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Diversity of nematodes in Antarctica under changing climatic conditions

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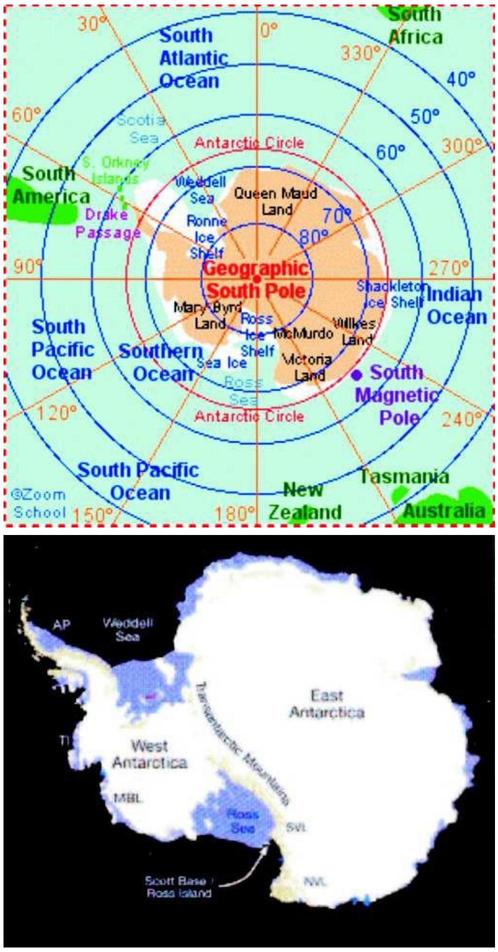
ABSTRACT

Antarctica covers an area of about 14 million Km^2, more or less double the size of Australia and equal to China and India combined together. The continent broadly represents three distinct climatic regions: the sub-Antarctic, maritime and continental Antarctica with the sub-Antarctic being the most favourable and continental Antarctica is being the most hostile environments. The long-term isolation and harsh climatic condition of Antarctica is reflected by the low number of nematode species as well as a high degree of endemism. Historical glaciations events and the current spatial isolation of habitable soils have led to a very patchy distribution of nematode communities and no apparent overlap in nematode species between maritime and continental Antarctica. The gentler climate in maritime Antarctica causes highest nematode diversities there rather than continental Antarctica. In recent years, rapid, albeit complex changes in local climate have been observed in Antarctica, particularly in the Antarctic Peninsula with substantial impacts on marine and terrestrial ecosystems. Nematode communities in Antarctica are directly as well as indirectly affected by the climate changes. Climate warming causes lower environmental stress, increases the duration of metabolic activity, growth rates and shorten life cycles; through these combined influences increase population sizes. Increasing temperatures may alter species composition and favourable opportunistic nematode species. A warmer and wetter climate increases the area of vegetated soil and plant species diversity. The range expansion and increased plant species diversity will provide a greater area of more favourable habitats for nematodes. Although there have been few empirical studies on the effect of climate changes on nematode communities in Antarctica, large-scale coordinated efforts to explore climate change impacts on such communities would give better information.

***Keywords*:** Antarctica, climate change, nematode diversity.

Antarctica is the southernmost continent of the earth surrounded by the Southern Ocean, comprising of three oceans: the Atlantic Ocean, the Indian Ocean and the Pacific Ocean. It surrounds the Geographic South Pole. It is the 5th largest continent of the earth with a land area of about 14 million sq. km., about double the size of Australia and equal to China and India combined together. The continent is almost circular in shape with an arm-the Antarctic Peninsula, protruding northward. It comprises of two distinct constituents: East Antarctica and West Antarctica, divided by the trans-Antarctic Mountain chain. It is the white continent of the earth, 98% of its land area is covered by ice and remaining 2% is the exposed area occupied by rocks and lakes. It is the highest continent with an average elevation of about 2300 meters above sea level; the coldest and windiest continent, technically a desert with practically no rainfall. It's a unique land with 6 months continuous day during summer from October to March and 6 months of continuous night during winter from April to September. It is a continent for all but for none without any permanent inhabitants; a place of peace, tranquility and science. It controls the key of global climate pattern and a virtual store house of information.

Antarctic terrestrial ecosystems represent some of the harshest environment on earth (Fountain *et al.*, 1999). The main limit of life in these ecosystems is low



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temperature which controls primary productivity and growth, survival rates and also impairs water availability (Nielsen *et al.*, 2011). This is confounded by low precipitation rates in the continent. Even a small increase in temperature and water availability may therefore have a great impact on the biotic communities throughout Antarctica (Wall & Virginia, 1999; Convey, 2003). Climate changes occur worldwide, that changes are likely to occur faster and reach greater magnitudes in the Polar Regions. The observed changes in climate in Antarctica do however show high spatial variability, and both increases and decreases in temperature and precipitation have been observed locally. However, a more directional warming and increased rates of precipitation are predicted for the twenty-first century (Steig *et al.*, 2009; Turner *et al.*, 2009). The current knowledge of climate change impacts on Antarctic terrestrial communities is poorly known. The impact of climate changes, focusing on temperature and precipitation changes influenced Antarctic nematode communities based on a literature review are being provided herein.

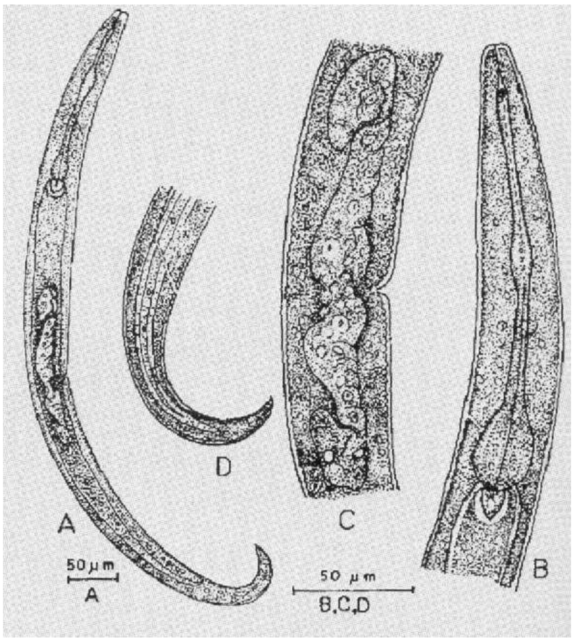
Antarctica : A Habitat

Antarctica covers an area of about 14 million Km^2, 1.5 times the size of the United States (Nielsen *et al.*, 2011). However, because of the very cold climate only 0.32% of this area is permanently ice-free (Ugolini and Bockheim, 2008). The continent broadly represents three distinct climatic regions: the sub-Antarctic, maritime and continental Antarctica with the sub-Antarctic being the most favourable and continental Antarctica is being the most hostile environments (Nielsen *et al.*, 2011). The average monthly temperature reaches 5-10° C during summer in the sub-Antarctica, 0-2ºC in Maritime Antarctica, while the average monthly temperature remains below freezing in continental Antarctica (Smith, 1994; Convey and Smith, 2006). The remoteness of Antarctica and weather patterns of the southern ocean has in combination with the harsh local climate, limited successful colonization events of species from other parts of the world (Convey *et al.*, 2008). Consequently, the terrestrial fauna of Antarctica shows a very high degree of endemism and a restricted diversity due to historical climate restraints (Nielsen *et al.*, 2011). The faunal diversity in maritime and continental Antarctic terrestrial ecosystems is therefore limited to about 520 species of invertebrates of which 170 are free-living endemics (Adams *et al.*, 2006; Convey, 2008; Push and Convey, 2008). The terrestrial species diversity of Antarctica follows the climate pattern, and more species are found in the gentler maritime climate than in the harsh continental climate.

Nematode Communities In Antarctica

The long-term isolation and harsh climatic condition of Antarctica is reflected by the low number of nematode species as well as a high degree of endemism. Historical glaciations events and the current spatial isolation of habitable soils have led to a very patchy distribution of nematode communities and no apparent overlap in nematode species between maritime and continental Antarctica (Andrássy, 1998; Maslen and Convey, 2006; Adams *et al.*, 2006; Andrássy and Gibson, 2007). The gentler climate in maritime Antarctica causes highest nematode diversities there rather than continental Antarctica. For example, 32 species have been recorded in maritime Antarctica compared with 23 species in continental Antarctica (Andrássy, 1998; Maslen and Convey, 2006; Andrássy and Gibson, 2007; Kito and Ohyama, 2008). (Nielsen *et al.*, 2011) recorded 28 nematode genera, new to Antarctica at Byers Peninsula of maritime Antarctica. Hazra (1994) was the first to record 5 genera/species of nematodes from the Schirmacher Oasis, East Antarctica. Hazra and Mitra (2002) studied the distribution pattern of nematodes in 36 sites of Schirmacher Oasis. Ghosh *et al.* (2003) described *Boleodorus motililus*, the first report of a new nematode species from Schirmacher Oasis area. Ghosh *et al.* (2005) described *Antarctenchus motililus*, a tylenchid nematode from the area.

Higher nematode abundances are associated with vegetated soils and plant cover has a strong influence on nematode community composition at least when compared with those found in bare soils (Convey, 2003b; Yergeau *et al.*, 2007). Many studies concluded that the nematode communities are structured mainly by abiotic factors, such as soil moisture and salinity (Powers *et al.*, 1998; Courtright *et al.*, 2001; Poage *et al.*, 2008), with little evidence for any discernable influence of biotic interactions on the composition of nematode communities (Hogg *et al.*, 2006). *Panagrolaimus davidi* Timm, 1971 tends to be related to nutrient-rich soils often associated with penguin rookeries while *Scottnema lindsayae* Timm, 1971 occurs at higher elevation sites in drier and saltier soils at Cape Bird, Ross Island, East Antarctica (Sinclair, 2001; Porazinska *et al.*, 2002). A survey of 368 samples collected in a range of microhabitats on 14 nunataks in Dronning Maud Land, East Antarctica showed that *Panagrolaimus* dominated ornithogenic soils while *Plectus* dominated in mosses (Sohlenius and Boström, 2008).



Antarctenchus motililus, Ghosh *et al.,* 2005

Climate Changes at Antarctica

In recent years, rapid, albeit complex changes in local climate have been observed in Antarctica, particularly in the Antarctic Peninsula, with substantial impacts on marine and terrestrial ecosystems (Ducklow *et al.,* 2007; Turner *et al.,* 2009). For instance, the average annual surface temperature increased by 0.56ºC per decade near the Faraday/Vernadsky Station of USA over the last 5 decades of the twentieth century, mainly due to higher winter temperature (Turner *et al.,* 2005). At larger scales, significant, albeit smaller increases in surface temperature have also been observed. Steig *et al.* (2009) studied that, the temperature increased by approximately 0.12ºC per decade between 1957 and 2006, with the most pronounced change occurring over West Antarctica (~0.17ºC) and a weaker change observed over East Antarctica (~0.10ºC). Different trends have been observed at smaller spatial and temporal scales, and temperatures have been stable or even decreasing in some regions within continental Antarctica (Thompson and Solomon, 2002; Bertler *et al.,* 2004; Turner *et al.,* 2005). Moreover, significant changes in snowfall and moisture regimes related to long-term climate variation have been observed in East Antarctica (Hodgson *et al.,* 2006).

Despite the observed idiosyncratic climate changes, a more directional warming and an increase in precipitation is expected to occur across Antarctica during the twenty-first century (Nielsen *et al.,* 2011). An assessment of the models, developed for the Intergovernmental Panel on Climate Change (IPCC) indicated that surface temperatures over the continent will increase by 3ºC, while precipitation will increase by 2.9 mm (Bracegirdle *et al.,* 2008). The expected temperature increases will be greatest over the continental high-altitude interior of East Antarctica and will be accompanied by a 20% increase in snowfall (Bracegirdle *et al.,* 2008), of which most will fall during winter (Turner *et al.,* 2009). Models have also shown that the frequency of temperature extremes, i.e. heat waves will increase that will lead to dramatic increases in moisture availability along the Antarctic coastline. For interior Antarctica, these heat waves is not large enough to lead to any significant melting and is therefore not likely have a great impact on moisture availability (Tebaldi *et al.,* 2006; Krinner *et al.,* 2007).

Effects of Climate Changes on Nematode Communities

Nematode communities at Antarctica are directly as well as indirectly affected by the climate changes. A few studies have already been explored the relationship between nematode communities and climate changes in Antarctica. The following impacts might be considered.

- Climate changes have large impacts on nematode communities as well, in particular through the development of plant communities on presently bare soils or a change in current composition of plant communities. A warmer and wetter climate increases the area of vegetated soil and plant species diversity. The range expansion and increased plant species diversity will provide a greater area of more favourable habitats for nematodes and other soil organisms, and enhance soil food web complexity and rates of nutrient cycling (Nielsen *et al.,* 2011).
- Climate warming causes lower environmental stress, increases the duration of metabolic activity, increases growth rates and shorten life cycles; through these combined influences increase population sizes (Convey, 2006; Turner *et al.,* 2009).
- The increased UV radiation associated with the development of the Ozone Hole over Antarctica is

often mentioned to be of high concern due to the potential impact on biotic communities (Weiler and Penhale, 1994; Kennedy, 1995). UV radiation might have an indirect influence on the nematode communities by damaging photo pigments and thus affecting primary productivity (Kennedy, 1995) and by reducing soil fungal growth (Hughes *et al.*, 2003).

- Increasing temperatures may alter species composition and favourable opportunistic nematode species (i.e. *Panadrolaimus davidi* Timm, 1971) over cold-adapted nematode species (i.e. *Scottnema lindsayae* Timm, 1971).
- The large climatic variation within Antarctica along both latitudinal and elevational gradients is likely to provide opportunities for local species to find suitable habitats during climate change.
- Other factors those influenced nematode communities include changes in cloud cover, wind speed, nutrient deposition, concentration of pollutants etc. (Kennedy, 1995; Wall, 2007; Turner *et al.*, 2009).

Overall, the nematode communities of Antarctica are considered simple with few species (Wall and Virginia, 1999) and show very patchy distributions (Sohlenius and Boström, 2005). Though few in number, Antarctic nematode species are well adapted to their harsh environment. One survival strategy used by many Antarctic nematodes is anhydrobiosis (Treonis and Wall, 2005), in which the organisms desiccate in order to survive extreme water limitation and low temperature as well as other stresses (Wright *et al.*, 1992; Wharton and Barclay, 1993). Most species, however, are considered cold tolerant (psychrotrophic, i.e. maximal growth at higher temperatures) rather than cold adapted (psychrophilic, i.e. grow optimally at low temperatures) (Block *et al.*, 2009).

The Polar Regions are experiencing higher rates of warming than most other ecosystems. Although there have been few empirical studies on the effect of climate changes on nematode communities in Antarctica, large-scale coordinated efforts to explore climate change impacts on such communities would give better information. These will improve our ability to predict climate change impacts in other ecosystem types, not only in Polar Regions but also in other areas of the earth.

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