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A study of autotrophic communities in two Victoria Land lakes (Continental Antarctica) using photosynthetic pigments

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ABSTRACT

The composition of algal pigments and extracellular polymeric substances (EPS) was determined in microbial mats from two lakes in Victoria Land (Continental Antarctica) with different lithology and environmental features. The aim was to expand knowledge of benthic autotrophic communities in Antarctic lacustrine ecosystems, providing reference data for future assessment of possible changes in environmental conditions and freshwater communities. The results of chemical analyses were supported by microscopy observations. Pigment profiles showed that filamentous cyanobacteria are dominant in both lakes. Samples from the water body at Edmonson Point had greater biodiversity, fewer pigments and lower EPS ratios than those from the lake at Kar Plateau. Differences in mat composition and in pigment and EPS profile between the two lakes are discussed in terms of local environmental conditions such as lithology, ice-cover and UV radiation. The present study suggests that a chemical approach could be useful in the study of benthic communities in Antarctic lakes and their variations in space and time.

Key words: Antarctic lakes, microbial mats, algal pigments, EPS

1. INTRODUCTION

Many lakes and ponds in Antarctic ice-free areas provide an environment for phototrophic organisms that is more buffered than soils against desiccation, solar radiation and low temperatures (Bargagli 2005). A large proportion of organic matter in continental Antarctica is found as benthic mats of cyanobacteria, chlorophytes and phytoflagellates in freshwater ecosystems (Vincent 2000). These phototrophs support simple truncated food webs, which in Victoria Land (East Antarctica) include a wide range of heterotrophic bacteria, fungi, protozoans, and few species of rotifers, nematodes and tardigrades.

The biomass and morphology of freshwater microbial mats is affected by many factors such as the duration, thickness and transparency of the ice-cover, sediment features, water depth and chemistry (e.g., Hodgson *et al.* 2004; Sabbe *et al.* 2004). These mats generally show a vertical stratification of different cyanobacteria and contain high concentrations of extracellular polymeric substances (EPS), varying quantities of mineral sediments and large voids occupied by water (de lo Rios *et al.* 2004). EPS are probably involved in biofilm formation and adherence processes, and they are thought to play an important role in the survival and growth of cyanobacteria under extreme conditions because they provide protection against desiccation and predation (De Philippis & Vincenzini 1998). Typical pond mats have a heavily pigmented superficial layer of cyanobacteria: their black, brown or orange pigments very effectively screen out harmful UV radiation (Ehling-Schulz 1997; Squier *et al.* 2004). The underlying green layer has the highest photosynthetic rate in the mat and is supersaturated with oxygen. A few millimetres below, oxygen is depleted because it is consumed by bacterial decomposition.

Many Antarctic lakes lack an outlet; they therefore reflect biogeochemical processes occurring both in the lake and in the surrounding catchment and are among the most reliable early warning indicators of local climatic and environmental changes (e.g., Borghini & Bargagli 2004; Hodgson *et al.* 2006; Hodgson & Smol 2008). Simple phototrophic communities in Antarctic lakes are adapted to cope with extreme environmental conditions and are more exposed to ecological changes than freshwater communities at lower latitudes, where responses to external forcing and potential colonists are buffered by more complex biological interactions and feedback processes (Bargagli 2005). At Signy Island, for instance, climate warming is increasing primary production (Quayle *et al*. 2002). Although Victoria Land is one of the most important limnological regions in Continental Antarctica, only a few lakes such as those in the McMurdo Dry Valleys have been thoroughly investigated (e.g., Wharton *et al.*1993; Priscu 1998; Vopel & Hawes 2006; Vincent & Laybourn-Parry 2008). Very few data are available on lacustrine mats in northern Victoria Land, and all are from microscopy studies. This study is part of a multidisciplinary project aimed at creating a database of the biological and ecological characteristics of lakes and ponds. Previous studies (Borghini & Bargagli 2004; Borghini *et al.* 2007; 2008) have shown that those in the region have very different biogeochemical characteristics.

Despite the low taxonomic resolution, HPLC analysis of sedimentary pigments could be a rapid tool for compiling a database of the main algal groups present. This is because some photosynthetic pigments in planktonic and benthic phototrophs, for example chlorophyll-*a* (chl-*a*) and β-carotene (β-car), are ubiquitous among the different taxa, whereas others (e.g., lutein, fucoxanthin and zeaxanthin) are markers of specific algal groups (Chlorophyta, diatoms and cyanobacteria, respectively; e.g., Jeffrey *et al*. 1997).

Preliminary surveys on water chemistry and sedimentary pigments (Borghini *et al*. 2007) found that two lakes in areas with different lithology, latitude and environmental characteristics (Edmonson Point and Kar Plateau) have very different prototroph communities, but similar water chemistry. This study aimed to better characterize these communities through the analysis of EPS and algal pigments and through microscopic observation of microbial mats. In particular, it aimed to: a) assess whether biotic variations are linked to different environmental conditions and; b) compare microscopic and chemical data for the study of microbial mats in Victoria Land lakes. The chemical approach, simpler and less time-consuming than microscopic analysis, may be useful in extensive studies of mats and their temporal and spatial variations in composition and responses to changing environmental conditions. Sediment samples were also analyzed using a technique that is more sensitive and selective than that used in the previous work.

2. METHODS

2.1. Study area

Kar Plateau is a coastal ice-free area (roughly 4 km^2 wide, at an altitude of about 160 m) located in the northern Granite Harbour region (Fig. 1). Granitic bedrocks form an upland which is confined to the North by a glacier and to the South and the East by a granite cliff capped by dolerite (Taylor 1914). Kar Plateau has a very rich moss and lichen flora compared to other ice-free areas in the region (Seppelt *et al*. 1995), and some of the ponds and small lakes have no ice-cover in summer. Although there are some studies on soils (Ugolini 1977), mosses and lichens (Schofield & Ahmadjian 1972, Seppelt *et al.* 1995; Cannone 2006) from this area, to our knowledge there are no data for algae from lakes and ponds. Borghini *et al*. (2007) analyzed water samples from the biggest lake at Kar Plateau and found that their chemistry is affected by marine aerosol and elements leached from rocks and soils; according to the classification based on total N and P concentrations (Volleiweider & Kerekes 1982), it is a meso-euthrophic lake.

Edmonson Point is one of the largest (about 6 km^2) of the few low-lying ice-free coastal areas in northern Victoria Land (Fig. 1). The area comprises relatively gently sloping gravel and cobble beaches and numerous knolls (200-300 m high) and moraines separated by small valleys. The volcanic substrate is generally dark and solar radiation leads to rapid snowmelt in summer, with the formation of ephemeral streams and ponds. In small valleys and depressions the availability of water and nutrients (mainly from nesting Adelie penguins and south polar skuas) favours the development of moss and algae communities and a wide range of freshwater habitats (from oligotrophic to eutrophic conditions). Broady (1985) studied the morphological taxonomy of microalgal and cyanobacterial communities at Edmonson Point and reported 42 taxa in algal mats, soils, bryophytes and rocks. More recently, Cavacini & Fumanti (2005) reported 102 taxa from the same area applying morphological taxonomy: mostly Cyanobacteria with subordinate Bacillariophyta and minor Xanthophyta. These authors found that this community composition is rather common in freshwater habitats along the Victoria Land coast (from Cape Hallett to Wright Valley); however, autotrophic communities at Edmonson Point have the highest diversity. Lake 14, located in a small depression about 300 m from the coastline, is eutrophic and its sediments are covered by extensive microbial mats (Borghini *et al*. 2007).

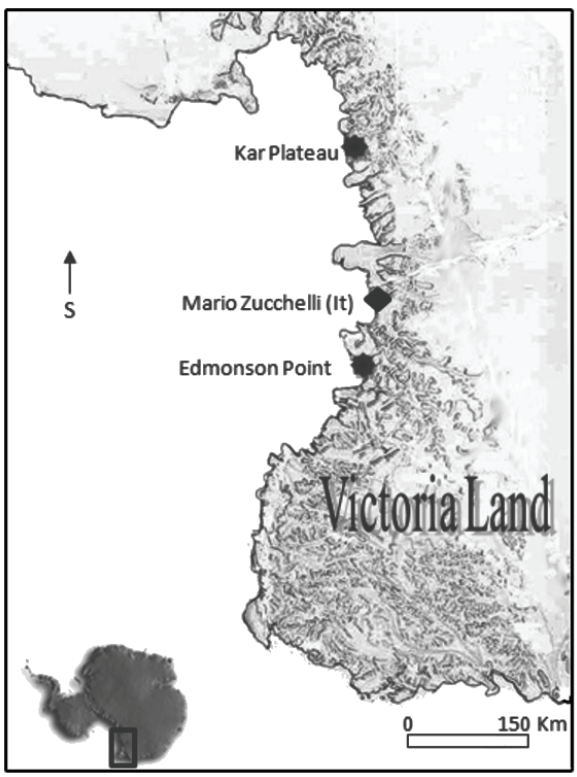

Fig. 1. Sampling stations in Victoria Land.

2.2. Sampling

Three mat samples were collected from the largest lake at Kar Plateau and from Lake 14 at Edmonson Point during the last week of January 2005; the main

characteristics of the two water bodies are summarized in table 1. Microbial mats were hand-sampled about 0.5 m from the littoral zone using a metal corer and gloves. Sediment samples were collected by a metal hand-corer about at the same distance of the mats in the littoral zone free from microbial mats. Samples wrapped in silver paper were brought back to the Italian "M. Zucchelli" Antarctic Station and stored at -20 °C for transport to Italy. The samples were preserved frozen and in the dark until analysis.

Tab. 1. Main environmental characteristics and water chemistry (mean ion concentrations in µg mL^{-1} and conductivity in µS cm^{-1}) and sediment (S and P in µg g^{-1} dw; TOC, TC and TN in %; from Borghini *et al*. 2007) of the two lakes.

	Kar Plateau	Edmonson Point
Latitude S	76.91065°	74.32942°
Longitude E	162.54123°	165.13292°
Altitude (m)	160	20
Catchment lithology	granitic	volcanic
Distance from the sea (m)	500	500
Estimated surface (m^2)	2900	4000
Presence of birds	few	few
Ice-cover (at the time of sampling)	partial	no ice
Mats and sediments sampling depth (cm)	30	30
Lake depth (m)	4	1
TN	3.50	2.10
TP	0.10	0.15
Na^+	50.84	63.09
K^+	3.60	6.28
Mg^{2+}	15.77	5.07
Ca^{2+}	23.08	6.96
Cl^-	162.22	115.21
SO_4^{2-}	2.27	5.89
pH	9.1	9.3
Conductivity	993	1180
S	365	539
P	515	587
TC	0.50	1.53
TN	0.13	0.20
TOC	0.30	0.69

2.3. EPS analysis

Total EPS were extracted with 2% EDTA in lyophilized fractions of known weight. The extracted carbohydrates were determined using the phenol-sulphuric method (Herbert *et al.* 1971) with glucose as the standard. The protein content in the EPS was determined according to Bradford (1976) using bovine serum albumin as the standard.

2.4. Photosynthetic pigment and Total Organic Carbon (TOC) analysis

About 2 g of freeze-dried bulk sediment and 0.2 g of lyophilized mat were extracted with 5 mL of acetone by sonication and stored for 1 hour at 5 °C in the dark. The procedure was repeated three times. Extracts were centrifuged at 3500 rpm for 10 min and filtered before atmospheric pressure chemical ionization- liquid chromatography-mass spectrometry and photodiode array (APCI LC-MS-PDA) analysis. Ammonium acetate 0.1 M (10% of the sample) was added to the sample just before HPLC injection. 50 µL of sample were injected into reversed-phase columns (Spherisorb ODS2 Hypersil, 150 × 4.6 mm ID, 5 µm particle size equipped with ODS2 pre-column) were used along with a solvent system and gradients slightly modified from Pinckney *et al*. (1996). LC-MS was performed using a Thermo system comprising a Finnigan surveyor autosampler, a MS pump and a Finnigan LTQ. APCI LC-MS was performed in the positive ion mode, and MS instrument settings were as follows: capillary temperature of 250 °C, APCI vaporizer temperature of 350 °C, discharge current of 5.5 µA, discharge voltage of 4 kV, sheath gas flow rate of 40 a.u. (arbitrary units), auxiliary gas flow rate of 14 a.u., sweep gas flow rate of 0 a.u.

Peaks were identified by their absorption spectra at their maximum wavelength and characteristic MS^2 fragmentation. Pigment quantification was performed by comparing the HPLC peak areas with those of standards (chlorophyll-*a*, chlorophyll-*b*) from Sigma-Aldrich Chemie Gmbh and alloxanthin, antheraxanthin, 19'-butanoyloxyfucoxanthin, cantaxanthin, α- and β,β-carotene, chlorophyllide-*a*, chlorophyll-*c*2, chlorophyll-*c*3, divinyl chlorophyll-*a*, fucoxanthin, diadinoxanthin, echinenone, 19'-hexanoyloxyfucoxanthin, lycopene, myxoxanthophyll, neoxanthin, peridinin, pheophytin-*a*, pheophorbide-*a*, lutein, prasinoxanthin, violaxanthin, zeaxanthin) from the International Agency for ^{14}C Determination VKI in Hoersholm, Denmark and using published extinction coefficients (Hurley & Watras 1991; Villanueva *et al*. 1994; Jeffrey *et al*. 1997) when standards were unavailable. The specific extinction coefficient used for scytonemins was 112.6 L g^{-1} cm^{-1} (Vincent *et al*. 2004). When extinction coefficients were unavailable or when no structurally or spectrally similar pigment existed, the value of 2500 for β,β-carotene was used (Jeffrey *et al*. 1997). Results are expressed in ng g^{-1} dry wt for mat and ng g^{-1} TOC for sediment samples. Mat and sediment samples were analyzed in duplicate with a precision of <10%. The taxonomic inferences made from the HPLC analyses were verified through the observation of mat samples under a light microscope.

TOC concentrations were determined using an elemental analyzer (2400 Series II, Perkin-Elmer) prior to acid treatment, applied in order to remove carbonates. All samples were analyzed in triplicate. Blanks were run during each analytical session to verify the absence of contamination, and a certificate reference soil sample (GBW-07411) was used to check the accuracy of CHNS analysis.

3. RESULTS

Under the microscope the microbial mats from the lake at Kar Plateau appeared green, with a quite homogeneous unlayered structure; they consisted almost exclusively of the nostocal *Anabaena* sp., with minor

Tab. 2. Average compound concentrations (expressed in µg g^{-1} dw and mg TOC^{-1} in mat and sediment samples, respectively) from Edmonson Point (EP) and Kar Plateau (KP) lakes. t: trace quantities. Main UV-Vis absorbtion bands (nm) and MS data (m/z) are reported.

	UV/Vis (nm)	[M+H] (m/z)	Microbial mats		Sediments	
			EP	KP	EP	KP
Unidentified UV photoprotective compound	338		1.64			
Unidentified carotenoid	454					0.29
Scytonemin derivative	356, 456, 580				2.34	4.05
Reduced scytonemin	356, 442, 580	547	26.70	418	27.85	16.63
Scytonemin derivative	384, 460, 570		1.43			39.38
Unidentified UV photoprotective compound	340					2.56
Scytonemin	388	545	1.15	500	7.46	2.09
Scytonemin	388	545	2.90	222	8.25	3.02
Fucoxanthin	452	641	t		t	
Unidentified UV photoprotective compound	328		2.50			5.93
Unidentified carotenoid	466, 496, 528				0.21	
Unidentified carotenoid	466, 496, 528		0.40		0.39	
Unidentified carotenoid	468, 496, 530		1.46		0.37	
Unidentified carotenoid	440, 474, 504		62.60		1.68	
Unidentified carotenoid	482, 504				0.82	
Neoxanthin	414, 436, 464	583			1.71	
Unidentified carotenoid	450, 474, 504		36.20		2.35	
Unidentified carotenoid	420, 450, 476		1.24		0.66	
Unidentified carotenoid	448, 474, 504		9.38	2.69	1.28	
Unidentified carotenoid	444, 474, 504				0.55	
Myxoxanthophyll	450, 474, 504	760	2.10	0.96	3.27	
Unidentified carotenoid	444, 474, 504		1.71		0.25	
Unidentified carotenoid	440, 474		2.18		0.19	
Lutein	418, 446, 474	551		t		
Zeaxanthin	422, 452, 476	569	1.80	0.29	3.24	
Unidentified carotenoid	444, 468, 498		1.37		0.68	
Unidentified carotenoid	474		0.54		t	
Unidentified carotenoid	445, 474, 504				0.13	
Unidentified carotenoid	440, 468, 498				0.15	
Unidentified carotenoid	474				0.68	
Unidentified carotenoid	444, 468, 498				0.15	
Unidentified carotenoid	444, 468, 498				0.06	
trans-Canthaxanthin	474	565	8.54	3.02	0.22	
cis-Canthaxanthin	370, 466	565	0.96			
Bacteriochlorophyll-*a*	366, 606, 770		6.36		4.47	
Chlorophyll-*b*	468, 650	907		t	0.73	
Chlorophyll-*a*	430, 664	893	73.20	63.30	19.13	1.19
Chlorophyll a epimer	430, 664	893	t	3.27	0.41	
Echinenone	466	551	9.91	2.98	0.59	
Bacteriopheophytin-*a*(p)	358, 526, 750	889		t		
Pyropheophytin-*b*	654	827			t	
Pheophytin-*a*	408, 664	871	35.0	10.1	5.66	1.78
trans-ß,ß-Carotene	422, 452, 476	537			0.12	
Pheophytin a epimer	408, 666	871			0.38	
Pyropheophytin-*a*	408, 666	813			1.02	0.48

Chroococcus sp. and rare Chlorophyta organisms. Mats from Lake 14 had orange surfaces and green undersides and, like those from other East Antarctic lakes (Taton *et al*. 2006), mainly consisted of filamentous cyanobacteria (Oscillatoriales), Chroococcales and diatoms.

Pigment concentrations in superficial sediments and mats from the two lakes (Tab. 2) revealed that although scytonemins (both native and derivatives) were dominant in samples from Kar Plateau, they were present in much lower concentrations in samples from Edmonson Point. Mats from the two lakes contained myxoxanthophyll, zeaxanthin and echinenone (markers of cyanobacteria) and comparable chl-*a* concentrations. Samples from Edmonson Point had a higher number of unidentified carotenoids, with a UV-Vis spectrum resembling that of myxoxanthophyll. Only samples from Lake 14 contained traces of fucoxanthin, whereas those from Kar Plateau contained lutein and traces of chl-*b*, which indicate the presence of diatoms and Chlorophyta, respectively.

The ratio between scytonemins and cyanobacterial carotenoids (Scyt:TCC) and that between scytonemins and total chl-*a* (Scyt: Tchl*a*) were about 30 times higher in the Kar Plateau Lake than in Lake 14 (Scyt:TCC 44.4 and 1.5 respectively; Scyt: Tchl*a* 10.8 and 0.44 respectively), whereas the TCC:Tchl*a* ratio was comparable in the two lakes (0.32 and 0.25 at Lake 14 and Kar Plateau, respectively).

Carbohydrate concentrations in Kar Plateau mats (Tab. 3) were 3-5 times higher than those in mats from

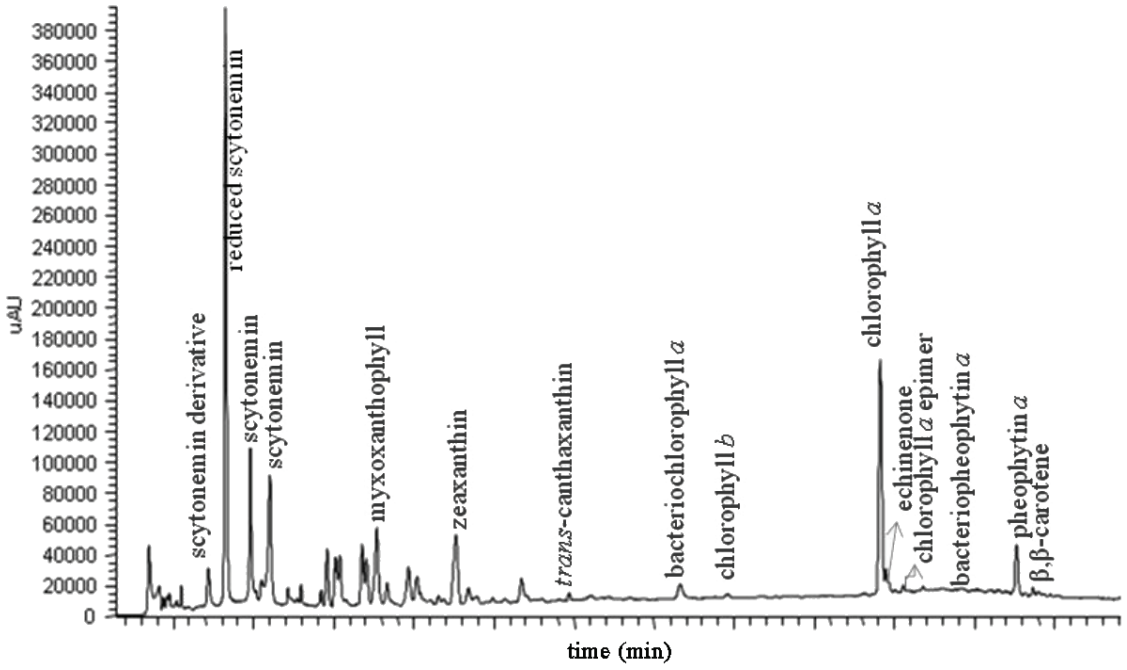

Fig. 2. HPLC-PDA (200-800 nm) chromatogram of Edmonson Point sediment sample.

Lake 14, whereas total protein concentrations in samples from the two lakes were comparable (Tab. 3).

Chl-*a*, chl-*b* and related pheophytins, lutein, fucoxanthin, scytonemins, a series of unidentified carotenoids and bacteriochlorophyll-*a* were detected in sediment samples (Tab. 2, Fig. 2). Sediments showed lower pigment diversity than mats and had high pheophytin contents.

Tab. 3. Average carbohydrate and protein concentrations (expressed in mg g^{-1} dw ± SD) and their ratio.

Site	Carbohydrates	Proteins	Carbohydrate/Protein
Lake 14			
sample 1	25.47 ± 4.33	2.74 ± 0.07	9.29
sample 2	11.74 ± 1.43	2.34 ± 0.28	5.02
sample 3	22.07 ± 4.76	1.90 ± 0.13	11.61
Kar Plateau			
sample 1	63.36 ± 2.51	3.70 ± 0.65	17.12
sample 2	118.60 ± 3.28	3.39 ± 0.73	34.98
sample 3	156.83 ± 12.81	1.76 ± 0.24	89.11

4. DISCUSSION

The higher pigment diversity at Edmonson Point agrees with the microscopy data: only 3 taxa in Kar Plateau mats and 7 taxa (1 Oscillatoriales, 1 Nostocales, 2 filamentous cyanobacteria, 1 Chroococcales, 1 *Nitzschia* sp., 1 pennate diatom) in Lake 14 mats.

The chlorophyll and carotenoid concentrations in table 2 are in the same range as those reported for mat collected at Lake Fryxell (McMurdo Dry Valleys; Buffan-Dubau *et al*. 2001). When compared with the pigment pattern reported by Vincent & Quesada (1994) and Buffan-Dubau *et al*. (2001) for Nostoc commune and oscillatoriacean mats from lakes and streams in the Dry Valleys, the composition of mats from Lake 14 (low levels or no scytonemins and high concentrations of myxoxanthophyll, echinenone and canthaxanthin) resembled that of oscillatoriacean mats. In contrast, scytonemin was the major peak in the Kar Plateau sample, like in the N. commune mats. Scytonemin is produced by some cyanobacteria as extracellular sheaths; like myxoxanthophyll and canthaxanthin (Vincent & Quesada 1994), it is UV-inducible and protects organisms against the deleterious effects of UV radiation (Garcia-Pichel & Castenholz 1991).

Biological receipt of UVR was estimated from the sum of scytonemin and related pigments, expressed as a ratio, and total cyanobacterial carotenoids (TScyt:TCC). Estimates of cyanobacterial receipt of PAR+UVR were derived using an index based on the ratio of cyanobacterial carotenoids to total chlorophyll-*a* (TCC:TChl*a*). To investigate the proportion of metabolic effort cells expended on photo-protection versus photosynthetic production, scytonemins were expressed as a ratio with total chlorophyll-*a* (TScyt:TChl*a*, Hodgson *et al*. 2005). The ratios between photoprotective pigments and carotenoids to chl-*a* concentrations suggest a stronger UV stress in the Kar Plateau Lake in spite of its more persistent ice-cover. However, as mat samples were collected from the littoral zone of the two lakes, we cannot exclude that the ice-cover does not vary greatly between the two lakes. The carbohydrate/total protein ratio for the Kar Plateau Lake is higher than that for Lake 14, suggesting that conditions are more stressful at the former site. The carbohydrate/total protein ratio may provide information on trophic status: when N and P are

lacking, proteic synthesis is reduced, a high carbohydrate/total protein ratio therefore suggests that nutrients are unbalanced. Diatoms, for instance, may increase EPS production when nutrients are lacking (Alcoverro *et al*. 2000). Otero & Vincenzini (2004) proposed a model for the synthesis of EPS in cyanobacteria; their results demonstrated that, in Nostoc, EPS serve as a sink for fixed carbon when C/N metabolism is unbalanced. Increases in UV radiation can also determine higher EPS production in cyanobacteria (e.g., Ehling-Schulz *et al*. 1997).

Sediments are the main sinks of solute and particulate matter in the catchment, comprising both phytoplankton and phytobenthos communities: the higher pigment diversity and chl-*a* concentrations measured in the Edmonson Point sediment samples may therefore indicate a richer planktonic population in Lake 14, whereas the high pheophytin content in the sediments indicates a high degree of pigment degradation. As in a previous study (Borghini *et al*. 2007), the pigment diversity of Kar Plateau sediments was lower than that of sediments from eutrophic sites in the same region.

Pheophytin a was the main breakdown product of chl-*a*. Although the distributions of chl-*a* and its degradation products are closely related, several processes such as senescence, photodegradation, bacterial degradation and herbivore grazing, as well as environmental factors, affect their relative concentrations. Many attempts have been made to identify specific sources of particular chl a products. Chlorine steryl esters (CSEs) are usually regarded as specific markers of grazing activity (Squier *et al*. 2005). No CSEs were found in the superficial sediment of the studied lakes, suggesting scarce grazing.

Although *Anabaena* sp. has been detected quite regularly in Antarctic lakes (e.g., Vincent *et al*. 1993; Jungblut *et al*. 2005; Singh *et al*. 2008), most benthic autotrophic communities are dominated by oscillatorian cyanobacteria (e.g., Nadeau & Castenholz 2000; Taton *et al*. 2003; Sabbe *et al*. 2004). The different species composition in the two studied lakes with comparable trophic status and water chemistry (Borghini *et al*. 2007) may be ascribed to different local environmental conditions such as ice-cover characteristics, UV radiation receipt and catchment lithology. The first affects mat structure and composition both directly by physical disturbance and indirectly by influencing light availability (Sabbe *et al*. 2004; Quesada *et al*. 2008). The ice-cover was more persistent at Kar Plateau, whereas Lake 14 waters were characterized by strong water evaporation in summer and consequent salinization, with rapid changes in environmental conditions. Lacustrine conductivity was always higher at Lake 14 than at the Kar Plateau Lake. Oscillatorian species, common in hypersaline lakes (Oren 2000; Jungblut *et al*. 2005), are more sensitive to visible and UV irradiance (Nadeau *et al*. 1999). The *Nodularia* genus is frequently found in mat communities of the McMurdo Ice Shelf (Taton *et al*. 2003), possibly because their ability to fix nitrogen is advantageous in these highly oxic environments; for example, *Nostoc* sp. is found in the lacustrine mats of the Dry Valleys and McMurdo Ice Shelf (e.g., Howard-Williams *et al*. 1989; Vincent *et al*. 1993; Hawes & Schwarz 1999; Jungblut *et al*. 2005). Nostocales generally have UV-screening compounds which enable them to survive in high UV environments (Leavitt *et al*. 2001). These factors could explain the dominance of *Anabaena* sp. in the Kar Plateau mat.

Lithological differences may also affect biotic composition: biological stratification in mat communities has been found to be associated with mineralogical stratification (de los Rios *et al*. 2004). The stochastic nature of colonisation (Davey & Clarke 1991) and historical factors (Vyverman *et al*. 2007) must also be considered. Similarly, morphological-taxonomical analyses of benthonic communities in the lakes and ponds of the Larsemann Hills and Bølingen Is. (East Antarctica) revealed the presence of 26 diatom morphospecies and 33 cyanobacterial morphotypes. Different cyanobacterial assemblages were present in deep lakes and shallow ponds (Sabbe *et al*. 2004; Taton *et al*. 2006).

5. CONCLUSIONS

The benthic communities of two meso-eutrophic lakes in Victoria Land have very different structure and composition. Filamentous cyanobacteria are dominant in both lakes: Nostocales with a homogeneous profile are found in the Kar Plateau Lake, whereas laminated Oscillatoriales dominate Lake 14. The pigment-inferred biodiversity in the former mat is low when compared with not only lower latitude environments in Maritime Antarctica (in line with the general trend of decreasing diversity with increasing latitude) but also environments in the same region (Lake 14 at Edmonson Point) and of continental Antarctica in general; the pigment profile agrees with microscopy results. The ratio of photoprotective pigments to chl-*a* and that of carbohydrates to total proteins were higher in the Kar Plateau Lake than in Lake 14, suggesting that UV stress was greater in the Kar Plateau Lake. This consideration and the higher evaporation rate at Lake 14 may explain the Oscillatoriales dominance at Edmonson Point.These differences in mat composition and pigment profiles could be due to local environmental conditions such as lithology, ice-cover and UV radiation. This study demonstrates how a chemical approach can be a valuable tool for studying the composition of the lacustrine biota and environmental conditions, and may provide an useful baseline for assessing possible future changes in Antarctic freshwater ecosystems extending the set of lakes.

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