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SHORT NOTE

Extremely large aggregations of collembolan eggs on Humble Island, Antarctica: a response to early seasonal warming?

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Abstract In January 2007 we discovered numerous large aggregations of collembolan eggs on Humble Island near Palmer Station (64°46′S, 64°03′W). These aggregations were found in damp areas under rocks, moss, mats of the terrestrial alga *Prasiola crispa*, and at the interface between vegetation and the rocky substrate. Aggregations ranged in size from hundreds of eggs to the largest, whose estimated size exceeded 2 million eggs. Such aggregations were not observed in previous years. Associated with these aggregations were two collembolan species, *Cryptopygus antarcticus* (Willem) and *Friesea grisea* (Schaffer). Spring warming occurred approximately 7 weeks earlier in 2006 compared to the previous year. This early warming and consequent extended period of relatively high temperatures may have modified thermal and hydric conditions favoring collembolan growth and development and the formation of these large aggregations.

Keywords Collembola · Reproduction · Egg aggregation · Antarctic arthropod

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Introduction

Collembola and mites are the most abundant and taxonomically diverse arthropods on the Antarctic Peninsula and its islands. Research on terrestrial arthropods in this region has focused primarily on their distribution, feeding habits and their ecophysiology, especially related to their tolerance of extreme temperature, desiccation and other environmental stresses (Convey 1996; Strong 1967). However, relatively little information is available concerning their reproductive biology and factors governing their populations dynamics. This brief communication reports on extremely large aggregations of collembolan egg masses that occurred following an unusually long period of microhabitat warming.

Materials and methods

We first observed the egg aggregations on January 24, 2007 and continued observations intermittently until February 23, 2007 in connection with other fieldwork on Humble Island, located approximately 1 km from Palmer Station (64°46′S, 64°03′W). This area was covered in trondhjemitic rubble of which 50% was covered by the terrestrial alga, *Prasiola crispa*, and extensively enriched from Adelie penguin and elephant seal guano. In connection with microclimatic studies of other terrestrial arthropods on islands near Palmer Station, we had deployed temperature loggers (HOBO Water Temp Pro, Onset Computer, Pocasset, MA, USA) at nearby sites. The closest loggers were within 600 m on nearby Torgersen Island. These loggers were placed in microhabitats comparable to those in which we observed the collembolan egg aggregations and where we routinely observed *Cryptopygus antarcticus* and larvae of the midge *Belgica antarctica* (Chironomidae, Diptera).

Results

Aggregations were found under rocks at the base of a 3–4 m high cliff face running uphill at a shallow angle to the west. The area of highest concentration was a 10 m long swath that extended 2 m out from the base of the cliff. The bright yellow egg masses were typically found in moist areas under rocks, moss, mats of *P. crispa*, and at the interface of vegetation and the substrate. Two springtail species, the isotomid *C. antarcticus* (Willem) and the neanurid *Friesea grisea* (Schaffer), were present in the aggregations. Adults numbered in the thousands, with *C. antarcticus* significantly outnumbering *F. grisea*. Numerous newly hatched individuals and juveniles of various sizes were also present. By January 30, 2007 the eggs were less brightly colored and partially collapsed, apparently due to hatching. By late February, most eggs appeared to have hatched, however large numbers of collembolans remained at the aggregation sites. During the previous two field seasons we did not examine the specific sites on Humble Island where the large egg aggregations were found, but we commonly observed adults of *C. antarcticus*, yet we never saw more than a few eggs in any location, despite many days in the field.

We found aggregations of eggs of various sizes from 10s to 10,000s, but one was significantly larger than the others (Fig. 1). The largest aggregation was found at the base of the cliff between a partially emerged rock and the substrate. The aggregation formed a triangle, measuring 15 × 12 × 11 cm, containing furrows filled with collembolan eggs (Fig. 1b). The eggs covered approximately 60% of the triangle's surface. Using Heron's formula [Area = SQRT($s(s-a)(s-b)(s$-c)) where the three sides; a, b, and c are known and s = $a + b + c$] the area was determined to be 783 cm^2. Using macrophotographs (Fig. 1), we estimated that there were 36 eggs/mm^2. Consequently, we estimate that there were approximately 1,700,000 eggs in the surface layer of the aggregation. Since some of the egg clusters were several layers deep (Fig. 1c, d), we estimated there were an additional 8 eggs/mm^2, resulting in a final approximation of >2,000,000 eggs for the largest aggregation. Combined with the neighboring smaller aggregations the total numbers of eggs likely exceeded 4 million.

Summer-like temperatures came unusually early in spring 2006 and continued into summer 2007 (Fig. 2). Following the winter of 2005, microhabitat temperatures first rose above 0°C on December 5 and mostly remained above this value until mid-March 2006, a pattern closely matching that of microhabitat conditions in 1978–1979 (Baust and Lee 1980). In contrast, during 2006–2007 microhabitat temperatures reached 0°C on October 18 and generally remained high until March 2007. Consequently, when we

Fig. 1 **a** Egg masses were found along this cliff face on Humble Island. **b** Photograph of the largest egg mass found beneath a rock. Egg masses are located in light colored bands above and below the point of the white arrow. **c** Close-up of collembolans on egg mass. The smaller, shiny species is *Cryptopygus antarcticus*, while the larger, light grey species is *Friesea grisea.* **d** Close-up of egg mass. The scale at the bottom of the photograph is in millimeters

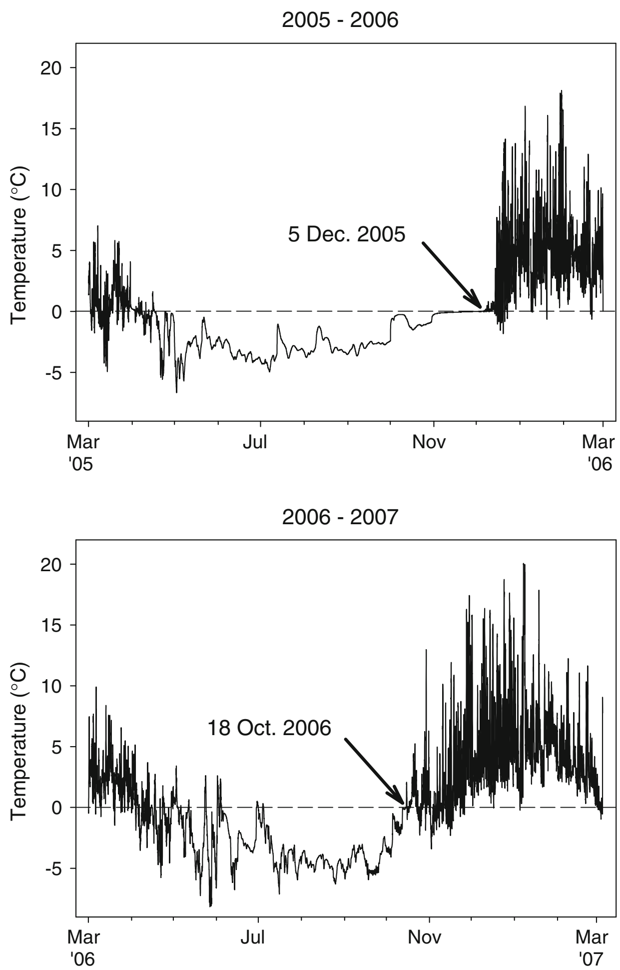

Fig. 2 Onset of permissive temperatures (i.e., >0°C) during the austral spring and summer at a representative collembolan microhabitat site on Torgersen Island near Humble Island. Microhabitat temperatures were measured from 2005 to 2007 using single-channel temperature loggers (HOBO Water Temp Pro, Onset Computer, Pocasset, MA, USA)

discovered the aggregations in late January the microhabitat temperatures had been above 0°C for ~14 weeks, whereas the previous year at this time they would have been elevated for only 7 weeks.

Discussion

To our knowledge this is the largest aggregation of collembolan eggs ever reported in the Antarctic or elsewhere. Although *C. antarcticus* is the most abundant species and most widely distributed terrestrial arthropod in the Maritime Antarctic (Tilbrook 1967), we found no reports of egg masses approaching the size we observed. Tilbrook (1967) reported finding 24,000 newly hatched larvae of this species following heat extraction from a single small sample of mosses and lichens. In his extensive review of collembolan biology, Hopkin (1997) noted that a mass of 10,000 eggs was reported in a laboratory population of *Folsomia candida*.

The range of body sizes of *C. antarcticus* associated with the egg masses indicated individuals of varying ages. Overlapping generations are common in this species, which requires 3–7 years to complete its life cycle (Burn 1984). Furthermore, this long-lived species appears to be more opportunistic and flexible in the timing of its feeding and reproductive activities than more short-lived species that oviposit synchronously (Burn 1984; Convey 1996).

Our observations are consistent with those of Hayward et al. (2004), who reported that *C. antarcticus* and *F. grisea* are often found together, although hygropreferences differ between the two species. Both species also rely on aggregation pheromones and additional semiochemicals that act as oviposition stimulants, thus aggregation and egg laying are both enhanced by chemical signaling (Benoit et al. Unpublished data). Although there is no evidence for cross species attraction between these two collembolans, both likely benefit from the lower rates of body water loss that occur as aggregation size increases.

The early warming in 2006 also coincided with a dramatic advance in the timing of adult emergence of *B. antarctica.* Adults commonly emerge and lay eggs in January, as we observed in 2005 and 2006, and as reported previously (Edwards and Baust 1981). However, we found very few adults in January 2007 compared to the previous 2 years. Instead, we observed aggregations of dead adults and evidence of eggs that had already hatched and whose resulting larvae had dispersed, apparently weeks earlier.

On the Antarctic Peninsula, microarthropod populations and their selection of microhabitats are primarily limited by water availability, rather than extreme cold (Convey et al. 2003; Hayward et al. 2004; Kennedy 1993; McGeoch et al. 2006). In addition to the direct effects of higher temperatures on activity and growth rates, climatic warming can have significant indirect effects on Antarctic communities through the increased availability of water, and the release of nutrients and their effects on plant productivity (Wasley et al. 2006). The unusually long period of spring/summer warming in 2006–2007, moist microhabitats, and abundant amounts of *P. crispa*, a preferred food of *C. antarcticus* (Bokhorst et al. 2007), may have provided an especially opportune time for collembolan growth and reproduction.

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