

DIVERSITY OF EUGLENOPHYCOTA AND BACILLAROPHYCOTA IN THE NORTH-EASTERN AREAS OF PAKISTAN

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Abstract: Altogether 115 species of algae with solitary or colonial organisations belonging to 2 phyla, 2 classes, 2 orders, 15 families and 31 genera have been collected from various freshwater habitats in several districts of the Punjab Province, some areas of Frontier Province in Pakistan as well as Azad Kashmir during December 2003 and July 2006. They included 4 genera and 45 species as new record from Pakistan. Members Bacillariophycota with 29 genera and 75 species were more prevalent (65.21 %) than Euglenophycota with 2 genera and 40 species (34.78 %). Bacillariophyceae appeared to be the most highly distributed class with single order and 14 families containing 29 genera and 75 species. Family Naviculaceae with 29 species was most commonly found (25.22 %). *Euglena* with 34 species was the most commonly occurring genus (29.56 %). Almost 77.5 % of euglenoids were planktic and benthic both, and 22.5 % were purely planktic. While 64 % diatoms occurred as epiphytes, 22.66 % as planktic and epiphytic both, and 13.33 % as pure planktic individuals. Greatest proportion of algal collections (58.26 %) was made from Lahore City and its neighbouring areas. Largest number of the collected species of Euglenophycota was found in summer (47.5 %). The frequency of their occurrence remained the same during autumn and spring (20 % each), while during winter their occurrence was 12.5 %. Enormous number of the collected species of Bacillariophycota was found in winter (42.66 %), their frequency gradually decreased in spring (26.66 %), summer (25.33 %) and autumn (10.66 %).

Keywords: Freshwater algae, taxonomy, frequency of occurrence, distribution

Introduction

For the first time 49 freshwater diatoms were described from the region now included in Pakistan [1]. Later on, an account of 62 diatoms was given about the undivided Punjab [2], a larger part of which is now included in Pakistan. A detailed investigation on the taxonomy of 102 species belonging to 25 genera of freshwater diatoms was carried out from Peshawar Valley of North Western Frontier Province (N. W. F. P.) [3]. Apart from that several attempts were also made to describe marine diatoms from the coastal waters of Karachi [4-7] and other areas of Sindh [8-9].

Some species of freshwater diatoms were further reported from Punjab [10-13], N. W. F. P.

[14-16], Balochistan [17-18], Sindh [19-27] and Azad Kashmir [28]. A few studies were also made on the euglenoids of N. W. F. P. [29-30]. But no composite study was carried out on the diversity of Euglenophycota and Bacillariophycota from any area of the country. Therefore, a wide range research program was started in March 2003 to make a detailed investigation on the members of these Phyla and a large collection of diatoms and euglenoids was made from freshwater habitats of various districts of the Punjab, certain areas of N. W. F. P. and Azad Kashmir.

Materials and Methods

Algal collections were made during December 2003 and July 2006 from various areas of the districts of Gujranwala, Jhang, Kasur,

Lahore, Sargodha, Sheikhpura and Sialkot in the province of the Punjab, and Jaangira and Swat in North Western Frontier Province of Pakistan (N. W. F. P.) as well as Chenari and Neelum Valley in Azad Kashmir. Planktic, epiphytic and benthic algae were collected from various freshwater habitats *e.g.* rain pools, road-side ponds, fountain-water tanks, permanent water reservoirs, rivers, rice fields, canals and irrigation channels during different seasons of the year. The specimens were collected using phytoplankton net of 5-10 μM mesh. Water samples obtained by Nansen bottle from 3-4 m depth were filtered to separate planktic individuals. Epiphytic individuals were obtained by crushing the twigs, leaves and other parts of the collected vegetation, and benthic organisms were picked up by forceps from walls and other solid substrata. The algal specimens collected from different sources were centrifuged, preserved in plastic bottles containing 3% formalin solution and brought to Karachi.

In the laboratory, the specimens were picked up using a dropper from the samples collected from various sources, placed in 10% glycerin mounts and studied under Zeiss Stereomicroscope. Identification of the specimens down to the species level was carried out with the help of authentic literature [4,31-42].

Results and Discussion

One hundred and fifteen species of planktic, epiphytic and benthic algae with solitary or colonial organizations belonging to two Phyla, two Classes, two Orders, fifteen Families and thirty-one Genera were collected from various freshwater habitats. The collected specimens were investigated cytologically and morphologically, and on the basis of such characters they were taxonomically determined up to the species level. Although all of them were found to be taxonomically known species [31-35,37,41,42],

most of them were new records from these areas [4,12,13,15,29,30,43-47]. The collected species have been systematically arranged according to the newly proposed classification [48] and presented in the Table 1. Out of these, 4 genera and 45 species have been reported for the first time from Pakistan, including 25 species of Euglenophycota and 4 genera and 20 species of Bacillaroptycota. New taxonomic nomenclature [48] has been used here.

Taxonomic Diversity

The taxonomic studies revealed that members of the Phylum Bacillaroptycota with 29 genera and 75 species were found to be more prevalent (65.21%) than the Phylum Euglenophycota, which included 2 genera and 40 species, and thus was a smaller phylum (34.78%) than Bacillaroptycota in diversity (Table 2). Similarly, Bacillariophyceae appeared to be the most highly distributed class as compared to the class Euglenophyceae. Same conclusion may be drawn about the order Bacillariales in comparison with Euglenales, because both the phyla and classes concerning with the collected material are monotypic. Diatoms were usually found more abundantly than the euglenoids [49-51].

Euglenaceae appeared to be the most highly distributed (34.78%) family with its 40 species, because it is the only family of the Order Euglenales to which the collected specimens belonged. While the Order Bacillariales was represented by 14 families, among them Naviculaceae with 29 species was most commonly found (25.22%). Next to it were the Families Cymbellaceae and Nitzschaceae with 9 or 10 species, each one of them was represented by 7.82-8.69% of the total collection. At other localities also, these families were found to be more prevalent than the others [31,32,39,40,52-54]. The Families Bacillariaceae, Gomphonemaceae, Swirellaceae,

Tabellaraceae, Thalassiosiraceae, Epithemaceae and Eunotaceae with 1 or 2 species were the most poorly represented families (0.86-1.73% each).

At the generic level, *Euglena* with its 34 species occurred most commonly (29.56%, Table 2). It has been observed as the most prevalent genus in different other habitats as well [35,36,55]. It was followed by the Genera *Cymbella* with 10 species (8.69%), *Nitzschia* with 9 species (7.82%), *Navicula* and *Pinnularia* with 8 species (6.95% each). *Bacillaria*, *Anomoeoneis*, *Fragilaria*, *Fragilariforma*, *Frustulia*, *Luticola*, *Mastogloia*, *Neidium*, *Stauroneis*, *Tabellaria*, *Cyclotella*, *Epithemia*, *Rhopalodia* and *Eunotia* with one species each, were the very poorly represented genera (0.86% each) in the present collection. Usually they were observed to be of rare occurrence [56-58].

Habitat Diversity

The collected species were found to occur in four different ways of living (Table 2): (1) only in planktic condition, (2) only in epiphytic habitat, (3) both in planktic and epiphytic conditions (sometimes free-floating, sometimes attached with other algae and water plants), (4) both in planktic and benthic habitats (sometimes free-floating, sometimes attached with hard substrata). No epilithic, epipsammic or epipellic alga was collected. Euglenoids occurred in only two conditions *i.e.* 1 and 4, the categories 2 and 3 were absent in them. Almost 77.5% of them were planktic and benthic both, while 22.5% were purely planktic. This condition was exhibited by both the genera *i.e.* *Euglena* and *Phacus*. As euglenoids are motile and flagellated individuals, they usually prefer planktic habitat [35,36,53,55].

The collected diatoms were more variable in their habitat diversity. They exhibited the

habitat categories 1, 2 & 3, none of them was found simultaneously in planktic and benthic conditions. Almost 64% of them occurred as epiphytes, 22.66% as planktic and epiphytic both, and 13.33% as pure planktic individuals. There are several Families such as Achnanthaceae, Bacillaraceae, Diatomaceae, Fragilaraceae, Gomphonemaceae, Nitzschaceae, Surirellaceae, Swirellaceae, Tabellaraceae, Thalassiosiraceae, Epithemaceae and Eunotaceae, in which no purely planktic individual was observed. In this way, members of the Phylum Bacillariophycota differed from those of the Euglenophycota in habitat diversity. As the diatoms are non-motile and non-flagellated individuals, they usually occur in attached conditions either as epiphyte or simple benthos [33,34,38,41,59].

Among all the collected species (115), it was observed that 41.73% occurred as pure epiphytes. It appeared that the epiphytic habitat was mostly preferred by them, when members of both the phyla were considered together, while 26.95% of them were found both in the planktic and benthic conditions. The other two categories of habitat *i.e.* purely planktic and epiphytic (simultaneously) were almost equal (16.52 and 14.78%, respectively).

Diversity of Localities

The algae were collected from nine different localities, where the collected species exhibited variations in their diversities (Table 3). The greatest proportion of algal collections (58.26%) was made from Lahore City and its neighbouring areas. The largest collections of blue-green and green algae were also made from this district during previous studies [60,61]. Probably, it is due to the presence of innumerable water bodies such as rivers, canals, tube wells and fountain-displaying areas at Lahore [45,62]. Other groups of freshwater algae were also found in abundance at

Lahore [11,63-65]. It was followed by the districts of Gujranwala (15.65%) and Kasur (13.04 %), where appreciable collections were made. The poorest diversity was shown in the collections from the districts of Jhang and Sargodha in the Punjab Province (2.60 and 3.47%) and also from the areas of N. W. F. Province (3.47%). During previous studies, poor growth of algae was also recorded for the districts of Attock, Jhang and Sargodha [10,61,66].

Diversity of algal collection from cold areas of N. W. F. P. and Azad Kashmir was not comparatively good (3.47 and 6.08%). Sufficient areas from these places could not be visited, due to difficulties in approach such as poor road conditions and earthquake in mountainous areas. Much greater diversities have been shown from these areas in previous studies [28,67].

Seasonal Diversity

Members of both the phyla were found in all the four seasons of the year (Table 4). Most of the species of Euglenophycota were collected in summer (47.5%), while the frequency of their occurrence remained the same during autumn and spring (20% each), and during winter it was only 12.5%. But most of the species of Bacillaro-phycota were collected in winter (42.66%), the smallest number of them were found in autumn (10.66%), while in the rest of the two seasons they occurred in almost equal proportion (26.66 and 25.33%). In this way, the euglenoids completely differed from the diatoms in their seasonal

diversity. Similar diversity of the euglenoids was observed in other localities [37,56,68,69].

Among the euglenoids, *Euglena* exactly followed the same pattern of seasonal diversity which was exhibited by the phylum itself, but *Phacus* differed from this plan. It was absent during winter, and occurred in exactly the same proportion (33.33% each) in the three other seasons. Both genera have also exhibited similar differences in their seasonal diversity at other habitats as well [29,30,35,53,55].

Among the diatoms, different genera behaved variably in their pattern of seasonal diversity. *Cymbella* occurred mainly (50%) in spring, *Navicula* (75%) and *Nitzschia* (44.44%) were found mainly in winter, while they were collected in all the four seasons of the year. The species of *Surirella*, *Tabellaria*, *Rhopalodia* and *Eunotia* were only found in spring, while they were absent in other seasons. The species of *Anomoeoneis* and *Neidium* occurred only in summer; they were not found in other seasons. The species of Bacillaria, *Luticola* and *Stauroneis* were found only in autumn, being absent in other three seasons. The species of several genera such as *Amphora*, *Gyrosigma*, *Mastogloia*, *Cymatopleura*, *Cyclotella* and *Epithemia* occurred during winter season only and could not be collected in other seasons of the year. Certain genera were found in any two seasons and remained absent in the other two seasons. In this regard, the genera of the naviculoid diatoms exhibited great variation in their seasonal diversity among themselves, as has also been observed previously [31,32].

Algal Taxa	Habitat	1	2	3	4	5	6	7	8	9
<i>A. hungarica</i> (Grunow) Grunow in Cleve et Grunow	Planktic & Epiphytic	-	-	-	-	-	-	-	+	-
Cocconeis Ehrenberg										
<i>C. pediculus</i> Ehrenberg	Epiphytic	-	-	-	-	+	-	-	-	-
<i>C. placentula</i> Ehrenberg	Epiphytic	-	-	-	+	-	-	-	-	-
Family Bacillariaceae										
Bacillaria J. F. Gmelin in Linnaeus*										
<i>B. paxillifer</i> (O. F. Müller) Hendey*	Epiphytic	-	-	-	-	+	-	-	-	-
Family Cymbellaceae										
Cymbella C. A. Agardh										
<i>C. affinis</i> Kützing	Planktic & Epiphytic	-	-	-	-	-	-	-	-	+
<i>C. austriaca</i> Grunow	Planktic & Epiphytic	-	-	+	-	-	-	-	-	-
<i>C. cymbiformis</i> C. A. Agardh	Planktic & Epiphytic	-	-	-	+	-	-	+	-	-
<i>C. ehrenbergii</i> Kützing*	Planktic & Epiphytic	-	-	-	+	-	-	-	-	-
<i>C. gracilis</i> (Rabenhorst) Cleve	Planktic	-	-	+	-	-	-	-	-	-
<i>C. helvetica</i> Kützing	Epiphytic	-	-	-	+	-	-	-	-	-
<i>C. naviculiformis</i> (Auerswald) Cleve	Epiphytic	-	-	+	-	-	-	-	-	-
<i>C. stuxbergii</i> Cleve	Epiphytic	-	-	-	-	-	-	-	-	+
<i>C. tumida</i> (de Brébisson) Van Heurck	Epiphytic	-	-	-	+	-	-	-	-	-
<i>C. ventricosa</i> C. A. Agardh	Epiphytic	-	-	+	-	-	-	-	-	+
Family Diatomaceae										
Diatoma Bory de Saint-Vincent										
<i>D. anceps</i> (Ehrenberg) Grunow	Epiphytic	-	-	-	+	-	-	-	-	-
<i>D. elongatum</i> (Lyngbye) C. A. Agardh	Epiphytic	-	-	-	+	-	-	-	-	-
<i>D. vulgare</i> Bory de Saint-Vincent	Epiphytic	-	-	-	+	-	-	-	-	-
Family Fragilaraceae										
Anomoeoneis Pfitzer										
<i>A. sphaerophora</i> (Kützing) Pfitzer	Planktic & Epiphytic	-	-	-	+	-	-	+	-	-
Fragilaria Lyngbye										
<i>F. ulna</i> (Nitzsch) Lange-Bertalot	Epiphytic	-	-	-	+	-	-	+	-	-
<i>D. elongatum</i> (Lyngbye) C. A. Agardh	Epiphytic	-	-	-	+	-	-	-	-	-
<i>D. vulgare</i> Bory de Saint-Vincent	Epiphytic	-	-	-	+	-	-	-	-	-
Family Fragilaraceae										
Anomoeoneis Pfitzer										
<i>A. sphaerophora</i> (Kützing) Pfitzer	Planktic & Epiphytic	-	-	-	+	-	-	+	-	-
Fragilaria Lyngbye										
<i>F. ulna</i> (Nitzsch) Lange-Bertalot	Epiphytic	-	-	-	+	-	-	+	-	-
<i>D. elongatum</i> (Lyngbye) C. A. Agardh	Epiphytic	-	-	-	+	-	-	-	-	-
<i>D. vulgare</i> Bory de Saint-Vincent	Epiphytic	-	-	-	+	-	-	-	-	-
Family Fragilaraceae										
Anomoeoneis Pfitzer										
<i>A. sphaerophora</i> (Kützing) Pfitzer	Planktic & Epiphytic	-	-	-	+	-	-	+	-	-
Fragilaria Lyngbye										
<i>F. ulna</i> (Nitzsch) Lange-Bertalot	Epiphytic	-	-	-	+	-	-	+	-	-
<i>D. elongatum</i> (Lyngbye) C. A. Agardh	Epiphytic	-	-	-	+	-	-	-	-	-
<i>D. vulgare</i> Bory de Saint-Vincent	Epiphytic	-	-	-	+	-	-	-	-	-
Family Fragilaraceae										
Anomoeoneis Pfitzer										
<i>A. sphaerophora</i> (Kützing) Pfitzer	Planktic & Epiphytic	-	-	-	+	-	-	+	-	-
Fragilaria Lyngbye										
<i>F. ulna</i> (Nitzsch) Lange-Bertalot	Epiphytic	-	-	-	+	-	-	+	-	-
Fragilariforma (J. Ralfs) D. M. Williams et F. E. Round*										
<i>F. virescens</i> (J. Ralfs) D. M. Williams et F. E. Round*	Epiphytic	+	-	+	+	-	-	-	-	-

Algal Taxa	Habitat	1	2	3	4	5	6	7	8	9
Synedra Ehrenberg										
<i>S. radians</i> Kützing	Epiphytic	-	-	-	+	-	-	-	-	-
<i>S. tabulata</i> (C. A. Agardh) Kützing	Epiphytic	-	-	-	+	-	-	+	-	-
Family Gomphonemaceae										
Gomphonema Ehrenberg										
<i>G. ghosea</i> Abdul-Majeed	Epiphytic	-	-	-	-	-	-	-	+	+
<i>G. major</i> A. Cleve in Dial	Epiphytic	-	-	-	+	-	-	-	-	-
Family Nitzschaceae										
Nitzschia Hassall										
<i>N. angustata</i> (W. Smith) Grunow	Epiphytic	-	-	-	+	-	-	-	-	+
<i>N. communis</i> Grunow*	Planktic & Epiphytic	-	-	-	-	-	+	-	-	-
<i>N. frustulum</i> (Kützing) Grunow in Cleve et Grunow*	Planktic & Epiphytic	-	-	+	-	-	-	-	-	-
<i>N. linearis</i> (C. A. Agardh) W. Smith	Planktic & Epiphytic	-	-	-	+	-	-	-	-	-
<i>N. obtusa</i> W. Smith	Planktic & Epiphytic	-	-	-	+	-	-	-	-	-
<i>N. punctata</i> (W. Smith) Grunow*	Planktic & Epiphytic	-	-	-	+	-	-	-	-	-
<i>N. regula</i> Hustedt*	Planktic & Epiphytic	-	-	+	-	-	-	-	-	-
<i>N. subtilis</i> Grunow*	Epiphytic	-	-	+	-	-	-	-	-	-
<i>N. vermicularis</i> (Kützing) Hantzsch in Rabenhorst	Epiphytic	-	-	-	+	-	-	-	-	-
Family Naviculaceae										
Amphora Ehrenberg ex Kützing										
<i>A. coffeaeformis</i> (C. A. Agardh) Kützing	Epiphytic	-	-	+	-	-	-	-	-	-
<i>A. ovalis</i> (Kützing) Kützing	Epiphytic	-	-	+	-	-	-	-	-	-
Caloneis Cleve in Cleve et Grove										
<i>C. lanceolata</i> Kützing*	Epiphytic	+	-	-	-	-	-	-	-	-
<i>C. lepidiformis</i>	Epiphytic	-	-	-	+	-	-	-	-	-
<i>C. silicula</i> (Ehrenberg) Cleve	Epiphytic	-	-	-	+	-	-	-	-	-
Frusulia Rabenhorst										
<i>F. rhomboides</i> (Ehrenberg) De Toni	Planktic	-	-	-	-	-	-	-	+	-
Gyrosigma Hassall										
<i>G. acuminatum</i> (Kützing) Rabenhorst	Epiphytic	+	-	+	-	-	-	-	-	-
<i>G. scalproides</i> (Rabenhorst) Cleve	Planktic & Epiphytic	+	-	-	-	-	-	-	-	-
<i>G. tenuissimum</i> (W. Smith) Griffith et Henfreyh	Epiphytic	-	+	-	+	-	-	-	-	-
Luticola D. G. Mann in F. E. Round, R. M. Crawford et D. G. Mann										
<i>L. mutica</i> (Kützing) D. G. Mann in F. E. Round, R. M. Crawford et D. G. Mann	Epiphytic	-	-	-	-	-	+	-	-	-
Mastogloia Thwaites ex W. Smith										
<i>M. smithii</i> Thwaites ex W. Smith	Epiphytic	-	-	+	-	-	-	-	-	-
Navicula Bory emend. Cleve										
<i>N. ammophila</i> Grunow*	Planktic	+	-	-	-	-	-	-	-	-
<i>N. affine</i> (Ehrenberg) Pfitzer	Epiphytic	-	-	-	+	-	-	-	-	-
Pinnularia (Ehrenberg) Ehrenberg										
<i>P. appendiculata</i> (C. A. Agardh) Cleve*	Planktic & Epiphytic	+	-	-	-	-	-	-	-	-
<i>P. gibba</i> (Ehrenberg) W. Smith	Epiphytic	-	-	-	+	-	-	-	-	-
<i>P. gracilens</i> J. Frenguelli	Epiphytic	-	-	-	+	-	-	-	-	-
<i>P. karelica</i> Cleve*	Epiphytic	-	-	-	+	-	-	-	-	-
<i>P. major</i> (Kützing) Cleve	Epiphytic	-	-	-	-	-	-	-	-	+
<i>P. nobilis</i> (Ehrenberg) Ehrenberg	Planktic & Epiphytic	-	+	-	-	-	-	-	-	-
<i>P. stauroptera</i> (Grunow) Rabenhorst	Epiphytic	-	-	+	-	-	-	-	-	-
<i>P. sudetica</i> (Hilse) Hilse*	Epiphytic	-	-	+	-	-	-	-	-	-
Stauroneis Ehrenberg*										
<i>S. minor</i> (E. V. Østrup) A. Cleve-Euler*	Epiphytic	-	-	-	+	-	-	-	-	-
Neidium Pfitzer										
Family Surirellaceae										

Algal Taxa	Habitat	1	2	3	4	5	6	7	8	9
Colletonema de Brébisson ex Kützing										
<i>C. eximium</i> (Thwaites) Kützing	Planktic & Epiphytic	-	+	-	-	-	-	-	-	-
<i>C. neglectum</i>	Planktic & Epiphytic	-	+	-	-	-	-	-	-	-
<i>C. subcohaerens</i> (Thwaites) Kützing	Planktic & Epiphytic	-	-	-	+	-	-	-	-	-
Surirella Turpin										
<i>S. delicatissima</i> F. W. Lewis	Epiphytic	-	-	-	+	-	-	-	-	-
<i>S. ovalis</i> de Brébisson	Epiphytic	-	-	-	+	-	-	-	-	-
Family Swirellaceae										
Cymatopleura W. Smith*										
<i>C. elliptica</i> (de Brébisson) W. Smith*	Epiphytic	+	-	-	-	-	-	-	-	-
<i>C. solea</i> (de Brébisson) W. Smith*	Epiphytic	+	-	-	-	-	-	-	-	-
Family Tabellariaceae										
Tabellaria C. G. Ehrenberg ex F. T. Kützing										
<i>T. fenestrata</i> (Lyngbye) Kützing*	Epiphytic	-	-	-	+	-	-	-	-	-
Family Thalassiosiraceae										
Cyclotella (Kützing) de Brébisson										
<i>C. operculata</i> (C. A. Agardh) Kützing	Epiphytic	-	-	-	-	-	-	-	+	-
Family Epithemaceae										
Epithemia de Brébisson										
<i>E. argus</i> (Ehrenberg) Kützing	Epiphytic	-	-	-	+	-	-	-	-	-
Rhopalodia O. F. Müller										
<i>R. gibba</i> (Ehrenberg) O. F. Müller	Planktic & Epiphytic	-	-	-	-	-	-	+	-	-
Family Eunotaceae										
Eunotia Ehrenberg										
<i>E. arcus</i> Ehrenberg	Epiphytic	-	-	-	+	-	-	-	-	-

1 = Gujranwala, 2 = Jhang, 3 = Kasur, 4 = Lahore, 5 = Sargodha, 6 = Sheikhpura, 7 = Sialkot, 8 = N. W. F. P., 9 = Azad Kashmir, * = first record from Pakistan.

Table 2. Habitat diversity exhibited by the algal species collected from north-eastern areas of Pakistan.

Algal Taxa	Collected Species		Planktic		Epiphytic		Planktic & Epiphytic		Planktic & Benthic	
	No	%	No	%	No	%	No	%	No	%
Family Euglenaceae										
<i>Euglena</i> Ehrenberg	34	29.56	7	20.58	-	-	-	-	27	79.41
<i>Phacus</i> Dujardin	6	5.21	2	33.33	-	-	-	-	4	66.66
Family Achnantheaceae										
<i>Achnanthes</i> Bory de Saint-Vincent	2	1.73	-	-	1	50	1	50	-	-
<i>Cocconeis</i> Ehrenberg	2	1.73	-	-	2	100	-	-	-	-
Family Bacillariaceae										
<i>Bacillaria</i> J. F. Gmelin in Linnaeus	1	0.86	-	-	1	100	-	-	-	-
Family Cymbellaceae										
<i>Cymbella</i> C. A. Agardh	10	8.69	1	10	5	50	4	40	-	-
Family Diatomaceae										
<i>Diatoma</i> Bory de Saint-Vincent	3	2.60	-	-	3	100	-	-	-	-
Family Fragilaraceae										
<i>Anomoeoneis</i> Pfitzer	1	0.86	-	-	-	-	1	100	-	-
<i>Fragilaria</i> Lyngbye	1	0.86	-	-	1	100	-	-	-	-
<i>Fragilariforma</i> (J. Ralfs) D. M. Williams et F. E. Round	1	0.86	-	-	1	100	-	-	-	-
<i>Synedra</i> Ehrenberg	2	1.73	-	-	2	100	-	-	-	-
Family Gomphonemaceae										
	2	1.73	-	-	2	100	-	-	-	-

Algal Taxa	Collected Species		Planktic		Epiphytic		Planktic & Epiphytic		Planktic & Benthic	
	No	%	No	%	No	%	No	%	No	%
<i>Gomphonema</i> Ehrenberg	2	1.73	-	-	2	100	-	-	-	-
Family Nitzschaceae	9	7.82	-	-	5	55.55	4	44.44	-	-
<i>Nitzschia</i> Hassall	9	7.82	-	-	5	55.55	4	44.44	-	-
Family Naviculaceae	29	25.22	9	31.03	17	58.62	3	10.34	-	-
<i>Amphora</i> Ehrenberg ex Kützing	2	1.73	-	-	2	100	-	-	-	-
<i>Caloneis</i> Cleve in Cleve et Grove	3	2.60	-	-	3	100	-	-	-	-
<i>Frustulia</i> Rabenhorst	1	0.86	1	100	-	-	-	-	-	-
<i>Gyrosigma</i> Hassall	3	2.60	-	-	2	66.66	1	33.33	-	-
<i>Luticola</i> D. G. Mann in F. E. Round, R. M. Crawford et D. G. Mann	1	0.86	-	-	1	100	-	-	-	-
<i>Mastogloia</i> Thwaites ex W. Smith	1	0.86	-	-	1	100	-	-	-	-
<i>Navicula Bory emend. Cleve</i>	8	6.95	8	100	-	-	-	-	-	-
<i>Neidium</i> Pfitzer	1	0.86	-	-	1	100	-	-	-	-
<i>Pinnularia</i> (Ehrenberg) Ehrenberg	8	6.95	-	-	6	75	2	25	-	-
<i>Stauroneis</i> Ehrenberg	1	0.86	-	-	1	100	-	-	-	-
Family Surirellaceae	5	4.34	-	-	2	40	3	60	-	-
<i>Colletonema</i> de Brébisson ex Kützing	3	2.60	-	-	-	-	3	100	-	-
<i>Surirella</i> Turpin	2	1.73	-	-	2	100	-	-	-	-
Family Swirellaceae	2	1.73	-	-	2	100	-	-	-	-
<i>Cymatopleura</i> W. Smith	2	1.73	-	-	2	100	-	-	-	-
Family Tabellariaceae	1	0.86	-	-	1	100	-	-	-	-
<i>Tabellaria</i> C. G. Ehrenberg ex F. T. Kützing	1	0.86	-	-	1	100	-	-	-	-
Family Thalassiosiraceae	1	0.86	-	-	1	100	-	-	-	-
<i>Cyclotella</i> (Kützing) de Brébisson	1	0.86	-	-	1	100	-	-	-	-
Family Epithemaceae	2	1.73	-	-	1	50	1	50	-	-
<i>Epithemia</i> de Brébisson	1	0.86	-	-	1	100	-	-	-	-
<i>Rhopalodia</i> O. F. Müller	1	0.86	-	-	-	-	1	100	-	-
Family Eunotaceae	1	0.86	-	-	1	100	-	-	-	-
<i>Eunotia</i> Ehrenberg	1	0.86	-	-	1	100	-	-	-	-
Grand Total	115	-	19	16.52	48	41.73	17	14.78	31	26.95

No = Number of species, % = percentage.

Table 3. Distribution of algal species in different localities (1-9) of the north-eastern areas of Pakistan.

Algal Taxa	*1	2	3	4	5	6	7	8	9
Phylum Euglenophycota	4	2	-	30	2	4	3	-	-
Class Euglenophyceae	4	2	-	30	2	4	3	-	-
Order Euglenales	4	2	-	30	2	4	3	-	-
Family Euglenaceae	4	2	-	30	2	4	3	-	-
<i>Euglena</i> Ehrenberg	4	2	-	25	2	4	1	-	-
<i>Phacus</i> Dujardin	-	-	-	5	-	-	2	-	-
Phylum Bacilliarophycota	14	2	15	37	1	2	5	4	7
Class Bacilliarophyceae	14	2	15	37	1	2	5	4	7
Order Bacillariales	14	2	15	37	1	2	5	4	7
Family Achnantheaceae	-	-	-	1	1	-	-	1	1
<i>Achnanthes</i> Bory de Saint-Vincent	-	-	-	-	-	-	-	1	1
<i>Cocconeis</i> Ehrenberg	-	-	-	1	1	-	-	-	-
Family Bacillariaceae	-	-	-	-	1	-	-	-	-
<i>Bacillaria</i> J. F. Gmelin in Linnaeus	-	-	-	-	1	-	-	-	-
Family Cymbellaceae	-	-	4	4	-	-	1	-	3

Algal Taxa	*1	2	3	4	5	6	7	8	9
<i>Cymbella</i> C. A. Agardh	-	-	4	4	-	-	1	-	3
Family Diatomaceae	1	-	-	3	-	-	-	-	-
<i>Diatoma</i> Bory de Saint-Vincent	1	-	-	3	-	-	-	-	-
Family Fragilaraceae	1	-	1	5	-	-	3	-	-
<i>Anomoeoneis</i> Pfitzer	-	-	-	1	-	-	1	-	-
<i>Fragilaria</i> Lyngbye	1	-	-	1	-	-	1	-	-
<i>Fragilariforma</i> (J. Ralfs) D. M. Williams et F. E. Round	1	-	1	1	-	-	-	-	-
<i>Synedra</i> Ehrenberg	-	-	-	2	-	-	1	-	-
Family Nitzschaceae	-	-	3	5	-	1	-	-	1
<i>Nitzschia</i> Hassall	-	-	3	5	-	1	-	-	1
Family Naviculaceae	10	2	7	10	-	1	-	1	1
<i>Amphora</i> Ehrenberg ex Kützing	-	-	2	-	-	-	-	-	-
<i>Caloneis</i> Cleve in Cleve et Grove	1	-	-	2	-	-	-	-	-
<i>Frustulia</i> Rabenhorst	-	-	-	-	-	-	-	1	-
<i>Gyrosigma</i> Hassall	2	1	1	1	-	-	-	-	-
<i>Luticola</i> D. G. Mann in F. E. Round, R. M. Crawford et D. G. Mann	-	-	-	-	-	1	-	-	-
<i>Mastogloia</i> Thwaites ex W. Smith	-	-	1	-	-	-	-	-	-
<i>Navicula</i> Bory emend. Cleve	6	-	1	3	-	-	-	-	-
<i>Neidium</i> Pfitzer	-	-	-	1	-	-	-	-	-
<i>Pinnularia</i> (Ehrenberg) Ehrenberg	1	1	2	3	-	-	-	-	1
<i>Stauroneis</i> Ehrenberg	-	-	-	1	-	-	-	-	-
Family Surirellaceae	-	-	-	5	-	-	-	-	-
<i>Colletonema</i> de Brébisson ex Kützing	-	-	-	3	-	-	-	-	-
<i>Surirella</i> Turpin	-	-	-	2	-	-	-	-	-
Family Swirellaceae	2	-	-	-	-	-	-	-	-
<i>Cymatopleura</i> W. Smith	2	-	-	-	-	-	-	-	-
Family Tabellariaceae	-	-	-	1	-	-	-	-	-
<i>Tabellaria</i> C. G. Ehrenberg ex F. T. Kützing	-	-	-	1	-	-	-	-	-
Family Thalassiosiraceae	-	-	-	-	-	-	-	1	-
<i>Cyclotella</i> (Kützing) de Brébisson	-	-	-	-	-	-	-	1	-
Family Epithemaceae	-	-	-	1	-	-	1	-	-
<i>Epithemia</i> de Brébisson	-	-	-	1	-	-	-	-	-
<i>Rhopalodia</i> O. F. Müller	-	-	-	-	-	-	1	-	-
Family Eunotaceae	-	-	-	1	-	-	-	-	-
<i>Eunotia</i> Ehrenberg	-	-	-	1	-	-	-	-	-
Grand Total	18	4	15	67	3	6	8	4	7
Percentage out of 115 species	15.65	3.47	13.04	58.26	2.60	5.21	6.95	3.47	6.08

*1 = Gujranwala, 2 = Jhang, 3 = Kasur, 4 = Lahore, 5 = Sargodha, 6 = Sheikhpura, 7 = Sialkot,

8 = N. W. F. P., 9 = Azad Kashmir.

Table 4. Seasonal distribution of the algae collected from north-eastern areas of Pakistan.

Algal Taxa	Coll. Sp.	Spring		Summer		Autumn		Winter	
		No	%	No	%	No	%	No	%
Phylum Euglenophycota	40	8	20	19	47.5	8	20	5	12.5
Class Euglenophyceae	40	8	20	19	47.5	8	20	5	12.5
Order Euglenales	40	8	20	19	47.5	8	20	5	12.5
Family Euglenaceae	40	8	20	19	47.5	8	20	5	12.5
<i>Euglena</i> Ehrenberg	34	6	17.64	17	50	6	17.64	5	14.70
<i>Phacus</i> Dujardin	6	2	33.33	2	33.33	2	33.33	-	-

Algal Taxa	Coll. Sp.	Spring		Summer		Autumn		Winter	
		No	%	No	%	No	%	No	%
Phylum Bacillariophycota	75	20	26.66	19	25.33	8	10.66	32	42.66
Class Bacillariophyceae	75	20	26.66	19	25.33	8	10.66	32	42.66
Order Bacillariales	75	20	26.66	19	25.33	8	10.66	32	42.66
Family Achnanthes	4	1	25	1	25	1	25	1	25
<i>Achnanthes</i> Bory de Saint-Vincent	2	1	50	-	-	-	-	1	50
<i>Cocconeis</i> Ehrenberg	2	-	-	1	50	1	50	-	-
Family Bacillarieae	1	-	-	-	-	1	100	-	-
<i>Bacillaria</i> J. F. Gmelin in Linnaeus	1	-	-	-	-	1	100	-	-
Family Cymbellaceae	10	5	50	1	10	1	10	4	40
<i>Cymbella</i> C. A. Agardh	10	5	50	1	10	1	10	4	40
Family Diatomaceae	3	-	-	2	66.66	-	-	1	33.33
<i>Diatoma</i> Bory de Saint-Vincent	3	-	-	2	66.66	-	-	1	33.33
Family Fragilaraceae	5	1	20	4	80	-	-	-	-
<i>Anomoeoneis</i> Pfitzer	1	-	-	1	100	-	-	-	-
<i>Fragilaria</i> Lyngbye	1	-	-	1	100	-	-	-	-
<i>Fragilariforma</i> (J. Ralfs) D. M. Williams <i>et</i> F. E. Round	1	-	-	1	100	-	-	-	-
<i>Synedra</i> Ehrenberg	2	1	50	1	50	-	-	-	-
Family Nitzschaceae	9	1	11.11	3	33.33	2	22.22	4	44.44
<i>Nitzschia</i> Hassall	9	1	11.11	3	33.33	2	22.22	4	44.44
Family Naviculaceae	29	5	17.24	5	17.24	3	10.34	17	58.62
<i>Amphora</i> Ehrenberg <i>ex</i> Kützing	2	-	-	-	-	-	-	2	100
<i>Caloneis</i> Cleve <i>in</i> Cleve <i>et</i> Grove	3	1	33.33	1	33.33	-	-	1	33.33
<i>Frustulia</i> Rabenhorst	1	-	-	1	100	-	-	-	-
<i>Gyrosigma</i> Hassall	3	-	-	-	-	-	-	3	100
<i>Luticola</i> D. G. Mann <i>in</i> F. E. Round, R. M. Crawford <i>et</i> D. G. Mann	1	-	-	-	-	1	100	-	-
<i>Mastogloia</i> Thwaites <i>ex</i> W. Smith	1	-	-	-	-	-	-	1	100
<i>Navicula</i> Bory <i>emend.</i> Cleve	8	1	12.5	1	12.5	1	12.5	6	75
<i>Neidium</i> Pfitzer	1	-	-	1	100	-	-	-	-
<i>Pinnularia</i> (Ehrenberg) Ehrenberg	8	3	37.5	1	12.5	-	-	4	50
<i>Stauroneis</i> Ehrenberg	1	-	-	-	-	1	100	-	-
Family Surirellaceae	5	3	60	2	40	-	-	-	-
<i>Colletonema</i> de Brébisson <i>ex</i> Kützing	3	1	33.33	2	66.66	-	-	-	-
<i>Surirella</i> Turpin	2	2	100	-	-	-	-	-	-
Family Swirellaceae	2	-	-	-	-	-	-	2	100
<i>Fragilaria</i> Lyngbye	1	-	-	1	100	-	-	-	-
<i>Fragilariforma</i> (J. Ralfs) D. M. Williams <i>et</i> F. E. Round	1	-	-	1	100	-	-	-	-
<i>Synedra</i> Ehrenberg	2	1	50	1	50	-	-	-	-
Family Nitzschaceae	9	1	11.11	3	33.33	2	22.22	4	44.44
<i>Nitzschia</i> Hassall	9	1	11.11	3	33.33	2	22.22	4	44.44
Family Naviculaceae	29	5	17.24	5	17.24	3	10.34	17	58.62
<i>Amphora</i> Ehrenberg <i>ex</i> Kützing	2	-	-	-	-	-	-	2	100
<i>Caloneis</i> Cleve <i>in</i> Cleve <i>et</i> Grove	3	1	33.33	1	33.33	-	-	1	33.33
<i>Frustulia</i> Rabenhorst	1	-	-	1	100	-	-	-	-
<i>Gyrosigma</i> Hassall	3	-	-	-	-	-	-	3	100
<i>Luticola</i> D. G. Mann <i>in</i> F. E. Round, R. M. Crawford <i>et</i> D. G. Mann	1	-	-	-	-	1	100	-	-
<i>Mastogloia</i> Thwaites <i>ex</i> W. Smith	1	-	-	-	-	-	-	1	100
<i>Navicula</i> Bory <i>emend.</i> Cleve	8	1	12.5	1	12.5	1	12.5	6	75
<i>Neidium</i> Pfitzer	1	-	-	1	100	-	-	-	-
<i>Pinnularia</i> (Ehrenberg) Ehrenberg	8	3	37.5	1	12.5	-	-	4	50
<i>Stauroneis</i> Ehrenberg	1	-	-	-	-	1	100	-	-

Algal Taxa	Coll. Sp.	Spring		Summer		Autumn		Winter	
		No	%	No	%	No	%	No	%
Family Surirellaceae	5	3	60	2	40	-	-	-	-
<i>Colletonema de Brébisson ex Kützing</i>	3	1	33.33	2	66.66	-	-	-	-
<i>Surirella Turpin</i>	2	2	100	-	-	-	-	-	-
Family Swirellaceae	2	-	-	-	-	-	-	2	100
<i>Cymatopleura W. Smith</i>	2	-	-	-	-	-	-	2	100
Family Tabellaraceae	1	1	100	-	-	-	-	-	-
<i>Tabellaria C. G. Ehrenberg ex F. T. Kützing</i>	1	1	100	-	-	-	-	-	-
Family Thalassiosiraceae	1	-	-	-	-	-	-	1	100
<i>Cyclotella (Kützing) de Brébisson</i>	1	-	-	-	-	-	-	1	100
Family Epithemaceae	2	1	50	-	-	-	-	1	50
<i>Epithemia de Brébisson</i>	1	-	-	-	-	-	-	1	100
<i>Rhopalodia O. F. Müller</i>	1	1	100	-	-	-	-	-	-
Family Eunotaceae	1	1	100	-	-	-	-	-	-
<i>Eunotia Ehrenberg</i>	1	1	100	-	-	-	-	-	-
Grand Total	115	28	24.34	38	33.04	16	13.91	37	32.17

Coll. Sp. = Collected species, No = number of species, % = percentage.

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