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FIRST REPORT ON DIVERSITY OF CYANOPROKARYOTES AND ALGAE ON FEATHER OF SNOW PETREL (*PAGODROMA NIVEA* FORSTER) IN BROKNES PENINSULA OF LARSEMANN HILLS, EAST ANTARCTICA

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Abstract: Antarctica is the coldest, driest place and fifth largest continent on this earth. The Larsemann Hills area is located approximately halfway between Vest fold Hills and Amery Ice Shelf on South-eastern coast of Prydz Bay which includes two main peninsulas, the western named Stornes and the eastern named Broknes. During the survey it was very interesting to observe cyanoprokaryotes and algal samples growing on the feathers of bird Snow petrel (*Pagodroma nivea* Forster) in Broknes Peninsula of Larsemann Hills, East Antarctica. The snow petrel is the only member of the genus *Pagodroma*. It is one of only three birds that breed exclusively in Antarctica and has been seen at the Geographic South Pole. Altogether 16 species of cyanoprokaryotes and algae belonging to 09 genera were recorded. This is the first study report of cyanoprokaryotes and algae from feather of Snow petrel bird from Broknes peninsula of Larsemann Hills, East Antarctica. All the species reported for the first time as a new record from this area.

Keywords: Algae, Antarctica, Broknes peninsula, Cyanoprokaryotes, *Pagodroma nivea,* Snow petrel.

INTRODUCTION

Larsemann Hills (69°23'S, 76°53'E), in the Prydz Bay, is an ice-free oasis on the Ingrid Christensen Coast, Princess Elizabeth Land, located approximately midway between the eastern extremity of the Amery Ice Shelf and the southern boundary of the Vestfold Hills. This ice-free coastal oasis named after Mr. Larsemann Christensen. It is the second largest (area of 50 square km) of only four major ice-free oases found along East Antarctica. Larsemann Hills region includes two main peninsulas, the western named Stornes and the eastern named Broknes. In between these two peninsulas, there are number of islands of varying dimensions and some unnamed promontories.

Larsemann Hills area is potentially at noticeable environmental risk, due to the presence of four research stations and an ice runway which is used often, within a few square km : Law Base (Australia, established in 1986, and regularly visited and resupplied by Australian expedition members mostly during the summer months), Zhong Shan (People's Republic of China, permanently occupied since 1988), Progress I Station and ice runway (Russian Federation, now abandoned and largely dismantled), and Progress II. India's 3rd Indian Research Station: Bharati commissioned in 2012. In Larsemann Hills, human impact is more than Schirmacher Hills, as existing stations are situated in close proximity to

each-other. Anthropogenic impact in the Larsemann Hills has resulted from construction and other activities related to station operations and resupply.

There are several lakes in the Larsemann Hills (Gillieson *et al*., 1990), ranging from small ephemeral ponds to large water bodies. Some of these water bodies are ice free for the very short period of time or partially ice free in the summer months when the water temperature increase rapidly, reaching about + 8°C in some of the shallower ones. For the remainder of the year (8 -10 months), they are covered with about 2.0 m of ice.

Pagodroma nivea Forster belongs to family Procellariidae commonly known as Snow Petrel (Turbott, 1990). This species is closely linked with ice, occurring mainly in areas with 10-50% ice cover. It feeds mainly on krill, fish, squid and carrion, feeding mostly on the wing by dipping but also by diving and surface-seizing. Breeding starts in November in most areas, forming colonies of variable size on cliffs and rock faces (Del Hoyo *et al*., 1992). The Snow Petrel is known to nest at many localities in Antarctica. It probably nests in suitable habitats over most of the region. Konovalov (1962) estimated the population of Antarctic Petrels at Svarthamaren to be 1 million. Pande *et al*. (2017) studied status of seabirds nesting including Snow Petrel in islands of Broknes peninsula and other areas of Larsemann Hills.

Cyanoprokaryotes are the first primitive form of life called as prokaryotes might have been emerged / originated about 3.5 billion years ago. The cyanoprokaryotes (blue-green algae) performing photosynthesis originated about 3.0 billion years ago (Cassidy, 2009). It has been uniquely positioned in evolutionary hierarchy of earliest living world, predominantly even during Precambrian era (Schopf, 1975, 1994, 1996). Increase in concentration of oxygen on the earth crust, recorded about 2.4 billion years ago considered as cyanoprokaryotes an architect of earth's atmosphere as they are 'nature's first and foundational mother and father for causing photosynthesis', entailed to form pure ecological niche on our planet and precisely stands as founder of the aquatic food-chain.

They occurs even in wide range of habitats and have been distributed all over land and water system often in such an environments where there is no other vegetation possibly due to their adaptive capability to extreme adverse environmental conditions with respect to different climatic/environmental factors, availability of nutrients, etc. Their occurrence even in wide range of ecologically stress conditions and extreme habitats proves that they are very tolerant. They occur in fresh-water ecosystem like lakes, ponds, rivers, wetland, etc. and marine water system like salt marshes and pans, estuaries, brackish waters and ocean.

Sampling of the coastal areas from the Vestfold Hills (Dhargalkar, 1990) to the Larsemann Hills by some workers indicates that the flora of the Ingrid Christensen Coast is relatively uniform and restricted to bryophytes, lichens and algae. Sabbe *et al*. (2003) reported Diatom flora in the fresh and saline water Lakes of Larsemann Hills and Rauer Island. Some exploration confirmed that phytoplankton comprises autotrophic nanoflagellates, dinoflagellates and *Cosmarium* from different water bodies and benthic communities of the deep water lakes are dominated by thick cyanobacterial mats (Ellis-Evan *et al*., 1998). It has long been believed that birds have to be major distributors of cyanoprokaryotes and algae.

However, as far as Indian work is concerned on cyanoprokaryotes and algal diversity of Larsemann Hills, Antarctica, Bharati and Niyogi (2015) studied phytoplankton only up to class level. So taxonomic studies of cyanoprokaryotes and algae are very much required. Cyanoprokaryotes and algal studies carried out under the Indian Scientific Expedition programme in and around the Schirmacher Oasis, have so far focused on phytoplankton, algae, lichens and fungi but no cyanoprokaryotes and algal diversity studies have been undertaken from Broknes peninsula of Larsemann Hills, East Antarctica. But no work has been done on the

studies on cyanoprokaryotic and algal diversity on feather of bird Snow petrel so far. Keeping this in the view, author attempted to study the factual cyanoprokaryotes and algal diversity profile on the feathers of bird Snow petrel (*Pagodroma nivea* Forster) in Broknes peninsula of Larsemann Hills, East Antarctica by taxonomic enumeration.

MATERIALS AND METHODS

The author participated in the Indian Scientific Expedition to Antarctica to carry out cyanoprokaryotes and algal diversity studies in Broknes peninsula of Larsemann Hills, East Antarctica during the austral summer and surveyed the same.

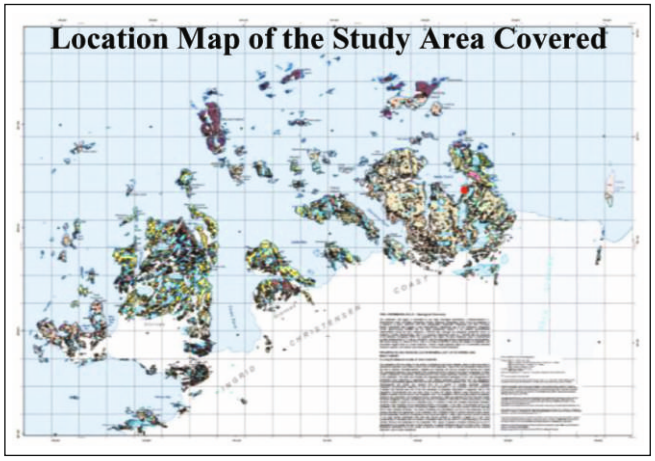


Fig. 1: Base Map of Larsemann Hills, Antarctica.

Collection and preservation of samples

The samples were collected by scrapping gently from the feather with the help of forcep. The samples were preserved in screw cap sampling vials of Tarsons. Specimen vials were further marked by glass marker about sample number, location, type of water bodies and date of collection. Collected samples were preserved by adding 2-3 drops of 4% formalin solution.

Identification and Taxonomic enumeration

Specimens were observed under Leica DM 2500 Microscope and photomicrographs of each specimen were taken by DFC 500 digital camera with annotation using Leica QWin V 3.2 Image Processing and Analysis Software and Leica Application Suit V4.

Specimens were identified by consulting standard books, monograph like Tiffany and

Site Description

This region includes two main or bigger peninsulas, the western, named Stornes and the eastern named Broknes. Stornes peninsula was not covered during the survey due to Antarctic Specially Protected Area (ASPA) restriction. As per the Map (Fig. 1 and 2) during the austral summer period, samples were collected from feather of Snow Petrel bird (*Pagodroma nivea*) in Broknes peninsula of Larsemann Hills, East Antarctica (Fig. 3 and 4). All the samples were processed and maintained properly for study.

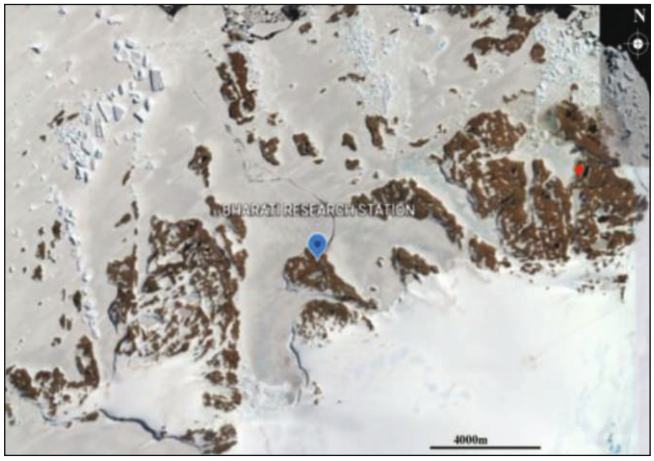


Fig. 2: Satellite Imagery Map of Larsemann Hills, Antarctica.

Britton (1952), Desikachary (1959), Prescott (1982), Komárek and Anagnostidis (1998, 2005), Krammer and Lange-Bertalot (2008), Guiry (2021) and taxonomic enumerations were done. The authority name of each species is cited in the text as described in 'Authors of Plant Names' (Brummitt and Powell, 1992).

Fig. 3: Cyanoprokaryotes and Algae on feather of bird Snow Petrel (*Pagodroma nivea* Foster) in Broknes peninsula of Larsemann Hills, East Antarctica.

Fig. 4: Sample after collection in sampling vial.

RESULTS

Systematic Enumeration

Systematic studies provide basic information on the cyanoprokaryotes and algal diversity observed on feather of bird Snow Petrel (*Pagodroma nivea* Forster) in Broknes peninsula of Larsemann Hills, East Antarctica. Taxonomic enumeration of identified cyanoprokaryotes and algae are described here along with their details including nomenclature and distribution.

Chroococcales
Chroococcaceae
Chroococcus Nägeli

1. *Chroococcus quaternarius* M.D. Zalessky, Rev. Gen. Bot. 38: 33, t. 11, f. 3. 1926. Komárek & Anagn., Cyanoprokaryota Part 1: Chroococcales 19(1): 293, f. 384. 1998.

Colonies forming nest like thallus composed of small sub colonies with 2-4-8-16 or more clustered cells, irregularly or in slightly packet like slightly quadrangular arrangements, enveloped by individual, clearly delimited mucilaginous colourless envelops; cells more or less spherical, later hemispherical, irregular-rounded or with rounded angular outline (Fig 5).
Dimension: Colony 18.31μm to 20.11 μm in diameter.
Environment: Freshwater.

2. ***Chroococcus turgidus*** (Kütz.) Nägeli, Gatt. Einzell. Alg. 46, 1849; Komárek & Anagn., Cyanoprokaryota Part 1: Chroococcales 19(1): 302, f. 407. 1998. *Protococcus turgidus* Kütz.Tab. Phycol. 1: 5, t. 6. 1846.

Solitary cell, mostly colonies usually 2-32 celled or more, individual cell with hyaline lamellate sheaths; cells spherical or sometimes widely oval, later during successive fission hemispherical or in form of segment of a sphere, intensely blue-green, rarely olive green, homogeneous or finely granular (Fig. 6).
Dimension: Cells 27.77 μm to 29.11 μm in diameter.
Environment: Freshwater.

Oscillatoriales
Oscillatoriaceae
Oscillatoria Vaucher ex Gomont

3. *Oscillatoria curviceps* C. Agardh ex Gomont, Syst. Alg., 68, 1824; Desikachary, Cyanophyta 209, t. 38, f. 2. 1959.

Trichome blue-green, not constricted at the cross-walls, not or very slightly attenuated at the end; apical cells flat-rounded, not capitate, sometimes with slightly thickened cell wall (fig. 7).
Dimension: Trichome 8.60 μm to 12.05 μm in diameter and cells 2.2 to 2.5 μm long.
Environment: Freshwater.

4. *Oscillatoria froelichii* Komárek & Anagn., Cyanoprokaryota Part 2: Oscillatoriales 19(2): 594, f. 887. 2005.

Trichome more or less straight, not constricted at the cross-walls, granules in cell content; cells short; trichome cylindrical not attenuated or attenuated at the end; apical cells on well-developed trichome with distinct, hyaline rounded to hemispherical calyptra (Fig. 8).
Dimension: Trichome 8.21 μm to 16.05 μm in diameter and cells 3.0 to 3.80 μm long.
Environment: Freshwater.

5. *Oscillatoria limosa* C. Agardh ex Gomont, Disp. alg. suec. 35, 1812; Tiffany & Britton, The Algae of Illinois 342, t. 93, f. 1076. 1952.
Thallus usually blue-green or sometimes dark blue-green; trichome straight, not constricted at

the cross-walls; cross-walls usually granular; end cell flatly rounded with slightly thickened outer membrane (Fig. 9).
Dimension: Trichome 9.67 - 12.05 µm in diameter and cells 2.1 0 - 2.42 µm long.
Environment: Freshwater.

6. *Oscillatoria producta* W. West & G.S. West, Brit. Antarct. Exped. 1907-9, 1: 294, t. 25, figs. 86-90. 191; Komárek & Anagn. Cyanoprokaryota Part 2: Oscillatoriales 19(2): 599, f. 900. 2005.

Trichome solitary, blue-green, more or less straight, slightly constricted at the cross-walls, apical cell distinctlty narrow, cylindrical, elongated and rounded (Fig. 10).
Dimension: Trichome 5.00 - 7.2 µm in diameter and cells 1.7 - 2.2 µm long.
Environment: Freshwater.

7. *Oscillatoria tenuis* C.Agardh ex Gomont, Ann. Sci. Nat. Bot. 16: 220, t. 7, f. 2 - 3. 1892; Prescott, Algae of the Western Great Lakes Area 491, t. 110, f. 14. 1982.

Trichome blue-green more or less straight or slightly flexuous, especially at the anterior end, not tapering towards the end; apical cell smooth, not capitate (Fig. 11).
Dimension: Trichome 4.00 - 6.8 µm in diameter and cells 2.5 - 3.5 µm long.
Environnent: Freshwater.

Phormidium Kütz. ex Gomont

8. *Phormidium lucidum* Kütz. ex Gomont, Ann. Sci. Nat. Bot. Ser. 7, 16: 179, t. 5, f. 11 - 12. 1983; Komárek & Anagn. Cyanoprokaryota Part 2: Oscillatoriales 19(2): 479, f. 718 b & d. 2005.

Thallus dark blue-green to dull blue-green; filaments more or less parallel arranged; sheath mucilaginous; trichomes olivaceus to bright blue-green, slightly constricted at ungranulated or finely granulated cross-walls; straight or sometimes more or less attenuated at the ends, sometimes mucronate-capitate; apical cells sometimes capitate with rounded or nearly conical calyptra (fig. 16).
Dimension: Trichome 5.6 - 8.36 µm in diameter and cells 2.2 - 2.7 µm long.
Environnent: Freshwater.

9. *Phormidium taylorii* ('taylori') (Drouet & Strickland) K. Anagn., Preslia 73: 371. 2001 ; Komárek & Anagn. Cyanoprokaryota Part 2: Oscillatoriales 19(2): 451, f. 661. 2005. *Lyngbya taylorii* Drouet & Strickland in Strickland Amer. J. Bot. 27: 631, f. 1. 1940.

Filament blue-green, parallel arrangement; sheath thin, firm colourless; trichomes cylindrical, not tapering towards ends, not or sometimes only slightly constricted at ungranulated cross-walls; cells with granular cell content; apical cells convex (Fig. 17).
Dimension: Trichome 4.0 - 6.90 µm in diameter and cells 2.2 - 6.7 µm long.
Environnent: Freshwater.

Lyngbya C. Agardh ex Gomont

10. *Lyngbya semiplena* J.Agardh ex Gomont, Ann. Sci. Nat. Bot. Ser.: 138, t. 3(3): figs. 7 - 11. 1892; Komárek & Anagn. Cyanoprokaryota Part 2: Oscillatoriales 19(2): 611. f. 929. 2005.

Thallus dark or dirty yellowish-green or dark green ; filaments creeping and decumbent at the base, elongated, erect or sometimes coiled at the end; sheath colourless slightly mucilaginous, homogeneous initially, lamellated when aged; trichomes blue-green, not constricted at the cross-walls, sometimes slightly attenuated at the end; cells very short; apical cells rounded-conical (Fig. 19).
Dimension: Trichome 5.0 - 7.91 µm in diameter and cells 2.3- 3.13 µm long.
Environment: Freshwater and Marine.

Synechococcales
Pseudanabaenaceae
Pseudanabaena Lauterborn

11. *Pseudanabaena moniliformis* Komárek & H. Kling, Arch. Hydrobiol. Suppl. 88 (Algol. Stud. 61): 27, figs. 3, 14: 3a. 1991; Komárek & Anagn. Cyanoprokaryota Part 2: Oscillatoriales 19(2): 92, f. 74. 2005.

Trichome solitary, straight or waved, maximum with 26 cells, constricted at the cross-walls, cells cylindrical (Fig. 12).
Dimension: Trichome 2.6-5.5 µm in diameter and cells 3.5- 3.8 µm long.
Environment: Freshwater.

Chlorophyta
Trebouxiophyceae
Chlorellales
Chlorellaceae
Geminella Turpin

12. *Geminella ellipsoidea* (Prescott) G.M.Smith, Fresh-w. Alg. U.S., ed. 2: 146, 1950; *Hormidiopsis ellipsoideum* Prescott, Algae of the Western Great Lakes Area 101, t. 7, f. 1 - 2. 1982.

Cells transversely elliptic, arranged in linear series in groups of 4 each group enclosed by a wide, hyaline and homogeneous gelatinous sheath. Chloroplast a parietal band as wide as the cell but not entirely encircling the wall with 1 pyrenoid (Fig. 18).
Dimension: Cells up to 8.95 µm in diameter.
Environment: Freshwater.

Chlorophyceae
Sphaeropleales
Sphaeropleaceae
Radiofilum Schmidle

13. *Radiofilum flavescens* G.S.West, J. Bot. 37: 57, t. 394, f. 10 - 11. 1899; Prescott, Algae of the Western Great Lakes Area 103, t. 7, f. 10. 1982.

Filament composed of transversely ellipsoidal or sub quadrate cells in a narrow gelatinous sheath, chloroplast a parietal plate (Fig. 20).
Dimension: Cells 6.2 µm to 15.0 µm in diameter and 4.9 µm to 10.0 µm long.
Environment: Freshwater.

Bacillariophyceae
Fragilariophycidae
Fragilariales
Fragilariaceae
Fragilariforma D.M.Williams & Round

14. *Fragilariforma constricta* (Ehrenb.) D.M.Williams & Round, Diat. Res. 3: 265, 1988. *Fragilaria constricta* Ehrenb., Ber. K. Akad. Wiss. Berlin 143, 1841.

Valves broadly linear, sometimes more or less deeply concave in middle; abruptly rounded poles; pseudoraphe narrow, linear (Fig. 13).
Dimension: Cells 8.6 µm to 12.74 µm in diameter and up to 28.0 µm long; striae 12-17 in 10 µm.
Environment: Freshwater.

Fragilaria Lyngbye

15. *Fragilaria pinnata* var ***pinnata*** Ehrenb., 415, t. 3: f. 6- 8. 1843; K. Krammer & H.Lange-Bertalot, Bacillariophyceae Part 3: Centrales, Fragilariaceae, Eunotiaceae 3: t. 133, f 5 - 7. 2008.

Valve broadly to narrowly elliptical, with evident linear pseudoraphe; transverse striation prominent, almost rib-like, sometimes radial with finer cross lines (Fig. 14).
Dimension: Cells 6.01 µm to 12.74 µm in diameter and up to 28.0 µm long; striae 8.0 to 12.0 in 10 µm.
Environment: Freshwater and Marine.

Naviculales
Diadesmidaceae
Luticola D.G.Mann

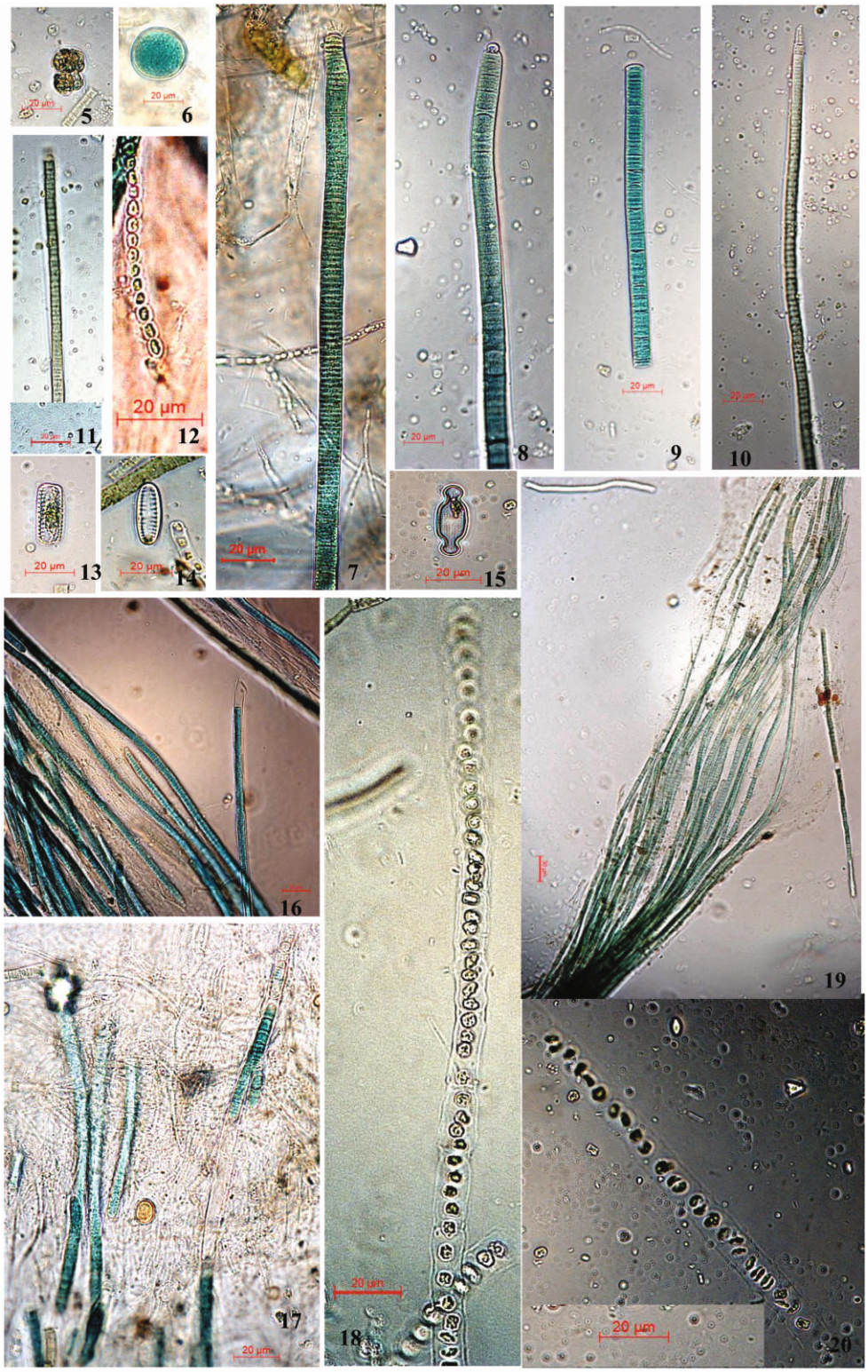
16. *Luticola muticopsis* (Van Heurck) D.G. Mann, in Round, Crawford & Mann, Diatoms: 671. 1990; *Navicula muticopsis* Van Heurck Rapp. Sci. Voy. Belgica, Diatomées 12, t. 2: f. 181. 1909.

Valve surface striated, thin, straight, axial area nerrow, central area wide, rostrate, capitate end (Fig. 15).
Dimension: Cells 6.1 µm to 10.05 µm in diameter and 10.0 µm to 25.3 µm long; striae 15-17 in 10 µm.
Environnent : Freshwater.

DISCUSSION

Altogether 16 species of cyanoprokaryotes and algae observed on feathers of bird Snow Petrel (*Pagodroma nivea* Forster) from Broknes Peninsula of Larsemann Hills, East Antarctica. A sum of 11 species of cyanoprokaryotes belongs to 05 genera followed by 03 species of 03 genera of Bacillariophyceae and 02 species of 02 genera of Chlorophyta were observed.

In cyanoprokaryotes, author recorded maximum number of 05 species of genus *Oscillatoria* Vaucher ex Gomont *namely O. curviceps* C. Agardh ex Gomont, *O. froelichii* Komárek & Anagn., *O. limosa* C.Agardh ex Gomont, *O. producta* W. West & G.S. West and *O. tenuis* C.Agardh ex Gomont; followed by 02 species of *Phormidium* Kütz. ex Gomont *viz. P. lucidum* Kütz. ex Gomont and *P. taylorii ('taylori')* (Drouet &



Figs 5 - 20: **Cyanoprokaryotes and Algae on Feather of Bird - Snow Petrel (*Pagodroma nivea* Forster) from Broknes Peninsula of Larsemann Hills, East Antarctica.**

5. *Chroococcus quaternarius* M.D.Zalessky, 6. *Chroococcus turgidus* (Kütz.) Nägeli, 7. *Oscillatoria curviceps* C.Agardh ex Gomont, 8. *Oscillatoria froelichii* Komárek & Anagn., 9. *Oscillatoria limosa* C.Agardh ex Gomont, 10. *Oscillatoria producta* W. West & G.S. West, 11. *Oscillatoria tenuis* C.Agardh ex Gomont, 12. *Pseudanabaena moniliformis* Komárek & H. Kling, 13. *Fragilariforma constricta* (Ehrenb.) D.M.Williams & Round, 14. *Fragilaria pinnata* var *pinnata* Ehrenb., 15. *Luticola muticopsis* (Van Heurck) D.G. Mann, 16. *Phormidium lucidum* Kütz. ex Gomont, 17. *Phormidium taylorii ('taylori')* (Drouet & Strickland) K. Anagn., 18. *Geminella ellipsoidea* (Prescott) G.M.Smith, 19. *Lyngbya semiplena* J.Agardh ex Gomont and 20. *Radiofilum flavescens* G.S.West

Strickland) K. Anagn.; 02 species of *Chroococcus* Nägeli - *C. quaternarius* M.D. Zalessky, *C. turgidus* (Kütz.) Nägeli. However, only a single species of *Lyngbya* C.Agardh ex Gomont - *L. semiplena* J. Agardh ex Gomont and *Pseudanabaena* Lauterborn- *P. moniliformis* Komárek & H. Kling were recorded from feather of Snow Petrel bird (*Pagodroma nivea* Forster) from Broknes peninsula.

Probably some saturated fatty acid and protein of the feather (keratin) provide the suitable environment for the growth of cyanoprokaryotes and algae. Cyanoprokaryotes and algal biogeography in Antarctica offer many challenges and opportunities to study the nature and rates of adaptation in the harsh climatic conditions and geographically isolated habitats on the continent and to investigate how much of the cyanoprokaryotes and algal diversity evolved *in situ*. This is the first steps of the study of the cyanoprokaryotes and algal diversity from feather of bird Snow Petrel (*Pagodroma nivea* Forster) in Broknes Peninsula of Larsemann Hills, East Antarctica. Now this study provides a precise idea of the cyanoprokaryotes and algal diversity of this area. All the species described here are reported for the first time from feather of Snow Petrel bird in Broknes Peninsula of Larsemann Hills, East Antarctica as new record because this is the first study report of cyanoprokaryotes and algal diversity observed on feather of Snow Petrel (*Pagodroma nivea* Forster) from this area and from India.

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