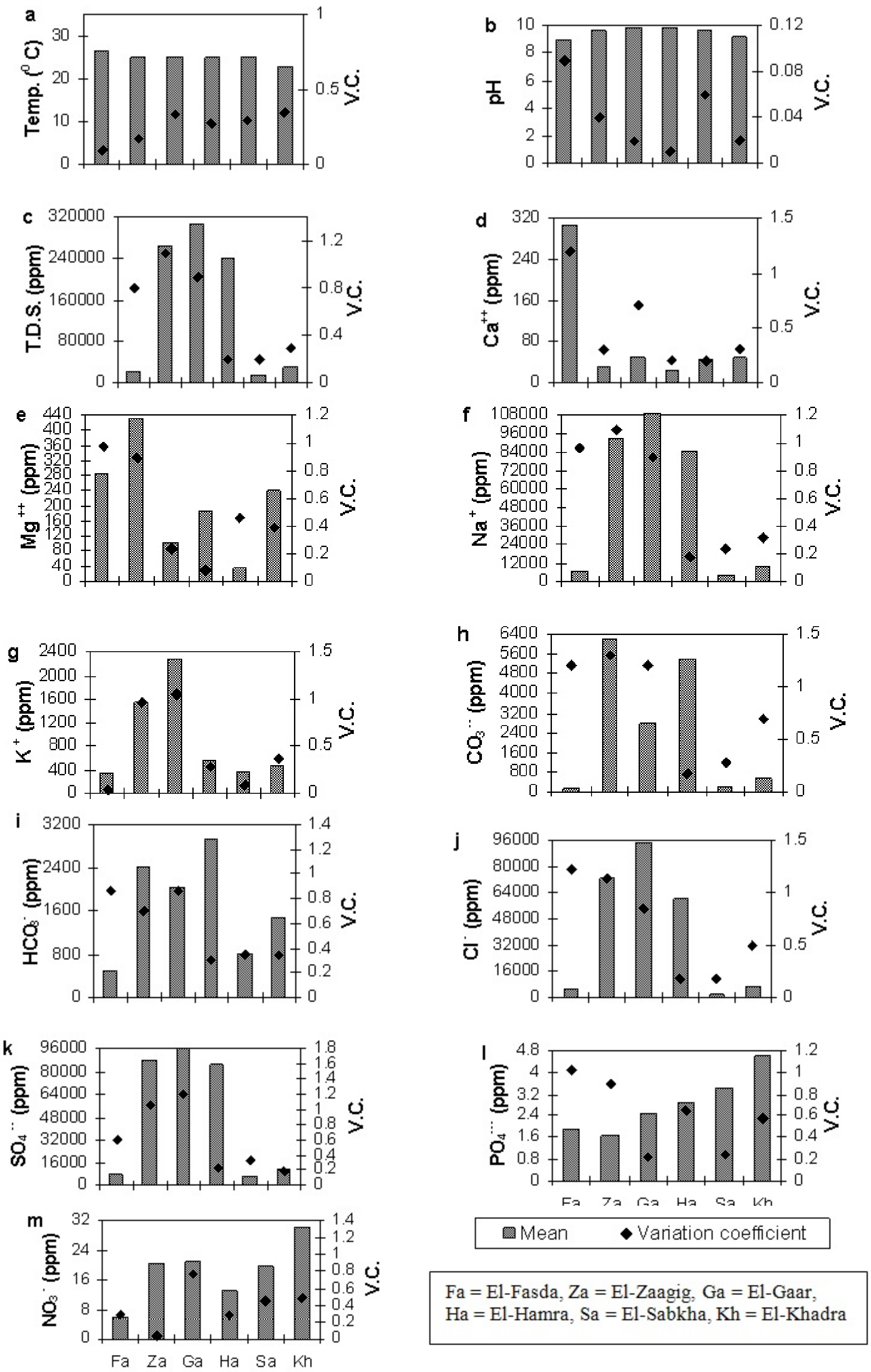

Fig. 2: Mean values and variation coefficients for the main physical and chemical variables in the investigated lakes.

Table 3: Qualitative distribution of cyanobacterial taxa in the investigated lakes and wetlands of Wadi El - Natrun region
1 = El – Gaar Lake, 2 = El – Sabkha Lake, 3 = El – Khadra Lake, 4 = El – Zaagig Lake, 5 = El – Karnak wetland, 6 = El – Hamra Lake, 7 = Um El – Risha Lake, 8 = El – Fasda Lake.

(+) = present, (-) = absent, (P) = Plankton, (B)= Benthic, (*) = new record to Egypt

TAXA	1	2	3	4	5	6	7	8
Class : Chroococcophyceae								
Order : Chroococcales								
Family : Chroococcaceae								
Microcystis aeruginosa Kütz. P B	+	+	-	-	+	+	+	+
Microcystis litoralis (Hansgirg) Forti B	+	-	-	-	-	-	-	-
Gloeocapsa crepidinum Thuret B *	-	-	-	-	-	+	-	-
Gloeocapsa decorticans (A.Br.)Richter B	-	-	-	-	+	-	-	-
Gloeocapsa gelatinosa Kütz. B	-	-	-	-	+	+	+	+
Gloeocapsa minor (Kütz.) Hollerbach B	+	+	-	-	+	+	+	+
Gloeocapsa punctata Näg. B	-	-	-	-	-	-	-	+
Gloeocapsa turgida (Kütz.) Hollerbach P B	+	+	+	+	+	+	+	+
Synechococcus aeruginosus Näg. P B	+	+	+	+	+	+	+	+
Synechococcus cedrorum Sauvageau B	-	+	-	-	+	-	+	+
Synechococcus elongatus Näg. B	+	+	-	+	+	+	-	+
Synechocystis aquatilis Sauv. B	-	+	-	-	-	-	-	+
Synechocystis crassa Woronichin B	+	+	-	+	+	-	+	+
Synechocystis pevalekii Ercegovic B	-	-	-	-	-	+	-	-
Synechocystis salina Wisleling P	-	-	-	-	-	+	-	-
Synechocystis sallensis Skuja. B	+	+	+	-	+	+	+	+
Isocystis pallida Woronich. B *	-	-	-	-	-	+	-	-
Rhabdoderma lineare Schmidle & Lauterborn B	+	-	+	-	-	-	+	+
Gomphosphaeria aponina Kütz. P B	+	-	+	-	+	-	-	-
Merismopedia aeruginea Bréb. B *	-	-	-	-	-	-	-	+
Merismopedia glauca (Ehrenb.) Näg. B	-	-	-	-	-	-	-	+
Merismopedia minima Beck B	-	-	-	-	-	-	-	+
Merismopedia punctata Meyen B	-	-	-	-	-	-	-	+
Dactylococcopsis acicularis Lemm. B	-	-	-	+	-	-	-	+
Dactylococcopsis facicularis Lemm. B	-	-	-	-	-	+	-	-
Class : Chamaesiphonophyceae								
Order : Pleurocapsales								
Family : Pleurocapsaceae								
Myxosarcina burmensis Skuja P B	+	-	+	-	-	+	+	+
Myxosarcina spectabilis Geitler B *	-	-	-	-	-	+	-	-

Table 3: Continued

Xenococcus acervatus Setchell et Gardner [B *]	+	-	-	-	-	+	-	-
Class : Hormogonophyceae								
Order : Nostocales								
Family : Oscillatoriaceae								
Arthrospira platensis f.grannulata Desikachary [P B *]	-	-	+	-	-	+	-	-
Spirulina gigantea Schmidle [P B]	-	+	-	-	-	-	-	-
Spirulina labyrinthiformis (Menegh.) Gomont [P B]	+	+	+	+	+	+	+	+
Spirulina major Kütz. ex Gomont [B]	-	-	+	-	-	-	-	-
Spirulina platensis (Nordst.) Geitler [P B]	+	+	+	-	-	+	-	-
Spirulina subtilissima Kütz. ex Gomont [B]	+	+	-	+	+	+	-	+
Oscillatoria animalis Ag. ex. Gomont [B]	-	-	-	-	-	+	-	-
Oscillatoria annae Van Goor [P B]	+	+	-	-	+	+	-	+
Oscillatoria boryana Bory ex Gomont [B]	-	-	-	+	-	-	-	-
Oscillatoria chalybea (Mertens) Gomont [B]	-	-	+	-	-	-	-	-
Oscillatoria claricentrosa Gardner [B]	+	+	-	+	+	-	+	+
Oscillatoria curviceps Ag. ex Gomont [B]	-	+	-	+	+	+	+	-
Oscillatoria foreoui Frémy [B *]	+	-	-	-	-	-	+	-
Oscillatoria geminata Menegh. [P B]	+	+	+	+	+	+	+	+
Oscillatoria laete-virens (Crouan) Gomont [P B]	-	+	-	+	+	+	+	-
Oscillatoria limosa Ag. ex Gomont [B]	+	-	-	-	+	+	+	+
Oscillatoria margaritifera (Kütz.) Gomont [B]	+	-	-	-	+	+	-	-
Oscillatoria nigroviridis Thawaites ex Gomont [B]	+	-	-	-	+	+	-	-
Oscillatoria obscura Bruhl. et. Biswas [B]	-	-	-	-	+	+	-	-
Oscillatoria okeni Ag. ex Gomont [B]	+	+	-	+	+	+	+	-
Oscillatoria princeps Vaucher [B]	+	-	-	-	+	+	-	+
Oscillatoria pseudogeminata G.Schmid. [P B]	+	+	+	+	+	+	+	+
Oscillatoria sancta (Kütz.) Gomont [B]	-	-	-	-	+	+	-	-
Oscillatoria splendida Grev.ex Gomont [P B]	-	+	+	-	+	+	+	+
Oscillatoria subbrevis Schmidle [P B]	+	+	-	-	+	+	+	+
Oscillatoria subtilissima Kütz. ex De Toni [B]	+	-	-	-	-	-	+	-
Oscillatoria tenuis Ag. ex Gomont [B]	+	+	+	-	+	+	+	+
Oscillatoria sp1. [B]	-	-	-	-	+	+	-	+
Phormidium ambiguum Gomont [P]	-	+	-	-	-	-	-	-
Lyngbya confervoides C. Ag. ex Gomont [B]	+	-	-	-	+	+	-	-

Table 3: Continued.

Lyngbya major Menegh. ex Gomont [B]	-	-	-	-	+	+	-	-
Lyngbya majuscula Harvey ex Gomont [B]	-	-	-	-	+	+	-	-
Lyngbya martensiana Menegh. ex Gomont [B]	-	-	-	-	+	+	-	-
Lyngbya semiplena (C.Ag.) J.Ag. ex Gomont [B]	-	-	-	-	+	+	-	+
Schizothrix penicillata (Kütz.) Gomont [B *]	+	-	-	-	+	-	-	+
Schizothrix sp1. [B]	-	+	-	-	-	-	-	-
Family : Nostocaceae								
Anabaenopsis circularis (G.S.West) Wolosz. et Miller [B]	-	-	-	-	-	-	-	+
Anabaenopsis Elenkinii Miller [P B *]	+	+	+	-	-	-	-	+
Cylindrospermum iyengarii Randj. [B *]	-	-	-	-	-	+	-	+
Nostoc linckia (Roth) Bornet ex Born. et Flah. [B]	-	-	-	-	+	-	-	-
Nostoc paludosum Kützing ex Born. et Flah. [B]	-	-	-	-	-	+	-	-
Anabaena affinis Lemmermann [B]	+	+	+	+	-	+	+	+
Anabaena ambigua Rao, C.B. [B *]	-	+	-	+	-	+	-	-
Anabaena circinalis var. crassa Ghose [B]	-	-	-	+	-	+	-	-
Anabaena doliolum Bharadawja [B *]	-	-	-	-	+	-	-	-
Anabaena fertilissima Rao, C.B. [B *]	+	-	-	-	-	-	-	-
Anabaena iyengarii Bharadawja [B]	-	+	+	+	+	+	-	+
Anabaena laxa (Rabehn.)Born .et Flah. [B *]	+	+	+	-	+	+	-	+
Anabaena naviculoides Fritsch. [B *]	+	-	-	-	+	+	-	-
Anabaena orientalis Dixit. [B *]	-	-	-	-	-	+	-	-
Anabaena oscillaroides Bory ex Born. et Flah. [B]	-	-	-	-	-	+	-	-
Anabaena sphaerica Born. et Flah. [B *]	+	+	-	+	-	+	+	+
Anabaena torulosa (Carm.) Lagerh. ex Born. et Flah. [B *]	-	-	-	-	-	-	-	+
Pseudanabaena catenata Lauterb. [P B *]	-	+	+	-	+	-	-	+
Pseudanabaena schmidlei Jaag.O. [B *]	-	+	+	+	+	+	+	+
Nodularia spumigena Mertens ex Born. et Flah. [B]	+	+	+	+	+	+	+	+
Family : Rivulariaceae								
Leptochaete stagnalis Hansgirg [P]	-	+	-	-	-	-	-	-
Calothrix braunii (A.Br.) Born. et Flah. [P B]	-	+	-	-	-	-	-	-

Cyanobacterial Assemblages: A total of 86 cyanobacterial taxa, among species and varieties, were identified for the study area (Table 3). Most of the species were be associated with the benthic and periphytic habitats, and only few taxa may be considered regular plankton organisms.

Qualitatively, cyanoprokaryotes depend mainly on the members of the genus *Oscillatoria* (22 taxa) and *Anabaena* (12 taxa) (Table 3). The highly distributed taxa in all investigated lakes and wetlands of Wadi El-Natrun were represented by cyanoprokaryotes of *Gloeocapsa turgida*, *Synechococcus aeruginosus*,

Table 4: Statistical analysis of Variance (ANOVA)

Source of variation	Degree of freedom (d.f.)	Sum. Sq. (SS)	Mean Squares (MS)	F value (MS/MS error)
Species	85	6267.06	73.73	5.32**
Seasons	3	21.71	7.24	0.52
Location	7	115.50	16.50	1.19
Species X Seasons	255	4199.38	16.47	1.19**
Species X Location	595	14036.16	23.59	1.70**
Seasons X Location	21	266.31	12.68	0.92
Error	1785	24726.73	13.85	
Total	2751	49632.85		

•• $p > 0.01$
N.B. One was added to all values.

Table 5: Statistics of Digital Numbers (DNs) of SPOT and Landsat images.

Images	Bands number	Bands name	Minimum	Maximum	Mean	Standard deviation
SPOT	1	Green	0	255	147.522	53.026
	2	Red	0	255	193.347	39.438
	3	InfraRed	0	255	198.181	35.744
Landsat	1	Blue/Green	12	147	90.872	18.529
	2	Green	24	118	69.156	12.089
	3	Red	32	113	62.932	8.020
	4	Near infrared	15	167	111.734	16.721
	5	Near middle infrared	1	214	136.120	28.176
	6	Thermal infrared	2	188	114.871	27.667

Table 6: Reflectance (DN values) in visible blue band

Lakes	Reflectance in blue band	
	Winter	Summer
El – Gaar	30	254
El – Sabkha	34	47
El – Khadra	30	106
El – Zaagig	27	255
El – Hamra	32	255
Um El – Risha	35	252
El – Fasda	27	255

Spirulina labyrinthiformis, *Oscillatoria geminate*, *Oscillatoria pseudogeminata and Nodularia spumigena*.

Each lake had its own cyanobacterial type depending on the quantitative frequency of the taxon during the study period. El – Gaar Lake was characterized by a type of cyanobateria of *Oscillatoria nigroviridis*, *Oscillatoria pseudogeminata* and *Oscillatoria tenuis*. The cyanoprokaryotic type of El – Sabkha Lake was composed of *Anabaenopsis Elenkinii* and *Oscillatoria pseudogeminata*. *Spirulina platensis* was the monospecific inhabitant of El – Khadra Lake, where it is usually make the blooming during winter season. *Oscillatoria pseudogeminata* was constituted the algal type of El – Zaagig Lake. The cyanobacterial type of El – Karnak wetland was characterized by *Nodularia spumigena*, *Oscillatoria tenuis* and *Oscillatoria splendida*. The Chroococcean cyanobacterium of *Gloeocapsa turgida* and hormogonean cyanobacterium of *Lyngbya confervoides* were reflected the cyanobacterial type of El – Hamra Lake. Um El – Risha Lake had cyanobacterial character represented by *Oscillatoria tenuis* and *Gloeocapsa gelatinosa*. *Schizothrix penicillata*, *Oscillatoria tenuis* and *Oscillatoria subbrevis* were constituted the cyanobacterial type of El – Fasda Lake.

Analysis of ANOVA (Table 4) indicated the highly significant effect of species ($P < 0.01$). This finding confirmed the previous results which indicated the distinguished cyanobacterial type of each lake. The interaction between the species and the corresponding environmental variables (seasons, localities), showed highly significant. The most frequent species were *Oscillatoria subbrevis* of 9.7 % and *Oscillatoria okeni* of 6.9 %.

Remote Sensing: The statistical analysis of SPOT and Landsat images was calculated according to Digital Numbers values (DNs) for each band (Table 5).

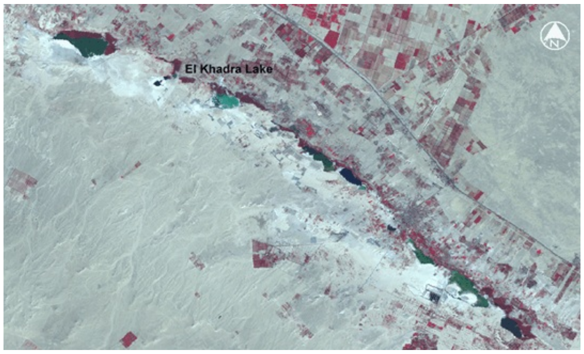

Fig. 3: False color composite image of Wadi El-Natrun depression during winter season.

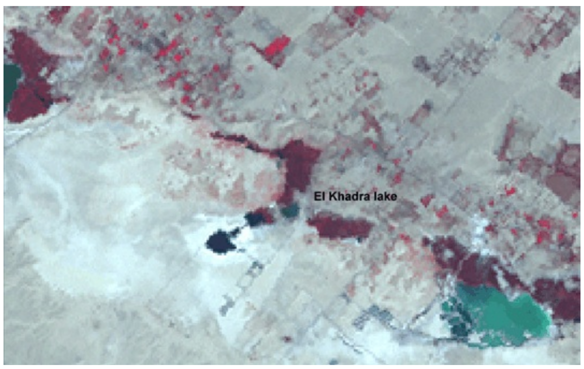

Fig. 4: Magnified false color composite image showing the reddish tone which detected in El-Khadra lake during winter season.

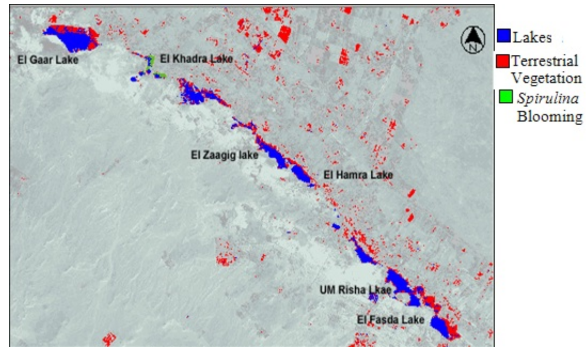

Fig. 5: GIS based map of Wadi El-Natrun depression during winter season.

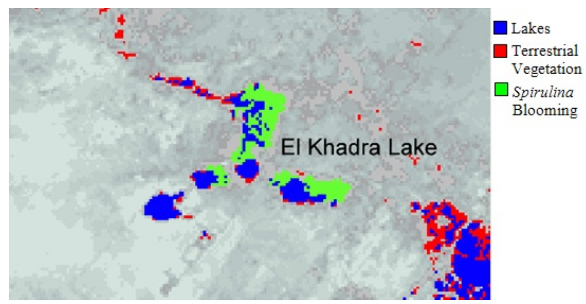

Fig. 6: Magnified GIS based map of Wadi El-Natrun depression during winter season showing blooming of *Spirulina* in El-Khadra Lake.

From SPOT image analysis, it was cleared that all bands have the highest value of DN of highest range of 255, and the lowest values of zero, indicating the presence of high reflective desert areas and water bodies. Concerning the Landsat bands, infrared bands were attainted very low reflectance values of one and two, which were indicative of the almost complete absorbance of the infrared radiation by water bodies.

The comparative results of SPOT and Landsat images were as follows: 1- The total surface area of the investigated lakes was 11.27 Km^2 in winter (Landsat image) while it was 7.45 Km^2 in summer (SPOT image). 2- The surface areas of the lakes decreased in summer than in winter, due to seasonal dryness of some lakes during summer and this was easily observed in the summer image. This reflects a biodiversity loss due to the reduction of the lakes during summer season and the beginning of autumn season. 3- By comparing the water depth and salinity in the two seasons, it was observed that water salinity and depth are interlinked. In summer, water depth decreased due to evaporation causing an increase in water salinity. Salts are accumulated on the surface of lakes, and this affects very much the reflectance (DN values), particularly in visible blue band (Table 6). In winter, the reverse data was indicated. 4- Referring to the false color composite image, a reddish tone was detected in El – Khadra Lake during winter season in the Landsat image (Fig. 3; 4). With the help of ground truth observations, such reddish tone was due to the heavy blooming of monospecific blue green alga/cyanobaterium, identified as *Spirulina platensis.*

Discussion: The results obtained in this study are evidence of the important difference in both limnological features and algal assemblages across the investigated lakes and its wetlands from the permanent lakes (El-Gaar, El-Sabkha, El-Karnak, El-Hamra) to temporally shallow lakes (El-Zaagig, Um El-Risha, El-Khadra, El-Fasda).

Such difference may be associated to the persistent of the cyanobacterial vegetation cover and to its irregular occurrence.

Concerning the hydrogen ion concentration of the investigated lakes, the average pH values ranged between 9 and 9.8. The relatively highly alkalinity may owing to the high concentrations of HCO_3^- / CO_3^{--} together with Na^+ and Cl^- as major cations[19,18,16,27].

According to the classification system proposed by Grant and Tindall[19], Grant and Horikoshi[18], Grant[16] and Jones *et al.*[27], it was revealed that the salinity of the investigated lakes can be classified as brines due to Cl^- ions exceeds CO_3^{--} concentration.

The average concentration of Ca^{2+} and Mg^{2+} ranged between (20 to 310 ppm for Ca^{2+}) and (38 to 430 ppm for Mg^{2+}), while those of CO_3^{--} and HCO_3^- of about (150 to 6200 ppm for CO_3^{--}) and (500 to 2950 ppm for HCO_3^-) (Fig. 2d, 2e, 2h, 2i). From the previous findings, the average concentrations of Ca^{2+} and Mg^{2+} were relatively low in comparing with that of CO_3^{--} and HCO_3^- concentrations in the investigated lakes, such observation confirmed the classification and conclusion of Grant and Tindall[19], Grant and Horikoshi[18], Grant[16] and Jones *et al.*[27], in which they were stated that the summation of CO_3^{--} and HCO_3^- greatly exceeds those of Ca^{2+} and Mg^{2+} leading to the creation of alkaline earth cations, leaving Na^+, Cl^- and HCO_3^- / CO_3^{--} as the major ions in solution.

In accordance to the most hypothetical salt formation in the investigated lakes, two major water types were recorded; these were sodium chloride and sodium sulphate. This finding was confirmed the observations resulting from the hydrogeological studies of Atwa[6] and Goma[17].

From the available Egyptian phycological literatures of Hamed[21], it was found that twenty taxa of cyanobacteria were represented as new records to the Egyptian algal flora (Table 4).

The technologies of remote sensing and GIS significantly provided spatial information about the whole study area. A layout (GIS-based map) was obtained in which, monitoring and assessment of blooming of *Spirulina platensis* inhabiting El-Khadra Lake was determined in addition to the spatial distribution of terrestrial vegetation and the investigated lakes (Fig. 5; 6). The alkaline pH and saline eutrophic condition favored the blooming[38,33]. This alga (*Spirulina platensis*) which was detected by the tool of remote sensing acts as a very important natural resource entity for its medicinal importance[12,9,23,8,28]. The availability of satellite imagery for the two seasons, winter and summer, helped in assessing the seasonal variations that occur in the area of study. e.g. the area of lakes, which was apparent by comparing the lake size in both images. This indicates how much reduction in lakes occurs in summer. The salinity variation of lakes in the two seasons was a characteristic that was detected by comparing the DN values of the blue band in the two images.

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