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TAXONOMIC STRUCTURE OF THE ALGAL FLORA OF IRAN

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Keywords: Algal flora; Taxonomic quotient; Water body; Iran.

Abstract

Algal floristic work carried out in Iran between 1853 and 1981 have been reviewed and compared with the results obtained in a series of recent studies (2000-2007). Algal samples for the recent studies were collected mainly from different inland aquatic habitats. On the basis of data from published and the recent studies, the systematic list of algae shows the occurrence of 1304 species and 1559 infra-specific taxa in Iran. However, 1213 species (1443 infra-specific taxa) revealed from the recent studies included 812 species (979 infra-specific taxa) as new reports for Iran (63% of the total species recorded). Analysis on taxonomic structure of algal flora of Iran testifies its richness. The basic parameters of a regular diversification of flora, values of genera quotient, spectra of leading taxa confirm that the highest percentage is contributed by Bacillariophyta (43%) of the total number of specific and infra-specific taxa followed by Chlorophyta (25%), Cyanophyta (15%) and Euglenophyta (8%). On an interrelation among divisions of algae, the algal flora of Iran appeared to be closer to that of Turkmenistan.

Introduction

Preserving biological diversity needs research on species richness of certain taxonomic groups in different administrative and natural territories. So far, the algal diversity of Iran has been investigated very insufficiently. According to Compere (1981) L. Rabenhorst (1853) reported first several species of freshwater diatoms (Bacillariophyta) from South Persia, Iran but without mentioning habitats. In 1842, soil samples were collected by Kotschy from the territories between Percipolis, Shiraz and Bushehr which cover modern provinces, namely Fars, Esfahan, Bahtiaria and Cheharmehal, Busher. Later Ehrenberg studied them and revealed 45 species of algae (Ehrenberg, 1854), out of which, 29 species became valid. In 1899, J.B. Petersen identified 8 species of algae studying samples collected by O. Paulsen from the Purlieus of Tehran (Petersen, 1930). Later on, D.A. Tarnogradskiy collected 9 samples from the Anzali Swamp in November 1922 and Woronichin (1925) published 13 species of algae from those collections.

The first remarkable studies on the algal flora of Iran by Löffler (1959, 1961) appeared 100 years after the very first report by Rabenhorst (*l.c.*). The works of Löffler can be considered as the first authentic study on the algal flora of Iran. Later on, Hirano (1973) and Wasylik (1975) reported 406 infra-specific taxa. From the soil algae of Sahara-Gobi desert area, 29 species from the arid soils have been mentioned for Iran (Novichkova-Ivanova, 1980).

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In autumn of 1972, the Belgian multi-purpose expedition investigated deserts of the central, eastern and middle Iran, mainly Dašt-e Kavir, Dašt-e Lut and hollow Jazmuriyān. Botanist of the above-mentioned expedition J. Leonard collected samples of algae, which became a subject of study in P. Compere's work (Compere, 1981). The samples of algae were collected from 21 different places and about 300 species and varieties were presented. Of these 66% was diatom, 17% green and 14% blue-green algae. Two species of diatom *Nitzschia curvata* Compere, *N. iranica* Compere and one form *Navicula egregia* Hust. fa. *elongata* Compere were described as new to science (Compere, 1981). Till 2000, an estimated 580 algal taxa were known from Iran.

A series of studies on algae of Iran was conducted between 2000 and 2007 based on 535 samples collected from 125 water bodies from all over Iran (Dogadina *et al.* 2002; Zarei-Darki, 2002, 2004 a, b, 2006, 2007). The habitats included 64 rivers, 19 reservoirs, 19 ponds, 7 lakes, 2 swamps, 2 *Karizes* (a kind of artificial underground channel), 2 water-falls, and 10 springs of which 6 were thermal with water temperature ranged from 34-52°C (Fig. 1).

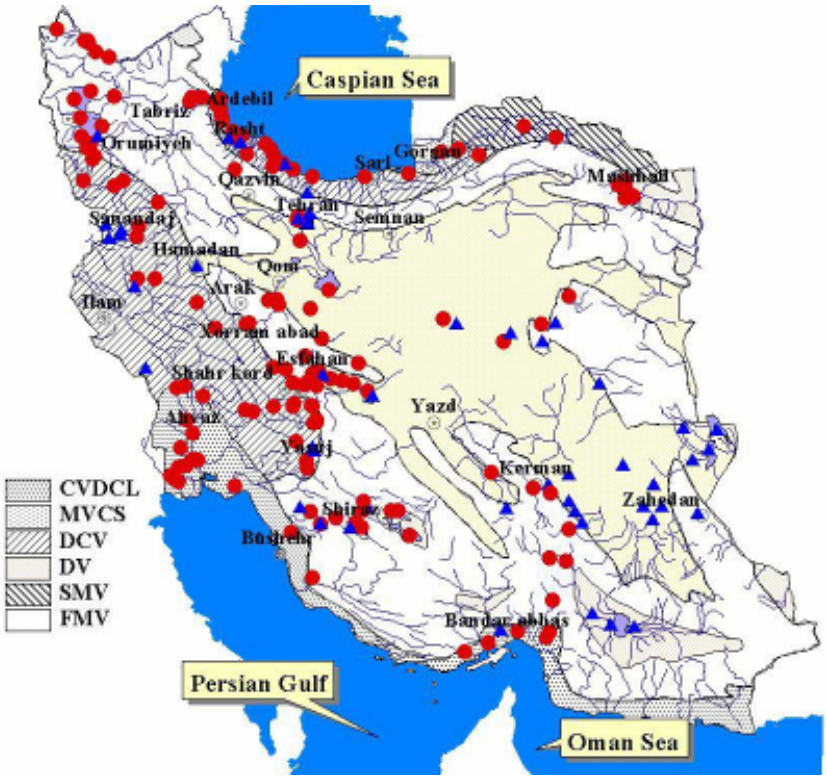

Fig. 1. Schematic map of Iran with sampling sites: deciduous vegetation (DCV), steppe mountain vegetation (SMV), friganoid mountain vegetation (FMV), desert vegetation (DV), complex vegetation of deserted coastal lowlands (CVDCL), meadow-salt marsh vegetation of southern coast of Caspian sea (MVCS), ● – author's collections (2000-2007); ▲- the literary data.

The present paper attempts to analyze the taxonomic structure of algal flora of Iran based upon published information starting from L. Rabenhorst to P. Compere (1853-1981) and also data obtained from recent studies based upon samples collected between 2000 and 2007 by the author. The algal flora of Georgia (Chkhaidze, 1987), Turkmenistan (Kogan, 1973), Central Asia (Muzafarov, 1965), Vietnam (Tien, 1982) and Ukraine (Wasser and Tsarenko, 2000; Tsarenko and Petlevanniy, 2001) were also compared with that of Iran.

Overall algal diversity of Iran

Algae from different water bodies of Iran revealed the occurrence of 1213 species and 1443 infra-specific taxa (infra-specific taxa), which included 812 species (979 infra-specific taxa) as new report for Iran (about 63% of the general species diversity). But 91 algal species (116 infra-specific taxa) from the previous studies on the territorial boundary of Iran could not be confirmed in the recent studies. So, by adding 91 species and 116 infra-specific taxa as obtained from the literature survey to the data accumulated in the recent studies, the total number of algal species now reached 1304 (1559 infra-specific taxa) for Iran (Table 1). The algal species of Iran belong to 8 divisions, 15 classes, 37 orders, 96 families and 262 genera (Table 1). Among the divisions, Bacillariophyta is the largest followed by Chlorophyta, Cyanophyta and Euglenophyta. The percentage of each division is given in Table 2. In the following sections, classification of Zerov (1972) is followed.

Diversity within algal divisions

Cyanophyta has made up almost 15% of the total number of specific and infra-specific taxa of Iran (Table 2). The recent studies revealed 174 species including 201 infra-specific taxa. About 126 taxa appeared as new reports from Iran. From literary data the wide-spread cyanophytic species belonged to the genera *Gloeocapsa* (Kütz.) Hollerb., *Merismopedia* (Meyen) Elenk., *Microcystis* (Kütz.) Elenk., *Oscillatoria* Vauch., *Phormidium* Kütz. and *Synechocystis* Sauv. Some sporadically recorded cyanophytes are *Synechocystis pevalekii* Erceg. (Parišān Lake), *Microcystis testacea* (Näg.) Elenk. (Lirbāzār rudgā River), *Aphanothece nostocopsis* Skuja (Parišān Lake), *Chamaesiphon incrustans* Grun. (Toroq Reservoir), *Phormidium paulsenianum* Boye-Pet. (Orumiyeh Lake), *Ph. toficola* (Näg.) Gom (Šatt-e mongār Lake), *Microcoleus sociatus* W. *et* G.S. West (Mahallāt Thermal spring), *Anabaena azollae* Straburg (Anzali Swamp), and *Rivularia aquatica* (de Wild.) Geitl. (Vošmgir Reservoir).

Euglenophyta is the fourth largest division in Iran in terms of species and infra-specific numbers. In the research conducted during 2000-2007, 121 euglenoid taxa were recorded as new reports. Earlier, four species of euglenoid algae recorded by Wasylik (1975) and Compere (1981) were also found to occur in the present investigation.

Table 1. Taxonomic spectrum, proportion of flora and genera saturation of algal flora of Iran.

Algal division	Number of class, order, families, genera, species and varieties and forms in the corresponding division*						P	Genera saturation by taxa	
	C	O	F	G	S	V		S	I
Cyanophyta	3	5	17	35	202	231	1:2.10:11.9:13.6	1:5.8	1:6.6
Euglenophyta	1	2	4	12	100	125	1:3:25:31.3	1:8.3	1:10.4
Chrysophyta	2	4	9	13	25	30	1:1.4:2.8:3.3	1:1.9	1:2.3
Xanthophyta	1	5	8	24	59	61	1:3:7.4:7.6	1:2.5	1:2.5
Bacillariophyta	1	2	9	49	517	671	1:5.4:57.4:74.6	1:10.6	1:13.7
Dinophyta	1	2	8	11	36	42	1:1.4:4.5:5.3	1:3.3	1:3.8
Cryptophyta	1	1	1	2	13	13	1:2:13:13	1:6.5	1:6.5
Chlorophyta	5	16	40	116	352	386	1:2.9:8.8:9.7	1:3	1:3.3
Total	15	37	96	262	1304	1559	1:2.7:13.6:16.2	1:4.9	1:5.9

*C (class), O (order), F (family), G (genus), S (species), V (variety and form), P (proportion of flora: F to V) and I (infra-specific taxon)

Table 2. A comparison of taxonomic spectrum between the algal flora of Iran and some other countries*.

Algal division	Georgia		Turkmenistan		Central Asia		Vietnam		Ukraine		Iran	
	number of taxa	% in flora	number of taxa	% in flora	number of taxa	% in flora	number of taxa	% in flora	number of taxa	% in flora	number of taxa	% in flora
Cyanophyta	396	16.24	219	22.48	615	22.05	344	24.53	795	13.03	231	14.82
Euglenophyta	156	6.40	25	2.57	111	3.98	78	5.56	554	9.08	125	8.02
Chrysophyta	30	1.23	5	0.51	25	0.90	14	0.99	296	4.85	30	1.92
Xanthophyta	52	2.13	6	0.62	36	1.29	5	0.35	343	5.63	61	3.91
Bacillariophyta	819	33.59	443	45.48	1097	39.33	388	27.67	930	15.24	671	43.04
Pyrrophyta**	41	1.68	22	2.26	45	1.61	30	2.13	337	5.52	55	3.52
Chlorophyta	921	37.78	252	25.87	852	30.55	539	38.44	2586	42.39	386	24.76
Other	23	0.95	2	0.21	8	0.29	4	1.22	260	4.26	-	-
Total	2438	100	974	100	2789	100	1402	100	6101	100	1559	100

* Georgia (Chkhaidze, 1987), Turkmenistan (Kogan, 1973), Central Asia (Muzafarov, 1965), Vietnam (Tien, 1982) and Ukraine (Wasser and Tsarenko, 2000; Tsarenko and Petlevanniy, 2001).
** Includes Dinophyta and Cryptophyta; the former name is kept for better comparison with the literature data.

Euglena anabaena Mainx was found only in Halil rud River and *E. mutabilis* Schmitz was recorded both from Halil rud and Minãb Rivers; while *E. oxyuris* Schmarda in a number of rivers, reservoirs, ponds and swamp habitats (water temperature 16-28°C, pH 6.5-8.0). *Trachelomonas hispida* (Perty) Stein *emend*. Defl. var. *duplex* Defl. occurred in Qešlãq River and Hasanlu Reservoir.

The occurrence of Chrysophyta is known only from the recent studies. The most frequently occurring and wide-spread species are *Dinobryon divergens* Imhof., *Kephyrion rubri-claustri* Conr. and *Lagynion triangulare* (Stokes) Pasch. Occasionally occurring species include *Chrysococcus ornatus* Pasch., *Dinobryon sertularia* Ehr., *D. sociale* Ehr., *Kephyrion valkanovii* Huber-Pest. and *Pseudokephyrion schilleri* (Schill.) Conr.

Altogether 56 species and 58 infra-specific taxa of Xanthophyta have been recorded in the recent studies; but the occurrence of species like *Botrydiopsis eriensis* Snow, *Botryochloris minima* Pasch. (Novichkova-Ivanova, 1980) and *Vaucheria sessilis* (Vauch.) D.C. (Woronichin, 1925) reported in previous studies could not be confirmed. The majority of Xanthophyta representatives was noted seldom, and a few of these species, namely *Arachnochloris striata* Pasch., *Chlorothecium clava* Pasch., *Stipitococcus apiculatus* Prescott and *Tetraedriella impressa* Pasch., were recorded only in Šãdgãn Pond, and Mohammad ãbãd and Sivand Rivers, and Anzali Swamp, respectively.

Diatoms (Bacillariophyta) dominated in all the investigated water bodies of Iran. More than 90% of species and infra-species (i.e. 479 species and 612 infra-specific taxa) were revealed by the recent studies with 217 species (303 infra-specific taxa) as new records for Iran. Some of the newly recorded diatom species of Iran are *Aulacoseira italica* (Ehr.) Sim., *Cyclotella bodanica* Grun., *C. caspia* Grun., *Diatoma ehrenbergii* Kütz., *Eunotia diodon* Ehr., *Melosira lineate* Ag., *M. undulata* (Ehr.) Kütz. var. *normannii* Arn., *Stephanodiscus astraea* (Ehr.) Grun., *Synedra gaillonii* (Bory) Ehr. and *Thalassiosira bramaputrae* (Ehr.) Hak.

Out of 36 species of dinophytes, only two were known before (Löffler, 1961; Wasylik, 1975), namely *Ceratium hirundinella* (O. Müll.) Bergh. and *Peridiniopsis oculatum* (Stein) Bourr. Dinophytes represented in the plankton of Qešlãq River and Reservoir, Sanandaj City were *Glenodinium lemmermannii* Zach., *Gonyaulax polyedra* Stein, *Gymnodinium palustre* Schill., *Peridiniopsis charkowiensis* (Matv.) Bourr., *P. oculatum* (Stein) Bourr., *Peridinium aciculiferum* Lemm. and *P. pseudolaeve* Lef.

No species of Cryptophyta was recorded for Iran before the recent studies. Most frequent cryptophytes are *Chroomonas acuta* Uterm., *Ch. coerulea* (Geitl). Skuja, *Ch. rosenbergae* Hub.-Pest., *Cryptomonas borealis* Skuja, *C. marssonii* Skuja and *C. parapyrenoidifera* Skuja.

Chlorophyta is the second largest algal division in Iran. Class Chlorophyceae occupies leading position among other classes of green algae and is represented by 9 orders, 27 families, 209 species and 221 infra-specific taxa. As a result of processing samples from polytypic water bodies of Iran during 2000-2007, 200 species (211 infra-specific taxa) were identified, of them 165 species (176 infra-specific taxa) are new for the country. Frequently occurring species are *Chlamydomonas angulosa* Dill, *Ch. snowiae* Printz, *Coelastrum microporum* Näg. in A. Br., *Dunaliella minuta* Lerche, *Kirchneriella irregularis* (G. Sm.) Korsch., *Micractinium pusillum* Fres., *Monoraphidium irregulare* (G. Sm.) Kom.-Legn. in Fott, *Oocystis borgei* Snow, *Pediastrum boryanum* (Turp). Menegh., *Planctococcus sphaerocystiformis* Korsch., *Scenedesmus acuminatus* (Lagerh.) Chod., *S. ellipticus* (W. *et* G. S. West) Chod., *S. quadricauda* (Turp.) Breb., *Schroederia setigera* (Schröd.) Lemm., *Tetraedron minimum* (A. Br.) Hansg. and *Tetrastrum triangulare* (Chod.) Kom. From the order Chlorodendrales under the class Prasinophyceae, two species, namely *Tetraselmis arnoldii* (Pr.-Lavr.) Norris, Hori & Chihara and *T. contracta* (Carter) Butcher, were recorded from rivers, reservoirs and swamps.

Among the new findings from Ulvophyceae, noteworthy species are *Geminellopsis fragilis* Korsch., *Klebsormidium dissectum* (Gay) Ettl *et* Gärtn., *Stichococcus bacillaris* Näg., *Ulothrix flacca* (Dilw.) Thur., *U. zonata* (Web. *et* Mohr.) Kütz. and *Uronema confervicolum* Lagerh.

From Zygnematophyceae, *Mougeotia sphaerocarpa* Wolle, *Spirogyra bogeana* Trans., *S. condensata* (Vauch). Kütz., *S. ellipsospora* Trans., *S. micropunctata* Jao, *S. pratensis* Trans., *Zygnema insigne* (Hass.) Kütz. and *Z. pectinatum* (Vauch.) Ag. have been recorded for the first time in Iran during recent studies.

Charophyceae known earlier (Compere, 1981) have also been found to occur during the recent studies. *Chara gymnophylla* A. Br. was found to grow within water temperature 14-28°C, pH 6.5-7.0 in the Halil rud River and Šatt-e mongãr Lake, and *Ch. vulgaris* L. *emend*. Wallr. in Halil Rud River, Šãdgãn Pond and Gãvxuni Swamp (14-28 °C, pH 6.5-8.5). For the first time in Iran, *Chara uzbekistanica* Hollerb. was found in the Šatt-e mongãr Lake and Gãvxuni Swamp (20-28°C, pH 6.5-8.5). However, *Nitella hyalina* (DC.) Ag. could not be recorded in the recent studies.

Taxonomic quotients

It is known that the factor which testifies connection between number of species, genera and families determines the ‘face’ of flora with the greatest clarity (Tolmachev, 1974). 'Proportions of flora' and generic factor concern to a group of parameters of taxonomic diversity. The s/f (species/families) is estimated as a ratio between the number of species and number of family of a particular group (e.g. class); g/f (genera/families) and s/g (species/genera) are determined in a like manner. Generic factor shows generic

richness of algal flora by species and infra-specific taxa. According to some authors, richer floras differ from less rich floras by higher values of these parameters (Shmidt, 1980, 1984). Additionally, generic factor is considered as a factor of taxonomic diversity that does not depend on area.

Comparison of genera quotient values among divisions shows that the greatest specific richness is seen in Bacillariophyta followed by Euglenophyta, Cryptophyta and Cyanophyta (Table 1). In spite of high number of species in algal flora, Chlorophyta occupies sixth place. Apparently, it is explained by the presence of the large number of genera with little species number, e.g. 84 genera represented only by one or two species out of 116 total genera in Iran's algal flora.

For the algal flora of Iran as a whole, rather high values of general genera quotient (4.9) (Table 1) testifies the richness of investigated flora. Such conclusion is proved to be true by the comparison of values of the genera quotient for some other floras. For example, genera quotient was 2.8 for system of lake Chany (Safonova, 1973), and 3.8 for water bodies of Yakutia (Vasilieva, 1989).

Comparison of algal flora of Iran with those of other countries

Table 2 shows a comparison of taxonomic spectrum of algal flora of different countries with that of Iran. The choice of the countries was arbitrary. The only generalized data brought in the literature (Muzafarov, 1965; Kogan, 1973; Tien, 1982; Chkhaidze, 1987; Wasser and Tsarenko, 2000; Tsarenko and Petlevanniy, 2001) were used in the paper. The compared countries and regions rather differ on the terrain, natural settings, remoteness from Iran, a degree of a level of algal flora knowledge and many other attributes. However, ostensibly such comparison is useful to reveal general regularity and characteristic features in the algal structures of these regions.

Absolute values of all comparable floras differ markedly and indeed depend on degree of algal study in the country. Therefore, proportion (in %) a division occupies in the total algal flora was preferred than its absolute value.

In all the compared floras as presented in Table 2, the basic role is played by two divisions, namely Chlorophyta and Bacillariophyta, occupying top two positions in taxonomic spectra. Contribution of these two divisions in the algal flora of Iran looks very close to the algal flora of Turkmenistan. This can be explained by the geographical location and presence of the general orographical and climatic attributes of the two countries. In other floras, the 1st place is occupied by the green algae considerably leaving behind diatoms as it is evident in the flora of Ukraine range. In all the compared floras, the 3rd place in taxonomic spectra is occupied by blue-green algae. It is evident that the diversity of Cyanophyta in some neighboring geographical regions (Turkmenistan, Central Asia) is very high compared with Iran. But contrary to it, in Iran, luxuriant growth of Cyanophyta is common in the rice fields and obviously a study on these

habitats could add a few more taxa to the list of Iran. Parameters of the relative contribution on other divisions of algae when compared, the data obtained for Iran shows a concurrence with the data of other floras in most cases.

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