

The Ecology of Algae from and Around Bolan River, Balochistan, Pakistan

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ABSTRACT

Altogether, two hundred and forty eight (248) algal taxa existing in 6 phyla, 10 classes, 16 orders, 36 families, and 80 genera have been collected from a variety of freshwater and soil habitats, of district Kachhi Balochistan. Among various phyla, Bacillariophycota by 86 species (34.68%), Cyanophycota was represented by 59 species (23.79%), Volvophycota by 52 species (20.97%), Chlorophycota by 41 species (16.53%), Euglenophycota by 7 species (2.82%) and Charrophycotaby 2 species (1.21%). For the purpose of collection, ten different sites of the district like Sir-i-Bolan, Goni Pera, Mach, Bibi Nani, Kirtha, Gokurt and certain areas of Dhader, Mithari, Bhag, Qazi waga were surveyed during a study (2013-2017) and simultaneously they have been investigated on the ground of morphological and cytological aspects. They have been determined taxonomically and described on the basis of such characters. Most of the taxa were reported for the first time from this region of study but all of them appeared to be taxonomically known species.

INTRODUCTION

Introduction and map of study area has already been published in our previous paper^[1]. The areas which are now integrated in Pakistan were first time worked out by Ghose for algae^[2]. He described a number of blue green algal taxa from freshwater habitats of Lahore^[3]. Randhawa was another phycologist who worked on Chlorophyceae members of Lahore^[4,5]. Misra et al., studied the fresh water algae of Eastern Uttar Pradesh, India. These communications dealt with morphological and taxonomical description of different fresh water algae distributed in class Chlorophyceae and Bacillariophyceae. Lot of work on freshwater algae of Pakistan has been done. A widespread study on freshwater algal species belonging to class Cyanophyceae, Chlorophyceae, Xanthophyceae, and Bacillariophyceae from various vicinities of Charsadda District was carried out by Sarim and Zaman^[6]. From different Districts of Punjab large collections on green algae were worked out by Ali et al.^[7]. Sarim et al., reported a contribution to the algal flora of Peshawar from various freshwater habitats. Members of Chlorophyceae dominated their collections. Ali et al., illustrated green algae from Punjab and its adjoining areas of Pakistan. The recent report on diversity of green algae was described in Swat by Ali et al.^[8-10].

In Balochistan Province, the work done is meager. However, Faridi reported 5 species of Charophyceae. Hussain et al., described 92 species of Spirogyra for the first time for Balochistan, of which 13 species were new records for Pakistan. Hussain and Anjum, reported 20 more species from snail shells of Khuzdar and Cymbella (10 spp.), Navicula (11 spp.) from the freshwater habitats of Quetta to Pishin valley. Hussain et al., identified freshwater algae of Hanna Urak valley and also reported some freshwater algae from Ziarat^[11-14]. Anjum et al., worked out epileptic algae from Balochistan and also made a survey for Oscillatoria genus in Quetta to Pishin valley. Zaidi et al., observed the phytosociological studies on Bacillariophyceae of Quetta district and worked on algal flora of surface and ground water of Quetta district^[15,16]. Zaidi and Hussain described 1000 freshwater algal species from the province of Balochistan. Shameel studied new species of Chara from coastal areas of Balochistan^[17,18]. In our recent study two species *Pediastrum simplex* var. *echinulatum* Wittrock 1883 in Wittrock et Nordstedt 1883 and *Penium cucurbitinum* Bisset 1884 were recorded first time for Pakistan from the district.

MATERIALS AND METHODS

The algal materials growing in various habitats were collected in different ways. Algal material was scrapped from the surface of moist soil for edaphic algae. Very small and floating algae i.e., planktonic types were collected with the help of strainer, with intermediate sized nets, epilithic and epioikotic or epipellic algae were gently detached from their respective substrata

without breaking the holdfast. Twigs of submerged water plants having epiphytic algae were also gently squeezed. For preliminary identification, the specimens were carefully observed in the field. The material was numbered, dated and preserved in 5% formalin.

The collected materials were taken to the laboratory and each of which was examined under microscope for separation of different types existed. The specimens were a little stained within iodine solution to make cell-walls and other structures further evidently visible. The semis permanent slides of each sample were prepared using glycerin jell and were examined under different magnification of compound microscope. After a detailed investigation under, microphotography was made with the help of Microsystem. And with the use of calibrated optical micrometer different dimensions were measured [19].

The collected materials of algae were determined taxonomically with the help of standard literatures [20-36].

RESULTS AND DISCUSSION

In the present study a total of 248 algal species belonging to the 6 phyla with Bacillariophycota (86 species), Cyanophycota (59 species), Volvophycota (52 species), Chlorophycota (41 species), Euglenophycota (7 species) and Charophycota (3 species). These were distributed among 10 classes, 16 Orders, 37 families which were reported from District Kachhi (Table 1). All of them were identified up to species level. *Pedistrum simplex* (Meyen) Corda var. *echinulatum* (Wittrock) and *Penium cucurbitinum* Bisset

Table 1. Distribution of freshwater algae from and around the Bolan River, District Kachhi Balochistan in Pakistan.

| Algae with systematic position | Habitat | Localities | | | | | | | | | |
|--|------------|------------|---|---|---|----|---|---|---|---|----|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Kingdom: Monera | -- | - | - | - | - | - | - | - | - | - | - |
| Phylum: Cyanophycota | -- | - | - | - | - | -- | - | - | - | - | - |
| Class : Chroocophyceae | -- | - | - | - | - | - | - | - | - | - | - |
| Order : Chroococcales | -- | - | - | - | - | - | - | - | - | - | - |
| Family: Chroococcaceae | -- | - | - | - | - | - | - | - | - | - | - |
| Aphnocapsa (Nageli) | | | | | | | | | | | |
| <i>A. littoralis</i> | Edaphic | - | - | - | - | + | - | - | - | - | - |
| <i>A. grevillei</i> | Planktonic | - | - | - | - | + | - | - | - | - | - |
| <i>A. incerta</i> | Planktonic | - | - | - | - | + | - | - | - | - | - |
| Chroococcus (Nägeli) | | | | | | | | | | | |
| <i>C. varius</i> | Planktonic | - | - | - | - | + | - | - | - | - | - |
| <i>C. limneticus</i> | -- | - | - | - | - | - | + | - | + | - | - |
| <i>C. limneticus</i> var. <i>elegans</i> | Planktonic | - | - | - | + | - | - | + | - | - | - |
| <i>C. turgidus</i> | Planktonic | + | + | + | + | + | + | + | + | - | - |
| <i>C. tenax</i> | Epilithic | + | + | + | - | + | - | - | - | - | - |
| <i>C. minor</i> | Planktonic | + | - | + | - | - | - | - | + | + | - |
| <i>C. aphanocoagoides</i> | Planktonic | - | - | - | - | + | - | - | - | - | - |
| <i>C. disperses</i> var. <i>mino</i> | Planktonic | - | - | - | - | + | + | - | - | - | - |
| <i>C. pulcherrimus</i> | Planktonic | + | - | - | - | - | - | - | - | - | - |
| Coelosphaerium (Naegeli) | | | | | | | | | | | |
| <i>C. dubium</i> | Planktonic | + | - | + | - | + | - | - | - | - | - |
| <i>C. kuetzingianum</i> | Planktonic | + | - | + | + | + | - | - | - | - | - |
| <i>C. naegelianum</i> | Planktonic | + | - | + | - | + | - | - | - | - | - |
| Gomphosphaeria (Kuetz) | | | | | | | | | | | |
| <i>G. aponina</i> | Planktonic | - | - | + | - | + | - | - | - | - | - |
| Synechococcus (Nägeli) | | | | | | | | | | | |
| <i>S. aeruginosus</i> | Epipellic | - | - | - | - | + | - | - | - | - | - |
| Merismopedia (Meyen) | | | | | | | | | | | |
| <i>M. convoluta</i> | Planktonic | + | - | + | + | + | - | - | - | - | - |
| <i>M. trollerii</i> | Planktonic | - | - | + | + | + | + | - | + | - | - |
| <i>M. elegans</i> | Planktonic | + | - | - | - | + | - | - | - | - | - |
| <i>M. tenuissima</i> | Planktonic | - | - | + | - | - | + | - | - | - | + |
| <i>M. glauca</i> | Planktonic | + | + | - | - | - | - | + | + | - | - |
| <i>M. punctata</i> | Planktonic | - | + | + | - | + | - | + | - | + | - |

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|--|------------|---|---|---|---|---|---|---|---|---|---|---|
| Microcystis (Kützing ex Lemmermann) | | | | | | | | | | | | |
| <i>M. aeruginosa</i> | Planktonic | - | - | - | - | + | + | - | - | - | - | - |
| <i>M. viridis</i> | Planktonic | - | - | - | - | - | - | - | + | - | - | - |
| Family: Entophysalidaceae | | | | | | | | | | | | |
| Johannesbaptistia J. de Toni | | | | | | | | | | | | |
| <i>J. pellucid</i> | Epipellic | - | - | + | - | + | - | - | - | - | - | - |
| Class: Nostocophyceae | -- | | | | | | | | | | | |
| Order: Nostocales | -- | | | | | | | | | | | |
| Family: Nostocaceae | -- | | | | | | | | | | | |
| Anabaena Bory de Saint-Vincent | | | | | | | | | | | | |
| <i>A. inaequalis</i> | Planktonic | - | - | - | - | + | - | - | - | - | - | - |
| Family: Oscillatoraceae | -- | | | | | | | | | | | |
| Borzia Cohn ex Gomont | -- | | | | | | | | | | | |
| Lyngbya (Agardh 1824) | | | | | | | | | | | | |
| <i>L. major</i> | Epipellic | - | - | + | - | - | + | - | - | - | - | - |
| <i>L. versicolor</i> | Epipellic | - | - | - | - | + | + | - | - | - | - | - |
| <i>L. birgei</i> | Epipellic | - | - | - | - | + | + | - | - | - | - | - |
| <i>L. majuscula</i> | Epipellic | - | - | - | + | - | + | - | - | - | - | - |
| <i>L. taylorii</i> | Epipellic | + | - | - | - | - | - | - | - | - | - | - |
| Oscillatoria (Vaucher 1903) | | | | | | | | | | | | |
| <i>O. sancta</i> | Planktonic | - | - | - | + | - | - | - | - | - | - | - |
| <i>O. limosa</i> | Planktonic | - | - | - | + | - | + | - | - | - | - | - |
| <i>O. curviceps</i> | Planktonic | - | - | - | + | - | - | - | - | - | - | - |
| <i>O. princeps</i> | Planktonic | - | - | - | - | + | - | - | + | - | - | - |
| <i>O. subbrevis</i> | Planktonic | - | + | - | - | - | - | - | - | - | - | - |
| <i>O. rubescense</i> | Planktonic | - | - | + | - | - | - | - | - | - | - | - |
| <i>O. Formosa</i> | Epipellic | + | - | - | + | - | + | + | + | + | + | + |
| <i>O. prolifica</i> | Planktonic | - | - | + | + | - | - | - | - | - | - | - |
| <i>O. agardhii</i> | Planktonic | - | - | - | + | - | - | - | - | - | - | - |
| <i>O. raoi</i> | Epipellic | - | + | - | + | - | - | - | - | - | - | - |
| <i>O. geminate</i> | Planktonic | - | + | + | - | + | - | - | - | - | - | - |
| <i>O. tenuis</i> | Planktonic | - | - | - | + | + | + | + | - | + | + | + |
| <i>O. tenuis var. natans</i> | Planktonic | - | - | + | - | - | - | - | - | - | - | - |
| Family: Rivularaceae | | | | | | | | | | | | |
| Calothrix Agardh ex Bornet and Flahault | | | | | | | | | | | | |
| <i>C. fusca</i> | Planktonic | - | - | - | + | - | - | - | - | - | - | - |
| Gloeotrichia J.G. Agardh | | | | | | | | | | | | |
| <i>G. natans</i> | Planktonic | - | - | - | + | - | - | - | - | - | - | - |
| Homoeothrix | | | | | | | | | | | | |
| (Thuret ex Bornet & Flahault) | | | | | | | | | | | | |
| Kirchner | | | | | | | | | | | | |
| <i>H. Juliana</i> | Epipellic | + | - | - | - | - | - | - | - | - | - | - |
| Phormidium (Kuetzing) | | | | | | | | | | | | |
| <i>P. tenue</i> | Epipellic | + | - | + | - | - | - | - | - | - | - | - |
| <i>P. foveolarum</i> | Epipellic | - | - | - | - | + | - | - | - | + | - | - |
| <i>P. lucidum</i> | Epipellic | - | - | - | - | + | - | - | - | - | - | - |
| <i>P. minnesotense</i> | Epipellic | - | - | + | - | + | - | - | - | - | - | - |
| <i>P. inundatum</i> | Epipellic | - | - | + | + | - | - | - | - | - | - | - |
| Schizothrix (Kuetzing) | | | | | | | | | | | | |
| <i>S. tinctoria</i> | Epipellic | - | - | + | - | - | - | - | - | - | - | - |
| Spirulina (Turpin) | | | | | | | | | | | | |

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|--|------------|---|---|---|---|---|---|---|---|---|---|
| <i>S. major</i> | Planktonic | - | - | - | - | + | - | - | - | - | - |
| <i>S. princeps</i> | Planktonic | - | + | - | - | - | - | - | - | - | - |
| Family: Scytonemataceae | | | | | | | | | | | |
| Scytonema A. Agardh | | | | | | | | | | | |
| <i>S. archangelii</i> | Epilithic | - | - | - | + | - | - | - | - | - | - |
| <i>S. ocellatum</i> | Epilithic | - | - | - | + | - | - | - | - | - | - |
| <i>S. tolypothricoides</i> | Planktonic | - | - | - | - | + | - | - | - | - | - |
| Kingdom: Protista | | | | | | | | | | | |
| Phylum: Volvophycota | | | | | | | | | | | |
| Class: Volvophyceae | | | | | | | | | | | |
| Order: Chlorococcales | | | | | | | | | | | |
| Family: Coelastraceae | | | | | | | | | | | |
| Coelastrum (Naegeli 1849) | | | | | | | | | | | |
| <i>C. microporum</i> var. <i>ocetaedrium</i> | Planktonic | - | - | - | + | - | + | - | - | - | - |
| <i>C. indicum</i> | Planktonic | + | - | - | - | - | - | - | - | - | - |
| Family: Hydrodictyceae | | | | | | | | | | | |
| Pediastrum (Meyen, 1829) | | | | | | | | | | | |
| <i>P. simplex</i> var. <i>echinulatum</i> | Planktonic | - | - | - | - | - | - | - | + | - | - |
| <i>P. duplex</i> var. <i>regulosum</i> | Planktonic | + | - | - | - | - | - | - | - | - | - |
| <i>P. integrum</i> | Planktonic | + | - | + | + | - | - | - | - | - | - |
| <i>P. boryanum</i> | Planktonic | + | - | + | + | + | - | - | - | - | - |
| Family: Oocystaceae | | | | | | | | | | | |
| Chlorella (Beijerinck) | | | | | | | | | | | |
| <i>C. vulgaris</i> | Planktonic | - | - | - | - | + | - | - | - | - | - |
| Closteriopsis (Lemmermann) | | | | | | | | | | | |
| <i>C. longissimi</i> | Planktonic | - | - | - | - | - | - | - | - | + | + |
| Monoraphidium Komarkova-Legnerova | | | | | | | | | | | |
| M. arcuatum | Planktonic | - | - | + | - | - | - | - | - | - | - |
| Family: Scenedesmaceae | | | | | | | | | | | |
| Scenedesmus (Meyen) | | | | | | | | | | | |
| <i>S. quadricauda</i> | Planktonic | - | - | - | - | + | - | - | - | - | - |
| <i>S. acuminatus</i> | Planktonic | - | - | - | - | - | - | - | - | + | - |
| <i>S. obtusus</i> | Planktonic | - | - | + | - | + | - | - | - | - | - |
| <i>S. disciformis</i> | Planktonic | + | - | - | - | + | - | - | - | - | - |
| <i>S. bijuga</i> | Planktonic | + | - | - | + | - | + | + | - | - | + |
| <i>S. bijugatus</i> | Planktonic | + | - | + | - | - | - | - | - | - | - |
| <i>S. arcuatus</i> | Planktonic | + | - | + | - | - | - | - | - | - | - |
| <i>S. arcuatus</i> var. <i>platydisca</i> | Planktonic | + | - | - | - | - | - | - | - | - | - |
| <i>S. planctonicus</i> | Planktonic | - | - | - | - | + | - | - | - | - | - |
| Order: Chlorosarcinales | | | | | | | | | | | |
| Family: Palmellaceae | | | | | | | | | | | |
| Sphaerocystis (Chodat 1897) | | | | | | | | | | | |
| <i>S. schroeterii</i> | Planktonic | - | - | - | + | - | - | - | - | - | - |
| Palmodictyon (Kuetzing) | | | | | | | | | | | |
| <i>P. viride</i> | Planktonic | - | - | - | - | - | + | - | - | - | - |
| Order: Volvocales | | | | | | | | | | | |
| Family: Chlamydomonaceae | | | | | | | | | | | |
| Chlamydomonas (Ehrenberg) | | | | | | | | | | | |
| <i>C. polypyrenoideum</i> | Planktonic | + | - | - | - | - | - | - | - | - | - |
| Class: Desmidophyceae | | | | | | | | | | | |
| Order: Desmidales | | | | | | | | | | | |

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|---|----------------------|---|---|---|---|---|---|---|---|---|---|
| Family: Desmidiaceae | | | | | | | | | | | |
| Cosmarium Corda ex Ralfs | | | | | | | | | | | |
| <i>C. moniliformis</i> | Planktonic | - | - | + | - | - | + | - | - | - | - |
| <i>C. bioculatum</i> | Planktonic/attached | - | - | - | - | + | - | - | - | + | - |
| <i>C. subtumidium</i> Planktonic/attached | Planktonic/attached | + | - | - | - | - | - | - | - | - | + |
| <i>C. misellum</i> | Planktonic | - | - | + | - | - | - | - | - | - | - |
| <i>C. cucumis</i> | Planktonic | - | + | - | - | - | + | + | + | - | - |
| <i>C. impressulum</i> | Planktonic | + | - | - | - | - | - | - | - | - | - |
| <i>C. pachydermum</i> var. <i>aethiopicum</i> | Planktonic | - | - | - | - | - | - | - | - | - | - |
| <i>C. nitidulum</i> | Planktonic/attached | - | - | - | + | - | - | - | + | - | - |
| <i>C. constrictum</i> | Planktonic | - | + | - | - | - | - | + | - | - | - |
| <i>C. circular</i> | Planktonic | + | - | - | - | - | - | - | + | - | - |
| <i>C. sportella</i> var. <i>subnudum</i> | Planktonic | - | - | + | - | - | - | - | - | - | - |
| <i>C. subcrenatum</i> | Planktonic/attached | - | - | + | - | - | - | - | - | - | - |
| <i>C. subcostatum</i> | Planktonic | - | - | - | - | - | - | + | - | - | - |
| <i>C. formosulum</i> var. <i>nathorstii</i> | Planktonic | + | - | - | - | - | - | - | - | - | - |
| <i>C. monomazum</i> | Planktonic | - | + | - | - | - | - | - | - | - | - |
| <i>C. obtusatum</i> | Planktonic/attached | - | + | - | - | - | - | - | - | - | - |
| <i>C. Brebissonii</i> | Planktonic | + | - | - | - | - | - | - | - | - | - |
| <i>C. ocellatum</i> var. <i>notatum</i> | Planktonic | - | - | - | - | - | + | - | - | + | - |
| <i>C. paraganatoides</i> | Planktonic | + | - | - | - | - | - | - | + | - | + |
| <i>C. botrytis</i> | Planktonic/attached | - | - | - | + | - | - | - | - | - | - |
| <i>C. subcucumis</i> | Planktonic | - | - | - | - | - | - | + | - | - | - |
| <i>C. conspersum</i> | Planktonic | - | - | - | - | + | - | - | + | - | + |
| <i>C. margaritatum</i> | Planktonic/attached | + | - | - | - | + | - | - | - | - | - |
| <i>C. tetraophthalmum</i> | Planktonic | + | - | + | - | - | - | - | - | - | - |
| Closterium (Nitzsch) | | | | | | | | | | | |
| <i>C. moniliferum</i> | Epilithic | + | - | + | + | + | + | + | - | - | - |
| <i>C. littorale</i> | Epilithic | - | - | + | - | + | - | - | - | - | - |
| Penium (Brebisson) | | | | | | | | | | | |
| <i>P. cucurbitinum</i> | Planktonic | + | - | + | - | + | - | - | - | - | - |
| Euastrum (Ehrenberg) | | | | | | | | | | | |
| <i>E. spinulosum</i> | Planktonic | - | - | - | + | + | - | - | - | - | - |
| Staurastrum (Meyen) | | | | | | | | | | | |
| <i>S. margaritaceum</i> | Epilithic | + | - | + | + | - | - | - | - | - | - |
| <i>S. punctulatum</i> | Planktonic/attached | - | - | + | + | - | - | - | - | - | - |
| <i>S. alternans</i> | Planktonic | + | - | - | - | - | - | - | - | - | - |
| Kingdom: Phycota | | | | | | | | | | | |
| Phylum : Chlorophycota | | | | | | | | | | | |
| Class : Ulvophyceae | | | | | | | | | | | |
| Order : Ulotrichales | | | | | | | | | | | |
| Family: Ulotrichaceae | | | | | | | | | | | |
| Binuclearia (Wittrock) | | | | | | | | | | | |
| <i>B. tectorum</i> | Planktonic | - | - | + | - | - | - | - | - | - | - |
| Geminella (Turpin) | | | | | | | | | | | |
| <i>G. interrupta</i> | Planktonic | - | - | + | + | - | - | - | - | - | - |
| Ulothrix (Kützing) | | | | | | | | | | | |
| <i>U. tenerrima</i> | Epilithic/ Epiphytic | - | - | + | - | - | - | - | - | - | - |
| <i>U. tenuissima</i> | Epilithic | - | - | + | - | + | - | - | - | - | - |
| <i>U. moniliformis</i> | Planktonic | - | - | + | - | - | - | - | - | - | - |
| Order: Microsporales | | | | | | | | | | | |

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| Family: Microsporaceae | | | | | | | | | | | | |
| Microspora (Thuret) | | | | | | | | | | | | |
| <i>M. loefgrenii</i> | Epilithic/ Epiphytic | + | - | - | - | - | - | - | - | - | - | - |
| Order: Coleochaetales | | | | | | | | | | | | |
| Family: Coleochaetaceae | | | | | | | | | | | | |
| Coleochaete de Brébisson | | | | | | | | | | | | |
| C. pulvinata | Epiphytic | - | - | + | - | - | - | - | - | - | - | - |
| Class: Zygnemophyceae | | | | | | | | | | | | |
| Order: Oedogoniales | | | | | | | | | | | | |
| Family: Oedogoniaceae | | | | | | | | | | | | |
| Bulbochaete (C. A. Agardh) | | | | | | | | | | | | |
| <i>B. intermedia</i> | Epiphytic | - | - | - | - | + | - | - | - | - | - | - |
| Oedogonium (Link) | | | | | | | | | | | | |
| <i>O. foveolatum</i> | Planktonic/attached | + | - | + | - | - | - | - | - | - | - | - |
| <i>O. vulgare</i> | Planktonic | + | - | + | - | - | + | - | - | - | - | - |
| <i>O. bohemicum</i> | Planktonic/attached | + | + | - | + | + | - | + | - | - | - | - |
| Order: Zygnemales | | | | | | | | | | | | |
| Family: Zygnemaceae | | | | | | | | | | | | |
| Mougeotia (C. A. Agardh) | | | | | | | | | | | | |
| <i>M. genuflexa</i> | Planktonic | - | - | - | - | + | - | + | - | - | - | - |
| <i>M. scalaris</i> | Planktonic/attached | - | - | + | - | + | - | - | - | - | - | - |
| <i>M. abnormis</i> | Planktonic | + | - | + | - | + | + | - | - | - | - | - |
| <i>M. calcarea</i> | Planktonic | - | - | - | - | + | - | + | - | - | - | - |
| <i>M. sphaerocarpa</i> | Planktonic | + | - | - | - | + | - | - | - | - | - | - |
| Spirogyra (Link) | | | | | | | | | | | | |
| <i>S. narcissiana</i> | Planktonic | - | - | - | - | - | + | + | - | - | - | - |
| <i>S. rectangularis</i> | | - | + | - | - | - | - | - | - | - | - | + |
| <i>S. tetrapla</i> | Planktonic | - | - | + | - | - | - | + | - | - | - | - |
| <i>S. acanthophora</i> | Planktonic | - | - | + | - | - | - | - | + | - | - | - |
| <i>S. gracilis</i> | Planktonic | + | - | + | - | - | - | - | - | - | - | - |
| <i>S. condensate</i> | Planktonic/attached | - | - | - | + | - | - | + | + | - | - | - |
| <i>S. juergensii</i> | Planktonic | - | + | + | - | - | - | - | - | - | - | - |
| <i>S. subsalsa</i> | Planktonic | - | - | + | - | - | - | - | - | - | - | + |
| <i>S. porticalis</i> | Planktonic | - | - | + | - | - | + | - | + | - | - | - |
| <i>S. mirabilis</i> | Planktonic | + | - | + | - | - | - | - | - | - | - | - |
| <i>S. submaxima</i> | Planktonic | - | - | - | - | + | - | - | - | - | + | + |
| <i>S. occidentalis</i> | Planktonic | - | + | + | - | - | - | - | - | - | - | - |
| <i>S. setiformis</i> | Planktonic | - | - | + | - | - | - | + | - | - | - | - |
| <i>S. ellipsospora</i> | Planktonic | - | - | - | - | + | - | - | - | - | - | + |
| <i>S. scorbiculata</i> | Planktonic | - | - | + | - | - | - | + | - | - | - | - |
| Zygnema (C. A. Agardh) | | | | | | | | | | | | |
| <i>Z. spontaneum</i> | Planktonic | - | + | - | - | - | + | + | - | - | - | - |
| <i>Z. ovedanum</i> | Planktonic | - | - | + | - | - | - | - | + | - | - | - |
| <i>Z. tenue</i> | Planktonic | - | - | + | + | - | - | - | - | - | - | - |
| <i>Z. pectinatum</i> | Planktonic | + | - | - | - | - | - | - | - | - | - | - |
| <i>Z. excrassum</i> | Planktonic | - | - | - | - | - | + | + | - | - | - | - |
| <i>Z. kashmirensis</i> | Planktonic | - | - | - | - | + | - | - | - | - | - | - |
| <i>Z. sterile</i> | Planktonic | + | - | + | - | - | - | - | - | - | - | - |
| Class: Siphonocladophyceae | | | | | | | | | | | | |
| Order: Cladophorales | | | | | | | | | | | | |
| Family: Cladophoraceae | | | | | | | | | | | | |

| | | | | | | | | | | | | |
|---|----------------------|---|---|---|---|---|---|---|---|---|---|---|
| Cladophora (Kützing) | | | | | | | | | | | | |
| <i>C. fracta</i> | Epilithic | - | - | - | + | + | - | + | - | - | - | - |
| <i>C. glomerata</i> | Epilithic | + | + | + | - | + | + | + | - | - | - | - |
| <i>C. glomerata</i> fa. <i>Kuetzingiana</i> | Epilithic | + | - | + | - | - | - | - | - | - | - | - |
| Phylum: Euglenophycota | | | | | | | | | | | | |
| Class: Euglenophyceae | | | | | | | | | | | | |
| Order: Euglenales | | | | | | | | | | | | |
| Family: Euglenaceae | | | | | | | | | | | | |
| Euglena (Ehrenberg) | | | | | | | | | | | | |
| <i>E. sanguine</i> | Planktonic | - | - | - | - | - | - | - | - | + | - | + |
| <i>E. acus</i> | Planktonic | - | - | - | - | - | - | - | - | + | - | - |
| <i>E. obtuse</i> | Planktonic | - | - | - | - | - | - | - | - | + | - | - |
| <i>E. viridis</i> | Planktonic | - | - | - | - | + | - | - | - | + | - | - |
| <i>E. gracilis</i> | | - | - | - | - | + | - | - | - | - | - | - |
| Phacus (Dujardin) | | | | | | | | | | | | |
| <i>P. acuminatus</i> | Planktonic | - | - | - | - | - | - | - | - | + | - | - |
| Lepocinclis (Perty) | | | | | | | | | | | | |
| <i>L. acuta</i> | Planktonic | - | - | - | - | - | - | - | - | + | - | - |
| Phylum: Charophycota | | | | | | | | | | | | |
| Class: Charophyceae | | | | | | | | | | | | |
| Order: Charales | | | | | | | | | | | | |
| Family: Characeae | | | | | | | | | | | | |
| Nitella Linnaeus (C. Agardh) | | | | | | | | | | | | |
| <i>N. tenuissima</i> | Epilithic | - | - | - | - | + | - | - | - | - | - | - |
| Chara Linnaeus | | | | | | | | | | | | |
| <i>C. vulgaris</i> | Epilithic | + | + | + | + | + | + | - | - | - | - | - |
| <i>C. fragilis</i> | Epilithic | - | - | - | + | + | + | + | - | + | - | - |
| Phylum: Bacillaroophycota | | | | | | | | | | | | |
| Class: Bacillaroophyceae | | | | | | | | | | | | |
| Order: Bacillariales | | | | | | | | | | | | |
| Family: Achnantheaceae | | | | | | | | | | | | |
| Achnanthes (Bory) | | | | | | | | | | | | |
| <i>A. microcephala</i> | Planktonic | - | - | - | - | - | - | - | + | - | - | - |
| Cocconeis (Ehrenberg) | | | | | | | | | | | | |
| <i>C. placentula</i> | Epiphytic | + | - | + | + | + | - | - | - | - | - | - |
| <i>C. placentula</i> var. <i>lineata</i> | Epiphytic | + | - | - | - | - | - | - | - | - | - | - |
| <i>C. pediculus</i> | Planktonic | - | - | - | - | + | - | - | - | - | - | - |
| Psammothidium (Bukhtiyarova & Round) | | | | | | | | | | | | |
| <i>P. lacustre</i> | Planktonic | - | - | - | - | - | - | - | + | - | - | - |
| Family: Bacillariaceae | | | | | | | | | | | | |
| Bacillaria J. F. Gmelin in Linnaeus | | | | | | | | | | | | |
| <i>B. paxillifer</i> | Planktonic | - | - | - | - | - | - | - | - | - | + | - |
| Family: Cymbellaceae | | | | | | | | | | | | |
| Amphora (Ehrenberg) | | | | | | | | | | | | |
| <i>A. ovalis</i> | Planktonic | - | - | - | + | - | - | - | - | - | - | - |
| Cymbella (C.A. Agardh) | | | | | | | | | | | | |
| <i>C. naviculiformis</i> | Planktonic | + | - | + | - | + | - | + | - | + | - | - |
| <i>C. cuspidate</i> | Epiphytic | - | - | - | - | + | - | + | - | - | - | - |
| <i>C. affinis</i> | Planktonic | - | - | + | + | + | - | - | - | + | + | - |
| <i>C. prostrata</i> | Epilithic/Planktonic | + | - | + | + | + | - | + | - | - | - | - |

| | | | | | | | | | | | |
|--|------------|---|---|---|---|---|---|---|---|---|---|
| <i>C. ventricosa</i> | Planktonic | - | - | - | - | + | + | - | - | - | - |
| <i>C. parva</i> | Planktonic | - | - | + | + | - | - | - | + | - | - |
| <i>C. aspera</i> | Planktonic | - | + | + | + | + | - | - | - | + | + |
| <i>C. lanceolate</i> | Epilithic | + | - | + | + | + | + | + | + | - | - |
| Family: Diatomaceae | | | | | | | | | | | |
| Diatoma De Candle | | | | | | | | | | | |
| <i>D. anceps</i> | Planktonic | - | - | + | - | - | - | - | - | - | - |
| <i>D. heimale</i> | Planktonic | - | - | - | - | + | - | - | - | - | - |
| <i>D. heimale</i> var. <i>mesodon</i> | Planktonic | - | - | - | - | + | - | - | - | - | - |
| <i>D. vulgare</i> | Planktonic | - | - | + | - | - | - | - | - | - | - |
| <i>D. vulgare</i> var. <i>breve</i> | Planktonic | + | - | - | - | - | - | - | - | - | - |
| <i>D. vulgaris</i> | Planktonic | - | - | + | - | - | - | - | - | - | - |
| Family: Epithemaceae | | | | | | | | | | | |
| Denticula (Kuetz) | | | | | | | | | | | |
| <i>D. elegans</i> | Planktonic | - | - | - | - | + | - | - | - | - | - |
| Epithemia (Brebisson) | | | | | | | | | | | |
| <i>E. zebra</i> | Planktonic | + | - | - | - | - | - | - | - | - | - |
| <i>E. argus</i> | Planktonic | - | - | - | + | + | - | - | - | - | - |
| Rhopalodia (Mueller) | | | | | | | | | | | |
| <i>R. ventricosa</i> | Planktonic | + | - | - | - | - | - | - | - | - | - |
| <i>R. gibba</i> | Planktonic | + | - | - | - | - | - | - | - | - | - |
| Family: Fragilariaceae | | | | | | | | | | | |
| Fragilaria (Lyngbye) | | | | | | | | | | | |
| <i>F. vaucheriae</i> | Planktonic | + | - | - | - | - | - | + | - | - | - |
| <i>F. pinnata</i> | Planktonic | - | - | + | + | + | + | - | - | - | + |
| <i>F. capucina</i> | Planktonic | - | - | + | - | + | + | - | - | + | - |
| <i>F. virescens</i> | Planktonic | - | + | - | - | + | - | - | + | - | - |
| Synedra (Ehrenberg) | | | | | | | | | | | |
| <i>S. acus</i> | Planktonic | - | - | - | - | + | - | - | - | - | - |
| <i>S. delicatissima</i> var. <i>angustissima</i> | Planktonic | - | - | - | - | + | + | + | - | - | - |
| <i>S. ulna</i> | Planktonic | + | + | + | + | + | + | + | - | + | - |
| <i>S. ulna</i> var. <i>aequalis</i> | Planktonic | + | - | - | - | + | - | - | - | - | - |
| <i>S. ulna</i> var. <i>contracta</i> | Planktonic | + | - | + | - | - | - | - | - | - | - |
| Family: Naviculaceae | | | | | | | | | | | |
| Amphipleura (Kuetzing) | | | | | | | | | | | |
| <i>A. pellucida</i> | Planktonic | - | - | + | - | - | - | - | - | - | - |
| Anomoeoneis (Pftzer) | | | | | | | | | | | |
| <i>A. sphaerophora</i> | Planktonic | - | - | - | - | - | - | - | - | - | + |
| <i>A. exilis</i> | Planktonic | - | - | - | - | + | - | - | - | - | - |
| <i>A. serians</i> | Planktonic | + | - | - | - | - | - | - | - | - | - |
| Mastogloia (Thwaitesin W. Smith) | | | | | | | | | | | |
| <i>M. elliptica</i> | Planktonic | + | - | - | - | - | - | - | - | - | - |
| <i>M. smithii</i> | Planktonic | - | + | - | - | + | - | - | - | - | - |
| <i>M. smithii</i> var. <i>Amphicephala</i> | Planktonic | - | + | - | - | + | - | - | - | - | - |
| Navicula (Bory) | | | | | | | | | | | |
| <i>N. tuscula</i> | Planktonic | - | + | - | - | - | - | - | - | - | - |
| <i>N. salinarum</i> | Planktonic | - | - | - | - | + | - | - | - | - | - |
| <i>N. cryptocephala</i> | Planktonic | - | - | + | - | - | - | - | - | + | - |
| Haslea (R. Simonsen) | | | | | | | | | | | |
| <i>H. crucigera</i> | Planktonic | - | - | + | - | - | - | - | - | - | - |
| Diploneis (Ehrenberg) | | | | | | | | | | | |

| | | | | | | | | | | | | |
|--|------------|---|---|---|---|---|---|---|---|---|---|---|
| <i>D. elliptica</i> | Planktonic | - | - | + | - | - | - | - | - | - | - | - |
| Family Pinnulariaceae | | | | | | | | | | | | |
| Pinnularia (Ehrenberg) | | | | | | | | | | | | |
| <i>P. nobilis</i> | Epiphytic | + | - | + | - | - | - | + | - | - | - | - |
| <i>P. braunii</i> | Epiphytic | + | - | - | - | + | - | - | - | - | - | - |
| Caloneis (Cleve) | | | | | | | | | | | | |
| <i>C. bacillaris</i> | Planktonic | - | + | - | - | - | - | - | - | - | - | - |
| Stauroneis (Ehrenberg) | | | | | | | | | | | | |
| <i>S. phoenicentron</i> | Planktonic | - | + | - | - | - | - | + | - | + | - | - |
| <i>S. phoenicentron</i> var. <i>amphilepta</i> | Planktonic | - | + | - | - | - | - | - | - | + | - | - |
| <i>S. phyllodes</i> | Planktonic | - | - | - | - | - | - | - | - | + | - | - |
| <i>S. anceps</i> | Planktonic | - | - | + | - | - | - | - | + | + | - | - |
| Gyrosigma (Hassal) | | | | | | | | | | | | |
| <i>G. attenuatum</i> | Planktonic | + | - | - | - | + | - | - | - | + | - | - |
| <i>G. wormleyi</i> | Planktonic | - | - | - | - | - | - | - | - | - | - | + |
| <i>G. acuminatum</i> | Planktonic | - | - | + | - | - | + | + | - | - | - | - |
| <i>G. eximium</i> | Planktonic | - | - | - | - | - | - | - | - | + | - | - |
| <i>G. orbitum</i> | Planktonic | - | - | - | - | - | - | - | - | + | - | - |
| <i>G. scalproides</i> | Planktonic | - | - | - | - | - | - | - | - | - | - | + |
| <i>G. spencerii</i> | Planktonic | - | - | - | - | - | - | - | - | + | - | - |
| <i>G. kuetzingii</i> | Planktonic | - | - | - | - | - | - | - | - | + | - | - |
| <i>G. hippocampus</i> | Planktonic | - | - | - | - | - | - | - | - | - | + | - |
| Pleurosigma (W.M. Smith) | | | | | | | | | | | | |
| <i>P. angulatum</i> | Planktonic | - | - | + | - | - | - | - | - | - | + | - |
| Family: Gomphonemaceae | | | | | | | | | | | | |
| - | | | | | | | | | | | | |
| Gomphonema (C.A. Agardh) | | | | | | | | | | | | |
| <i>G. subapiculatum</i> | Planktonic | - | - | - | - | + | - | - | - | - | - | - |
| <i>G. ghosea</i> | Epiphytic | + | - | - | - | + | - | - | - | - | - | - |
| <i>G. abbreviatum</i> | Planktonic | - | - | - | - | + | - | - | - | - | - | - |
| <i>G. olivaceum</i> | Planktonic | - | - | + | - | - | - | - | - | - | - | - |
| <i>G. gracile</i> var. <i>dichotoma</i> | Epiphytic | - | - | - | + | + | - | - | - | - | - | - |
| <i>G. angustatum</i> | Planktonic | - | - | - | + | - | - | - | - | - | - | - |
| <i>G. lanceolatum</i> | Planktonic | + | - | - | - | - | - | - | - | - | - | - |
| Gomphoneis (Cleve) | | | | | | | | | | | | |
| <i>G. herculeana</i> | Planktonic | - | - | + | + | - | - | - | - | - | - | - |
| Family: Nitzschaceae | | | | | | | | | | | | |
| Nitzschia (Hassal) | | | | | | | | | | | | |
| <i>N. brevissima</i> | Planktonic | - | - | - | - | - | + | - | - | + | + | - |
| <i>N. vermicularis</i> | Planktonic | - | - | + | - | - | - | - | - | + | - | - |
| <i>N. sigmoidae</i> | Planktonic | - | - | - | - | - | - | + | - | + | + | - |
| <i>N. obtuse</i> | Planktonic | - | - | - | - | + | - | + | - | - | - | - |
| <i>N. hungarica</i> | Planktonic | - | - | - | + | - | - | - | - | + | - | - |
| <i>N. linearis</i> | Planktonic | + | - | - | - | + | - | - | - | - | - | - |
| Family: Surirellaceae | | | | | | | | | | | | |
| Surirella (Turpin) | | | | | | | | | | | | |
| <i>S. ovata</i> | Planktonic | - | - | - | - | - | - | + | - | - | - | - |
| <i>S. apiculate</i> | Planktonic | - | - | - | - | - | - | - | - | - | - | + |
| Family: Swirellaceae | | | | | | | | | | | | |
| Cymatopleura (W. Smith) | | | | | | | | | | | | |
| <i>C. solea</i> | Planktonic | + | - | - | - | - | - | - | - | + | - | - |
| <i>C. elliptica</i> | Planktonic | + | - | - | - | - | - | - | - | + | + | + |

| | | | | | | | | | | | | |
|--|------------|---|---|---|---|---|---|---|---|---|---|---|
| Family: Tabellariaceae | | | | | | | | | | | | |
| Tabellaria (Ehrenberg) | | | | | | | | | | | | |
| <i>T. fenestrata</i> | Planktonic | - | - | + | - | - | - | + | - | + | - | |
| Family: Eunotaceae | | | | | | | | | | | | |
| Eunotia (Ehrenberg) | | | | | | | | | | | | |
| <i>E. monodon</i> | Planktonic | + | - | + | - | + | - | - | - | - | - | - |
| Frustulia (C.A. Agardh) | | | | | | | | | | | | |
| <i>F. rhomboides</i> | Planktonic | - | - | - | + | - | - | - | + | + | - | |
| Order: Biddulphiales | | | | | | | | | | | | |
| Family: Coscinodiscaceae | | | | | | | | | | | | |
| Cyclotella (Kützing and Brébisson) | | | | | | | | | | | | |
| <i>C. meneghiniana</i> | Planktonic | - | - | + | - | - | - | - | - | + | - | |
| 1= Sir-i-Bolan, 2= Goni Pera, 3= mach, 4= Bibi Nani, 5= Kirtha, 6= Gokurt, 7= Dhader, 8= Mithari, 9= Bhag, 10= Qazi Waga. += Present and - = absent. | | | | | | | | | | | | |

was first time recorded for Pakistan (Sumalani and Asrar, 2014). Kachhi District has remarkable altitudinal variations favoring various types of vegetations. This great altitudinal variation with a distinct difference in the climate and habitat might have produced a great diversity also in algal flora. It was found from the previous study that different algal species were dominant at diversified ecological condition i.e., found as attached to soil, epilithic, epipellic, epiphytic, planktonic or free floating. Similar observations were made by Shrestha that algae are heterogeneous and diverse nature in distribution [37].

Taxonomic Diversity

Studies on taxonomic diversity of algae showed that the members of the phylum Bacillariophycota with 32 genera with 86 species were shown to be dominating than the other algal phyla, while phylum Cyanophycota included 18 genera and 59 species ranking second in abundance. The phylum volvocophycota and Chlorophycota with their new concept contained 14 genera each with 52 species and 41 species respectively. Phylum Euglenophycota displayed 3 genera with 7 species and Charophycota appeared to be the smallest phylum in diversity having only 2 genera with 3 species [38].

The class Bacillariophyceae found to be the largest class with 32 genera and 86 species and exhibited the largest species diversity with 34.54% of the collected algae. It was further followed by the classes Chroocophyceae with 10 genera and 33 species with 13.25%, Class Desmidophyceae representing 5 genera and 32 species with 12.85; with 9 genera and 21 species, Class Volvocophyceae showed 8.43%, Class Zygnemophyceae (Shameel, 2006) with 6 genera and 31 species showing 12.45%. The Class Ulvophyceae showing 5 genera with 7 species and Class Euglenophyceae with 3 genera and 7 species contained 2.81% each of the total collected algae. The Class Siphonocladophyceae with 1 genus and 3 species and the class Charophyceae having 2 genera with 3 species, appeared to be the least distributed classes and contained only 1.2% of the total algae collected. The fact that the class Charophyceae with least diversity of 1.2% was observed because the Charophycan members are not so commonly represented in Pakistan [39,40].

Study at ordinal level displayed the Bacillariales was most frequently distributed Order with 31 genera and 85 species showing the largest diversity with 34.14% of the collected algae in it. As the orders Bacillariales belongs to the class Bacillariophyceae that come out to be the most greatly distributed class as has previously been expressed above. It was followed by the order Nostocales with 10 genera and 33 species exhibiting 13.25%, Desmidiales with 5 genera and 32 species comprising 12.85%, Zygnemales with 3 genera and 27 species including 10.84% and Chroococcales with 8 genera and 26 species counting 10.44% of the total collected algae. While rest of the orders were represented very poorly (>3%) among the collected population. Similarly Volvocales, Microsporales, Coleochaetales and Biddulphiales were the most feebly distributed orders with only 1 genus with just 1 species each, showing only 0.4% representation by each one of them in the population of the collected algae.

Diversity of Localities

In the present study, 10 different localities were visited for algal collection. The largest number of species was found at the Kirtha site, displaying 19.47% diversity of the collected species. It was followed by the collections of Mach site with a diversity of 18.65%. These areas were further followed by the cold areas of Sir-i-Bolan, showing a significant number of species, having 12.7% diversity. Bibi Nani and Dhader also displayed 10.45% and 8.2% diversities, respectively. The areas of Bhag and Gokurt sites were quite poor in the distribution of algae, exhibiting a diversity of 7.58% and 7.2% respectively. The smallest number of species was observed in Mithari and Goni Pera sites, with a very slight difference, showing diversities of 5.94% and 5.74%, respectively. The Qazi Waga site displayed a least diversity of different algal phyla exhibiting only 4.1%.

Habitat Diversity

In this collection out of the total explored species, an overwhelming number was found in the planktonic condition. Approximately 85.54% of the collected species found in planktonic condition. Although most of such species were not real plankton,

but they were found in the detached condition during collection. Such observations were previously found on the occurrence of blue-green algae^[41,42]. Edaphic condition was the next category in which individuals were collected, including about 6.42%. About 5.62% of the collected species were found as epipellic, epilithic or epiphytes. These were the major habitats, in which collected algae commonly occurred. Only a few species occurred in this condition making 2.41%.

CONCLUSION

In the above-mentioned previous study, the collected blue-green algae occurred in edaphic habitat in an appreciable amount (Naz et al., 2004 a, b, c). Apart from edaphic habitats all the other categories were missing among collected species of the Charophyta and only three species could be collected and therefore no suitable generalization may be made with these data. Usually, they mainly grow in the benthic condition, attached at the bottom of ponds or slow running water channel^[43-45].

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