

Ballooning in high Arctic linyphiids: a case of behavioural atrophy?

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Summary

Ballooning was investigated in high Arctic linyphiids on Svalbard during the summers of 2003 and 2004, using a modified version of the Ballooning Index method. Evidence of aeronautic behaviour was restricted to 3 discoveries of silk cast-off lines on artificial take-off points during 2003. It is hypothesised that although linyphiids may have dispersed to the archipelago by ballooning, this behaviour has since atrophied.

Introduction

Ballooning has been adopted by many spiders as an effective means of dispersal at both local and more distant scales. Spiders balloon by climbing local prominences and either simply dangling on a silk thread and waiting to be swept away or by “tip-toeing”, casting a line of silk into the prevailing winds and casting off into the airstream (Bristowe, 1939; Weyman, 1993). Once in the airstream, their flight is largely passive and their final destinations are decided by where they are deposited by wind movements, although Suter (1991) notes that modifications of silk extension and posture potentially enable spiders to exercise some control over their rate and point of descent respectively. Morse (1993) directly observed the take-off and landing of crab spiderlings and calculated they covered mean distances of 2.7 ± 2.3 m; however, these observations belie the distances travelled by many spiders. Spiders may balloon repeatedly to move out of habitats and many travel distances too great for simultaneous observations of take-off and landing. Darwin (1913, originally published in 1845) provided one of the earliest observations of this “habit of sailing through the air” with his description of spiders floating down on to the deck of the *Beagle* when it was 60 miles off the coast of Brazil, while Bristowe (1939), collating the observations of fellow arachnologists, cited vertical movements of 4.3 km and horizontal movements of 322 km.

It is generally agreed that spider ballooning generally occurs during daylight and under clear skies and when wind speeds are <3 m/s (Duffey, 1956; Richter, 1970; Wingerden & Vugts, 1974; Greenstone, 1990) although the precise meteorological and behavioural factors both stimulating and facilitating ballooning are still under investigation (Weyman, 1993, 1995; Suter, 1999). The uncertainty surrounding these factors, however, may not reflect lack of knowledge so much as the general complexity of atmospheric properties at both micro and macro scales (Suter, 1999).

Although most other families are known to use ballooning (Coyle, 1983, 1985; Dean & Sterling, 1985), linyphiids are the most significant constituents of

arachnid aerial fauna (Greenstone *et al.*, 1987). Their small size makes them ideally suited to aeronautic dispersal — although spiders as heavy as 25.5 mg have been recorded ballooning, the majority of ballooners weigh less than 2 mg (Greenstone *et al.*, 1987) — and, unlike many other groups, they are able to balloon as both adults and juveniles (Weyman, 1993).

Sixteen of the 18 species of spiders recorded on Svalbard are linyphiids (Coulson, 2000). Bristowe (1939) was an early exponent of the theory that spiders had colonised Spitsbergen by ballooning. Holm (1958) also believed that aerial dispersal was the most likely means by which spiders had colonised the archipelago, noting that it is only the larger spider species on Greenland (i.e. those less likely to be aerially dispersed) that are not also present on Svalbard. Studies of terrestrial habitats around Kongsfjorden on West Spitsbergen have identified seven spider species, all linyphiids: *Erigone psychrophila* Thorell, *Erigone arctica* (White), *E. tirolensis* L. Koch, *Collinsia spetsbergensis* (Thorell), *Meioneta nigripes* (Simon), *Mughiphantes sobrius* (Thorell) and *Hilaira glacialis* (Thorell) (Coulson *et al.*, 2003; Hawes, 2003; Hodkinson *et al.*, 2004). Spiders are the dominant predators of terrestrial arthropod communities on Svalbard, are ubiquitous even at sites without significant community development, and have been implicated in arthropod facilitation of plant and animal succession on deglaciated terrain (Hodkinson *et al.*, 2001; Hodkinson, Webb *et al.*, 2002).

The aim of this study was to identify the importance of ballooning as a means of landscape and local scale dispersal of spiders in different habitats around Kongsfjorden, West Spitsbergen.

Methods

Investigations were carried out during the summers of 2003 (17 June–19 July) and 2004 (1 July–12 August) in the vicinity of the former mining town of Ny Ålesund, Kongsfjorden, Svalbard ($78^{\circ}55'N$). In 2003, spider traps were located along a successional gradient of community development from recently deglaciated terrain to established tundra extending from the Midtre Lovénbreen glacier (*c.* 1.5 km) (Hodkinson *et al.*, 2003, 2004; Hawes, 2003). Six sites representing various degrees of community development along the chronosequence were chosen, with approximate ages of 1–5, 10, 40, 60, 100 and 150–200 years respectively (ages determined by visual comparison of site positions with those of Hodkinson *et al.* (2004)). They are designated, respectively, as the glacial snout, supraglacial til, end moraine (proximal), end moraine (distal), alluvial outwash plain, and tundra ridge.

Spiders were captured using a modified version of the Ballooning Index (BI) method (Thorbeck *et al.*, 2002). Linyphiids were offered ballooning opportunities in the form of an array of 30 cm (above ground level) sticks planted vertically into the ground in a straight line 1 m apart at each site (10 at each site) (Fig. 1). Sellotape rolled back on itself to provide an adhesive capture surface was applied to the top 5 cm of the sticks to



Fig. 1: “Sticky-stick” for trapping ballooning spiders in 2003; with 2 captured chironomids on the sellotape; Midtre Lovénbreen glacier in the background (photo: TCH).

capture any spiders attempting to balloon away. Duffey (1956), employing the same capture principle with a sticky grease, noted problems of trap “clogging” by other insects, but the use of readily replaceable sellotape circumvented this problem and allowed the adhesive quality of the traps to be monitored and regularly refreshed in response to “clogging” as well as loss of adhesive properties as a result of rain.

Aerial deposition of spiders was monitored using water-filled (*c.* 3–4 cm depth) transparent (to ensure deposition was random and not a function of colour attraction) plastic trays (10 × 16 cm). A skirt (width = 2 cm) of sellotape (allowing replacement after loss of adhesion) was applied to the lips of each tray to trap any surface arthropods attempting to enter them. Ten trays were placed 2–3 m apart at each of the 6 sites.

As trapping success was extremely limited in 2003 (see below), in 2004 the trapping protocol was modified. In addition to the two most successional distinct (in terms of animal and plant community development) sites of the previous year (the top and bottom of the Lovénbreen glacial foreland) a further four sites — representing a greater variety of habitats — were sampled. These included a semi-polar desert, an alluvial outwash plain, an Arctic mire, and the base of nutrient-rich bird cliffs. Trapping was again carried out with sticks, but this time using OecoTAK A1 (Oecos, Herts, UK). Also, to eliminate stick height as a deterrent factor for spiders, and to identify height preferences of ballooners, 15 sticks each, at heights of 1.5, 5, 10, 15, and 30 cm (above ground level), were planted in parallel lines at each site.

Nomenclature adopted throughout is that of Platnick (2004).

Results

Spider captures

The water traps caught a few Collembola and Acari, but did not capture any aerially deposited spiders. The arrays of “sticky-sticks” offering ballooning opportunities to spiders at each site on the Midtre Lovénbreen during 2003 were frequently found to have caught chironomids (Fig. 1), but no spiders were trapped on any of the arrays and silk “casting-off” lines were found on only three separate occasions, all at different sites — at the end moraine (proximal) (24 June), glacial snout (5 July), and the supraglacial til (8 July). In 2004, although chironomids and other Diptera were frequently caught by the sticks, no spiders were captured on the sticks. The use of OecoTAK as a much stronger adhesive precluded the presence of cast-off lines as any climbing spiders would have been caught immediately.

Meteorological conditions

Mean wind speeds over the sampling period in 2003 were 2.19 ± 0.2 m/s, i.e. below the wind speeds which are not favourable for ballooning (>3 m/s) (Duffey, 1956; Richter, 1970; Wingerden & Vugts, 1974; Greenstone, 1990) (Fig. 2). With the exception of a few peaks between 3–4.5 m/s, daily means were consistently lower than <3 m/s (Fig. 2). The three days when “casting-off” lines were found were all during periods of minimal wind speeds. Mean air temperature over the sampling period was 2.03 ± 0.44 °C. Temperatures in June were consistently <4 °C, but from the beginning of July onwards warmed up progressively with a maximum mean temperature of 7.96 °C (Fig. 3).

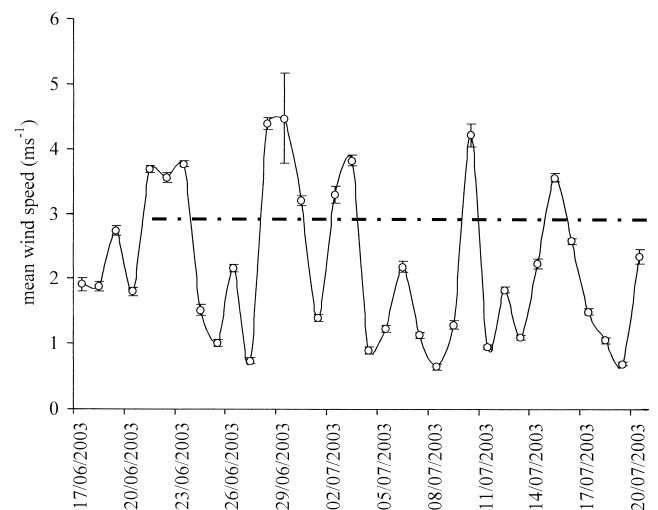


Fig. 2: Mean daily wind speeds (\pm SE) at Ny Ålesund for the sampling period in 2003; dashed line indicates the maximum threshold windspeed reported as favoured by spiders for ballooning. Meteorological measurements courtesy of Norwegian Air Quality Institute (NILU).

Discussion

Taken together, the low trap success over both summers and with both experimental protocols suggests that ballooning activity is minimal in high Arctic linyphiids. Although Coulson *et al.* (2003) trapped a number of arachnids in their sticky traps, only seven of these could be said to have been legitimately aerially dispersed as all others probably climbed onto the traps. While it is possible that spiders climbing up on yellow sticky traps (Coulson *et al.*, 2003; Hawes, unpublished data) are trying to balloon, the more parsimonious explanation is probably that, like the dipterans, yellow is highly attractive to them. Those that were definitely aerially dispersed could be representative of either the low frequency of aerial ballooners or of more stochastic dispersal (spiders caught up accidentally by winds). Given the short duration of summers on Svalbard (*c.* mid June–August), it is unlikely that the seasonality of ballooning found in temperate areas was a factor contributing to the low trapping success of the study.

There are a number of reasons why aeronautic behaviour may have atrophied in Svalbard's linyphiids. First, cursorial dispersal may be favoured in high Arctic habitats where the likelihood of aerial deposition in adverse habitats (fjords, snowbanks, streams, glaciers) is so high. Secondly, although wind speeds favoured ballooning, other unknown meteorological factors may be unfavourable for ballooning in a high Arctic context, particularly temperature. For example, vertical convective movements of air from the ground layer, which enable ballooners to enter the airstream, may have less of a gradient at high latitudes where warming of land surfaces is greatly reduced in comparison with lower latitudes.

There may also be fewer ecological stimuli for linyphiids to disperse aerially on Spitsbergen: (a) predatory pressures are minimal as they are the top arthropod predators on land, and the only insectivorous macrofauna are the small numbers of snow buntings (*Plectrophenax nivalis*); (b) invertebrate prey (particularly

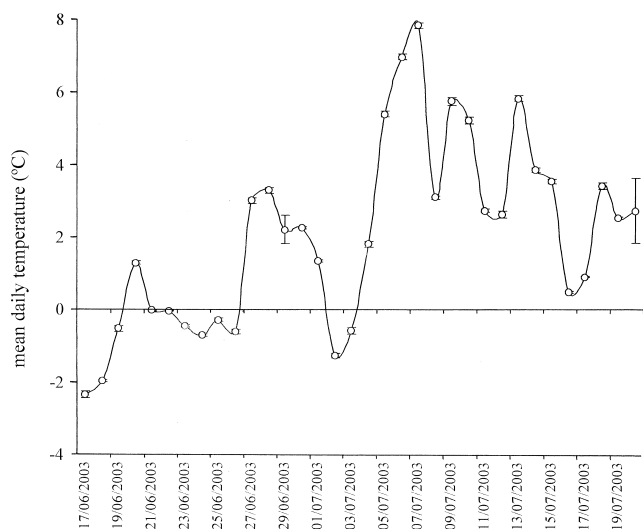


Fig. 3: Mean daily air temperatures (°C, \pm SE) at Ny Ålesund for the sampling period in 2003. Meteorological measurements courtesy of Norwegian Air Quality Institute (NILU).

Collembola) are ubiquitous at even the most vegetatively undeveloped sites (Hodkinson, Webb *et al.*, 2002; Hodkinson *et al.*, 2004; Hawes, 2003); (c) conspecific pressures may also be reduced, as observations suggest that the limited availability of favourable microrefugia confers some degree of conspecific tolerance, with egg laying *Hilaira glacialis* females, for example, sharing the same rocks (Hawes, pers. obs.).

Within an evolutionary context, these observations (or rather, lack of them!) sit well with the general trend for increasing flightlessness in insects — in terms of both brachyptery (wing reduction) and aptery (wing loss) — with increasing latitude (Roff, 1990; Strathdee & Bale, 1998). The high Arctic aphid, *Acyrtosiphon svalbardicum*, which feeds on *Dryas octopetala* on tundra sites around Kongsfjorden, for example, does not produce alate forms in response to typical dispersal cues such as overcrowding (Strathdee, 1994) and to date only one alate form of this species has been found (Hodkinson, Coulson *et al.*, 2002).

The BI method is specifically aimed at identifying the initiation of ballooning behaviour and has been validated by comparisons with suction trap collections in agroecosystems (Thorbeck *et al.*, 2002). Surface-active linyphiids were abundant at all of the trapping loci on Svalbard (Hawes, 2003; unpublished data), but evidence of ballooning behaviour was meagre. It is suggested that the amount of aerial plankton over high Arctic habitats is greatly reduced in comparison with temperate climes. The behaviour may have atrophied as a result of the effects of biotic and/or abiotic factors.

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