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 meniscus Schumann, Anomooneois 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 labyrinthisformis 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, salt pans

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. Salt pans are constructed for the production of raw salt from the seawater by evaporation. The main characteristic of salt pans 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 et al. 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 salt pans of Humma, Odisha. Hence, an attempt has been made to document information on the algal diversity in
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°49ʹ5.91ʺN and Longitude 85°16ʹ29.067ʺE) 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. Salt pans’ water samples were collected by a plankton net of 25 µm mesh size (Hydro-Bios Kiel, Cat. No. 438001). The visually occurring algae in the salt pans 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: Preserved 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 salt pans, Humma. S1, S2, S5 and S6: shallow evaporation pond, S3: shallow pond connected to creek, S4: evaporation pond.

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 and 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 salt pans are presented in Table 1. 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:** Chroococcales  
**Family:** Merismopediaeae  
**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, diffusent but distinct, 3-6 μm, pale blue green. Cells oval or hemispherical, 3-8 μm in diameter.  
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

<table>
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<td>Temperature (°C)</td>
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<td>27.5-28.5</td>
<td>26.1-31.6</td>
<td>33.1-34.6</td>
<td>28.1-29.6</td>
<td>27.1-32.2</td>
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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...
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.

ord: *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, 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 Anagnostitidis 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. 2i), 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;
Genus: **Lyngbya** C. Agardh ex Gomont 1892

20. **Lyngbya aestuarii** Liebmann 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.

Epipellic; site (S1), voucher no. HSP19; date: 21.12.2018; site (S3), voucher no. HSP42, date: 18.06.2019.

**Division:** **Bacillariophyta**

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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.

Epipellic; site (S1), voucher no. HSP19; date: 21.12.2018; site (S3), voucher no. HSP42, date: 18.06.2019.

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

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.

Epipellic; 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.

Epipellic; site (S2), voucher no. HSP2, date: 07.06.2016; voucher no. HSP53, date: 18.06.2019.
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: 18.06.2019.

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: *Pleurosigma* W. Smith, 1852

26. *Pleurosigma normani* 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

27. *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 and 10-13 µm broad.  
Planktic; site (S2); voucher no. HSP7, date: 07.06.2016,

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

28. *Amphora ovalis* 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

29. *Anomoeoneis sphaerophora* Pfitzer 1871
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 slight 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. 3l)
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: Chlorodendrophyceae
Order: Chlorodendrales
Family: Chlorodoraceae
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.
Planktic; site (S4), voucher no. HSP13, date: 07.06.2016, voucher no. HSP46, date: 18.06.2019.

Class: Pyramimonadophyceae
Order: Pyramimonadales
Family: Polyblepharidaceae
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,

**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 et 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 subsalisa 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 salt pans and slaterns of Southern Coast of India (Arora et al. 2013). The rest of other algal species are previously reported from this region 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 subsalisa 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 varying 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 Salt pans of India (Thanjudin et al. 2002, Nagasathya and Thajuddin 2008, Sugumar et al. 2011). Furthermore, it is observed that salt pans of Humma are an important habitat of bioresources in terms of the presence of important microalgal species such as Spirulina labyrinthiformis Kützing ex Gomont, Spirulina major Kützing ex Gomont, Spirulina subsalisa 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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