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SHORT COMMUNICATION

Capturing the elusive camel spider (Arachnida: Solifugae): effective methods for attracting and capturing solifuges

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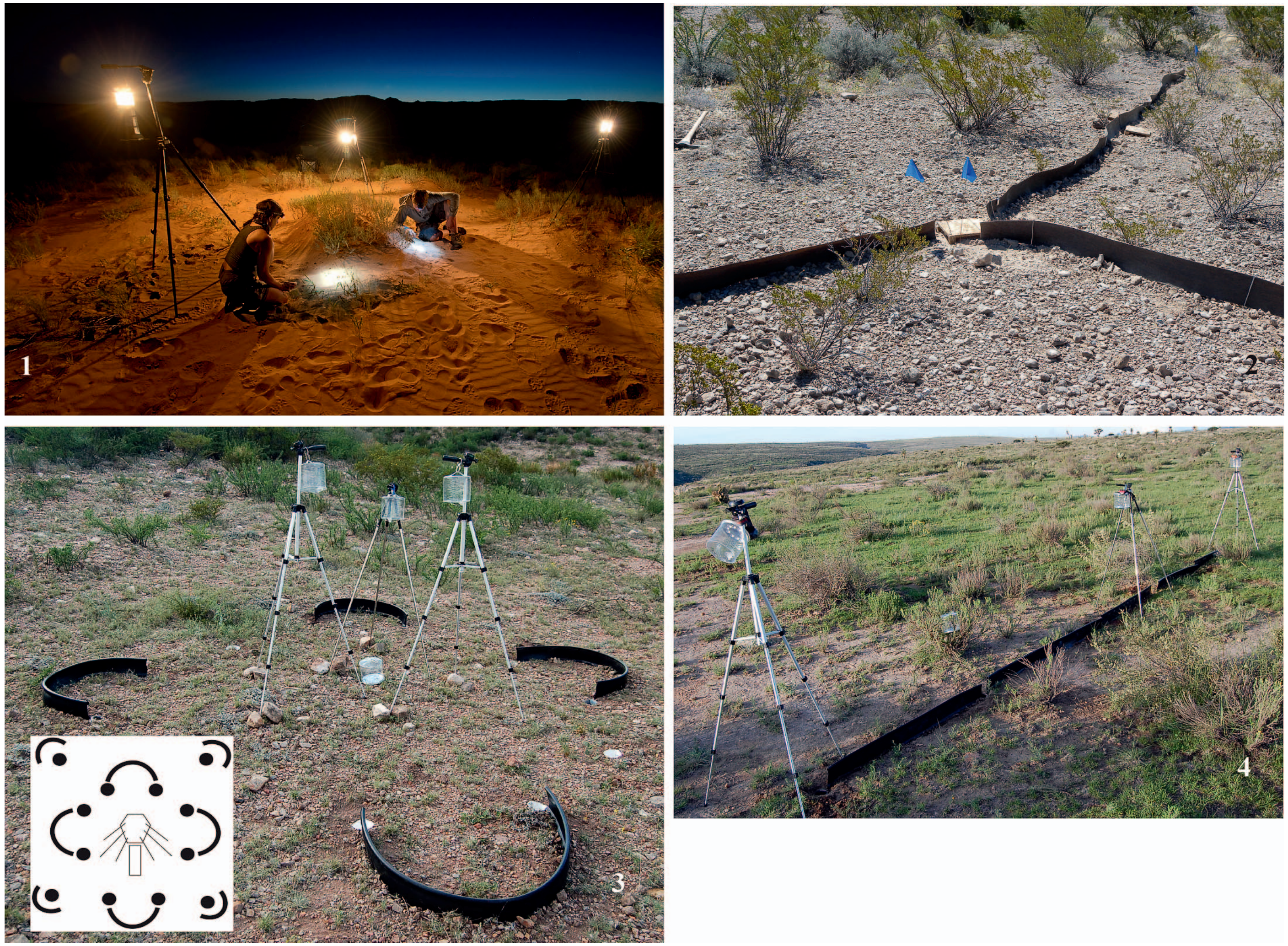
Abstract. Camel spiders (Arachnida: Solifugae) are a notoriously difficult group of arachnids to study. They are almost all strictly nocturnal, fast moving predators that are difficult to find, collect, and rear. In this paper, we present methods for both attracting solifuges in desert field sites and collecting them efficiently using a combination of light attraction and pitfall trapping techniques. Although many of these methods have been used by solifuge collectors for decades, they are not typically described in detail in the literature nor have the methods been consolidated in a single paper. We hope that doing so will enable others to more efficiently target this group of arachnids.

Keywords: Solpugids, wind scorpions, pitfall trap, light trap

Solifugae, known colloquially as camel spiders, are mostly nocturnal arachnids known for their powerful two-segmented chelicerae, voracious appetites, and fast running speeds (Punzo 1998a; Beccaloni 2009). They are dominant predators in arid habitats worldwide (Banta & Marer 1972; Cloudsley-Thompson 1977; Polis & McCormick 1986; Wharton 1987; Punzo 1994). Solifuges are also notoriously difficult to study. They are challenging to keep alive in a laboratory setting and nearly impossible to raise to maturity in captivity, with only one researcher reporting some small success in rearing (Punzo 1998b). As a result of challenges inherent in the study of camel spiders, only the first author's lab regularly publishes on their phylogeny, taxonomy, and biology (Brookhart & Cushing 2002, 2004, 2005, 2008; Cushing et al. 2005, 2014, 2015; Catenazzi et al. 2009; Conrad & Cushing 2011; Cushing & Casto 2012; Cushing & Brookhart 2016). Herein we present methods, many adopted from capture techniques for other taxonomic groups (particularly reptiles), that we have co-opted and further developed over the years that have proven effective in attracting and capturing these elusive arachnids in an attempt to encourage other researchers to begin collecting and studying these animals so that we may learn more about the many aspects of solifuge biology that remain mysteries. Many of these techniques, such as light trapping and pitfall trapping, have been used for decades to attract and collect solifuges; however, at best, researchers refer to these techniques in passing in their methods sections and have not provided details about these collecting techniques. Thus, the authors felt it would be useful to consolidate successful collecting techniques for these elusive arachnids into one paper.

Two methods that have been used to attract and collect solifuges are light attraction and pitfall trap sampling. It has long been known that solifuges are attracted to light, where they hunt insects that are also attracted to this stimulus (Pocock 1897; Turk 1947; Cloudsley-Thompson 1961, 1977; Punzo 1998a; Catenazzi et al. 2009; Conrad & Cushing 2011; Belozorov 2013). It is not known what draws the solifuges to the light source – whether it is the light itself or the vibrations from insect prey. Nevertheless, setting light stimuli in arid habitats or visiting permanent lights such as buildings in these environments is a good way to find hunting solifuges. Solifuges typically begin visiting these light sources after sunset when insects have begun swarming the lights. Solifuges that come to the lights can be grabbed by hand if the collector is fast enough and if the collector wants to keep the animals alive. Alternatively, they can be shot with a focused stream of 70–75% ethanol (Hewitt 1919). Spraying with alcohol has proved to be a very effective method for slowing and killing solifuges. A squirt bottle filled with water could be used to slow down solifuges if the collector wants to keep the animals alive (but the moisture should be wicked from the animal in that case). If a site lacks permanent lights on buildings or structures, temporary lights can be hung on tripods in the field to create a concentrated pool of light (Fig. 1). Lights are illuminated just after sunset; insects and solifuges begin appearing at this light pool one to two hours after that (Fig. 1). Table 1 provides the success rate for collecting at both temporary lights such as those shown in Fig. 1 or permanent lights. As can be seen in Table 1, more solifuges can be collected around permanent lights than around temporary lights. Solifuges are typically found hunting near permanent lights just after sunset. It takes collectors several hours waiting and watching around temporary lights to collect as many solifuges as are found in one hour around permanent lights.

For years, solifuges have been collected from field sites using pitfall traps (Muma 1980; Griffin 1990). A modified pitfall trap array using drift fences was used for solifuges by Xavier & Suesdek Rocha (2001) (Fig. 2). This pitfall trap array traces its origin to the field of herpetology (Gibbons & Semlitsch 1981; Bury & Corn 1987; Corn 1994) and the capture of solifuges as bycatch of herpetological pitfall sampling is evident from collecting label data. This technique has been used successfully by the first author's lab for the past 12 years. The drift fences are 12–13 cm wide plastic landscape fencing; pitfall traps are 13 cm diameter, 9.5 cm deep plastic Tupperware containers one-third to one-half filled with lab-grade propylene glycol. Vink et al. (2005) demonstrated the effectiveness of propylene glycol for molecular tissue preservation. One pitfall trap is placed at the end of each of the three drift fence arms, which are each approximately 10 m long; one pitfall trap is placed in the middle of the array where the three arms converge; and two pitfall traps are placed on either side of the approximate center of each drift fence arm, as close to the fence as possible. This arrangement maximizes capture success of any cursorial arthropod (including solifuges) out hunting in the general



Figures 1–4.—1. Creating a pool of light to attract solifuges in a desert habitat. 2. A 10-cup pitfall trap array using three 10 m long pieces of landscape fencing. One pitfall trap is placed at the intersection of the three drift fence arms; two are placed on either side of the middle of each arm; and one is placed at the end of each of the three drift fence arms. Pitfall traps are one-third to one-half filled with lab-grade propylene glycol. The array can be left in place for up to four weeks, depending on habitat and conditions (i.e. in very hot deserts during the height of the summer, the preservative will evaporate if not re-filled before four weeks). 3. Butterfly Light Trap. Small drift fence segments (plastic landscape fencing) link pairs of small pitfall traps half filled with 96% ethanol. Individual drift fence segments can be placed around individual small pitfall traps set in between the linked traps, creating a discontinuous ring of fencing (these individual drift fence pieces are missing in the photo). This arrangement allows the light from the center suspended lamps to continue attracting approaching arthropods. Pitfall traps should be placed at the outer edge of the pool of light. Inset: Diagram of Butterfly Light Trap. The object in the middle is the light source, the curved structures represent the drift fence segments, black circles represent the pitfall cups. Pitfalls can be filled with 95% ethanol since researchers will check traps the following morning. 4. Caterpillar Light Trap. Small drift fence segments are arranged in a long line with small pitfalls placed in between segments. Pitfalls are half filled with 95% ethanol. Lights are suspended at the ends of the line of fencing and in the middle in order to illuminate the entire line of fencing.

Table 1.—Efficacy of permanent light collecting versus temporary light collecting as documented from field notes recorded between 2005 – 2017.

Method	Total # Locations Between 2005–2017	Mean # Solifuges per hour ± SD	Range (# specimens coll. per hour)
Permanent Lights	41	3.8 ± 3.10	0 – 11
Temporary Lights	65	1.2 ± 1.9	0 – 8

vicinity. Lids of some sort should be suspended over the pitfall traps to keep out rainwater and debris, minimize evaporation, and minimize interference by larger animals investigating the liquid inside the cups. Propylene glycol is harmless to mammals; but some mammals may be attracted to the odor or the sweet taste of this preservative. We suspend wooden lids over our pitfall traps using three nails inserted into three corners of the wooden lid and then extending into small square wooden "feet" that suspend the lids about 2–3 cm above the soil. The diameter of containers utilized as pitfall traps should be wide enough that larger species of solifuges can be captured. We do not recommend the use of small diameter jars, tubes, or other containers for this reason. The lids suspended over the cups should be larger than the diameter of the cup itself to minimize rainwater from entering the cup. The pitfall trap array can be left in place for up to four weeks. It is not recommended to leave the pitfalls in place for longer than that time. In very hot deserts during the middle of the hottest part of the season, the preservative will evaporate if left in place for four weeks and should be checked and replaced well before that time. Pitfall traps are not effective ways to collect live solifuges since solifuges will readily climb out of dry traps and/or will cannibalize one another in the trap before they can be removed. Table 2 presents the success rate of these pitfall arrays used by the first author since 2005.

Recently, during a collecting trip in the Chihuahuan Desert of central Mexico, the authors used a modified light-trapping method for solifuges that utilizes both lights and pitfall traps. Such a combined technique was suggested and illustrated in a letter from R.F. Lawrence to Jack O. Brookhart (DMNS Research Associate) written in 1963. Lawrence suggests suspending a light directly over a pitfall trap (a copy of this letter was provided to PEC). The modified light-trapping design we developed, which we call the "Butterfly Light Trap," consists of a ring of small pitfall traps placed around the pool of light cast by three or four lamps suspended on a cluster of tripods (Fig. 3 and inset). Small flexible segments of drift fence about 1 m in length are bent such that the ends connect adjacent pitfall traps. Gaps are left in between drift fence segments or additional small sections of drift fence can be bent around individual pitfall traps placed in between the linked pairs such that a small piece of drift fence is placed behind the individual pitfalls (Fig. 3 inset). By thus creating breaks in the drift fence encircling the pool of light, a light stimulus can still be seen by a small arthropod approaching the light pool (if the drift fence sections were completely encircling the pool of light, then the light stimulus might disappear in shadow as a small ground-dwelling arthropod approaches). The second modified light trap we call the "Caterpillar Light Trap." The second author noted that since illuminated buildings in desert environments serve as strong attractants to hunting solifuges, we could create an artificial "building" by laying small 1 m segments of drift fence interspersed with pitfall traps and shining lights directly on this small artificial "wall" (Fig. 4). In both modified light trap designs, we used very small pitfalls and filled these with 96% ethanol since the pitfalls would be left in place just for one or two nights. Adding drift fences and pitfall traps to a light stimulus increases the efficacy of the light stimulus in not only attracting solifuges but also capturing them, since otherwise

Table 2.—Efficacy of 10-cup pitfall arrays as documented from field notes recorded between 2005 – 2017. Total number of arrays set between 2005–2017 = 70.

Trap duration and Solifuge Capture Efficiency	Mean ± SD	Range
Trap duration (days)	34.5 ± 14.6 days	2 – 58 days
# Solifuges Captured	11.3 ± 12.0 solifuges	0 – 50 solifuges

collectors must rely on seeing approaching solifuges before the animals run out of the pool of light. We tested the Butterfly Light Trap design on two consecutive nights at field sites in Mexico during the summer of 2017. During the first night, we set up the traps but otherwise did not stay up to monitor them. In the morning, we found 1 solifuge in the pitfall traps and the second night, we collected three solifuges from the traps. This success rate is on par with multiple observers monitoring the pools of light for 4–6 hours during the night. We tested the Caterpillar Light Trap at only one field site in Mexico and found 1 solifuge in a trap the next morning. The lights we used were low-power solar light with two-three hour duration (the only lights we had available during that field expedition). Using stronger lights that have a longer duration would certainly prove more effective. The advantage of these modified Light/Pitfall trap designs is that collectors can set them up but do not have to monitor the lights for many hours in order to capture the low number of solifuges attracted to such temporary light sources (Table 1).

When placing Butterfly Light Traps, Caterpillar Light Traps, or pitfall trap arrays in field sites, multiple traps should be utilized at each site to maximize the potential different habitats or corridors sampled since solifuges are known to be habitat or substrate specific (e.g., Lawrence 1963; Crawford 1988; Griffin 1990; Dean & Griffin 1993). For example, if you are sampling in a dune system, one trap system should be placed on top of the dunes; another between dune ridges to maximize topographic variability existing at a site and, by extension, to increase possible taxonomic diversity sampled. Although solifuges are a challenging group of arachnids to study, we hope that presenting effective methodology in one place for attracting these animals and collecting them may encourage more researchers to explore the biology of this poorly understood taxon.

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