PHYTOPLANKTON SPECIES COMPOSITION AND BIODIVERSITY INDICES IN AUDA MARSH- SOUTHERN IRAQ

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ABSTRACT

This study was aimed to investigate the trophic status of the marshes by phytoplankton diversity. The Phytoplankton community and four biodiversity indices were studied in Auda marsh southern Iraq in the period between January 2018 to January 2019. A total of 146 species were identified belonging to 8 classes as follows: Bacillariophyceae (85 taxa), Euglenophyceae (26 taxa), Cyanophyceae (16 taxa), Chlorophyceae (11 taxa), Mediophyceae (3 taxa), Coscinodiscophyceae (2 taxa), Conjugatophyceae (1 taxa), Trebouxiophyceae (1 taxa), and Dinophyceae (1 taxa). The most predominant diatom was *Nitzschia* (15 species), and followed by the other genera *Phacus* (11 species), *Navicula* and *Euglena* (10 species). The Shannon-Weiner diversity, Richness index and Evenness index were recorded a low value in wet 2019 and a high values in wet (for Shannon Weiner and Evenness indices) and dry (for Weiner and Evenness indices) 2018. The Jaccard index showed equal similarity between study sites, while the highest seasonal similarity was recorded between wet and dry 2018 and lowest similarity was between wet2018 and wet2019. According to the biodiversity indices Auda marsh has high diversity. The results revealed that Auda marsh is mesotrophic according to phytoplankton species composition.

Keywords: algae, biodiversity, code IQ, IBA, mesopotamian marshes, trophic indices, wetlands

تركيب الهائمات النباتية والتنوع الحيوي في هور العودة جنوب العراق

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المستخلص

تهدف هذه الدراسة إلى معرفة الحالة الاغتذائية لهور العودة من خلال ادلة التنوع للهائمات النباتية .تمت دراسة مجتمع الطحالب الهائمة فضلا عن اربعة من ادلة التنوع في هور العودة خلال فترة الدراسة (من كانون الثاني 2018 الى كانون الثاني 2019). بلغ عدد الانواع الهائمات النباتية 146 نوع تنتمي الى 8 صفوف, 85 نوع من الطحالب العصوية Bacillariophyceae,تبعت بالطحالب اليوغلينية 26 Euglenophyceae نوع, 16 نوع من الطحالب الخضر المزرقة Cyanophyceae, 11 نوع من الطحالب الخضر Chlorophyceae, 3 انواع من Mediophyceae, نوعان من Coscinodiscophyceae, ونوع واحد فقط لكل من Trebouxiophyceae, Conjugatophyceaeو Dinophyceae. كان جنس *Nitzschia* السائد بـ 15 نوع, يليه 11 *phacus* نوع,و 10 انوع لكل من الجنسان *Navicula* و *Euglena*. كما لوحظت تباين زمني في عدد الأنواع خلال فترة الدراسة. سجلت قيم الدلائل شانون وينر والغنى و التجانس للتنوع اوطأ قيم في موسم الرطب 2019 واعلى قيم في موسم الرطب (لدلائل شانون والتجانس) و الجاف (للغنى) 2018 ,3.21. أظهر دليل التشابه تشابها عاليا بين مواقع الدراسة، في حين تم تسجيل أعلى تشابه بين موسمي الرطب والجاف 2018 وأدنى تشابه كان بين موسمي الرطب 2018 و 2019 أوضحت النتائج أن هور العودة معتدل التغذية نظرا لتكوين أنواع الهائمات النباتية.

الكلمات المفتاحية: الطحالب, التنوع, رمز IQ, IBA, اهوار بلاد ما بين النهرين, ادلة الحالة الاغتذائية, الاراضي الرطبة

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INTRODUCTION

Wetlands are the most important ecosystems for humans, offering several regulatory services. Wetlands are described as the kidneys of nature, they also serve as water reservoirs, mitigators of floods and they play a role in recharging groundwater. Moreover, they act as a source of income through fishing, agricultural activities and cattle grazing (2). The Mesopotamian marshes are one of the largest complexes of wetlands in the middle east, extending across three Iraqi governorates. These marshes are important in the maintenance of biodiversity in the middle east because of their large size, and the vegetation rich in macrophytes. These marshes are appropriate natural area for reproduction, growth and biodiversity of many flora and fauna including migrating birds (23). Phytoplankton are primary producers and have a big role as a source of food for many organisms, carbon dioxide fixations which contribute approximately 40% of the global fix annually and provide oxygen to an aquatic system (28). Phytoplankton have a spatial and temporal distribution due to variation of physicochemical and biological characteristics of water, and trophic status (oligotrophic/ eutrophic). Many of phytoplankton species are considered as bioindicators and their communities used in biological indices of an aquatic ecosystem illustrating the ecological status of the environment. These algae are sensitive to environmental changes, so any alteration may lead to changes in their diversity and domination (14). Auda marsh is one of eight minor Iraqi marshes and is considered as an Important Bird Area (IBA) with code IQ 072,which is located within Mayssan governorate between Latitude line 31 ° 33'N -Longitude line 46 ° 51’E (1). A few works published on algal diversity in Auda Marsh. These studies focused on abundance, taxonomy and diversity of algae communities. The objectives of this study were to investigate the algal community structure in Auda marsh and to evaluate the marsh function. Al-Saffar and Al- Obaidi (5) recorded 193 species of phytoplankton, they found that Auda marsh with high salinity and low dissolved oxygen level has poor water quality conditions as compared with its source Al-Haddam River. Al-Thahaibawi (6) was recorded 246 phytoplankton species in Auda marsh and according to the biodiversity indices found the marsh had high diversity. Al-Hassny and Al-Bueajee (3) studied the compositions of epiphytic diatoms on some aquatic plants in Auda marsh and identified 111diatom species. The Shannon-Weaver Index, ranged between (0.24-2.57) so the epiphytic diatom community has had a moderate diversity. This study was aimed to investigate composition and biodiversity of phytoplankton community of Auda marsh and determined its trophic status.

MATERIALS AND METHODS

Sampling area

Three sections (S) were selected in Auda marsh for this study. The S1 was located north of the marsh, while S 2 was situated in the center of the marsh and S3 was located south of the marsh (Table 1, Figure1). The Geographical Positioning System (GPS) was used to identified the study sections.

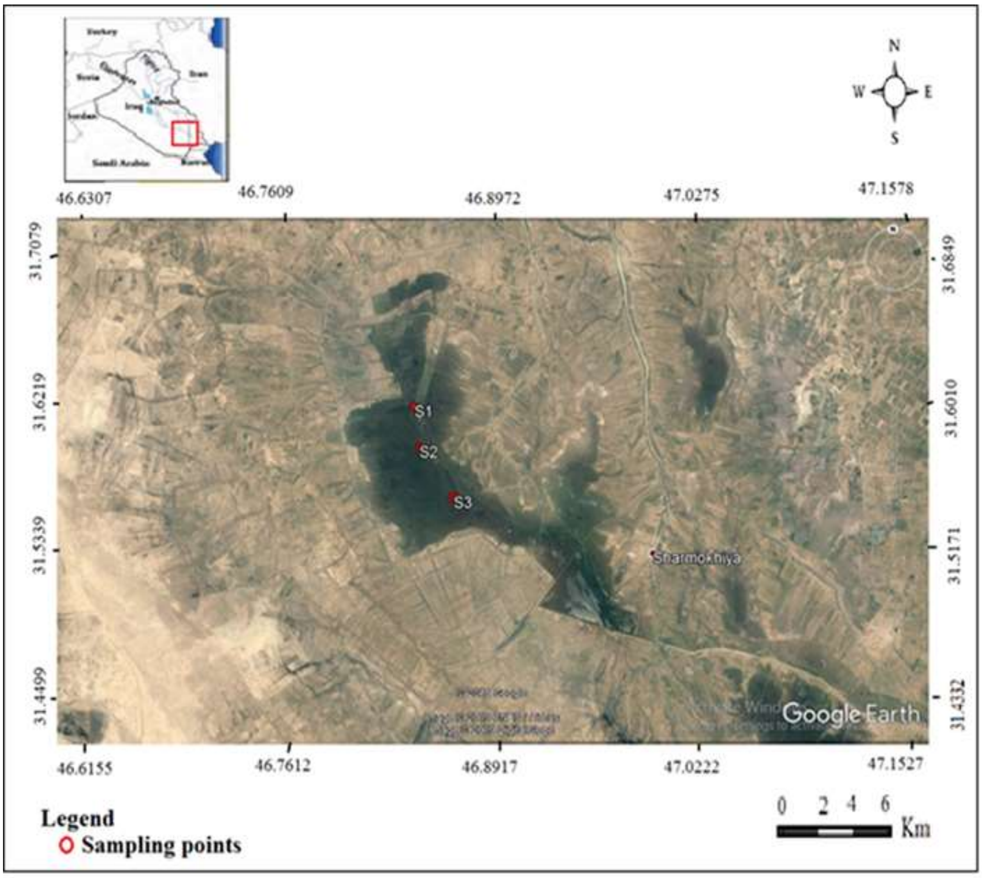

Fig. 1.The study area (Auda marsh) map

Table1. Geographical positioning system (GPS) and some characterize of the study area

Section	Long	Lat.	Properties				
			Vegetation and activities	WT C°	S ‰	TN µg/l	TP µg/l
S1	"21.94'50°46	"45.1'36°31	Low vegetation cover	22.18	4.32	1.08	0.16
S2	"28.86'50°46	"32.52'35°31	Domination of *Phragmites australis* and less human activities	23.02	4.67	1.32	0.13
S3	"37.68'51°46	"2.97'34°31	Free -floating plant, Human activities	23.33	3.11	2.37	0.16

S=Section; Long =Longitude (East Wards); Lat.= Latitude (North Wards); WT=Mean of Water Temperature; S ‰= Mean of Salinity; TN= Mean of Total Nitrogen; TP= Mean of Total Phosphorus.

Qualitative and quantitative studies

phytoplankton samples were collected from the study area on a monthly bases from January 2018 to January 2019 and the results were expressed seasonally as wet and dry seasons according to the values of relative humidity provided by the Ministry of Transportation/ Iraqi Meteorological organization and Seismology (22). Phytoplankton quality was estimated according to APHA(American Public Health Association) (25). One liter of each sample was preserved by Lugol's solution (1ml /100 ml sample) in one liter Duran cylinder and left to settle for 10-15 days, then concentrated to 100 ml and the process is repeated to reach 10 ml. Phytoplankton species were identified under light microscope (with magnification power 400x and 1000x), diatoms were clarified by using concentrated nitric acid then identified by using permanent slides according to (27). While, temporary slides were prepared for non-diatom species. Microtransect method was used for the counting of the diatom species (100 x) . While, hemocytometer slide (400 x) was used for the counting of non-diatom algae according to Salman *et al.,* (27). Two references were used for identifying algal species (26, 31).

Biodiversity Indices

Four biodiversity indices were applied to the investigated environmental status according to Magurran (20). These indices are Shannon Index, Richness Index, Evenness Index, and Jaccard Index (Table 2).

Table 2. Biodiversity indices used in the study(20)

Indices	Equations	Abbreviations
Shannon-Weaver Index	$H = \sum_{i=1}^{S} P_i \log_2 P_i$	H = The Shannon diversity index Pi = The proportion of a species i relative to total number of species present N S =The number of species
Richness Index	D= (S-1)/ln N	D = Richness Index. S = The number of species. N = The number of individuals.
Evenness Index	E = H / ln S	H = Shannon Weiner Value. S = Total number of species in the site.
Jaccard Index	(Ss%)=a/(a-b-c)×100	a = Total number of species on host plant a. b = Total number of species on host plant b. c = Total number of species present on both host plants a and b

RESULTS AND DISCUSSION

Phytoplankton Composition

Phytoplankton have an important role in carbon and energy flux in the food chain of the marsh, so it's important to study their species composition to recognize the effect of their interaction with other environmental factors and marsh hydrology (32). A total of 146 phytoplankton species were identified in Auda marsh belonging to 48 different genera. The predominant class was Bacillariophyceae (85 taxa) during the study period which indicated the stability of marsh conditions and this result (dominance of diatoms) was noticed in previous studies on this marsh (5, 6) also observed in other Iraqi marshs (18, 30). The following classes are Euglenophyceae (26 taxa), Cyanophyceae (16 taxa), Chlorophyceae (11 taxa), Mediophyceae (3 taxa), Coscinodiscophyceae (2 taxa), and one taxa for each of Conjugatophyceae, Trebouxiophyceae and Dinophyceae (Table 3, 4). These results varied from other studies on Iraqi marshes that recorded different sequences of major classes as follows: Bacillariophyceae, Chlorophyces, Cyanophyceses while other classes were of less importance (5, 6, 8). The highest number of species (125 spp.) was recorded in dry season, while 91 species in wet season 2018 and 50 species in wet season 2019 this might be related to hydrology regime and dilution of the nutrient associated with the high level of water in the marsh (32).Auda marsh suffered from drought regime before 2004 and re-flooded after 2004 (figure 2). The phytoplankton species composition response to re- flooding were noticed by other researchers (5, 6). These responses differ in term of total identified phytoplankton which ranged from 193 species during the period from November to August 2007after re-flooding in 2004 to 246 species in the period 2012-2013 in which the marsh had a good hydrology and vegetation cover. While in present study the species identified are reduced to approximately 50% (146 species of phytoplankton). These results are attributed to the semi-dry conditions in the early periods of the study (wet and dry season of 2018) and eventually re-flooding by the recent floods in Iraq during wet season of 2019 period. This indicates that phytoplankton community did not respond similarly to re-flooding (9). This response may be because the phytoplankton community dynamics was affected by complicated interactions between physical, chemical, and biological factors (8).

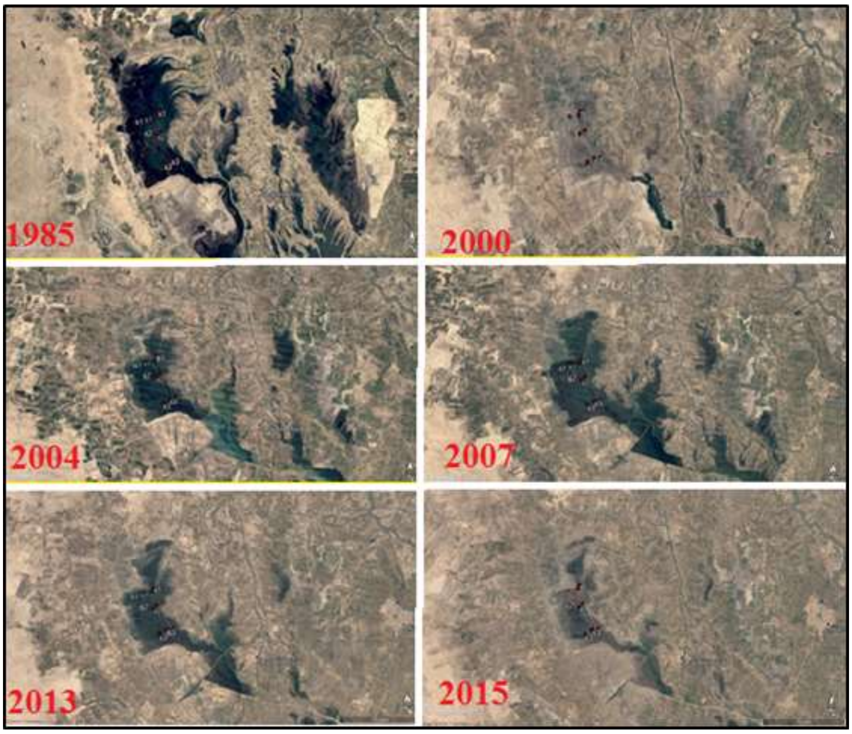

Figure 2. Auda marsh map in different periods

Spatial variations were noticed for a number of species. The high number species (99 spp.) were recorded in S 2, followed by 85 species in S1 and lowest number of species (81 spp.) was in S 3. The most representative genera in terms of species richness was Nitzschia (15 spp.). The other dominant species were *Phacus* (11 spp.) *Euglena* and *Navicula* (10 spp.). These results suggest that the non-dried sections (S1 and S2) have more response to re-flooding than semi-dry section (S3). Because phytoplankton responding to re-flooding depend upon natural fluctuation of water-level and drought events (9). Table 5 illustrates the values of percentage abundance of algal classes during the study period. Bacillariophyceae was dominant in S 3 and S2 at wet season of 2018 (90.45 and 71.38). The domination of diatoms in internal Iraqi waters is a common phenomenon, due to their capability to withstand a wide range of changes in environmental conditions and the availability of silica in the Iraqi basins which is used in the diatom frustule structure (17). The dominant abundance of diatoms may be an indication to the mesotrophic conditions of the water bodies (10).The results showed an increases in the abundance of centric diatoms belonging to Mediophyceae class (*Cyclotella* spp.) compared to other species in all study sites during wet season 2019 which is characterized by flooding events, this agrees with Lee (19), that found that the flooding period corresponded with an increase in diatom abundance rather than other algal groups. On the other hand many researchers have considered *Cyclotella* spp. as an indicator for oligotrophic environmental conditions (31). The oligotrophic conditions during flooding event may occur due to decreased water temperature and increased turbidity which correspond to the decline in the photosynthesis process (6). The short life cycle of diatoms and their response to environmental changes give a relative state of habitat restoration (4). The previous studies in the Auda marsh noticed that the percentage of identified diatoms was 69.43% of total number of species (5) during the period between 2006-2007, and decreased to 48.78% between 2012-2013 (6).While in the present study the percentage of diatoms reached to 59.59%. This may be related to the differences in the nutrient storage capacity of diatoms, and being more affected by hydrological regime fluctuation of marsh (12). Flooding and drought events may result in altering the productivity and community composition that in turn lead to changes in the trophic status of an aquatic ecosystem (19).This study was revealed the Euglenophyceae recorded in April 2018 (dry season) high number of species belonging to two genera *Phacus* and *Euglena*, while other months of each season were low, this result could be due to the rainfall in this month, which can be attributed to the influx of domestic sewage, increasing the organic matter and the nutrient loading, thus providing appropriate environmental conditions for Euglenophyceae, where the Euglenophyceae structure depend on a variety of biotic and abiotic environmental factors (13). This result was also noticed in Auda marsh (6), that recorded highest species number of Euglenophyceae in spring and summer seasons (dry season), while 1 species of *Phacus* and 2 species of *Euglena*was reported in autumn. However through our observations during the study period no ecosystem management was executed of the marsh, and the intervention of local population in the closure and opening of the marsh inlets and different land exploitation caused confusion in describing some of the differences within the marsh.

Table 3. Seasonal number of species

Class	2018		2019	Number of species	Percentage of species number %
	Wet Season	Dry Season	Wet Season		
CYANOPHYCEAE	9	12	8	16	10.95
CHLOROPHYCEAE	5	8	3	11	7.5
CONJUGATOPHYCEAE	1	1	-	1	0.7
TREBOUXIOPHYCEAE	-	1	-	1	0.7
EUGLENOPHYCEAE	14	24	13	26	17.81
MEDIOPHYCEAE	2	3	2	3	2.05
COSCINODISCOPHYCEAE	1	2	1	2	1.37
BACILLARIOPHYCEAE	57	73	24	85	58.22
DINOPHYCEAE	1	1	-	1	0.7
Total	90	125	51	146	100

Table 4. List of phytoplankton species at the study area during study period.

Taxa	2018		2019	Common species
	Wet Season	Dry Season	Wet Season	
PHYLUM: CYANOBACTERIA				
CLASS: CYANOPHYCEAE				
Anabaena sp.	+	-	-	
Chroococcus dispersus (Keis.) Lemmermann	+	+	+	*
C. minutus (Kütz.) Naegeli	+	+	+	*
C. turgidus (Kütz.) Nägeli	+	+	-	
Lyngbya. major Meneghinii	-	-	+	
Lyngbya. sp.	-	+	-	
Merismopedia glauca Nägeli	+	+	+	*
M. minima G.Beck	-	+	-	
M. tenuissima Lemmermann	-	+	-	
Oscillatoria amoena Gomont	-	+	-	
O. limnetica Lemmermann	-	+	-	
O. limosa C.Agardh ex Gomont	-	+	-	
O. tenuis Agardh	+	-	+	
Phormidium tenue (Menegh.) Gomont	+	+	+	*
Spirulina laxa G.M.Smith	+	+	+	*
S.major Kützing	+	-	+	
PHYLUM: CHLOROPHYTA				
CLASS: CHLOROPHYCEAE				
Ankistrodesmus falcatus (Corda) Ralfs	-	+	-	
Chlamydomonas sp.	-	+	+	
Crucigenia tetrapedia Kirchner West & West	-	+	-	
Kirchneriella irregularis (G.M.Smith) Korschikov	+	+	+	*
Microspora pachyderma (Wil.) Lagerheim	+	+	-	
Pediastrum tetras (Ehrenberg) Ralfs	-	+	-	
Scenedesmus bijuga (Turp.) Lagerheim	+	-	+	
S. dimorphus (Turpin) Kützing	-	+	-	
S. quadricauda (Turp.) de Brébisson	+	+	-	
Tetraëdron minimum (A. Braun) Hansgirg	+	-	-	
T. tringulare Korshikov	-	+	-	
CLASS: TREBOUXIOPHYCEAE				

Oocystis crassa **Wittrock**	-	+	-	
PHYLUM: CHAROPHYTA				
CLASS:CONJUGATOPHYCEAE(ZYGNEMATOPHYCEAE)				
Coelastrum microporum **Nägeli**	+	+	-	
PHYLUM: EUGLENOZOA				
CLASS: EUGLENOPHYCEAE				
Euglena acus **Ehrenberg**	+	+	+	*
E. convulata **Korshikov**	-	+	-	
E. elastic **Prescott**	-	+	-	
Euglena gracilis **G.A.Klebs**	+	+	-	
E.granolata **(G.A.Klebs) F.Schmitz**	-	+	-	
E. oxyuris var. minor **(Skvortzov) Popova**	+	+	+	*
E. polymorpha **Dangeard**	+	+	+	*
E. proxima **A.P.Dangeard**	-	+	-	
E. spirogyra **Ehrenberg**	-	+	+	
E. virdis **(O.F.Müller)**	-	+	-	
Lepocinelis.acuta **Prescott**	-	+	-	
L. fusiformis **(Carter) Lemmermann**	+	+	+	*
L. ovum **(Ehrenberg) Lemmermann**	-	+	-	
L. glabra **Drezepolski**	-	+	-	
Phacus acutus **Pochmann**	+	-	+	
P. anacoelus **Stoke**	-	+	-	
P. caudatus **Swirenko**	+	+	-	
P. chloroplastes **Prescott**	+	+	+	*
P. curvicoda **Swirenko**	+	+	+	*
P. longicauda **(Ehr) Dujardin**	+	+	+	*
P. nordstedtii **Lemmermann**	+	+	-	
P. orbicularis **K.Hübner**	-	+	+	
P. spirogyra var. maxima **Prescott**	+	+	+	*
P.totus **(Lemm.) skvortzow**	+	+	+	*
Phacus sp.	-	-	+	
Trachelomonas sp.	+	+	-	
PHYLUM: BACILLARIOPHYTA				
CLASS: MEDIOPHYCEAE				
Cyclotella meneghiniana **Kützing**	+	+	+	*
C. striata **(Kütz.) Grunow**	-	+	-	
cyclotella sp.	+	+	+	*
CLASS: COSCINODISCOPHYCEAE				
Coscinodiscus lacustris **Grunow**	+	+	-	
Melosira sp.	-	+	+	
CLASS: BACILLARIOPHYCEAE	-	-	-	
Achnanthes brevipes **var.** ***intermedia*** **(Kütz.) Cleve**	-	-	+	
A. exigua **Grunow**	+	+	-	
A. microcephala **(Kütz.) Grunow**	+	+	+	*
A. minutissima **Kützing**	+	+	+	*
Amphiprora alata **Kützing**	+	+	+	*
A. paludosa **W.Smith**	+	+	-	
Amphora coffeaeformis **Agardh**	+	+	+	*
A. maxicana **var.** ***major*** **Cleve**	-	+	-	
A. ornata **Bailey**	-	+	+	
A.venata **Kützing**	+	-	-	
Anomoeoneis exilis **(Kütz.) Cleve**	+	+	+	*
Bacillaria paxillifer **(Müll.) Hendy**	+	+	-	
Caloneis permagna **(Bail.) Cleve**	+	+	-	
Campylodiscus clypeus (Ehrenberg) Ehrenberg ex Kützing	+	+	+	*
Cocconeis pediculus **Ehrenberg**	+	+	-	
C. placentula **Ehrenberg**	+	+	+	*
C. placentula **var.** ***euglypta*** **(Ehr.) Cleve**	+	+	+	*
C. placentula **var.** ***lineata*** **(Ehr.) Cleve**	+	+	-	
Cymbella affinis **Kützing**	+	+	-	
C. cistula **(Hemp.) Grunow**	-	+	-	
C. parva **(W. Smith)Kitchn**	+	-	-	
C. tumida **(Bréb.)V. Heurck**	+	+	-	
C. turgida **(Greg.) Cleve**	+	+	-	

***C. ventricosa* Kützing**	+	+	-	
***Cymbella* sp.**	-	+	-	
***Diploneis ovalis* (Hisle) Cleve**	+	+	-	
***D. paulla* (Schum.) Cleve**	-	+	-	
***Epithemia zebra* (Ehr.) Kützing**	-	+	-	
***Eunotia valida* Hust.**	-	+	-	
***Eunotia pectinalis* (Kützing) Rabenhorst**	-	+	-	
***Eunotia* sp.**	-	+	-	
■*Fragilaria construens (*Ehrenberg) Grunow	-	+	-	
***Fragilaria* sp.**	-	+	-	
***Gomphonema constrictum* Ehrenberg**	+	+	-	
***G. constrictum* var.*capitata* (Ehr.) Cleve**	+	+	-	
***G. gracile* Ehrenberg**	-	+	-	
***G. longiceps* Ehrenberg**	+	-	-	
***G. olivaceum* (Lyng.) Kützing**	+	+	-	
***G. parvulum* (Ehr.) Grunow**	+	+	+	*
***Gyrosigma acuminatum* (Kütz.) Rabenhorst**	+	+	-	
***G. distrodum* var.*parkeri* Harrisson**	-	+	-	
***G. spenceri* (W. Smith) Cleve**	+	+	-	
***Mastogloia braunii* Grunow**	+	+	-	
***M. smithii* Thwaites**	+	+	-	
***M. smithii* var. *amphicephala* Grunow**	+	+	-	
***M. smithii* var. *lacustris* Grunow**	-	+	-	
***Navicula cincta* (Ehr.) Kützing**	-	+	-	
***N. cryptocephala* Kützing**	-	+	-	
***N. cryptocephala* var. *veneta* (Kütz.) Grunow**	+	+	-	
***N. cuspidata* Kützing**	+	-	-	
***N. pusilla* W. Smith**	+	-	-	
***N. radiosa* Kützing**	+	+	+	*
***N. radiosa* var. *tenella* (Bréb.) Grunow**	+	+	-	
***N. spicula* (Dick.) Cleve**	+	+	+	*
***N. viridula var. rostellata* (Kütz.) Cleve**	-	+	-	
***Navicula* sp.**	+	+	+	*
***Nitzschia acicularis* W.Sm.**	+	+	+	*
***N. amphibia* Grunow**	+	+	-	
***N. apiculata* (Greg.) Grunow**	+	+	-	
***N. filiformis* (W. Smith) Hustedt**	+	+	+	*
***N. granulata* Grunow**	+	+	-	
***N. ignorata* Krasske**	+	+	+	*
***N. kützingiana* Hilse**	+	-	+	
***N.longissma (* Breb.) Ralfs**	-	+	+	
***N. microcephala* Grunow**	+	+	-	
***N. obtusa* W. Smith**	-	+	-	
***N. palea* (Kütz.) W. Smith**	+	-	-	
***N. romana* Grunow**	+	+	-	
***N. sigma* (Ehr.) W. Smith**	-	+	-	
N. tryblionella var. victoriae Grunow	-	+	-	
Nitzschia sp.	+	+	+	*
***Pleurosigma salinarum* Grunow**	+	-	-	
Pleurosigma sp	-	+	-	
***Rhoicosphenia curvata* (Kütz.) Grunow**	-	+	-	
***Rhopalodia gibba* (Ehr.) Müller**	+	+	-	
***Rhopalodia gibba* var. *ventricosa* (Ehr.) Grunow**	+	+	-	
***Surirella ovata* Kützing**	+	+	-	
Surirella sp.	-	+	-	
***Synedra affinis* Kützing**	+	+	-	
***S. amphicephala* Kuetzing**	+	+	+	*
***S. capitata* Ehrenberg**	+	-	-	
***S. fasciculata* (Kütz.) Grunow**	-	-	+	
***S. ulna* (Nitz.) Ehrenberg**	+	+	+	*
***S. ulna* var. *biceps* Kützing**	-	+	+	
***S. tenera* Gregory**	+	-	-	
PHYLUM: MIOZA				
CLASS: DINOPHYCEAE				
***Glenodinium pulvisculus* (Ehrenberg) F.Stein**	+	+	-	

(+)Presence; (-) Absence; (*)Common species; (■) Recorded for the first time in Iraq

Table 5. The values of percent abundance of Algal classes

Section	S1			S2			S3		
Season / Class	Wet 2018	Dry 2018	Wet 2019	Wet 2018	Dry 2018	Wet 2019	Wet 2018	Dry 2018	Wet 2019
CYANOPHYCEAE	15.35	21.35	9.88	9.76	8.41	14.53	1.70	1.67	6.64
CHLOROPHYCEAE	0.11	0.19	0.19	0.39	0.25	1.57		0.58	1.73
CONJUGATOPHYCEAE	0.13	-	-	-	-	-	-	-	-
EUGLENOPHYCEAE	2.67	2.33	5.94	7.50	4.81	4.01	0.53	2.25	0.67
MEDIOPHYCEAE	20.63	27.98	56.70	10.83	23.72	36.15	7.31	29.98	36.92
BACILLARIOPHYCEAE	60.96	48.12	27.29	71.38	62.73	43.49	90.45	65.49	54.05
DINOPHYCEAE	0.15	0.04	-	0.14	0.08	0.25	-	0.03	-
TOTAL	100	100	100	100	100	100	100	100	100

Biodiversity Indices

All biodiversity indices values are illustrated in table 6. The Shannon-Wiener index of phytoplankton community ranged from 1.93 in wet 2019 at S1 to 3.21 in wet 2018 at S3. The index value was evenly distributed in dry and wet 2018, while it was relatively lower in wet 2019 due to the low number of phytoplankton species.

Table 6. Biodiversity indices values in Auda marsh during study period

Index	Section	2018		2019
		Wet Season	Dry Season	Wet Season
Shannon-Weaver Index	S1	2.5	2.82	1.93
	S2	3.15	3.01	2.26
	S3	3.21	2.88	2.09
Richness Index	S1	2.68	3.25	1.18
	S2	2.89	2.97	1.48
	S3	2.91	2.8	1.17
Evenness Index	S1	0.2	0.2	0.15
	S2	0.23	0.22	0.17
	S3	0.24	0.2	0.16

Generally, Shannon-Wiener index values were more than 1 during the study period in all marsh sections, which indicates high diversity of phytoplankton species (19). Diversity reaches its highest value whenever all species are present with the same numerical abundance, while decreasing in index values (less than 1) indicates domination of certain species of phytoplankton owing to appropriate environmental conditions. The variations of phytoplankton composition reflects the changes in water conditions, thus used to evaluate the status of the aquatic environment. Shannon- Weaner index is directly proportional to the number of species in the sample and the similarity of the species distribution (20). In the three marsh sections, species diversity was relatively high, which indicates good environmental conditions to the development of many species, thus according to Shanthala (29) the marsh had moderate trophic status. There is a negative correlation between Shannon–Wiener index and the pollution, thus Auda marsh water was in slight pollution or mostly clean water (Table7).

Table 7. Pollution level based on a Shannon–Wiener index (29)

Diversity level	Shannon Wiener index	Pollution level
High	3.0–4.5	Slight
Moderate	2.0–3.0	Light
Less	1.0–2.0	Moderate
Very less	0.0–1.0	Heavy pollution

The present study revealed from the richness index that maximum recorded value was 3.25 during dry 2018 in S1, while the minimum value was 1.17 in S3 during wet 2019. Also the study revealed from the richness index that the maximum recorded value was 3.25 during dry2018 in S1. While the minimum value was 1.17 in S3 during wet 2019. From seasonal variation of richness index values it is clear that the highest values are recorded during the dry season, while the lowest values recorded during wet 2019, which indicates the high diversity in Auda marshes and that the environmental conditions were suitable for the phytoplankton growth and diversity (8), this agrees with other studies (6), (30).The dry season in comparison with wet season, has an increase in irradiance, temperature, and newly circulated nutrients thus producing favorable conditions for many species. While in wet seasons, only a few species persisted under high stress that coincided with the flood period, the phytoplankton abundance and diversity were dropped, and the increasing in water level due to flooding events caused the shifting in water body from turbid, high algal abundance state to clear state (19). Evenness index values exceed 0.2 in all study areas and seasons except in wet 2019 where the value ranged between 0.15- 0.17, which indicates the distribution of the biomass among species within the community and they were not moderate (20). Low evenness index values give a clear indication of the dominance of some species. The important point in relation to biodiversity index was the decrease of indices values during the wet 2019 where the flooding occurs, during the flooding event phytoplankton diversity, biomass, and abundance decreased, this shifting in phytoplankton composition corresponded with a decrease in diversity during this extreme flooding event (11). In relation to seasonal similarity of phytoplankton species distribution, Jaccard index showed the highest similarity (0.59) was between dry and wet 2018, while the lowest (0.33) similarity was between the dry 2018 and the wet 2019 (Table 8). However, the spatial similarity was approximately equal among the study sites (Table 9), may be related to the similarity of some physicochemical properties between study sections (Table 1).

Table 8. Jaccard index values for phytoplankton species in Auda marsh

	wet2018	dry2018	wet2019
wet2018			
dry2018	0.59		
wet2019	0.39	0.33	

Table 9. Jaccard index values for phytoplankton species in Auda marsh among the study sections

	S1	S2	S3
S1			
S2	0.51		
S3	0.50	0.57	

A few works on phytoplankton in Auda marsh in comparison with other Iraqi marshes (Table 10). It's very clear that Iraqi marshes became responsive to rehabilitation after the southern marshes desiccation by ex-government (15).

Table 10. The difference in phytoplankton community structure during four decades

Marshes	Number of species	Refrences
Qurna Marshes	129	(24)
Central marsh	68	(21)
Al-Mdayna & Al-Chebayesh	100	(7)
Al-Hammar	116	(16)
Al-Hewaizeh	199	(30)
Central Marshes	215	(30)
Al-Hammar	179	(30)
Auda marsh	193	(5)
Auda marsh	246	(6)
Auda marsh	146	Present study

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