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# A 7000-year Record of Oribatid Mite Communities on a Maritime-Antarctic Island: Responses to Climate Change

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## Abstract

We studied the fossil remains of the common Antarctic oribatid mites, *Alaskozetes antarcticus* and *Halozetes belgicae*, in sediment cores from two lakes in adjacent catchments on Signy Island, South Orkney Islands, maritime Antarctic. The aim was to examine the response of these species to 7000 yr of documented environmental change. Mites colonized the island shortly after the ice sheet retreated and habitats became available. A temperate period in the Holocene (c. 3800–1400 cal. yr BP) led to population expansion by factors of 7 (both species) in one catchment and 5.1 and 2.3 for both species in the other. This mid-Holocene hypsithermal is thought to have involved increases in habitat size, productivity, temperature, and moisture availability. Mite populations went into decline as conditions cooled. A period of short cold summers from c. 1400 cal. yr BP persisting to the middle of this century continued to impose restrictions on the biota. These results suggest that mite populations will respond positively to the recent rapid regional warming documented in the maritime Antarctic. However, on Signy Island this prediction is complicated by a similarly recent and rapid expansion of the populations of Antarctic fur seals (*Arctocephalus gazella*), which has not occurred previously since deglaciation, damaging the mites' habitats and exerting a new set of ecological constraints.

## Introduction

Research on the Antarctic Peninsula and maritime-Antarctic islands has shown that modern communities of terrestrial invertebrates are subject to a range of environmentally imposed selective pressures (Convey, 1996a, 1996b, 1997). The twin pressures imposed by low temperatures and availability of liquid water are generally accepted as being particularly important influences on the ecology and physiology of microarthropods, which form the largest and most visible animal component of Antarctic terrestrial ecosystems (Block, 1996). These selective pressures have led to communities comprising species that show typically "adversity selected" life history features (Greenslade, 1983; Southwood, 1988; Convey, 1996b). These life history strategies are characterized by high levels of responsive flexibility and the possession of adaptations or preadaptations to tolerate widely varying environmental conditions. Although the life histories of terrestrial invertebrates have been studied on seasonal or life-cycle time scales (Cannon and Block, 1988; Convey, 1994; Block and Convey, 1995), there is little information available on community responses to longer term, millennial-scale processes of environmental change.

We studied the fossil remains of two oribatid mites, *Alaskozetes antarcticus* (Michael) and *Halozetes belgicae* (Michael), currently common on Signy Island, South Orkney Islands, maritime Antarctic. Oribatid mites ("moss mites") are small free-living microarthropods which are found worldwide in terrestrial and freshwater habitats. Mites develop through egg, one or two larval, and three nymphal life stages before molting to the adult. Adult oribatid mites have a hard resistant cuticle that is well preserved in most terrestrial and limnic sediments (Solhøy and Solhøy, 2000; Solhøy, 2001).

Due to the absence of the confounding factors of direct human impact and an associated lack of alien introductions, Antarctic terrestrial environments are ideally suited to the study of community compositional changes involving species such as the free-living oribatid mites. Although rarely studied in an historical context, these

species have distinct habitat preferences that may allow them to respond quickly to environmental change (Solhøy and Solhøy, 2000; Erickson and Solod, 2002). Knowledge of the physiological and life history strategies of individual mite species indicates that they have sufficient physiological and ecological scope to quickly respond to environmental change (Convey, 1996b, 2000). They can, therefore, be good indicators of changes in habitat availability and productivity, which in turn can be linked to large-scale changes in climate (temperature, precipitation). For a review of the use of oribatid mites in tracking environmental changes using lake sediments see Solhøy (2001).

## STUDY SITE

Signy Island (60°43'S, 45°36'W, Fig. 1) is a 20 km<sup>2</sup> island in the South Orkney archipelago. It lies at the confluence of the ice-bound Weddell Sea and the warmer Scotia Sea, and its climate is influenced by the cold and warm air masses from these two respective areas (Quayle et al., 2002). Currently it has a moist climate typical of the maritime Antarctic (Walton, 1984). Mean annual air temperatures are sub-zero (−3°C), but mean monthly temperatures exceed 0°C for up to four months in summer, and annual precipitation ranges from 350 to 770 mm (Ellis-Evans and Lemon, 1989). Permafrost is present below an active layer of 0.3–0.7 m (Chambers, 1966). Currently, approximately 32% of the island is covered by a low altitude, relatively thin (<267 m), low density ice cap, which is believed to have completely covered the island during the Last Glacial Maximum, and has retreated (and fluctuated) since c. 7000 cal. yr BP (Holdgate, 1967; Smith, 1990). Between 1903 and 1991 mean annual air temperatures in the South Orkney Islands have shown an increase from −5.1°C to −3.1°C (linear regression of British Antarctic Survey archive data) along with a c. 35–45% reduction in the areas covered by glaciers, snowfields, and permanent ice (Light, 1976; Smith, 1990; Noon et al., 2001; Quayle et al., 2002) and a 7–8 m decrease in glacier thickness since 1951

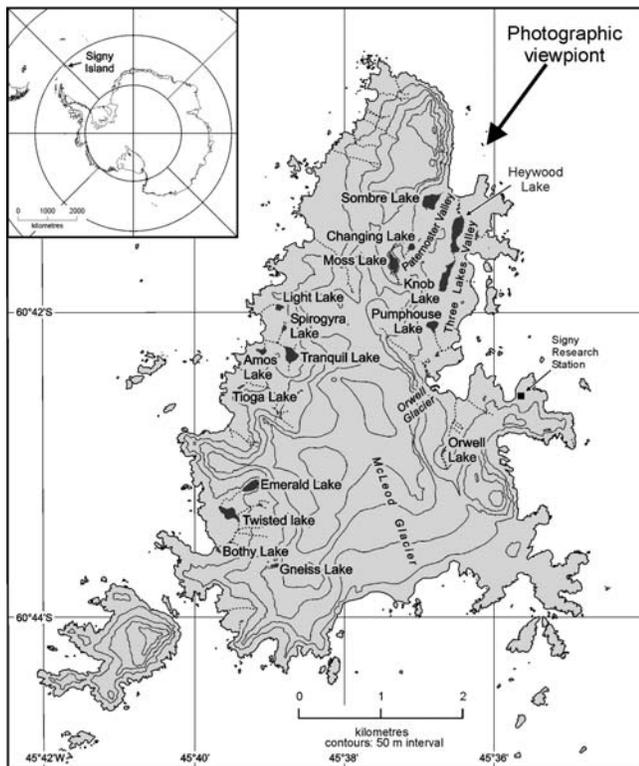
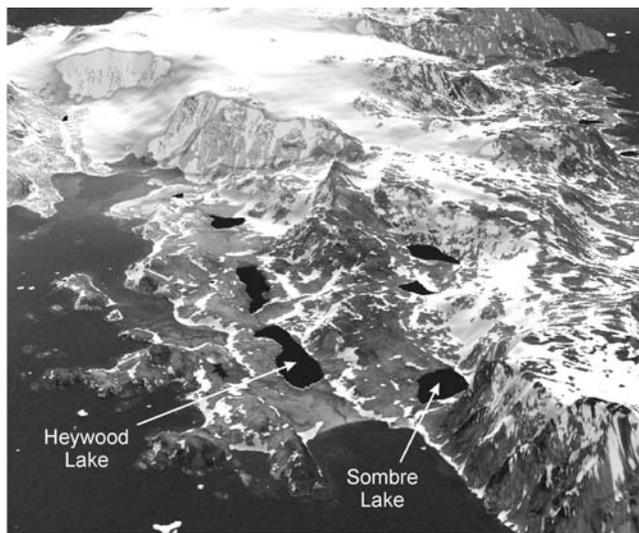


FIGURE 1. Map of Signy Island showing the locations of Heywood Lake and Sombre Lake (lower panel) and a digital elevation model projection of the lakes and their catchments (upper panel).

(Smith, 1990). It is the isolated oceanic and low altitude setting of Signy Island that has made this ice cap more sensitive to fluctuations in climate than comparable locations elsewhere in the Antarctic (Smith, 1990), and it has responded quickly to the recent rapid regional warming of the Antarctic Peninsula region (Svarca et al., 1998; Vaughan et al., 2003), with increased sedimentation rates in the lakes since 1950 (Appleby et al., 1995).

The catchments of the two lakes studied here, Sombre Lake and Heywood Lake, are on the northeast coast of Signy Island. Heywood Lake is situated in an adjacent valley to Sombre Lake in a catchment that includes no permanent ice fields. The lake is c. 200 m from the sea and covers an area of 4.2 ha. There are several inflow streams from moss banks and neighboring lakes, including some flowing via seal wallows. Sombre Lake is situated on a coastal plain, 150 m from the

sea with a small inflow (melt water) stream, and outflow. The lake covers an area of 2.4 ha. Records indicate rapid retreat of glacial ice from the shoreline of Sombre Lake since 1948 (Light, 1976) and most of the catchment is now ice-free. In recent years, both lakes have experienced the impact of an increasing number of visiting fur seals causing nutrient enrichment of their catchments (Smith, 1988; Hodgson and Johnston, 1997; Hodgson et al., 1998) and the lake water (Jones and Juggins, 1995; Butler, 1999).

Holocene climate changes on Signy Island have previously been reconstructed using multi-parameter paleolimnological studies of Heywood and Sombre Lakes (Jones et al., 2000). These analyses show that Signy Island has experienced considerable environmental change during the last 7000 yr. Briefly, these can be summarized as (1) deglaciation and cool conditions (c. 7000–3800 cal. yr BP); (2) a mid-Holocene hypsithermal (MHH), also known as the Holocene climate optimum (c. 3800–1400 cal. yr BP); and (3) cooling, instability, and recent environmental change (c. 1400 cal. yr BP to present).

Ice-free areas of Signy Island are comparatively well vegetated, with a fellfield-type vegetation consisting predominantly of mosses and lichens (Smith, 1972). Peat deposits derived from turf-forming mosses (particularly *Polytrichum alpestre* and *Chorisodontium aciphyllum*) are also present (Fenton, 1982). Although structurally simple, these terrestrial ecosystems experience rapid fluctuations in environmental conditions associated with the freezing and thawing of water (Convey, 1996b). They are particularly sensitive to even small fluctuations in climate, and have little resilience to disturbance (Smith, 1990).

#### AUTECOLOGY

In parallel with the simplicity of plant communities, the diversity and trophic complexity of faunal communities are also low (Block, 1984; Convey, 2001). The largest terrestrial animals found on Signy Island are oribatid mites, while only a single predatory arthropod is present in the terrestrial community. The two species of oribatid mites that form the focus of the current study are both primarily terrestrial. However, both are found and can be active and survive for extended periods in aquatic (marine and freshwater) habitats (Goddard, 1979; Pugh, 1994; Pugh and MacAllister, 1994). Thus these terrestrial mites may also feed in the littoral environment of freshwater bodies, which can support a simple cyanobacterial mat community together with algae and some benthic mosses. In terrestrial habitats, the short summer active season may be extended somewhat by occupation of an under-snow air space or cavity formed when absorption of solar energy by soils or plants creates a “greenhouse” in which temperatures are high enough to allow positive levels of net photosynthesis by microbiota, lichens, and mosses and feeding activity by invertebrates (Convey, 2001).

Both *A. antarcticus* and *H. belgicae* are distributed along the west coast of the Antarctic Peninsula, the Scotia Arc region, and sub-Antarctic islands (Pugh, 1994; Block and Convey, 1995; Block and Stary, 1996). Today *A. antarcticus* is widely distributed on Signy Island below 200 m, where it is often found in large numbers, including exuviae and corpses, usually in areas rich in either organic debris or foliose algae (*Prasiola crispa*). It is most abundant on lower ground by the sea, but generally avoids the littoral and splash zones where *H. belgicae* is generally most abundant. Although present, *A. antarcticus* is not found in dense aggregations in moss-turf communities (Goddard, 1979). The life cycle and development of *A. antarcticus* is sensitive to temperature, showing disproportionate growth responses to small positive temperature increments above 0°C (Convey, 1997), while becoming stressed at temperatures above about 15°C (Goddard, 1979; Young, 1979). *A. antarcticus* has a typical life cycle of 5 yr on Signy Island, with juvenile instars generally achieving a single molt each year (Convey, 1994), but has sufficient

developmental flexibility for this period to become shortened under more favorable environmental conditions.

*Halozetes belgicae* shows some overlap in habitat occupation with *A. antarcticus*. However, it is generally distinguished by its association with crustose lichens on which it is observed to graze (P. Convey, personal observation; S. Ott, personal commun.), and it is frequently found on rocks near the sea, often in the supralittoral or splash zones. This suggests a greater salinity tolerance than *A. antarcticus* and is not unexpected as members of the genus typically occupy littoral habitats (Goddard, 1979; Pugh, 1994). *H. belgicae* does not share the affinity for nitrogen-enriched areas typical of *A. antarcticus*. It is usually found in lower abundance in freshwater pools and lakes, although is often present in wet moss carpet communities. Finally, *H. belgicae* is normally found in small numbers rather than dense aggregations.

Using this autecological data, we interpret the presence of high mite concentrations in lake sediments as being due to a greater development of crustose lichens, or organic debris in the lake catchment, as appropriate, as a consequence of warmer and wetter conditions. However, we recognize that alternative explanations for high sediment mite concentrations exist, including the direct effects of warmer conditions, greater erosion leading to increased in-wash of catchment material, or more suitable conditions leading to greater survival in the lake.

The aim of this study was, therefore, to document and interpret changes in the relative abundance of these two species of oribatid mites in the context of known climate changes spanning the period from the deglaciation of Signy Island (c. 7000 cal. yr BP) to the present. We also speculate how life history and ecological strategies of these species may have been used to best exploit these changes in the ecological landscape, and on the impacts of recent rapid regional warming.

## Methods

To distinguish regional (i.e., climate) effects from purely catchment or authigenic changes, we examined the sedimentary record in paired lakes with similar geology and climate but different catchments. Surface to basement sediment cores were collected from the deepest part of the lakes using a combination of a modified piston corer for the uppermost sediment and a Livingstone piston corer (Livingstone, 1955) for the lower sediments. Cores were dated using radiometric methods ( $^{210}\text{Pb}$  and  $^{137}\text{Cs}$ ) for the surface sediments (Appleby et al., 1995) and AMS  $^{14}\text{C}$  of discrete aquatic moss remains and bulk sediments by the U.K. Natural Environment Research Council Radiocarbon Laboratory (Hodgson et al., 1998a; Jones et al., 2000). Dating of aquatic moss macrofossils reduces errors associated with the carbon reservoir effect and the inwash of allochthonous carbon (Hodgson et al., 2004). Age depth models were constructed with linear interpolation calculated using seven moss samples from Heywood Lake together with one bulk sediment sample at 45 cm (anomalous moss dates at 69 and 121 cm were omitted). The age depth model for Sombre Lake was based on nine moss samples together with two bulk sediment samples at 227 and 251 cm (one anomalous moss date at 79 cm was omitted). Radiocarbon dates are reported as conventional radiocarbon years BP (relative to A.D. 1950) and calibrated using the program CALIB 4.3 (Stuiver and Reimer, 1993). No reservoir correction is applied to dates from lacustrine sediments, because near-surface sediment dates indicate that  $^{14}\text{C}$  in modern freshwater surface sediments is likely to be in near equilibrium with modern atmospheric  $\text{CO}_2$ .

Cores were stored at 4°C for c. 1–2 yr, although we recommend deep-freezing to maintain the integrity of morphological and biochemical fossils over longer time periods (Leavitt and Hodgson, 2001; Solhøy, 2001). On return to the laboratory they were sub-sampled at 5 cm intervals, and a total of 98 samples examined for sub-fossil mites. Samples were prepared by washing 2 cm<sup>3</sup> of bulk sediment through

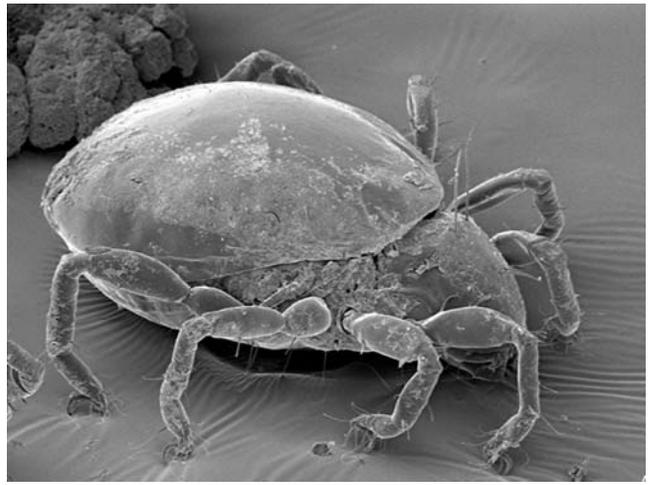


FIGURE 2. Scanning electron micrograph of the oribatid mite *A. antarcticus*.

a 125 µm sieve to remove fine inorganic particles. The remaining material was placed in a Perspex counting chamber and disaggregated from sediment clumps using distilled water and gentle manual sorting of the sediment with a needle. Free-living Acari (mites) of the order Cryptostigmata (*A. antarcticus*, *H. belgicae*) were enumerated systematically using a low-powered dissection microscope at 12–25× magnification. Taxonomy was carried out under a higher power light microscope with reference to Signy Island species descriptions given in Goddard (1979). *A. antarcticus* carapaces (Fig. 2) were typically c. 1012–1150 µm in length and those of *H. belgicae* c. 563–724 µm. Both species' carapaces were heavily sclerotized and showed no visible sign of degradation under light microscopy. Counts were expressed as an annual flux calculated from the dry mass accumulation rate. Reconstruction of past environmental conditions was carried out with reference to descriptions of their ecological optima and present-day distributions given in Goddard (1979). The cores were divided into three distinct climate epochs following Jones et al. (2000).

## Results

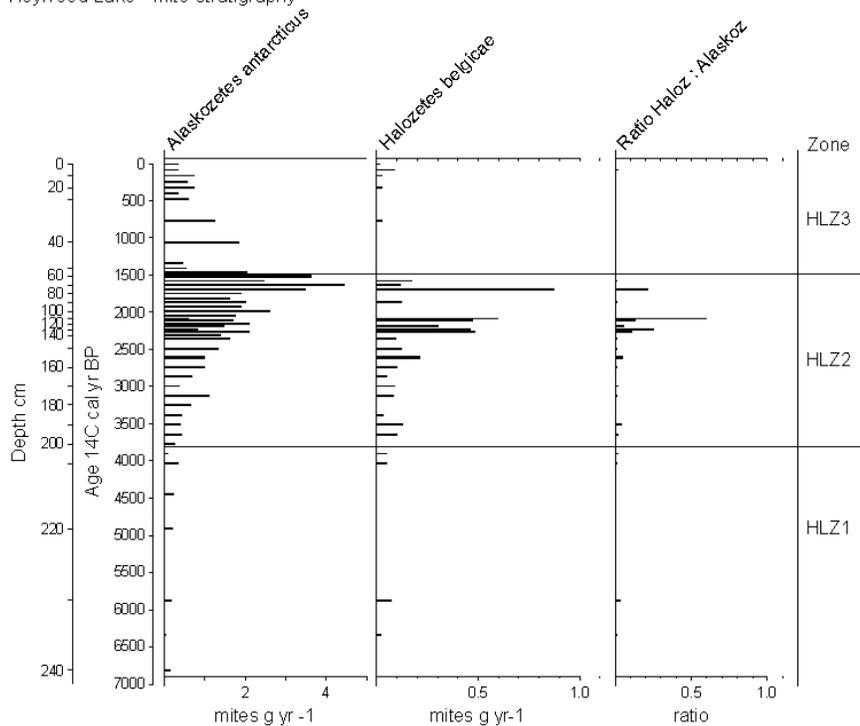
Mites were found in both cores. There were marked changes in the annual flux over time (Fig. 3) and marked differences in abundance in each of the Zones which represent the climate epochs of Jones et al (2000) (Table 1). In Heywood Lake a total of 1318 *A. antarcticus* and 80 *H. belgicae* carapaces were counted. The mean ratio of *A. antarcticus* to *H. belgicae* was 16.5. In Sombre Lake a total of 1415 *A. antarcticus* and 461 *H. belgicae* carapaces were counted with a mean ratio of 3.1.

### CLIMATE EPOCHS

Heywood Lake Zone 1 (c. 7000–3800 cal. yr BP) contained low but relatively constant numbers of *A. antarcticus*. In Heywood Lake Zone 2 (c. 3800–1475 cal. yr BP) there was a marked increase in the abundance *A. antarcticus* from a mean of 0.07 (HLZ1) to a mean of 0.43 (HLZ2), as well as in the frequency of moss spores and moss fragments (data not shown). Heywood Lake Zone 3 (c. 1475 cal. yr BP to present) was characterized by a decreased abundance of most macrofossils, although moss fragments remained abundant. *H. belgicae* was at its highest abundance relative to *A. antarcticus* in Zone 2 and was proportionately less common in Zones 1 and 3 (Fig. 3a).

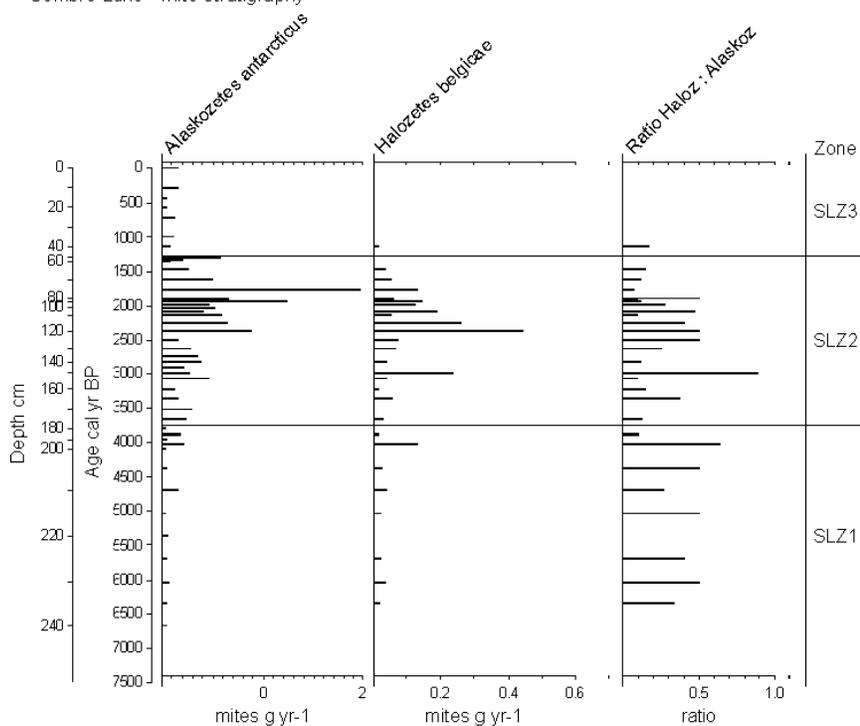
Sombre Lake Zone 1 (c. 7000–3750 cal. yr BP) was characterized by very low abundances of mites, although *A. antarcticus* was present

Heywood Lake - mite stratigraphy



a

Sombre Lake - mite stratigraphy



b

FIGURE 3. Fossil mite stratigraphies in (a) Heywood Lake and (b) Sombre Lake. Zones are derived from cluster analyses of multiproxy paleoecological data (Jones et al., 2000).

at low levels throughout. In Sombre Lake Zone 2 (c. 3750–1275 cal. yr BP) there was a clear increase in numbers of both *A. antarcticus* and *H. belgicae*, and in moss fragments, as seen in Heywood Lake. Sombre Lake Zone 3 (c. 1275 cal. yr BP to the present) showed clear decreases in both mite species. *H. belgicae* achieved its highest relative abundance in Zones 1 and 2 before becoming sparse in Zone 3 (Fig. 3b).

The general correspondence between the mite records from both lakes suggests that the patterns of change are more likely to have been

climate-driven than authigenic or locally influenced. Similarly, despite their different niche preferences, both mite species show similar responses in terms of their annual flux, suggesting climate forcing is the overriding feature determining species abundance. Examination of the relative abundances of *H. belgicae* and *A. antarcticus* does reveal some differences in the species' responses. While *A. antarcticus* was always dominant in both lake sediments, *H. belgicae* was found at relatively higher abundances in Zone 1 in Sombre Lake when compared with Heywood Lake.

## Discussion and Conclusions

Despite their different niche preferences, both mite species showed similar responses in their sub-fossil record from the two study lakes on Signy Island, suggesting that climate forcing has been the overriding feature determining both species' abundance. Further, it also suggests that habitat diversity is of less importance than habitat availability (size), which is determined by the extent of ice-free area, temperature, and moisture.

### ZONE 1: POST-GLACIAL COLONIZATION (C. 7000–3800 CAL. YR BP)

At the Last Glacial Maximum (22,000 to 19,000 cal. yr BP) most, if not all, of Signy Island is thought to have been covered by the South Orkney ice cap (Sugden and Clapperton, 1977). This is believed to have extended out to the continental shelf margins and obliterated all terrestrial habitats. This ice cap started to retreat sometime before 7000 cal. yr BP (Herron and Anderson, 1990) and the catchments of the lakes, and the lakes themselves, had ice free areas soon after 6000 cal. yr BP. Our data suggest that *A. antarcticus* was the pioneer species in the Heywood Lake catchment but was closely followed by *H. belgicae*, with both species present in the early samples of Sombre Lake. By 5586–5493 cal. yr BP the thick terrestrial moss banks, which are now a feature of the island, began to accumulate (Fenton and Smith 1982; Smith, 1990).

Cool conditions persisted during the deglaciation. Slow sedimentation rates and the limited mite numbers found in both lakes suggest conditions of low nutrients and productivity, consistent with cool conditions, and possibly extended periods of winter catchment snow cover. The persistence of short cold summers appears to have continued to restrict the opportunity for rapid growth and reproduction and, without a sufficient net accumulation of nutrients in the system, mite population growth was constrained. The higher relative abundance of *H. belgicae* in Zone 1 sediments suggests a catchment vegetation dominated by lichens rather than mosses, and a lack of the (vertebrate) nutrient enrichment with which *A. antarcticus* is associated. This is consistent with lichens being among the primary colonizers with the development of thick moss carpets occurring over a longer time scale.

The source and route of post-glacial colonists remains enigmatic. Given the current assumption of an absence of coastal refugia in the South Orkney Islands, a number of plausible but unproven routes exist that would facilitate transport from sites in the sub-Antarctic (e.g., South Georgia) or, possibly, the northern Antarctic Peninsula or South Shetland Islands, where both species occur. It is well-known that many oribatid mites can survive extended immersion in seawater (Pugh and MacAllister, 1994), hence permitting the possibility of transport on floating debris, ice-rafted stones (cf. Coulson et al., 2002), or the bodies of birds (Gressitt, 1982). However, it is clear from the contemporary occurrence of both species at sites recently exposed by retreating ice, that their colonization mechanisms are both rapid and effective. The only alternative is that small local glacial refugia existed for the mites through the Last Glacial Maximum.

### ZONE 2: POPULATION EXPANSION (C. 3800–1400 CAL. YR BP)

A temperate period in the Holocene, the "Mid-Holocene hypsithermal" (MHH) c. 3800–1400 cal. yr BP (Jones et al., 2000; Hodgson et al., 2004), appears to have released the mites from a number of environmental constraints. Numbers of both species expanded considerably in both catchments. Sombre Lake showed a marked increase in mites between c. 3750 and 1750 cal. yr BP, while Heywood Lake similarly showed a large increase after c. 3800 cal. yr BP, which peaked at c. 1600 cal. yr BP.

Any reduction in the thermal or water availability constraints on mite development are likely to have encouraged this population growth

TABLE 1

Summary of mean and maximum mite annual flux (number of specimens per gram per year) in the three zones of Heywood Lake (HL) and Sombre Lake (SL).

Lake zone	<i>Alaskozetes antarcticus</i>		<i>Halozetes belgicae</i>	
	Mean	Max.	Mean	Max.
HL Zone 1	0.75	1.84	0.02	0.09
HL Zone 2	1.68	4.44	0.15	0.87
HL Zone 3	0.24	0.43	0.04	0.13
SL Zone 1	0.07	0.16	0.002	0.015
SL Zone 2	0.43	1.97	0.07	0.44
SL Zone 3	0.085	0.2	0.03	0.13

by a number of separate but related routes. Shortening of the life cycle will have resulted in more rapid maturation and egg production while also probably increasing juvenile survival to adulthood as a result of the mites' inherent life history flexibility allowing maturity to be reached after fewer over-wintering events (cf. Convey, 1997, 2000). Systematic reduction in levels of environmental stress may also have allowed diversion of energetic resources from stress adaptations to reproduction (Convey, 1998), potentially further increasing populations.

At both sites, *A. antarcticus* was more abundant overall than *H. belgicae*. This is likely to reflect a closer proximity of its typical preferred habitats to the lake margins than those of *H. belgicae*. The population expansion in the mite communities during this period, as indicated by numbers recovered, has not been matched to the present day, suggesting that, during the MHH, the combination of habitat availability, productivity, nutrients, temperature, and moisture were all at their Holocene optima. Further characterization of the MHH is provided by studies of the lake sediments (Jones et al., 2000) which report higher Holocene mean dry mass accumulation rates, nutrients, and reconstructed chlorophyll *a* concentrations during this zone accompanied by an increased frequency of aquatic moss layers and well-developed benthic cyanobacterial mats.

It is plausible that, during this period, mites of exposed habitats, such as crustose lichens exposed to solar radiation, could have been active year-round. Given low solar angles experienced in winter, it is less likely that sub-snow communities could have remained similarly active year-round, although it should be noted that similar contemporary communities of oribatid mites on the more northerly sub-Antarctic island of South Georgia rarely experience temperatures below  $-2^{\circ}\text{C}$  and do continue both foraging and reproductive activity throughout the winter (West, 1982).

Despite the increased area of available terrestrial habitat and less harsh conditions experienced during this period, there is no evidence for new oribatid mite species being able to colonize these catchments. Likewise, no new species have been detected on Signy Island during the recent and much shorter period of contemporary warming. This observation suggests either that viable propagules did not reach the island for the 2400 yr of Zone 2, or that strong selective pressures imposed by the isolation and climate of the maritime-Antarctic were sufficient (and continue to be so) to preclude long distance colonization by sub-Antarctic or lower latitude species. Implicit in this suggestion is that the two study species do possess sufficient capabilities to enable successful long distance transfer between potential refugia and Signy Island (see above).

### ZONE 3: POPULATION DECLINE (C. 1400 CAL. YR BP TO PRESENT)

Paleolimnological studies have shown that the decreases in mite abundance in both lakes during this period are paralleled by decreases in

mean dry mass accumulation rates, nutrients, and reconstructed chlorophyll *a* concentrations (Jones et al., 2000). Biological production was again consistent with cooler climatic conditions and an extended duration of annual snow and ice cover in the catchments and on the lakes. Short, cold summers would have imposed restrictions on the biota by reducing the windows when environmental conditions were suitable for growth, hence leading to an increased over-wintering requirement on individuals and leading to lower reproductive output and population decline. Cooling would also have resulted in decreased (temporal and spatial) liquid water availability and a reduction in water input to the catchments (although note that the combination of more rapid melting of winter snowfall and extended summer length in Zone 2 may also lead to decreased water availability as the summer progresses). This is likely to have reduced the growth or coverage of mosses and algae such as *Prasiola crispa*, but to have had less effect on the growth or colonization of epilithic lichens. Elsewhere in the Antarctic, cool dry conditions are also known to have caused a decline in lake levels, with some lakes evaporating to dense brines or complete dryness (Doran et al., 1994).

### RECENT RAPID REGIONAL WARMING

Recent rapid regional warming of the Antarctic Peninsula/Scotia Arc region (Vaughan et al., 2003) has already caused accelerated retreat of the Signy Island ice sheet and “permanent” snow banks (c. 35–45% areal loss since 1950) resulting in more habitat becoming available for colonization. Lakes on the island have seen increased sedimentation rates since 1950 A.D. resulting from increased catchment erosion following deglaciation (Appleby et al., 1995). Using the MHH as an analog, we would predict a substantial increase in mite populations over the next few decades. However, as yet no increase has been detected despite the examination of several sediment layers across this interval.

A possible explanation lies in the recent expansion in numbers of Antarctic fur seals (*Arctocephalus gazella*) using terrestrial habitats on the island to rest and molt during the latter part of summer. This increase, linked to human influences on the Southern Ocean, is unprecedented since deglaciation (Hodgson and Johnston, 1997; Hodgson et al., 1998) and has caused considerable damage to low-lying terrestrial habitats, particularly leading to the destruction of large areas of moss carpet and lichen vegetation in the low lying catchments of the two study lakes, and elsewhere on the island (Smith, 1988). Damage occurs through two main routes: direct physical trampling and disturbance, and excessive input of nutrients via feces and urine. Although specific physiological studies of the responses of the two oribatid mites to these new environmental stresses have not been undertaken (but see Block and Convey, 1995), it appears that conditions over much of the seal-disturbed areas are unsuitable for the survival of more than a remnant mite population. A new set of ecological constraints has emerged that may override climate forcing in controlling terrestrial invertebrate population sizes in the immediate future.

### Acknowledgments

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