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Prokaryotic assemblages within permafrost active layer at Edmonson Point (Northern Victoria Land, Antarctica)

Maria Papale[a], Antonella Conte[a], Anu Mikkonen[b], Luigi Michaud[a,1], Rosabruna La Ferla[c], Maurizio Azzaro[c], Gabriella Caruso[c], Rodolfo Paranhos[d], S. Cabral Anderson[d], Giovanna Maimone[c], Alessandro Ciro Rappazzo[c], Carmen Rizzo[a], Nunziacarla Spanò[a], Angelina Lo Giudice[a,c,*], Mauro Guglielmin[e]

[a] Department of Chemical, Biological, Pharmaceutical and Environmental Sciences, University of Messina, Messina, Italy
[b] Department of Biological and Environmental Sciences, University of Jyvaskyla, Jyvaskyla, Finland
[c] Institute for Coastal Marine Environment, National Council of Research (IAMC-CNR), Messina, Italy
[d] Institute of Biology, Federal University of Rio de Janeiro, Prédio do CCS, Cidade Universitária do Fundao, Rio de Janeiro, Brazil
[e] Dipartimento di Scienze Teoriche e Applicate, University of Insubria, Varese, Italy

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ABSTRACT

This study was aimed at gaining insights on the prokaryotic community (in terms of both taxonomic composition and activities) inhabiting the active layer at Edmonson Point, an ice-free area on the eastern slope at the foot of Mount Melbourne (Northern Victoria Land, Antarctica). Samples were collected during the thawing period, when microbial physiological activities are restored to utilize previously frozen organic substrates. Despite the very small cell sizes ($< 0.1\ \mu m^3$), indicating the occurrence of stressed, dormant and/or starved cells, the prokaryotic communities appeared to be metabolically active in the decomposition of high molecular weight (> 600 Da) substrates, as indicated also by the obtained rates of enzymatic hydrolytic activities over proteolytic, glycolitic and phosphoric compounds. Taxonomical composition showed that Proteobacteria, Actinobacteria and Firmicutes dominated the prokaryotic community, with most of their members playing crucial roles in organic matter turnover, as well as nitrogen cycling, or entering a viable but not cultivable state to cope with continuously changing environmental conditions, such as in the case of the active layer. Finally, non-autochthonous bacteria (mainly of marine origin) were detected and they probably contribute to the organic matter turnover within such cold terrestrial habitat.

This research provides the first comprehensive account of the prokaryotic communities inhabiting the Antarctic permafrost and contributes to existing information on the response of their abundance and metabolism in a permafrost area that undergoes to seasonal changes (e.g. in terms of temperature, water availability and ice presence).

1. Introduction

Polar regions are severely vulnerable to the climate change and are likely to be more susceptible by global warming than other regions (Ganzert et al., 2011). Warmer temperatures could cause not only inland ice retreat, but also prokaryotic community shifts (which may enhance microbial invasion, establishment of cosmopolitan genotypes and loss of endemic taxa) which in turn may impact on the ecosystem biogeochemistry and functioning (Frank-Fahle et al., 2014; Kleinteich et al., 2017). Thus, scientific interest towards such complex microbial communities is increasing more and more aiming at understanding/predicting how they react to current and future environmental changes. Most soils in and around the Arctic and Antarctic regions (as well as those located in high latitudes) are affected by permafrost. This latter is characterized by a near-surface seasonally thawed zone called "active layer" where ground thaws during the summer and freezes again in the following winter (French et al., 2009). In Continental Antarctica, the thickness of the active layer (ALT) undergoes extensive spatial variations (0–160 cm; Vieira et al., 2010; Guglielmin and Cannone, 2012; Guglielmin et al., 2014), and has increased of 1 cm *per* year (Guglielmin and Cannone, 2012), mainly due to the increase of the incoming radiation and the reduction of the lasting snow cover. Among the ice-free

* Corresponding author. Istituto per l'Ambiente Marino Costiero, Consiglio Nazionale delle Ricerche (IAMC-CNR), Spianata S. Raineri 86, 98122, Messina, Italy.
E-mail address: angelina.logiudice@iamc.cnr.it (A. Lo Giudice).

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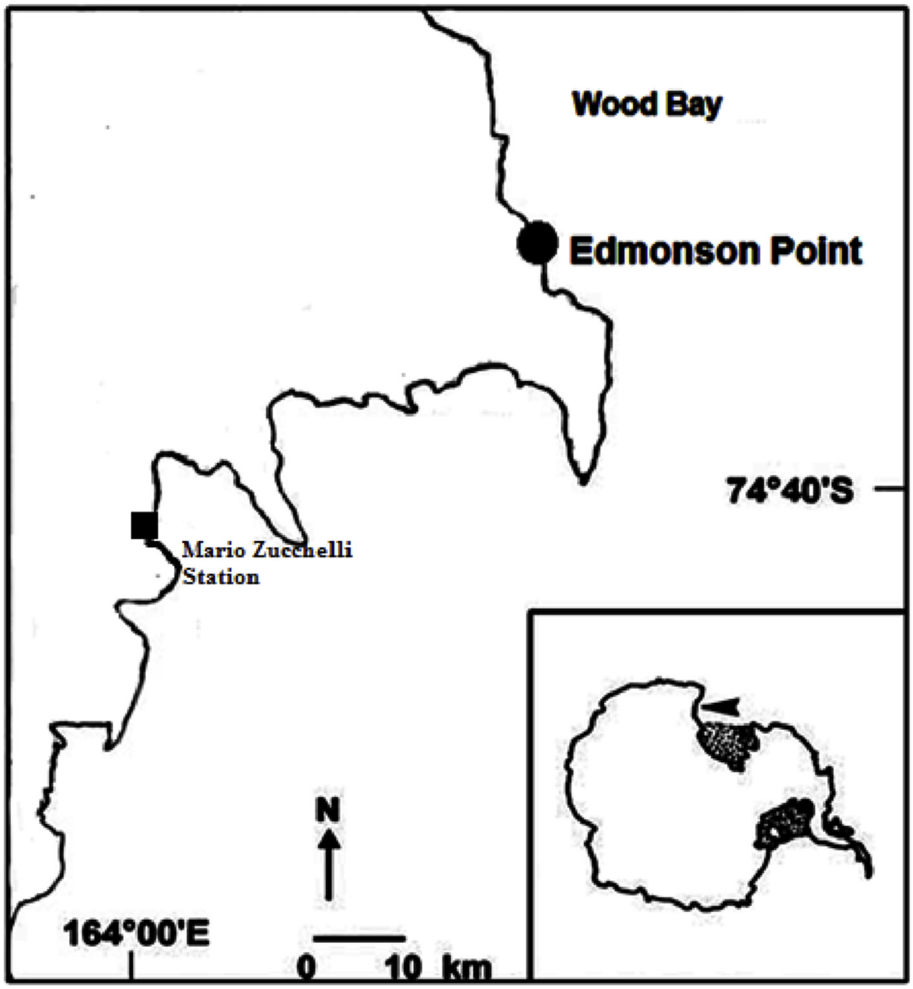

Fig. 1. Sampling site.

areas of the Continental Antarctica, Edmonson Point is quite peculiar because it is an "oasis" in which is possible to find the larger patches of mosses of all the Victoria Land that in some places can form a carpet thicker than 5 cm. Moreover it is one of the few places in Continental Antarctica in which ground water flow through the active layer has been documented. In addition it is also one of the places where snow patches occur largerly and melt earlier because the black color of the basalts and the volcanic ash outcropping absorbed large amount of solar radiation. The active layer is thus characterized by harsh conditions in terms of prolonged subzero temperatures (at least 340 days *per* year), strong temperature fluctuations, wide water content fluctuations with very long dry periods and poor nutrient availability, and long-term background radiation exposure (e.g. Steven et al., 2006). Nevertheless, most ecological, hydrological, and biogeochemical activities take place within such extreme ecological niche (Kane et al., 1991; Hinzman et al., 2003), which is colonized by cold-adapted psychrotolerant rather than true psychrophilic microbial communities (Steven et al., 2009; Wagner and Liebner, 2009; Wilkins et al., 2013). Such microorganisms possess peculiar physiological flexibility and adopt efficient survival mechanisms (e.g. the development of resilience/resistance mechanisms, low metabolic rates or stages of anabiosis or dormancy) over geological times to cope with extreme environmental conditions (Steven et al., 2006, 2007; Ponder et al., 2008; Wagner, 2008).

Permafrost thawing due to the ALT thickening has global implications for carbon biogeochemical cycling since it restores microbial physiological activities (Gilichinsky et al., 2008) and microorganisms are the main drivers of carbon mineralization (Mann et al., 2014). The mineralization of organic matter and the release of previously frozen carbon as carbon dioxide and methane in thawing permafrost are among the most important potential feedbacks from terrestrial ecosystems to the atmosphere (Dutta et al., 2006; Rodionow et al., 2006; Zimov et al., 2006; Schuur et al., 2008, 2009). However, the current knowledge of the activity, structure and ecology of the microbial communities and their influence on carbon dynamics and ecosystem stability within the active layer remain poorly understood and mainly limited to investigations of methane-cycling communities of Arctic and Alpine regions (Martineau et al., 2010; Yergeau et al., 2010, 2012; Graef et al., 2011; Goordial et al., 2016).

The active layer is particularly sensitive to ecological changes in response to climate seasonal and long-term variations. Accordingly, the microbial populations inhabiting are supposed to play a key role in the ecosystem biogeochemistry and functioning. In particular, during the thawing period previously frozen organic substrates are released, becoming again available, thus allowing the recovery of microbial physiological activities In this context, two main questions are: i) Which kinds of microbial activities occur in a freshly-thawed permafrost active layer? ii) Which are the main prokaryotic phylogenetic groups playing such activities? To find answers to these questions, during a thawing period (Antarctic summer) the prokaryotic communities inhabiting the permafrost active layer of an underexplored Antarctic area, like Edmonson Point, were analyzed. This is a wide ice-free area on the eastern slope at the foot of Mount Melbourne (Antarctica). which was chosen as the study site owing to its particular surface and subsurface characteristics. The site - designated Antarctic Specially Protected Area