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Floristic study of Naviculaceae species (Bacillariophyceae) in inland waters of Iran.

Ali Naseri*[1], Masoumeh Shams Kahrizsangi [2], Bita Aafsordeh[1]
[*1] *Environment Organization, Department of Environment, Alborz Province, Iran.*
[2]*Department of Biology, Faculty of Biological Science and Technology, University of Isfahan, Islamic Republic of Iran*
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Email for correspondence: naseriaza@yahoo.com

Abstract

The study of diatoms is necessary because they are the sources of oxygen in rivers, and also constitute the basic primary productivity chain and are used in determining water pollution levels. Iran is a large country with a great diversity of aquatic ecosystems including rivers, springs, seas shallow, lakes, waterfalls, lagoons, and wetlands. Despite the many types of aquatic habitats, there has been a limited study of the diatom flora. The present communication deals with the taxonomic- floristic study of family Naviculaceae with 10 genera and 181 species with emphasis to *Navicula* Bory genus from various rivers and lake from Iran.
Keywords: Bacillariophyta, Naviculaceae, *Navicula*, Iran.

Introduction

Diatoms are unicellular, sometimes colonial algae found in almost every aquatic habitat as free-living photosynthetic autotroph, colorless heterotrophs, or photosynthetic symbiotic. They may occur as plankton or periphyton, with most brownish- green films on the glacial, alpine pools, hot spring, rocks or aquatic plants (Schmaljohann & Röttger, 1978). The cells are surrounded by a rigid two-part boxlike cell wall composed of silica, called the frustule.

The chloroplast contain chlorophylls a, c_1, and c_2 with the major carotenoid fucoxanthin. Bacillariophyceae can be divided into 2 orders as biddulphiales (centrales) and Bacillaiales. Centrales is primarily a marine planktonic group having cell with gonoid or centric ornamentation as *Cyclotella*. Bacillariales or pennales order contains cell that occure both in freshwater and marine environment and common genera are such as *Navicula*, *Nitzschia*, *Amphora* and *Cymbella*. Bacillariophyta divided to 11 order and 16 family (Whitford & Schumacher, 1984). *Navicula* Bory (1822), is a genus of boat-shaped diatom algae comprising over 1200 species (Guiry & Guiry, 2021)

In rivers and streams, diatoms reflect the status of the water environment and they are a valuable tool as indicators of water quality assessment and monitoring because of their wide geographic distribution, well studied ecology, case of collection and sensitivity to physical, chemical and biological changes in water, contributing to the primary productivity of ecosystems (Shams et al., 2012) .

Iran has climatic and geologic regions with 1.6 million km^2. There are several taxonomical researches about diatoms in Iran as: southern Iran (Hulburt et al., 1981), northern Iran (Ganjian et al., 1998; Jamaloo et al., 2006; Pourgholam et al., 2010; Masoudi et al., 2012; Soltanpour-Gargari et al., 2011; Zarei-Darki, 2009), central and southeastern Iran (Compère, 1981); central Iran (Afsharzadeh et al., 2003; Cheraghpour et al., 2013; Löffler, 1959; (Moghadam, 1976; Shams et al., 2012; Atici & Shams, 2017; Zarei-Darki, 2011); central and western Iran (Hirano

Email for correspondence: naseriaza@yahoo.com

1973); northwestern Iran (Nejadsattari, 2005; Panahy-Mirzahasanlou et al., 2018); and large-scale surveys of Iran (Wasylik, 1975; Zarei-Darki, 2009, 2011). Diatoms are used in biomonitoring (Atazadeh et al., 2007; Shams & Karimian Shamsabadi, 2019) and paleoecological and paleolimnological studies (Whitford & Schumacher, 1984; Snyder et al., 2001). The aim of this study is documenting the first checklist of Naviculaceae (class Bacillariophyceae) in the Iranian diatom flora and introduced the report of new records for Iran.

Material and Methods

Current study is provided only on floristic research of Naviculaceae from 1972 to July 2021. The provided resources include dissertations, and thesis of students, articles, and resources of University Libraries. Old taxonomic name of diatoms in most resources converted to the update names using the algaebase. They are depicted in the bracket in table 1.

Some resources used in this study such as: Anzali Lagoon and Marbareh ,Tizab & Karaj riveres (Nejadsattari et al., 2005; Ramezanpour, 2004; Kheiri, 2019); Kordan & Taleghan rivers (Mehrani-Adl et al., 2020; (Naseri & Nooorzi, 2021); Central and South–eastern, Iran Gavkhouni Wetland and Zayandeh Rood Lake (Compère, 1981; Shams et al., 2012; Shams & Karimian Shamsabadi, 2019); Lake Urmia: (Mohebbi, 2019), Guilan and Golestan Province: (Ahmadi-Musaabad et al., 2019; Noroozi et al., 2019), Lake Neure (Neor) & Balikhli River: (Nejadsattari, 2005); (Panahy-Mirzahasanlou et al., 2018, 2020), Goharbaran region: (Makhloogh et al., 2017); area:); Bandar Abbas, Hormuz and Bushehr areas (Subba-Rao & Al-Yamani, 1998; Fatemi et al., 2005; Saeedi & Ashja-Aradalan, 2009); coastal waters of the Caspian Sea and Ramsar: (Soltanpour-Gargari et al., 2011; Bagheri & Fallahi, 2014; Nasrollahzadeh-Saravi et al., 2015; Omidmoazam et al., 2020); Gharasou River: (Atazadeh et al., 2007), Boujagh National Park: (Noroozi et al., 2009); Southern Caspean: (Fallahi, 1993); Kashkan River (Safiallah et al., 2020); Rivers in Turkey and Iran (Atici & Shams, 2017); Helleh River (Farhadian et al., 2015), and Algae of aquatic ecosystems of Iran (Zarei-Darki, 2009, 2011). The taxa name are classified base on to Guiry & Guiry (2021).

Results

Results of study show that Naviculaceae (class Bacillariophyceae) has 10 genera and 181 species in Iranian water resources including of *Navicula* (127 species); *Caloneis* (25 species); *Gyrosigma* (19 species); *Hippodonta* (3 species); *Haslea* (2 species); *Khursevichia*, *Seminavis*, *Kobayasiella*, *Microcostatus* (each of 1 species. They are shown in Figure, and Table 1.

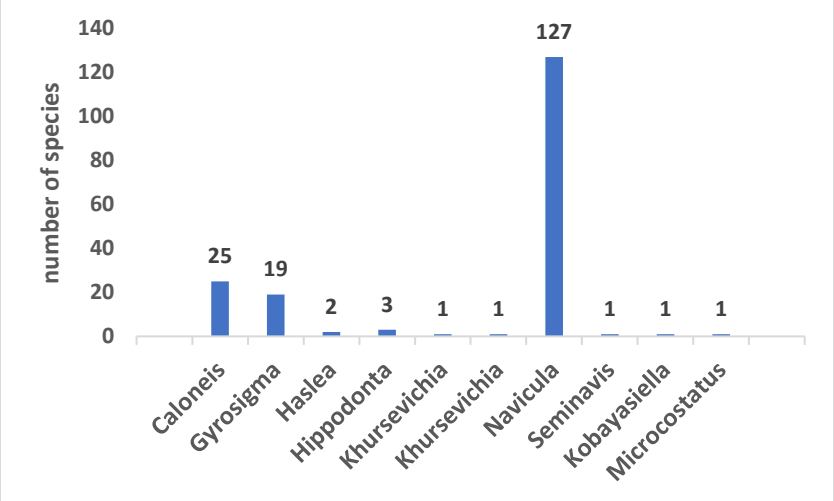

Figure1. The numbers species and genera of Naviculaceae of inland waters of Iran.

Table 1. Checklist of Naviculaceae (Bacillariophyta) in inland waters of Iranian.

Naviculaceae	*C. schumanniana* (Grunow) Cleve
Caloneis	*C. sublinearis* McCall
C. aequatorialis Hustedt	*C. ventricosa* F. Meister (*C. silicula* **var**. *ventricosa* Cleve; *Navicula ventricosa* Ehrenberg)
C. alpestris (Grunow) Cleve	*C. ventricosa* **var**. *truncatula* (Grunow) Meister (*C. silicula* **var**. *truncatula* (Grunow) Cleve)
C. amphisbaena (Bory) Cleve	*C. westii* (W.Smith) Hendey
C. amphisbaena **var**. *subsalina* (Donkin) Cleve (*Navicula subsalina* Donk)	*Caloneis* sp (**2**)
C. bacillum (Grun.) Cleve	***Gyrosigma***
C. budensis (Grunow) Krammer (*C. macedonica* Hustedt)	*G. acuminatum* (Kützing) Rabenhorst (*G. spenceri* (W.Smith) Griffith & Henfrey)
C. clevei (Lagerstedt) Cleve	*G. acuminatum* **var**. *brebissonii* (Grunow) Cleve
C. **cf**. *inflata* (Hustedt) Metzeltin & Lange-Bertalotb	*G. attenuatum* (Kutz.) Rabenh.
C. fontinalis (Grunow) Cleve-Euler	*G. baicalense* **var**. *minus* Komarenko
C. elongata (Grunow) Boyer	*G. distortum* (W.Smith) J.W.Griffith & Henfrey
C. lancettula (Schulz) Lange-Bertalot &Witkowski	*G. kuetzingii* (Grunow) Cleve
C. leptosoma (Grunow) Krammer	*G. peisone* (Grunow) Hustedt
C. limosa (Kützing) R.M.Patrick (*C. silicula* **var**. *gibberula* (Kützing) Cleve)	*G. rautenbachiae* Cholnoky
C. molaris (Grunow) Krammer	*G. scalproides* (Rabenhorst) Cleve
C. obtusa (W.Smith) Cleve	*G. sciotoense* (W.S.Sullivant) Cleve (*G. nodiferum* (Grunow) Reimer)
C. permagna (Bailey) Cleve	*G. spenceri* **var**. *curvula* (Grunow) Reimer
C. silicula (Ehrenberg) Cleve	*G. strigilis* (W.Smith) J.W.Griffin & Henfrey

G. wormleyi (Sullivant) Boyer (*G. parkeri* (M.B.Harrison) Elmore)

Gyrosigma sp (**6**)

Haslea

H. crucigera (W.Smith) Simonsen (*Navicula crucigera* (W.Smith) Cleve)

H. spicula (Hickie) Bukhtiyarova (*Navicula spicula* (Hickie) Cleve)

Hippodonta

H. capitata (Ehrenberg) Lange-Bertalot, Metzeltin & Witkowski (*Navicula capitata* (Ehrenberg) R.Ross)

H. costulata (Grunow) Lange-Bertalot, Metzeltin & Witkowski (*Navicula costulata* Grunow)

H. hungarica (Grunow) Lange-Bertalot, Metzeltin & Witkowski (*Navicula capitata* **var**. *hungarica* (Grunow) R.Ross)

Khursevichia

K. jentzschii (Grunow) Kulikovskiy, Metzeltin & Lange-Bertalot in Kulikovskiy & al. (*Achnanthes jentzschi* (Grunow) P.Schulz)

Navicula

N. amphiceropsis Lange-Bertalot & U.Rumrich

N. antonii Lange-Bertalot

N. arenaria Donkin

N. bacillum **var**. *minor* (Grunow) Cleve

N. baicalensis Skvortsov & C.I.Meyer

N. bicephala Hustedt

N. broetzii Lange-Bertalot & E.Reichardt

N. capitatoradiata H.Germain ex Gasse

N. hasta Pantocsek

N. heufleri Grunow

N. cari Ehrenberg (*N. graciloides* A.Mayer)

N. cari **var**. *cincta (*Ehrenberg) Lange-Bertalot

N. caterva Hohn & Hellermann

N. cincta (Ehrenberg) Ralfs

N. constricta Ehrenberg

N. cryptocephala Kützing

N. cryptotenella Lange-Bertalot

N. cryptotenelloides Lange-Bertalot

N. erifuga Lange-Bertalot

N. escambia (R.M.Patrick) Metzeltin & Lange-Bertalot

N. exigua W.Gregory

N. expansa Hagelstein

N. farta Hustedt

N. fluens Hustedt

N. germainii J.H. Wallace

N. gibbula Cleve

N. gottlandica Grunow

N. gregaria Donkin

N. grunovii O'Meara (*N. lacustris* Grunow)

N. perrotettii **f.** *minor* O.Müller

N. phyllepta Kützing

N. incerta Ehrenberg

N. kefvingensis (Ehrenberg) Kützing (*N. peregrina* **var**. *kefvingensis* (Ehrenberg) Cleve)

N. koeiei Foged

N. kotschyi **var**. *rostellata* (Hustedt) Lange-Bertalot

N. lanceolata Ehrenberg

N. laterostrata Hustedt

N. leonardii Compèr

N. liber **var**. *tenuistriata* (Cleve) Zimermann

N. lucidula Grunow

N. margalithii Lange-Bertalot

N. menisculus Schumann

N. menisculus **var**. *obtusa* Husted

N. minima Grunow

N. moerckii Foged

N. moskalii Metzeltin, Witkowski & Lange-Bertalot

N. notha J.H.Wallace

N. novaesiberica Lange-Bertalot

N. oblonga (Kützing) Kützing

N. odiosa J.H. Wallace

N. metareichardtiana Lange-Bertalot & Kusber (*N. reichardtiana* Lange-Bertalot

N. peregrina (Ehrenberg) Kützing

N. phylleptosoma Lange-Bertalot

N. pseudolanceolata Lange-Bertalot

N. upsaliensis (Grunow) M.Peragallo (*N. menisculus* **var**. *upsaliensis* Grunow)

N. radiosa Kützing

N. recens (Lange-Bertalot) Lange-Bertalot

N. rhynchocephala Kützing

N. rostellata Kützing

N. sabiniana R.M. Patrick

N. salinarum Grunow

N. salinarum **f.** *capitata* Schulz

N. semen Ehrenberg

N. septataeoides Hustedt

N. schroeteri F.Meister

N. simulata Manguin

N. staffordiae Bahls

N. subrhynchocephala Hustedt

N. subtilissima **f.** *baicalensis* Skvortsov & C.I.Meyer

N. supleeorum Bahls

N. tamnaeana Guermeur

N. tantula Hustedt

N. tenelloides Hustedt

N. tenella Brébisson ex Kützing (*N. radiosa* **var**. *tenella* (Brébisson ex Kützing) Van Heurck)

N. tripunctata (O.F. Müller) Bory de SaintVincent

N. trivialis Lange-Bertalot

N. weberi Bahls

N. zanonii Hust.

N. sp (**26**).

N. tuscula **f.** *intermedia Kisselev*	***Seminavis***
N. undosa Ehrenberg	*Seminavis strigosa* (Hustedt) D. & E.Amilli
N. vandamii Schoeman&Archibald.	**Naviculales incertae sedis (Family)**
N. veneta Kützing (*N. cryptocephala* **var**. *veneta* (Kützing) Rabenhors)	***Kobayasiella***
N. vilaplanii (Lange-Bertalot and Sabater) Lange-Bertalot and Sabater	*K. subtilissima* (Cleve) Lange-Bertalot (*Navicula subtilissima* Cleve)
N. viridula (Kützing) Ehrenberg	***Microcostatus***
N. viridula **var**. *rostrata* Skvortsov	*M. krasskei* (Hustedt) J.R.Johansen & Sray
N. viridulacalcis Lange-Bertalot	

Note: old taxon name is depicted in the bracket.

Discussion

Iran was classified into three phytogeographical areas Saharo-Sindian region (south of Iran), Euro-Siberian region (north of Iran), and Irano-Turanian Region which occupied the central and west part of Iran (Sabeti 1976).

The providing individually families of diatoms to researchers are necessary for quick access. Currently study is only focused on species of Naviculaceae families for the diatom flora of Iran.

Irano–Turanian Region is biggest area of Iran with wide biodiversity. These regions includes the Zagros Mountains and Central Plateau of Iran with 1000 to 2000 m elevation. Based on the references of checklist Naviculaceae 58 percent of species belong to this area.

The Caspian Sea (north of Iran) which contains the Euxino–Hyrcanian sub–humid vegetation in the Euro–Siberian Region. The Caspian Sea is 424000 km^2 area and Volga River is one of importance main source of water (Fallahi 1991). The Khalijo–Omanian Region (south of Iran) includes the mangrove forests and the Persian Gulf and Oman Sea coast. It has wide of biodiversity (Koo–Lee & Kleine 2009)**.**

The Karaj River is 245 km in the Central Iranian Plateau. It is one of the longest rivers in Iran (Bakhtiari 2008). The *Navicula moskalii* and *N. viridulacalcis* reported in this river (Kheiri et al., 2018).

Neure Lake is located in the 42 Km southwest of Ardebil Province. Some of records as *N. bicephala* Hustedt reported for it (Nejadsattari 2005).

Kurdan River is 25Km distant from Karaj city and located in Kurdan city. Some of records including *N. margalithii* Lange-Bertalot, *N. odiosa* J.H. Wallace and *Microcostatus krasskei* are reported from this area (Mehrani–Adl et al., 2020).

The Kashkan River with 900 km length is flowing from the Zagros Mountains. It is located in the Lorestan province. *N. caterva* is recorded in this area by Safiallah et al. (2020).

One hundred fifty species of epiphytic which 35 of their taxa belong to diatoms were reported from Anzali Lagoon. *Gyrosigma distortum* is recorded in this area (Nejadsattari et al., 2005).

Other checklists are used for providing checklist Naviculaceae. It includes checklist of phytoplankton taxa of the Caspian Sea (Bagheri & Fallahi 2014), and algae of aquatic ecosystems of Iran (Zarei–Darki 2011). Unlike them, in checklist Naviculaceae is focused on

diatoms. There is no picture of taxa in some floristic studies, especially in student thesis, therefore the presence of those taxa is doubtful. In the checklist of phytoplankton taxa of the Caspian Sea by Bagheri & Fallahi (2014), 158 phytoplankton is been identified which 70 species of them belongs to diatoms.

Only four species *N. cryptocephala* Kutzing, *N. gregaria* Donkin, *N. pusilla* W. Smith, *N.radiosa* Kutzing are reported in the checklist of phytoplankton taxa of the Caspian Sea (Bagheri & Fallahi 2014). One hundred and five species of *Naviculaceae* are reported in algae checklist of aquatic ecosystems of Iran which Fifty-eight species of them is for *Navicula* genus (Zarei–Darki 2011).

Khursevichia jentzschii (Grunow) Kulikovskiy, Metzeltin & Lange-Bertalot in Kulikovskiy & al. (*Achnanthes jentzschi* (Grunow) P.Schulz) is only reported in checklist algae of aquatic ecosystems of Iran (Zarei–Darki 2011). *Haslea crucigera* (W.Smith) Simonsen (*Navicula crucigera* (W.Smith) Cleve) and *H. spicula* (Hickie) Bukhtiyarova (*Navicula spicula* (Hickie) Cleve) are reported in algae of aquatic ecosystems of Iran (Zarei–Darki 2011), streams in Ramsar: (Soltanpour-Gargari et al., 2011) and Caspian Sea (Nasrollahzadeh-Saravi et al., 2015).

According to the sources used of Naviculaceae family, 26 species of *Navicula*, *Caloneis* (2 spp), *Gyrosigma* (6 spp), have not been identified. The *Kobayasiella subtilissima* and *Microcostatus krasskei* could not be referred to any family**.**

Conclusion

Comparing the checklist of Naviculaceae showed that some of species are widespread in Iran as *Navicula* has high species number. The checklist Naviculaceae of Iran was provided for the first time. It contains 10 genera and 181 species. Some of species names have changed based on this update**.**

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