Potential Wetland habitats of Schirmacher Oasis, Antarctica.

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Abstract

Biologically, phytoplankton and benthic algae dominates most lakes of the Schirmacher Oasis that experience large seasonal variations in their populations. The bulk of the biomass and primary productivity is contributed by cyanobacteria, diatoms, and green algae, which form thick luxuriant mats several meters thick. Benthic algae, foundation species regulate many of the processes that characterize wetland ecosystems by controlling dissolved oxygen concentrations, sediment formation, nutrient uptake and retention and account for a significant amount of total primary production. In this review, an overview on which foundation species define the structural features and ecosystem functioning of representative freshwater wetlands and how they influence and respond to hydrology, nutrient and habitat dynamics have been assessed.

Key words: *Foundation species, Cyanobacteria, Schirmacher Oasis, wetland, habitats*

Introduction

Antarctica covers nearly 9 % of earth's land mass and it is the fifth largest of earth's seven continents. It is remote, isolated; inhospitable and frozen all the year round that it has neither human nor animals as permanent residents. It is the driest and windiest continent on the earth, located in the most southerly position of all continents; it encircles the South Pole, extending its long arm - the Antarctic Peninsula towards the tip of South America. It covers an area of 14 million sq. km of which less than 3 % is rocky ice free exposed area that gets buried under the snow during Antarctic winter (Gould, 1971).

The exposed rocky areas are few in Antarctica, such as the Trans Antarctic Mountain Range, the Peninsular Arm and the Ellsworth – Whitmore Ranges, exposed solitary nunataks etc. Nunataks are an exposed rocky area of a ridge, mountain or peak that protrudes above the ice sheets. High wind and steep slops prevent snow and ice from accumulating on these nunataks. Nunataks are usually angular or jagged in shape due to freeze-thaw weathering.

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While most of the continent is covered with thick layer of ice, the Schirmacher Oasis is one of the most unique rocky area having fresh water lakes and home to a variety of extremophiles (organisms that live in extreme environmental condition) along with lichens, mosses, communities of microbes and nematodes. A continuous cycle of freezing and melting in winter and summer brings a large amount of changes in physico-chemical and biological properties of waters and bottom sediments. There are instances where the lakes are even subjected to drying in course of time as a result of negative water balance.

In addition to continental land mass, Antarctica has several large and small islands. Some of Antarctic islands are permanently linked to main land by ice, whereas others are connected by seasonally formed sea ice during winter and get separated during summer. Much of the continent’s coastline is fringed by small and large ice shelves.

The ocean surrounding the Antarctic continent form extreme habitats for many specially adopted organisms living within the internal structure and on the surface of the sea-ice. It is a home to much unique and fascinating animal life starting from penguins and seals to glass sponges and colossal squids.

Wetlands

A wetland is an area of land that is either covered by water or saturated with water permanently or seasonally. The wetlands are fed by ground water, seepage from an aquifer, spring and even from a nearby river or lake. The coastal wetlands are influenced by tides. The depth and duration of this seasonal flooding varies. Wetlands are not necessarily always wet, but they will show signs of water (hydrology indicators) even if it is not present at the time. Wetlands vary widely because of global, regional and local differences in soils, topography, climate, hydrology, water chemistry, vegetation and other factors.

A number of countries have adopted the RAMSAR wetland definition and classification as a starting point to inventory wetlands (Ramsar Bureau, 2000). Although, they have used this approach, they developed their own systems to meet their resource management needs (Davis, 1994). In India, Ministry of Environment, Forest and Climate Change (MoEF&CC) notified guide lines to identify wetlands of all Indian states and Union territories including two groups of island. The Guide line underwent modification several times and final guideline notification was issued in 2019 (MoEF&CC , 2019).

Many wetlands are seasonal in nature and are dry during one or more seasons every year. The hydro period has a strong influence on the type of wetland and support different wetland plants (hydrophytes) and animals that are adapted to variation of the hydro period. The saturation of wetland soil determines the vegetation types that are uniquely adapted to their watery (hydric) soil. Wetlands are critical habitats for many plants and animals, including numerous threatened and endangered species. They provide vital and valuable ecosystem services such as flood control and the maintenance of water quality. They exhibit significant wetland features and processes and provide critical breeding and feeding habitat for a number of animals.

Although, there is general belief that Antarctica is the only continent devoid of wetlands, however, recent reports have recognized that wetland do exist in Antarctica where thousands of fresh water and saline lakes harbor and support variety of animals and plant species. Antarctic wetlands are dominated by filamentous cyanobacteria algae and are exposed to severe conditions, of which the changes in the desiccation–rehydration and freeze–thaw cycles are two of the most significant (Sabacka, *et al.*, 2006; Moorhead, 2007). A Restricted Zone in the Pyramid Trough in the McMurdo Dry Valleys in Southern Victoria Land was created in recognition of its particular abundance and variety of surface water features and microbial communities and evaluated environment-biota relationships (Jungblut *et al.*, 2012), To understand the structure and function of polar wetland ecosystems, investigation of the hydro-ecology of the Wormherder Creek wetland (,McMurdo Dry Valleys) during the warm and sunny summer of 2008 – 2009 was carried out, when the wetland was hydrologically reactivated (Wlostowski *et al*., 2018).

Schirmacher Oasis, Antarctica.

Study Area

The Schirmacher Oasis lies between latitude 70^{0}44’ 33 “ to 70^{0}46’30” S and longitude 11^{0}22’40” to 11^{0}54’00” E. The area is approximately 34 km^2 (13 sq. mi) and is 70 km south of Princess Astrid Coast, Queen Maud Land in East Antarctica and is on average 100 meters above sea level (Richter, 1995). It is 25 km long and up to 3 km wide (at broadest place) ice-free plateau.

In Schirmacher Oasis there are more than 100 fresh water lakes of varying sizes and depths. During summer, some part of the lake surfaces remain covered with frozen ice and floating broken ice. A continuous cycle of freezing and melting in winter and summer brings a large amount of changes in physico-chemical and biological properties of waters and bottom sediments making them very complex ecosystems. Ponds/lakes are also typically dominated by conspicuous microbial mats that can reach very high biomass, completely covering the bottom of ponds/lakes (Hawes *et al*., 1993; Vincent & James, 1996).

Biologically, phytoplankton and bacteria plankton populations are present in most lakes and experience large seasonal variations in their populations, often related to the light. However, the bulk of the biomass and primary productivity is contributed by cyanobacteria, diatoms, and green algae, which are growing in thick luxuriant mats several meters thick (Verlekar *et al.*,1996; Ellis-

Evans, 1996; Vincent, 2000). These mats are grazed up on by communities of rotifers, ciliates, and crustacean although zooplanktons are present at low densities.

The biological communities of Antarctic lakes utilize truncated food chains characterized by the microbial loop in which heterotrophic and phototrophic bacteria and small eukaryotic phytoplankton are consumed by heterotrophic nano flagellates (HNAN), which are themselves consumed by larger organisms (Laybourn-Parry, 1997).

Faunal diversity

Terrestrial animals of the sub and maritime Antarctic include arthropods (primarily springtails and mites) and mollusks. Higher insects include spiders, beetles and flies; most are confined to the less severe areas (e.g. sub Antarctic islands). Micro invertebrate groups such as nematodes, tardigrades, rotifers are also numerically well represented (Ingole *et al.,* 1987). The midge (*Parochlus steineni)* the only winged insect native to the Antarctica is found in fresh water lake and wetter places. Although, these groups are represented by a small numbers of species their population densities are often high.

In the first Indian Antarctic Expedition, Sengupta and Qasim (1983) and Matondkar and Gomes (1983) made biological and chemical studies on the ice shelf and in freshwater lakes of the Schirmacher Oasis. Later, Ingole and Parulekar (1987,1990), Ingole and Dhrgalkar (1998) and Verlecar *et al.* (1996) published comprehensive scientific reports on micro fauna present in the water-moss communities. Ingole and Parulekar (1993) reported 7 micro faunal groups, viz., Protozoa, Turbellaria, Nematoda, Oligochaeta, Tardigrada, Rotifera and Acarina. The maximum density of micro-invertebrate was associated with the silt sediment having bacteria -algal layer and moss (Davis, 1980; MCInnes & Ellis-Evans, 1990; Ingole & Parulekar, 1993). A bacterial biodiversity of different habitats of the Schirmacher Oasis, Antarctica and their capability to survive under freezing condition and highlights their biotechnological potential (Shivaji *et al*., 2017). Further extremophiles like the ones that survive under freezing temperatures are all the more important due to their ability to carry out biological processes under extreme freezing temperature.

Arif (1995) recorded Nematode, Mite, Collembola, Diptera (adult and larvae) and Lepidoptera (moth) from moss and soil of lake area. Mitra (1999) and Barman(2000) studied moss inhabiting invertebrate fauna of the Schirmacher Oasis and reported 17 species of Protozoa, 1 species of Rotifera, 2 species of Tardigrada, 5 species of Nematoda, 2 species of mite and 2 families of collembolan and recorded two species of tardigrads namely *Hypsibius chilensis* and *Macrobiotus polaris* from the Oasis. On the basis of data so far available, it can be inferred that the groups like mite, rotifera, protozoa and nematodes have higher range of adaptability in Antarctica (Bohra *et al*., 2010; Sanyal *et al*., 2017).

Among the birds a few pair of Antarctic Skua, Tern, Cape, Snow and Wilson’s Storm petrels and Adelie penguins spend some time in the Shirmacher Oasis indicting sustainability of biological diversity. Islands support high numbers of many species of invertebrates, many types of flying birds, penguins and seals. The islands provide animals with shelter and hard ground on which to breed and moult. Some of these animals feed only on land, while the surrounding waters are a major food source for the land-based marine predators.

Floral diversity

The Schirmacher Oasis was first studied by Komarek and Ruzicka (1966) and reported that the blue green algae were highly productive even at low temperature of 0° to -5° C. They reported that the Schirmacher Oasis lakes were highly productive and main component happens to be *Phormidium* spp which is large fan shaped colonies that supersaturated the water with oxygen. Filamentous cyanobacteria are often dominant and are exposed to severe harsh conditions of which the changes in the desiccation–rehydration and freeze–thaw cycles are two of the most stressors. The annual winter freeze, caused little harm to cyanobacteria but was fatal for more than 50% of the population of algae (Sabacka and Elser, 2006).

Kashyap (1990) identified three distinct habitats for macro algae of the fresh water lakes as a) association with moss beds, b) on soil and c) on quartz rocks in the water pools and Lake Bottom. Moss, *Bryum* sp. was associated with five species of unicellular algae, two *Nostoc* species and *Stigonema* species. Later, Pankow *et al*. (1990, 1991) reported 220 species of algae including 100 cyanobacteria taxa from 600 samples during 1988 and 1989 and 98 species of cyanobacteria from 251 samples respectively collected from the Schirmacher Oasis.

Six species such as *Phormidium angustissimum, P. tenue, P. uncinatum, Schizothrix vaginata, Nostoc kihlmanii* and *Plectonema terebrans* were abundant in the study area, since they grow luxuriantly in most of the areas surveyed. Nz-fixing species, both heterocystous and unicellular diazotrophs, contributed more than 50% to the counts. Green algae and diatoms also contributed to the flora. Over 30 species of algae, predominantly cyanobacteria (Cyanophyceae), were recorded from streams of the Schirmacher Oasis. The species composition varied between streams, glacial and snow drift melt water streams contained a distinctive community (Pandey *et al*., 1995).

Later, seven species of mosses and blue green algae (Pandey & Kashyap, 1995) and 23 species collected from Maitri region, 17 were crustose forms while 4 were foliose and 2 species were fruticose (Upreti and Pant, 1995). Nayak and Upreti (2005) reported total of 35 lichen species from 31 sites in the whole stretch of the Schirmacher Oasis and seven neighbouring nunataks. A total of 109 species of cyanobacteria (91 species were non heterocystous and 18 species were heterocystous) from 30 genera and 9 families were recorded (Singh *et al.*, 2008). Cyanobacteria have often been recorded as the dominant photoautotrophs in terrestrial habitats of the Antarctic ecosystem (Singh, 2012).

Rationale for characterizing Schirmacher lakes as wetlands

The Schirmacher Oasis represents a very important area in east Antarctica because its cyanobacterial diversity and distribution, which are more or less common with those in many other areas. The benthic algae are considered as foundation species as habitat creators by building biofilms on substrata where other producers and consumers live as nutrient cyclers through food web dynamics and biochemical processing of nutrients (Hagerthey *et al.*, 2011).

Foundation species are abundant organisms that facilitate whole communities of other species by creating complex habitat, ameliorating local biotic and abiotic stressors and enhancing resource availability (Dayton *et al*., 1972; Angelini *et al.*, 2011). These species also regulate nutrient cycling by storing nutrients, trapping debris and supporting gas exchange. It also facilitate the growth and survival of other plant and animal species, provide refuge from predators and competitors, alter micro climate and water availability, and stabilize substrata (Faunce and Serafy, 2008; Gaiser *et al.*, 2006). As a result, these foundation species are key drivers of biodiversity and ecosystem functioning in terrestrial, marine, and freshwater ecosystems.

Cyanobacteria play particular foundation roles by producing mucilage (extracellular polysaccharides-EPS) and calcium carbonate that binds the microbial mats together (Hagerthey *et al*., 2011). These microbial (periphyton) mats act as sponges that retain soil moisture, protecting algae and other plants, bacteria, fungi, and aquatic in fauna from grazing/predation (Gaiser *et al*., 2011). Kashyap (1990) recorded a wide range of blue green algae and *Nostoc commune* on soil surface and lake bottom with sediment having overlying felt of blue green algae such as *Osciliatoria*, *Choocous*, *Synechocytis* and some diatoms. Similarly, quartz rock favourd growth of green algae and diatom. The majority of algae recorded at the Schirmacher Oasis possess tough and coloured mucilage. These properties of algae may also help in light filtration and increasing water retention capacity (Verlecar *et al*., 1996).

Benthic algae regulate many of the processes that characterize wetland ecosystems by controlling dissolved oxygen concentrations, sediment formation, nutrient uptake and retention and account for a significant amount of total primary production (Richardson, 2008; McCormick *et al*., 1998; Wyatt *et al.*, 2010, 2012). The nutrient and grazing by mite, rotifers, protozoa and nematodes are important factors that regulate benthic algal biomass and community composition. The abundance of N-fixing cyanobacteria (*Nostoc*, *Anaebena*, *Haplosiphon*) were found in association with moss species (Kashyap, 1990). Abundance of algae (about 60% of algae) was nitrogen fixtures provide N inputs where large quantities of nutrients rendered inaccessible by the slowly decomposing organic matter. Similar results were reported from the lakes of Vestfold Hills, Antarctica by Davey (1983).

In many Antarctic freshwater ecosystems mat-forming Cyanobacteria were the most conspicuous member of the benthic biota and filamentous members of the *Oscillatoriales* were abundant in the mat communities, although the abundance and diversity of *Chroococcales* and *Nostocales* were also reported (Sabbe *et al*., 2004; Quesada *et al*., 2008). Similar community composition of mat forming cyanobacteria was recorded in the fresh water lakes of the Schirmacher Oasia (Verlecar *et al*., 1996).

The global climatic change is responsible for causing ecosystem state changes and decline in productivity in freshwater wetlands around the world (Kominoski *et al*., 2018). The foundation species will ultimately contribute to maintaining the resilience of wetland ecosystems facing numerous and severe threats around the world **(J**unk *et al.,* 2013). A detailed understanding of wetland foundation species dynamics can help to plan conservation measures under climate change, as these species characteristic will define whether ecosystems can adapt, persist or decline or whether all together new communities will take over (Kominoski *et al.,* 2018).

Present phenomena of rising temperature have resulted in rapid fundamental structural and functional changes in high altitude area. As permafrost thaws, the carbon that was locked in these wetland soils becomes available for aerobic and anaerobic decomposition, which will release greenhouse gases (CO_2 and CH4) back in to the atmosphere accelerating global warming, thereby increasing the rate of permafrost degradation (Jianghua and Roulet, 2014). Similar condition may be occurring in the exposed rocky areas of the Schirmacher Oasis environment that harbour numerous fresh water lakes and permafrost soil that need critical appraisal.

.Number of lakes from Schirmacher Oasis does not qualified for wetland (particularly deeper lakes), however lakes with shallow depth up to 6 m or less exhibit significant wetland features and processes and provide critical breeding and feeding habitat for a number of organisms considered to be wetland species. The lakes may be used for monitoring the effects of environmental changes with the succession of cyanobacteria and other algal forms. Antarctic microalgae growing in the stress condition (freeze–thaw cycles) have potential as sources of novel biochemical such as low temperature enzymes and anti-freeze proteins. Thus, they have high conservation significance.

The data presented here is not consistent in terms of wetland definition, types surveyed, inventory and methodology and that the information presented in this article is based on studies carried out during 1991 to 1994 from the Schirmacher Oaisis. However, the data reveals that shallow lakes, ponds and low lying areas of the Schirmacher Oasis qualify for wetland and can be an important tool to assess the climatic and anthropogenic changes. Therefore, a detailed study of the Schirmacher Oasis lakes is required to be carried out in the line with wetland definition criteria on priority basis.

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