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RESEARCH ARTICLE

Subaerial algal flora of Similipal biosphere reserve, Odisha, India

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Abstract Similipal biosphere is 2,750 km^2 (1,060 sq mi) in size and is located in the Mayurbhanj district of Odisha, India. The aim of this study was to collect and document various algal forms growing on tree bark, rock surfaces and other subaerial habitats in Similipal Biosphere Reserve. In the present study, a total of 27 algal species under 20 genera, 17 families and 9 orders of 4 divisions (Cyanoprokaryota, Chlorophyta and Charophyta, Bacillariophyta) are reported from different sites of Similipal biosphere reserve, Odisha. Out of 27 algal species, 23 species are recorded for the first time from this biosphere reserve; such as *Anabaena fuellebornii*, *Leptolyngbya foveolarum , Nostoc* sp., *Tolypothrix scytonematoides*, *Westiellopsis prolifica*, *Chlorella minuta*, *Chlorococcum* sp., *Coelastrella* sp., *Dictyococcus varians*, *Dictyochloropsis* sp., *Gloeocystis gigas*, *Kirchneriella aperta*, *Kirchneriella obesa*, *Monoraphidium contortum*, *Monoraphidium indicum*, *Monoraphidium tortile*, *Stichococcus minor*, *Symbiochloris irregularis*, *Cosmarium* sp., *Klebsormidium dissectum*, *Klebsormidium flaccidum*, *Gomphonema* sp., *Pinnularia borealis*.

Keywords: Algal diversity, Biosphere reserve, Subaerial algae

Introduction

Algae that survive on land are frequently found on stable, exposed surfaces above the soil. Subaerial algae thrive in India, and their presence gives most tree barks, buildings, and rocks a golden or reddish orange hue (Neustupa and Škaloud 2010). Terrestrial algae have adapted to grow in a variety of microhabitats, including damp soil and all exposed areas above the soil surface (Neustupa and Škaloud 2010). As a result, two kinds of non-aquatic algal species are identified on land: soil algae and sub-aerial algae (aerophytic algae). Algae that live above the soil line and at a distant from water are known as sub-aerial algae (Lopez-Bautista *et al.* 2007). The word "sub-aerial" refers to any habitat that is above the soil surface and is defined as "any environment exposed to the air or the atmosphere; not submerged" (Lopez-Bautista *et al.* 2007). Aero-terrestrial algae is another name for them. Tree bark and leaves, huge rocks, unpainted compound walls, old wood works, metals, exposed sections of old buildings, stone monuments, and other man-made structures are among the algal substrates in these ecosystems. They are classified as epiphytic (living on plants), epiphyllous (living on leaves), corticolous (living on bark, stems, or trunks of trees), epizoic (living on animals), lithophilous (living on stones, brick, or cement), epixylous (living on dead wood such as poles, posts, or doors) and epimetallous (inhabiting metals) (Lopez-Bautista *et al.* 2007). Subaerial algae can be found both as free-living organisms and as symbionts of fungal symbionts (lichens) (Gorbushina 2007). They are primarily microscopic unicellular, sarcinoid or filamentous and generally form colonies which appear as black, green, red, or

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brown patches(Gorbushina 2007).

Since the 19th century, researchers have been studying subaerial algae in various subaerial ecosystems. They are the most common, but least studied and neglected ones. In comparison to freshwater and marine algae, our understanding of the variety and distribution of algae in subaerial ecosystems is sparse and far behind (John *et al.* 2002, Gorbushina 2007). The diversity and distribution of subaerial algal communities in various microhabitats is not well studied and documented compared to freshwater and marine environments. There has been significant improvement in knowledge of subaerial algal distribution and their taxonomic status during the last two decades, but tropical regions remain poorly researched (Saber *et al.* 2022, Hofbauer and Gärtner 2021). Algae can be also found in dead wood, metallic poles, tree barks, and leaves (Saber *et al.* 2022, Hofbauer and Gärtner 2021).

Cyanoprokaryota, chlorophyta, charophyta and heterokontophyta are photosynthetic microorganisms found in terrestrial and subaerial environments. Although Chlorophycean members are predominantly freshwater algae, however this phylum also includes many common subaerial algal taxa (Ambika and Krishnamurthy 2018). Most chlorophyta species found in terrestrial habitat are mostly from Trebouxiophyceae and Ulvophyceae. *Klebsormidium* (Charophyta) is one of the most common green filamentous taxa of the subaerial algal community. The Bacillariophyceae and Xanthophyceae of Heterokontphyta are two families which are represented by subaerial forms (Lopez-Bautista *et al.* 2007). Cyanobacteria (blue-green algae) are photosynthetic prokaryotic microorganisms that thrive in a variety of environments, including exposed rock surfaces, hot deserts, arid areas, and tree bark, among others and the most common species are *Gloeocapsa lignicola, Aphanocapsa Testacea, Nostoc punctiforme, Phormidium rubritericola, Tolypothrix byssoidea* and *Scytonema mirabile* (Adhikary and Sahu 2000, Pattanaik and Adhikary 2005, Büdel 2002). The biological crust formed by epiphytic sub-aerial algal flora on tree barks has a diverse assemblage of corticolous algae, including Chlorophyceae and Cyanobacteria (Neustupa and Škaloud 2008). Several researchers have observed the presence of corticolous cyanobacteria belonging to the genera Gloeocapsa, Aphanocapsa, Phormidium, Stigonema, Tolypothrix, Fischerella, Lyngbya, Nostoc, Porphyrosiphon, Hapalosiphon, Lyptolyngbya, and others on tree bark (Neustupa and Škaloud 2010, Bhakta *et al.* 2014, Bhakta *et al.* 2015). In addition, Soil Crust algae of Similipal biosphere belonging to the genera Gloeocapsa, *Psudocapsa, Leptolynbya, Porphyrosiphon, Synechocystis, Scytonema, Tolypothrix, Coccomyxa, Microspora, Cylindrocapsopsis, Ulothrix and Trentepohlia* (Bhakta *et al.* 2015). Although some research on the algal diversity of subaerial flora of Similipal biosphere reserve is conducted but need to be explore more as these algae have possess potential bioactive compounds (Bhakta *et al.* 2015, 2014). In this context, the Similipal Biosphere Reserve in Odisha is an unexplored ecosystem that has to be investigated for subaerial habitat such as soil, rock, and tree bark. Due to its habitat these algae can synthesize several bioactive metabolites which can be used against several disease like cancer, diabetes and cardiovascular diseases. Hence, we focused the survey of algal diversity in this investigation to acquire information on the algal diversity occurring in the Similipal biosphere reserve in Odisha.

Materials and methods

The study sites: The Similipal Biosphere Reserve, is located in the centre region of Odisha's Mayurbhanj district, between 21° 28" and 22° 08" North latitude and 86° 04" and 86° 37" East longitude (Bhakta *et al*. 2014, Jena *et al.* 2006). The name Similipal comes from the 'Simul' (silk cotton) tree. In 1956, it was formally declared as a tiger reserve, and in 1973, it was placed under Project Tiger. In June of 1994, the Government of India designated it as a biosphere reserve. Since 2009, it has been a member of the UNESCO World Network of Biosphere Reserves. It is part of the Mayurbhanj Elephant Reserve, which contains three protected areas: Similipal Tiger Reserve, Hadagarh Wildlife Sanctuary, and Kuldiha Wildlife Sanctuary. It is situated at the eastern end of the eastern ghat (Ray 2014). The biosphere covers 4,374 square kilometres and includes 845 square kilometres of core forest (tiger reserve), 2,129 square kilometres of buffer land, and 1,400 square kilometres of transition space. Similipal is home to 1,076 blooming plants including 96 orchid species.

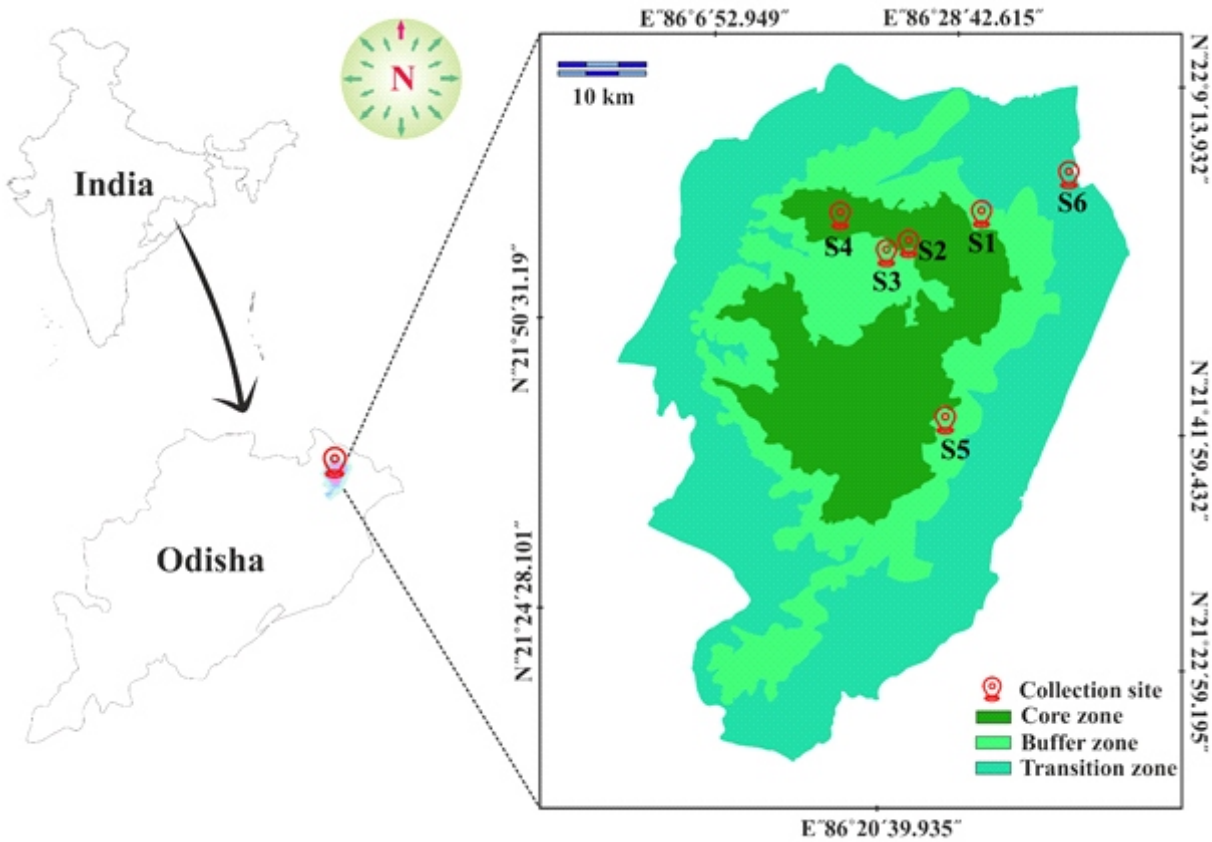

Figure 1: Map showing the sample collection sites of Similipal biosphere reserve, Odisha. S1: Bhajam, S2: Joranda, S3: Barehipani, S4: Chahala, S5: Devkund, and S6: Machhakandana.

Algal samples were collected in the Mayurbhanj area of Odisha's Similipal Biosphere Reserve in April 2021 and December 2022. Figure 1 depicts the map of collection site of Similipal Biosphere Reserve, Odisha.

Sampling: Epilithic, corticolous and epiphytic algal samples were collected in sterilised Tarson centrifuge tubes/plastic jars, using forceps, needles, petri dishes, scalpel and brushes.

Sample processing: Algal samples are particularly difficult to identify in their natural state due to the crust or dense connection with the tree bark. So, these were soaked in distilled water in petri plates and incubated under white light for 24 hours before observing under a microscope.

Microscopy and microphotography: Each algal sample in the form of filament, colony, or consortium was micro photo graphed with a phase contrast microscope (Olympus, Model No. BX53) fitted with a digital camera (Olympus Sc180).

Morphological identification: The morphological features of algal specimens were recorded and were identified by following published literature (Desikachary 1959, Bhakta *et al.* 2015, Bhakta *et al.* 2014, Jena *et al.* 2006, Neustupa and Škaloud 2008, Lopez-Bautista *et al.* 2007, Komárek and Anagnostidis 1999, Komárek 2005, Keshari and Adhikary 2014, Mahendra Perumal and Anand 2009, Komárek *et al.* 2013, Vijayan and Ray 2015, Kim and Lee 2014, Neustupa and Škaloud 2010, Das and Adhikary 2014, Komárek *et al.* 1983, Hindák 1977, Khaybullina *et al.* 2010, Nakano and Isagi 1987, West *et al.* 1912, Stace *et al.* 2005, Pradhan *et al.* 2021b, Pradhan *et al.* 2021a, Behera *et al.* 2021, Behera *et al.* 2020, Dash *et al.* 2020, Dash *et al.* 2021, Maharana *et al.* 2019, Shiels *et al.* 2019, Škaloud *et al.* 2016, Arguelles 2019)

Sample preservation: The algal forms in each sample were identified, sun dried and stored in a dark place. Each sample was given a unique voucher number and deposited in the Department of Botany, Maharaja Sriram Chandra Bhanja Deo University, Baripada.

Results

A total of 27 algal species belonging to 20 genera were recorded from 50 collected samples from Similipal biosphere reserve, Odisha. These species belonged to 9 orders and 17 families of four divisions such as Cyanoprokaryota (8 species), Chlorophyta (14 species), Charophyta (3 speceis) and Bacillariophyta (2 species).The microphotographs of identified algal species are shown Plate 2 and 3. The details of the systematic accounts of all the algal species are described below:

Systematic accounts and taxonomic enumeration of algal species:

Cyanoprokaryota
Order: Nostocales; **Family**: Nostocaceae; **Genus**: *Anabaena*

1. ***Anabaena fuellebornii*** Schmidle, 1902 (plate 1, fig. 1)
Mahendra Perumal and Anand 2009, p. 38, pl. 8, fig. 1
Trichomes slightly straight, thallus blue-green, cells are not equal in size, 8-10 µm long and 10-15 µm broad.
Habitat: black patches on rock surface; Voucher no. 590; Place of collection: Machhakandana, Similipal; Date: 26th November 2017
Order: Nostocales; **Family**: Oscillatoriaceae; **Genus**: *Leptolyngbya*

2. ***Leptolyngbya foveolarum*** (Gomont) Anagnostidis et Komárek 1960 (plate 1, fig. 2)
Shiels *et al.* 2019, p. 11, fig. 2 (10)
[Synonyms: *Plectonema boryanum* Gomont]
Filaments without heterocyst, akinetes, or true or false branching, trichomes are composed of single (chains of cells), trichomes are cylindrical and usually unsheathed, but a very thin hyaline sheath might be observed at trichome breakage, necridic cells are absent, trichomes are slightly constricted at the cross-walls, end cells rounded, cells are 3.11±0.57 µm long, 1.42±0.15 µm broad.
Habitat: on tree bark; Voucher no: 867; place of collection: Devkund; Date: 30th April 2018.

Order: Nostocales; **Family**: Nostocaceae; **Genus**: *Nostoc*

3. ***Nostoc*** **sp.** (plate 1, fig. 3)
Neustupa and Škaloud 2008, 2008, p. 808, fig-7
Filamentous, unbranched, cylindrical or spherical with intercalary and terminal heterocyst, 7-10 µm in long, 5-10 µm in broad, each filament is covered in a mucilaginous sheath, cells contain chlorophyll, cell barrel shaped,
Habitat: on rock surface, Voucher no: 590; Place of collection: Machhakandana; Date: 26th November 2017.

Order: Nostocales; **Family**: Scytonemataceae; **Genus**: *Scytonema*

4. ***Scytonema burmanicum*** Skuja 1949 (plate 1, fig. 4)
Desikachary 1959, p. 460, Pl. 97, Figs. 1-9
Thallus brownish, sheathed, sheath lamellated, brownish to clear, thick 5-6 µm, broad, filament pseudo branched, trichome slightly constricted at cross walls, heterocyst intercalary, rectangular to compressed, cells barrel shaped to compressed, broader than long, 8.6 µm long, 7.2 µm to 10 µm broad, cell content granular.
Habitat: on bark surface; Voucher no: 861; Place of collection: Devkund, Similipal; Date: 30th April 2018.

5. ***Scytonema javanicum*** (Kütz.) Bornet 1887 (plate 1, fig. 5)
Komárek *et al.* 2013, p. 178, fig. 3 (d)
Filaments 12–15, trichomes 6–10 (14) µm broad, sheaths colorless to yellow, bases of branches usually shortly parallel, trichomes usually compact, hormogonia separate, solitary, cells mostly isodiametric, sheath mostly smooth from the outsides.
Habitat: on rock surface; Voucher no: 011; Place of collection: Jaronda, Similipal; Date: 11th December 2020.

6. ***Scytonema schmidtii*** Gomont 1901 (plate 1, fig. 6)
Komárek *et al.* 2013, p. 186, fig. 10 (a-k)
Filaments cylindrical, binary branches, filaments

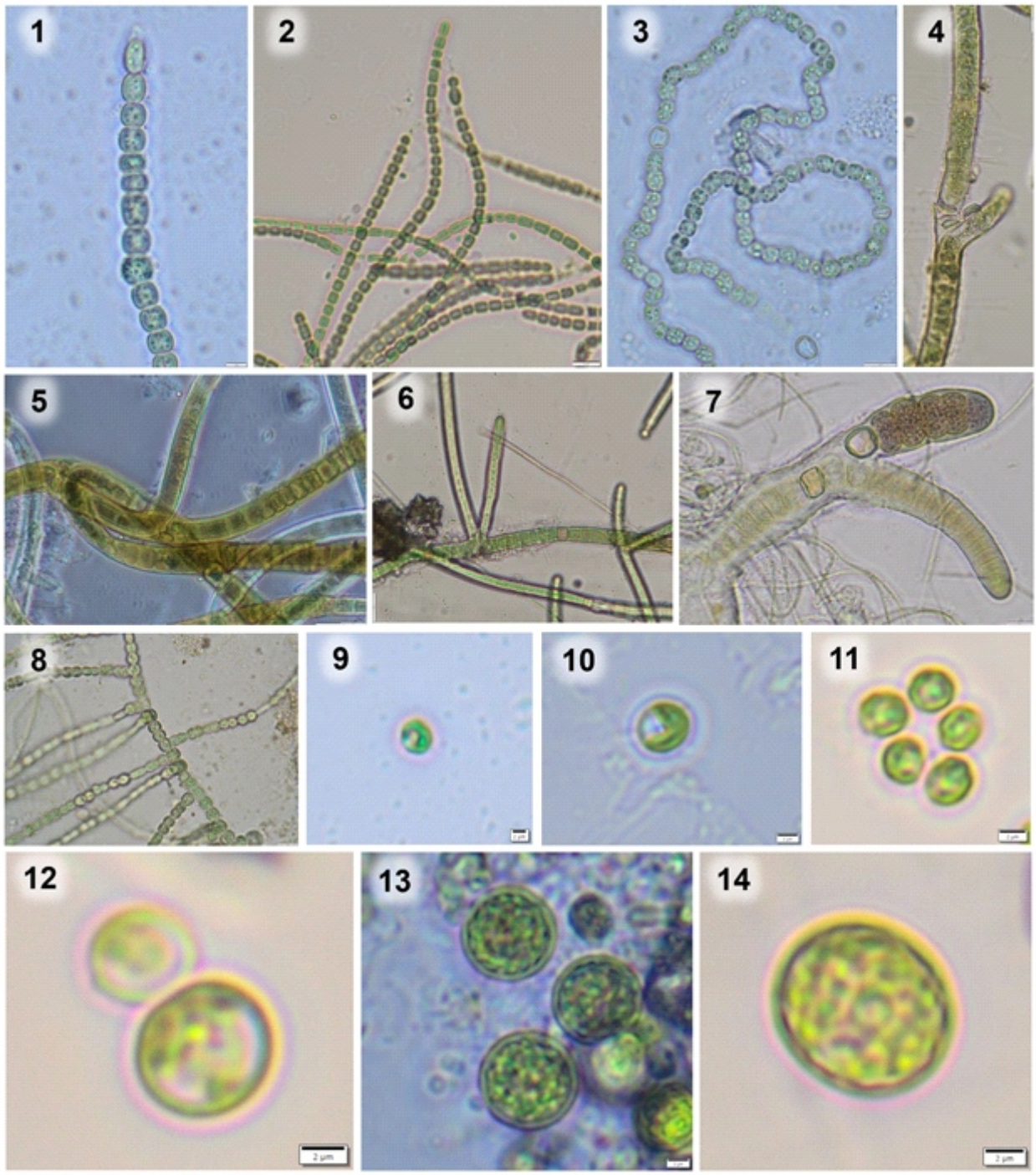

Plate 1 (1-14): Microphotographs of algal species,**1.** *Anabaena fuellebornii* Schmidle, **2.** *Leptolyngbya foveolarum* (Gomont) Anagnostidis et Komárek, **3.** *Nostoc* sp., **4.** *Scytonema burmanicum* Skuja,**5.** *Scytonema javanicum* (Kütz.) Bornet, **6.** *Scytonema schmidtii* Gomont, **7.** *Tolypothrix scytonematoides* (N.L.Gardner) Geitler, **8.** *Westiellopsis prolifica* Janet, **9.** *Chlorella minuta* (Nageli) Oltmanns, **10.** *Chlorella vulgaris* Beyerinck [Beijerinck], **11.** *Chlorococcum* sp., **12.** *Coelastrella* sp., **13.** *Dictyococcus varians* Gerneck, **14.** *Dictyochloropsis* sp.

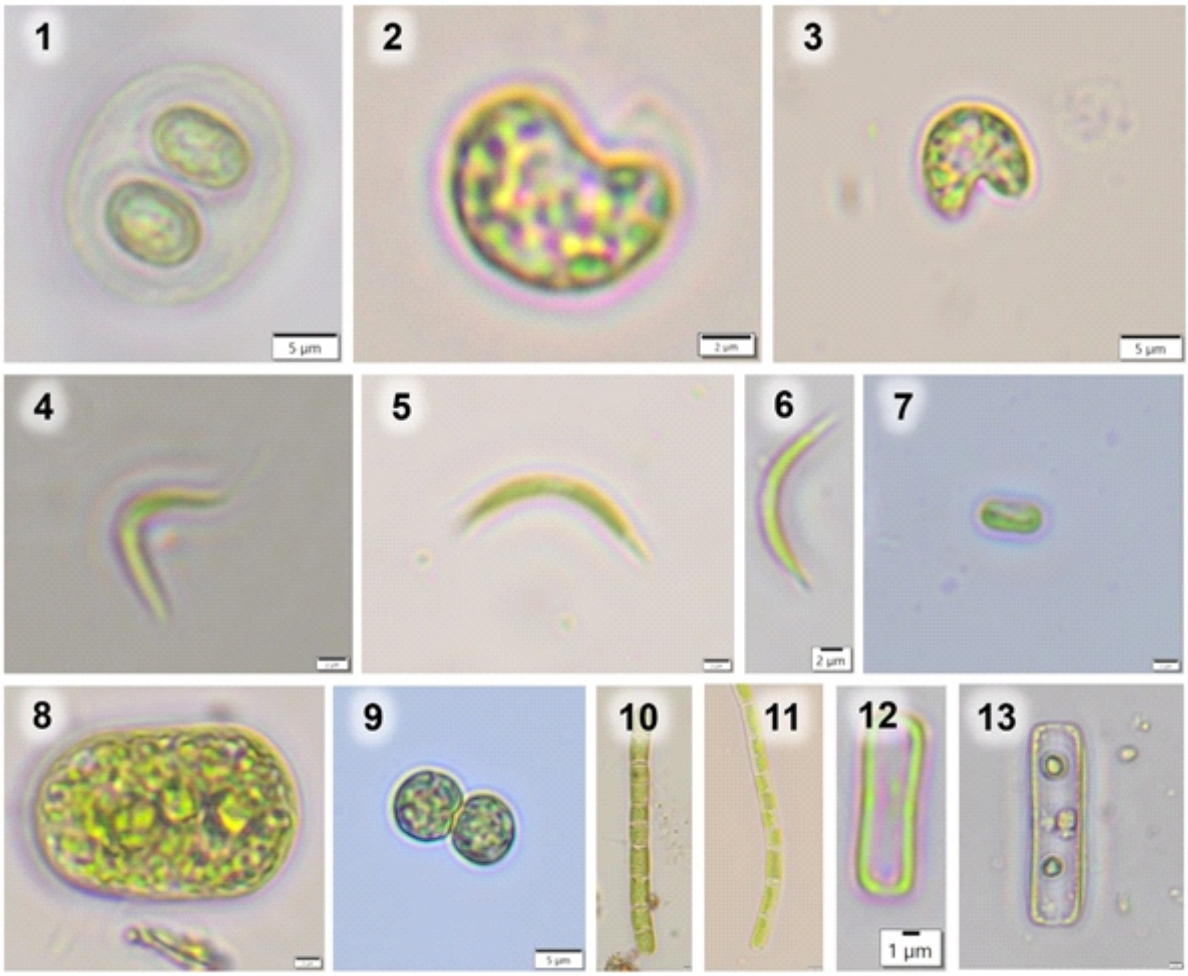

Plate 2 (1-13): Microphotographs of algal species, **1.** *Gloeocystis gigas* (Kützing) Lagerheim, **2.** *Kirchneriella aperta* Teiling, **3.** *Kirchneriella obesa* (West) West & G.S., **4.** *Monoraphidium contortum* (Thuret) Komárková-Legnerová, **5.** *Monoraphidium indicum* Hindak, **6.** *Monoraphidium tortile* (West & G.S.West) Komárková-Legnerová, **7.** *Stichococcus minor* Nägeli, **8.** *Symbiochloris irregularis* (Tak.Nakano & Isagi), **9.** *Cosmarium sp.*, **10.** *Klebsormidium dissectum* (F.Gay) H.Ettl & Gärtner, **11.** *Klebsormidium flaccidum* (Kützing) P.C.Silva, **12.** *Gomphonema* sp., and **13.** *Pinnularia borealis* Ehrenberg.

and branches straight, slightly curved or rarely slightly flexuous, intercalary Heterocyst, usually barrel–shaped,7.5 µm in long,10 µm in broad.
Habitat: black patches on rock surface; Voucher no: 019; Place of collection: Barehipani, Similipal, Date: 11th December 2020.

Order: Nostocales; **Family**: Tolypothrichaceae; **Genus**: *Tolypothrix*

7. *Tolypothrix scytonematoides* (N.L.Gardner) Geitler 1932 (plate 1, fig. 7)
Keshari and Adhikary 2014, p.47, fig-2 (c)
Long filaments bearing spherical, heterocyst arises at which false branching arises, heterocyst is intercalary,4 µm long ,12 µm broad, sheath is thin and not constant, cell cylindrical.
Habitat: Black patches on soil crust; Voucher no: 021; Place of collection: Barehipani, Similipal; Date: 11th December 2021.
Order: Nostocales; **Family**: Hapalosiphonaceae; **Genus**: *Westiellopsis*

8. *Westiellopsis prolifica* Janet 1941 (plate 1, fig. 8)
Pradhan *et al.* 2021, p. 3, fig.2
Filaments torulose and short barrel-shaped cells, 8-12 µm broad and as long as broad or slightly longer, branch-filaments thinner and elongate, not

constricted at the cross walls, with elongate cylindrical cells, 4-6 µm broad, heterocyst oblong cylindrical, 5-5.6 µm broad and 10.5-22 µm long.
Habitat: Green patches on rock surface; voucher no: 587; place of collection: machhakandana, Similipal; Date: 26th November 2017.

Chlorophyta

Order: Chlorellales; **Family**: Chlorellaceae; **Genus**: *Chlorella*

9. *Chlorella minuta* (Nageli) Oltmanns (plate 1, fig. 9)
Vijayan and Ray 2015, p. 789, Plate 3, fig. 41
Cell spherical, 5.28 µm diameter. Chloroplast cup-shaped. Pyrenoid invisible.
Habitat: Green patches on soil crust; Voucher no: 009, Place of collection: Joranda, Similipal; Date: 11th December 2020.

10. *Chlorella vulgaris* Beyerinck [Beijerinck], 1890 (plate 1, fig. 10)
[Synonym: *Chlorella communis Artari* 1906]
Kim and Lee 2014, p. 337, fig. 7 (e)
Cells spherical. Chloroplast broadly cup-shaped or band-shaped, filling one-half to three-quarters (Chung 1993). A pyrenoid visible. Cells 6.4 µm diameter.
Habitat: Greenish black patches on tree bark; Voucher no: 008; Place of collection: Joranda, Similipal; Date: 11th December 2020.

Order: Chlorococcales; **Family**: Chlorococcaceae; **Genus**: *Chlorococcum*

11. *Chlorococcum* sp. (plate 1, fig. 11)
Arguelles 2019, p. 11, pl. II, fig. 1
Unicellular with spherical or slightly oblong cells of varied size, the cell may be solitary or in irregular clumps, cell has a cup-shaped, parietal chloroplast, 1.98 µm diameter.
Habitat: dark green on rock surface; Voucher no: 587; Place of collection: Machhakandana, Similipal; Date: 26th November 2017.

Order: Sphaeropleales; **Family**: Scenedesmaceae; **Genus**: *Coelastrella*

12. *Coelastrella* sp. (plate 1, fig. 12)
Goecke et al., 2020, p. 05, Fig. 1 (a-d),
Neustupa and Škaloud 2008, p. 808, fig. 14
Unicellular dark green microalga, cellular and grows in variable forms from spheroidal to ellipsoidal. A single pyrenoid is visible; cells with a smooth polar thickening were observed as well as others still surrounded by sporangium walls, autospores in aggregation with a pyrenoid. The cells presented variable sizes, but usually were 7–10 µm long and 6–9 µm broad. Cell wall appears to be hyaline, chloroplast cup-shaped, A stricken and single pyrenoid was clearly visible.
Habitat: on soil crust; Voucher no-865, Place of collection: Devkund, Similipal; Date: 30th April 2018.

Order: Sphaeropleales; **Family**: Chlorophyceae; **Genus**: *Dictyococcus*

13. *Dictyococcus varians* Gerneck, 1907 (plate 1, fig. 13)
[Synonym: *Dictyococcus varians* Gerneck]
Vijayan and Ray 2015, plate 1, p. 787, fig. 12
Cell spherical ,11.22 µm diameter, green in colour
Habitat: black patches on rock surface; Voucher no: 002; Place of collection: Bhajam, Similipal; Date: 11th December 2020.

Order: Trebouxiales; **Family**: Trebouxiaceae; **Genus**: *Dictyochloropsis*

14. *Dictyochloropsis* sp. (plate 1, fig. 14)
Neustupa and Škaloud 2010, p. 57, fig. 3 (i)
Unicellular, Spherical green cells, globular,9.8 µm diameter, surrounded by a thick envelope, reticulate chloroplast, uninucleate, 7 - 45 µm diameter.
Habitat: On soil crust; Voucher no: 855; Place of collection: Devkund, Similipal; Date: 30th April 2018.

Order: Sphaeropleales; **Family**: Chlorophyceae; **Genus**: *Gloeocystis*

15. *Gloeocystis gigas* (Kützing) Lagerheim, 1883 (plate 2, fig. 1)
Mahendra, Peremal and Anand 2008, pl-11, p.70, fig. 8
2 celled, oval shape not attached to each other, each enveloped with light green colour layered mucilage and attached, colonies often forming well-developed macroscopical mucilaginous sheaths which is oval in shape,19.25 µm long and 15.4 µm broad.
Habitat: Black patches on soil crust; Voucher no: 025, Place of collection: Barehipani, Similipal;

Date: 11th December 2020.

Order: Sphaeropleales; **Family**: Selenastraceae; **Genus**: *Kirchneriella*

16. *Kirchneriella aperta* Teiling, 1912 (plate 2, fig. 2)
[Synonyms- *Kirchneriella* obesa var. aperta (Teiling) Brunthaler, Kirchneriella obesa var. pygmaea W. and G.S. West]
Prescott 1961, p. 259, pl. 58, figs. 6, 7
Cells slightly lunate, with the inner margins of the cell describing a much greater arc than the outer, cells 5.5 – 6 µm in diameter and 12- 15 µm long.
Habitat: On tree bark; Voucher no: 863; Place of collection: Devkund, Similipal; Date: 30th April 2018.

17. *Kirchneriella obesa* (West) West & G.S. (plate 2, fig. 3)
[Synonym: *Selenastrum obesum* West]
Das and Adhikary 2014, p. 176, pl. 13, fig. 25.
Coenobia 64 celled, irregularly arranged, cells strongly lunate with the ends almost near each other, outer side convex, ends of cells tapering with rounded bluntly pointed apices, cells 10-11 µm long and 6-7 µm broad; planktonic.
Habitat: On tree bark, Voucher no: 861; Place of collection: Devkund, Similipal; Date: 30th April 2018.
Order: Chlorococcales; **Family**: Chlorophyceae; **Genus**: *Monoraphidium*

18. *Monoraphidium contortum* (Thuret) Komárková-Legnerová 1969 (Plate 2, fig. 4)
[Basionym: *Ankistrodesmus contortus* Thuret]
[Synonym: *Ankistrodesmus falcatus* var.duplex (Kutzing) G.S. West]
Komárek and Fott 1983, p. 638, pl.178, fig.4
Fusiform cells, sigmoidaly bent, 33 – 35 µm long and 3 – 5.5 µm broad, chloroplast parietal.
Habitat: Black patches on tree bark; Voucher no: 018; Place of collection: Barehipani, Similipal; Date: 11th December 2020.

19. *Monoraphidium indicum* Hindak 1977 (plate 2, fig. 5)
Hindak 1977, p.105, pl. 44
Pg- 173, Das and Adhikary 2014 (plate 13, fig 14)
Cells singular, very thin, fusiform,narcuately curved, tapering gradually towords the end and pointed, 40-50µm long and 1.7-2.0 µm broad, chloroplast mostly covers the entire parietal perimeter of the cell, without pyrenoids.
Habitat: black patches on soil crust; Voucher no: 021; Place of collection: Barehipani, Similipal; Date: 11th December 2020.

20. *Monoraphidium tortile* (West & G.S.West) Komárková-Legnerová1969 (plate 2, fig. 6)
[Synonyms: *Ankistrodesmus tortilis* West & G.S.West, *Ankistrodesmus pseudobraunii* Belcher and Swale]
Das and Adhikary 2014, p. 174, pl. 13, fig. 20
Komárek and Fott 1983, p. 631, pl. 176, fig. 2
Cells fusiform, slightly bent, with thinly attenuated ends, 43-44 µm long and 3-4 µm broad, chloroplast fills the entire parietal perimeter of the cell; planktonic.
Habitat: On tree bark; Voucher no: 854; Place of collection: Devkund, Similipal; Date: 30th April 2021.

Order: Prasiolales; **Family**: Prasiolaceae; **Genus**: *Stichococcus*

21. *Stichococcus minor* Nägeli, 1849 (plate 2, fig. 7)
Khaybullina *et al.* 2010, p. 209, fig. 31
Cells solitary, sometimes in very short filaments (2–4 cells), cylindrical, with rounded ends, 4–5µm long, 1–3 µm broad. Chloroplast bright–green with smooth margin. Cytoplasm with small granules, oil droplets near poles of largest cells. This alga is very common in soils, on bark, and on rocks.
Habitat: Black patches on rock surface; Voucher no: 011; Place of collection: Joranda, Similipal; Date: 11th December 2020.

Order: Trebouxiales; **Family**: Trebouxiophyceae; **Genus**: *Symbiochloris*

22. *Symbiochloris irregularis* (Tak.Nakano & Isagi) (plate 2, fig. 8)
Škaloud et al. 2016, p. 9, fig. 5, (h–l)
[Basionym: *Dictyochloropsis irregularis*]
Cells ellipsoidal, ovoid, pyriform, reniform or irregularly oblong, up to 25 µm long and 18 µm broad.
Habitat: Bluish green patches on tree bark; Voucher no: 026; Place of collection: Chahala, Similipal: Date: 11th December 2020.

Charophytes

Order: Desmidiales; **Family**: Desmidiaceae; **Genus**: *Cosmarium*

23. *Cosmarium* sp. (plate 2, fig. 9)
Cells as long as broad, yellowish green to deep green, sinus constricted, narrow and linear, semi cells quadrate, flatted, slightly depressed at the middle, cells 46- 50 µm long and 43 – 47 µm broad, isthmus 14 – 15 µm broad.
Habitat: Green patches on soil crust; Voucher no: 009; Place of collection: Joranda, Similipal; Date: 11th December 2021.
Order: Klebsormidiales; **Family**: Klebsormidiaceae; **Genus**: *Klebsormidium*

24. *Klebsormidium dissectum* (F.Gay) H.Ettl & Gärtner, 1995 (plate 2, fig. 10)
Kim and Lee 2014, p.335, fig. 6 (b)
Filaments straight or slightly bent. Cell walls straight. Chloroplast encircling half to just over two-thirds of cell circumference. Cells 7-15 µm long, 5-8 µm broad.
Habitat: Bluish green patches on tree bark; Voucher no: 026; Place of collection: Chahala, Similipal; Date: 11th December 2021.

25. Klebsormidium flaccidum (Kützing) P.C.Silva, 1965 (plate 2, fig. 11)
[Synonym: *Chlorhormidium flaccidum* (Kuetzing) Fott]
Kim and Lee 2014 p.335, Fig. 6 (c)
Filaments long, bent or twisted, cells cylindrical, walls thin, chloroplast encircles, cells 8-20 µm long, 6.5-7 µm broad, 1 to 3 times longer than broad.
Habitat: Bluish green patches on tree bark; Voucher no: 026; Place of collection: Chahala, Similipal; Date: 11th December 2020.

Diatoms
Order: Cymbellales; **Family**: Gomphonemataceae; **Genus**: *Diadesmis*

26. *Gomphonema* sp. (plate 2, fig. 12)
Neustupa and Škaloud 2010, p. 53, fig. 1 (P)
Valves are elliptic, with apiculate apices, central area is broad and rounded, axial area tapers from the central area, narrower toward the ends, A rounded, thickened central nodule is visible on the interior valve, raphe is straight and filiform, striae are radiate, punctate, and crossed by longitudinal wavy lines, Striae are variable in length.
Habitat: Black patches on soil crust; Voucher no: 025; Place of collection: Barehipani, Similipal; Date: 11th December 2020.

Order: Naviculales; **Family**: Pinnulariaceae; **Genus**: *Pinnularia*

27. *Pinnularia borealis* Ehrenberg, 1843 (plate 2, fig. 13)
[Synonym: *Navicula borealis* (Ehrenberg) Kützing]
Stace *et al*. 2005, p. 65, fig. 2 (B)
Chloroplast present in cell, cell size 30-40 µm long, 8-15 µm broad, raphes slightly curved.
Habitat: Brown patches on soil crust; Voucher no: 016; Place of collection: Barehipani, Similipal; Date: 11th December 2021.

Discussion

Tropical semi-evergreen woods, tropical moist deciduous forests, dry deciduous hill forests, high level sal forests, and expansive meadows are present in kthis biosphere (Upadhyay *et al.* 2012). The Erenga Kharias and the Mankirdias are two tribes who live in the reserve's forests and are engaged in traditional agricultural pursuits (the collection of seeds and timber (Upadhyay *et al.* 2012). Similipal is home to a diverse assortment of wild creatures, including tigers and elephants, as well as 304 bird species, 20 amphibian species, and 62 reptile specie (Dash and Behera 2012). In addition to this, Similipal biosphere reserve are also good habitat for cyanobacteria and algal diversity (Bhakta *et al.* 2015; Bhakta *et al.* 2014; Jena *et al.* 2006). The finding of present study presented 27 subaerial algae reported from the Similipal biosphere reserve, Odisha. It is important to note that out of these 27 algal species, 23 subaerial algal species were recorded for the first time from the Odisha state, which included *Anabaena fuellebornii* Schmidle, *Leptolyngbya foveolarum* (Gomont) Anagnostidis et Komárek, *Nostoc* sp., *Tolypothrix scytonematoides* (N.L.Gardner) Geitler, *Westiellopsis prolifica* Janet, *Chlorella minuta* (Nageli) Oltmanns, *Chlorococcum* sp., *Coelastrella* sp., *Dictyococcus varians* Gerneck, *Dictyochloropsis* sp., *Gloeocystis gigas* (Kützing) Lagerheim, *Kirchneriella aperta* Teiling, *Kirchneriella obesa* (West) West & G.S., *Monoraphidium contortum* (Thuret) Komárková-Legnerová, *Monoraphidium indicum* Hindak, *Monoraphidium tortile* (West & G.S.West)

Komárková-Legnerová, *Stichococcus minor* Nägeli, *Symbiochloris irregularis* (Tak.Nakano & Isagi, *Cosmarium* sp., *Klebsormidium dissectum* (F.Gay) H.Ettl & Gärtner, *Klebsormidium flaccidum* (Kützing) P.C.Silva, *Gomphonema* sp., *Pinnularia borealis* Ehrenberg. Remaining 4 algal species previously reported from this area are: *Scytonema burmanicum* Skuja, *Scytonema javanicum* (Kütz.) Bornet, *Scytonema schmidtii* Gomont, and *Chlorella vulgaris* Beyerinck [Beijerinck] (Bhakta *et al.* 2015, Bhakta *et al.* 2014, Jena *et al.* 2006). Our findings of the present study are in agreement with the previous reports on subaerial algae diversity from several parts of India (Keshari and Adhikary 2014, Bhakta *et al.* 2015, Bhakta *et al.* 2014). Similar research was done on the dynamics of species richness of bark algae and cyanobacteria in South-East Asian rain forest mountainous settings and the species are belongs from green algae such as *Dictyochloropsis* spp., *Pseudomarvania aerophytica, Printzina effusa* and *Printzina lagenifera* of families Trebouxiophyceae, Chlorophyceae and Trentepohliales which are dominant (). Furthermore, it has been discovered that the Similipal biosphere reserve in Odisha is a key habitat for bio-resources in terms of the existence of important sub-aerial microalgal species, which have numerous applications in aquaculture and biotechnology. Moreover, these algae can be used as dietary supplements, natural antioxidants and can also be used in several ROS-associated diseases. In addition to this, Similipal biosphere reserve, Odisha are the unique and potential subaerial habitat as there are several species recorded for the first time in this study.

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