PALYNOLOGICAL ANALYSIS OF SURFACE SEDIMENTS IN A HIGH ARCTIC POND, REVEALING DESMIDS AS INDICATORS OF WETLANDS AND CLIMATE CHANGE

Vartika SINGH * and *Sophia BARINOVA* **

* Birbal Sahni Institute of Palaeosciences, Lucknow, India, IN-226007, vartika_singh@bsip.res.in, ORCID: 0000-0002-0448-0860.
** Institute of Evolution, University of Haifa, Mount Carmel, Abba Khoushi Avenue, 199, Haifa, Israel, IL-3498838, sophia@evo.haifa.ac.il, ORCID: 0000-0001-9915-2503.

DOI: 10.2478/trser-2022-0001

KEYWORDS: *Cosmarium*, Ny-Alesund, Palynomorphs, Cladocera, Thecamoebians.

ABSTRACT

This is a first attempt to study the palynological remains from the surface sediments of a pond near the Kongsfjorden coast in Ny-Alesund, Svalbard, Norway. The palynomorphs display a high relative abundance of desmids, Cladocera, thecamoebians, chironomids, and fungal remains inherent to the inland aquatic ecosystem. The *Cosmarium* indicators characterize water as neutral pH, fresh, mesotrophic, without organic pollution, Class 2 of Water Quality as in wetlands with coastal vegetation. The single procedure of palynological analysis excluding the acetolysis step, and bioindicators allows us to perceive the basic framework of the ecosystem, consisting of in-situ and transported remains. This approach could be effectively used for paleoenvironmental reconstructions in High Arctic Regions.

ZUSAMMENFASSUNG: Palynologische Analyse von Oberflächensedimenten eines Teiches in der Hohen Arktis und das Vorkommen von Desmiden als Beweis für Feuchtgebiete und Klimawandel.

Dies ist ein erster Versuch, die palynologischen Überreste aus den Oberflächensedimenten eines Teiches nahe der Küste des Kongsfjords in Ny-Alesund, Svalbard, Norwegen zu untersuchen. Die Palynomorphs weisen eine hohe relative Häufigkeit von Desmiden, Cladocera, Thecamöben, Chironomiden und Pilzresten auf, die dem Inland aquatischen Ökosystem inhärent sind. Die *Cosmarium*-Indikatoren charakterisieren Wasser als neutralen pH-Wert, frisch, mesotroph, ohne organische Verschmutzung, Klasse 2 der Wasserqualität wie in Feuchtgebieten mit Küstenvegetation. Das einzige Verfahren der palynologischen Analyse ohne den Schritt der Acetolyse und Bioindikatoren ermöglicht es uns, das Grundgerüst des Ökosystems bestehend aus in-situ und transportierten Überresten wahrzunehmen. Dieser Ansatz könnte effektiv für paläoökologische Rekonstruktionen in hocharktischen Regionen verwendet werden.

REZUMAT: Analiza palinologică a sedimentelor de suprafață ale unui iaz din Marea Arctică și prezența desmidelor ca dovadă a zonelor umede și a schimbărilor climatice.

Aceasta este o primă încercare de a studia rămășițele palinologice din sedimentele de suprafață ale unui iaz din apropierea coastei Kongsfjorden din Ny-Alesund, Svalbard, Norvegia. Palinomorfele prezintă o abundență relativă mare de desmidii, Cladocera, thecamoebiae, chironomide și rămășițe fungice inerente ecosistemului acvatic continental. Indicatorii *Cosmarium* caracterizează apa ca fiind cu pH neutru, proaspătă, mezotrofă, fără poluare organică, clasa 2 de calitate a apei ca în zonele umede cu vegetație de coastă. Procedura unică de analiză palinologică, excluzând etapa de acetoliză și bioindicatorii, ne permite să percepem cadrul de bază al ecosistemului constând din rămășițe in-situ și transportate. Această abordare ar putea fi utilizată eficient pentru reconstrucțiile paleomediului în regiunile arctice înalte.

INTRODUCTION

High Arctic ecosystems are experiencing some profound changes in the environmental and climatic conditions due to warming (Jiang et al., 2011). The small water bodies of the Arctic are sensitive to changes in environmental conditions like hydrology, temperature, and light, etc. The biota inhabiting these water bodies is subjected to environmental changes and responds to survive. The microscopic green algae are primary producers and form an important part of the terrestrial Arctic tundra ecosystem. The primary producers are directly affected by changes in the physical environmental factors such as light, temperature, etc. (Richter, 2018). The study of the biota of these ponds is, therefore, crucial to understand recent abrupt warming of the Arctic region and the impact of these changes on the ecosystem. In recent decades, viable prokaryotes and eukaryotes have been found isolated from deep horizons of ancient permafrost up to three million years old from depths of up to 400 meters in the Arctic regions of Siberia and Canada (Gilichinsky et al., 1995; Vishnivetskaya et al., 2001; Vorobyova et al., 1997), as well as from the lowest-temperature layers of Antarctica (Gilichinskiy et al., 1996).

The palynological remains could serve as an important tool to understand and study the ecological and environmental conditions of the past. The microscopic remains are linked to the surviving biota and are very useful for climate interpretations on a local and regional scale. Palynological studies from temperate and tropical regions have provided important palaeoclimate data based on established palynological proxies for various paleoclimate and paleoenvironmental parameters (Gelorini et al., 2011; Prager et al., 2012). On the other hand, there is only limited palynological proxy data of algal remains from the northern high latitude region. The palynological data based on pollen, diatoms, chironomids are also fragmentary (Holmgren et al., 2010). Due to the presence of tundra vegetation cover on high Arctic Svalbard, the pollen assemblage reflects only less diverse plant cover of the tundra vegetation where the high diversity is displayed by cyanobacteria, microalgae, lichens, etc. This makes it difficult to perceive recent climate fluctuations using pollen records of modern sediments. The study of microalgal palynological remains could be useful in recording rapid climate fluctuations of the Arctic region because they form the base of the ecological setup and are major contributors to the terrestrial vegetation cover (Birks et al., 2016). The Svalbard archipelago is experiencing some very drastic warming in recent years and is thus an important place to conduct paleoclimate research based on the study of palynological remains. They could also be potentially important to understand past climate conditions and to infer future ecological setup. The preserved remains of biota inhabiting the water bodies of the high Arctic region could be useful in deciphering the paleoecological and paleoenvironmental conditions.

The desmids are unicellular algae belonging to the conjugating green algae Class Zygnematophyceae. The desmids belonging to the Order Desmidiales are considered as true desmids (Denboh et al., 2001). The characteristic morphological feature of desmids is the presence of two symmetrical halves (semi-cells) separated by an isthmus. The nucleus of the desmid cell is located at the isthmus while the two semi-cells contain the chloroplast. The genus *Cosmarium* belongs to Desmidiales, the coccoid, unicellular freshwater algae and member of the Division Charophyta. The genus *Cosmarium* is the oldest and has the highest number of species that have a cosmopolitan to limited range. Desmids occur as a major group of phytobenthos in standing freshwater, terrestrial shallow water pools, ponds, and lakes. A high diversity population of desmids is found in mesotrophic, slightly acidic to the slightly alkaline environment (Coesel and Meesters, 2007; Coesel, 1982). The desmids of small shallow water bodies are susceptible to environmental stresses such as desiccation in warming conditions of the Arctic and are helpful in the ecological monitoring of freshwater habitats.

The remains of unicellular photosynthetic desmidian algae serve as a reflection of the ecological situation, since they form the basis of the food chain. They are all the more important for the high-altitude Arctic regions, where the ecological diversity is significantly lower compared to other climatic zones. This limits the number of species that can be used to reconstruct the paleoclimate remains of lacustrine sediments.

The preservation potential of green algae is low as it does not have many hard and resistant remains. Only a few forms including desmids have parts likely to be preserved. The Svalbard biota study as a representative High Arctic ecosystem is crucial as it provides fundamental information of the biotic communities thriving in the region. The changes in the population have been noticed in the form of addition or removal of forms or both. An attempt has been made to study the algal remains preserved in the surface sediments of a large pond. The algal remains have been identified as the empty semi cells of the desmids. The green algae member desmids have specific environmental requirements and are thus extremely sensitive to even subtle environmental fluctuations. They are both planktic and benthic.

Ny-Alesund, Svalbard acts as a representative High Arctic region (Fig. 1) for the study of present and past climatic variation.

Figure 1: Location map of studied lake in the Ny-Alesund, Svalbard, Norway.

The High Arctic region area experiences stresses such as freezing, desiccation, and high ultraviolet radiation from 24-hour daylight during summer and darkness during winter. The terrestrial biota of the Polar Regions experiences these environmental extremes. Polar biota show early signs of environmental shifts, especially climatic warming, as compared to the tropical regions where such changes are subtle and hard to record. Numerous shallow ponds are a frequent feature of an Arctic landscape and are rich in biodiversity. The rapidly changing environmental conditions and the resulting biotic response are critical in understanding ecosystem shifts and rearrangements. The terrestrial biota of arctic ponds holds important information on changing environmental conditions. Algae can frequently be used over pollen as a traditional terrestrial palaeoclimatic proxy in Polar Regions, where pollen data has limited importance because some past studies have suggested that the terrestrial ecosystem represented by higher plants/vascular plants has not shown any significant change in the past 70 years (Treut et al., 2007; Prach et al., 2010; Nikulina et al., 2016). On the contrary, the limnological diatom proxy data from lakes have provided evidence of marked shifts in lake ecosystems in the 20th century due to warming (Jiang et al., 2011).

The studies on lake sediments of Svalbard are mainly based on the traditional biotic palaeolimnological proxies like diatoms, chrysophytes, chironomids, and pollen. Algal palynomorph have not been considered in a more comprehensive way that cover most of the terrestrial habitats involving the study of surface sediments as well as lake core sediments. The palynomorph data can provide information about the varied biota inhabiting various sub environments, their ecological preferences, and the trophic status of a water body (McCarthy et al., 2018). This can serve as important baseline data that can be traced back in time to understand and reconstruct palaeoenvironmental and palaeoclimatic conditions. A more systematic and detailed observation of the modern ecosystem components, especially the less studied micro biotic components, is highly crucial and critical to consolidate our understanding of environmental and climatic conditions of the more recent past and during the interglacial periods. The Svalbard archipelago is a unique place to carry out climate-related studies because the Arctic is experiencing drastic changes due to warming and shrinking ice cover, due to its location at the gateway (mendley) of the Arctic Ocean, where the warm West Spitsbergen current and cold East Greenland current enter the Arctic Ocean through the Fram Strait. The biota inhabiting Svalbard is subjected to various stresses and their response in the form of adjustments and rearrangements of the ecosystem is important to understand.

MATERIAL AND METHODS

Description of study site

The pond is located at an elevation of 54 m above sea-level on the west coast region of Ny-Alesund, Svalbard (Figs. 1-2). This pond was investigated under the Norwegian-Russian joint project study on the effect of climate change and related stressors on fresh and brackish water ecosystems in Svalbard using invertebrate fauna (Dimante-Deimantovica et al., 2015). It has been classified as a large pond based on the area covered by the pond and depth. The pond is about 1.2 km away from the Kongsfjorden coast and covers an area of approx. 0.2 ha with an average depth of about one m. The pH of the water has been measured as 8.44, conductance (EC) 195 µS/cm, and temperature of 6.5°C during the summer month of August (Dimante-Deimantovica et al., 2015).

Figure 2: Landscape imagery of studied lake (encircled) in the Ny-Alesund, Svalbard, Norway.

The Lake surface sediment was manually collected as the top five cm of sediment, including the water-sediment interface sediment from the lake margin. The sediment sample was air-dried at 30°C in a hot air oven of the Kings Bay marine laboratory. The completely dried sediment was then carefully packed and sent to the laboratory of Birbal Sahni Institute of Palaeosciences for further processing. The sediment was processed to recover the microfossils including desmids. The dry sediment sample (five g) was processed following the standard procedure for the extraction of dispersed organic matter. The procedure involves the use of 35% cold hydrochloric acid (HCl) for the removal of carbonate content, followed by treatment with 30% hydrofluoric acid (HF). Acid was removed by washing with deionized water after the treatment with acids HCL and HF. The recovered organic matter was sieved using 20-micron mesh. Slides were mounted using glycerine jelly and were studied under the Leitz Laborlux D microscope at 400x and 1000x. The identification followed (Prescott et al., 1981, 1982; Forster, 1982; Croasdale and Flint, 1988; Dillard, 1991). The palynomorphs were counted to 200 counts. The slides of the studied material are deposited in the museum of the Birbal Sahni Institute of Palaeosciences, Lucknow vide statement no. 1554.

Desmid species, indicators of environmental conditions, were used to collect ecological, species-specific information (Barinova et al., 2006, 2019; Barinova, 2017a) and water quality classification ranks (Barinova, 2017b). Index saprobity S was calculated on the base of species-specific index saprobity (Barinova et al., 2006, 2019) and abundance of each species in samples.

RESULTS

The palynological/organic-walled micro remains have been recovered from the surface sediments of a small pond and consist of desmid genus *Cosmarium* (Fig. 3), cladocerans, black opaque debris, chironomids, thecamoebians, phytoclasts, and fungal remains (Fig. 4).

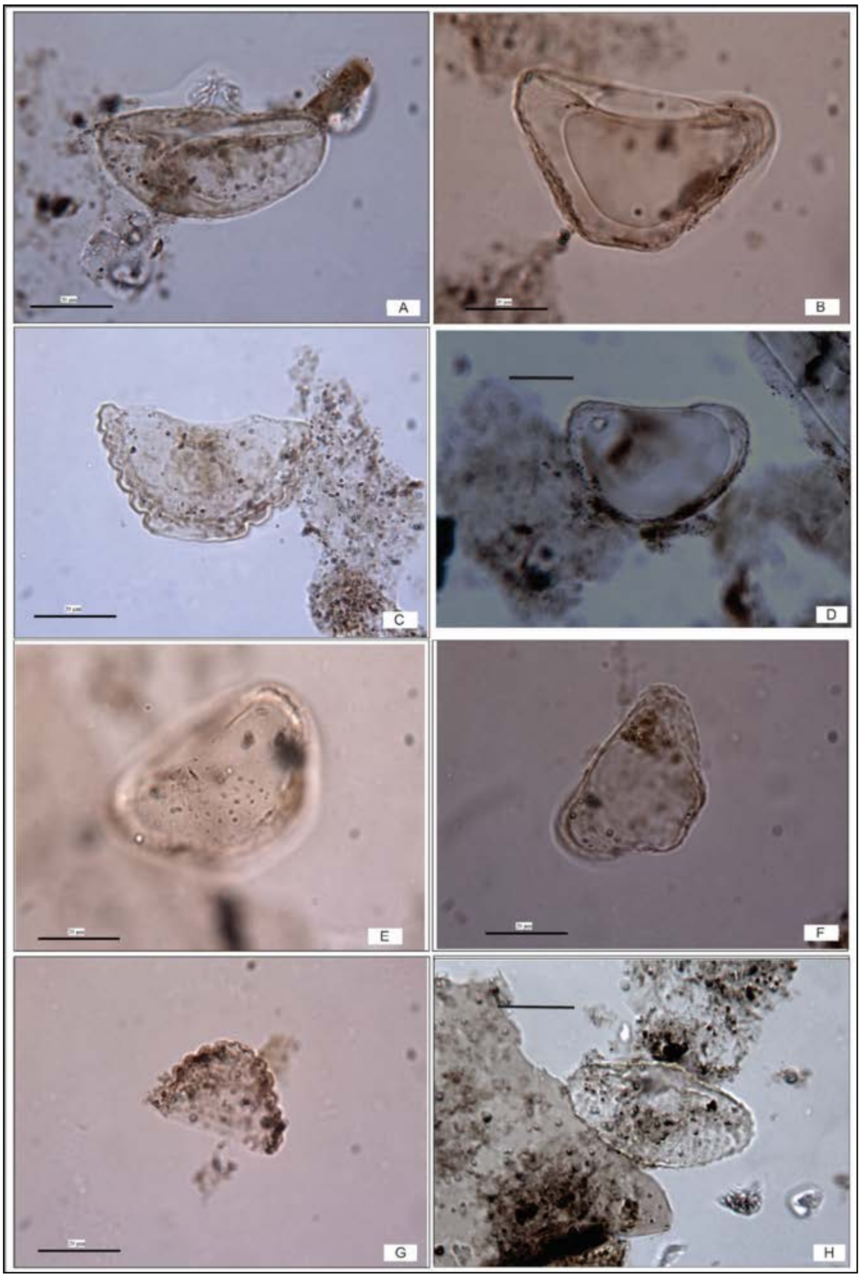

Figure 3: *Cosmarium* forms in sediments; A. *Cosmarium punctulatum* (EFP F23/3; BSIP S. No. 16262); B. *C. turpinii* (EFP Q54/3; BSIP S. No. 16258); C. *C. crenatum* (EFP H24/1; BSIP S. No. 16262); D. *C. botrytis* (EFP L52/3 16262); E. *C. Granatum* (EFP P40/2 S. No. 16258); F. *C. protractum* (EFP V33/2; S. No. 16262); G. *C. excavatum* (EFP F40/3; BSIP S. No. 16262); H. *C. formosulum* (EFP R22/4 BSIP S. No. 16260). EFP – England finder position, BSIP S. No. BSIP Slide Number, Scale Bar-20 µm.

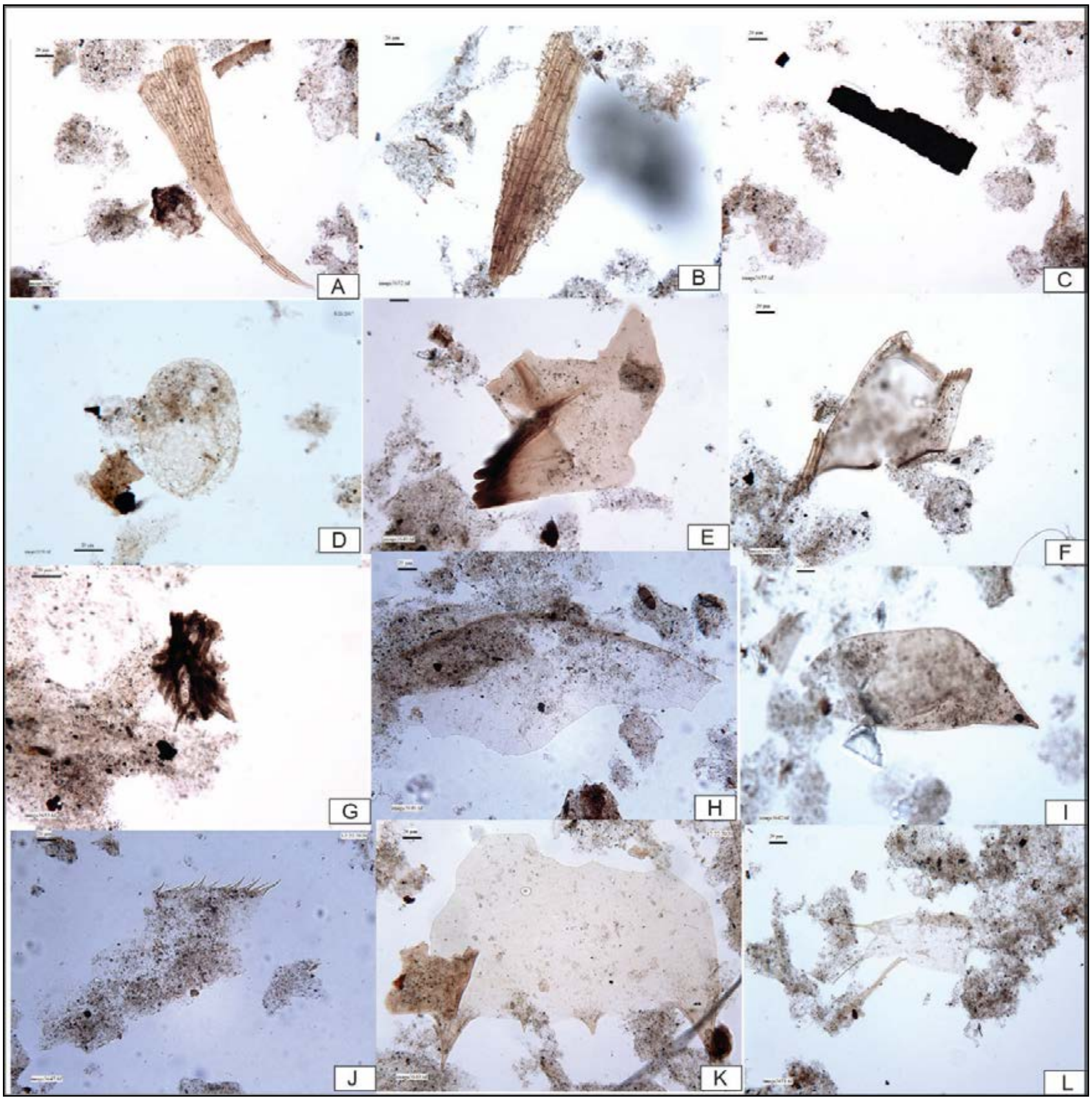

Figure 4: Other palynomorphs; A, B- Phytoclasts (A. EFP D39/3, B. EFP U36/4, BSIP S. No. 16261); C. Black Opaque (EFP K38/3, BSIP S. No. 16261); D. Thecamoebian (EFP Q38/4, BSIP S. No. 16260); E, F. Chironomid remains (E. EFP R43/1, BSIP S. No. 16258; F. EFP Q42/2, BSIP S. No. 16261); G. Fungal remains (EFP K51/3, BSIP S. No. 16261); H.-L. Cladoceran remains (H. EFP S26/1, BSIP S. No. 16258; I. P42/4 BSIP S. No. 16258; J.-K. 23/2 BSIP S. No. 16258, K. R34/4 BSIP S. No. 16261, L. S27/1, BSIP S. No. 16261). EFP – England finder position, BSIP S. No. BSIP Slide Number, Scale Bar-20 µm.

Other components viz. cladocerans, black opaque debris, chironomids, thecamoebians, phytoclasts, and fungal remains have the relative abundance of 17%, 15%, 7%, 6%, 4%, and 4% respectively (Fig. 5). The relative abundance of the palynomorphs consists of highest desmid concentration with 46% of total recovered remains (Fig. 5). Desmid semi-cells are the most abundant component of the palynomorph assemblage and largely belong to the genus

Cosmarium. The identified species of *Cosmarium* are *Cosmarium punctulatum*, *C. protractum*, *C. turpinii*, *C. formosulum*, and *C. granatum*. Among the recovered desmid genus *Cosmarium*, the recorded species of highest relative abundance is *C. punctulatum* (43%) followed by *C. protractum* (19%), *C. turpinii* (11%), *C. formosulum* (8%), whereas the species *C. granatum*, *C. excvatum*, *C. crenatum*, and *C. botrytis* have the relative abundance of about 4% (Fig. 6).

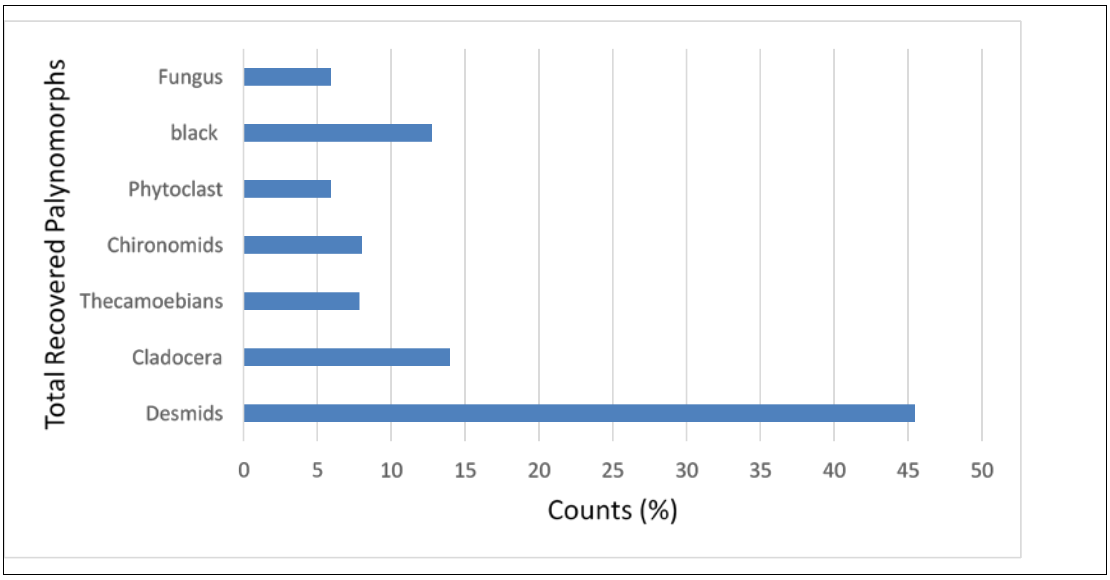

Figure 5: Relative abundance of the palynomorphs.

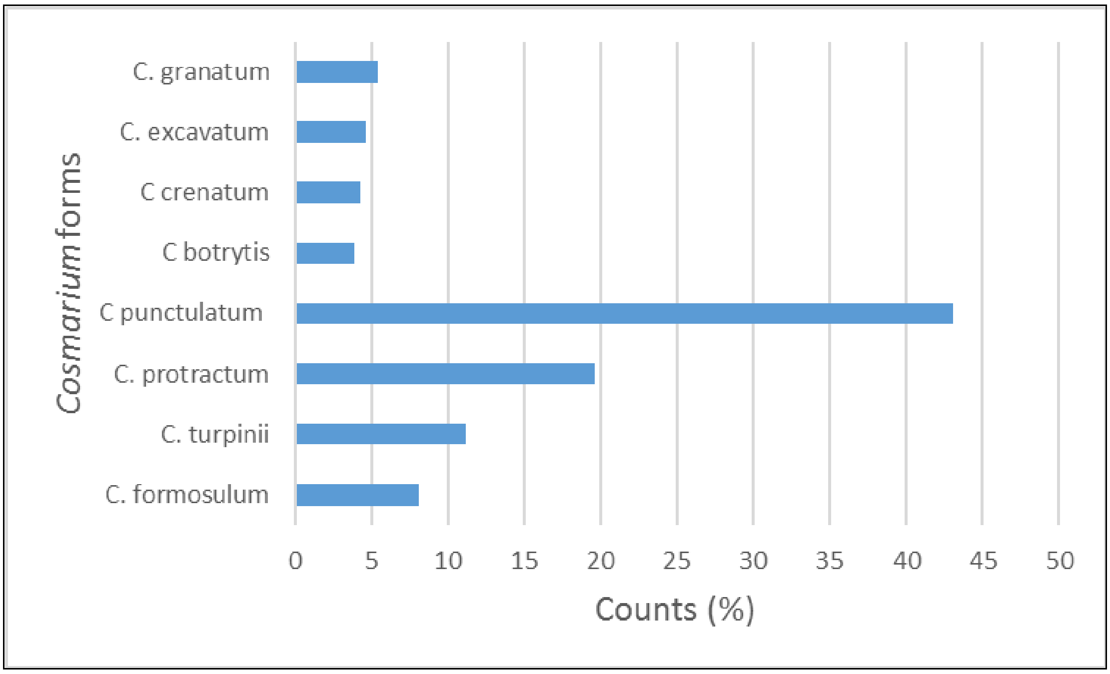

Figure 6: Relative abundance of the *Cosmarium* forms.

All revealed species of *Cosmarium* were inhabitants of planktonic-benthic communities that usually exist in shallow standing waters (Tab. 1). They will be indicators of well or middle oxygenated waters with neutral pH and low salinity. Species-specific index saprobity S varied in range 0.7-1.9 that correlated with saprobity self-purification zones affiliated to Class 2 and 3 of Water Quality. Index saprobity S that calculated for whole community was 1.29 that correspond to Class 2 of Water Quality. Species of *Cosmarium* in studied lake survived in mesotrophic to meso-eutrophic condition.

Table 1: Ecological preferences of revealed species of *Cosmarium* remains with percent in samples; Habitat (Hab): P-B – plankto-benthic, B – benthic, aer-aerophiles. Oxygenation and water moving (Oxy): st-str – low streaming water, aer-aerophiles. pH (pH): acf – acidophil, ind – pH indifferent. Halobity degree (Sal): i – oligohalobes-indifferent, hb – halophobes. Saprobity (Sap): o-x – oligo-xenosaprob, o-a – oligo-alpha-mesosaprob, o – oligosaprob. Trophic state (Tro): o – oligotraphentic; m – mesotraphentic; me – meso-eutraphentic. "–" property is unknown.

Species	Hab	Oxy	pH	Sal	Sap	Index S	Tro	Percent in samples
Cosmarium botrytis Meneghini ex Ralfs	P-B	st-str	ind	i	o-a	1.9	m	4
Cosmarium crenatum Ralfs ex Ralfs	B, aer	aer	ind	–	–	–	m	4
Cosmarium excavatum Nordstedt	–	–	acf	–	–	–	o	4
Cosmarium formosulum Hoff	P-B	–	ind	–	o-a	1.8	me	8
Cosmarium granatum Brébisson ex Ralfs	B	st-str	ind	i	o	1.2	m	4
Cosmarium protractum (Nägeli) De Bary	P-B	–	ind	–	–	–	me	19
Cosmarium punctulatum Brébisson	P-B	–	ind	hb	o	1.3	m	43
Cosmarium turpinii Brébisson	P-B	–	ind	i	o-x	0.7	me	11

Modern desmid record of Svalbard

The desmids are present as both benthic and planktic algae in water bodies ranging from small pools of water to lakes and streams. The previous studies provide a record of living algal samples from different aquatic habitats of Svalbard. Lenzenweger and Lütz (2006) reported 58 taxa of desmids from the snow and terrestrial samples collected from the Kongsfjord coast near Ny-Alesund. Kim et al. (2008, 2011) have studied and reported the sporadic occurrence of *Cosmarium undulatum* in the soil and freshwater samples collected from mud puddles, moss bogs, glacial meltwater stream, and other water bodies in and around Ny-Alesund, Svalbard during the years 2006 and 2009. They have demonstrated the presence of *Cosmarium undulatum*, and its annual fluctuation with higher numbers reported in 2006 as compared to 2009. Richter et al. (2015) recorded desmids *Cosmarium costatum* var. *costatum, C. granatum, C. holmiense, C. hornavense, C. speciosum, C. undulatum* collected from various aquatic habitats around Hornsund fjord. Five species of *Cosmarium* were recorded from the snow samples collected in Petuniabukta (Kvíderová, 2012). In an interesting study, Richter (2018) studied hydro-terrestrial habitats of the Hornsund fjord region of Svalbard. The study included cyanobacterial and microalgal communities, which are important components of terrestrial vegetation in Svalbard and reported 64 species of desmids from 20 hydro-terrestrial habitats. *C. crenatum* were recovered from two lakes and five ponds with an alkaline pH range of 7-9. *C. formosulum* and *C. punctulatum* were recorded from two lakes with a pH range of 7.3-7.9. Our findings from the studied lake represent only eight species of *Cosmarium* from 457 with known ecological properties. Bioindication that was firstly implemented for Svalbard aquatic communities shows similar results of environment assessment, as were found previously in respect of water pH (Richter, 2018) and for close related well studied regions such as Kola Peninsula (Denisov and Barinova, 2015), where there were found 16 species of *Cosmarium* as bioindicators of similar environmental conditions. Four of them were found in Svalbard also. Bioindication by revealed species of *Cosmarium* can characterize the studied lake as shallow with a well-developed coastal community of algae, low saline, neutral or low alkaline waters and mesotrophic condition during the studied sediment deposition. The present of such a large number of desmid species can also characterize the studied lake as a wetland (Adamus and Brandt, 1990) where desmids can find the best environments for flourishing.

The study of living algae provides crucial baseline data of desmids that inhabit the High Arctic region, especially during the rapid warming scenario. On the other hand, palynological data in the form of preserved remains (palynomorphs) recovered from the surface sediments represents a modern analogue with important implications for Quaternary paleoenvironmental, palaeoecological, and palaeoclimate studies.

The fossil record of desmids

The empty semi-cells as well as complete desmids are preserved in sediments and leave a sedimentary record. However, there are fewer studies on the occurrence of fossil desmids from the past sedimentary record. The fossils record of desmids comparable to the modern desmid morphotypes dates back as early as from Late Proterozoic sequence of the chert beds of uppermost Tindir Group limestones, Tindir Creek, Yukon Territory, Canada, which has shown similarity to the modern genus *Staurastrum* (Allison and Awramik, 1989). Besides having a long geological record dating back to Cambrian, desmids have been rarely reported and studied from other deep time sequences. The Quaternary record of desmids is also meager which could be easily compared to the modern morphotypes and serves as valuable paleoenvironmental proxy data. This makes desmids much understudied and unconventional yet potentially promising tool for future studies. Desmids have also been used to study the anthropogenic impact in the Great Lake region of Canada. In this study they have been used as proxy of water quality assessment, anthropogenic impact (McCarthy et al., 2018).

Other palynomorphs

The palynological remains of desmids form a major fraction of all the preserved acid-resistant organic constituents and the other recovered biotic remains belong to Cladocerans, chironomids, thecamoebians, and fungi. In addition to this, undifferentiated plant remains have also been recovered and are classified as phytoclasts and the dark coloured opaque fragments are classified as opaque black (Fig. 4) (Tyson, 1995). The studied palynomorphs derived from the surface sediments take in to account all the acid-resistant organic remains of organisms inhabiting the water body as well as transported and/or in situ fragments. The remains are preserved in the surface sediments after the death and disintegration of the biota. The organic-walled microfossils have a better chance of preservation than the calcareous forms because they are not affected by dissolution.

The study involving all the preserved palynological organic remains provides more information on the ecological setup of any aquatic environment and its surroundings (Gilichinsky et al., 1995; Vishnivetskaya et al., 2001). The complete assemblage contains organic remains of primary producers (algae), consumers (protists and other zooplankton), and decomposers (fungi, etc.). The recovered palynomorph assemblage includes different ecosystem components in the form of green algae *Cosmarium* as primary producers, Cladocerans, Thecamoebians, and Chironomids as consumers, fungi representing decomposers (Fig. 7). Phytoclasts and black opaque particles display transported components that are deposited in the pond from the surrounding areas. Organic walled algal remains are derived from the green algae desmid. The Cladocerans are small crustaceans that are commonly found in freshwater aquatic habitats. Chironomids larvae are produced by the insects, non-biting midges. Cladocerans and chironomids feed on algae, chironomid larvae are opportunistic and other than algae, they feed on all kinds of detritus available to them including dispersed particles of wood. The organic-walled body parts of Cladocerans (Figs. 4H, L) and mouthparts of chironomid larvae (Figs. 4E, F) are preserved in the sediments (Fig. 4). They have been used in paleolimnological studies from Svalbard (Brooks and Birks, 2004; Birks et al., 2016).

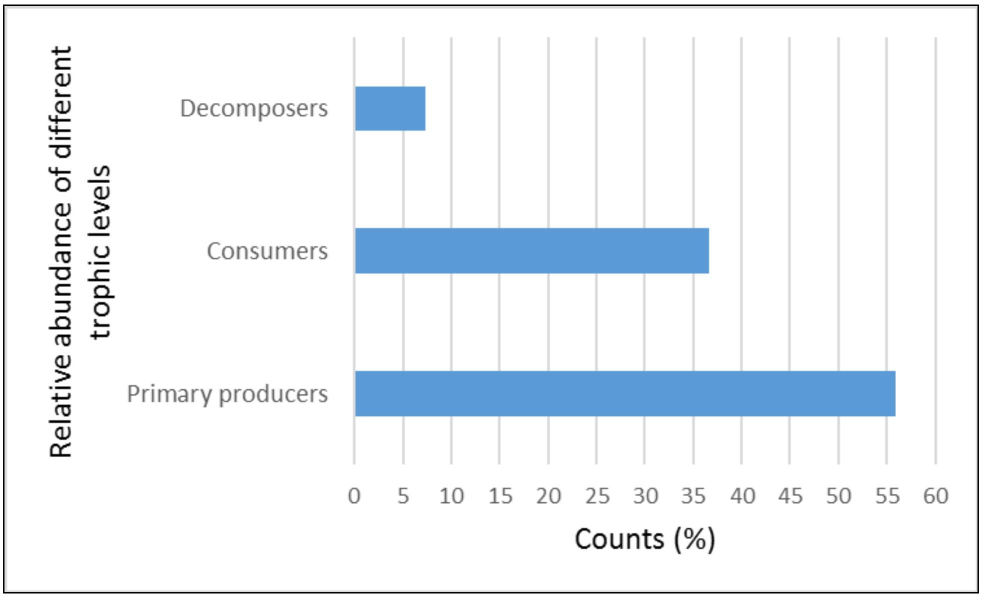

Figure 7: Relative abundance of producers, consumers, and decomposers.

Cladocerans and chironomids are an important part of the aquatic food web because being primary consumers, they form a link between producers and secondary consumers. Their role becomes even more significant in the small aquatic habitats of the High Arctic, where ecosystems generally have low species richness. Thecamoebians are eukaryotic heterotrophic protists that are found in fresh as well as brackish water conditions (Fig. 4D). They feed on algae, bacteria, fungi, and other small organisms. The autogenous (test secreted by the individual) and xenogenous (test made up of particles picked from the surrounding) tests of the camoebians get preserved in the sediment (Singh et al., 2015). Despite their presence in the sediments and environmental significance, they have not been systematically studied and utilized in recent environmental monitoring, assessment, and palaeoenvironmental reconstructions from Svalbard.

Apart from the above-discussed microfossils, the recovered plant remains which retain some cellular structure but could not be assigned to any specific plant genera, are classified as phytoclasts (Figs. 4A, B) (Tyson, 1995). They could be the remains of algae, bryophytes, and vascular plants. The presence of algal fragments could be related to their growth and presence in the pond or transport from an area close to the pond. On the contrary, the black opaque particles are allochthonous and transported by melt water streams or by the wind to get deposited in the pond. Some internal cellular structures are visible in phytoclasts but are indiscernible in the black opaque component (Fig. 4C). The microscopic fungal remains are scarcely reported from Svalbard. Fungal elements provide a signature of the decomposers and are an important component of an ecosystem. The microscopic remains of fungi are recovered in the form of fungal hyphae and spores (Figs. 4G, H).

This is a first attempt to study all the preserved organic remains from the High Arctic Region of Svalbard and is an initial study that can be extended both spatially and temporally to generate a more extensive and meaningful data set.

The relative abundance of recovered palynomorphs

The relative abundance of the palynomorphs recovered from the surface sediments shows a dominant presence of half-cells of desmids forming about half of the total palynomorph assemblage. The abundance of desmids is displayed by one identified genus *Cosmarium*, which is represented by eight identified species (Fig. 3). Among the recovered semi-cells, the semi-cells of *C. punctulatum* (Fig. 3) have the highest abundance followed in decreasing order of abundance by *C. protractum* (Fig. 3), *C. turpinii* (Fig. 3), *C. formosulum* (Fig. 3), *C. granatum* (Fig. 3), *C. excvatum* (Fig. 3), *C. crenatum* (Fig. 3), and *C. botrytis* (Fig. 3). *C. punctulatum* strains are cosmopolitan but also include some tropical and polar strains. The recovered desmid assemblage shows the dominant presence of some forms over others, but overall diversity is low. Sub-polar, temperate, and Polar forms are abundant as compared to the cosmopolitan desmids which prefer benthic life habitats and meso-oligotrophic to meso-eutrophic nutrient conditions. In Ny-Alesund water bodies, the pH varies from about six to nine with large variations recorded in puddles and small ponds. Large ponds and lakes do not show a large variation in pH. The pH of the studied large pond has been measured in the summer of 2015 to 8.44 (Dimante-Deimantovica et al., 2015). The high relative abundance of *C. punctulatum* could be due to its wide range of pH tolerance because it has been reported from slightly acidic to alkaline habitats. However, *C punctulatum* has been recovered from a lake in Hornsund with pH 7.3 (Richter et al., 2018). The desmid assemblage record from snow samples and moss patches along the rim of ponds situated on the coast in Ny-Alesund includes the forms *C. botrytis*, *C. crenatum*, and *C. granatum* that are present in the surface sediments (Lenzenweger and Lütz, 2006). Desmids being primary producers form about 45% proportion of the total recovered palynomorphs/microfossils. The remaining 55% are displayed as consumers (30%) (Cladocera, chironomids, and thecamoebians), the relative abundance of primary consumer Cladocera (about 17%) is highest among the consumers along with chironomids and thecamoebians having relative abundances of 10% and 8% respectively.

CONCLUSIONS

The recovered desmid assemblage represented by only one genus and eight species from one pond could represent an assemblage devoid of any preservation bias because the prior studies show the occurrence of only one species, one genus, or even complete absence of desmids in ponds and lakes. This observation warrants more data and studies for further validation. Despite this, even now, the identified species of *Cosmarium* in the lake sediments allow us to characterize the environment as neutral pH, freshwater, mesotrophic, without organic pollution, Class 2 of Water Quality, and representing a wetland with well-developed coastal vegetation.

The presence of palynomorphs of the aquatic biota and transported elements in the surface sediments provide information on many components of the ecological set up of a High Arctic pond.

The study involving different ecological components provides important information on the biological interactions within the aquatic ecosystem, the impact of allochthonous components on the aquatic ecosystem, and the influence of physical parameters impacting a terrestrial ecosystem.

The implications of the study are especially important because the Arctic Regions are undergoing drastic changes due to warming. The same approach can be effectively used to study and understand the past ecological conditions and ecosystem makeup during fluctuating environmental and climatic conditions.

ACKNOWLEDGEMENTS

We gratefully acknowledge the Director of Birbal Sahni Institute of Palaeosciences, Lucknow, India and the Directors of the Institute of Evolution, University of Haifa, Israel for providing permission, continuous support and encouragement to carry out collaborative research work. We are also thankful to the Director ESSO-NCPOR, Goa, India and the Kings bay AS, Ny-Alesund, Svalbard for providing the logistics and laboratory facilities in Ny-Ålesund, Svalbard. This is a BSIP contribution no. BSIP/RDCC/Publication no. 76/2020-2021.

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