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ANTARCTIC BENTHIC FAUNA IN THE GLOBAL CLIMATE CHANGE

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ABSTRACT: In the last 50 years a significant climatic shift has been observed along the Antarctic Peninsula (air and seawater temperature rise, glacial retreat, localized instances of lowered shallow waters salinities). Many Antarctic marine benthic invertebrates are adapted to specific environmental conditions (e.g. low stable temperatures, high salinity and oxygen content). Changes caused by global climate changes and subsequent glacial melting can be expected to have significant impacts on species physiology and distribution. The rise of sea water temperature coupled with such additional stress factors as melt water run-off, increased ice disturbance, disruption of food webs or invasion of alien species can be a serious problem for their long-term survival.

KEY WORDS: Antarctic, climate change, marine ecosystem, benthos.

ANTARCTIC MARINE ENVIRONMENT

The Southern Ocean is isolated from other marine environments by the Antarctic Circumpolar Current and Polar Front, which can be observed as a significant change in surface water temperature and salinity, and be detectable to depths exceeding 1000 m. They form a strong barrier to free north-south exchange of water, isolating Antarctic shelf fauna from other continental shelf faunas of the world (Clarke *et al.* 2005, Kim and Thurber 2007).

Waters of the Southern Ocean outside the intertidal zone are characterized by low (from -1.8°C to +1.5°C) and highly stable temperatures, with the total annual variation rarely exceeding 3°C in the region of Antarctic Peninsula, and

1.5°C at high Antarctic (Peck 2005). The other stable environmental factors are high seawater salinity and high oxygen content (Peck 2005). Other characters of the Antarctic environment vary markedly with the change of seasons. Photoperiod fluctuates between no direct sunlight during austral winter to 24 hrs sunlight during the summer. About 10–15 million km^2 of sea ice forms in winter and melts in summer. In the result, the Southern Ocean is characterized by intense seasonality of phytoplankton productivity. In many places primary production is restricted to 2–3 months a year, reducing food availability for benthic organisms (Peck 2005, Barnes and Clarke 1995).

Antarctic bottom environments are also characterized by physical disturbance by ice phenomena (icebergs, anchor ice, growlers), which scour sea floor and destroy fauna living there (Gutt 2001). This disturbance varies with depth, bottom topography, currents and proximity to ice fronts and glaciers, with Antarctic tubular icebergs bulldozing sea floor to the depth of ca 600m (Gutt and Starmans 2001). It was estimated that every square meter of the Antarctic shelf will be impacted by an iceberg once in every 340 years (Gutt 2001).

ANTARCTIC BENTHIC FAUNA

The Antarctic region is the most faunistically distinct part of the world ocean (O'Loughlin *et al.* 2011). The Southern Ocean, surrounding the Antarctic continent, comprise 9.6% of the world ocean and is home to thousands of invertebrate species living on its bottom (Clarke 2003). The exact number of Antarctic benthic species is unknown due to inaccessibility of some areas (e.g. Amundsen Sea, Bellingshausen Sea) and difficulties connected with deep-sea sampling, which comprises ca 80% of the Southern Ocean (Clarke 2008). The number of benthic macroinvertebrate species described from the Southern Ocean currently exceeds 4100 (Clarke 2008), but the total macrofaunal richness may well exceed 17 000 (Gutt *et al.* 2004). Therefore, species richness of the Antarctic continental shelf is comparable to the shelf faunas of Hawaii or north-west Europe, and more diverse than that of the Arctic (Clarke 2008). Species richness of the Southern Ocean benthos vary across major taxonomical groups. Pycnogonids, polychaetes, ascidians, amphipods and some echinoderm groups are well represented, whereas gastropods, isopods, sponges and bivalves are relatively poorly represented (Clarke and Johnston 2003).

Particularly striking features of the Southern Ocean are the lack of decapods, high level of endemism and vertical zonation of benthic communities. Outside Antarctica decapods such as crabs or lobsters comprise a key component of the shallow waters (Gili *et al.* 2006). In the Antarctic their role is played by numerous sea stars and nemerteans (Dayton *et al.* 1974, McClintock 1994, Gibson 1983). High endemism of Southern Ocean benthos is a key biogeographic and evolutionary feature, with the percentage of endemic species especially high in groups such as pycnogonids and amphipods (90% and more) or polychaetes, holothurians and bryozoans (>50%) (Clarke 1996). The lack of significant littoral or intertidal fauna in the Antarctic and strong vertical zonation in subtidal benthic communities is the consequence of different ice phenomena (e.g. sea ice, anchor ice, ice foot, growlers, icebergs) (Dayton *et al.* 1974).

Antarctic benthic invertebrates are characterized by physiological rates, such as metabolic, growth, development or activity rates, being considerable lower than in temperate species (e.g. Pearse *et al.* 1991, Brey and Clarke 1993, Arntz *et al.* 1994, Peck and Robinson 1994, Chapelle and Peck 1995, Peck *et al.* 2000, Peck 2002, Peck *et al.* 2004a, McClintock *et al.* 2008). Growth and development rates of Antarctic benthic organisms are about five times slower than of similar species from lower latitudes (Arntz *et al.* 1994, Peck *et al.* 2000, Pearse *et al.* 1991, Peck Robinson 1994). In many species (e.g. caridean shrimp *Chorismus antarcticus*, bivalve *Lissarca miliaris*, sea urchin *Sterechinus neumayer*) a strongly seasonal pattern of growth was observed, with organisms ceasing to feed during austral winter due to limited food supply (Clarke 1996, Brockington, Clarke 2001). In consequence, Antarctic benthic invertebrates have extended life spans. Brachiopod *Liothyrella uva* lives to over 50 years and does not reproduce until it is 20 years old (Peck, Holmes 1990), sea star *Odontaster validus* lives to 100 years (Pearse 1969), and bivalve *Yoldia eightsi* to over 40 years (Nolan, Clarke 1993). The metabolic rates in Antarctic bottom invertebrates are 8 to 27 times lower than in species living in 20°C, resulting in extreme low levels of activity (long periods of rest, slower walking, swimming or burrowing) and ability to stay 4–7 months without food (Peck 2005, Klages, Gutt 1990; Brockington *et al.* 2001, Barnes, Clarke 1995; Dayton *et al.* 1974).

The other feature typical to the Antarctic benthic invertebrates is the significantly wider depth ranges in comparison with temperate or tropical fauna (Brey *et al.* 1996).

These characteristics of Antarctic benthic invertebrates are the effect of adaptation to conditions prevailing in extreme environment (low temperature, intermittent food supply), as well as unique past history of Southern Ocean ecosystem.

PAST HISTORY OF ANTARCTIC BENTHIC FAUNA

The Southern Ocean fauna has evolved *in situ* over a long period of time, during which it has been subject to the fragmentation of Gondwana, variation in glacial extent, isolation (both geographical and climatic) from the outside oceans and a substantial decline in temperature of ca 15–20°C (Clarke 1996).

In late Jurassic period southern latitudes were dominated by the supercontinent of Gondwana surrounded by temperate waters (Clarke 1990). By the late Cretaceous Gondwana had started to fragment with South America, Africa, India and Australia separating and drifting north. The separation of the Tasman Ridge and opening of the Drake's Passage (about 34 Myr ago) lead to the establishment of Antarctic Circumpolar Current, isolating the Southern Ocean and initiating cooling processes (Aronson, Blake 2001; Rogers 2009, Gili *et al.* 2006). Fossils from Seymour Island and James Ross Island suggest that at that time shallow-water communities were similar to those from lower latitudes (Aronson, Blake 2001). One of the consequences of the Antarctic cooling was a dramatic change in the biodiversity of marine ecosystems, with the loss of major top predators (e.g. sharks, crabs, lobsters) and a reduction in the biodiversity of such groups as bivalve mollusks and gastropods with calcareous shells (Thatje *et al.* 2005). It seems likely that extinction of crabs and lobsters was caused by their inability to adapt physiologically to very low water temperatures (Thatje *et al.* 2005), although the rapid onset of seasonality of primary production may have also played a role (Clarke 1990). The reduction in the diversity of large calcareous gastropods and bivalves may be explained by the extra energetic costs of precipitating calcium carbonate from seawater at lower temperatures (Clarke 1990).

Mean sea-water temperature decreased from about 15°C in the early Tertiary to the present range of +2°C to –1.8°C with several periods of rapid temperature changes (Clarke 1990). A large ice mass covered Antarctic continent. It was very dynamic and in the last 2 Myr it has cyclically advanced and retreated (Barnes, Conlan 2007). In glacial maxima ice edge advanced across the continental shelf erasing benthic fauna. In consequence, the shelf habitats have to be repeatedly colonized during ice retreat, resulting in repeated shifts in the distribution of species (Rogers 2009; Barnes, Conlan 2007). Survival of the benthic fauna was possible in the deep sea (hence the eurybathy – Brey *et al.* 1996) or in refugia on the continental shelf resulting from the diachronism in maximum ice extant (Thatje *et al.* 2005).

The loss or diversity reduction of many taxonomical groups resulted in the evolutionary radiation and endemism of others (e.g. pycnogonids, isopods, amphipods, predatory gastropods, notothenioid fishes), which may be driven by periodic advances and retreats of the Antarctic ice sheet (Clarke *et al.* 2004).

The extinction of active skeleton breaking (durophagous) top predators such as crabs or teleost fishes, decreased the predation pressure and allowed dense crinoid and ophiuroid populations to flourish at shallow depths (Aronson, Blake 2001). Shallow-water communities of epifaunal suspension feeders were typical for Paleozoic marine environments before the evolution of durophagy (Aronson, Blake 2001). Outside the Southern Ocean such benthic communities are at present observed only in the deep-sea (Gili *et al*. 2006).

In consequence of long history of isolation, glacial oscillation and cooling, modern Antarctic shelf fauna is characterized by endemic species with metabolism and lifestyle adapted to low temperatures and seasonality of primary production, forming peculiar benthic communities distinctly differing from those living outside the Southern Ocean.

GLOBAL CLIMATE CHANGES ALONG THE ANTARCTIC PENINSULA

The Antarctic Peninsula is one of the areas of the globe that are currently experiencing rapid regional climatic change (King 1994, Vaughan *et al*. 2003).

Throughout the twentieth century global air temperatures increased by 0.3–0.6°C (Hughes 2000), and current climatic models predict further warming (IPCC 2001, 2007). Global seawater temperatures have risen by 0.06°C during the last half century (Levitus *et al.* 2000) with a predicted increase of 2°C over the next 100 years (IPCC 2001, 2007). Especially rapid changes were observed along the Antarctic Peninsula, with air temperatures having risen by ca 3°C in the last 50 years at some localities, and winter minimums by over 5°C (King *et al.* 2003). There is no significant trend, either warming or cooling, in East Antarctica, and data collected in some sites suggest a cooling trend (Turner *et al.* 2005). The warming observed in the region of the Antarctic Peninsula has had a significant impact on the terrestrial ice sheet. The majority (87%) of glacier termini retreated during the past 50 years (Cook *et al.* 2005). In the same time, loss of seven ice shelves were noted (Vaughan, Doake 1996).

Antarctic seawater temperatures are also rising, both in sub-surface water masses (Gille 2002, Robertson *et al.* 2002), and in shallow waters along the Western Antarctic Peninsula (Meredith, King 2005) and around South Georgia (Whitehouse *et al.* 2008), with measured or calculated changes since 1950s ranging from 0.17°C to 1°C, depending on depth or region.

Some indications of sea ice extent reductions are also observed (Curran *et al.* 2003), with especially significant changes in the Bellingshausen and Amundsen seas (Zwally *et al.* 2002, Clarke *et al.* 2007). Data for the western Antarctic Peninsula showed 40% reduction in annual mean sea ice extent over a 26-year period (Smith, Stammerjohn 2001).

Localized instances of lowered shallow waters salinities resulting from melted freshwater discharge were also noted (Nihashi *et al.* 2005; Kidawa, Janecki personal observations), although the overall trend shows a significant increase in the salinity of the summer ocean surface (Meredith, King 2005).

On the basis of current evidence, it seems probable that the warming of the Antarctic Peninsula region will continue, but without more comprehensive data and a firm understanding of all interrelated mechanisms controlling regional climate change, it is impossible to predict future changes with any degree of certainty (Clarke *et al.* 2007).

ECOLOGICAL CONSEQUENCES OF CLIMATE CHANGE FOR ANTARCTIC MARINE BIOTA

Climate change is already having significant impact on some components of the Antarctic food web. Changes in phytoplankton concentration and composition along the western shelf of the Antarctic Peninsula associated with long-term climate modification were noted (Montes-Hugo *et al.* 2009) as well as significant shifts in bird and seal populations sizes in the Southern Ocean (Barbraud, Weimerskirch 2001; Croxall *et al.* 2002, Weimerskirch *et al.* 2003). There are also indications that populations of *Pleuragramma antarcticum*, a key fish species of the trophic web, whose reproduction is closely associated to sea ice, declined locally, to be replaced by myctophids, a new food item for predators (after SCAR Report 2009).

There are very few long-term studies of Antarctic benthic invertebrates, and currently it is impossible to detect potential effects of climate change (Clarke *et al.* 2007), but there were some experimental evidence and field observations done which may help to ascertain future fate of the bottom fauna.

Seawater warming

All currently tested Antarctic benthic invertebrates are highly strongly stenothermal (Peck *et al.* 2004b, Peck 2005, Young *et al.* 2006). Many die in temperatures between 5°C and 10°C (Peck 1989, Peck *et al.* 2002, Peck *et al.* 2004b). The most sensitive are brachiopod *Liothyrella uva* and bivalve *Limopsis marionensis* which die at temperature of 4ºC (Pörtner *et al.* 1999, Peck 1989). Other, such as the bivalve *Laternula elliptica* (Peck *et al.* 2002) and the limpet *Nacella concinna* (Peck 1989) survived in experiments to temperatures of about 10ºC.

Temperature sensitivity of Antarctic benthic invertebrates can be explained by the oxygen limitation hypothesis (Pörtner 2002, Pörtner *et al.* 2007). In a given temperature range all functions of an organism can be completed using solely aerobic metabolism. Outside this range, organism progressively loses aerobic scope and need to use anaerobic pathways to provide the required energy (Pörtner 2002). Data collected for some Antarctic benthic invertebrates (bivalve *Laternula elliptica*, isopod *Glyptonotus antarcticus*, limpet *Nacella concinna*, brachiopod *Liothyrella uva*) suggest that at higher temperatures oxygen demand can rapidly outstrip oxygen supply mechanism (Robertson *et al.* 2001, Peck 2002, Peck *et al.* 2002, Peck 2005).

The environmental range in which growth and normal physiological functioning can occur is usually narrower than the tolerance limits of any species (Newell, Branch 1980; Peck *et al.* 2004b, Rupp, Parsons 2004). Current research showed that activity (e.g. locomotion, swimming, reburying) of Antarctic benthic invertebrates is sensitive to temperature rise. Limpet *Nacella concinna* and the large bivalve *Laternula elliptica* suffered 50% failure in vital biological functions (righting and reburying) at 2–3°C and complete loss at 5°C (Peck *et al.* 2004b). The Antarctic scallop *Adamussium colbecki* was even more temperature limited, and lost the ability to swim at temperatures 1–2°C, although the lethal temperature for this species was between 5°C and 6°C (Peck *et al.* 2004b). Severe loss of motor coordination in sea stars *Odontaster validus* was observed at temperatures of 4–5°C. It was mainly caused by sea stars switching from „typical" to „untypical" ways of performing the activity, suggesting that at higher temperatures animals were unable to generate sufficient force to successfully complete the behaviour in the „typical" way. Although such phenomenon will not probably impair the sea star survival, it is a significant indicator of the change in the physiological capacity of an animal (Kidawa *et al.* 2010).

Antarctic marine species may have some of the most restricted scopes of any fauna (Barnes, Peck 2008). Acclimation experiments showed that species such as scallop *Adamussium colbecki*, bivalve *Laternula antarctica* and brittle star *Ophionotus victoriae* are unable to acclimate to 3°C (Barnes, Peck 2008; Peck *et al.* 2009b). But other species, sea star *Odonatser validus* was shown to be acclimated to higher temperatures, righting itself when turned over at temperatures up to 8°C and feeding up to 7°C (Peck *et al.* 2008).

Factors that can influence thermotolerance of Antarctic benthic invertebrates are individual size (Peck *et al.* 2009a) and geographical location (Morley *et al.* 2009). When temperatures were raised acutely smaller individuals belonging to several taxa survived to higher temperatures than large animals, which can strongly affect the species' reproductive potential (Peck *et al.* 2009a). It was also established that limpets *Nacella concinna* from South Georgia have a lower critical limit (5.1–10.0°C) than *Nacella concinna* from the colder environments of Signy Island and Adelaide Island (10.0–12.5°C) (Morley *et al.* 2009).

Although most individuals were sensitive to warming, some degree of diversity was observed in sea stars *Odontaster validus* and ispods *Serolis polita*, with a small proportion of animals able to perform successfully even at higher temperatures (Janecki *et al.* 2010, Kidawa *et al.* 2010). Such phenomenon implies the existence of considerable variability within these species, which can make them less vulnerable to future warming trends.

At present, data from the laboratory experiments suggests that temperature increase will impair the ability of Antarctic benthic invertebrates to perform vital biological function critical for their long term survival. Therefore, it can be assumed that their ability to cope with future environmental change is limited, and they can successfully perform only in a narrow range of temperatures.

On the other hand, some field observations show that the geographic range of many Antarctic species extends to locations (e.g. South Georgia) with higher summer and winter sea temperatures than elsewhere in the Southern Ocean (Barnes *et al.* 2006, Barnes, Peck 2008). Substantial population of species shown in experiments to be vulnerable to small temperature variations (e.g. *Nacella concinna*, *Laternula* *elliptica*, *Odontaster validus*) were found on South Georgia living at 2–3°C above typical temperatures for higher latitude Antarctic shallow waters (Barnes *et al.* 2006, Barnes, Peck 2008).

Salinity changes

There is only scant data on the effect of salinity decline on Antarctic marine invertebrates. Small salinity changes slowed development rate, decreased the percentage of embryos reaching morula stage and reduced viability of embryos of sea urchin *Sterechinus neumayeri*, suggesting its greater stenohaline limitation in comparison to tropical and temperate species of sea urchins (Cowart *et al.* 2009). Significant behavioural responses to meltwater (Davenport 2001) and increased mortality in lowered salinity (Davenport, Macalister 1996) were observed in limpets *Nacella concinna*. Interactive effects between temperature and salinity on vital biological functions of *Serolis polita* were observed, so that isopods were more vulnerable to lower salinities when exposed to higher temperatures (Janecki *et al.* 2010).

Seawater acidification

The sharp increase of carbon dioxide in the atmosphere results in more CO_2 dissolving in surface sea water leading to its acidification, and – in consequence – to increase of calcium carbonate solubility, which Antarctic benthic invertebrates precipitate to produce shells or skeletons (Barnes, Peck 2008). With increasing acidity many organisms will face a greater energetic cost to build and maintain their shells or skeletons. Thinning of shells makes them more susceptible to predators or mechanical damage typical for shallow waters (Barnes, Conlan 2007), which may result in depletion of thin-shelled sessile species (Barnes, Peck 2008).

Increased ice disturbance

Ice disturbance by icebergs is one of the major factors structuring Antarctic benthic communities (Teixidó *et al.* 2004, Lee *et al.* 2001, Peck *et al.* 1999, Gutt, Starmans 2001). Grounded or scouring icebergs severely damage large areas of sea floor, changing its topography, altering sediments, modifying bottom current flow and destroying whole benthic communities (Peck *et al.* 1999, Gutt, Starmans 2001; Barnes, Conlan 2007).

Although, it was estimated that every square meter of the Antarctic shelf down to 600 m will be scoured by an iceberg once in every 340 years (Gutt 2001), some areas are impacted more often. For example, frequency of iceberg scouring at Signy Island was estimated at once every 50–75 years (Peck, Bullough 1993). Video transects from the eastern Weddell Sea recorded that in intensively scoured areas about 80% of seafloor was disturbed (Gutt Starmans 2001). Current data show that scouring lead to almost compete removal of bottom macrofauna and >90% of meiofauna (Peck *et al.* 1999, Lee *et al.* 2001). Recovery rates of Antarctic benthic communities are very slow (Brown *et al.* 2004). Recolonisation begins with an invasion of mobile organisms, many of them scavengers exploiting organisms killed by the scouring, followed by pioneer species with a fast recruitment and growth rates (ascidians, bryozoans, polychaetes, gorgonians). The next stage begins with the arrival of slow growing and reproducing taxa such as sponges, and ends with extremely slow-growing hexactinellid glass sponges attaining the height of ca 40 cm, forming three-dimensional structures and providing a special habitat for an associated fauna (Gutt *et al.* 1996, Johst *et al.* 2006, Teixido *et al.* 2007). Recovery time of such benthic communities was estimated to be even 250–500 years (Gutt 2000). The recovery is not deterministic but follows highly complex pathways of succession (Gutt, Starmans 2001; Teixido *et al.* 2007, Teixido *et al.* 2004). The local removal of benthic fauna by ice scouring and subsequent recolonisation creates a patchy pattern on sea floor, generating a community mosaic and increasing the total variability of Antarctic benthos (Gutt 2000, Teixido *et al.* 2007).

Regional warming observed in the region of Antarctic Peninsula is likely to increase the breaking up of ice shelves and – in consequence – scouring frequency of the seafloor, so bottom fauna living in one of the most highly disturbed environment may suffer even more disturbance (Brown *et al.* 2004). But on the other hand, ice disturbance is considered a common event in the evolutionary history of the Southern Ocean, with significant fluctuations in the intensity of ice scouring (Clarke *et al.* 2007), and Antarctic benthic species seem well adapted to such events (Peck *et al.* 1999)

Invasion by alien species

The evolution of Antarctic marine biota has taken place relatively unaffected by biotic exchange (Clarke *et al.* 2007). The Southern Ocean is isolated from the outside seas by the complex barrier of Antarctic Circumpolar Current and Polar Front. Pelagic larvae of potential invading species would have to survive the large and abrupt temperature (4–5°C) and salinity (>0.5) changes across the Polar Front (Kim, Thurber 2007). However, a few larvae of decapod crustaceans and adults of others (e.g. spider crab *Hyas araneus* from boreal and subarctic waters) have recently been found around South Shetland Islands (Thatje, Arntz 2004). Small populations of lithodid crabs, long known from South Georgia, are now present in deep waters off the continental shelf in the Bellingshausen Sea at temperatures >1°C (Thatje *et al.* 2005). It is unknown if they have recently colonized this area or been there for some time (Barnes 2005). Lithodid crabs occur frequently in the Subantarctic Region, although they are limited by physiology and life history from living and breeding in waters permanently below 0°C (Thatje *et al.* 2005). Future warming may enable them to reconquer the Southern Ocean after about 15 Myr of absence. The return of durophagous (shell crushing) top predators would reshape Antarctic benthic communities. Such invasion would probable affect crinoids and ophiuroids, flourishing in the Antarctic due to the disappearance of crabs after global cooling, as well as thin shelled molluscs, and asteroids currently playing the role of benthic top predators (Aronson, Blake 2001; Thatje *et al.* 2005).

Three possible gateways to the Southern Ocean are proposed: migration through the abyssal depths in case of eurybathic species, migration through the shelves of the Scotia Arc Islands, or transport of larvae with eddies forming in the Antarctic Circumpolar Current (Clarke *et al.* 2005).

Disruption of food webs

Changes in phytoplankton concentration and composition along the Antarctic Peninsula were already observed (Montes-Hugo *et al.* 2009). The warming of the surface waters accompanied by large reductions in the extent and duration of sea ice cover may potentially result in further changes (e.g. disappearance of sea algae). That may cause a cascade through higher trophic levels, both in the water column and on the sea bottom (after SCAR Report 2009).

Similarly, the potential reduction in number or even removal of any of the key species from the benthic ecosystem, may disrupt ecological interactions which stabilize benthic communities, and may reduce functional diversity in the Antarctic food-web, especially if different species or different functional groups (e.g. prey *versus* predator) will be affected to a different degree (Clarke *et al.* 2007).

At present there are no data showing disruption in benthic food-web, although some observation suggesting the switch in dominance of krill and salps along the western coast of the Antarctic Peninsula were noted (Ross *et al.* 2008). The complexity of interactions between the environmental factors (e.g. temperature, salinity, sea ice, currents, mixing) and biological processes makes it impossible to predict the outcome of climate change observed in the area of Antarctic Peninsula (Clarke *et al.* 2007).

CONCLUSIONS – VULNERABILITY *VERSUS* ROBUSTNESS OF ANTARCTIC BENTHIC FAUNA

Antarctic Peninsula is experiencing rapid regional climatic change which may significantly change benthic environment, although it is impossible to predict the scope and speed of changes. No trend of climate change is observed in East Antarctic.

Current research suggests that Antarctic benthic fauna can successfully perform only in a narrow range of environmental factors and have only a limited ability to withstand future environmental change, but geographic range of many Antarctic species extends to locations with higher sea temperatures than elsewhere in the Southern Ocean.

Future warming will make Antarctic open to invasive species. Benthic fauna, having evolved in isolated, stable and cold environment, is vulnerable to alien predators and /or competitors.

Past history of ca 30 Myr show Antarctic benthic biota to be resilient to major temperature and ice changes, able to recolonise the continental shelf after each glacial maximum

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