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Water Quality and Phytoplankton Communities in Lake Al-Asfar, Al-Hassa, Saudi Arabia

A.A. Fathi, M.A. Al-Fredan and A.M. Youssef
Department of Biology, College of Science, King Faisal University, Saudi Arabia

Abstract: Some characteristics of Lake Al-Asfar, Al-Hassa, Saudi Arabia were monitored over a period of one year. Seasonal differences in the quantitative and qualitative composition of the phytoplankton communities in Lake Al-Asfar were marked. The maximum crop density was recorded in spring, whereas lowest values occurred in winter. The total crop densities were mainly a reflection of the trends in counts of Chlorophyceae. Four algal groups were recorded during the investigation: Bacillariophyceae, Chlorophyceae, Cyanophyceae and Euglenophyceae. Thirty nine species were identified allover the period of the investigation. Out of these, 14 species belong to Chlorophyceae, 15 belong to Bacillariophyceae, 7 to Cyanophyceae and 3 to Euglenophyceae. *Chlorella* sp., *Chlorococcus humicola*, *Monoraphidium contortum*, *Oedogonium* sp., *Cyclotella meneghiniana*, *Gyrosigma* sp., *Fragilaria capucina, Navicula lanceolata*, *Surirella obonga*, *Synedra acus*, *Tabellaria* sp. and *Oscillatoria* sp. were observed in a high rank of occurrence. Seven algal species were moderately common and 3 species were frequently recovered, most of them belong to Bacillariophyceae. The remaining recorded species were rarely recovered. Generally, the species data suggests that the water of Lake Al-Asfar can be considered as eutrophic.

Key words: Al-Asfar lake, phytoplankton, water chemistry, wetland

INTRODUCTION

Water chemistry exhibit variable physical and chemical characteristics and consequently variable planktonic compositions (Fathi *et al*., 2001; Fathi and Flower, 2005). These variations depend mainly on the type and nature of the water area itself as well as on the manmade additions or runoff of minerals and chemicals from agriculture soils (Mohammed *et al*., 1986). Surveys of water chemistry and algal vegetation at nine stream sites in the Asir Mountains, Saudi Arabia, were made by Whitton *et al*. (1986). Okla (1987) studied the algal micro facies in upper tuwaiq mountain limestone (Upper Jurassic) near Riyadh, Saudi Arabia. Hussain *et al*. (1996) surveyed a 16.5 km long irrigation canal in Al-Kharj City, for its water chemistry and Charophyte periodicity and density. Al-Homaidan and Arif (1998) studied the seasonal succession of bloom-forming algae over a period of 3 consecutive years (1992-1995) in relation to the trophic changes taking place in a semi-permanent rain-fed pool at Al-Kharj, Saudi Arabia. Shaikh *et al*. (2004) studied the Phytoplankton ecology and production in the Red Sea off Jeddah, Saudi Arabia. Recently, Al- Fredan and Fathi (2007) studied the edaphic algae in Al-Hassa region.

Wetlands are very important natural areas. Millions of water birds depend on them. Wetlands have on average the richest biodiversity of all ecosystems. By using wetlands more effectively, recreational activities have become possible, such as fishing, boating and bird watching. This has generated money from visitors and provides sustainable development opportunities. The main reason

Corresponding Author: Adel A. Fathi, Department of Biology, College of Science, King Faisal University, 31982 Al-Hassa, P.O. Box 55076, Saudi Arabia

wetlands are so important is because they are important water provider. Nowadays wetlands are capable of providing alternative sources of income for local communities (Flower *et al*., 2001).

Arid environments are the most diverse ecosystems of Saudi Arabia. However, much of their hydrobiology and its component biotic information are still unknown to the scientific community (Al-Kahtani *et al*., 2007). Al-Asfar Lake is one from the important shallow wetland lakes. It is located on the eastern region of Saudi Arabia, Al-Hassa Province. However, much of their limnology and its biotic information are still unknown to the scientific community. Accordingly, this study will be conducted Al-Asfar Lake to report the results on a routine sampling seasonally of water chemistry and algae over a one year period, which it could be the first record.

MATERIALS AND METHODS

The Studied Area and Climate

Al-Asfar Lake is one from the important shallow wetland lakes. It is located on Al-Hassa, eastern region of Saudi Arabia. Al-Hassa Province is one of the largest oases in the world and located in the southern part of the eastern region of Saudi Arabia. It is situated between 25° 05' and 25° 40' northern latitude and 49° 55' eastern longitude. Al-Asfar Lake is located east of the oasis of Al-Hassa, grow on the banks of many plant. The lake is the site of the confluence of migratory birds from outside the area visited by dozens of the virtues of birds. The lake formed a result of wastewater a farm in the oasis of Al-Hassa.

Sampling Physico-Chemical Characteristics

A regular visit was monitoring the spring over a period of one-year (March 2007 to February 2008). Surface water samples were collected monthly from different sites within the lake. The sites were distributed to give good spatial representation of water quality. Temperature, pH, conductivity, total dissolved salts and dissolved oxygen of the lake water were measured at each location. pH was measured using a pH meter (370 pH meter Jenway, UK), conductivity and total dissolved salts using a calibrated Conductivity Meter (470 Conductivity meter, Jenway, UK). Dissolved oxygen was measured according to the Winkler method (Strickland and Parsons, 1972). Total alkalinity, phosphate-P, nitrate-N, chloride, silicate and major cations were measured in the lake water samples according to Adams (1991). Sodium and potassium concentrations were determined photometrically by flame emission according to Golterman and Clymo (1971). The results were calculated as mean values of triplicate measurements made on each water sample from each of the four sampling stations.

Quantitative and Qualitative Analysis of Phytoplankton

Chlorophyll's content of water was determined according to the method described by Strickland and Parsons (1972). For phytoplankton analysis, 1 L water samples were fixed in the field with acidified Lugol' s solution. In the laboratory samples were allowed to settle for at least 36 h, after which time the supernatant was carefully removed and the remaining volume adjusted to a fixed volume. This sample was kept at 4°C until analysis. Phytoplankton counts were done using a phase contrast Carl Zeiss (Jena Med2 microscope) at 100 and 40x magnification, following the Utermöhl technique (Utermöhl, 1958). Diatoms were examined in permanent preparations after cleaning in hydrogen peroxide to reveal frustules sculpture, which is essential for species level identification. The permanent slides used for diatom examination were prepared mainly according to Barber and Haworth (1981).

For algal counting, the simplified methods described by Willen (1976) and Hobro and Willen (1977) were followed. Counts of phytoplanktonic algae (unicellular, colonial or filamentous) were expressed as cells per liter. Cell numbers were calculated as mean values of triplicate measurements at each of the four sampling stations. The algal taxa were identified according to standard references, including Smith (1950), Fott (1972), Bourrelly (1981), Komarek and Fott (1983), Prescott (1987) and Krammer and Lange-Bertalot (1986, 1988, 1991a, b). Brillouin' s index (H) as described by Pielou (1966) was used for quantitative analysis of species diversity.

RESULTS AND DISCUSSION

It is well known that, the physical and chemical characteristics controlling life in aquatic habitats, either saline or brackish water, lead to the appearance of special types of biota (Fathi and Kobbia, 2000; Fathi *et al*., 2001; El-Naghy *et al*., 2004; Fathi and Flower, 2005; Al-Kahtani *et al*., 2007).

The average water temperature of Lake Al-Asfar was subjected to seasonal variations. The temperature of water reached its minimum in winter (16.8°C) while the maximum (30.4°C) was recorded in summer (Table 1). The water temperature of Al-Asfar Lake generally followed that of the air, due to the shallow depth and large expanse of surface as compared with the volume (Ruttner, 1963). In the present investigation the lake did not show proper thermal stratification, as it is extremely shallow (maximum depth 1.5 m). Allott (1986) reported that thermal stratification is weak in the shallowest lakes. Generally, it can be said that any increase or decrease in standing crop of phytoplankton at Al-AsfarLake seemed to be strongly correlated with fluctuation in water temperature. This is in accordance with results obtained by Mohammed and Fathi (1990), Fathi and Kobbia (2000), Fathi *et al*. (2001), Fathi and Abdelzahar (2003) and Fathi and Flower (2005).

Change in pH value was always in the alkaline side. It fluctuated between 7.35 in winter and 8.12 in summer. Generally, this general tendency to the alkaline side may be due to the increased photosynthetic activity of planktonic algae, which was also previously recorded by El-Wakeel and Waihby (1970), Kobbia *et al*. (1995), Fathi and Kobbia (2000) Fathi *et al*. (2001) and Fathi and Flower (2005). The lowest pH and alkalinity values recorded in Al-Asfar lake may be due to greater amount of in flowing agriculture water and also to the decomposition of plankton and organic matter (Badawy *et al*., 1995; El-Nagar *et al*., 1997, 1998; Fathi and Abdelzahar, 2003).

The conductivity and the total dissolved salts (TDS) of water were found to be higher in summer (11.93 mS cm^{-1} and 7.13 g L^{-1}, respectively) but dropped to a minimum level in winter (8.80 mS cm^{-1} and 5.32 g L^{-1}, respectively). The highest value of its electrical conductivity and TDS could be attributed mainly to the high pollution levels in water, resulted from the high nutrient loads of wastewater (Kobbia *et al*., 1995; Fathi *et al*., 2001). On the other hand Fathi *et al*. (2001) and Flower *et al*. (2001) reported that the fluctuations of salinity of North Egyptians lakes from time to time, could be explained by the differences of the input amount of drainage water.

Table 1: Chemical composition of the Al-Asfar Lake water during the investigation period

Parameters	Spring	Summer	Autumn	Winter
Temperature (°C)	21.00	30.40	20.00	16.80
pH	7.78	8.12	7.78	7.35
Conductivity (mS)	10.37	11.93	10.52	8.80
TDS (g L^{-1})	6.22	7.13	6.31	5.32
Dissolved O_2 (g L^{-1})	12.57	14.80	8.32	5.29
Alkalinity (mg L^{-1})	470.00±2.04	376.00±3.15	141.40±5.24	117.20±2.14
Chloride (g L^{-1})	1.60±0.10	2.16±0.15	1.78±0.15	1.76±0.10
Nitrate-N (mg L^{-1})	1.02±1.00	1.09±0.50	1.67±0.20	2.05±0.15
Phosphate-P (mg L^{-1})	1.75±0.25	1.47±0.25	2.01±0.30	2.73±0.16
Silicate (mg L^{-1})	3.33±0.12	3.85±0.20	3.62±0.30	2.62±0.15
Sodium (g L^{-1})	1.40±0.00	2.10±0.00	1.38±0.00	1.25±0.00
Potassium (mg L^{-1})	31.50±0.00	32.00±0.00	30.00±0.00	21.00±0.00
Calcium (mg L^{-1})	56.05±0.30	62.50±0.20	51.00±0.20	42.00±0.20
Magnesium (mg L^{-1})	34.22±0.10	44.00±0.20	29.81±0.15	16.00±0.20
COD (mg L^{-1})	7.22±0.10	44.00±0.20	15.81±0.15	16.00±0.20

Means±SD (n = 3)

Dissolved oxygen is an important parameter for identification of different water masses. The oxygen content of the investigated lake water tended to be higher in summer (14.80 mg L^{-1}) and lower in winter (5.29 mg L^{-1}). The relatively high concentrations of dissolved oxygen recorded in this study (summer) could be mainly attributed to light intensity rather than photosynthetic activity of phytoplankton. Mohammed and Fathi (1990), Fathi *et al*. (2001) and Fathi and Abdelzahar (2003) due to the increased photosynthetic activity of phytoplankton populations. In this respect, Talling (1976) noticed that oxygen super saturation due to photosynthetic activity is often encountered in regions with abundant phytoplankton.

Total alkalinity of Al-Asfar Lake water reached its minimum in winter (117 mg L^{-1}), whereas the maximum was recorded in spring (470 mg L^{-1}), this increases may be due to the bacterial decomposition of organic substrates (Abdel-Satar and Elewa, 2001).

Monovalent and divalent cations play very important role in the productivity of inland water. Calcium and magnesium are reported to be of importance for phytoplankton production (Hussein, 1989). In the present study the values of divalent (calcium and magnesium) and monovalent cations (sodium and potassium) were relatively high at all samples, irrespective of some minor fluctuations in seasonally readings. Levels of calcium and magnesium were found to fluctuate within the ranges of 42.00-62.50 mg L^{-1} and 16.00-44.00 mg L^{-1}, respectively. On the other hand the concentrations of sodium were found to be higher throughout the study period, which exceeded those of calcium, magnesium and potassium in the lake water. It fluctuated from 2.10 g L^{-1}(in summer) to 1.25 g L^{-1} (in winter). Generally, Al-Asfar Lake water showed rather higher values of sodium content. Despite its major role in algal growth and photosynthesis, there are only a few instances of either magnesium deficiency or toxicity in lakes (Goldman, 1960). Magnesium is usually present in aquatic system in large amounts relative to plant needs. Both sodium and potassium play important role in the productivity of water (Cole, 1983; Goldman and Horne, 1983). Talling and Talling (1965) suggested that the amounts of sodium, calcium and chloride determine the species present rather than quantitative development of phytoplankton.

Chloride attained their maximum in summer (2.16 g L^{-1}) and dropped to their minimum in spring (1.60 g L^{-1}). The high concentrations of chloride recorded in this study (summer) could be mainly attributed to drain water discharge or to high summer temperature which accelerate evaporations. It seemed probable that ions play significant role in biomass and standing crop, stated that chlorides appear to limit algal production directly in nature, but in the form of NaCl.

The maximum value of nitrate was found in winter 2.05 mg L^{-1} and the minimum value in spring 1.02 mg L^{-1}. The highest values of nitrate-N reflect the direct effect of the agriculture runoff (Gharib and Soliman, 1998), while the lowest values of nitrate-N are indicative of phytoplankton uptake. On the other hand, phosphate content tended to be high also in winter but lower in the other seasons. The recorded high phosphate values probably due to the release of great amounts of adsorbed phosphate from the bottom sediments or to drainage water (Gharib and Soliman, 1998). On the other hand the lowest values of phosphate concentrations could be attributed to the vigorous uptake by the heavy blooms of phytoplankton (Mohammed and Fathi, 1990; Fathi and Kobbia, 2000; Fathi *et al*., 2001; Fathi and Flower, 2005). Silicate levels fluctuated between the seasons without any regular trend. The observed fluctuations in silicate concentrations were probably related to variation in silicate uptake by diatom (Fathi and Kobbia, 2000).

The chemical oxygen demand was taken in the present study as a measure of the oxygenated state and additionally the amount of organic \matter in water as well. The data of this study show that COD tended to be higher in summer (44.00 mg L^{-1}) and lowered on the other seasons. The increase in COD could be attributed to the high organic matter content that produces about poor oxygenated state of water (Fathi and Zaki, 1999; Fathi and Kobbia, 2000; Aly and Yahya, 2002; Fathi *et al*., 2001; Fathi and Abdelzahar, 2003).

On the other hand chlorophyll's content in spring exceeded that recorded in other samples (Fig. 1), which could be attributed to vigorous phytoplankton growth (Fathi and Kobbia, 2000; Fathi and Abdelzahar, 2003).

It is well known that, the changes in physico-chemical characteristics of any water mass lead to concomitant qualitative and quantitative changes in phytoplanktonic organisms (Mohammed *et al*., 1986). The data of this study shows that there are marked seasonal differences in the quantitative and qualitative composition of the phytoplankton communities in Al-Asfar (Table 2, Fig. 2). In terms of total cell number the maximum count (163×10^6 cell L^{-1}) was recorded in spring, whereas the lowest densities occurred in winter (11×10^6 cell L^{-1}). The changes in total algal counts throughout the investigation coincided closely with in Chlorophyceae abundance. It is worthy to mention that in summer sample some blue green algal genera were recorded in a high abundance.

Four algal groups were recorded throughout the investigation period, Bacillariophyceae, Chlorophyceae, Cyanophyceae and Euglenophyceae. (Table 2, Fig. 3). The total percentage composition of the four main phytoplankton groups shows that Chlorophyceae dominated the phytoplankton of Al-Asfar throughout the study period. Bacillariophyceae ranked second. Ranking third were the Cyanophyceae, which were least abundant in the summer. Euglenophyceae ranked fourth in order of dominance.

The data included in Table 2 further revealed that a total of 39 species were identified allover the period of the investigation. Out of these, 14 species belong to Chlorophyceae, 15 belong to

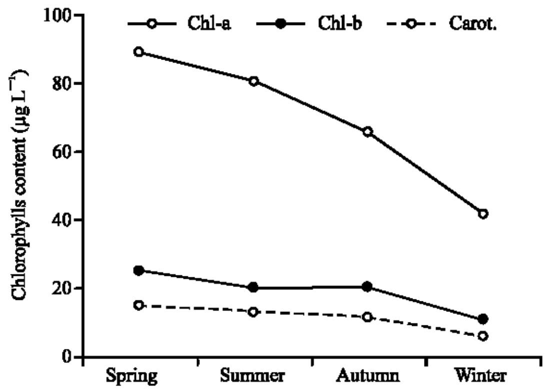

Fig. 1: A seasonal variation of chlorophyll's content in Al-Asfar Lake during the investigation period

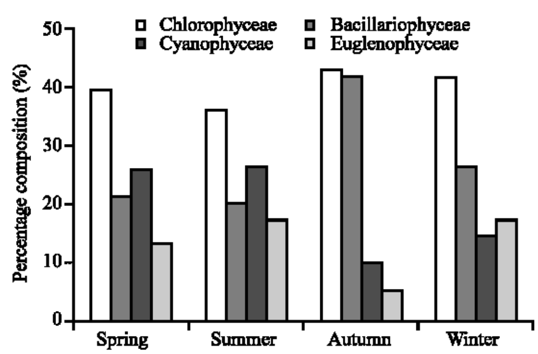

Fig. 2: The percentage composition of the main algal groups recorded at Al-Asfar Lake during the investigation period

Table 2: Relative occurrence of the phytoplankton on Al-Asfar Lake during the study period

Algal taxa	Spring	Summer	Autumn	Winter
Chlorophyceae				
Actinastrum hantzschii Lagerh.	+	+		
Actinastrum sp.	+	++	+	+
Chlorella sp.	++++	++++	++	++
Chlorococcus humicola (Nag)	++++	+++	++	+
Crucigenia sp.			+	+
Gleocystis major Gerneck			+	+
Monoraphidium contortum Komarava	++	++	++	+
Oedogonium sp.	++	+++	++	+
Pandorina sp.		+		
Scenedesmus acuminatus Chodat			+	
Scenedesmus bijuga (Turp.) Lag.				+
Scenedsmus quadriquda (Breb).	+	++		
Schroederia setigera Lemm.		+		
Tetraedron muticum Hansgirg	+	+		
Bacillariophyceae				
Amphora ovalis Kutz		+		
Cocconies sp.	++	++	+	+
Cyclotella meneghiniana	++++	+++	+	+
Cymbella cistula	++	++	+	+
Diatoma sp.	+	+		
Fragilaria capucina	+++	+++	+	+
Gyrosigma sp.	++++	++++	++	+
Navicula lanceolata	++++	+++	+	+
Navicula sp.	++	++		
Nitzschia sp.	++	++	+	+
Stephanodiscus invisitatus	+	+		
Surirella obonga	+++	+++	+	+
Synedra acus Kutz	+++	+++	+	+
Synedra ulna	+	++	+	+
*Tabellar*ia sp.	+++	++	+	+
Cyanophyceae				
Anabaena sp.	+	+		
Chroococcus turgidus Nagel	++	+		
Lyngbya sp.	++	+	+	
Microcystis aeruginosa (Kleb.) Geitler	+	+		
Microsystis flos-aquse	+	+		
Oscillatoria sp.	+++	++	+	
Phormidium sp.	+	+	+	+
Euglenophyceae				
Euglena acus Ehrenberg	+	++		
Euglena promixa Dangeard	+	++		
Phacus sp.		+		
Diversity index (H)	2.08	1.02	1.87	0.66

High: ++++, Moderate: +++, Frequent: ++, Rare: +

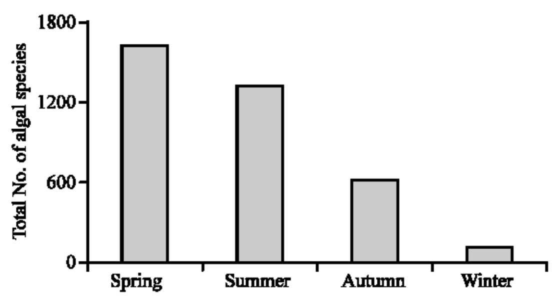

Fig. 3: Phytoplankton abundance (No. x10^5 L^{-1}) for Al-Asfar Lake during the investigation period

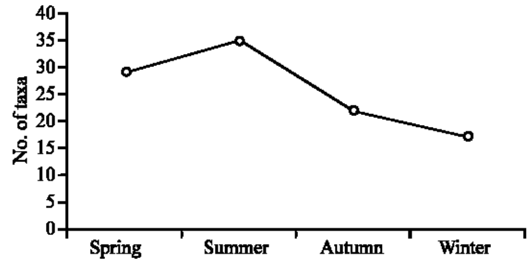

Fig. 4: Seasonal variations of the species richness (total number of phytoplankton taxa encounted per standard sample count of Al-Asfar Lake phytoplankton, during the investigation period

Bacillariophyceae, 7 to Cyanophceae and 3 to Euglenophyceae. The maximum number of phytoplankton taxa (species richness) on any one sampling period (35 species) occurred in spring, while the minimum (17 species) was in winter (Fig. 4). *Chlorella* sp., *Chlorococcus humicola Monoraphidium contortum*, *Oedogonium* sp., *Cyclotella meneghiniana*, *Gyrosigma* sp., *Fragilaria capucina*, *Navicula lanceolata*, *Surirella obonga*, *Synedra acus, Tabellaria* sp. and *Oscillatoria* sp. were observed in a high rank of occurrence. Seven algal species were moderately common such as (*Ankistrodesmus fusiformis*, *Cymbella cistula*, *Nitzschia* sp. *Synedra ulna*, *Phormidium* sp. and *Euglen prmoxia* and *Euglena acus*). On the other hand 3 species were frequently recovered, most of them belong to Bacillariophyceae. The remaining recorded species were rarely recovered. Generally, the phytoplankton crop showed a remarkable increase indicted high level of eutrophication in Lake Sector.

The data of Table 2 also shows that the maximum diversity index 2.08 was estimated on summer, while the minimum 0.66 was in winter. It should be noted that biological indices of species diversity, based mainly on the composition of phytoplankton have been proposed by Pielou (1966) and Nygaard (1978) may indicate the pollutional state of water. There are several numerical attempts (Sabae and Rabeh, 2000) to express degrees of oligotrophy and eutrophy from a consideration of species complements rather than from nutrient levels (Shaaban *et al*., 1985). Nosseir and Abou El-Kheir (1970), Fathi and Zaki (1999), Fathi *et al*. (2001) and Fathi and Flower (2005) believe that the biological estimation of the degree of eutrophication and pollution of aquatic ecosystems is probably more informative than chemical determinations. According to the phytoplankton one could consider that the water of Al-Asfar are eutrophic. According to scales of Staub *et al*. (1970), Al-Asfar is indicates heavy polluted in autumn and winter and moderate pollution in spring and summer. In conclusion, the investigated lake area is contaminated with discharge waters enriched with chemicals fertilizers in addition to domestic and industrial effluents. These are manifested by high amounts of organic matter, a high concentration of nutrients (causing eutrophication).

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