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ALGAL DIVERSITY OF SALTPANS, HUMMA (GANJAM), ODISHA, INDIA

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A total of 39 algal species were recorded from Saltpans of Humma. These algal species belonged to 23 genera of five divisions; Cyanobacteria, Bacillariophyta, Euglenophyta, Chlorophyta and Charophyta. Out of these 39 algal species, 11 halophilic algal species, such as *Gomphosphaeria salina* Komárek & Hindák, *Phormidium kolkwitzii* Komárek and Anagnostidis, *Microcoleus vaginatus* Gomont ex Gomont, *Symploca cartilaginea* Gomont ex Gomont, *Nodularia spumigena* Mertens ex Bornet et Flahault, *Navicula menisculus* Schumann, *Anomoeoneis sphaerophora* Pfitzer, *Anisonema acinus* Dujardin, *Tetraselmis indica* Arora and Anil in Arora & al., *Printziella biflagellata* Skvortsov, and *Nitella hyalina* (De Candolle) C. Agardh. were recorded for the first time from the Odisha state. Some important microalgal species are recorded in the present investigation such as *Spirulina labyrinthiform*is Kützing ex Gomont, *Spirulina major* Kützing ex Gomont, *Spirulina subsalsa* Oersted ex Gomont, *Chlorella vulgaris*, *Tetraselmis indica* Arora & Anil. *Printziella biflagellata* Skvortsov, which are having many applications in aquaculture and in biotechnology.

Keywords: Algal diversity, cyanobacteria, salinity, saltpans

Odisha state has a coastline of 485 km with a wide range of marine environments which provide a good scope to explore marine biodiversity resources for human welfare. Saltpans are constructed for the production of raw salt from the seawater by evaporation. The main characteristic of saltpans is the change of salinity from normal saline conditions to hypersaline conditions, which is a serious environmental concern. Saltpan ecosystem is highly variable, where the organisms are subjected to vulnerable physicochemical disturbances. Salinity is a very important ecological factor impelling the species diversity in the marine environment. Generally the hypersaline conditions of the solar saltpan ecosystems represent low species diversity. Algal diversity dynamics is changed according to the salinity factor of marine habitats. The algae are abundantly present in the marine environment and also have been reported from the extreme saline environment such as salterns, brine lakes and salt springs where the salinity condition is about two to seventeen times more than the ocean (Oren 2012; Ventosa *et al.* 2015). Moreover, the occurrence of some species of cyanobacteria, diatoms and green algae is restricted only to the high salinity level salt pans and hypersaline environments. (Korovessis and Lekkas 2000). These organisms play a very important role in the recycling of materials (nutrients and other substances) in the saltpan ecosystem and occupy important membership in biogeochemical cycles (Kabilan *et al.* 2012). There is little information available on algal diversity of salt pan environments in India (Thajuddin *et al.* 2002, Irenewilsy *et al.* 2008; Nagasathya and Thajuddin 2008, Ashok Kumar *et al.* 2011, Modassir *et al.* 2011; Sugumar *et al.* 2011, Arora *et al.* 2013). In Odisha, although substantial work has been done on freshwater algal diversity (Jena *et al.* 2005, Jena *et al.* 2006 a, b, c; Ratha *et al.* 2006, 2007, Jena and Adhikary 2007, Adhikary *et al.* 2009, Jena and Adhikary 2011, Adhikary and Jena 2012, Behera *et al.* 2020, Dash *et al.* 2020) and few reports on marine algal diversity are available (Rath and Adhikary 2005, Maharana *et al.* 2019, Rath and Adhikary 2006), no published record is available on the halophilic algae from saltpans of Humma, Odisha. Hence, an attempt has been made to document information on the algal diversity in

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the saltpans of Humma (Ganjam), Odisha, East Coast of India.

MATERIALS AND METHODS

The study sites: The algal samples were collected from salt pans located near village Humma (Latitude 19˚49′5.91″N and Longitude 85˚16′29.067″E) of Ganjam district, Odisha. The algal samples were collected during June 2016, December 2018 and June 2019. A total of 6 sites (S1-S6) which included shallow evaporation pond (S1, S2, S5, S6), shallow pond connected to the creek (S3) and evaporation pond (S4) were selected for sampling. The details of collection sites are shown in figure 1.

Sampling: A total of 55 samples were collected in sterilized centrifuge tubes/plastic jars. Saltpans' water samples were collected by a plankton net of 25 µm mesh size (Hydro-Bios Kiel, Cat. No. 438001). The visually occurrening algae in the saltpans such as epilithic, benthic and epiphytic, were collected by using forceps, needle and brush. The physio-chemical parameters of water samples such as salinity, pH, temperature, and conductivity were recorded by water analyzer (Globe Instruments, Model no. 3570G) on the spot.

Sample preservation: One set of the sample was preserved in 4% (v/v) formaldehyde on the spot and the other set comprising planktic samples was fixed in 0.5% Lugol's iodine solution for microscopic observation. A voucher number was given to each sample and deposited at the Department of Botany, Berhampur University.

Microscopy and microphotography: Preseved samples were observed under a phase-contrast microscope (Olympus, Model no. BX53). The microphotographs of each species were taken by the digital camera (Olympus SC180) attached with a phase-contrast microscope.

Morphological identification: The morphological characteristics of algal species were recorded and algal species were identified by following published literature (Desikachary 1959; Pal *et al.* 1962; Philipose 1967; Iyenger and Desikachary 1981; Cox 1996; Komárek

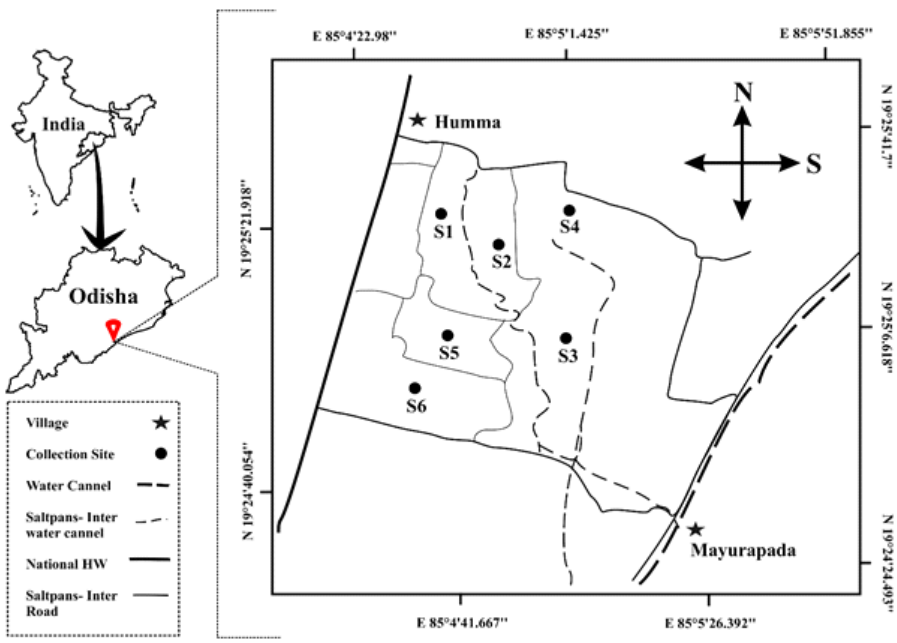

Figure. 1: Map showing the sample collection sites of saltpans, Humma. S1, S2, S5 and S6: shallow evaporation pond, S3: shallow pond connected to creek, S4: evaporation pond.

Table1: Table 1: Physico-chemical parameters of six collection sites of saltpans, Humma (Gangam), Odisha, India

Parameters	S1	S2	S3	S4	S5	S6
Salinity (ppt.)	38-44	40-46	30-34	50- 58	35-38	30-35
pH	7.6-7.7	7.6-7.7	8.4-8.9	7.4-8.2	7.9-8.7	8.8-8.8
Temperature (°C)	26.5-27.5	27.5-28.5	26.1-31.6	33.1-34.6	28.1-29.6	27.1-32.2
Conductivity (ms/cm)	15.1-16.4	16.1-17,1	30.1-33.1	14.1-18.1	15.1-22.1	20.9-22.6

and Anagnostidis 1999; Wołowski and Hindak 2005; Komárek and Anagnostidis 2005; Adhikary *et al.* 2009; Karthick *et al.* 2013;Komárek 2013).

RESULTS

A total of 39 algal species were recorded from Saltpans of Humma. These species belonged to 12 orders and 19 families of five divisions: Cyanobacteria, Bacillariophyta, Euglenophyta, Chlorophyta and Charophyta. Further, these algal species were represented by 23 genera : *Merismopedia, Gomphosphaeria, Chroococcus, Spirulina, Phormidium, Microcoleus, Symploca, Oscillatoria, Lyngbya, Nodularia, Navicula, Gyrosigma, Pleurosigma, Stauronies, Amphora, Anomoeoneis, Nitzschia, Anisonema*, *Chlorella*, *Tetraselmis*, *Printziella, Nitella a*nd *Chara*. It was observed that among five divisions, the Cyanobacteria was dominant (56% of the total species) followed by Bacillariophyta (25% of total species). The details of the physico-chemicals parameters of saltpans are presented in Table1. The salinity of shallow evaporation pond, temporarily seawater holding pond and creek ranged between 30-46 ppt and the salinity of evaporation pond ranged between 50-58 ppt. The other physico-chemicals parameters like pH, temperature and conductivity were not significantly different among the six sites. Moreover, the occurrence of Cyanobacterial species were more in the evaporation pond (S4) with salinity (50-58 ppt) during 2016-2019. The microphotographs of identified algal species are shown figs. 2 & 3. The details of the systematic accounts of all the algal species are described below:

Systematic Accounts and Taxonomic Enumeration of Algal Species

Division:**Cyanobacteria**
Class: **Cyanophyceae**
Order: **Chroocaccales**
Family: **Merismopediaceae**
Genus: ***Merismopedia*** Meyen**,** 1839

1. ***Merismopedia glauca*** (Ehrenberg) Kützing 1845 (Fig. 2a), Komárek and Anagnostidis 1999, p. 177, fig. 225; Jena *et al.* 2005, p. 71, pl. 1, fig. 1.
Colonies mostly small, flat, quadrate with 16-64 cells, less densely or irregularly arranged cells; colonies mucilaginous, diffluent but distinct, 3-6 µm, pale blue green. Cells oval or hemispherical, 3-8 µm in dimeter.
Planktic; site (S2); voucher no. HSP05, date: 07.06.2016; site (S6); voucher no. HSP16, date: 21.12. 2019.

Family: **Gomphosphaeriaceae**
Genus: ***Gomphosphaeria*** Kützing, 1836
2. *Gomphosphaeria salina* Komárek & Hindák 1988 (18) (Fig. 2b), Komárek and Anagnostidis 1999, p. 221, fig. 291.
Colonies microscopic, usually solitary, sporadically spherical, 100-112 µm long, with radially inclined cells; mucilaginous, colourless, wide, hyaline; cells obovoid or marginally cup-shaped, homogenous, brightly blue-green.
Planktic; site (S1); voucher no. HSP03, date: 07.06.2016, voucher no. HSP33, date: 18.06.2016.

Family: **Chroococcaceae**

Genus: ***Chroococcus*** Nägeli 1849

3. *Chroococcus minutus* (Kützing) Nägeli, 1849 (Fig. 2c), Komárek and Anagnostidis 1999, p. 296, fig. 391.

Cells solitary or in microscopic, few celled colonies (2-8 cells), cells embedded in homogenous gelatinous mass, cells spherical or oval pale blue green in colour, 4-6 µm in diameter.

Planktic; site (S1); voucher no. HSP34, date: 18.06.2019.

4. *Chroococcus prescottii* Drouet & Daily in Drouet, 1942 (Fig. 2d), Komárek and Anagnostidis 1999, p. 288, fig. 377-381.

Colonies microscopic with 4 cells, cells more

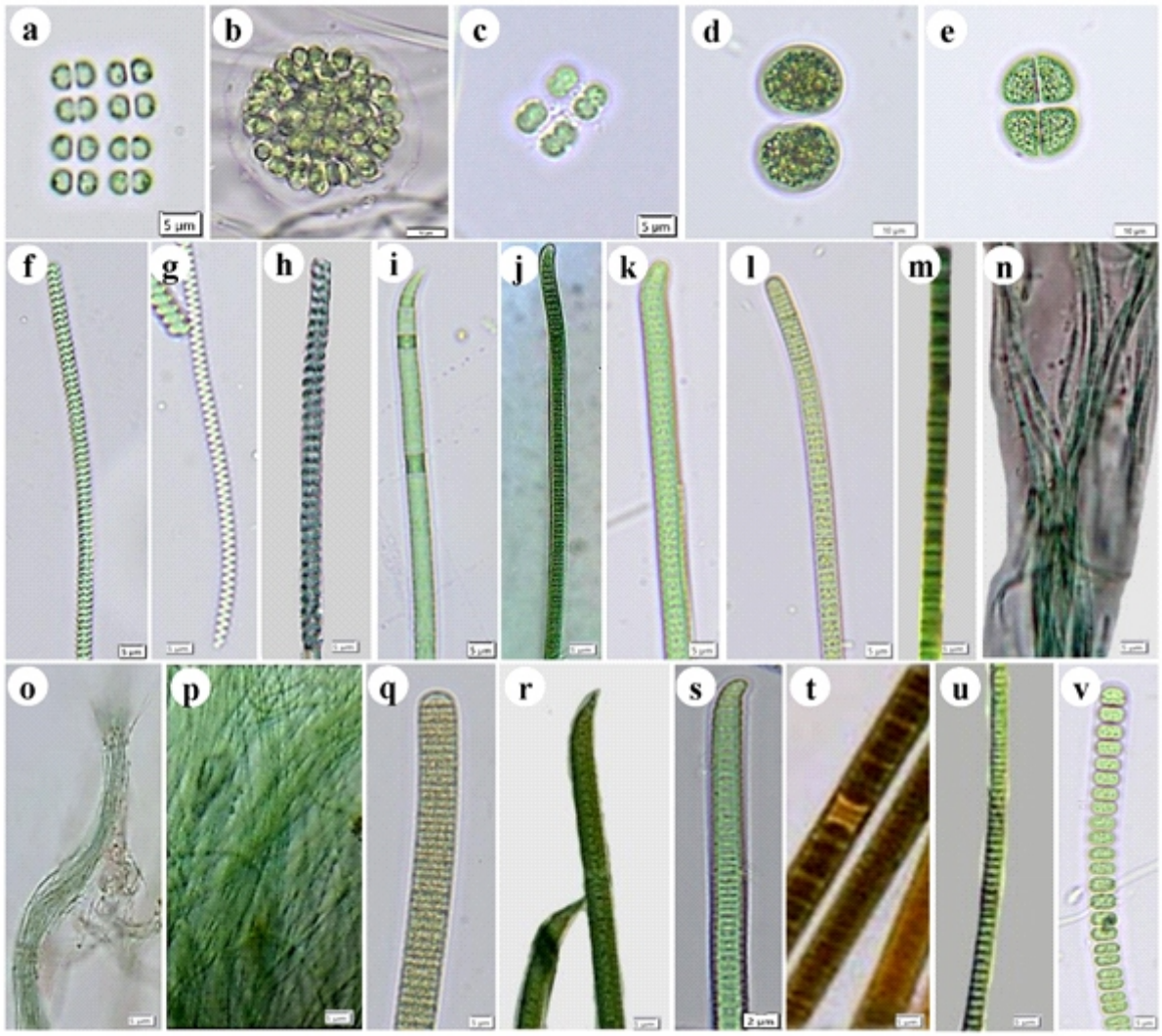

Figure 2 (a-v): Microphotographs of cyanobacterial species, (a) *Merismopedia glauca* (Ehrenberg) Kützing, (b) *Gomphosphaeria salina* Komárek & Hindák, (c) *Chroococcus minutus* (Kützing) Nägeli (d) *Chroococcus prescottii* Drouet & Daily in Drouet, (e) *Chroococcus turgidus* (Kützing) Nägeli, (f) *Spirulina labyrinthiformis* Kützing ex Gomont, (g) *Spirulina major* Kützing ex Gomont, (h) *Spirulina subsalsa* Oersted ex Gomont, (i) *Phormidium animale* (C. Agardh ex Gomont) Anagnostidis & Komárek, (j) *Phormidium bulgaricum* (Komarek) Anagnostidis et Komárek, (k) *Phormidium formosum* (Bory ex Gomont) Anagnostidis et Komárek, (l) *Phormidium kolkwitzii* Komárek in Anagnostidis, (m) *Phormidium retzii* (Agardh) Kützing ex Gomont, (n) *Microcoleus chthonoplastes* Thuret ex Gomont, (o) *Microcoleus vaginatus* Gomont ex Gomont, (p) *Symploca cartilaginea* Gomont ex Gomont, (q) *Oscillatoria limosa* Agardh ex Gomont, (r) *Oscillatoria salina* Biswas, (s) *Oscillatoria tenuis* Agardh ex Gomont, (t) *Lyngbya aestuarii* Liebman ex Gomont, (u) *Lyngbya semiplena* J. Agardh ex Gomont, (v) *Nodularia spumigena* Mertens ex Bornet et Flahault.

or less sub-spherical or irregularly oval shaped, are arranged in rectangular, often slightly lamellate envelope, blue green colour, 6-7 µm diameter.
Planktic; site (S6); voucher no. HSP32, date: 21.12.2018; epipelic; site (S4), voucher no. HSP45, date: 18.06.2019.

5. ***Chroococcus turgidus*** (Kützing) Nägeli, 1849 (Fig. 2e) , Adhikary *et al.* 2009, p. 12, p. pl. 11, fig. 15; Maharana *et al.* 2019, p. 739, pl. 2, fig. 6.

Colonies microscopic, generally 2-4-celled, rarely in solitary, spherical, granulated, ellipsoidal,13-25 µm; sheath hyaline, 2-3 µm thick, often lamellate, blue-green.
Planktic; site (S2); voucher no. HSP05, date: 07.06.2016; voucher no. HSP37, date:18.06.2019.

Ordrer: **Spirulinales**
Family: **Spirulinaceae**
Genus: ***Spirulina*** Turpin ex Gomont 1892

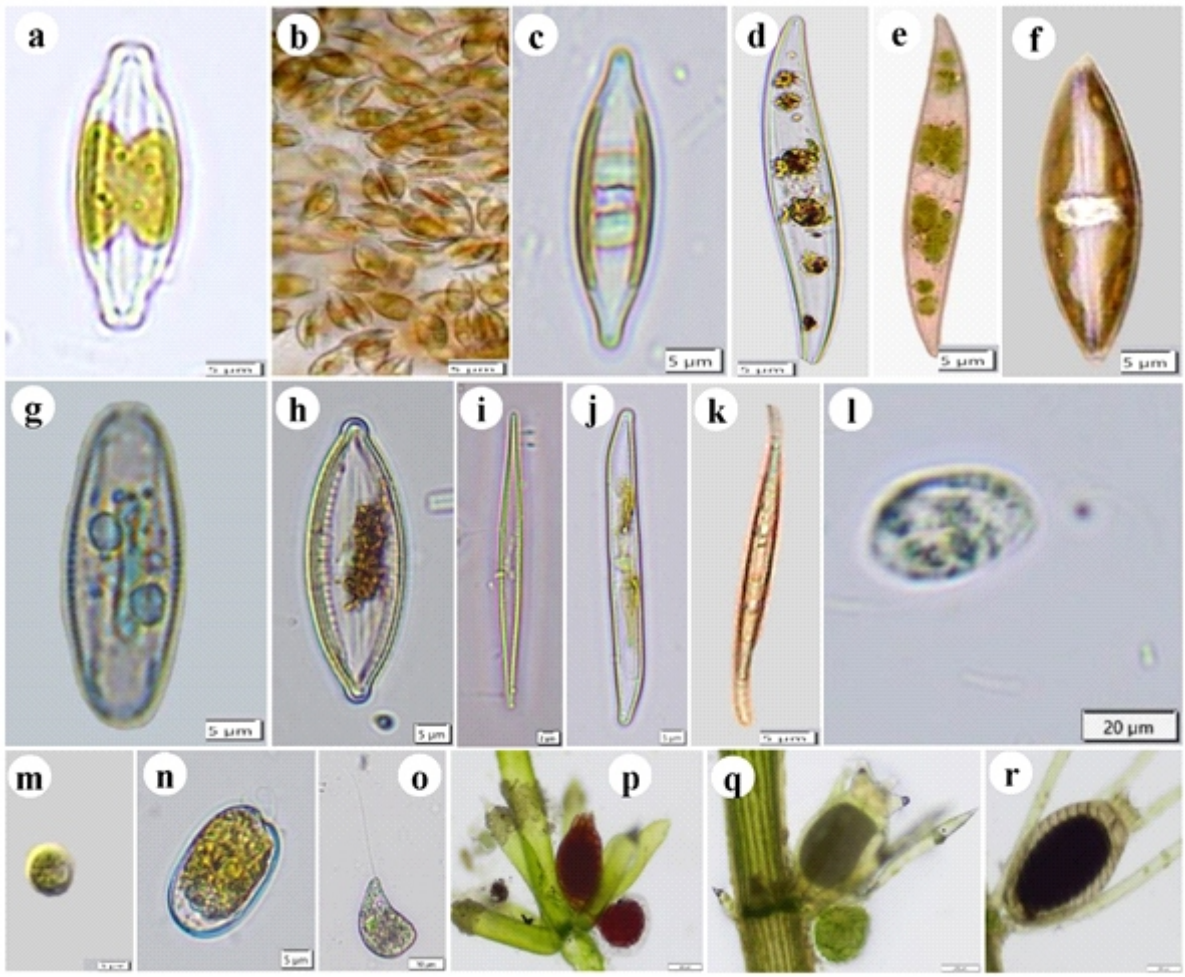

Figure 3 (a-r): Microphotographs of algal species, (a) *Navicula menisculus* Schumann, (b) *Navicula pelliculosa* (Kützing) Hilse, (c) *Navicula salinarum* Grunow, (d) *Gyrosigma acuminatum* (Kützing) Rabenhorst, (e) *Pleurosigma normanii* Ralfs, (f) *Stauroneis pusilla* Ehrenberg, (g) *Amphora ovalis* (Kützing) Kützing, (h) *Anomoeoneis sphaerophora* Pfitzer, (i) *Nitzschia agnita* Hustedt, (j) *Nitzschia obtusa* W. Smith, (k) *Nitzschia sigma* (Kützing) W. Smith, (l) *Anisonema acinus* Dujardin, (m) *Chlorella vulgaris* Beyerinck [Beijerinck], (n) *Tetraselmis indica* Arora & Anil in Arora & al., (o) *Printziella biflagellata* Skvortsov, (p) *Nitella hyalina* (De Candolle) C. Agardh, (q & r) *Chara globularis* Thuiller

6. *Spirulina labyrinthiformis* Kützing ex Gomont, 1892 (Fig. 2f), Komárek and Anagnostidis 2005, p.146, fig.171; Jena *et al*. 2005, p. 71, pl. 1, fig. 2.
Thallus flaky, thin, smooth, blackish green or dark blue-green; trichomes not often solitary, free floating, forming mats, pale to bright blue-green, regularly and thickly spirally coiled with right handed screw like, simultaneous rapid gliding, 0.8-1.4 µm wide, 77-120 µm long, but often are very long. Cells pale blue-green, 2.2-3 µm wide. Coils mostly short and straight, tightly joined one with another, apices rounded.
Epipelic; site (S1); voucher no. HSP1, HSP2, date: 07.06.2016; epipelic; site (S4), voucher no. HSP43, date: 18.06.2019.

7. *Spirulina major* Kützing ex Gomont, 1892 (Fig. 2g), Komárek and Anagnostitidis 2005, fig.174, p.148
Trichome pale to bright blue green, mostly solitary, rarely agglomerated to mostly microscopic, fragile, bright to dark blue-green thallus, 1-3 µm wide, coiled regularly screw like, slightly constricted cross walls, 280-820 µm long; coils left handed, distance between spirals, 2.5-4.5 µm.
Planktic; site (S1); voucher no. HSP10, date: 07.06.2016; site (S2); voucher no. HSP47, 21.12.2018.

8. *Spirulina subsalsa* Oersted ex Gomont, 1892 (Fig. 2h), Komárek and Anagnostidis 2005, p.150, fig.176; Adhikary *et al.* 2009, p. 13, pl. 12, fig. 2.
Thallus soft, thin, mucilaginous, bright blue-green to blackish, solitary, trichomes straight or variously curved, sometimes circle like (spirally) coiled, not constricted at the cross walls, 1-2 µm wide, (rarely with irregularities); coils dextral, regularly tightly joined to one another, nearly parallel arranged, only exceptionally (especially at the trichome ends), somewhat irregularly loosely coiled and not attaching together with very intense right handed screw like rotation and simultaneous gliding.
Free floating; site (S4); voucher no. HSP27, date: 21.12.2018; voucher no. HSP44, date: 18.06.2019.

Order: **Oscillatoriales**
Family: **Phormidiaceae**
Genus: ***Phormidium*** Kützing ex Gomont, 1892

9. *Phormidium animale* (C. Agardh ex Gomont) Anagnostidis & Komárek 1988 (Fig. 2i), Adhikary *et al.* 2009, p.13, pl. 13, fig. 8.
Thallus blue green to dark blue green; trichome straight, long, attenuated, not constricted at cross walls; cells 2.5-4 µm broad and 1-2 µm long; end cell longer than other cells, apical cell pointed.
Epipelic; site (S1), voucher no. HSP3, date: 07.06.2016; site (S6), voucher no. HSP29, date: 21.12.2018.

10. *Phormidium bulgaricum* (Komárek) Anagnostidis and Komárek 1988 (Fig. 2j), Komárek and Anagnostidis 2005, p. 442, fig. 642.
Filaments usually without sheaths, bluish green; trichomes among other cyanobacteria in mats, straight or slightly curved, very slightly constricted at cross-walls; cells cylindrical, 1-5 µm long, with pale blue-green, homogenous content, usually granulated, no granulation at cross walls; apical cells widely-rounded.
Free floating; site (S5), voucher no. HSP14, date: 07.06.2016; site (S5), voucher no. HSP50, date: 18.06.2019.

11. *Phormidium formosum* (Bory ex Gomont) Anagnostidis and Komárek, 1988 (Fig. 2k), Komárek and Anagnostidis 2005, p. 421, fig. 602.
Thallus slightly blue green to blackish green; trichomes straight, long, bright blue green, 4-6.5 µm wide, extremely motile with oscillation, slightly constricted at cross walls, slightly granulated, slightly attenuated towards ends and bent; sheaths very thin or not visible, cells are isodiametric or broader than long; apical cells obtuse-conical or rounded-conical or acutely rounded, not capitate, no calyptra.

Free floating; site (S1), voucher no. HSP35, date: 21.12.2018.

12. ***Phormidium kolkwitzii*** Komárek in Anagnostidis 2001 (Fig. 2l), Komárek and Anagnostidis 2005, p. 409, fig. 576.
Thallus membranaceus, blue green, or solitary trichomes, 5-6 µm wide, not constricted and not granulated at cross walls, attenuated towards ends, generally curved; sheaths not found or very fine cells are wider than long, apical cell without calyptra and rounded in shape.
Epipelic; site (S5), voucher no. HSP15, date: 07.06.2016, voucher no. HSP47, date: 18.06.2019.

13. ***Phormidium retzii*** (Agardh) Kützing ex Gomont 1892 (Fig. 2m), Komárek and Anagnostidis 2005, p. 454, fig. 666; Adhikary and Jena 2012, p. 220, pl. 1, fig. 3.
Thallus bluish-green; trichome straight, cross wall slightly constricted; apical cell obtuse-rounded; sheath thin; cells as long as or shorter than broad, 7.8-11.2 µm broad, 5-11µm long, without calyptras.
Epipelic; site (S1), voucher no. HSP1, date: 07.06.2016; site (S3), voucher no. HSP41, date: 18.06.2019.

Family: **Microcoleaceae**
Genus: ***Microcoleus*** Desmazières ex Gomont, 1892

14. ***Microcoleus chthonoplastes*** Thuret ex Gomont 1892 (Fig. 2n), Komárek and Anagnostidis 2005, p. 534, fig. 806; Jena *et al.* 2008, p. 12, pl. 1, fig. 3.
Thallus widely exapanded, bluish green, gelatinous; trichome in a bundles; straight, irregularly curve; sheaths variably thick, diffluent, colourless or yellowish; cells are cylindrical, longer than broad, 3-5µm broad, 4-9 µm long, gradually attenuated at the ends, mostly open, apical cell acute conical and not capitate.
Epipelic; site (S1), voucher no. HSP1, date: 07.06.2016; site (S3), voucher no. HSP21, date: 29.12.2018.

15. ***Microcoleus vaginatus*** Gomont ex Gomont 1892 (Fig. 2o), Komárek and Anagnostidis 2005, p. 536, fig. 804.
Filaments solitary, sometimes membranaceus, soft, blackish green to dark blue-green, variably curved; sheaths usually colourless, not lamellate, containing usually numerous densely entangled with often rope-like contorted trichome; trichomes long, 4-7 µm wide, not constricted, often granulated cross-walls, usually attenuated at the ends, motile; cells are shorter than wide, 2.4-5.5 µm long; apical cells, bluntly-rounded or obtuse conical, hemispherical calyptras sometimes present.
Epipelic; site (S1), voucher no. HSP17, date: 21.12.2018; site (S6), voucher no. HSP31, date: 21.12.2018.

Genus: ***Symploca*** Kützing ex Gomont 1892

16. ***Symploca cartilaginea*** Gomont ex Gomont 1892 (Fig. 2p), Komárek and Anagnostidis 2005, p. 485, fig. 723
Filaments arranged densely and parallel, forming bundles, dull blue green, sheath thick, cell 2-3 µm cell longer than broad, 3-5 µm long., not constricted at cross wall, apical cell obtuse.
Epipelic; site (S1), voucher no. HSP1, date: 07.06.2016; site (S3), voucher no. HSP42, date: 18.06.2019.

Family: **Oscillatoriaceae**
Genus: ***Oscillatoria*** Vaucher ex Gomont, 1892

17. ***Oscillatoria limosa*** Agardh ex Gomont, 1892 (Fig. 2q), Komárek and Anagnostidis 2005, p. 593, fig. 886; Jena *et al.* 2008, p.11, pl. 1, fig. 4.
Thallus blue green to dark bluish green; trichome straight, slightly curved, not attenuated, cross wall not constricted, frequently granulated, slightly motile and oscillating with round hand rotation; sheath not visible or very thin, colourless; cells shorter than broad, 11-14 µm broad, 5-7 µm long;

apical cell flatly rounded, convex, covered with slightly thick cell wall without calyptra.
Epipelic; site (S1), voucher no. HSP1, date: 07.06.2016; site (S3), voucher no. HSP41, date: 18.06.2019.

18. ***Oscillatoria salina*** Biswas, 1926 (Fig. 2r)
Komárek and Anagnostidis 2005 p. 601, fig. 906.
Thallus membranous, blue-green; trichome straight or slightly bent, trichome ends attenuated, not constricted at cross walls, cell 3.3-5.5 µm broad and 1.5 to 2.7 µm long; apical cells elongated, hyline, arcuate and pointed.
Epipelic; site (S2), voucher no. HSP2, date: 07.06.2016; site (S6), voucher no. HSP53, date: 18.06.2019.

19. ***Oscillatoria tenuis*** Agardh ex Gomont, 1892 (Fig. 2s), Jena *et al.* 2005, p. 69, pl. 1, fig. 6; Komárek and Anagnostidis 2005, p. 587, fig. 878

Thallus flat, mats or clusters, blue-green, generally thin, mucilaginous; trichomes straight or slightly irregularly curved, not constricted (or very slightly constricted) at cross walls, not granulated at cross walls, blue-green, 6.5-12.5 µm wide, cylindrical, not attenuated, slightly curved at the ends; cells always shorter than wide, 2.5-3.5 µm long; apical cells rounded, not capitates.
Epipelic; site (S2), voucher no. HSP2, date: 07.06.2016; voucher no. HSP53, date: 18.06.2019.

Genus: ***Lyngbya*** C. Agardh ex Gomont 1892

20. ***Lyngbya aestuarii*** Liebman ex Gomont, 1892 (Fig. 2t), Komárek and Anagnostidis 2005, p. 621, fig. 947-948; Jena et al. 2008, p. 12, pl. 1 fig. 7.
Forming dense floating masses of dark of ferruginous colour, sheaths distinct, thick, lamellate, deep yellowish brown, articulations, 3-6 times as broad as long, protoplast frequently granulated; trichomes 10-16 µm or more in broad; apices slightly attenuate capitates with slightly thickened end wall, separation disc clearly visible, hormogonia clearly visible.
Free floating; site (S4), voucher no. HSP11, date: 07.06.2016, site (S4), voucher no. HSP43, date: 18.06.2019.

21. ***Lyngbya semiplena*** J. Agardh ex Gomont, 1892 (Fig. 2u), Komárek and Anagnostidis 2005, p. 611, fig. 929.
Thallus caespitose, mucous, expanded, dark or dirty yellowish-green or dark green. Filaments creeping and decumbent at the base, coiled. 7.5-14 µm wide; sheaths colourless or mucilaginous or slightly lamellate; trichomes 6.5-11.5 µm wide, not constricted cross walls and not granulated; cells shorter than long; apical cells rounded-conical with calyptra.
Free floating; site (S2), voucher no. HSP21, date: 07.06.2016; site (S5), voucher no. HSP50, date: 18.06.2019.

Order: **Nostocales**
Family: **Aphanizomenonaceae**
Genus: ***Nodularia*** Mertens ex Bornet et Flahault, 1888

22. ***Nodularia spumigena*** Mertens ex Bornet et Flahault, 1888 (Fig. 2v), Komárek 2013, p 907, fig. 1181
Filaments solitary or in irregular clusters, 8-13 µm wide, with wide variability in shape, straight or slightly curved or irregularly spirally and compactly coiled, forming free floating scummy colonies; trichomes cylindrical, constricted at the cross walls, not attenuated towards ends; sheaths thick, fine, usually distinct; cells discoid or cylindrical or shortly barrel shaped, with aerotopes, cells 3-5 µm wide and 6-12 µm long; heterocytes transversely oval in shape, 4-7 µm and 7-13 µm long; akinetes compressed and almost spherical, 6-10 µm wide and 8-12 µm long.
Epipelic; site (S1), voucher no. HSP19; date: 21.12.2018; site (S3), voucher no. HSP42, date: 18.06.2019.

Division: **Bacillariophyta**

Class: **Bacillariophyceae**
Order: **Naviculales**
Family: **Naviculaceae**
Genus: ***Navicula*** Bory de St. Vincent, 1822

23. ***Navicula menisculus*** Schumann 1887 (Fig. 3a), Cox 1996, p.71, fig. 23, g
Valves broadly lanceolate with gently pointed apices, 15-50 µm long, usually < 11 µm broad, striae visible in live material.
Planktic; site (S4); voucher no. HSP13, date: 07.06.2016

24. ***Navicula pelliculosa*** (Kützing) Hilse, 1883 (Fig. 3b), Cox 1996, p.75, fig. 24, h
Cells slightly longer, valves more linear-elliptical, 9-13 µm long, 4-6 µm broad.
Planktic; site (S6); voucher no. HSP16, date: 07.06.2016; site (S5) voucher no. HSP49, date: 18.6.2019.

25. ***Navicula salinarum*** Grunow 1880 (Fig. 3c)
Rath and Adhikary 2005, p. 88, pl. 12, fig. 82 & pl. 21, fig. 181.
Valves broadly to elliptic-lanceolate with quite narrowly rostrate apices, 22-40 µm long, 8-14 µm broad, strongly radiate at center of valve, barely visible in fresh material.
Planktic; Site (S1), voucher no. HSP4, date: 07.06.2016, voucher no. HSP36, date: 18.06.2019.

Family: **Pleurosigmataceae**
Genus: ***Gyrosigma***, Hassall 1845

26. ***Gyrosigma acuminatum*** (Kützing) Rabenhorst 1853 (Fig. 3d), Rath and Adhikary 2005, p. 89, pl. 13, fig. 87 & pl. 22, fig. 185.
Valves linear, with obliquely truncate, narrowing evenly to rather blunt, sigmoidal, deflected apices, 60 -180 µm long, 11-19 µm broad; striae often visible in live material (16-18 in 10 µm).
Planktic; site (S2), voucher no. HSP5, date: 07.06.2016, voucher no. HSP37, date: 18.06.2019.

Genus: ***Pleurosigma*** W. Smith, 1852

27. ***Pleurosigma normanii*** Ralfs, 1861 (Fig. 3e), Rath and Adhikary 2005, p.88, pl. 13, fig. 8; Jena et al. 2006, p. 385, pl. 2, fig. 8.
Valves broadly lanceolate, slightly sigmoid with sub-acute ends, 196-320 µm long and 36-62 µm broad; transverse striae 20-25 in 10 µm, oblique striae 20 in µm.
Planktic; (S1), voucher no. HSP3, HSP4, date: 07.06.2016; site (S3), voucher no. HSP40, date: 18.06.2019.
Family: **Stauroneidaceae**
Genus: ***Stauroneis*** Ehrenberg, 1843

28. ***Stauroneis pusilla*** Ehrenberg 1854 (Fig. 3f), Rath and Adhikary 2005, p. 82, pl. 12, fig. 75.
Valves solitary, linear-lanceolate, with short protracted rostrate ends, thin raphe, straight, narrow axial area, gradually widening towards the center, central area stauros-shaped, central area margins is slightly transverse, 25-34 µm long and10-13 µm broad.
Planktic; site (S2); voucher no. HSP7, date: 07.06.2016,

Order: **Thalassiophysales**
Family: **Catenulaceae**
Genus: ***Amphora*** Ehrenberg ex Kützing, 1844

29. ***Amphora ovalis*** (Kützing) Kützing, 1844 (Fig. 3g), Jena *et al.* 2006c, p. 391, pl. 3, fig. 18.
Cells large, 30-70 µm long, 12-17 µm broad, strongly biconvex, ventral valve margin weakly concave; valve markings visible, striae continuous on the dorsal side of the valves, 10-13 in 10 µm at centre.
Planktic; site (S1), voucher no. HSP1, date: 07.06.2016; site (S5), voucher no. HSP48, date: 18.06.2019.

Order: **Cymbellales**
Family: **Anomoeoneidaceae**
Genus: ***Anomoeoneis*** Pfitzer, 1871

30. ***Anomoeoneis sphaerophora*** Pfitzer 1871

(Fig. 3h)
Valves broadly lanceolate to lanceolate elliptic 40µm long ,15µm wide with acute apices.
Planktic; site (S1), voucher no. HSP3, date: 07.06.2016; site (S6), voucher no. HSP53, date: 18.06.2019.

Order: **Bacillariales**
Family: **Bacillariceae**
Genus: ***Nitzschia*** Hassall, 1845

31. ***Nitzschia agnita*** Hustedt, 1957 (Fig. 3i)
Karthick *et al.* 2013, fig. 126.
Valves usually 30-120 µm long, 3-5 µm broad, with finely drawn out, but rounded apices.
Planktic; site (S2), voucher no. HSP5, date: 07.06.2016; site (S1), voucher no. HSP19, date: 21.12.2018.

32. ***Nitzschia obtusa*** W. Smith, 1853 (Fig. 3j)
Jena *et al.* 2006c, p. 391, pl. 3, fig. 24.
Cells >120 µm long and >7 µm broad, valves linear sigmoid, with a very sight constriction at the central raphe endings, tapering quite abruptly to bluntly rounded apices.
Planktic; site (S1), voucher no. HSP3, date:07.06.2016; site (S2), HSP20, date: 21.12.2018.

33. ***Nitzschia sigma*** (Kützing) W. Smith, 1853 (Fig. 3k), Rath and Adhikary 2005, p. 91, pl. 13, fig. 92.Valves linear, slightly sigmoid in gridle view, in valve view almost straight, considerably diminished in size at the extremities and elongated, 120-280 µm long, 8-13 µm broad, kiel punctuate 5-6 in 10 µm.
Planktic; site (S1), voucher no. HSP3, date:07.06.2016; site (S2), HSP22, date: 21.12.2018.

Division: **Euglenphyta**
Class: **Euglenophyceae**
Order: **Sphenomonadales**
Family: **Sphenomonaceae**
Genus: ***Anisonema*** Dujardin,1841

34. ***Anisonema acinus*** Dujardin,1841 (Fig. 3*l*)
Hindák 2005, p. 50, fig. 344 a, b
Cells obovoid, sometimes bell shoed, strongly flattened with euglenoid movement. Two unequal emergent flagella, heterodynamic cell 16-19×27-30 µm rigid with longitudinal furrow, anterior end rounded posterior end widely rounded.
Planktic; site (S6), voucher no. HSP16, date: 07.06.2016.

Division: **Chlorophyta**
Class: **Trebouxiophyceae**
Order: **Chlorellales**
Family: **Chlorellaceae**
Genus: ***Chlorella*** Beijerinck, 1890

35. ***Chlorella vulgaris*** Beyerinck [Beijerinck], 1890 (Fig. 3m), Philipose 1967, p. 173, fig. 82 (a).
Free living, usually solitary or in small colonies, spherical and with thin cell membrane, cells are 5-10 µm in diameter.
Planktic; site (S7), voucher no. HSP7, date: 07.06.2016; site (S5), voucher no. HSP29, date: 21.12.2019.

Class: **Chlorodendrophycea**e
Order: **Chlorodendrales**
Family: **Chlorodendracea**e
Genus: ***Tetraselmis*** F.Stein, 1878

36. ***Tetraselmis indica*** Arora & Anil in Arora *et al.* 2013 (Fig. 3n), Arora *et al.* 2013. p. 69, fig. 1 & fig. 2-4
Cell motile, cells a little compressed, 9–26 µm long, 8–19 µm wide, bilaterally symmetrical, oval in shape to elliptical, chloroplasts yellow green, cup-shaped, cells containing a pyrenoid located in the posterior third of the cell, one or sometimes several conspicuous orange-red eyespots are located below the level of the pyrenoid and flagella 04.
Planktic; site (S4), voucher no. HSP13, date: 07.06.2016, voucher no. HSP46, date: 18.06.2019.

Class: **Pyramimonadophyceae**
Order: **Pyramimonadales**
Family: **Polyblepharidaceae**

Genus: ***Printziella*** Skvortsov, 958

37. *Printziella biflagellata* Skvortsov 1958 (Fig. 3o), Iyenger and Desikachary 1981, p.172, fig. 85
Cells like an isosceles triangle with rounded corners and less convex sides with round posterior and narrowing distinctly to the anterior, anterior end pointed and lightly obtuse, convex on one side and concave on the other, 25 µm long and 15 µm wide, flagella 52 µm long, motile.
Planktic; site (S6), voucher no. HSP32, date: 21.12.2018; site (S3), voucher no. HSP41, date: 18.06.2019,

Division: **Charophyta**
Class: **Charophyceae**
Order: **Charales**
Family: **Characeae**
Genus: ***Nitella*** C. Agardh, 1824

38. *Nitella hyalina* (De Candolle) C. Agardh, 1824 (Fig. 3p), Pal *et al.* 1962, p. 72, figs. 133-142.
Plant monoecious, the main axis is 7-8 cm height, internodes 2-4 times the length of branchlets; primary branchlets 7-8, 1-3 times furcate; primary rays at the first furcation 6-10; fertile whorls with shorten compact branchlets and forming small heads on special branches. Secondary rays 3-4 in sterile whorls and 5-6 in fertile whorls. Antheridia 250-320 µm in diameter and oogonia 370-480 µm diameter and 570-655 µm long, spiral cells showing 8-9 convolutions; coronula 28-38 µm high, produced above the antheridia, both are orange or dark brown in colour on mature.
Submerged; site (S2), voucher HSP6, date: 07.06.2016, site (S5), voucher no. HSP30, date: 21.12.2018.

Genus: ***Chara*** Linnaeus 1753

39. *Chara globularis* Thuiller 1799 (Fig. 3q, r) Adhikary *et al.* 2009, p. 80., pl. 36., fig. 1-4.
Plant monoecious, stem stout, 8-20 cm height, stem slender, 400-700 µm in diameter. internodes 1-2 times the length of the whorl; branchlets 6-7 in a whorls, straight, very long, consisting of 8-11 segments of which the upper 1-3 are ecorticate, cortical cells of branchlets twice as numerous as the bract cells; bract cells usually 7, varying in length, equal or shorter than the oogonium, only one anterior pair developed, posterior cells rudimentary, at sterile nodes frequently absent; antheridia and oogonia solitary, at the 2-4 lowest branchlets nodes; antheridia 320-400 µm in diameter; oogonium 850-900 µm long, 500-720 µm wide; spiral cells showing 134-17 convolutions; coronula 178-200 µm high, 200-367 µm wide at the base, individual cells erect, usually truncate at the apex; oospore black, 600-700 µm long, 347-475 µm wide; with 11-13 well pronounced ridges.
Submerged; site (S5), HSP29, 21.12.2018; site (S2) voucher no. HSP38, date: 18.06.2019.

DISCUSSION

The finding of our present study represented that, all of these 39 halophilic algae are the first time reported from the hypersaline habitat i.e. saltpans, Humma. It is important to note that out of these 39 algal species 11 halophilic algal species such as *Gomphosphaeria salina* Komárek & Hindák, *Phormidium kolkwitzii* Komárek and Anagnostidis, *Microcoleus vaginatus* Gomont ex Gomont, *Symploca cartilaginea* Gomont ex Gomont, *Nodularia spumigena* Mertens ex Bornet et Flahault, *Navicula menisculus* Schumann, *Anomoeoneis sphaerophora* Pfitzer, *Anisonema acinus* Dujardin, *Tetraselmis indica* Arora and Anil in Arora e*t al.*, *Printziella biflagellata* Skvortsov, and *Nitella hyalina* (De Candolle) C. Agardh. were recorded for the first time from the Odisha state.

Furthermore, it is found that among these 39 algal species, 13 algal species are previously reported from Southern India (Thajuddin *et al.* 2002, Nagasathya and Thajuddin 2008, Sugumar *et al.* 2011) and of these 12 species are belonging to Cyanobacteria;

Merismopedia glauca (Ehrenberg) Kützing, *Gomphosphaeria salina* Komárek & Hindák, *Chroococcus turgidus* (Kützing) Nägeli, *Spirulina labyrinthiformis* Kützing ex Gomont, *Spirulina subsalsa* Oersted ex Gomont, *Microcoleus chthonoplastes* Thuret ex Gomont, *Oscillatoria limosa* Agardh ex Gomont, *Oscillatoria salina* Biswas, *Oscillatoria tenuis* Agardh ex Gomont, *Lyngbya aestuarii* Liebman ex Gomont, *Lyngbya semiplena* J. Agardh ex Gomont and one from the Chlorophyta i.e. *Tetraselmis indica* Arora and Anil, from hypersaline saltpans and slaterns of Southern Coast of India (Arora *et al.* 2013). The rest of other algal species are previously reported from this region from either from brackish water (Chilika lagoon) or from marine environments of East coast of India (Rath and Adhikary 2005, Jena *et al.* 2008, Maharana *et al.* 2019).

Moreover, it was observed in the present study that few algal species viz. *Chroococcus prescottii* Drouet & Daily in Drouet, *Spirulina labyrinthiformis* Kützing ex Gomont, *Spirulina subsalsa* Oersted ex Gomont, *Lyngbya aestuarii* Liebman ex Gomont and *Tetraselmis indica* Arora & Anil in Arora *et al.* were dominant at the site S4 (Evaporation pond having very less water) with salinity varing from 50 to 58 ppt. Our findings in this investigation in terms of salinity and the occurrence of the algal species were quite similar to the previous reports on halophilic cyanobacterial diversity from the Saltpans of India (Thanjudin *et al.* 2002, Nagasathya and Thajuddin 2008, Sugumar *et al.* 2011). Furthermore, it is observed that saltpans of Humma are an important habitat of bio-resources in terms of the presence of important microalgal species such as *Spirulina labyrinthiformis* Kützing ex Gomont, *Spirulina major* Kützing ex Gomont, *Spirulina subsalsa* Oersted ex Gomont, *Chlorella vulgaris, Tetraselmis indica* Arora & Anil. *Printziella biflagellata* Skvortsov, which are having many applications in aquaculture and biotechnology.

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