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SHORT COMMUNICATION

Notes on the behavior and the pendulous egg-sacs of *Viridasius* sp. (Araneae: Viridasiidae)

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Abstract. The natural history and biology of the recently erected family Viridasiidae is virtually unknown, although members of *Viridasius* Simon, 1889 are frequently used in cladistical or toxicological studies. Therefore, we report on laboratory observations made of the feeding and mating behavior and describe the egg-sac of a species tentatively assigned to *Viridasius*. The spiders were mostly nocturnal and built a large, silken retreat for molting. Females built pendulum-like egg sacs consisting of a silken, string-like stalk and an oval repository. The egg-sacs were covered actively with substrate by the female. Our observations corroborate the positioning of the Viridasiidae outside of the Ctenidae, because pendulous and camouflaged egg-sacs are not known from any ctenid species to date.

Keywords: Ctenidae, reproduction, silk, trait

The taxon Viridasiinae was introduced as a subfamily of the Ctenidae by Lehtinen (1967) for several species of *Viridasius* Simon, 1889 (but not *Vulsor* Simon, 1889) from Madagascar. This classification was maintained until recently Polotow et al. (2015) revealed that Viridasiinae are probably Dionycha and arose independently from other ctenids. Consequently, the clade comprising the two genera *Viridasius* and *Vulsor* was raised to family status (corroborated by Bayer & Schönhofer (2013) and Henrard & Jocqué (2017)). The occurrence of the family is restricted to Madagascar (Polotow et al. 2015). However, both genera were never formally revised, although (probably undescribed) members of *Viridasius* and *Vulsor* were frequently used in cladistical or toxicological studies (e.g., Silva Dávila 2003; Bayer & Schönhofer 2013; Eggs et al. 2015; Polotow et al. 2015; Oldrati et al. 2017). Although nothing is published about the natural history or biology of *Viridasius*, the genus is bred in captivity by laboratories and pet owners. However, reproduction behavior, natural history and mating experiments can contribute significantly to species separation (Barth & Schmitt 1991; Dahlem et al. 1987; Töpfer-Hofmann et al. 2000) and different traits related to reproduction behavior are often used in cladistical analyses, e.g., egg-sac deposition (e.g., Ramirez 2014; Polotow et al. 2015).

Especially in the Ctenidae and other Lycosoidea, egg-sac treatment and deposition varies. In Amazonian species of the still poorly defined genus *Ctenus* Walckenaer, 1805, spiders were observed carrying their egg-sac in the chelicerae (*Ctenus amphora* Mello-Leitão, 1930, *Ctenus crulsi* Mello-Leitão, 1930, *Ctenus manauara* Höfer, Brescovit & Gasnier, 1994; photos of *C. crulsi* available online at www.wandering-spiders.net), while at least one species, *Ctenus villasboasi* Mello-Leitão, 1949, attaches its egg-sac to the ground surface and guards it (Höfer et al. 1994), similar to *Phoneutria* Perty, 1833 (Hazzi 2014; pers. obs.; photo available online at www.wandering-spiders.net). The recently described *Californctenus cacachilensis* Jiménez, Berrian, Polotow & Palacios-Cardiel, 2017 was observed producing whitish egg-sacs, which were also attached to corners or sides of their terrarium and not carried around (Jiménez et al. 2017). All species of *Ancylometes* Bertkau, 1880 for which breeding behavior is known carry their egg-sac, which is covered by a thick layer of hard and purplish-brown silk, in the chelicerae (Höfer & Brescovit 2000; photo available online at www.wandering-spiders.net), whereas in *Cupiennius salei* (Keyserling, 1877) the white egg sac is attached to the spinnerets of the female, similar to Lycosidae (Barth 2002, own observations). In Dionycha, egg sacs are carried in the chelicerae by members of Sparassidae (Ross et al. 1982; Jäger 2003), but observations on members of other families suggest that most species in some way or the other deposit their eggs, often guarded directly by the female (e.g., Pollard 1983; Jocqué & Dippenaar-Schoeman 2006; Ramirez 2014). However, no such observations were made for the genus *Viridasius*. Therefore, our intention is to describe the form and structure of an egg-sac built by a species of *Viridasius* together with a report on some observations of their behavior in captivity. Additionally, we provide photographs of the genitalia to allow a future identification of our material after a revision of the genus.

Three specimens of a possibly undescribed *Viridasius* species (Figs. 1 & 2) were bought as juveniles from an exotic pet exhibition in July 2016. The specimens were kept in small plastic boxes of 15 x 10 x 15 cm at room temperature until their final molt and then transferred to larger boxes (approximately 20 x 20 x 25 cm) with cork rear panels. The spiders were fed with two or three crickets of adequate size once a week. The substrate used was a mixture of unfertilized potting soil and red sand. The sand covered the bottom of the terrarium to drain humidity; the potting soil formed a continuous layer above. A curved piece of thin bark (200 mm x 50 mm; diameter 4–5 mm) was placed on the bottom of each container as a retreat. Photographs of the genitalia were made with Software Automontage © (Syncroscopy, Cambridge, UK) and a Leica DFC 495 Digital camera, connected to a Leica Z6 APO (Leica Microsystems, Wetzlar, Germany). Specimens are deposited in the collection of the Staatliche Museum für Naturkunde, Karlsruhe (collection number SMNK-ARA 14750).

During the day, all three specimens could be found under the curved piece of bark and became mostly active in the night. After its final molt, the male started to wander around in the daytime as well. Subadult and adult specimens often disregarded prey which was transferred to their box in the daytime and hunted only during the dawn or night, while younger stages voraciously went after prey as soon as it was introduced into their boxes. Before molting the first time in our care, the spiders produced a large silken retreat, consisting of a very strong and tear-resistant silk, under the piece of bark. The retreat was large enough to contain the spider including the legs and was often incrusted with substrate. It was also used for hiding at daytime and was consequently expanded for following molts. When we destroyed the silken retreat, a new one was only built for molting. Two specimens (one male, one female) reached adulthood in November/December 2016, the second female finally molted in late January 2017 and reached a considerably larger body size of about 25 mm compared to about 20 mm of the other female. The male was transferred to the box of the smaller female on 24 January 2017 at around 3 pm. The male approached the female very slowly, under constant tapping and moving of his forelegs. The female showed no

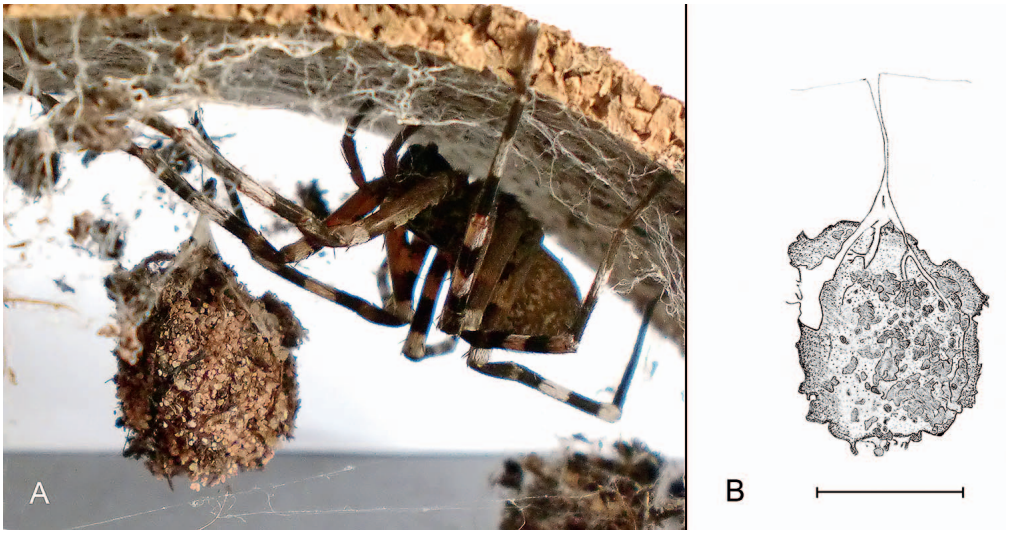

Figure 1.—*Viridasius* sp., Egg-sac camouflaged with sand and earth. A. Female with egg-sac, B. Drawing (scale line = 10 mm).

sign of aggression, but moved towards the male and started to lift the forelegs alternately, while getting repeatedly tapped on the body and legs by the male. After about two minutes, the male suddenly moved over the body of the female. The mating position and procedure corresponded well to descriptions by Foelix (2011, Fig. 7.27C) and Stratton et al. (1996). The entire mating took place at the rear panel of cork installed in the terrarium. The female showed no sign of aggression during and shortly after the copulation and remained passive throughout the whole procedure, which typically resulted in a nearly horizontal positioning of its body due to the copulation activities of the male, while some of its legs were still attached to the rear panel (see video S1, available online at http://dx.doi.org/10.1636/JoA-S-17-058.S1). The male showed pronounced epigynal scratching before and between insertions. At least once, it seems like the male performed multiple insertions with one palp. Insertions lasted for about 20–30 seconds. The entire mating process, including the approach and the courtship behavior, took place in about 30 minutes. Afterwards, the male was chased away by the female and removed by us from the terrarium. The male lived for several more weeks and died on 17 April 2017. In the following months after the mating the female produced three egg-sacs, two of which contained eggs. All three egg-sacs were attached to the underside of the curved piece of bark in the silken retreat (first and second) or the upper glass panel of the terrarium. The egg-sacs consisted of a silken, string-like stalk of about 15 mm length and an egg-shaped repository of 15–18 mm length and 12–14 mm width (Fig. 1). All egg sacs, including the third one without eggs, were actively camouflaged by the female with substrate, such that nearly no silk (except for the silken stalk) was visible when we found the egg-sacs. Because the red sand (visible on the egg-sac in Fig. 1A) was covered by a thin layer of potting-earth, the female had to move considerable amounts of substrate. The silk of the egg-sac was strong and was not torn apart easily, but was easily penetrable with a needle and not stiff or paper-like, but flexible. From both egg sacs 30–35 spiderlings emerged, approximately 4–5 weeks after deposition. After emergence, no unfertilized eggs were found. Because the egg-sacs were removed and opened by us to prevent cannibalistic feedings on the eggs or the spiderlings by their mother, we are not able to report on the release mechanism. Some cannibalism was observed soon after the dispersal of the spiderlings, so the original number was possibly somewhat higher. However, most of the time until separation, the spiderlings behaved peacefully. The female died on 29 June 2017. The unmated female was still alive during the preparation of the manuscript.

With respect to recent phylogenetic results (Polotow et al. 2015; Henrard & Jocqué 2017), it is not entirely surprising that females of *Viridasius* construct egg-sacs which would be very atypical for a ctenid spider. The construction of a pendulous and well camouflaged egg-sac was, to the best of our knowledge, never reported for a species of Ctenidae, particularly African genera (e.g., Henrard & Jocqué 2017, see also introduction) and could be a special attribute of the Family Viridasiidae. However, similar pendulous egg-sacs are built by *Tamopsis* Baehr & Baehr, 1987 (Hersiliidae) (Baehr & Baehr 1987), *Agroeca* Westring, 1861 (Liocranidae), the pirate spiders of the genus *Ero* C.L. Koch, 1836 (Mimetidae), *Theridiosoma gemmosum* (L. Koch, 1877) (Theridiosomatidae) and the cave-dwelling genus *Meta* C.L. Koch, 1836 (Tetragnathidae) (Roberts 1995). Nielsen (1932) reported on intraspecific variation of egg-sac deposition in an agelenid species, which builds pendulous as well as attached egg sacs, showing that this trait should be used with care in phylogenetic analyses, especially in agelenid species or related families. We could not observe any significant variations in the architecture of the egg-sacs built by *Viridasius* sp., and even the third egg-sac, which contained no eggs, was pendulous and covered with earth and sand. To our knowledge, differing egg-sacs within one species were also never observed in other free-hunting spiders. However, because our observations were made on a single female, we cannot exclude the possibility that egg-sac variations occur within the natural population of this species or under different ecological parameters.

The female was often found nearby the first two egg-sacs (Figs. 1 & 2), but was easily chased away by us. Because both were built in their retreat, the position of the female near the egg-sacs could be an artefact of captivity, and we suppose females may abandon their well-camouflaged egg-sacs in nature. We can only speculate about the function of the pendulum-like form. Egg-sacs are a barrier for egg-predators and parasitoids and costly for the spider (Austin 1985). It is feasible that a hanging, camouflaged egg-sac is harder to locate for both types of antagonists, not only visually, but on a tactile level as well. However, the pendulous egg-sacs of *Ero* are frequently parasitized by different parasitoids, as are egg-sacs of *Agroeca* (Finch 2005), so the intense camouflaging could be a result of an evolutionary arms race between *Viridasius* and different parasitoids, possibly not only masking the egg-sac, but also serving as a sort of protection. We are not able to say if the constant incrustations with substrate observed on the surface of the retreats serve as camouflage or were an artefact of captivity; nevertheless, in some cases, the covering was dense and showed similarities to the camouflage of the

Figure 2.—*Viridasius* sp.: A. Living male; B. Living female; C. Epigyne; D. Male pedipalpus (retrolateral, ventral); Scale lines = 1 mm.

egg-sac. It is also possible that our observations on the egg numbers are biased by the small size of the mated female, and that larger females are able to produce more eggs per clutch, as observed by Eberhard (1979) or Skow & Jacob (2003).

We hope that our observations facilitate the description of egg-sacs in other genera, especially other Viridasiidae, and a revision of *Viridasius,* since Madagascar is traditionally affected by heavy deforestation and good taxonomical knowledge is urgently needed to provide conservation managements for these stunning and fascinating spiders. We are very thankful to Rainer Breitling (Manchester, United Kingdom) for help with literature and to two anonymous reviewers and the editor Thomas C. Jones for their constructive and helpful comments which greatly improved the article.

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