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Key Biodiversity Areas: Rapid assessment of phytoplankton in the Mesopotamian Marshlands of southern Iraq

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Abstract

Between the summers of 2005 and 2007, studies have been conducted for five seasons in several marsh locations in southern Iraq. During five surveys, 317 taxa of phytoplankton belonging to six major groups were identified. These included: 204 taxa of Bacillariophyceae (represented by 13 Centrales and 191 Pennales, thus 14% and 27% respectively of all taxa recorded), 59 Chlorophyta (28%), one Cryptophyta (4%), 39 Cyanophyta (21%), 10 Euglenophyta (2%) and four Pyrrophyta (4% of all the taxa recorded). The Central Marsh, Hammar Marsh and the Hawizeh Marsh had higher phytoplankton populations compared to all other studied sites. The dominant phytoplankton groups throughout the study area were the Bacillariophyceae, Chlorophyta and Cyanophyta. The dominant species were *Cyclotella meneghiniana*, *Kirchneriella irregularis* and *Nitzschia palea.* A progression in the richness and biodiversity of species occurred during winter. These three phytoplankton groups were dominant in waters of southern Iraq and were responsible for most of the species richness and diversity observed. Generally, sites changed from summer to winter according to the changing conditions associated with nutrients, salinity, temperature, and light intensity. These controlling factors influenced phytoplankton biomass from season to season.

Keywords

Phytoplankton, Iraq, marshlands

Introduction

Aquatic ecosystems are dynamic with several biotic and abiotic variables changing in space and time. From 2005 to 2007, after reflooding of the southern marshes, the Key Biodiversity Areas (KBA) project led by Nature Iraq undertook ecological surveys of flora and fauna across southern Iraq (Rubec and Bachmann 2008). The KBA Project was involved a rapid assessment in several marshes to understand changes that took place in the physicochemical characteristics of the marshes and consequently changes in phytoplankton composition. Most of the surveys occurred in the Central Marsh, Hammar Marsh, Hawizeh Marsh, Middle Euphrates, the Khor al-Zobayr, the Seasonal Marshes and the Shatt al-Arab. Although, the phytoplankton flora in some of these marshes has been studied previously, the present study contributes new information on the current status of phytoplankton populations and their diversity in these ecosystems. This is in relation to physicochemical characteristics of these waters after several decades of major environmental degradation caused by conflict, dam building in the Tigris-Euphrates Basin and directed drainage by the previous regime.

Wetlands are ecosystems in which the soil, despite periodic fluctuations in water level, is more or less continuously waterlogged. Non-marine wetlands generally have a water depth less than 2 m and, by this definition comprise as much as 6% of the land area of the earth's surface (Mitsch and Gosselink 1993). Studies have shown that marshes are suitable areas for the growth of several types of algae and higher aquatic plants. The marshes of southern Iraq seem especially suitable for growth of algae so that they diversify widely due to the shallow waters, the slow flow of the water attributable to low gradients and suitable nutrient concentrations and temperatures (Yaaqub 1992). Therefore, these algae have been widely used for water quality monitoring, and as they are primary producers, they are easily affected by physical and chemical variations in their environment (Bartram and Balance 1996).

Temporal and spatial distributions of phytoplankton are determined by a variety of environmental factors, including sunlight, the availability of essential nutrients and water temperature. Hinton and Maulood (1980, 1982) showed that at least 77 diatom taxa and 101 non-diatom taxa are known from the brackish waters of southern Iraq, the Shatt al-Arab and the Hammar Marsh. A total of 129 algal species and 63 genera were in the marshes near Qurna (Pankow et al. 1979, Al-Saboonchi et al. 1982). Some 72 Bacillariophyta, 28 Chlorophyta, 26 Cyanophyta, two Euglenophyta, and one Cryptophyta have been recorded in Hammar Marsh (Nurul-Islam 1982). Dinoflagellates have also been recorded in the marshes (Evans 2001).

Materials and methods

For qualitative studies of phytoplankton, samples were taken by a phytoplankton net manufactured by Hydro-Bios (23 µm in pore diameter), which was placed into the water 10 to 15 cm below the water surface and pulled at an appropriate speed for 10 to15 min. The phytoplankton collected was transferred to a polyethylene container and preserved by adding Lugol's solution at a ratio of 1:100 with 40% formaldehyde until analyzed in the laboratory. The non-diatoms were identified by taking a drop of the sample on a slide with a slide cover, and then examined using a compound microscope (x10, x40 and x100). For diatom identification, a water sample was mixed with an equal volume of nitric acid in a 15 ml test tube to dissolve the organic matter surrounding the diatoms. The diatoms were precipitated by centrifuge and permanent slides were made using Canada balsam or Naphrax and a hot plate (Patrick and Riemer 1975).

For the quantitative study of phytoplankton, one-liter water samples were collected in polyethylene containers and preserved with a Lugol/formaldehyde solution (as described above). Following sedimentation the total number of phytoplankton organisms was counted (Furet and Benson-Evans 1982). Permanent slides were prepared and diatoms were identified using a compound microscope. Smith (1950), Prescott (1944, 1982) and Thompson (1959) were references used in phytoplankton identification. The Shannon-Wiener Diversity Index (H) was used to determine the diversity and compare among stations. This was done using the statistical software CANOCO 4.5 package (Ter Braak and Šmilauer 2002); the equation is:

$$H = -\sum (Ni/N)^{*} \; Ln \; {}^{*}(Ni/N)$$

N = the hall summation of species density in the single station

Ni = density of single species

Study area

Most of the field sites in southern Iraq had not been surveyed since at least 1979 or earlier. An initial February and March 2005 survey was restricted to seven sites in southern Iraq. It was limited by practical and security issues in that period and seen as a start-up, experience-building exercise. All other southern KBA sites were included in the subsequent 2005 through 2007 surveys. In order to facilitate field survey logistics, seven major wetland areas as shown in Fig. 1 and Table 1 were defined.

Results and discussion

Throughout the five surveys conducted, 317 phytoplankton taxa belonging to six major algal categories were identified. These include 204 Bacillariophyceae (13 Centrales and 191 Pennales representing 14% and 27% of the total taxa recorded respectively); 59 Chlorophyta (28% of all taxa recorded); one Cryptophyta (4%); 39 Cyanophyta (21%); 10 Euglenophyta (2%); and 4 Pyrrophyta (4%).

During summer 2005 survey, Cyanophyta had the highest total count (90,207.1 $\times 10^3$ cells L^{-1}). The dominant Cyanophyta species were *Anabaena* sp., *Microcystis aeruginosa*, *Merismopedia convolute*, *Oscillatoria geitleri*, *Oscillatoria limnetica*, and *Lyngbya*

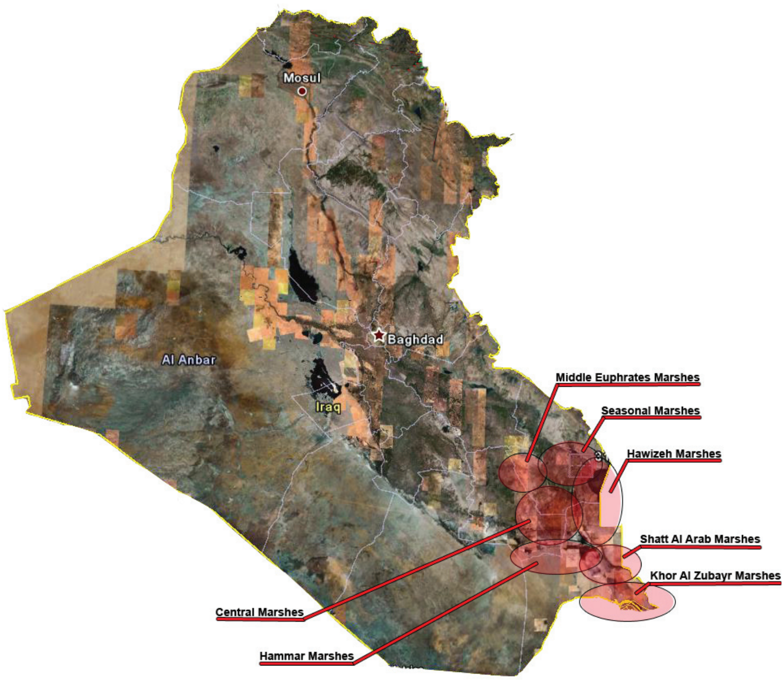

Figure 1. Major wetlands of southern Iraq indicating specific locations of marshes surveyed for phytoplankton assessment.

Table 1. The seven major wetland areas of southern Iraq.

Major Wetland Area	Area	Governorates
Hammar Marshes (HA)	20 field sites covering 350,000 ha	Thi Qar, Basrah
Central Marshes (CM)	24 field sites covering 705,000 ha	Thi Qar, Wasit, Missan
Hawizeh Marshes (HZ)	Seven sites covering 235,000 ha	Missan
Mesopotamian Marshes (MP)	Four field sites covering 30,000	Muthanna, Babil, Wasit
Seasonal Marshes (SM)	Five sites covering 5,200 ha	Missan
Shatt al-Arab Marshes (SA)	Four sites covering 16,500 marshes	Basrah
Khour al-Zobayr Marshes (KZ)	Four sites covering 20,000 ha	Basrah

limnetica. These genera of Cyanophyta are known for their ability to produce potential toxic substances especially *Anabaena*, *Lyngbya* and *Microcystis* (Sivonen and Jones 1999, Carmichael 2001). These species are also among the most abundant Cyanophyta in fresh and brackish waters (Huisman et al. 2005). *Microcystis* possesses gas vesicles that make them buoyant. This characteristic may have aided in the dominance of this species because it allows it to receive more light than species lacking gas vesicles (Seckbach 2007). Most of these dominant Cyanophyta prefer relatively alkaline, warmer, saline and nutrient-rich waters (Wehr and Sheath 2003, Al-Saadi and Sulaiman 2006).

The Cyanophyta were followed in abundance by the diatoms, Chlorophyta and Pyrrophyta, as shown in Appendix 1.

During both the winter and summer 2006 surveys, Chlorophyta had the highest total counts (37,308.9 × 10^3 cells L^{-1} and 23,180.8 × 10^3 cells L^{-1} respectively). The Chlorophyta is known to occur primarily in freshwater. It was mainly dominated by *Kirchneriella irregularis*, *Scenedesmus quadricauda*, *Monoraphidium contortum* and *Coelastrum astroideum.* Non-motile chlorophytes were a component of the plankton community (e.g. *Monoraphidium*, *Coelastrum* and *Scenedesmus*). Under moderate conditions, these species are most abundant in freshwater ecosystems especially during the summer, when light and temperature are near their seasonal maximum and nutrients become a limiting factor. The diatoms followed the chlorophytes during both seasons in terms of abundance (41,804.5 × 10^3 cells L^{-1}) and were dominated by *Cyclotella atomus*, *Cyclotella meneghiniana*, *Achnanthes minutissima*, *Fragilaria ulna*, *Fragilaria vaucheriae*, *Nitzschia gracilis*, *Nitzschia longissima* and *Nitzschia palea. Cyclotella meneghiniana* is known to prefer relatively slow flowing, saline and alkaline waters (Stoermer and Smol 2004).

Achnanthes minutissima was one of the dominant pennate diatoms probably because this species is physiologically more active than larger diatom cells. This would partly be due to its large surface to volume ratios (Allen 1977). Usually, dominant algal groups of nutrient-rich, temperate freshwater wetlands include pennate diatoms, typically genera such as *Achnanthes*, *Fragilaria*, *Navicula* and *Nitzschia* (Stevenson et al. 1996). In the winter 2007 survey, Bacillariophyceae/Pennales had the highest total count (29,674.2 × 10^3 cells L^{-1}). The dominant species was *Nitzschia palea,* one of the most common species in this genus, which is often found in organically polluted waters (Palmer 1969). In addition, *Oscillatoria limnetica* was the main cyanophyte, *Peridinium cinctum* the main dinoflagellate and *Kirchneriella irregularis* the main chlorophyte observed. In the summer of 2007 survey, the chlorophytes that had the highest total counts (54,473.4 × 10^3 cells L^{-1}) were *Kirchneriella irregularis*, *Scenedesmus quadricauda* and *Monoraphidium convolutum.*

Generally, in all of these surveys, the highest cell concentrations were in the Central Marsh, Hammar Marsh and Hawizeh Marsh (Table 2). Among the 24 sites in the Central Marsh, those with the highest diversity were Al Kinziryi, the Al Hammar Area and Al Fhood. From the 20 sites in the Hammar Marsh, the most diverse site was Al Sallal. Ojayradah was the most diverse site among the seven sites in the Hawizeh Marsh.

Therefore, algal assemblages may differ between restored and extant wetlands and could be valuable indicators of restoration success because algal species composition and diversity would differ in low- and high-nutrient wetlands (John 1993, Mayer and Galatowitsch 1999 as cited in Stevenson et al. 2006). Sites obviously also revealed changes from summer to winter, associated with changes in nutrients, temperature and light intensity. Therefore, changes in seasonality as shown by varying environmental variables could strongly affect phytoplankton variability (Abdul-Hussein and Mason 1988). Variations in the annual temperature regime appear to be the major cause of temporal variability of phytoplankton in the area, as observed by Gayoso (1998).

Table 2. Total count (× 10^3 cell L^{-1}) and percentage of identified phytoplankton groups in locations surveyed during summer 2005 to summer 2007. Major wetland areas: Hammar Marshes (HA), Central Marshes (CM), Hawizeh Marshes (HZ), Mesopotamian Marshes (MP), Seasonal Marshes (SM), Shatt al-Arab Marshes (SA), Khor al-Zobayr Marshes (KZ).

Survey	Sites	Bac./ Centrales		Bac./ Pennales		Chloro-phyta		Crypto-phyta		Cyano-phyta		Eugleno-phyta		Pyrro-phyta	
		T. C.	%	T. C.	%	T. C.	%	T. C.	%	T. C.	%	T. C.	%	T. C.	%
Summer 2005	**CM**	10598.6	43.3	19385.0	49.5	22602.7	56.9	2917.5	87.9	43060.4	47.7	1751.3	65.2	457.0	3.0
	HA	10282.8	42.0	9820.5	25.1	12346.9	31.1	355.3	10.7	31237.5	34.6	821.2	30.6	499.2	3.3
	HZ	340.9	1.4	4328.4	11.1	4387.5	11.1	46.3	1.4	11983.1	13.3	112.9	4.2	294.1	1.9
	SA	2877.4	11.8	3917.0	10.0	347.4	0.9	0.0	0.0	654.2	0.7	0.0	0.0	54.4	0.4
	KZ	270.1	1.1	154.4	0.4	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0
	MP	91.0	0.4	1556.3	4.0	10.1	0.0	1.0	0.0	3271.9	3.6	1.0	0.0	13903.9	91.4
	SM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total	24460.8	100.0	39161.6	100.0	39695.6	100.0	3320.1	100.0	90207.1	100.0	2686.4	100.0	15210.6	100.0
Winter 2006	**CM**	9436.7	79.6	20155.6	53.5	35860.9	96.1	2889.2	33.2	1778.0	19.0	2756.8	77.9	193.3	31.8
	HA	311.5	2.6	6394.7	17.0	86.7	0.2	19.2	0.2	733.8	7.8	0.0	0.0	19.2	3.2
	HZ	1114.1	9.4	6305.5	16.7	980.2	2.6	4710.1	54.0	6313.4	67.5	733.7	20.7	151.2	24.9
	SA	581.9	4.9	2278.5	6.0	363.0	1.0	751.8	8.6	219.5	2.3	37.2	1.1	226.4	37.2
	KZ	133.6	1.1	214.6	0.6	0.0	0.0	0.0	0.0	271.7	2.9	9.1	0.3	9.1	1.5
	MP	279.4	2.4	2321.8	6.2	18.1	0.0	344.2	3.9	38.2	0.4	0.0	0.0	9.1	1.5
	SM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total	11857.2	100.0	37670.7	100.0	37308.9	100.0	8714.5	100.0	9354.6	100.0	3536.8	100.0	608.3	100.0
Summer 2006	**CM**	3752.7	20.0	7209.2	31.3	17254.7	74.4	2128.6	97.5	3539.6	22.1	652.4	48.2	2256.2	48.4
	HA	11638.3	61.9	7063.5	30.7	1575.4	6.8	54.3	2.5	865.8	5.4	511.5	37.8	1703.6	36.5
	HZ	280.1	1.5	3654.1	15.9	2778.2	12.0	1.0	0.0	11223.9	70.1	178.2	13.2	112.8	2.4
	SA	2769.8	14.7	4440.5	19.3	1073.2	4.6	0.0	0.0	366.6	2.3	0.0	0.0	72.4	1.6
	KZ	249.9	1.3	262.1	1.1	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	479.9	10.3
	MP	102.2	0.5	382.1	1.7	499.3	2.2	0.0	0.0	19.1	0.1	12.1	0.9	36.2	0.8
	SM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total	18793.0	100.0	23011.5	100.0	23180.8	100.0	2183.9	100.0	16016.0	100.0	1354.2	100.0	4661.1	100.0

Survey	Sites	Bac./ Centrales T. C.	%	Bac./ Pennales T. C.	%	Chloro-phyta T. C.	%	Crypto-phyta T. C.	%	Cyano-phyta T. C.	%	Eugleno-phyta T. C.	%	Pyrro-phyta T. C.	%
Winter 2007	**CM**	9861.7	63.6	11345.6	38.2	8166.7	42.6	5869.2	64.8	455.2	7.1	56.5	5.4	905.5	22.6
	HA	1946.3	12.5	5734.9	19.3	8605.9	44.9	1240.9	13.7	1486.8	23.3	81.5	7.7	2571.6	64.2
	HZ	1771.9	11.4	4102.8	13.8	1495.8	7.8	1023.4	11.3	3691.3	57.9	0.0	0.0	199.3	5.0
	SA	528.0	3.4	2334.7	7.9	299.1	1.6	289.7	3.2	83.6	1.3	63.4	6.0	108.8	2.7
	KZ	1161.8	7.5	153.6	0.5	434.9	2.3	625.0	6.9	489.2	7.7	272.7	25.9	153.9	3.8
	MP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	SM	247.9	1.6	6002.6	20.2	154.0	0.8	9.1	0.1	173.2	2.7	579.7	55.0	63.4	1.6
	Total	15517.6	100.0	29674.2	100.0	19156.4	100.0	9057.3	100.0	6379.3	100.0	1053.8	100.0	4002.5	100.0
Summer 2007	**CM**	5206.2	33.8	25491.5	68.0	33188.9	60.9	878.5	39.0	455.2	10.1	880.3	73.7	626.2	31.5
	HA	8125.3	52.8	7133.0	19.0	13017.4	23.9	1222.8	54.2	2230.2	49.4	283.1	23.7	743.7	37.4
	HZ	191.1	1.2	1501.5	4.0	7655.6	14.1	126.8	5.6	1026.8	22.8	11.1	0.9	126.9	6.4
	SA	1480.0	9.6	1416.3	3.8	542.9	1.0	9.1	0.4	763.8	16.9	0.0	0.0	55.4	2.8
	KZ	134.6	0.9	121.3	0.3	28.2	0.1	0.0	0.0	9.1	0.2	0.0	0.0	63.4	3.2
	MP	244.9	1.6	1842.7	4.9	40.4	0.1	18.1	0.8	27.2	0.6	19.2	1.6	371.4	18.7
	SM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total	15382.1	100.0	37506.3	100.0	54473.4	100.0	2255.3	100.0	4512.3	100.0	1193.7	100.0	1987.0	100.0

According to richness and diversity indicators, the authors observed that there is an improvement in water quality in the southern Iraqi marshes especially in winter. This may be attributed to the fact that in winter nutrient levels are higher due to seasonally higher rainfall and thus higher runoff from the surrounding lands. Oxygen concentrations are also higher at lower temperatures. Canonical Correspondence Analysis (CCA) was used to elucidate the relationships between biological assemblages of the phytoplankton samples and their environment to determine the phytoplankton richness and diversity in the marshes. As a result, there was an increase in the phytoplankton richness and diversity of these marshes, as illustrated in Figs 2 and 3.

Each object shape in Fig. 2 demonstrates a phytoplankton sample obtained during the surveys, indicating the diversity and richness during the five surveys. Diversity and richness values of the first two surveys during the summer of 2005 and the winter of 2006 were scattered compared with the values recorded during the 2007 winter and summer, where they started to develop and increase in numbers.

Fig. 3 demonstrates that the phytoplankton diversity ranged between 1.6–2.1 during summer 2005 and winter 2006, while diversity values became higher during the following surveys ranging between 2.1 and 2.4, meaning that the diversity increased.

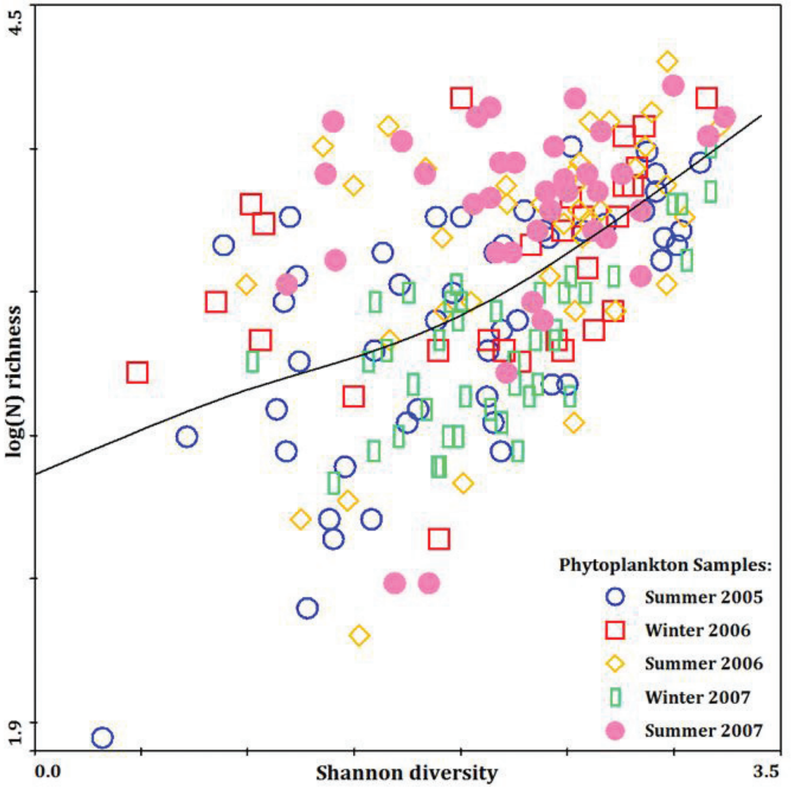

Figure 2. Seasonal phytoplankton diversity and richness in all sites.

It is clear that the diversity during the first two surveys was lower compared to the following surveys where the diversity began to even out and fluctuate to a lesser degree. The increase in the phytoplankton diversity and richness were most likely related to the environmental conditions that also started getting more stable.

An important reason for the success of certain algal species in wetland habitats is their ability to tolerate variations in water level and desiccation. Water levels may fluctuate several times in a few months or persist for several years. Algae that are subjected to a variable moisture regime must have the capacity to adapt to tolerate the extremes of these environmental conditions (Wehr and Sheath 2003). Thus, many factors may contribute to phytoplankton diversity and production in wetlands, including nutrients, temperature, light, macrophytes, etc. (Stevenson et al. 1996). As in other water bodies, nutrient conditions, climate, and geology influence species composition but in wetlands, water level, plant composition and degree of mixing with other water bodies are also important for the phytoplankton community (Goldsborough and Robinson 1996).

In the southern Iraqi marshes, the authors observed that diatoms, Chlorophyta and Cyanophyta were the dominant phytoplankton groups, which agrees with the findings of Goldsborough and Robinson (1996).

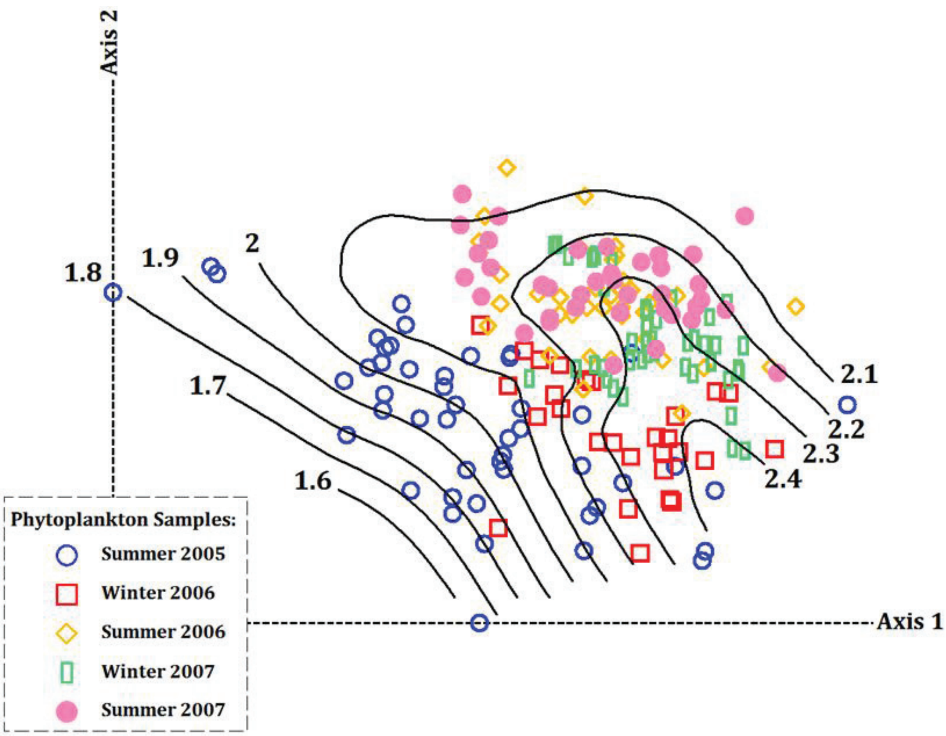

Figure 3. Seasonal phytoplankton diversity contour in all sites.

Conclusions and recommendations

The main conclusions from these studies are:

The phytoplankton groups that dominate the southern marshes are diatoms, Chlorophyta and Cyanophyta, with other groups having a low number of species;

In all sites of the southern marshes of Iraq studied, especially in the Central Marsh, Hammar Marsh and Hawizeh Marsh, phytoplankton richness and diversity increased from 2005 to 2007.

Based on these studies, several recommendations relevant to the management of the marshes of southern Iraq are made by the authors:

Phytoplankton should be used for ongoing biological monitoring and as indicators for organic pollution in the marshes;

The controlling factors influencing phytoplankton biomass may vary from season to season and phytoplankton biomass may be more sensitive and responsive to environmental variables in winter and summer as compared to autumn and spring. Monitoring programs should be flexible to allow for adjustment to these changing environmental conditions;

Monitoring studies should focus on the main parameters that have the greatest effects on the phytoplankton community. These are: light penetration, temperature, pH, water flow, nutrient levels and land use, in particular for water buffalo and cattle grazing.

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References

Abdul-Hussein MM, Mason CF (1988) The phytoplankton community of a eutrophic reservoir. Hydrobiologia 169: 265–277.

Allen TFH (1977) Scale in microscopic algal ecology: a neglected dimension. Phycologia 16:253–257. Cited in Wehr JD, Sheath RG (2003).

Al-Saadi HA, Sulaiman NA (2006) Phycology. Amman, Jordan: Al-Yazori Press. (In Arabic).

Al-Saboonchi AA, Mohammed ARM, Barak NA (1982) A study of phytoplankton in the Garma Marshes, Iraq. Iraqi J. Mas.Sci.1(1): 67–78.

Bartram J, Balance R (Eds) (1996) Water Quality Monitoring: Practical Guide to the Design and Implementation of Freshwater Quality Studies and Monitoring Programmes. London, United Kingdom: E and F.N. Spon Co.,

Carmichael WW (2001) A mini-review of cyanotoxins, toxins of cyanophyta (blue-green algae). Cited in de Koe et al. (2005).

Chorus I, Bartram J (Eds) (2005) Toxic Cyanophyta in Water: A Guide to Their Public Health Consequences, Monitoring and Management. London, United Kingdom: E. and F.N. Spon Co. Cited in Huisman et al. (2005).

De Koe WJ, Samson RA, van Egmond HP, Gilbert J, Sabino M (Eds) (2005) Mycotoxins and Phycotoxins in Perspective at the Turn of the Millennium. Wageningen, The Netherlands: Ponsen and Looyen Inc. pp. 495–504. in Huisman et al. (2005).

Edmonston WT (1959). Freshwater Biology. New York, USA: John Wiley and Sons, Inc.

Evans MI (2001) The Ecosystem in Iraqi Marshlands: Prospects. Proceedings of a Conference of the AMAR International Charitable Foundation. London, United Kingdon.

Furet JE, Benson-Evans K (1982) An evaluation of the time required to obtain complete sedimentation of fixed algal prior to enumeration. Br. Phycol. J. 17: 253–258.

Gayoso AM (1998) Long-term phytoplankton studies in the Bahía Blanca estuary, Argentina. ICES Journal of Marine Science 55: 655–660.

Goldsborough LG, Robinson GGC (1996) Pattern in wetlands, pp. 77–117 in Stevenson RJ, Bothwell ML, Lowe RL (Eds) (1996).

Hinton GCF, Maulood BK (1980) Some diatoms from brackish water habitats in southern Iraq. Nova Hedwigia 33: 475–486.

Hinton GCF, Maulood BK (1982) Contributions to the algal flora of Iraq: the non-diatom flora of the southern marshes. Nova Hedwigia 37: 49–63.

Huisman J, Matthijs HCP, Visser PM (2005) Harmful Cyanophyta. Dordrecht, The Netherlands: Springer Inc. (e-book).

John J (1993) The use of diatoms in monitoring the development of created wetlands at a sandmining site in western Australia. Hydrobiologica 269/270: 427–436, p. 222 as cited in Stevenson et al. (2006).

Mayer PM, Galatowitsch SM (1999) Diatom communities as ecological indicators of recovery in restored prairie wetlands. Wetlands 19: 765–774, p. 222 as cited in Stevenson et al. (2006).

Mitsch WJ, Gosselink JG (1993) Wetlands. 2nd ed. New York, USA: Van Nostrand-Reinhold.

Nurul-Islam AKM (1982) Marsh algae from southern Iraq. Int. Rev. Gesamt. Hydrobiol. 67(2): 245–60. Cited in Evans (2001).

Palmer JD (1996) Rubisco surprises in dinoflagellates. Plant Cell 8:343–345. Cited in Wehr JD, Sheath RG (2003).

Pankow H, Al-Saadi HA, Huq MF, Hadi RAM (1979) On the algal flora of the marshes near Qurnah (southern Iraq). Willdenowia 8(3):493–506.

Patrick R, Reimer CW (1975) The Diatoms of the United States. Vol. 2, Monograph No. 13. Philadelphia, USA: Academy of Natural Sciences.

Prescott GW (1944) How to Know the Freshwater Algae. Duduque, USA: Wm. C. Brown Company Publishers.

Prescott GW (1982) Algae of the Western Great Lakes Area. Dubuque, USA: Wm. C. Brown Publishers.

Rubec CDA, Bachmann A (2008) The Key Biodiversity Areas Program in Iraq: Objectives and Scope 2004–2008. Unpublished Project Report. Sulaimani, Kurdistan, Iraq: Nature Iraq

Seckbach J (2007) Algae and Cyanophyta in Extreme Environments. Dordrecht, The Netherlands: Springer Inc. (e-book).

Sivonen K, Jones GJ (1999) Cyanophytal toxins, pp. 41–111 in Chorus I, Bartam J (2005).

Smith GM (1950) The Freshwater Algae of the United States. New York, USA: McGraw-Hill Book Company.

Stevenson RJ, Bothwell ML, Lowe RL (1996) Algal Ecology: Freshwater Benthic Ecosystems. San Diego, USA: Academic Press.

Stevenson RJ, Pan Y, Kociolek JP, Kingston JC (Eds) (2006) Advances in Algal Biology: A Commemoration of the Work of Rex Lowe. Hydrobiologica 561: 221–238.

Stoermer EF, Smol JP (2004) The Diatoms Applications for the Environmental and Earth Sciences. Cambridge University Press. (e-book: netLibrary).

Thompson RH (1959) Algae. Cited in Edmonston WT (1959).

Ter Braak CJF, Šmilauer P (2002) CANOCO Reference Manual and CanoDraw for Windows User's Guide: Software for Canonical Community Ordination (version 4.5). Ithaca, NY, USA: Microcomputer Power.

Wehr JD, Sheath RG (2003) Freshwater Algae of North America. San Diego, USA: Elsevier Inc.

Yaaqub A (1992) Algae of southern Iraqi marshes. Proceedings of the Forum on Southern Iraqi Marshes Environment. December 20–21, 1992. Basrah, Iraq. (In Arabic).

Appendix 1.

List of phytoplankton species identified during KBA-South Survey 2005–2007

CYANOPHYTA

Anabaena sp.
Aphanocapsa sp.
Aphanothece sp.
Calothrix sp.
Chroococcus dispersus
Chroococcus limneticus
Chroococcus minor
Chroococcus minutus
Chroococcus turgidus
Chroococcus sp.
Coccoid algae
Gloeocapsa turgidus
Gomphosphaeria aponina
Leptolyngbya perelegans
Lyngbya limnetica
Merismopedia convolute
Merismopedia glauca
Microcystis aeruginosa
Nostoc sp.
Oscillatoria acuminata
Oscillatoria amoena
Oscillatoria amphibium
Oscillatoria angustissimum
Oscillatoria chalybeum
Oscillatoria curviceps
Oscillatoria earlei
Oscillatoria geitleri
Oscillatoria limnetica
Oscillatoria limosa
Oscillatoria minima
Oscillatoria subberis
Oscillatoria tenuis
Oscillatoria tenuis var. *natans*
Oscillatoria sp.
Spirulina laxa
Spirulina major
Tolypothrix sp.

EUGLENOPHYTA

Euglena acus
Euglena convoluta
Euglena minuta
Euglena sp.
Lepocinclis sp.
Phacus gigas
Phacus longicauda
Phacus orbicularis
Phacus sp.
Trachelomonas sp.

PYRROPHYTA

Dinobryon divergens
Dinobryon sertularia
Glenodinium quadridens
Peridinium cinctum

CRYPTOPHYTA

Chroomonas nordstedtii
Actinastrum hantzschii
Ankistrodesmus falcatus

CHLOROPHYTA

Ankistrodesmus sp.
Botryococcus braunii
Botryococcus protuberans
Botryococcus protuberans var. *minor*
Botryococcus sp.
Characium sp.
Chlamydomonas sp.
Closterium sp.
Coelastrum astroideum
Coelastrum microporum
Coelastrum reticulatum
Cosmarium formosulum
Cosmarium hammeri
Cosmarium setuiforme

Cosmarium subcostatum
Cosmarium sp.
Crucigenia tetrapedia
Dictyospaerium sp.
Kirchneriella irregularis
Micractinium pusillum
Monoraphidium contortum
Monoraphidium convolutum
Monoraphidium sp.
Mougeotia sp.
Oedogonium cardiacum
Oedogonium sp.
Oocystis sp.
Ophiocytium bicuspidatum
Pandorina morum
Pediastrum boryanum
Pediastrum duplex
Pediastrum simplex
Pediastrum simplex var. *duodenium*
Pediastrum tetras
Pediastrum tetras var. *tetraodon*
Rhizoclonium sp.
Scenedesmus abundans
Scenedesmus acuminatus
Scenedesmus acuminatus var. *tetradesmoides*
Scenedesmus acutus
Scenedesmus arcuatus var. *platydiscus*
Scenedesmus bijuga
Scenedesmus bijuga var. *alternans*
Scenedesmus dimorphus
Scenedesmus quadricauda
Scenedesmus sp.
Schoederia antillarum
Spirogyra subsalsa
Spirogyra sp.
Staurastrum natator
Tetraedron caudatum
Tetraedron minimum
Tetraedron regulare
Treubaria setigera
Ulothrix sp.

BACILLARIOPHYTA

a-Centrales

Chaetoceros sp.
Coscinodiscus lacustris
Coscinodiscus sp.
Cyclotella atomus
Cyclotella kuetzingiana
Cyclotella meneghiniana
Cyclotella ocellata
Cyclotella radiosa
Cyclotella stelligera
Cyclotella striata
Stephanodiscus astrea

b- Pennales

Achnanthes affinis
Achnanthes biasolettiana
Achnanthes clevi
Achnanthes conspicua
Achnanthes hungarica
Achnanthes lanceolata
Achnanthes microcephala
Achnanthes minutissima
Achnanthes sp.
Amphiprora alata
Amphora coffeaeformis
Amphora ovalis
Amphora veneta
Amphora sp.
Aneumastus tusculus
Anomoeoneis exilis
Anomoeoneis sphaerophora
Bacillaria paxillifer (also known as *Bacillaria paradoxa*)
Brachysira exilis
Caloneis bacillum
Caloneis permagna
Caloneis silicula = *Caloneis ventricosa*
Campylodiscus clypeus
Cocconeis pediculus
Cocconeis placentula
Cocconeis placentula var. *euglypta*
Cocconeis placentula var. *lineata*

Cymatopleura solea
Cymbella affinis
Cymbella affinis var. *excisa*
Cymbella aspera
Cymbella cistula
Cymbella cistula var. *maculata*
Cymbella cymbiformis
Cymbella differta
Cymbella leptoceros
Cymbella microcephala
Cymbella parva
Cymbella prostrata
Cymbella pusilla
Cymbella sinuate
Cymbella tumida
Cymbella turgida
Cymbella ventricosa
Cymbella sp.
Denticula sp.
Diatoma elongatum
Diatoma elongatum var. *tenuis*
Diatoma tenue var. *elongatum*
Diatoma vulgare
Diploneis elliptica
Diploneis interrupta
Diploneis ovalis
Diploneis pseudoovalis
Diploneis sp.
Epithemia sorex
Epithemia turgida
Epithemia zebra
Epithemia zebra var. *porcellus*
Epithemia zebra var. *saxonica*
Eunotia formica
Eunotia pectinalis
Eunotia sp.
Fragilaria acus
Fragilaria acus var. *angustissima*
Fragilaria brevistriata
Fragilaria capitata
Fragilaria capucina
Fragilaria construens
Fragilaria pulchella
Fragilaria tabulata
Fragilaria ulna
Fragilaria ulna var. *biceps*
Fragilaria ulna var. *oxyrhynchus*
Fragilaria vaucheriae
Gomphoneis olivacea
Gomphonema acuminatum
Gomphonema angustatum
Gomphonema attenuatum
Gomphonema augar
Gomphonema constrictum var. *capitata*
Gomphonema gracile
Gomphonema gracile var. *turris*
Gomphonema intricatum
Gomphonema intricatum var. *pumila*
Gomphonema olivaceum
Gomphonema parvulum
Gomphonema sphaerophorum
Gomphonema tergestinum
Gomphonema turris
Gyrosigma acuminatum
Gyrosigma attenuatum
Gyrosigma macrum
Gyrosigma peisonis
Gyrosigma scalproides
Gyrosigma spencerii
Gyrosigma spencerii var. *nodifera*
Gyrosigma tenuirostrum
Gyrosigma sp.
Hantzschia amphioxys
Mastogloia braunii
Mastogloia elliptica
Mastogloia elliptica var. *dansei*
Mastogloia smithii
Mastogloia smithii var. *amphicephala*
Mastogloia smithii var. *lacustris*
Navicula anglica
Navicula atomus
Navicula bryophila
Navicula crucicula
Navicula cryptocephala
Navicula cryptocephala var. *intermedia*
Navicula cryptocephala var. *veneta*

Navicula cuspidata
Navicula gracilis
Navicula oblonga
Navicula parva
Navicula pseudotuscula
Navicula pupula
Navicula pygmaea
Navicula radiosa
Navicula radiosa var. *tenella*
Navicula rhynchocephala
Navicula similis
Navicula spicula
Navicula sp.
Neidium productum
Nitzschia acicularis
Nitzschia amphibia
Nitzschia angustata
Nitzschia angustata var. acuta
Nitzschia apiculata
Nitzschia clausii
Nitzschia commutata
Nitzschia cumutata
Nitzschia dissipata
Nitzschia fasciculata
Nitzschia filiformis
Nitzschia fonticola
Nitzschia frustulum
Nitzschia frustulum var. perminuta
Nitzschia gracilis
Nitzschia granulata
Nitzschia hungarica
Nitzschia inconspicua
Nitzschia intermedia
Nitzschia longissima
Nitzschia lorenziana
Nitzschia lorenziana var. *subtilis*
Nitzschia microcephala
Nitzschia obtusa
Nitzschia palea
Nitzschia punctata
Nitzschia punctata var. *coarctata*
Nitzschia romana
Nitzschia scalaris
Nitzschia sigma
Nitzschia sigma var. *rigidula*
Nitzschia sigmoidea
Nitzschia umbonata
Nitzschia tryblionella
Nitzschia tryblionella var. *levidensis*
Nitzschia tryblionella var. *victoriae*
Nitzschia umbonata
Pinnularia sp.
Plagiotropis lepidoptera
Pleurosigma angulatum
Pleurosigma elongatum
Pleurosigma obscurum
Pleurosigma salinarum
Pleurosigma sp.
Rhoicosphenia curvata
Rhopalodia gibba
Rhopalodia gibba var. *musculus*
Rhopalodia gibba var. *ventricosa*
Rhopalodia musculus
Rhopalodia parallela
Stauroneis phenicenteron
Stauroneis sp.
Surirella angustata
Surirella biseriata
Surirella capronii
Surirella ovalis
Surirella ovata
Surirella ovata var. *africana*
Surirella robusta
Tryblionella debilis