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# Short Note
# Abundance of aerobic anoxygenic bacteria in freshwater lakes on James Ross Island, Antarctic Peninsula

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## Introduction

Aerobic anoxygenic phototrophic (AAP) bacteria are common in oceanic planktonic communities, as well as in limnic habitats (Mašín *et al.* 2008, Medová *et al.* 2011, Čuperová *et al.* 2013). They require organic substrates for respiration and growth, but are able to obtain cellular energy from light using bacteriochlorophyll *a*-containing reaction centres (Yurkov & Csotonyi 2009). The presence of AAP bacteria in polar lakes was first documented by Labrenz *et al.* (2009) who isolated four aerobic bacteriochlorophyll *a*-producing strains (*Roseisalinus antarcticus*, *Roseibaca ekhonensis*, *Roseovarius tolerans*, *Staleya guttiformis*) from the meromictic hypersaline heliothermal Ekho Lake. These isolates represent psychrotolerant organisms with growth temperatures of 3–35°C. Most studies of aerobic phototrophs have been conducted in tropical and temperate regions. Here, we provide the first enumeration of AAP bacteria in Antarctic polar lakes.

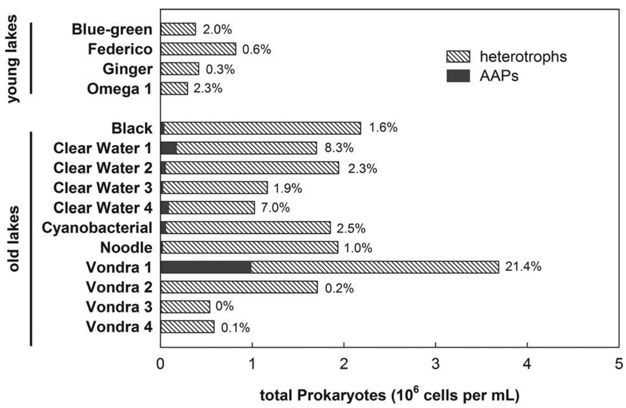


**Fig. 1.** Abundance of heterotrophic and aerobic anoxygenic phototrophic (AAP) bacteria in freshwater lakes, James Ross Island. Percentage expresses the fraction of the planktonic prokaryotic community.

## Methods

### *Sampling*

The study was conducted on James Ross Island, north-east Antarctic Peninsula during the summer of 2009 (January/February). The lakes were classified as 'young' with a maximum expected age of decades to a century and 'old' that originated several thousand years ago. Most of the sample sites were 'old' stable shallow lakes. Blue-green, Ginger and Omega 1 are classified as 'young' kettle lakes and Federico as a young moraine lake (Nedbalová *et al.* 2013; a detailed description can be found at http://dx.doi.org/10.1017/S0954102015000590). The surface layer was sampled from the shore. Infrared epifluorescence microscopy was used to analyse the planktonic community (Medová *et al.* 2011). Heterotrophic, phototrophic and cyanobacterial cells were distinguished by comparing the images recorded in the blue (all DNA-containing cells), red (cyanobacteria and algae) and infrared (AAPs and cyanobacteria) channels. Water temperature was 0.3–9.2°C, oxygen saturation 86–180%, pH 7.1–9.5, conductivity 33–4,000 µS $cm^{-1}$, dissolved organic carbon (DOC) 0.68–9.10 mg $l^{-1}$ (mean: old lakes 4.2 mg $l^{-1}$, young lakes 1.0 mg $l^{-1}$), dissolved inorganic nitrogen as $NO_3$-N 0–95 µg $l^{-1}$ and $NH_4$-N 0–107 µg $l^{-1}$, and soluble reactive phosphorus (SRP) 3.6–113.4 µg $l^{-1}$ (mean: old lakes 13.5 µg $l^{-1}$, young lakes 73.8 µg $l^{-1}$)

### *Data analysis*

Statistical analyses used CANOCO 5. Data were log-transformed, centred and standardized by species.

## Results

Epifluorescence microscopy revealed AAP bacteria in 14 of 15 lakes (Fig. 1). The bacterial morphotypes were rods of varying length (typically 1–3 µm). Abundance varied from 0 to $7.9 \times 10^5$ cells $ml^{-1}$ (mean: $8.0 \times 10^4$,

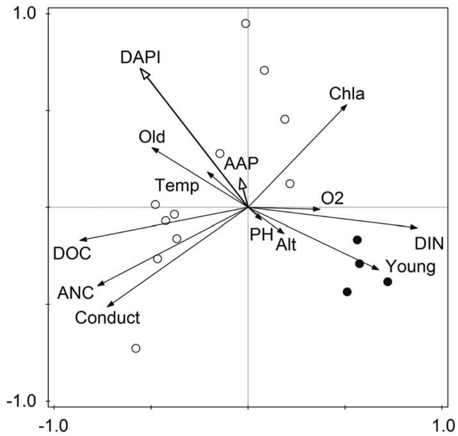


**Fig. 2.** Principal component analysis on correlation matrix. The relationship among measured environmental variables taken as 'species'. The first axis explained 40.9% of total variance. The abundance of aerobic anoxygenic phototrophic (AAP) and heterotrophic (DAPI) bacteria are passively projected as covariates onto the diagram. White circles = scores of 'old' lakes, black circles = scores of 'young' lakes. Alt = altitude, ANC = acid neutralizing capacity, Chla = chlorophyll *a* concentration, Conduct = conductivity, DOC = dissolved organic carbon, DIN = dissolved inorganic nitrogen, Old = 'old' type of lakes as a factor, SRP = soluble reactive phosphorus, Temp = temperature, Young = 'young' type of lakes as a factor.

median: $2.0 \times 10^4$) with the highest at Lake Vondra 1. The AAP bacteria represented up to 21.4% (median: 1.6%) of the total prokaryotic community (Fig. 1). Heterotrophic counts were approximately one order of magnitude higher ($3.69 \times 10^6$ cells ml$^{-1}$; mean: $1.2 \times 10^6$, median: $1.3 \times 10^6$). Principal component analysis (PCA) suggests that AAP bacteria abundance in the lakes was mainly influenced by water temperature and lake age (Fig. 2).

## Discussion

The observed AAP abundance was one order of magnitude lower than cell counts reported from oligotrophic lakes in temperate regions, but their relative proportion was comparable to freshwater and peat bog lakes in Central Europe (Mašín *et al.* 2008, Čuperová *et al.* 2013, Lew *et al.* 2015).

The positive correlation between AAP abundance and temperature corresponds to observations from freshwater oligotrophic limnic systems (Mašín *et al.* 2008, Lew *et al.* 2015). A higher proportion of AAP bacteria was predominantly observed in old stable shallow lakes with higher DOC and lower SRP concentrations and well-developed cyanobacterial mats. A positive correlation between AAP abundance and DOC has also been documented in oligotrophic alpine lakes in Central Europe (Čuperová *et al.* 2013). In summary, temperature, lake age and DOC content were the most important environmental factors controlling AAP growth.

In conclusion, AAP bacteria appear to have adapted to Antarctic conditions and may play a significant role in the microbial food web in polar freshwater ecosystems.


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## Author contribution

LN and JE arranged the lake sampling and provided the water samples. HM analysed the samples and enumerated the AAP bacteria. All authors contributed to the preparation, improvement and editing of the manuscript.

## Supplemental material

Supplemental material will be found at http://dx.doi.org/10.1017/S0954102015000590.

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