Colonization of algae and cyanobacteria on calcareous remains of dead animals in Larsemann Hills, East Antarctica

The Larsemann Hills (60°20′–60°30′S, 75°55′–76°30′E), is an ice-free coastal oasis of 50 km^2, located approximately halfway between the Vestfold Hills and the Amery Ice Shelf on the southeastern coast of Prydz Bay, Princess Elizabeth land, East Antarctica, bordered by two main peninsulas, Broknes and Stornes and several islands. It is the second largest of only four major ice-free oases. A congenial microclimate along with adequate freshwater during summer provide a hospitable environment for the aquatic as well as terrestrial biota. The major temperature-regulating factor is the persistent katabatic winds blowing from the northwest direction during summer, which increase the air temperature to 8–10°C with mean monthly temperature slightly above 0°C, which plays a significant role in the distribution and diversity of various flora and fauna. Cyanobacteria and certain algae are primary components of aquatic and terrestrial biomes of Antarctica[1]. Their diversity and distribution in the Larsemann Hills are unknown, except a few aquatic records on the cyanobacteria and diatoms from different freshwater lakes and marine habitats of Prydz Bay[2–5].

During the XXXV Indian Scientific Expedition to Antarctica (ISEA) in 2015–16, one of the present authors (D.S.) had observed cyanobacterial and algal colonization on the calcareous remains of dead animals dispersed in various places of Larsemann Hills. Twelve such samples were collected from McLeod Island, Cook Island and Broknes Peninsula (Figure 1). Table 1 presents details of the samples which have been deposited in the Cryptogamic Unit of the Central National Herbarium, Howrah (CAL). The cyanobacteria and algae were gently scrapped up from the calcareous substrates using forceps and scalpel. Light microscopic observations and morphological studies were made with a Nikon microscope Ni–11 attached with Nikon Digital Camera DS–Ri1–U3 and Nikon Imaging Software NIS–D+EDF and Scanning Electron Microscopic study was made under FEI Quanta 200 Scanning Electron Microscope.

So far there have been only two records of algal growth on bones. Reeb *et al.*[6] reported growth of the microalga *Stichococcus* inside the bone remnants of a bison carcass in Yellowstone National Park, USA. Algal colonization on the skeletal remnants of mammals in the polar region was reported by Raabova and Kovacik[7]. They have documented 14 taxa of cyanobacteria and algae from the bones of whale, seal and reindeer around the central part of Svalbard Archipelago in Petuniabukta, including *Pseudodictyochloris multinucleata*, *Tetracystis pulchra*, *Heterococcus papillosus* and *Xanthonema debile* as new distributional records from Svalbard. This communication documents the algal consortia on such calcareous substrates from the Antarctic region.

Bones of south polar skua (*Catharacta maccormicki*) and snow petrel (*Pagodroma nivea*) are a form of mineralized collagen composed of mainly type-I collagen and osteocalcin protein. After death of the birds, the bones are scattered mostly near the coastal areas and become porous after corrosion due to strong wind activity. These pores or micro-spaces provide a sheltered and moist habitat suitable for algal growth. The remnants of starfish and sea urchin were collected from very shallow lakes and seepages where they were partially submerged. A total of 11 taxa were collected from these habitats, including seven species of cyanobacteria, one green alga and three diatoms (Figure 2).

The submerged skeletal remains of starfish and the test of sea urchin were colonized mostly by species of cyanobacteria such as *Oscillatoria simplissima*,

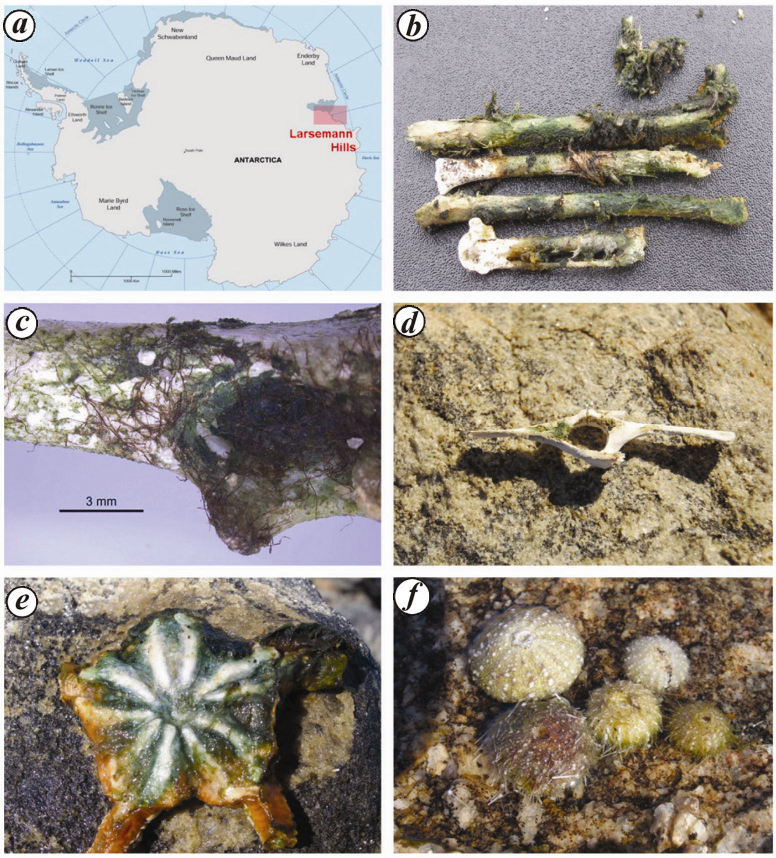

Figure 1. Growth and collection of cyanobacteria and algae from the calcareous remains of animals in Larsemann Hills, East Antarctica. ***a***, Map of Antarctica showing the Larsemann Hills. ***b***, ***c***, Algal biofilms on the bones of snow petrel and south polar skua. ***d***, Growth of *Prasiola crispa* on south Polar skua bone. ***e***, Cyanobacterial colonization on skeletal remains of Antarctic starfish. ***f***, Algal growth on the test of sea urchins.

Table 1. Details of the calcareous samples collected from Larsemann Hills, East Antarctica

Sample	Collection site	Colonizing cyanobacteria/algae
Shell/Test of Antarctic sea urchin (*Sterechinus neumayeri*)	Cook Island	*Gloeocapsopsis aurea*, *Achnanthidium minutissimum*
Skeletal remains of Antarctic starfish (*Odontaster validus*)	McLeod Island	*Oscillatoria simplissima*, *Microcoleus autumnalis*, *Leptolyngbya glacialis*, *Coleofasciculus chthonoplastes*
Bones of snow petrel (*Pagodroma nivea*)	Broknes Peninsula	*Nostoc commune*, *Oscillatoria sancta*, *Luticola muticopsis*, *Pinnularia borealis*
Bones of south polar skua (Catharacta maccormicki)	Broknes Peninsula	*N. commune*, *O. sancta*, *L. muticopsis*, *P. borealis*, *Prasiola crispa*

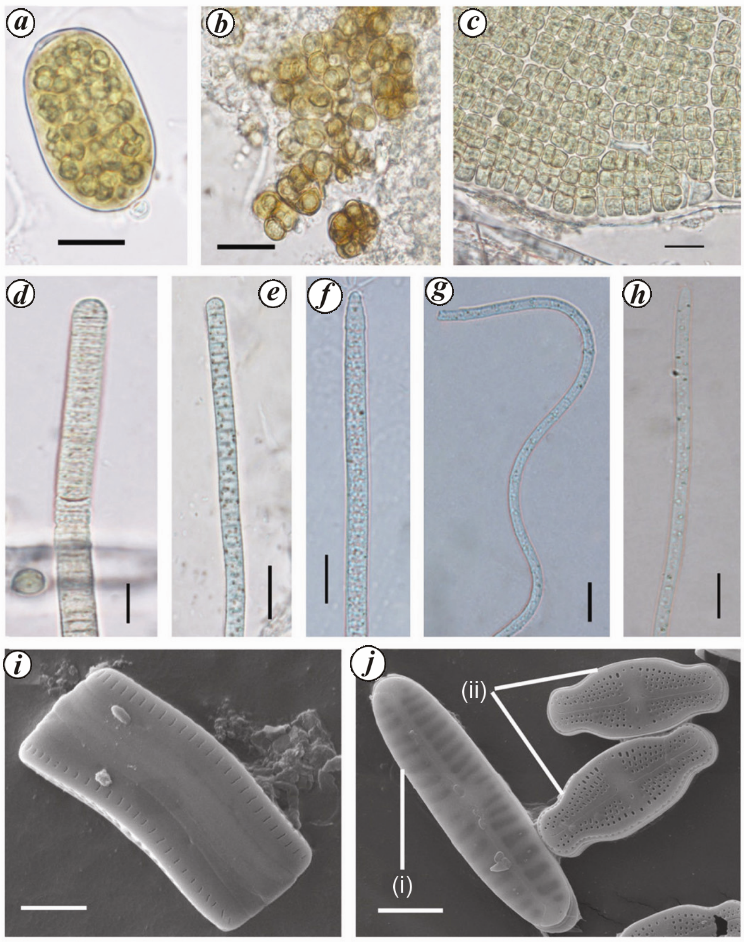

Figure 2. Photomicrographs of cyanobacteria and algae colonizing on skeletal remains in Larsemann Hills, East Antarctica. ***a***, *Nostoc commune*; ***b***, *Gloeocapsopsis aurea*; ***c***, *P. crispa*; ***d***, *Oscillatoria sancta*; ***e***, *O. simplissima*; ***f***, *Microcoleus autumnalis*; ***g***, *Leptolyngbya glacialis*; ***h***, *Coleofasciculus chthonoplastes*; ***i***, *Achnanthidium minutissimum*; ***j***, (i) *Pinnularia borealis*, and (ii) *Luticola muticopsis* (scale bar: ***a***–***h***, ***j*** = 20 μm; ***i*** = 2 μm).

Gloeocapsopsis aurea, *Microcoleus autumnalis*, *Leptolyngbya glacialis* and *Coleofasciculus chthonoplastes* and one species of diatom, *Achnanthidium minutissimum.* Most of the algal species occurring on these two substrates were hydro-terrestrial forms, which are assumed to be colonized on the calcareous substrates by repeated water flow over them. *O. simplissima* and *L. glacialis* were also found growing profusely in the nearby lakes and seepages. The bird bones collected from several places in Broknes Peninsula, scattered on the soil and rocks, have different biofilms on their surfaces, including mostly terrestrial algae, viz. *Nostoc commune*, *Oscillatoria sancta*, *Luticola muticopsis* and *Pinnularia borealis*. *N. commune* is one of the dominant cyanobacterial species documented from diverse aquatic and terrestrial habitats around the continental and maritime Antarctica. *L. muticopsis* prefers terrestrial and sub-aerophytic habitats such as soil and damp moss patches[8,9]. The trebouxiophycean green alga *Prasiola crispa* was found growing on the skua bone (Figure 1 *d*). It is a well-known nitrophilic alga commonly occurring in the Antarctic region on the rocks and moist soil influenced by bird guano, specifically adjacent to penguin rookeries[10]. This alga has high tolerance to both temperature and UV stress; thus its physiology has been extensively studied by Antarctic biologists.

Compared with the algal diversity from similar substrates in the Arctic[7], the Antarctic biota on skeletal remains was dominated by cyanobacteria instead of coccal green algae, which were predominant on the mammalian bones in the Arctic. Further studies can be made in the future to understand any distributional commonality, endemism and phylogenetic relatedness between the taxa of these two polar habitats. The study of these extremophiles not only widens the distributional arena of the algae, but they can also be the preferred 'model' organisms for the study of adaptive strategies required to thrive in one of the harshest environments on the earth.

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ACKNOWLEDGEMENTS. We thank the Director, Botanical Survey of India (BSI), Kolkata for providing the necessary facilities. D.S. thanks the Director, National Centre for Antarctic and Ocean Research (NCAOR), Goa for providing the opportunity to participate in the XXXV ISEA; team leader Dr Shailendra Saini (NCAOR) and team members of the expedition for help and cooperation and Dr W. Arisdason (BSI, Kolkata) for critically going through the manuscript and providing useful suggestions.

Received 10 July 2016; revised accepted 27 December 2016

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