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ECOLOGICAL STUDIES ON WADI EL-RAIYAN LAKES 1- PHYSICO-CHEMICAL PROPERTIES AND PRODUCTIVITY

BY

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SUMMARY

Wadi El-Raiyan lakes lie in the lowest part of El-Fayom Depression in the Western Desert of Egypt. The present investigation deals with the seasonal fluctuation of physico-chemical characteristics and primary productivity of Wadi El-Raiyan-Lakes. The result showed that the water temperature ranged from 13.9 to 30.8 °C and follows more or less the air temperature 15.7 to 33.7 °C. The salinity ranged from 0.79 to 3.00 ppt. This means that the lakes are mixo-oligohaline. The depths ranged from 1.5 to 23 m while the secchi disc readings ranged from 0.8 to 2.2 m. The pH values lie always in the alkaline side and ranged from 8.8 to 9.1. The CO_3 values fluctuated from 18.16 to 30.97 mg/L, while HCO_3 varied from 130.18 to 182.51 mg/L. The lakes are characterized by high level of dissolved oxygen that ranged from 7.48 to 9.56 mg/L. The chemical oxygen Demand(COD) values varied from 1.7 5.3 mg/L. Magnesium concentrations (22.59 mg/L -616.8 mg/L) were much higher than calcium values (139.28 mg/L-341.67 mg/L). Organic nitrogen was much higher than other nitrogen forms and ranged from 0.77 mg/L to 2.05 mg/L. The orthophosphate concentrations ranged from 19 μg/L to 60.4 μg/L and organic phosphorus values fluctuated from 42.9 μg/L to 137 μg/L. Silicate-Si levels varied from 4.04 to 9.45 mg/L. The net primary productivity reached to its maximum value during Summer while its minimum was recorded in Winter. Its values varied from 120.81 to 221.4 mg C/m^3/h.

Wadi El-Raiyan has an area of 40000 feddans and lies in the Western Desert of Egypt about 130 Kilometers South West of Cairo and discovered by Linant de Bellefonds (1873). The reservor consists of three lakes which will finally contain 2 milliard cubic meters of water (Boraey, 1978). Zahran (1973) reported the geological history and origin of Wadi El-Raiyan Depression. He investigated also the climate and water supply in that area. Boraey (1978) provided a preliminary data on some ecological conditions of Wadi El-Raiyan Lakes. Ibrahim (1980) studied the chemical characters and phytoplankton population at some selected stations. Ibrahim (1983) investigated the effect of salinity on growth and metabolism of the desmid *Staurastrum boreal* isolated from Wadi El-Raiyan Waters.

Taha (1984) isolated some phytoplankton species from Wadi El-Raiyan Lakes. She studied the effect of some commonly used pesticides on growth and metabolic activities of these organisms.

Khalil (1984) reported the population dynamics of micro and macro fauna as well as phytoplankton in the first and second lakes of Wadi El-Raiyan. He studied also the effect of pollutants on some organisms inhabiting these lakes, representing different trophic levles. About Ela and Khalil (1987) investigated the toxicity of three commonly used pesticides namely Dimethoate, Lannate and Bayluscide on some aquatic organisms isolated from Wadi El-Raiyan. They found that Dimethoate was the most toxic, while Lannate was the least toxic.

Fouda and Saleh (1988) studied the benthic fauna of Wadi El-Raiyan Lakes and reported that benthic animals are confined to the littoral and shallow areas.

Saleh et al. (1988) investigated the distribution of heavy metals in the organisms living in Wadi El-Raiyan area. Fish and fisheries of Wadi El-Raiyan Lakes were treated by Fouda ad Salah (1987). They recorded twenty seven fish species some of them enter the lakes by drainage water from EL-Faiyoum Province e. g. *Tilapia zilli, Oreochromis niloticus. Sarotheroden galilaeus, Lates niloticus* and *Clarias lazera;* and the other have been introduced as fry e. g. Carp and Mullet species.

MATERIALS AND METHODS

Lakes Mororophometry

The Wadi El-Raiyan Lakes are located in the lowest part of the Faiyoum Depression in the Westrn Desert of Egypt about 130 km south west of Cairo . It consists of 2 lakes connected by means of channel. The first lake covers an area of about 52.8 km^2 while the second lake has an area about 26.5 km^2 and the third lake covers an area of about 110 km^2.

The samples were collected from seven stations and channel as shown in Fig. (1).

Analytical Methods

The samples were collected from the selective stations using 1.5 L Ruttner Sampler equipped with a mercury thermometer. The samples were filtered through a 0.45 Millipore filter before analysis. The samples were stored and refrigerated in plastic bottles and analyzed within few hours after arrival to Aquatic Plant Lab. at El-Zamalek Research Station. Egypt. The following parameters were determined.

***Physical Parameters:**

*** Air Temperature**

It was measured in site using thermometer graduated to 0.1 °C.

***Water Temperature**

It was measured directly by the mercury thermometer of the Ruther Sampler.

***Depth:**

The depth was measured for each station.

***Secchidisc:**

Water transparency was measured by Black/white standard secchidisc 25 cm in diameter.

***Chemical Parameters**

***Hydrogen Ion Concentration (pH):**

The pH was measured in site using Hydro-bios portable pH meter.

***Salinity:**

Chlorinity was determined according to Moh's method as described by Vogel (1953). Salinity was calculated acording to Meshal (1973):

$S‰ = (cl‰ \times 247) + 216.$

It was expressed as part per thousand ‰ .

***Dissolved Oxygen:**

It was determined according to Winkler's method as reported by Thompson and Ribonson (1953).

***Chemical Oxygen Demand:**

It was determined by Strickland and Parsons (1965).

***Calcium and Magnesium:**

They were determined after Katz and Navone (1964).

***Ammonia:**

It was determined colorimetrically after Booth and Lobring (1973).

•Nitrite:

It was determined by Barnes and Folkard's method (1951).

•Nitrate:

It was estimated using the cadmium reductio method as described by Nydahl (1976).

•The total organic Nitrogen:

It was determined using Kjeldahl method as reported by Mckenzie and Wallace (1954).

•Orthophosphate:

It was determined after Strickland and Parsons (1965).

•Organic phosphorus:

It was estimated by Gales et. al., method (1966) .

•Silicate:

It was measured by the molybosilicate method as described by Chow and Ribinson (1965).

•Productivity

The Gross productivity was measured by light dark bottles technique according to Strickland and Parsons (1968).

RESULTS

The present investigation provides the most recent and comprehensive survey on the physicochemical characters and phytoplankton ecology of the first and second lakes, while the third lake was represented by one station (see Fig. 1).

The general climate of Wadi El-Raiyan area is hot dry with scanty winter rain and year round bright sunshine. The physical and chemical parameters are givne in Fig. 2 and Fig. 3.

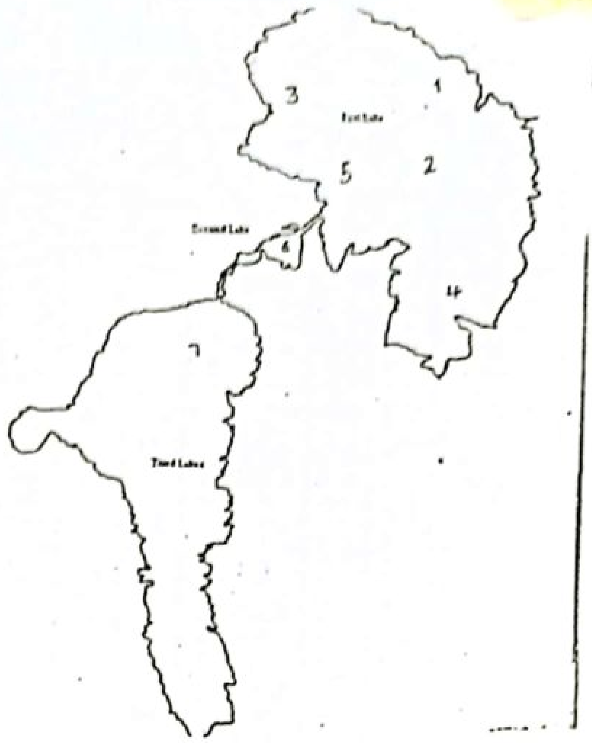

Fig. (1): The map of selected stations of Wadi El-Rayian Lakes.

•Air Temperature:

The air temperature reached its maximum in summer being 35 °C while it reached its minimum value in winter being 14.9°C.

•Water temperature:

The water temperature of the lake was slightly lower than the corresponding value of air temperature. Their minimum values of 12.8 °C and 12.7°C were a recorded in winter, while the maximum being 31.5 and 30.5°C occurred in summer for both surface and bottom layers.

•Depth:

Depths of wadi El-Raiyan Lakes vary from station to another due to the topographic variations. Their values ranged from a minimum of 1.5 m. at station 7 to 23 m. at station 4.

•Transparency:

Secchi disc values ranged from a minimum of 0.8m. in autumn to a maximum of 2.2 m. in summer.

Table (1): Chemical Paramcters in Wadi El-Rayian Lakes.

Pond	Season	Water Temperature		Depth	Salinity		pH		CO_3 mg/L.		HCO_3 mg/L.		DO mg/L.		COD mg/L.		Ca mg/L.		Mg mg/L.	
		Surface	Bottom	m	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
1	Winter	15.00	13.90	5.50	1.11	1.08	9.10	9.10	12.00	16.00	195.25	173.30	9.69	9.29	1.60	1.70	218.69	240.40	367.10	325.50
2		14.50	13.30	14.50	1.08	1.11	9.10	9.10	20.00	20.00	175.25	181.25	9.41	9.00	2.00	3.20	238.29	250.20	400.00	450.70
3		14.00	12.80	12.00	1.10	1.09	9.10	9.10	24.00	12.00	178.70	199.15	9.48	9.13	2.00	1.50	327.38	317.58	383.40	476.40
4		14.80	13.50	16.60	1.14	1.10	8.60	8.90	16.00	12.00	193.60	197.15	10.30	9.94	1.50	2.10	315.44	208.89	424.60	434.50
5		13.40	13.00	1.80	1.16	1.10	9.10	9.10	16.00	20.00	190.70	180.70	9.54	9.47	1.50	1.60	250.23	240.40	368.10	458.00
6		12.80	12.70	1.80	1.65	1.11	8.50	8.50	8.00	8.00	193.20	190.60	9.75	9.97	1.90	1.80	220.80	218.44	341.70	470.40
7		13.00	12.90	2.60	2.39	2.71	8.20	8.20	31.09	19.09	150.90	156.35	8.78	8.48	1.60	2.90	820.90	652.65	522.40	543.60
1	Spring	22.60	21.70	4.50	0.79	0.08	9.00	8.40	30.55	17.60	139.30	177.00	7.39	6.77	2.20	2.10	153.05	173.50	431.40	390.00
2		23.00	19.50	11.50	1.05	1.06	9.20	8.80	28.55	24.50	145.55	162.15	8.36	6.51	2.00	2.60	173.50	214.30	701.40	541.00
3		22.50	20.20	8.00	1.08	1.06	9.00	9.10	24.05	26.30	167.35	158.60	7.46	7.04	3.10	2.20	153.10	183.70	622.60	491.00
4		23.00	18.00	20.80	1.10	1.10	9.00	8.70	17.50	26.20	166.35	159.90	8.01	0.00	2.90	2.70	173.50	173.50	541.50	521.60
5		22.40	21.60	1.80	1.07	1.06	9.00	8.50	24.05	14.20	165.25	168.75	6.98	6.61	3.00	2.80	173.50	204.10	621.50	652.70
6		17.10	16.70	1.80	1.10	1.08	8.20	8.20	0.00	17.60	193.70	171.70	7.01	6.73	6.30	6.00	142.90	163.30	628.90	566.10
7		17.80	17.60	2.00	2.10	2.20	8.40	8.50	26.40	26.40	140.90	149.70	7.15	7.02	7.60	6.50	285.00	306.10	730.30	631.50
1	Summer	31.00	29.50	5.00	2.68	2.89	8.40	8.60	29.30	26.60	145.00	148.30	8.16	7.23	5.50	4.00	210.53	178.95	145.90	177.50
2		31.50	29.00	10.00	2.90	3.19	9.10	8.80	35.50	14.50	149.40	165.70	9.07	7.33	4.60	3.00	115.78	115.78	250.60	270.40
3		31.00	28.00	10.00	3.06	2.90	9.00	8.60	50.30	23.70	103.60	149.40	8.85	5.14	3.10	5.80	136.84	136.84	219.60	269.10
4		31.50	25.00	23.00	2.98	2.68	9.00	7.40	38.50	11.80	124.30	208.60	8.84	0.00	7.70	8.80	168.42	200.00	178.10	205.90
5		30.50	30.00	1.50	3.00	3.14	9.00	9.10	41.40	32.50	121.30	137.60	8.21	8.18	4.20	7.30	242.11	178.95	144.00	187.40
6		31.00	30.50	1.60	1.70	1.49	8.80	8.50	35.50	31.80	131.60	171.56	7.91	7.96	6.50	5.70	136.84	136.84	229.50	248.90
7		29.00	30.00	1.90	2.89	3.07	8.80	8.70	35.50	38.50	133.10	127.20	8.11	8.06	5.50	6.50	200.00	263.16	413.90	360.00
1	Autumn	20.00	19.50	3.00	1.06	1.08	9.40	9.40	34.00	42.50	131.80	114.80	9.75	9.71	6.10	4.40	130.00	110.00	271.80	316.80
2		20.50	20.00	10.00	1.13	1.09	9.30	9.30	34.00	42.50	127.50	114.80	9.58	9.03	5.60	4.70	140.00	130.00	326.00	324.60
3		20.00	19.50	8.00	1.15	1.15	9.50	9.50	42.50	42.50	110.50	119.00	9.85	9.64	5.00	5.90	125.00	135.00	320.20	308.80
4		20.50	20.00	17.00	1.05	1.07	9.10	9.10	25.50	34.00	153.00	131.80	8.88	8.52	5.00	5.30	100.00	140.00	276.00	337.40
5		20.00	20.00	2.00	1.13	1.19	9.90	9.90	29.80	42.50	161.50	110.50	9.79	9.07	6.10	5.80	140.00	270.00	296.20	265.00
6		20.50	20.50	2.00	1.19	1.16	9.80	9.80	17.00	17.00	153.00	153.00	9.61	9.50	3.90	5.70	130.00	135.00	220.00	427.40
7		20.00	20.00	1.50	2.49	2.59	9.30	9.30	31.00	25.50	127.00	140.30	9.13	9.72	4.50	7.60	210.00	200.00	596.00	579.00

Table (2): Nuterints and Productivity in Wadi El-Rayain Lakes.

Pond	Season	Ammonia		Nitrate		Nitrite		Org. Nitrogen		Orthophosphate		Org-phosphorus		Silicate		Gross Productivity
		Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	
1	Winter	49.20	115.00	2.30	10.80	85.30	228.40	0.93	0.63	28.90	11.40	45.30	37.20	16.12	15.18	98.86
2		56.80	47.30	2.00	4.80	96.70	95.10	0.22	1.49	0.00	12.20	101.30	53.30	16.25	13.35	69.37
3		62.40	33.30	2.30	3.40	97.30	78.60	0.72	0.84	16.20	10.50	55.00	37.00	13.33	15.83	19.80
4		62.30	78.10	3.10	4.00	83.00	102.70	0.59	0.63	71.50	0.00	28.30	49.60	13.23	16.12	324.29
5		53.90	86.20	2.00	3.30	100.50	81.60	0.82	1.21	0.00	54.00	49.90	30.70	16.63	16.50	30.22
6		108.70	70.90	0.00	0.00	112.10	97.90	0.99	0.81	12.20	12.20	33.80	38.80	59.62	15.15	190.69
7		56.30	65.40	0.00	0.00	29.30	44.90	1.12	0.63	4.10	12.20	40.50	75.40	21.83	23.58	816.62
1	Spring	139.00	413.80	8.30	6.40	115.40	474.20	0.58	0.19	40.70	41.10	47.30	97.70	7.25	9.23	62.61
2		97.00	190.70	0.90	5.40	118.30	366.70	1.30	0.56	35.90	34.10	52.10	52.70	8.15	9.15	283.93
3		76.40	160.90	4.60	4.00	114.70	136.70	1.12	1.09	29.30	43.40	49.40	35.60	9.75	8.35	198.90
4		123.00	249.90	1.30	12.60	131.00	500.30	0.84	4.47	27.90	32.60	53.60	63.90	9.33	9.10	161.57
5		100.20	136.70	5.60	3.60	151.30	162.00	0.66	1.12	32.60	37.40	45.60	60.40	8.76	10.62	17.46
6		110.00	126.90	3.80	1.90	196.00	156.00	0.67	1.29	19.00	28.50	23.00	69.00	6.73	7.41	66.79
7		30.80	47.30	0.00	0.00	268.00	160.00	1.44	0.98	66.50	114.00	29.00	17.00	11.22	9.42	52.78
1	Summer	130.30	132.70	29.80	19.80	293.30	417.00	1.57	0.93	26.40	17.60	96.20	52.30	18.22	17.78	259.80
2		83.90	70.70	0.00	0.00	14.60	4.90	1.83	1.21	26.40	19.80	163.20	31.80	16.89	16.44	93.59
3		74.30	152.70	0.00	0.00	4.90	24.30	1.21	1.11	26.40	46.20	33.40	19.60	16.67	16.44	31.29
4		114.70	1377.70	0.00	0.00	19.40	143.60	3.09	1.70	26.40	66.10	149.90	56.60	16.89	18.67	206.13
5		115.40	96.80	0.00	0.00	14.60	24.30	1.80	1.81	72.70	33.00	65.30	36.00	16.89	16.44	183.14
6		39.60	89.40	0.00	0.00	135.90	126.20	2.38	1.71	26.40	39.60	34.90	29.10	17.33	16.89	238.70
7		144.30	100.50	0.00	4.00	621.20	117.40	2.46	2.36	39.60	46.20	52.30	22.80	30.00	20.89	160.53
1	Autumn	618.20	67.40	14.30	12.40	161.50	11.90	1.43	2.15	43.60	49.80	76.40	78.20	12.40	9.97	271.00
2		183.30	163.00	10.30	10.30	147.90	24.00	1.06	1.48	60.20	105.80	91.80	22.20	9.97	16.30	134.13
3		30.00	84.30	10.30	9.30	41.00	34.80	0.56	0.71	43.00	37.00	144.40	90.40	10.79	7.81	268.33
4		131.70	168.00	10.30	12.40	416.10	93.40	0.73	0.84	130.70	43.60	403.30	324.40	10.96	8.80	171.13
5		78.70	39.30	10.30	10.30	28.90	41.20	3.24	5.51	37.20	49.80	42.80	46.20	10.63	8.31	243.19
6		39.30	36.00	8.30	8.30	119.10	128.70	1.23	0.93	40.20	43.60	80.00	148.40	9.97	9.30	30.60
7		78.70	67.40	31.00	34.60	96.40	627.00	2.59	2.09	87.20	236.60	130.80	317.00	7.97	8.47	67.90

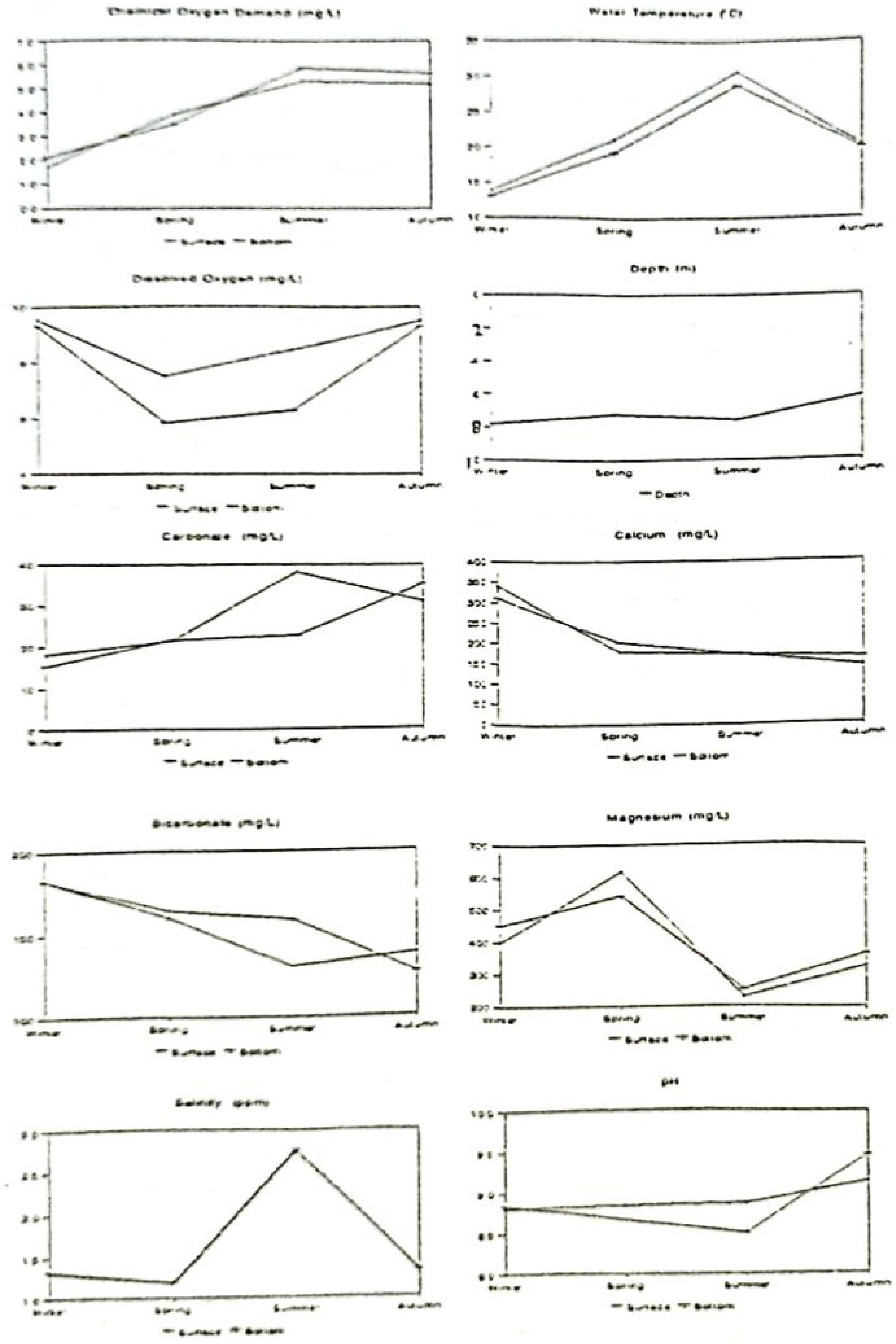

Fig. (2): Changes of CO_3-2; HCO_3-1; DO; COD; pH; Tmperature; Ca^{+2}; Mg^{+2}; Depth and Salinity.

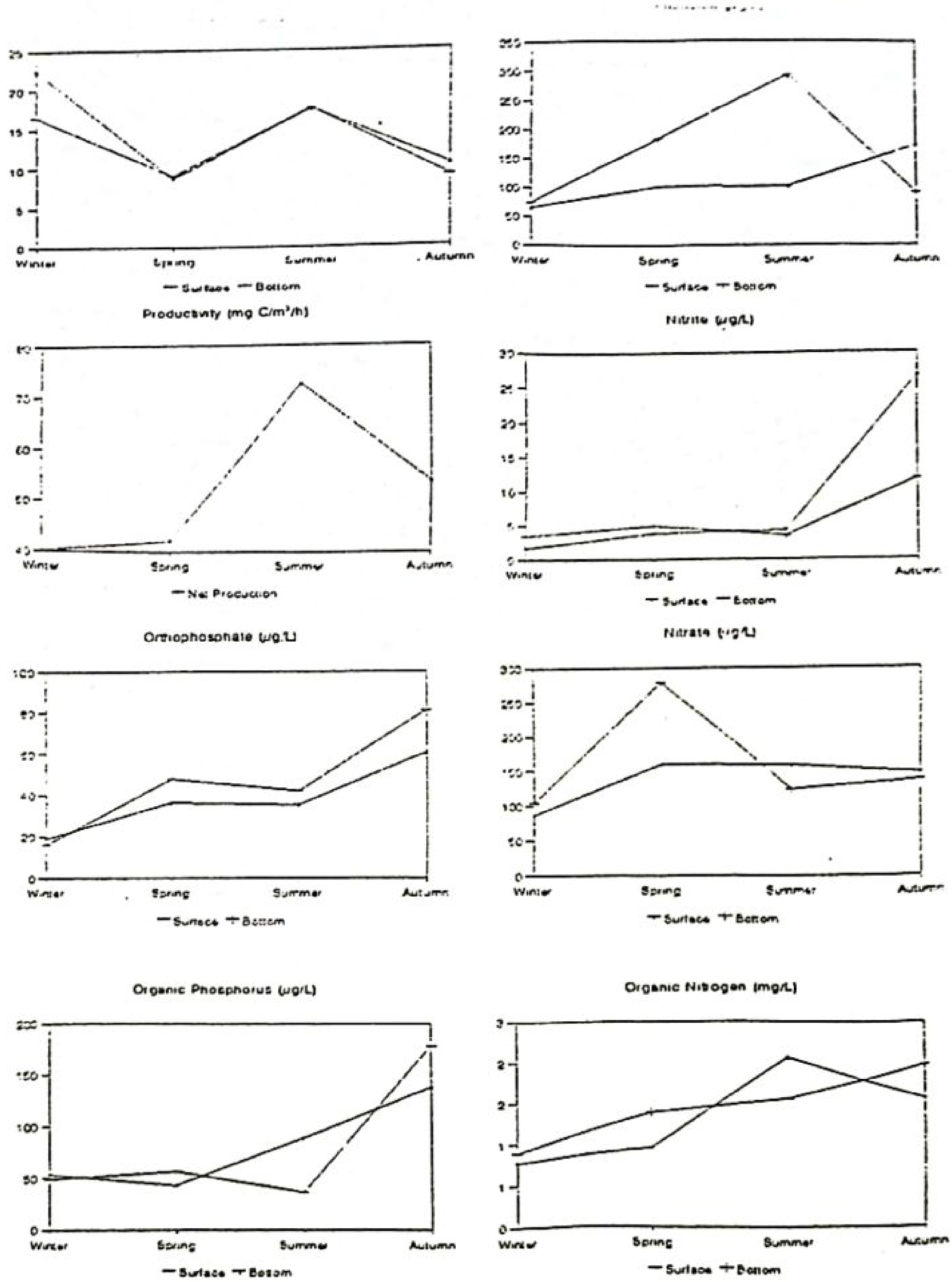

Fig. (3): Changes of Nutrients and Productivity in Wadi El-Rayian Lakes.

•Hydrogen Ion Concentration (pH):

The pH values lie always in the alkaline side. Their values ranged form a minimum of 8, 8, in winter and 8.5 in summer to a maximum of 9.1 and 9.5 , in autumn for both surface and bottom layers, respectively.

•Salinity:

Maximal salinities were always recorded at stations that lie away form the discharging point of El-Wadi Drain. Its value varied from 0.79 and 0.84% in spring to 3 and 3.19%, in summer for both surface and bottom layers. respectively.

•Alkalinity:

The alkalinity of Wadi El-Raiyan Lakes is characterized by increasing concentration of HCO_3^{-1} in comparison with CO_3^{-2}. The carbonate alkalinity of the surface and bottom water varied from a minimum of 18.16 and 15.30 mg/L. in winter, to a maximum of 30.97 and 35.21 mg/L. in autumn. HCO_3^{-1} contents ranged from a minimum of 130.18 mg/L. in summer and 126.31 mg/L. in autumn to a maximum of 182.51 and 182.64 mg/L. in winter for the surface and bottom waters.

•Oxygen:

Wadi El-Raiyan Lakes are characterized by high level of dissolved oxygen, especially in the surface layer. The dissolved oxygen values varied from a minimum of 7.48 and 5.81 mg/L. in spring to a maximum of 9.56 and 9.35 mg/L. in winter for the surface and bottom layers, respectively.

•Chemical Oxygen Demand (COD):

The chemical oxygen demand of the lake varied between a minimum of 1.7 and 2.1 mg/L. in winter and a maximum of 5.3 and 5.9 mg/L. in summer for surface and bottom waters.

•Hardness (Ca+2 and Mg+2):

Magnesium concentrations of the lake were much higher than the corresponding values of Ca^{+2}. Calcium contents of the lakes ranged from a minimum of 139.28 and 160, in autumn to a maximum of 341.67 and 309.79 mg/L. in winter for the surface and bottom layers. In the meantime, magnesium concentrations of the lake fluctuated from 225.9 and 251.4 mg/L, in summer to 616.8 and 542.0 mg/L. in spring for both surface and bottom layers, respectively.

•Nitrogen:

The inorganic nitrogen of the lake water is represented by NH_4, NO_2 and NO_3.The organic nitrogen contents of the lake was much higher than the inorganic forms.

•Ammonium-N:

NH_4-N concentration fluctuated from a minimum of 64.5 ad 73.5 µg/L, in winter to a maximum of 171.8 µg/L, in autumn and 291.5 µg/L, in summer, for surface and bottom layers, respectively.

•Nitrite-N:

Nitrite nitrogen contents varied from 1.7 and 3.5 µg/L, in winter to 26.6 µg/L, in autumn, for surface and botton layers.

•Nitrate-N:

Nitrate contents fluctuated from a minimum of 86.3 and 104 µg/L, in winter to amazimum of 159.3 and 278.5 µg/L, in spring.

•Organic nitrogen:

The organic nitrogen contents ranged from 0.77 mg/L, in winter and 0.81 mg/L, in spring to a maximum of 2.05 mg/L, in summer and 1.96 mg/L, in autumn, for both surface and bottom layers, respectivley.

•Orthophosphate and Organic Phosphorus:

•Orthophosphate:

Its concentrations vanied from 19.0 and 16.0 µg/L, in winter to 60.4 and 81.0 µg/L, in autumn for surface and bottom layers respectivley.

•Organic phosphorus:

Its contents fluctuated from 42.9, in spring and 35.8 μg/L, in summer to a maximum of 137.9 and 178.1 μg/L, in autumn for surface bottom waters.

•Silicate (SiO3-Si):

SiO_3-Si concentrations varied from a minimum of 4.04 and 3.58 mg/L, in spring to a maximum of 9.45 and 9.95 mg/L, in summer for the surface and bottom layers, respectively.

•Productivity:

The Gross production reached its maximum being 221.4 mg/c/m_3/h during winter, while it reached its minimum in spring being 120.81 mg/c/m^{23}/h.

DISCUSSION

The present study represents the most recent and comprehensive survey so far made on the physicochemical characters in the first and second lakes of Wadi El-Raiyan as well as the beging of the third depression. This survey entails the physical and chemical conditions i. e. temperature, pH, salinity, alkalinity, nutrient salts, nitrate, nitrite, ammonium, organic nitrogen, orthophosphate, organic phosphorus. Ca, Mg, silicate, Chemical Oxygen Demand (C.O.D.), dissolved oxygen (DO.), transparency.

The general climate of Wadi El-Raiyan area is hot dry with scanty winter rain and year round bright sunshine. The area is hyper-arid with mild winter and hot summer. The air temperatures fluctuated from an absolute minimum of 14.9°C. in winter to a maximum value of 35°C. in summer, with an annual amplitude value of 20.1°C. The water temperature of the lake were slightly lower than the corresponding value of air temperature and ranged from 12.8 and 12.7°C, in winter to 31.5 and 30.5°C, in summer for surface and bottom layers, respectivley. Its annual amplitude for both layers amounted to 18.7 & 17.8°C. This is however, no obvious thermal stratification in the first, second and the northern region of the third lake. The lakes can be considered as a homothermic, a phenomenon that affects the special distribution of phytoplankton and nutrients. Water temperature plays an important role in growth, proliferation and species composition of phytoplankton communities (MeQueen and Lean, 1987). This consequently affects the reproduction of all heterotrophic organisms, including fish. Temperature not only affects the growth of phytoplankton and other aquatic organisms but also the irradiance at which saturation occurs with an increase in temperature there is a proportional increase in the amount of light required to saturate the light reaction (Campbell and Bate, 1987). In winter, therefore light saturation occurs at half the irradiance required in summer.

The water depths in the lakes range between 1.5 and 23m. The eastern region of the first lake (station 4) is the deepest, while the southern basin of this lake is the shallowest region. In general, the middle, eastern, and western basins of the first lake are much deeper than the other sampling sites. On the other hand, the secchi disc reading indicated that the trophogenic layer extends to the bottom at shallow region (stations 5, 6& 7). Its values depend on phytoplankton density rather than on the amounts of colloidal humus and minerals in the water column. This means that the turbidity of the water is mainly due to autochthonous factor. This view is confirmed by the inverse correlation between secchi disc reading, and both chlorophyll a r=0.56 and the standing crop of phytoplankton r=0.65. In the meantime, there was no relation between secchi disc values and the suspended solids. Algal cells usually influence secchi disc and euophotic depth by absorbing band scatering light (Tilzer, 1988).

The pH values of Wadi El-Raiyan Lakes lie always in the alkaline sides. Its absolute values varied from a minimum 8.7, in spring to a moximum of 9.5, in autumn; with a total annual average value of 8.9 for both surface and botton layers. The pH values of Wadi El-Raiyan waters are clearly connected with the stage of phytoplankton development and the magnitude of phytoplankton biomass as represented by chlorophyll a. On the other hand, the dissolved oxygen and salinity of Wadi El-Raiyan have insignificant effect on pH values. The present results of pH agree with those reported by Saleh et al., (1988), who found that water pH of Wadi El-Raiyan Lakes showed a consistent increase in moving away from the origin.

The absolute values of surface water salinity ranged from a minimum of 1.184 g/l, in spring to a maximum of 2.74 g/L. in summer, with an annual average value of 1.638 g/L. The corresponding values of bottom water salinities were slightly high and varied from 1.2 g/L. in spring to 2.766 g/L. in summer, with a total annual average value of 1.658 g/L. The obvious increase in salinity during summer is due to increase in temperature and consequently increasing evaporation. In spring, minimum salinities were observed due to the discharge of large quantities of drainage water into the lakes during this period. There is a positive corelation between salinity and temperature (r=0.82). Water salinity is consistently increased in moving away from the emptying point of El-Wadi Drain into the first lake. In this connection, Hutchinson (1957) reported that the salinity of lake waters of closed drainage basins is governed not only by inputs of dissolved ions from runoff, but by the fate of this materials upon evaporation. The present salinities of the first and second lakes were slightly higher than the corresponding values reported by the previous investigations. This is mainly due to the rapid alteration in the water of these lakes as a result of large amounts of drainage discharging into the first lake via El-Wadi Drain.

The carbonate alkalinity in Wadi El-Raiyan Lakes varied from a minimum of 8 mg/L. in winter to a maximum of 50.3 mg/L. in summer, while the bicarbonate alkalinity ranged from 110.5 mg/L. in autumn to 208.6 mg/L. in summer. The total annual average value of carbonate alkalinity amounted to 27.18 mg/L., for the surface layer and 23.78 mg/L, for the bottom, while these of bicarbonate were 152.57 mg/L, for the surface and 157.92 mg/L, for the bottom. The alkalinity of Wadi El-Raiyan waters is due to the dissolved carbon dioxide which is found in the form of CO_2, HCO_3, CO_3 and undissociated H2CO_3 ,the constituted of CO_2 in the lakes is in equilibrium with each other and change with the change in pH. The obvious decrease in HCO_3 during autumn is mainly attributed to increasing photosynthetic activities of phytoplankton rather than the effects of O_2 and temperature. In this connection Khalil (1984) reported that CO_3 contents of Wadi El-Raiyan Lakes varied from 11.9 mg/L, in winter to 14.1 mg/L, in summer, while HCO_3 values ranged form 110.3 mg/L, in summer to 125.3 mg/L, in winter. The difference between the present and previous alkalinity of the lakes can be attributed to increasing salinity of the water that consequently increased HCO_3 and CO_3 contents. This view is confirmed by the positive correlation between salinity and alkalinity (r=0.81). On the other hand, the carbonate and bicarbonate contents of both surface and bottom layers are clearly connected with the stage of phytoplankton development and magnitude of the biomass (Niemi, 1972). The dissolved oxygen content in Wadi El-Raiyan lakes is usually affected by several factors such as , photosynthetic activity of phytoplankton, respiration of heterotrophic, and autotrophic organisms and decomposition of organic matter as well as temperature and S‰. The dissolved oxygen values in the surface layer varied from absolute minimum of 6.98 mg/L, in spring to 10.3 mg/L, in winter (percentage saturation 82.6 and 104%); with a total annual average value of 8.75 mg/L, in the bottom, its contents ranged from completely anoxia, in spring to 9.97 mg/L, in winter (100% saturation), with a total annual average value of 7.68 mg/L. The results of oxygen revealed the effective role of phytoplankton in the oxygen budget of Wadi El-Raiyan waters. This observation is confirmed by the distinct correlation between phytoplankton biomass as represented by chlorophyll a and dissolved oxygen (r= 0.75). The absence of oxygen from the bottom layer of the eastern basin of the first lake (station 4) is due to increase in the organic matter concentration. The major source of organic matter at this area is the cattle farm that lies in vicinity of this basin and discharging its waste into the lake. However, most of dissolved oxygen is consumed during the decomposition of these organic materials. The oxygen content of Wadi El-Raiyan was characterized by increasing its values during the turnover in autumn particularly during winter circulation to over 100% of saturation. Similar conditions were observed by earlier investigators (Saleh, et a., 1988 & Aboul-Ela and Khalil, 1988). The important role of Calcium in Wadi El-Raiyan Lakes is its effect on pH and the CO_2-HCO_3 system. Its values in the surface layer varied form absolute minimum of 100 mg/L, in autumn to 820 mg/L, in winter, with a total annual average value of 208.28 mg/L. Its contents in the bottom water ranged from absolute minimum of 110 mg/L, in autumn to 692.65 mg/L, in winter, with an annual average value of 211.34 mg/L. The level of Ca was usually high on moving away from the discharging point of El-Wadi Drain into the first lake. However, its contents in the southern basin (st. 7) were in most cases higher than the other region.

Calcium affects phytoplankton population through its buffering effect on lake pH (Lund, 1965). Magnesium ions in Wadi El-Raiyan lakes were much higher than Ca ions. Its contents in the surface layer varied between an absolute minimum of 144 mg/L, in summer to a maximum of 730 mg/L, in spring; with a total annual average value of 392.35 mg/L. In the meantime, its contents in the botton waters ranged from 110 mg/L, in autumn to a maximum of 692.65 mg/L, in winter; with a total annual average value of 211.34 mg/L. In general, water hardness (Ca & Mg) in Wadi El-Raiyan had significantly increased in moving away from the discharging point of El-Wadi Drain, without obvious correlation with salinity. This means that the increasing Ca & Mg in the lakes is mainly due to leaching of these ions from soils as water moves deep into the desert. The chemical oxygen demand (C.O.D.) represents the amount of oxygen required for oxidation of organic matters in the lake waters. Its values in the surface layer fluctuated from 1.5 mg/L, in winter to a maximum of 7.7 mg/L, in summer; with a total annual average value of 4.03 mgl. In the bottom water, its contents varied form 1.5 mg/L, in winter to 8.8 mg/L, in summer, with an annual average value of 4.28 mg/L. No correlation was observed between C. O. D. and neither phytoplankton biomass nor its crop. This however indicates that htere is a significant allochthonous organic load into the lakes rather than the autochthonous sources, probably sewage. It is noteworthy that there is no previous data dealt with C.O.D. in Wadi-El-Raiyan Lakes.

Nutrient salts play an important role in phytoplankton production in any aquatic ecosystem. The main sources of nutrient inputs into Wadi El-Raiyan Lakes are. (1) inflow of agricultural drainage water and sewage via El-Wadi Drain (2) Liberation of mutrients from the bottom sediment of the lakes (3) Excretions of the aquatic organisms inhabiting the lakes. Also, the death and decomposition of these organisms represent a significant source of nutrients into the lakes. The concentrations of nutrient salts (N.P & Si) in Wadi El-Raiyan Lakes were always exceeding the demand of primary producers.

Ammonia-N contents in the surface layer of the lakes ranged from absolute minimum of 39.3 µg/L, to a maximum value of 618.2 µg/L, in autumn; with a total annual average value of 110 µg/L, in the bottom water, it contents fluctuated form 39.3 µg/L, in autumn to 445.8 µg/L, in spring; with an annual average of 160.6 µg/L. The results reveal the high level of NH_4-N in the deep water of the lakes. This is mainly attributed to the denitrification processes that occur near the bottom. This phenomenon was observed also by Saleh et al., (1988), although the concentrations of NH4-N reported by them (range 0-150 µg/L) were slightly lower than the present results. In the meantime, the values of NH4-N reported by Khlil (1984) (range 0.71 to 2.85 ppm) were abnormally higher than the corresponding results presented by other investigation. The high level of NH4-N during winter is mainly due to increasing rate of the in-coming drainage and wastewater. Its contents, however, was significantly high at the discharging point of El-Wadi Drain into the lake and decreased on moving away from this site.

The unstable nitrite-N is more or less following NH4-N varitations in Wadi El-Raiyan Lakes. Its contents varied from complete depletion to 101.3 and 18.6 µg/L, in the surface and bottom layers, during autumn. Stations near the discharging point of El-Wadi Drain gave relatively high nitrite values being affected by drainage water. In general, the absence or presence of nitrite in small quantities might not be so peculiar as it is unstable anion. The present results of NO_2-N of the lakes agree with the previous data reported by Khalil (1984) and Salah et al., (1988).

Nitrate is more stable among inorganic nitrogenous compounds in the lakes. Its contents in the surface layer fluctuated from an absolute minimum of 4.9 µg/L to a maximum value of 621.2 µg/L, in summer. In the bottom waters, its concentrations ranged from 4.9 µg/L, in summer to 6.27 µg/L, in autumn. The total annual average values of both layers were 137.7 and 160.8 µg/L.

In general, nitrate concentration in Wadi El-Raiyan showed a very irregular distribution, being signifiantly high at the beginning of the first lake (station 1) and at the northern most basin of the third lake (station 7).

This means that the in-coming agricultural drainage water represents a significant source of NO_3-N into Wadi El-Raiyan Lakes. The present data of NO_3-N agree with the corresponding results reported by Saleh et al., (1988) while its values recorded by Khalil (1984) were abnormally high.

The organic nitrogen contents of the surface water ranged from an absolute minimum of 0.22 mg/L, in winter to a maximum value of 3.24 mg/L, in autumn; with a total annual average value of 1.33 mg/L. In the bottom water, its concentrations fluctuated from 0.56 mg/L, in spring to 5.51 mg/L, in autumn; with an annual average value of 1.3 mg/L,.
The organic nitrogen content in the lakes was positively correlated with phytoplankton biomass as represented by chlorophyll a (r=0.88). This leads to conclusion that phytoplankton represents the major source of organic nitrogen compounds in the lakes i. e. autochthonous origin.

The orthophosphate and organic phosphorus concentrations in both surface and bottom layers of the lakes had increased during winter, reaching the maximum in autumn. They showed a very irregular distribution along the selected sampling sites. The orthophosphate contents varied from complete depletion in winter to 72.7 µg/L, in summer and to 130.7 µg/L, in autumn, for both surface and bottom layers respectively. In the meantime, the organic nitrogen concentration in the surface water ranged from 23 µg/L, in spring to 405.3 µg/L, in autumn; with a total annual average value of 80.6µg/L. In the bottom layer, its values fluctuated from a minimum value of 17 µg/L, in spring to a maximum of 537 µg/L, in autumn; with an annual average value of 79.9 µg/L. The results reveal the positive relation between phytoplankton and organic phosphorus (r=0.88). This leads to the conclusion that phytoplankton is the major source of organic phosphorus in the lakes i. e. autochthonous origin. The wastewater represents the major source of organic phosphorus in Wadi El-Raiyan Lakes. This view is confirmed by the obvious decrease in organic phosphorus in the discharging point of El-Wadi Drain, while its values had significantly increased on moving away from this site.

Dissolved silicate does not seem to be limiting factor for phytoplankton growth in Wadi El-Raiyan Lakes, but is essential for diatoms grwth and flourishing. Large amount of silica are added to the lakes via the drainage water beside a supply of this component from sediments.

The absolute values of silicate in the surface water varied from a minimum of 0.73 mg/L, in spring to a maximum of 59.62 mg/L, in winter,with a total annual average value of 14.78 mg/L. In the bottom layer, its contents ranged from 7.41 mg/L, in spring to 20.89 mg/L, in summer, with an annual average value of 13.1 mg/L. The present results of silicate agree with that obtained by Khalil (1984), while the date reproted by Saleh et al., (1988) were abnormally low (range 0.3 to 0.4 mg/L,). In general, the values of silicate in the lakes are usually exceedingly the demand of diatoms. However, there was no obvious correlation between silicate contents and diatom growth. The bottom water had a surplus of silicate relative to the readly available in the surface layer. This can be attributed to the significant release of SiO_3-Si from bottom sediments.

The productivity was positively correlated with carbonate and bicarbonate (r=0.922 and r=0.867) for both carbonate and bicarbondate, respectively. Barrett (1953) found that hard waters are more productive than soft water. Moyle (1946) found that alkalinity of 40 ppm appears to be a reasonable good biological dividing line between hard and soft water. In this case Wadi El-Raiyan Lakes can be designated as hard water lakes, alkalinity about 200 ppm. There is also positive correlation between productivity and temperature (r=0.921) and between productivity and nutrients where r=0.537 for NO_3 and r=0.5 for PO_4. This data agrees with the studies of Sommer et al., (1986). They investigated that the gross production depends typically on temperature and nutrients variation, while silica had a negative correlation with productivity (r=0.064). This data agree with Vaquer and El-Hafa (1991). They found that SiO_2 are not limiting for the productivity or the predominated species (large diatoms) in the reservoir of Sainte Croix in France.

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