

Diversity of Desmids in the Thattekkad Bird Sanctuary, Kerala, India: A Comprehensive Exploration

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Abstract

Desmids are a group of exclusively freshwater green algae known for their remarkably diverse and captivating forms. Desmids are valued organisms due to their exceptional sensitivity to environmental changes, so they are considered to be potential tools for effective aquatic conservation management. The present study tries to account for the diversity of desmids in Thattekkad Bird Sanctuary, situated in Ernakulam District, the first Bird Sanctuary in Kerala and lies within the geographical limits of 10°08' N 76°41' E and 10.13° N 76.68° E. The study was carried out over a period of one year, from March 2022 to April 2023, and identified a total of seventy-four taxa, which are distributed under four families and 18 genera. Predominant genera included were *Cosmarium* (21), *Euastrum* (12), and *Staurostrum* (8). Notably *Heimansia pusilla* (L. Hilse) Coesel, *Euastrum praemorsum* (Nordstedt) Schmidle, *Euastrum jenneri* W. Archer, *Staurostrum saltans* Joshua var. *javanicum* Scott and Prescott, *Cosmarium clepsydra* Nordstedt var. *bicardia* (Reinsch) Croasdale are new reports to India, five species are new reports to Kerala and all species being novel to Thattekkad Bird sanctuary.

Introduction

Desmids are a diverse group of microscopic, freshwater green algae and they have garnered widespread recognition for their enchanting beauty, establishing themselves as an enthralling focal point within the realm of phycology. These algae display a distinct morphology, consisting of two symmetrical halves, referred to as semicells and they encompass both solitary and colonial species (Coesel and Krientz 2008). The cell wall of desmids displays distinct, symmetrical patterns of pores, scrobicules, and undulations, which serve as key features for species identification and classification (West and West 1904). In modern taxonomic classifications, desmids (Desmidiaceae) find their place in the phylum Charophyta within the class Zygnematophyceae, also called Conjugatophyceae (Ruggiero et al. 2015). They are further categorized into placoderm desmids, also known as true desmids, and saccoderm desmids, or false desmids, based on their cell structure (Coesel and Meesters 2007). While the majority of desmids inhabit freshwater environments, a few species are known to thrive in brackish water.

Desmids are valued organisms due to their exceptional sensitivity to environmental changes, enabling them to swiftly respond to even the most minute alterations in their aquatic habitats (Coesel 1977). This unique characteristic of desmids can be treated as potential tool for effective aquatic conservation management (Coesel 2001). The presence of even a small quantity of desmids is often indicative of acidic and oligotrophic water conditions (Wehr and Sheath 2003).

In previous decades, researchers have undertaken taxonomic studies of desmids in India (Komal et al. 2021; Vidyashree and Malammanavr 2021; Das 2020; Hemant et al. 2018; Maheswari and Baluswami 2017a; Maheswari and Baluswami 2017b; Das and Keshri 2013; Yasmin et al. 2011; Shukla et al. 2008; Suseela and Toppo 2007; Misra and Srivastava 2003) with notable attention given to various regions. However, when it comes to the southwestern state of Kerala, specific research on desmids has been limited (Shaji et al. 1988 and 1989; Shaji and Patel 1990 and 1991; Paul and Sreekumar 2007, 2011, 2013

and 2015; Jose et al. 2022; Jose and Xavier 2022). Kerala's forest ecosystems boast an abundance of freshwater resources, characterized by their oligotrophic and slightly acidic nature, creating an ideal habitat for desmids. Despite the wealth of freshwater ecosystems, comprehensive data are scarce. To address this gap, our study seeks to systematically document the diversity of desmids within the pristine Thattekkad Bird Sanctuary, nestled within the Western Ghats, a protected forest region.

Materials and Methods

Study area

Thattekkad Bird Sanctuary, the first Bird Sanctuary in Kerala state, is situated in Ernakulam District. This Sanctuary lies within geographical limits of 10°08' N 76°41' E and 10.13° N 76.68° E, with an area of 25.16 sq.km lying on the northern bank of the Periyar River (Fig. 1). Nearly 60% of the sanctuary consists of moist deciduous forests, remaining areas were distinguished as tropical wet evergreen, tropical semi-evergreen, riparian forests, and plantations. The sanctuary consists of several natural and artificial water sources to meet the needs of the wildlife. The Periyar and Edamalayar rivers drain the entire region of the bird sanctuary. The Bhoothathankettu Dam constructed across the Periyar River plays a significant role in the water cycle of Thattekkad Bird Sanctuary (Saby 2013)

Table 1
Latitude and longitude of sampling sites

Site. No.	Sampling sites	Latitude (N) and Longitude (E)
Site 1	Periyar	N10°07'59.18", E076°40'58.74"
Site 2	Edamalayar	N10°08'34.21", E076°41'02.28"
Site 3	Thattekkad center	N10°07'55.22", E076°41'11.31"
Site 4	Elenghikkal	N10°07'51.68", E076°41'22.67"
Site 5	Ovumkal	N10°08'37.69", E076°42'01.39"
Site 6	Marottichal	N 10°07'30.68" E 076°41'49.05"
Site 7	Chettipally	N 10°07'08.14" E 076°42'19.41"
Site 8	Arambankudi	N 10°08'38.84" E 076°43'14.09"

Sample collection and identification

For the desmid investigation, the collection was made from March 2022 to April 2023 from 8 sites (Table 1). The surface water samples were collected in plastic containers with the help of a plankton net of mesh size 20µm, and attached forms were collected by squeezing submerged plants. The collected samples were fixed in 4% formalin for permanent preservation and detailed identification (APHA 2012). Algal specimens were observed under the Leica DM 2000 microscope and microscopic examinations

were conducted at a magnification of 4 to 100 X. Digital photomicrographs and measurements were made with LAS (Leica application suite) software. The identification of different taxa was done based on relevant published literatures (Smith 1924; Scott and Prescott 1961; West and West 1904, 1905, 1908, 1912; West et al. 1925; Hirano 1956, 1957, 1992; Turner 1892; Shaji et al. 1989; John et al. 2011; Krieger 1932; John and Francis 2013) and online databases. The collected samples were preserved in the lab of Forest Botany department, KFRI, Peechi, Thrissur district in Kerala.

Results

This study highlights the amazing diversity of desmids in the Thattekkad bird sanctuary. A total of seventy four taxa of desmids were identified from the sanctuary, which belong to 18 genera under the order Desmidiales comprising four families; Desmidiaceae, Gonatozygaceae, Peniaceae and Closteriaceae. The collection consists of 21 species of *Cosmarium*, 12 *Euastrum*, 8 *Staurastrum*, 6 *Staurodesmus*, 6 *Micrasterias*, 5 *Pleurotaenium*, 2 *Xanthidium*, 2 *Desmidium*, 2 *Spondylosium*, 2 *Closterium*, 1 *Sphaeroszoma*, 1 *Haplotaenium*, 1 *Triploceras*, 1 *Actinotaenium*, 1 *Teilingia*, 1 *Heismania*, 1 *Gonatozygon*, and 1 *Penium*. Among these taxa *Heimansia pusilla* (L. Hilse) Coesel, *Euastrum praemorsum* (Nordstedt) Schmidle, *Euastrum jenneri* W.Archer, *Staurastrum saltans* Joshua var. *javanicum* A.M.Scott & Prescott, *Cosmarium clepsydra* Nordstedt var. *bicardia* (Reinsch) Croasdale are new reports to India. *Staurastrum cyclacanthum* West & West var. *armigerum* A.M.Scott & Prescott, *Cosmarium ocellatum* Eichl. & Gutw. var. *incrassatum* West and West, *Desmidium coarctatum* Nordst., *Euastrum coralloides* var. *trigibberum* Lagerheim, *Cosmarium freemanii* var. *verrucosum* A.M.Scott & Prescott are new report to Kerala.

Desmids belonging to Empire Eukaryota, Kingdom Plantae, Subkingdom Viridiplantae, Infrakingdom Streptophyta, and Order Desmidiales. (Guiry and Guiry 2021)

The taxonomic account of Desmids are given below;

Family: Gonatozygaceae

Genus: *Gonatozygon* De Bary, 1858

1. ***Gonatozygon aculeatum*** N. Hastings. (Pl. 1, fig. a)

Scott and Prescott, 1961, p.8, pl.1, fig.7.

Cells are straight with a length of 157 µm, and slightly wider at poles with a breadth of 13 µm and have long, needle-like spines covering their walls.

Collection site– Edamalayar

Family: Peniaceae

Genus: *Penium* Brebisson ex Ralfs, 1848

2. *Peniummargaritaceum* Brebisson ex Ralfs (Pl. 1, fig. b)

West and West, 1904, p. 83, pl. 8, figs 32-35.

Cells are large, 6- 12 times longer than their diameter, cylindrical with a distinct median constriction, and apices truncately rounded. cells 209 µm long and 14 µm broad. Cell walls are reddish brown in color and furnished with longitudinal rows of granules.

Collection site– Edamalyar

Family: Closteriaceae

Genus: *Closterium* Nitzsch ex Ralfs, 1848

3. *Closterium diana* ex Ralfs var. *diana* (Pl. 1, fig. c)

Kouwets, 1987. p. 201, pl. 2, figs. 23–28.

Cells are large, 11 times longer than their diameter. strongly curved cells with a length of 225 µm and breadth of 20 µm, with breadth gradually reducing to 6 towards the end.

Collection site– Chettipally

4. *Closterium toxon* West (Pl. 1, fig. d)

West and West, 1904, p. 160, pl. 20, figs. 13,14.

Cells narrow and linear, elongate, 26 times longer than their diameter, 292 µm long and 11 µm broad, straight for about two-thirds their length, with sub-parallel margins, towards the extremity cells inclined and gradually attenuated, cell wall smooth and colorless.

Collection site– Thattekkad Center

Family: Desmidiaceae

Genus: *Pleurotaenium* Nägeli, 1849

5. *Pleurotaenium coroniferum* (Borge) Krieg var. *multinodosum* Scott & Prescott (Pl. 1, fig. e)

Scott and Prescott, 1961, p. 15, pl.5, fig 2.

Cell length 294 µm, breadth 34 µm, isthmus 18 µm.

Collection site– Thattekkad center

6. *Pleurotaenium kayei* (W.Archer) Rabenhorst (Pl. 1, fig. f)

Scott and Prescott, 1961, p. 16, pl.5, fig 10,11.

Cell length 225 µm, breadth 54 µm, isthmus 24 µm.

Collection site–Chettipally

7. *Pleurotaenium nodosum* (Bail) Lund. (Pl. 1, fig. g)

Scott and Prescott, 1961, p. 16, pl.5, fig 3,4.

Cell length 251 µm, breadth 46 µm, isthmus 21 µm.

Collection site–Arambankudi

8. *Pleurotaenium ovatum* Nordst var. *inermius* (Pl. 1, fig. h)

Scott and Prescott, 1961, p. 17, pl.6, fig. 3,4.

Cell length 192 µm, breadth 72 µm, isthmus 36 µm.

Collection site–Chettipally

9. *Pleurotaenium verrucosum* (Bail.) Lund. var. *bulbosum* (Pl. 1, fig. i)

Scott and Prescott, 1961, p. 20, pl.5, fig 7,8.

Cell length 234 µm, breadth 38 µm, isthmus 36 µm.

Collection site–Periyar

Genus: *Haplotaenium* Bando, 1988

10. *Haplotaenium minutum* (Ralfs) Bando. (Pl. 1, fig. j)

(Synonym–*Pleurotaenium minutum* (Ralfs) Hilse)

Scott and Prescott, 1961, p. 16, pl.2, fig. 24.

Cell length 117µm, breadth 9 µm, isthmus 10.

Collection site–Ovumkal

Genus: *Triploceras* Bailey, 1851

11. *Triploceras gracile* f. *undulatum* (Scott & Prescott) R.A.Townsend. (Pl. 1, fig. k)

(Synonym– *Triploceras gracile* Bail. var. *undulatum* Scott & Prescott)

Scott and Prescott, 1961, p. 21, pl. 6, fig. 9.

Length 338 μm , breadth 40 μm , isthmus 19 μm .

Collection site—Periyar

Genus: *Euastrum* Ehrenberg ex Ralfs, 1848

12. ***Euastrumansatum*** Ehrenberg ex Ralfs (Pl. 1, fig. I)

Scott and Prescott, 1961, p. 22, pl. 9, fig. 1.

Cell length 86 μm , breadth 41 μm and isthmus 11 μm . Cells about twice as long as broad, deeply constricted, sinus narrowly linear with a dilated extremity; semicells pyramidal with a broad base.

Collection site— Periyar

13. ***Euastrumcoralloides*** var. ***trigibberum*** Lagerheim (Pl. 2, fig. a)

Scott and Prescott, 1961. p. 24, pl. 13, figs. 1, 2.

Cell length 38 μm , breadth 26 μm , and isthmus 7 μm . Cells solitary, longer than broad, Semicells five-lobed and possess five facial swellings on each semi-cell.

Collection site— Edamalayar

14. ***Euastrum denticulatum*** (Kirchn.) Gay var. ***quadrifarum*** fa. ***incisum*** Scott & Prescott (Pl. 2, fig. b)

Scott and Prescott, 1961, p. 25, pl. 13, fig. 12.

Cell length 30 μm , breadth 22 μm , isthmus 7 μm . Cells small, slightly longer than broad.

Collection site—Arambankudi

15. ***Euastrum elegans*** (Breb.) Kutz. ***elegans*** (Pl. 2, fig. c)

Hirano, 1992, p. 51, pl. 26, fig. 10 & 11.

Cell length 32 μm , breadth 21 μm and isthmus 5 μm . Semicells possess broadly rounded apices with deeper median constriction. Cell walls are generally smooth. Two stout spine like projections present on apex of each semicell.

Collection site—Elenghikkal

16. ***Euastrumjenneri*** Archer (Pl. 2, fig. d)

Hirano, 1992, p. 53, pl. 22, fig. 8. pl. 24, fig. 4.

Cells 60 µm long, 35µm broad and isthmus 9 µm wide. Cells of medium size, longer than broad.

Collection site –Ovumkal

17. ***Euastrum neosinuosum*** var. ***parallelum*** (Willi Krieger) Anissimova & Guiry. (Pl. 2, fig. e)

(Synonym–*Euastrum sinuosum* Lenorm. var. *parallelum* Krieg.)

Scott and Prescott, 1961, p.40, pl.9, fig.7.

Cell length 53 µm, breadth 31 µm, and isthmus 9 µm. Cells about one & quarter times longer than broad, semicells three lobed; polar lobe prominent and outstanding, quadrate cuneate.

Collection site–Chettipally

18. ***Euastrum praemorsum*** (Nordstedt) Schmidle. (2, fig. f)

Hirano, 1992, p.55, pl.25, fig.6.

Scott and Prescott, 1961. p. 33, pl.7, fig. 10.

Cells 62 µm long, 35µm broad and isthmus 9 µm wide.

Collection site– Thattekkad center

19. ***Euastrum sinuosum*** var. ***ceylanicum*** West & West (Pl. 2, fig. g)

Scott and Prescott, 1961, p. 40, pl. 7, fig .6.

Cell length 72 µm, breadth 35 µm, and isthmus 11 µm. Cells solitary, twice as long as broad, semicells five-lobed.

Collection site– Elenghikkal

20. ***Euastrum spinulosum*** (Pl. 2, fig. h)

Scott and Prescott, 1961, p.40, pl.10, fig.4.

Cell length 72 µm, breadth 35 µm, and isthmus 11 µm. Cells solitary, longer than broad, broadly rounded lateral lobes with granules arranged circularly.

Collection site–Marottichal

21. ***Euastrum sublobatum*** var. ***incrassatum*** Scott & Prescott (Pl. 2, fig. i)

Scott and Prescott, 1961, p.40, pl.14, fig.13.

Cell length 18 µm, breadth 12 µm, isthmus 5 µm. Cells about one & half times as long as broad, semicells subquadrate. Cell walls are smooth in nature.

Collection site–Chettipally

22. ***Euastrum subrostratum*** West & West var. ***reductum*** Scott & Prescott (Pl. 2, fig. j)

Scott and Prescott, 1961, p. 43, pl.14, fig. 5.

Cell length 32 µm, breadth 24 µm, isthmus 4.

Collection site–Arambankudi

23. ***Euastrum substellatum*** Nordstedt (2, fig. k)

Scott and Prescott, 1961, p.44, pl.11, figs. 1,2.

Cell length 47 µm, breadth 41 µm and isthmus 9 µm. Cells longer than broad.

Collection site– Elenghikkal

Genus: *Micrasterias* C.Agardh ex Ralfs, 1848

24. ***Micrasterias alata*** (Pl. 2, fig. l)

Scott and Prescott, 1961, p. 45, pl.15, fig 4

Cell length 166 µm, breadth 133 µm, isthmus 16 µm. Cells about one and half times longer than broad, semicells three lobed, polar lobe outstanding with two extended processes, later lobes trilobed with swollen base.

Collection site–Marottichal

25. ***Micrasterias americana*** (Ehr.) Ralfs (Pl. 3, fig. a)

West and West, 1905, p. 117, pl.53, fig. 4, 5 & pl. 54, figs. 1-3.

Cell length 118 µm, breadth 100, is µm isthmus 19 µm. Almost three lobed; polar lobe large broad and outstanding, lateral lobes rather small, incision between them open and not very deep.

Collection site–Ovumkal

26. ***Micrasterias foliacea*** (Pl. 2, fig. b)

Scott and Prescott, 1961, p.48, pl.20, fig,4.

Cell length 73µm, breadth 75 µm, isthmus 13 µm. Cells small, sometimes interlinked to form filaments, rectangular in outline, deeply constricted, sinus narrow and linear, semicells five lobed, basal part of the lobes are sup parallel.

Collection site–Edamalayar

27. ***Micrasterias pinnatifida*** (Kutz.) Ralfs (2, fig. c)

Scott and Prescott, 1961, p.51, pl.14, fig. 17, 18 & pl. 12, fig. 6.

Cell length 50 µm, breadth 55 µm, isthmus 9 µm. Cells broader than long. Semicells three lobed, with two interlobular incisions broadly rounded and deep, later lobes almost spindle shaped, projecting horizontally and attenuating to a narrow bilobed apex.

Collection site–Elenghikkal

28. ***Micrasterias radians*** (Pl. 3, fig. d)

Scott and Prescott, 1961, p.51, pl.23, fig,1.

Cell length 125µm, breadth 104 µm, isthmus 15 µm. Cells of medium size, sub circular, very deeply constricted, semicells five lobed, polar lobe with subparallel sides and expanded apex with furcate acuminate extremity.

Collection site–Periyar

29. ***Micrasterias zeylanica*** Fritsch var. ***rectangularis*** Scott & Prescott (Pl. 3, fig. e)

Scott and Prescott, 1961, p.53, pl.21, fig.5-7.

Cell length 52 µm, breadth 54 µm, isthmus 11 µm. Cells long as broad, semicells trilobed, polar lobe expanded with terminate spines on either side, lateral lobes rectangular in shape with acute spines.

Collection site–Elenghikkal

Genus: *Actinotaenium* (Nageli) Teiling, 1954

30. ***Actinotaenium cucurbita*** (Brébisson ex Ralfs) Teiling. (Pl. 3, fig. f)

(Synonym–*Actinotaenium cucurbita* (Brébisson ex Ralfs) Teiling var. *attenuatum* (G.S.West) Teiling)

Crosadale, 1992, p. 173, pl.10, fig 5.

Cell length 28 µm, breadth 18µm, isthmus 14µm. characterized by more or less cylindric cells, broadly rounded at the apex, and by stelloid chloroplasts incorporating a central pyrenoid.

Collection site– Edamalayar

Genus: *Cosmarium* Corda ex Ralfs 1848

31. ***Cosmarium bengalense*** (Pl. 3, fig. g)

Turner, 1892, p. 56, pl. 8, fig. 33.

Cell length 67 µm, breadth 39 µm, isthmus 15 µm. Semicells are hexagonal, the apical and basal angles of the semi-cell are broadly rounded and the cell wall is smooth. Swellings on lateral margins and slightly undulated margins.

Collection site–Periyar

32. ***Cosmariumceylanicum*** West & West f. ~~*minus*~~ Scott & Prescott (Pl. 3, fig. h)

Scott and Prescott, 1961, p. 56, pl.31, fig 5.

Cell length 31µm, breadth 25 µm, isthmus 7 µm. Marginal teeth more prominent

Collection site– Arambankudi

33. ***Cosmarium clepsydra*** Nordstedt ~~*bicardia*~~(Reinsch) Croasdale (Pl. 3, fig. i)

(Synonym:*Cosmarium bicardia* Reinsch)

Hirano, 1956, p. 104, pl 20, fig 16.

Cell length 30 µm, breadth 25µm, isthmus 7µm.

Collection site– Thattekkad center

34. ***Cosmarium connatum*** (Pl. 3, fig. j)

West and West, 1908, p. 25, pl. 67, fig 15-17.

Cell length 55 µm, breadth 41 µm, isthmus 33 µm. Cells large, longer than broad, moderately constricted, sinus very widely open with obtuse apex; semicells transversely subelliptic with a broad base, apex commonly very slightly flattened.

Collection site– Thattekkad center

35. ***Cosmariumcontractum*** Kirchner var. ***ellipsoideum*** (Elfving) West & G.S.West. (Pl. 3, fig. k)

West and West, 1905, p. 172, pl. 61, figs. 28,35.

Cell length 36 µm, breadth 26µm, isthmus 7µm. Cells shorter, as long as broad, semicells more exactly elliptic, although the apex is sometimes slightly flattened in the middle. Cell walls are usually smooth.

Collection site– Periyar

36. *Cosmarium contractum* Kirchner var. *pachydermum* Scott & Prescott (Pl. 3, fig. l)

Scott and Prescott, 1961, p.56, pl. 27, fig. 6.

Cell length 33 µm, breadth 25 µm, isthmus 6 µm. Cells rather small, longer than broad, very deeply constricted, sinus narrow towards apex, rapidly widening outwards; semicells subelliptic.

Collection site– Thattekkad center

37. *Cosmarium cuneatum* (Pl. 4, fig. a)

Scott and Prescott, 1961, p. 57, pl. 30, fig. 3.

Cell length 36 µm, breadth 40 µm, isthmus 10 µm. Cell hexagonal circular, as long as broad, very deeply constricted at the middle, cells with fairly four large granules just below the apex of semicell.

Collection site– Thattekkad center

38. *Cosmariumdecoratum* West & West. (Pl. 4, fig. b)

Scott and Prescott, 1961, p. 57, pl. 25, fig. 1.

Cell length 78 µm, breadth 63 µm, isthmus 25 µm. Cells large, longer than broad, cells deeply constricted, slightly dilated extremity. Cell walls are covered with large granules and many triangular pores are present at the center of the semicells.

Collection site– Chettipally

39. *Cosmariumfreemani* West & West var. *verrucosum* Scott & Prescott (Pl. 4, fig. c)

Scott and Prescott, 1961, p. 58, pl.31, figs. 3,4.

Cell length 34 µm, breadth 27 µm, isthmus 7 µm. Cells are slightly longer than broad. Possess five emarginate structures intramarginally, presence of two apical teeth.

Collection site–Ovumkal

40. *Cosmarium granatum* (Pl. 4, fig. d)

West and West, 1905. vol. 2, p. 186, pl. 63, figs. 1–3.

Cell length 30 µm, breadth 20 µm, isthmus 6. Cells small, long as broad, subrhomboid– elliptic, deeply constricted, sinus narrowly linear, slightly dilated at the apex, semicells truncate, pyramidate. Cell wall finely punctuated.

Collection site–Edamalayar

41. *Cosmarium lundelli* (Pl. 4, fig. e)

Scott and Prescott, 1961, p. 60, pl.25, fig 6.

Cell length 52 µm, breadth 53 µm, isthmus 21 µm. Cells large, subcircular, about as long as broad, deeply constricted, sinus linear with a dilated apex; semicells sub semicircular or pyramidate, basal angles broadly rounded.

Collection site– Thattekkad center

42. *Cosmarium lundellii* var. *ellipticum* West & West. (Pl. 4, fig. f)

Scott and Prescott, 1961, p. 61, pl.25, fig 8.

Cell length 49 µm, breadth 40 µm, isthmus 15 µm, smaller than type specimen, longer than broad, with a narrower isthmus.

Collection site– Periyar

43. *Cosmarium medioscrobiculatum* West & West var. *egranulatum* (Pl. 4, fig. g)

Scott and Prescott, 1961, p. 62, pl 26. fig, 3.

Cell length 49 µm, breadth 49 µm, and isthmus 19 µm. Cells comparatively large with equal length and breadth, isthmus wide with open sinus. Cell wall smooth, semicells hemispherical in shape with ear-like extensions on each side of semi cell.

Collection site–Marottichal

44. *Cosmarium norimbergense* Reinsch var. *depressum* (West & West) Willi Krieger & Gerloff. (Pl. 4, fig. h)

Scott and Prescott, 1961, p. 63, pl.32, fig 6

Cell length 16 µm, breadth 14 µm, isthmus 5 µm. Cells slightly longer than broad, median constriction deep, sinus dilated closed, vertically rectangular semicells, basal angles rectangular, cell wall smooth.

Collection site– Elenghikkal

45. *Cosmarium obsoletum* (Hantzsch) Reinsch var. *sitvense* (Pl. 4, fig. i)

Scott and Prescott, 1961, p. 63, pl. 25, fig 11

Cell length 43 µm, breadth 54 µm, isthmus 19 µm. Cells of medium size, transversely elliptic, a little broader than long, deeply constricted, sinus narrowly linear with a dilated apex; semicells semi-elliptic, basal angles submamillate and slightly thickened.

Collection site–Arambankudi

46. *Cosmarium ocellatum* & Gutw. var. *incrassatum* West and West. (Pl. 4, fig. j)

Scott and Prescott, 1961, p. 64, pl.32, fig 17.

Cell length 23 µm, breadth 19 µm, isthmus 4 µm. Cells small, longer than broad, deeply constricted, sinus narrow, linear, dilated towards apex, semicells pyramidate, basal angles and apex rounded.

Collection site– Ovumkal

47. *Cosmarium porteanum* Archer. (Pl. 4, fig. k)

Scott and Prescott, 1961, p.65, pl. 28, fig. 8.

Cell length 21 µm, breadth 17 µm, isthmus 7 µm. Deeply constricted, sinus gradually opening from a rounded extremity. Semicells subreniform and granulated, Cells rather small, long as broad, deeply constricted, sinus gradually opening from a rounded extremity, isthmus slightly elongated; semicells elliptic and granulate; granules rounded disposed in about ten vertical series.

Collection site– Chettipally

48. *Cosmarium pyramidatum* var. *stephanii* (Irene-Marie) Krieg. et Gerloff. (Pl. 4, fig. l)

Shaji et al., 1989, p.176, pl. 2, fig. 7.

Cell length 61 µm, breadth 36 µm, isthmus 12 µm. Cells large, longer than broad, deeply constricted, sinus very narrow and dilated towards apex; semicells pyramidate, basal angles well rounded. Cell wall minutely scrobiculate.

Collection site– Elenghikkal

49. *Cosmarium retusiforme* (Wille) Gutw. (5, fig. a)

Scott and Prescott, 1961, p.68, pl. 32, fig 15.

Cell length 25 µm, breadth 20 µm, isthmus 6 µm. Cells small, slightly longer than broad, deeply constricted, sinus narrow, linear, slightly dilated at apex; semicells pyramidate trapeziform with broad base and slightly retuse apex, basal angles rounded, apical angles obtuse, cell wall smooth.

Collection site– Thattekkad center

50. *Cosmarium trachypleurum* var. *nordstedtii* Gutw. (Pl. 5, fig. b)

Scott and Prescott, 1961, p. 72, pl.31, fig 6.

Cell length 36µm, breadth 30 µm, isthmus 6 µm

Collection site–Ovumkal

51. *Cosmarium vitiosum* Scott & Gronbl. var. *orientale* Scott & Prescott (Pl. 5, fig. c)

Scott and Prescott, 1961, p. 73, pl.31, fig 2.

Cell length 30µm, breadth 27 µm, isthmus 6 µm

Collection site–Periyar

Genus: *Xanthidium* Ehrenberg ex Ralfs, 1848

52. *Xanthidium acanthophorum* var. *raciborskii* Gutwinski. (Pl. 5, fig. d)

Scott and Prescott, 1961.p.79, pl 36, fig 12, pl. 37. fig. 1.

Length 45µm, breadth 40 µm, isthmus 11 µm.

Collection site–Arambankudi

53. *Xanthidium spinosum* (Joshua) W. & G.S.West. (5, fig. e)

Scott and Prescott, 1961, p. 84, pl.37, fig 2,3.

Length 45 µm, breadth 49 µm, isthmus 25 µm. Semicells transversely elliptic, margins somewhat undulate, spines short, cell wall punctuated, scrobiculations at the basal part of semicells, disposed in a horizontal or arch form of one to three series.

Collection site–Ovumkal

Genus: *Staurodesmus* Teiling, 1948

54. *Staurodesmus convergens* (Ehrenberg ex Ralfs) S. Lillieroth. (Pl. 6, fig. j)

(Synonym – *Arthrodesmus convergens* Ehrenberg ex Ralfs)

Scott and Prescott, 1961, p. 74, pl. 34, fig. 7-9

Cell length 40 µm, breadth 40 µm, breadth with arms 55 µm, and isthmus 12 µm. Cells are

mostly as long as broad. Cell walls furnished with single spines disposed of medium planes.

Collection site–Elenghikkal

55. ***Staurodesmus curvatus*** (W.B.Turner) Coesel & Van Geest ***latus*** (Scott & Prescott) Teiling (Pl. 5, fig. g)

(Synonym–*Arthrodesmus curvatus* Turn. var. *latus* A.M.Scott & Prescott)

Scott and Prescott, 1961, p.76, pl.33, fig 1-3.

Cell length 40µm, breadth 40 µm, isthmus 12.

collection site– Marottichal

56. ***Staurodesmus cuspidatus*** (Brébisson) Teiling. (Pl. 5, fig. h)

(Synonym– *Staurastrum cuspidatum* Breb.)

Scott and Prescott, 1961, p. 89, pl.53, fig 13.

West et al., 1923, P. 23, pl. 132, figs. 13-15.

Cell length 21 µm, breadth 18 µm, csp 35, isthmus 5 µm. Cells are small, slightly longer than broad, very deeply and broadly constricted, with a long cylindrical sinus about as long as a single semicell, and lateral angles of semicells terminating into a stout spine.

Collection site–Edamalayar

57. ***Staurodesmus extensus*** (O.F.Andersson) Teiling. (Pl. 5, fig. i)

(Synonym–*Arthrodesmus incus* (De Brebisson) Hassall. var. *extenses* Anderson)

Smith, 1924, p. 132, pl. 85, fig. 23-26.

Cell length 16 µm, breadth without spine 15 µm, breadth with spine 42 µm, isthmus 4 µm. Cells small, length about equal to breadth, semicells obversly triangular, semicells with a single long gradually attenuated spine, spines parallel to divergent.

Collection site– Thattekkad center

58. ***Staurodesmus triangularis*** (Lagerheim) Teiling (Pl. 5, fig. j)

(Synonym– *Staurastrum megacanthum* P.Lundell var. *orientale* Scott & Prescott)

Scott and Prescott, 1961, p. 98, pl.55, fig 5,6.

Cell length 34 µm, breadth 60 µm, isthmus 9 µm.

Collection site– Elenghikkal

59. *Staurodesmus mordax*() Compère var. *nudus* (Turn.) Compère. (Pl. 5, fig. k)

(Synonym– *Cosmarium nudum* (Turn.) Gutwinski)

Scott and Prescott, 1959, p. 63, pl. 30, fig.1,2.

Cell length 48 µm, breadth 46 µm, isthmus 13 µm

Collection site– Thattekkad center

Genus: *Staurostrum* Meyen ex Ralfs, 1848

60. *Staurostrum bigibbum* (Pl. 5, fig. l)

Scott and Prescott, 1961, p. 86, pl.53, fig 8.

Cells are small, 16 µm long, and 40 µm broad, semicells with triradiate arms in different planes of orientation. The Isthmus region is short with a length of 7 µm.

Collection site–Marottichal

61. *Staurostrumcerastes* var. *coronatum* Krieg. f. *inflatum* Scott & Prescott (Pl. 6, fig. a)

Scott and Prescott, 1961, p. 87, pl.56, fig 6.

Length 43 µm, breadth 60 µm and isthmus 9 µm, Cells slightly broader than long including processes, sinus open acutely and apex acuminate, semicells campanulate, lateral margins inflated, apical angles produced into a long, strongly incurved process, verrucose in the upper margin and smooth in the lower margin.

Collection site – Ovumkal

62. *Staurostrumcyclacanthum* West & West var. *armigerum* Scott & Prescott (Pl. 6, fig. b)

Scott and Prescott, 1961, p. 89, pl.57, fig 1-3.

Length 26 µm, breadth 47 µm, isthmus 9 µm. Cells twice as long as broad including processes, semicells triradiate with trifid verrucae at the proximal ends of the process.

Collection site–Chettipally

63. *Staurostrum saltans* Joshua var. *javanicum* Scott & Prescott (6, fig. c)

Scott and Prescott, 1961, p. 105, pl. 51, fig. 8,9.

Cell length 37 μm , breadth with arms 63 μm , breadth without arms 23 μm

isthmus 9 μm .

Collection site– Elenghikkal

64. *Staurastrum quadricornutum* Roy & Biss. (6, fig. d)

Scott and Prescott, 1961, p. 104, pl.59, fig 6.

Cell breadth with spines 27 μm , length with spines 33 μm , isthmus 11 μm .

Collection site–Periyar

65. *Staurastrum setigerum* (Pl. 6, fig. e)

West et al., 1923, p. 52, pl 136, fig 13, 14.

Length 35 μm without spines. breadth 30 μm without spines, length of spine 9 μm , isthmus 7 μm . Cells of medium size, a little longer than broad, deeply constricted, sinus acute and open, semicells elliptical, angles of semicells obtusely rounded and provided with 2-5 long stout spines. The surface of the cell is provided with several long but more delicate spines than those at the angles.

Collection site–Arambankudi

66. *Staurastrum woltereckii* (Pl. 6, fig. f)

Scott and Prescott, 1961, p. 118, pl.60, fig 1

Cell length 23 μm , breadth 33 μm , isthmus 6 μm .

Collection site– Ovumkal

67. *Staurastrum xanthium* (Pl. 6, fig. g)

Scott and Prescott, 1961, p. 119, pl.58, fig 10.

Cell length 39 μm , breadth 48 μm , isthmus 10 μm .

Collection site–Marottichal

Genus: *Heimansia* Coesel, 1993

68. *Heimansiapusilla* (Hilse) Coesel. (Pl. 6, fig. h)

Synonym– Cosmocladium pusillum L.Hilse

West et al., 1923, p. 201, pl.158, figs. 8-10.

Cell length 11 µm, breadth 9 µm and isthmus 3 µm. Cells small, slightly longer than broad, deeply constricted, sinus linear, semicells oblong elliptical, apex somewhat flattened, sides broadly rounded, cells united to form a colony, cells mostly with their broad surface perpendicular to the direction of the connecting gelatinous threads.

Collection site– Thattekkad center

Genus: *Teilingia* Bourrelly, 1964

69. ***Teilingiagranulata*** (J.Roy & Bisset) Bourrelly. (Pl. 6, fig. i)

(Synonym– *Sphaerososma granulatum* J.Roy & Bisset)

West et al., 1923, p. 213, pl. 160, figs. 6-7.

Length 8 µm, breadth 8 µm, isthmus 4. Cells are small, about as long as broad, constriction deep and open, semicells elliptical. Lateral margins are rounded, semicells with a group of minute granules at each lateral margin.

Collection site– Chettipally

Genus: *Sphaerososma* Corda ex Ralfs, 1848,

70. ***Sphaerososmalaeve*** var. ***latum*** West & West. (Pl. 6, fig. j)

Scott and Prescott, 1961, p. 121, pl.60, fig 13.

Cell length 14µm, breadth 19µm, isthmus 4µm.

Collection site–Arambankudi

Genus: *Spondylosium* Brébisson ex Kützing, 1849

71. ***Spondylosium nitens*** (Wall) Arch. var. ***triangulare*** (Pl. 6, fig. k)

Krieger, 1932, p. 220, pl. 26. Fig. 1.

Cell length 30 µm, breadth 27 µm, isthmus 8 µm. The cell is about as long as broad, sinus open and broadly rounded within. A variety has with the semicells 3-lobed, in vertical view triangular. The apices are evenly convex or truncately produced in the middle.

Collection site–Ovumkal

72. *Spondylosium secedens*(De Bary) W. Archer. (Pl. 6, fig. I)

West et al., 1923. p. 223, pl. 161, figs. 8-11.

Cell dimensions-Length 11 µm, breadth 12 µm, isthmus 5.

Cells small, slightly broader than long, cells subquadrangular, angles rounded, deeply constricted, sinus obtuse, semicells transversely oblong and angles broadly rounded, cells united into filaments, not twisted.

Collection site– Edamalayar

Genus: *Desmidium* C. Agardh ex Ralfs, 1848

73. *Desmidium coarctatum* (Pl. 7, fig. a)

Hirano, 1992, p. 89, pl.51, fig 13.

Cell length 24 µm, breadth 25µm, isthmus 20 µm. Filaments flattened, twisted, cells in frond view elliptical, broader than long, with a straight median constriction, sinus linear, basal angles of semicells acutely rounded, lateral margins slightly undulate.

Collection site– Marottichal

74. *Desmidiumswartzii* Agardh (Pl. 7, fig. b)

Scott and Prescott, 1961. p. 125, pl. 63, fig. 8.

Cell length 17 µm, breadth 30µm, isthmus 20 µm. Cells of medium size, about twice as long as broad, constriction not deep, but open and acute; cells narrowly oblong, extremely depressed. cells united to form twisting filamentous colonies.

Collection site– Thattekkad center

Discussion

From the previous decades onwards, there were many studies ongoing all over the world to document the diversity of desmids. Das (2020) researched the diversity of desmids in the Kokrajhar district, Assam, and published a preliminary checklist that included 71 desmid taxa. The same approach was implemented by Jose et al. (2022) at Karappuzha Dam in the Western Ghat region, Kerala, where they discovered 39 desmids. In both these studies, the most diverse genus was *Cosmarium*. In line with this trend, 22 taxa of *Cosmarium* were obtained out of 80 in our study.

The prior investigations conducted on the variety of algae in forest habitats were, Chimmony Wildlife Sanctuary (Jose and Xavier 2022), Kaziranga National Park (Yasmin et al. 2015), and Gangaikondan

Spotted Deer Sanctuary (Priya et al. 2020) are some among them. Eventhough there were comparatively small counts of desmids found in forest ecosystems. This leads us to the conclusion that there are still a lot of undescribed desmid species in forest ecosystems, in this current scenario this investigation on Thattekkad Bird Sanctuary is a contribution to the algal diversity of forest ecosystems.

Desmids are incredibly diverse and vary greatly in their structure and appearance, hence species-specific taxonomic studies were very common among them. Selected genera of desmids have frequently been evaluated by numerous researchers; the major studied species including *Cosmarium* (Aquino et al. 2016; Prasad et al. 1987; Nandi et al. 2019; Zarina et al. 2014; Zarina et al. 2012; Paul and Sreekumar 2015; Shyndanovina 2020; Ramos et al. 2021), *Closterium* (Zongo et al. 2011; Oliveira et al. 2013; Salla et al. 2012; Rekha and Sujathamma 2021) *Micrasterias* (Paul and Sreekumar 2007; Santos 2018; Silva and Felisberto 2015), *Euastrum* (Tessy and Sreekumar 2013), and *Pleurotaenium* (Paul and Sreekumar 2011). Similarly, the diversity of desmids in the Thattekkad bird sanctuary should also be thoroughly studied for the sake of genus-specific documentation.

Conclusion

The desmid biodiversity investigations conducted in Thattekkad bird sanctuary reveal a high level of diversification. 74 taxa of desmids were obtained from the study, among which the genus *Cosmarium* (21 taxa) made up the majority followed by *Euastrum* (12) and *Staurastrum* (8). *Heimansia pusilla* (L.Hilse) Coesel, *Euastrum praemorsum* (Nordstedt) Schmidle, *Euastrum jenneri* W.Archer, *Staurastrum saltans* Joshua var. *javanicum* Scott & Prescott are new report to India. *Staurastrum cyclacanthum* West & West var. *armigerum* Scott & Prescott, *Cosmarium ocellatum* Eichl. & Gutw. var. *incrassatum* West and West, *Desmidium coarctatum* Nordst., *Staurodesmus extensus* (O.F.Andersson) Teiling, *Euastrum coralloides* var. *trigibberum* Lagerheim, *Cosmarium freemanii* West & West var. *verrucosum* Scott & Prescott are new report to Kerala, all are new report to Thattekkad bird sanctuary.

Declarations

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Conflict of Interest

There are no financial/ commercial conflicts of interest.

Author contribution

Conceptualization: P. B Bibina, V. B Sreekumar; Methodology: P. B Bibina, A.P Praseetha, C. J Ammini; Formal analysis and investigation: P.B Bibina; Writing - original draft preparation: P. B Bibina; Writing - review and editing: P. Tessa Paul, V. B Sreekumar; Funding acquisition: V. B Sreekumar Resources: V. B Sreekumar Supervision: V. B Sreekumar.

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Plates

Plates 1 to 7 are available in the Supplementary Files section

Figures

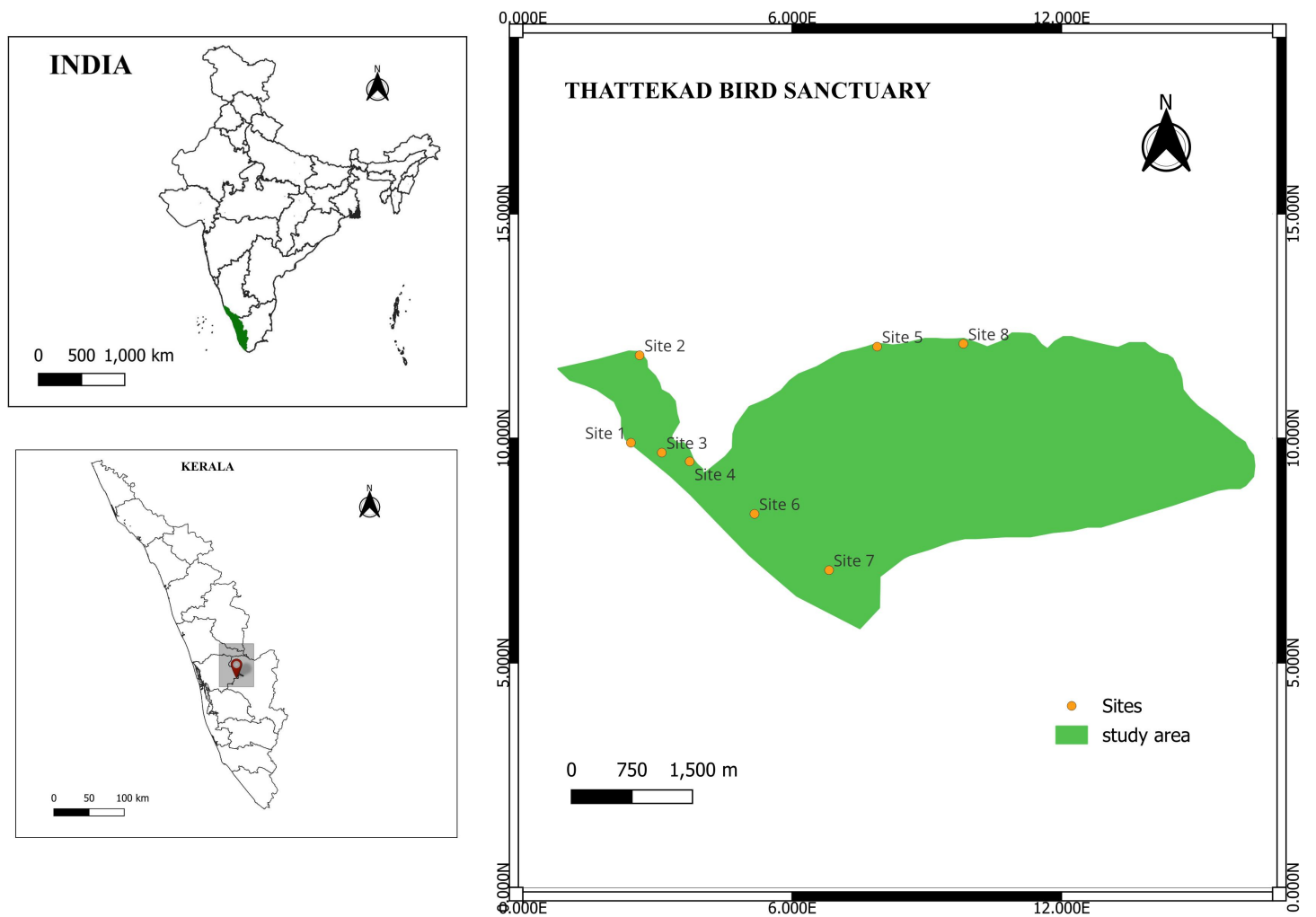


Figure 1

Map of Thattekad Bird Sanctuary with sampling sites

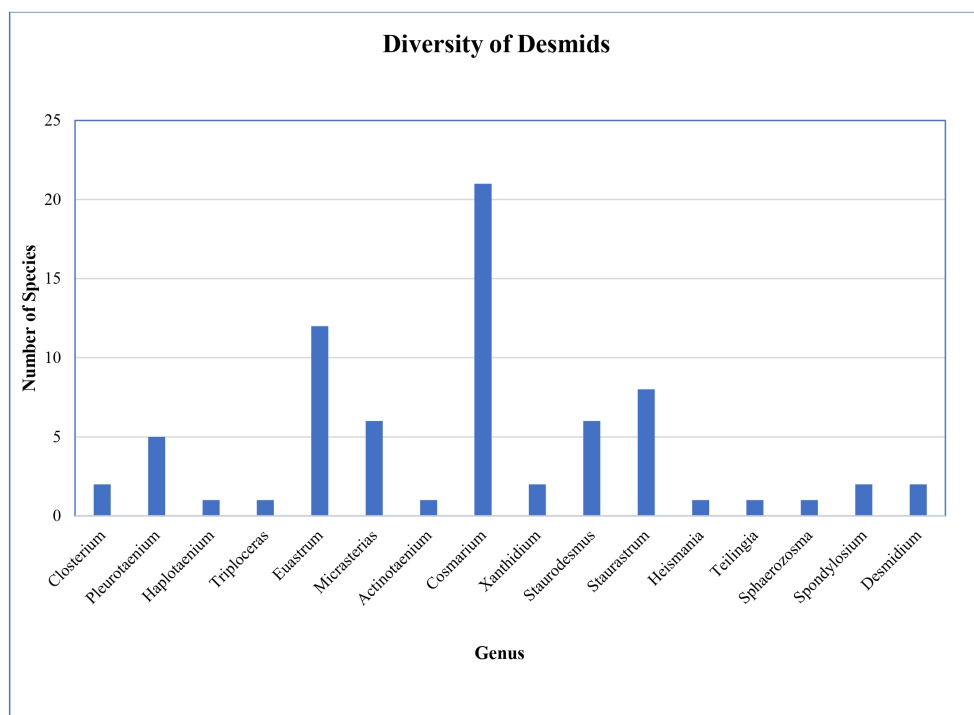


Figure 2

Bar diagram showing the diversity of desmids in Thattekkad Bird Sanctuary

Supplementary Files

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