Single mothers: Minotaur beetle females *Typhaeus typhoeus* (L.) (Coleoptera: Geotrupidae) nest on their own

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Abstract

Minotaur beetles *Typhaeus typhoeus* normally co-operate during nesting: the males collect the dung and the females prepare individual brood masses, well below the surface, for their offspring to develop in. Females are often found above ground towards the end of the season which suggests they could be nesting on their own. In order to test this, two females were trapped in mid-March 2012, placed in deep terraria and offered rabbit droppings. Subsequently, one beetle collected 362 droppings by the end of May and the other 172 droppings by mid-June. By October 2013 only the former had produced viable offspring. Later inspection revealed that both females had made their brood masses in a cluster near the bottom of the terrarium; brood masses were cylindrical with rounded ends, over 4 cm long and about 1.7 cm in diameter.

Introduction

Co-operation by male and female during nest-making in the Minotaur beetle *Typhaeus typhoeus*, has been well documented (Fabre, 1907a, b; Main, 1916-7; Lengerken, 1954; Brussaard, 1983).

These dung beetles spend most of their life underground. They emerge in the autumn and undergo a maturation-feeding period in shallow burrows which lasts about eight weeks. After that, the beetles are ready to begin nesting. They pair-up and dig a tunnel sometimes over one metre long and in the process create a mound of soil by the entrance to the burrow - a tell-tale sign of their presence. There is a clear division of labour. The male gathers dung, generally from herbivores, in a two-step operation. In the first step, the male drags a dropping backwards towards the nest entrance and pushes it down the burrow. The droppings land on a level platform, which functions as a larder and the pellets accumulate there. During the second stage the male goes to the larder and sends the pellets down a more or less vertical shaft to the female, who is busy lower down; occasionally the female comes up and fetches the pellets. The female prepares a brood mass with compacted dung next to each egg in a side branch to the main shaft. When the brood mass is finished, she

plugs the side branch and starts on a new side branch of the shaft, probably moving upwards. Meanwhile the male stands guard in the larder by the entrance to the main shaft and is known to fight conspecific intruders with his horns (Palmer, 1978; Fremlin & Nahaboo, 2010). The adults reproduce only once and die at the end of the season in May and June. There is no known brood care in the Geotrupidae as in many Scarabaeidae (Cambefort & Hanski, 1991; Klemperer, 1983).

In due course, the egg hatches and the larva makes its way to the brood mass where it develops further, moulting twice. The mature larva exits the brood mass by the way it entered, then moulting a third time to pupate in the soil, more or less where the egg was laid. Later, the teneral adult makes its way back through the brood mass and then climbs up the shaft to emerge above ground in the autumn of the following year; thus this species has a two-year cycle from emergence to emergence above the ground (Brussaard, 1983; Fremlin, pers. obs.).

I was intrigued by the fact that during the nesting season a significant number of females seem to be active in the field (Fremlin & Darby, 2010) when they should have been underground. Some questions arose. Had they lost their partners, and if so, would they be capable of nesting on their own as declared by Brussaard (1983)?

One way to answer the last question would be to capture some females late in the season, and observe their behaviour in captivity. The results of one such experiment are reported below.

Methods

Females

On 11 and 12 March 2012 two females were collected in pitfall traps baited with rabbit droppings placed near emergence holes in Hilly Fields, Colchester, Essex, TL985254. Trapping is a very effective way of capturing these mostly nocturnal beetles. These females had emerged in the autumn of 2011, and were still in good condition (Figure 1). They were weighed and their body length was measured with calipers (Table 1).

Terraria

Two large plastic swing bins were used without their lids. Their internal dimensions were as follows: 1 - Green bin (GB) 22.5x27.5x43 cm, 2 - Blue bin (BB) 26.5x28x55.5 cm. Both had been used in the past to rear Minotaur beetles successfully and had been cut in half vertically and taped together; this in order to allow for examination of their contents (Martínez & Trotta-Moreu, 2010). The bins were filled to within 4 cm of the top with sandy soil collected from

Figure 1. The female *Typhaeus typhoeus* placed in the BB. Note the transverse ridge in the pronotum and accumulation of soil in her legs. Photo taken on 12 March 2012.

the beetles' habitat in Hilly Fields. First, the soil was dried and weighed and then water was added gradually to the soil to make the moisture content around 10%. Both bins were covered with a fabric net, which was secured with an elastic strap around the top.

Rearing procedure

Each female was allocated to a bin, and the bins placed in a well-ventilated, unheated garage. On a regular basis, 30 rabbit droppings were left on top of the soil; their uptake was recorded regularly and then topped up to 30. Later on, in order to catch their offspring, pitfall traps, in the form of small plastic cups baited with rabbit droppings, were buried level with the soil surface and checked on a regular basis. Eventually, the bins were dismantled and their contents examined.

Results

Nesting

The female in the BB settled in very quickly and took pellets down assiduously until 23 May; on 4 June she was found dead on the surface. In total, she buried 362 pellets.

Date	Terrarium	Gender	Total length mm	Body length mm	Weight g
11/03/2012	GB	female	18.13	15.04	0.50
12/03/2012	BB	female	18.56	14.80	0.60
13/10/2013	BB	male	15.49	13.02	0.35
13/10/2013	BB	female	17.94	15.73	0.51
15/10/2013	BB	male	17.10	14.12	0.51
16/10/2013	BB	male	17.83	14.72	0.56
16/10/2013	BB	male	17.38	13.53	0.44
17/10/2013	BB	male	17.36	14.27	0.50
17/10/2013	BB	male	16.76	14.16	0.43
21/10/2013	BB	male	15.17	12.94	0.37

Table 1. Biometric data of the females captured in the spring of 2012 and their offspring which emerged in the autumn of 2013. Total length = the anterior edge of the head to the apex of the abdomen; body length = the anterior edge of the pronotum to the apex of the abdomen; GB = green bin; BB = blue bin.

The female in the GB promptly collected 20 pellets, but then paused for three weeks, before resuming collecting. Emergence holes kept appearing in different places. She was active until 12 June and collected a total of 172 pellets, and was not seen again.

Emergence of the offspring

A total of eight Minotaur beetles emerged from the BB between 7 and 21 October 2013. These were seven males and one female. The last to emerge was a male, which was very small; all were weighed and measured (Table 1). The beetles were released in the same habitat in which the original females were captured, Figure 2. No beetles emerged from the GB.

Dismantling of the terraria

On 20 February 2014 the bins were inspected. They were laid on their side, the tape was cut and the top half removed. The soil had completely dried out, except at the bottom.

BB - The brood masses were right at the bottom in one corner, in a cluster. All the brood masses were very friable; some had clear signs of feeding: a very thin wall of dung, which got filled with sand during the inspection (Figure 3). The brood masses were cylindrical with rounded ends, roughly over 4 cm long and about 1.7 cm in diameter, see inset.

Figure 2. The first male *T. typhoeus* to emerge in the BB being released by a rabbit latrine; it soon buried itself. Note the three forward-pointing horns in the pronotum. Photo taken 13 October 2013.

Figure 3. The BB opened up with the halves side-by-side; a couple of brood masses are arrowed. Scale -16 cm. Inset: collected brood masses with signs of feeding.

Figure 4. Left, a brood mass, still surrounded by sand. Centre, a broken brood mass and the remains of the female.

GB - A 'J'-shaped gallery, branched near the top, was still intact. Also nearer the top there were some mouldy rabbit droppings. The brood masses were clustered at about 10 cm from the bottom, and all, except a couple, were very friable; the body of the female was recovered (Figure 4).

Discussion

Both females were able to nest on their own; moreover they collected dung pellets within the range of previous rearing trials with a male and a female in the same bins. The more diligent female produced viable offspring of eight beetles. This is the best result I have ever had with Minotaur beetles reared in these bins using conventional trials with couples: four beetles; five and seven brood masses. It also compares well with other researchers' results. Under laboratory conditions Brussaard (1983) found that females made, on average, ten brood masses. Fabre (1907b) found eight brood masses in one of his trials. The BB female brood masses could have taken about 45 droppings each and this fits with previous findings of, on average, 40 rabbit pellets per brood mass (Brussaard, 1983; Fremlin, pers. obs.).

It was rather surprising that the female in the GB produced no offspring. She could have made about four brood masses. By the time that the bins were inspected, her brood masses were very friable but at least two showed no signs of feeding. When a larva develops to maturity only the thin walls of the brood mass remain. In my experience, mortality in the immature stage can be rather high in captivity. Sometimes I find first and second instar head capsules in a partially digested aborted brood mass. Mortality in the field is very difficult to determine. In dung beetles, which invest so much in nesting it is thought that it is to ensure the survival of their offspring. The parental investment is correlated with low fecundity (Cambefort & Hanski, 1991).

The potential fecundity of *T. typhoeus* is relatively low; in their family, Geotrupidae, the females have six ovarioles per ovary (Scholtz & Grebennikov, 2005; Martínez & Trotta-Moreu, 2010). Mature eggs found inside females are approximately 4 by 2 mm, just slightly larger than the eggs found in female Stag beetles *Lucanus cervus* that have accidentally been trodden on (Fremlin, pers. ob.). The latter is a much larger beetle with a total body length in the UK of 27- 43 mm (Harvey *et al.*, 2011) and with twice the number of ovarioles (Scholtz & Grebennikov, 2005). Reproduction for *T. typhoeus* is an enormous investment of time and energy. Brussaard (1983) describes how the couple stimulate each other while nesting; sometimes they copulate before the female lays an egg. When the female comes up to the larder to fetch a dung pellet she strokes the male's elytra. On other occasions the male goes down the shaft, sweeps the female elytra, and tries to copulate. This behaviour is interpreted as required stimulation for egg-laying. The captured females were not seen to experience courtship behaviour but, as they were collected towards the end of the season, they had probably experienced it before they were captured and quite possibly were already nesting on their own. In which case it shows how adaptable and determined they were.

Both females made their brood masses at the bottom of the bins. The way in which they branched out of the main shaft was impossible to determine. This is presumably because I should have tamped down the soil much more firmly when I loaded the bins. Some researchers have done this in the past (*e.g.*: Main, 1917; Klemperer, 1980, 1983; Brussaard, 1983). In any case, these clusters of brood masses seem to be rather different from what happens in a vertical terrarium; there the brood masses are generally made from the bottom upwards along the main shaft. In such terraria the brood masses are rather elongated, up to 12.5 cm in a terrarium with plates 11 mm apart (Brussaard, 1983; Fremlin, pers. obs.). By contrast, in a non-constricted space, they are shorter and fatter; more like cocktail sausages instead of chipolatas. The geotrupid beetle *Lethrus apterus* makes rather similar brood masses clustered

at the bottom of the shaft (von Lengerken, 1954). Remarkably, *L. apterus* uses fresh leaves instead of dung, but its nesting behaviour is very similar to that of Minotaur beetles.

The fact that only unused droppings went mouldy and not any of the brood masses, suggests that the females might have buccal secretions that suppress fungal activity. This is worth further investigation. It would also be interesting to find out if mated females at the beginning of the season would be able to nest on their own.

Conclusions

This experiment showed that the high incidence of female sightings towards the end of the season could be because they are nesting on their own, sometimes with success.

These single mothers took on their partners' nesting duties as well as their own. Given the advanced season, surely they had copulated; they did not need further stimulation to ovulate or to prepare the brood masses. The fact that one female did not produce viable offspring could be explained by the observation that mortality in captivity is high. There are still quite a few questions that need answering regarding the nesting of these fascinating beetles. Mainly, what is the nesting behaviour of isolated females at the beginning of the season and secondly, what affects the arrangement of the brood masses along the shaft. The latter could probably be solved by rearing the beetles in bins with moist soil, well tamped, and inspecting them soon after nesting has finished.

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