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Scale of temperature variability in the maritime Antarctic intertidal zone

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ABSTRACT

The Antarctic Peninsula is currently considered as one of the fastest changing regions on Earth yet temperature variability in some of its environments and habitats is not well-documented. Given the increased glacier retreat, summer melts, sea level rise and ozone losses the intertidal zone is likely to be one of the most rapidly altering of environments but also one of the least investigated in polar waters. This study aims to quantify summer temperature variability in some habitats of the intertidal zone at King George Island. Three transects were selected across tidal flat. Four temperature loggers were deployed at each of them from extreme low water spring tide level to extreme high water spring tide level between 07.12.2010 and 18.03.2011. All the loggers were deployed at the rocky substratum. The temperature range across the study tidal flat was between −2.26 °C and +21.18 °C. The average (summer) temperature obtained from 12 loggers varied from +1.89 to +3.26 °C. In all the three transects average temperature increased with tidal height. Much higher temperature variability was recorded at higher than at lower tide locations. Differences in temperature between the three study transects existed. Results obtained from the studied tidal flat show that several factors combined altogether, including: water movement by tidal forces, wave action, air temperature, sun light intensity, shore lithology and the presence of ice and snow in the area, seem to influence its temperature.

1. Introduction

Significant changes in Antarctic ecosystems have been observed in the last decade. Most of these reports refer to dramatic changes taking place along the Antarctic Peninsula. This region is considered to be currently one of the fastest changing environments on Earth, with air temperatures having risen by over 2 °C in the last 50 years at some sites (King and Harangozo, 1998; Turner et al., 2005). Models predict that maritime Antarctic terrestrial sites are likely to warm over the next 100 years, by possibly as much as 5 °C (King and Harangozo, 1998; Turner et al., 2009). Similarly there is also evidence that sea water temperatures are changing around Antarctica (Convey et al., 2009; Meredith and King, 2005; Turner et al., 2009). Current observations demonstrate that sea surface summer temperature has raised more than 1 °C in the area of Western Antarctic Peninsula and models predict that sea temperature will rise on average by 2 °C in the next 100 years (King and Harangozo, 1998; Meredith and King, 2005).

The Antarctic coastal marine ecosystem is considered to be one of the most constant marine coastal systems in the world (Barnes et al., 2006; Peck et al., 2006). Annually sea water temperature ranges between −1.8 °C and +3.8 °C in the region of maritime Antarctic and even less at high Antarctic sites (Barnes et al., 2006; Peck et al., 2006). Thus annual fluctuations of sea water temperatures are up to 5 °C, but usually less. On the other hand Antarctic intertidal zone is highly disturbed in comparison to the nearby subtidal owing to the effects of wave and ice action, temperature and salinity oscillations as well as desiccation and immersion during the tidal cycles (e.g. Barnes and Conlan, 2007; Davenport, 2001; Waller et al., 2006a). Although long term records of sea water, air temperature and various predicative models of these parameters now exist from the Antarctic region there are only a few temperature records from the intertidal zone (e.g. Clark et al., 2008; King and Harangozo, 1998; Peck et al., 2006; Waller et al., 2006a). Therefore baseline information about intertidal zone is still urgently needed especially in the context of currently observed global changes driven by increased temperatures.

Understanding fluctuations of temperature is extremely important as temperature and factors related to temperature determine organisms' physiology, performance and fitness, therefore, species occurrence and distribution (Clark et al., 2008; Hengeveld, 1990; Morley et al., 2009). In the Antarctic the majority of the few marine species tested under laboratory conditions are highly stenothermal dying in temperatures raised above +5 °C to +10 °C (Morley et al., 2012; Peck, 2005). It is most likely that the organismal upper temperature limits are set by limitation to aerobic scope or poor capacity to raise metabolic rates to perform work by marine organisms (Peck, 2005; Pörtner, 2001). It has been suggested that a 1 °C rise in summer sea temperatures around Antarctica could have severe ecological consequences for populations and communities of marine organisms but especially marine ectotherms (Hall and Thatje, 2011). Yet this dominant paradigm is sometimes questioned indicating that some Antarctic species might be more robust

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to temperature change than assumed by short-term experiments (Barnes and Peck, 2008).

This study aims to quantify temperature variability in the intertidal zone of maritime Antarctic from extreme low water spring tide level to extreme high water spring tide level at King George Island. We assumed that most of the temperature variability in this zone will be observed in the summer time. In winter, due to buffering effect of the ice foot sea water temperature is almost constant, therefore, temperature fluctuations are much less pronounced (Barnes, 1999; Scrosati and Eckersley, 2007). In contrast in summer the intertidal zone is often under variable influence of tides, wave and ice action or sunlight intensity (Clark et al., 2008). The study can potentially act as baseline for further investigations of this rapidly changing ecosystem enabling detection of ongoing changes driven by 'global warming'.

2. Material and methods

2.1. Study area

The study was conducted at King George Island—the largest of South Shetland Islands (Fig. 1). The investigation focused on the tidal flat in the vicinity of the Polish Antarctic Station "Arctowski" in Admiralty Bay (Figs. 1 and 2). The area is composed mostly of cobbles and pebbles, however, some patches of solid rock are also present. The size of the tidal flat is approximately 300 by 10 m.

Pieces of sea ice, mostly in winter, and growlers in the summer frequently cover the intertidal and sublittoral of the area (see Fig. 2). Total freezing of Admiralty Bay occurs irregularly. In addition, strong wave action is recorded in this zone (pers. observations). The maximum tidal amplitude in the area is approximately 2 m (Catewicz and Kowalik, 1984). All these forces cause movement and displacement of pebbles and cobbles of the tidal flat.

Annually the surface sea water temperature ranges from −1.9 °C to +3.8 °C (Rakusa-Suszczewski, 1995). In the littoral zone in the vicinity of the study area the measured range of sea water temperature during the summer was from 2.8 °C to 3.8 °C. Winter sea temperature in the same location was oscillating between −0.9 °C to −1.7 °C (Jazdzewski et al., 2001).

2.2. Protocol

Three transects (A, B, C, see Fig. 1) have been selected across tidal flat. Transects were expanding from extreme low water spring tide level (LT) to extreme high water spring tide level (HT). During austral summer between 07.12.2010 and 18.03.2011 at each transect four temperature-light intensity loggers (Onset, HOBO pendant temp/light UA002-64 loggers) were installed. Each logger was attached within a hole of the concrete block (100 × 70 × 20 cm) to ensure its stability and protection from waves, tides and ice. One of the loggers was installed at LT, one at HT and two evenly located in between (see Fig. 1 and Table 1). Additionally one logger was installed in subtidal nearby at 6 m depth. Loggers were programmed to record temperature every 5 min.

Temperature data were subjected to the analysis of variance (ANOVA) with transect and tidal height as a spatial factors. In order to improve normality and homogeneity of variances data were ln (x + 1) transformed.

3. Results and discussion

The interest in biological aspects of the Antarctic intertidal zone is growing recently, however, there are still very few investigations focusing exclusively on the physical parameters within this zone. The existing studies treat marginally these issues (e.g. Barnes and Brockington, 2003; Davenport, 2001; Waller et al., 2006b). To our knowledge this work is the most comprehensive investigation on seasonal variation of temperature across tidal flat from the Antarctic region. Each of the 12 loggers deployed took 28,966 records of temperature (ESM 1). The presented data indicate that although overall average temperature is very low (+2.43 °C ± 0.70 [SD]) the variation is high and was ranging from −2.26 °C (site B4) to +21.18 °C (site B4) (Fig. 3, ESM 1). Minimum average temperature reached +1.79 °C ± 1.22 SD and was recorded at site C1 while the maximum average temperature reached +4.10 °C ± 3.54 SD and was recorded at site B4. Only five degrees south along the Antarctic Peninsula from the study locality, at the Adelaide Island, during February also large fluctuations in the intertidal zone were recorded and ranged

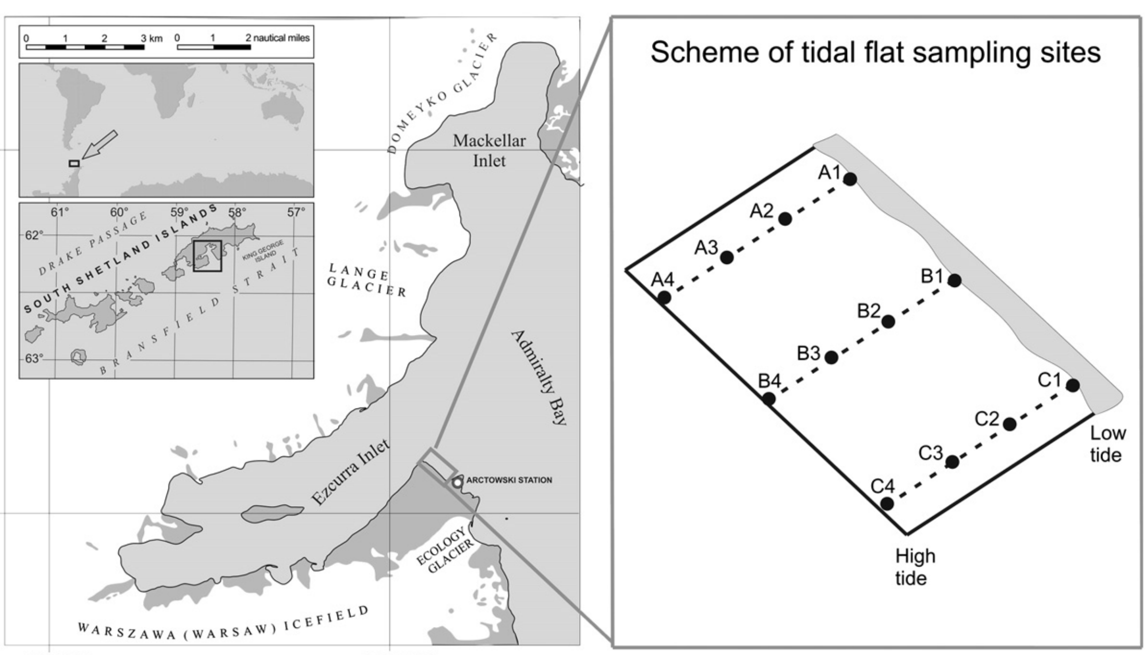

Fig. 1. Study area with logger deployment positions.