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Eco-Taxonomical Studies of Diatoms from a Central Indian River

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Abstract: This study investigates the taxonomy of diatom flora in the river Belan, located in the Vindhyan region. Diatom samples were collected by scraping a 3x3 cm area from cobble substratum at five different stations across all seasons between 2021 and 2023. A total of 119 diatom species were identified, distributed among 28 genera. Among these, *Cymbella* (17 species), *Navicula* (15 species), *Nitzschia* (12 species), *Achnanthidium* (9 species), *Gomphonema* (8 species), and *Fragilaria* (7 species) were identified as the most abundant genera with the highest number of species. The study also provides descriptions of the taxonomy of some of these abundant diatom taxa.

Keywords: Belan river • Diatom • Vindhyan region • *Cymbella* • *Navicula*

Introduction

Diatoms, single-celled algae, are pivotal primary producers in freshwater ecosystems, offering crucial insights into ecological conditions due to their rapid response to environmental shifts (Mann, 1999, Rimet, 2012). With over 200 taxa and an estimated 100,000 species globally, diatoms serve as sensitive indicators of water quality, responding to various pollutants and physico-chemical changes (Round et al 1990, Dixit et al 1992). Their presence on stable substrates like rocks and sediment underscores their ecological significance as primary producers, contributing significantly to atmospheric oxygen levels (Lowe and Laliberte 1996, Round et al 1990).

Taxonomic identification is fundamental to diatom research, which has a rich historical background globally, with studies conducted in various regions, including the Himalayas, Peninsular India, and the Andaman and Nicobar Islands (Hustedt, 1930, Patrick and Reimer 1966, Gandhi, 1952, 1955, 1998). These studies emphasize the importance of diatoms as early warning signals of environmental changes and bio indicators of river health, yet the Belan River's diatom communities remain unexplored (Morales, 2005, Pondar and Potapova 2007).

Diatom research has a rich and extensive history globally, with studies dating back to the early 20th century (Hustedt, 1930, Patrick and Reimer 1966, Morales, 2005, Pondar and Potapova 2007, Eduardo et al 2021). Various investigations have focused on diatom flora in regions such as the Himalayas, Vindhyan regions, Peninsular India, and the Andaman and Nicobar Islands (Gandhi, 1952, 1955, 1998, Sarode and Kamat 1984, Bhagat, 2002, Dickie, 1882, Carter, 1926, Jüttner et al 1998, Rothfritz et al 1997, Nautiyal and Nautiyal 1999a, b, Jüttner and Cox 2001, Khan, 2002, Nautiyal et al 2004a, b, Tiwari and Mishra 2023, Tiwari et al 2023a,b). Despite the extensive research conducted in various regions, the diatom communities in the Belan River remain unexplored. Therefore, this study was undertaken to fill this gap and determine the taxonomy of diatoms in Belan River. The present study will explore the diatom flora first time from the Belan river and will help as reference study for planning about river conservation and management.

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Material and Methods

Study area

The Belan river originates from Vindhyan ranges, district Sonbhadra. It drains northern Peninsula India, which may generally have received less monsoonal precipitation than the Himalaya to the north (Staubwasser and Weiss 2006). The study area is thus a potentially useful adjunct to paleoclimate analysis from high-precipitation Himalayan areas (Phadtare, 2000), or from arid NW India (Prasad and Enzel 2006) which has often been considered a standard reference area for northern Indian climate records. It is approximatly156 km long and flows towards west-north direction and drains in to the river Tons near Chakghat (Fig 1). Sampling locations is selected on considering variations in land use practices, accessibility, and diverse microhabitats such as substratum type, flow characteristics, and habitat variability. Sites will be selected based on the range of land use practices and substrate types observed along the river's course. The site S1 and S2 was situated in the upper stretch of the head region of river. The site located in this stretch was relatively pristine with sparse or no human population and settlements. It is covered with dense forest area. The riverbed was characterized by mixed type of substratum comprising rock, stone, cobble, and pebble and covered with periphyton. At S3, S4 and S5, here the riverbed comprised largely of pebble, gravel and silt substratum. Agriculture was the primary human activity along both banks of the river at a distance of approx. 500m from the riparian zone. Other activity included cattle bathing and abstraction of water for local irrigation (Table 1).

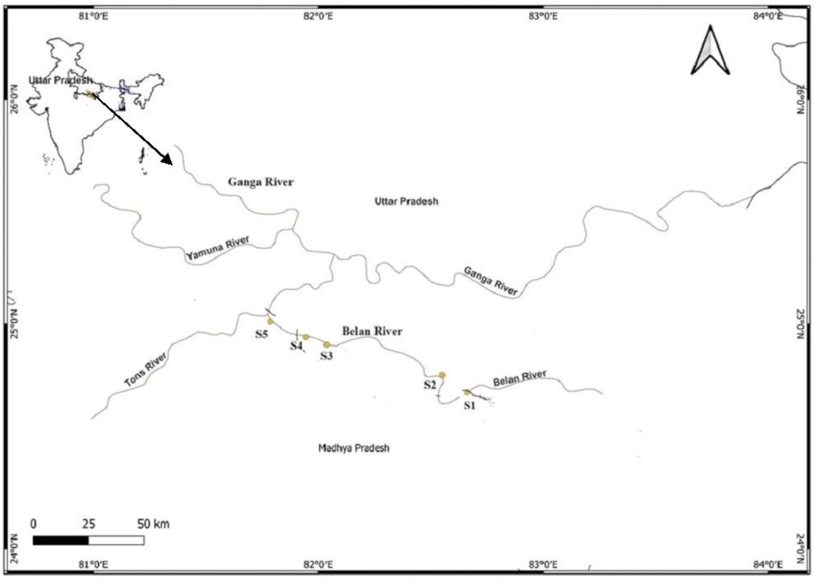


Fig 1. Map indicates location of Belan river, the black line indicates river along with sampling stations with yellow circle from S1to S5.

Table 1. Physiographical description of sampling station on the river Belan. Acronyms: Rocks (R), Boulder (B), Gravel (G), Pebbles (P), Cobbles (C), Sand (S), Forest (F), Agriculture (Ag), Village (V).

Stations	S1	S2	S3	S4	S5
Latitude ^{O}N	24°41’45”	24°46’21”	24°54’27”	24°56’32”	25°00’38”
Longitude ^{O}E	82°39’42”	82°33’00”	82°02’14”	82°56’40”	81°47’11”
Altitude (m)	249	200	119	118	113
Substrate	R- G-P-C	R-B-P-C-S	S	P-C-S	C-S
Land use	F	F	F + Ag	Ag	Ag +V

Sampling

Sampling procedures involved collecting diatom samples from five distinct stations, labeled as S1 to S5, from cobble stony substratum areas measuring 3 x 3 cm². Sampling was conducted during the winter, summer, and monsoon seasons spanning the years 2021 to 2023. The collected samples were preserved using 4% formaldehyde. To prepare permanent slides, standard protocols outlined by Krammer and Lange Bertalot (2000), Taylor et al (2005), and Nautiyal et al (2015) were followed. Taxonomic analysis was carried out using a combination of light microscopy and Scanning Electron Microscopy (SEM), utilizing a model FEI Quanta 250 Council of Scientific & Industrial Research- Central Drug Research Institute Lucknow. Standard identification keys provided by Gandhi (1998), Sarode and Kamat (1984), Taylor et al (2007), and Karthick et al (2013) were used for species identification.

Results and Discussion

Total of 119 diatom species have been identified first time from the Belan river, central India. They belong to 28 genera and 12 orders. However, Verma et al (2017) reported higher number of diatom taxa in other central Indian rivers, Ken (205), Paisuni (202), and Tons (211). Similarly, Grover et al (2017) reported 102 taxa in Chambal river of same ecoregion. The taxonomical and ecological description of 23 abundant diatom taxa is shown as under:

1. ***Melosira varians* Agardh (Fig 2a)**
   Valve diameter = 8-14 µm, valve mantle depth = 4-8 µ
   Description: -The cells are cylindrical and often form elongated chains, with a slightly convex valve face covered in small spines and lacking areolae. This species is cosmopolitan, thriving in both benthic and planktonic habitats, and is particularly abundant in eutrophic environments, sometimes occurring in slightly brackish waters.
2. ***Aulacoseira ambigua* (Grunow) Simonsen 1979 (Fig 2b)**
   Valve diameter = 4-17 µm, Valve mantle depth = 5-13 µm, Striae = 20-25 /10 µm
   Description: - Characterized by fine striation and the absence of elongated linking spines. Found in both the benthos and plankton of eutrophic rivers and lakes.
3. ***Aulacoseira granulata* (Ehrenberg) Simonsen 1979 (Fig 2c)**
   Valve diameter = 4-30 µm, Valve mantle depth= 5-24 µm, Striae density = 7-15 /10µm
   Description: - The terminal cell of the filament is distinguished by elongated linking spines. Found in both the benthos and plankton of eutrophic rivers and lakes.
4. ***Fragilaria ulna* (Kützing) Lange Bertalot 1980 (Fig 2d)**
   Valve length = (27)50-250(600) µm, Valve breadth = (1.5)2-9 µm, Striae density =7-15(24)/10µm
   Description: - The valves of this species are linear, with cuneate poles and sub-capitate apices. A distinct hyaline area is situated at the center of the cell, where ghost striae may be observable. When viewed from the girdle, the cells appear rectangular. This is cosmopolitan species is commonly found in the benthic regions of rivers. Due to its relatively large surface area, it can be easily suspended in the plankton. It is frequently encountered in mesotrophic to eutrophic, alkaline waters.
5. ***Fragilaria dilatata* (Brébisson) Lange-Bertalot 1993 (Fig 2e)**
   Valve length is 150-260 µm, width is 5-7 µm wide at center and 7-9 µm at poles.
   Description:- The valves are linear, with cuneate poles and sub-capitate apices. They have a narrow axial area and a round to rhombic central area, covering about

1/3 to rarely 1/2 of the valve width. The symmetry is isopolar and bilaterally symmetrical, with 7-9 striae per 10 µm. Found in slightly eutrophic conditions.

6. ***Tabularia fasciculata* (C.Agardh) D.M.Williams and Round 1986 (Fig 2f)**
   Valve length: -30-120 µm, Valve breadth: - 4.5-6 µm, Striae:- 12-14 /10µm
   Description:-:- Valves are linear with tapering margins close to protracted, rostrate poles. They are isopolar, isovalvae, and bilaterally symmetrical, with broad, short striae that are more or less parallel. The axial area is wide and lanceolate. A cosmopolitan species with a broad ecological amplitude, favoring moderately to high electrolyte concentrations.
7. ***Diatoma vulgaris* Bory 1824 (Fig 2g)**
   Valve length: - 9-60 µm, Valve breadth: - 8-15µm, Striae density: ->40µm Costae density: - 6-12µm
   Description: - Valves are lanceolate to elliptical with a very narrow axial area and thickened transverse costae. Found in mesotrophic to eutrophic waters with average electrolyte content. The cells form zig-zag colonies.
8. ***Eunotia incise* P.W. Smith ex W. Gregory, 1854 (Fig 2h)**
   Valve length: - 12-52.5µm, Valve breadth: - 2-6µm, Striae density: - 16-20/10µm
   Description: - The dorsiventral valve has a straight ventral margin and slightly asymmetrical apices. The striae are slightly radiate in the central part of the valve, becoming more radiate at the poles. Occurs in upland streams in acidic, oligotrophic, electrolyte-poor waters.
9. ***Cocconeis placentula* Ehrenberg 1938 (Fig 2i)**
   Valve length:- 14-35 µm,Valve breadth :- 5-20.5 µm,Striae density:- 16-24/10 µm RLV and 16- 20 /10 µm RLV
   Description: - valves are broadly elliptical, linear elliptical to lanceolata elliptical Occurring in meso- to eutrophic flowing and standing waters. Found in abundance on plants, wood and stone.
10. ***Diploneis subovalis* Cleve1894 (Fig 2j)**
    Valve length = 10-50 µm, Valve breadth = 8-20 µm, Striae density = 18-22 /10 µm
    Description: - Valves are elliptical to linear-elliptical, with clearly visible perforations in the foramina. A tropical freshwater diatom species, found in standing waters and occasionally in flowing waters. Occur in water with moderate to elevated electrolyte content.
11. ***Encyonema neogracile* Krammer, 1997, 142 (Fig 2k)**
    Valve length: - 20-50 µm, Valve breadth = 5-6.5 µm
    Description: - The valve is strongly dorsiventral, lanceolate, with slightly protracted, sharply rounded apices. The striae vary from 10-14 (9-18 near apices) per 10 µm. A cosmopolitan species found in oligotrophic, electrolyte-poor waters.
12. ***Encyonopsis minuta* Reichardt & Krammer, 1997, 95 (Fig 2l)**
    Valve length = 10-12.5 µm, Valve breadth = 3-3.5 µm, Striae density = 24-26 /10 µm
    Description: - Valves are weakly dorsiventral, with dorsally deflected raphe filiform and regular transapical striae. Cosmopolitan, Requires an oxygen rich environment.
13. ***Surirella angusta* kützing 1844 (Fig 3a)**
    Valve length: -17-60 µm, valve breadth: - 6-12.5 µm, Striae density: - 22-28 µm, Fibulae density: - 4-6 /10µm
    Description: - Linear valves with tapered margins towards the poles and narrow axial area. Striae are parallel in the center and slightly radiate towards the poles. Found worldwide in eutrophic waters with moderate electrolyte content.

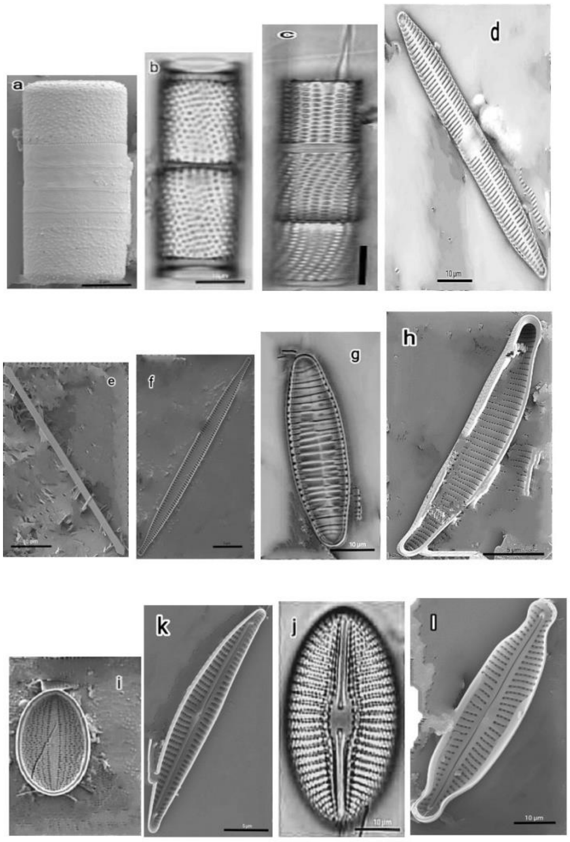
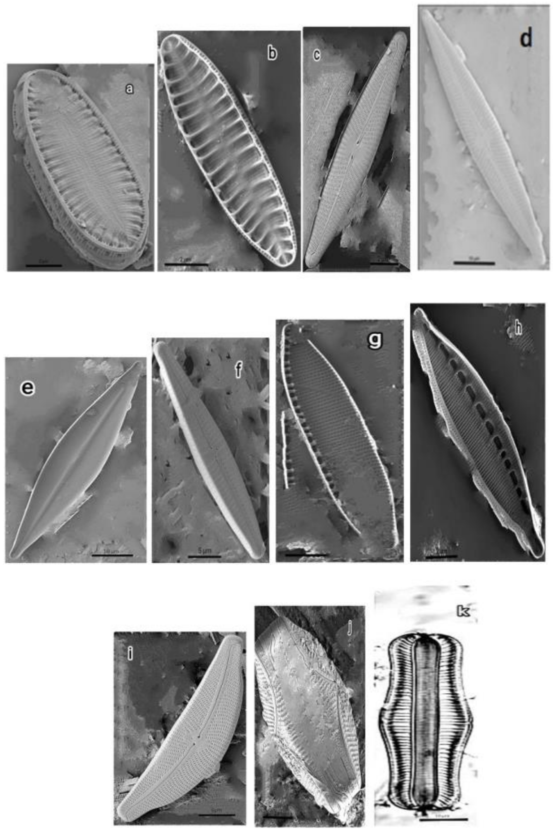


Fig 2. SEM images (a,e,f,h,j,k,l) L.M images(b,c,d,g,i,j,) (a) *Melosira varians* (b) *Aulacoseira ambigua* (c) *Aulacoseira granulata* (d) *Fragilaria ulna* (e) *Fragilaria dilatata* (f) *Tabularia fasciculata* (g)*Diatoma vulgaris* (h) *Eunotia incisia* (i) *Cocconeis placentula* (j) *Diploneis subovalis* (k) *Encyonema neogracile* (l) *Encyonopsis minuta*



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14. *Surirella minuta* (Fig 3b)

Valve length: -, 16-40 µm, Valve breadth: - 7-11 µm, Striae: - 20-26/10µm

Description: - Valves are linear to ovate with parallel striae in the center, becoming slightly radiate towards the poles. Common in benthic habitats, especially epilithic habitats. Thrives across a wide range of water chemistries.

***15. Navicula trivialis* Lange-Bertalot 1980 (Fig 3c)**

Valve length:- 25-65 µm, Valve breadth:- 9-12.5 µm, Striae density :- 11-15/ 10 µm

Description :- Wide lanceolate valves with radiate straie, almost parallel at the valve ends. Found globally in eutrophic waters with moderate electrolyte content.

16. ***Navicula radiosa* Kützing 1844 (Fig 3d)**

Valve length: - 45-105µm, Valve breadth: -8-12 µm, Striae density: - 14-18/10µm

Description: - These diatoms have narrowly lanceolate valves with rounded apices and strongly radiate striae. They are found in various water types but are sensitive to organic pollution.

17. ***Navicula cuspidata* (Kützing1990, 666 (Fig 3e)**
Valve length = 65-95.3 µm, Valve breadth = 9-17 µm, Striae density = 20-25 /10 µm
Description: - Valves are rhombic-lanceolate with slightly protracted and rounded apices. They are cosmopolitan, thriving in eutrophic waters with moderate to high electrolyte content.

18. ***Gomphonema exillissimum* (Grunow) Lange Bertalot and Metzeltin 1996 (Fig 3f)**
Valve length:-10-30 µm, Valve breadth: - 4-6 µm, Striae density: - 9- 17 / 10 µm
Description: - Valve shapes vary from lanceolate to rhombic-lanceolate with narrow rounded apices. These diatoms are typically found in circumneutral, oligotrophic waters.

19. ***Nitzschia palea* (Kützing) W Simth 1856 (Fig 3g)**
Valve length = 15-70 µm, Valve breadth = 2.5-5 µm, Striae density = 28-40 /10 µm, fibulae density=9-17µm
Description: - Linear-lanceolate valves with narrowed poles and acutely rounded or weakly capitate apices. They are widespread and tolerant to heavily polluted waters with moderate to high electrolyte content.

20. ***Nitzschia dissipata* (Kützing) Rabenhorst 1860 (Fig 3h)**
Valve length = (3)3.5-7(8) µm, Valve breadth = 12.5-85 µm, Striae density = (32)39-50 /10 µm, fibulae density = 5-11 µm
Description: - Lanceolate valves with often protracted apices. A cosmopolitan species found in waters of moderate to high electrolyte content.

21. ***Cymbella tumida* (Brébisson) Van Heurck 1880 (Fig 3i)**
Valve length = 35-95 µm, Valve breadth = 16-22(24) µm, Striae density = 8-11 (12-13 near apices) /10 µm, Number of stigmata = 1
Description: - These diatoms have strongly dorsiventral valves with swollen mid-regions. A cosmopolitan species found in oligo- to mesotrophic waters with moderate electrolyte content.

22. ***Epithemia sorex* Kützing 1844 (Fig 3j)**
Valve length = 8-70 µm, Valve breadth = 6.5-16 µm, Striae density = 10-15 /10 µm, Fibulae density = 5-7.5 /10 µm
Description: - Valves are strongly dorsiventral with broadly rounded protracted apices. A cosmopolitan species found in both flowing and standing waters of moderate to high electrolyte content.

23. ***Rhopalodia gibba* (Ehrenberg) O Müller 1895 (Fig 3k)**

Valve length: - 22-250 µm, Valve breadth: - 18-25 µm, Striae density: - 25/10 µm
Description: - Strongly dorsiventral valves with claw-like shape and rounded ventrally deflected apices. Supported by fibulae. Common in standing and slow-flowing waters with moderate to high electrolyte content.

Present study revealed that the diatom community was mainly dominated by Biraphids (*Navicula*, *Nitzschia*, *Gomphonema*, *Cymbella* and *Amphora*), followed by araphids (*Fragilaria*) and centrics (*Melosira* and *Aulacoseira*). The prevalence of biraphids (*Navicula, Nitzschia, Achnanthidium, Gomphonema*, *Cymbella* and *Amphora*) in the Belan river mirrors findings from other regions in India *viz* the Vindhyan region (Nautiyal et al 2017), the Indian Himalayan region (Jüttner et al 1996, Nautiyal et al 2004a, Nautiyal and Mishra 2013, Nautiyal et al 2015, Dimri and Sharma 2022, Sharma and Nautiyal 2023), the central Indian region (Grover et al 2017, Verma et al 2017, Srivastava et al 2017, Nautiyal et al 2017, Tiwari et al 2023a, Tiwari and Mishra 2023). 2 The Peninsular or other parts of India including the mountainous zones as Western Ghats are equally rich in biraphid flora

(Krishnamurthy 1954, Karthick et al 2011, Alakananda et al 2013).

The taxonomic richness of diatom taxa indicated that the upper stretch of the river was richer compared to the lower stretch. All along the river length, *Cymbella* (17 species) was highest taxonomic rich genera followed by *Navicula* (15 species), *Nitzschia* (12 species), *Achnanthidium* (9 species), *Gomphonema* (8 species), and *Fragilaria* (7 species). The upper stretch (S1 and S2) sites come under the more diverse probably due to the prevailing pristine condition and a lesser degree of anthropogenic stressors while S3, S4 and S5 was impacted with various anthropogenic activities like cattle bathing, water abstraction for agriculture, horticulture, cremation and other religious activities. The agriculture land is near to river at S5 caused fermentation process at river side (Stevenson and Van Dam, 2010). In the downstream sections, nutrients level increases due to inputs received from adjacent land use and anthropogenic activities. The substrate type (stone to clay) also impacts the distribution of benthic diatoms (Mendes et al 2012, Richards et al 2020).

The river Belan is one of the Central India Rivers having fluvial deposition which represent the overwhelming bulk of Indian Quaternary deposits. Additionally, the Belan sites provide paleoclimate information for the seasonal, humid southernmost Ganga Plains. This ecological and taxonomical study of diatom flora will help bio-assessment of the Belan River and useful for monitoring of environmental changes and river health.

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