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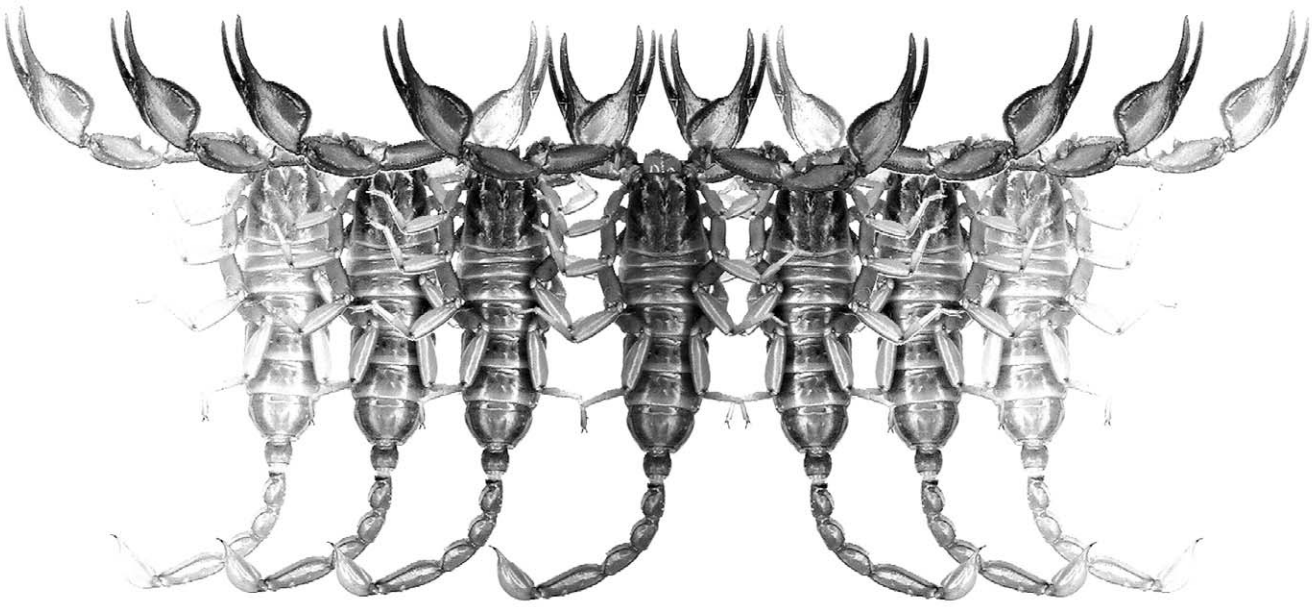

Serradigitus miscionei, the First Vaejovid Scorpion to Exhibit Parthenogenesis

Richard F. Ayrey

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Summary

Thelytokous parthenogenesis (all-female broods) is strongly suggested for the vaejovid species *Serradigitus miscionei* (Vaejovidae) from southern Arizona, USA. This conclusion is based on the examination of 187 specimens and 15 broods, all determined as females.

Introduction

When *Serradigitus miscionei* Ayrey, 2011 was described, it was noted that of the 22 adult specimens examined none were males (Ayrey, 2011). Including the type series, the author has now examined 187 specimens and all have been found to be females. Fifteen broods have been examined and all the 2nd instars were found to be females. The only logical explanation for this is that the species reproduces by thelytokous parthenogenesis. Parthenogenesis has been known to occur in 11 species of scorpions (Lourenco, 2008), but this is the first report of parthenogenesis in the family Vaejovidae. It is also the first report of parthenogenesis from North America.

Material Examined

Serradigitus miscionei Ayrey, 2011 [187 specimens] Walnut Gulch, Cochise County, Arizona, USA, 8 March 2009, 8 ♀, leg. R. Troup, (RA164, CAS; 166, RFA; 167, FK; 168, CAS; 169, 170, RFA; 171, CAS; 172,); same locality, 25 April 2009, 11 ♀, leg. T. Miscione (RA 165, RA 173, CAS; RA 174, RA 175, RA 176, RA 177, RA 178, RFA; RA 179, CAS; RA 180, RFA; RA 277, MS; RA 278, CAS); same locality, 11 August 2009, 3 ♀, 2nd instars of RA 169; same locality, 08 September 2009, 9 ♀, 2nd instars of RA 166; same locality, 09 September 2009, 11 ♀, 2nd instars of RA 167; same locality, 11 September 2009, 13 ♀, 2nd instars of RA 170; same locality, 26 September 2010, 1 ♀, leg. R. F. Ayrey (RA 297, RFA); same locality, 12 July 2014, 4 ♀, leg. R. Troup, (RA1005, RA1006, RA1007, RA1008, RFA); same locality, 12 August 2014, 15 ♀, 2nd instars of RA 1005; same locality, 15 August 2014, 12 ♀, 2nd instars of RA 1006; same locality, 10 August 2015, 12 ♀, 2nd instars of RA 1006; same locality, 15 October 2016, 3 ♀, 2nd instars of RA 1006; same locality, 1 September 2014, 1 ♀, 2nd instar of RA1007; same locality, 11 August 2015, 13 ♀, 2nd instars of RA1007; same locality, 17 August 2014, 13 ♀, 2nd instars of RA1008; same locality, 21 September 2016, 12 ♀, 2nd instars of RA1008. Near Colossal Cave, Pima County, Arizona, USA, 25 April 2009, 4 ♀, leg. R. F. Ayrey, (RA 182, CAS; RA 183, 184, 185, RFA). Near Sahuarita, Pima County, Arizona, USA, 18 June 2009, 3 ♀, leg. R. F. Ayrey, (RA 298, 299, 300); same locality, 3 October 2010, 2 ♀, leg. R. F. Ayrey, (RA 301, 302, RFA); same locality, 7 March 2011, 2 ♀, leg. R. F. Ayrey, (RA 432, MS; 433, RFA); same locality, 12 May 2013, 2 ♀, leg. R. F. Ayrey, (RA 785, 996); same locality, 8 August 2013, 12 ♀, 2nd instars of (RA 785), same locality, 6 August 2013, 14 ♀, 2nd instars of RA 996, same locality, 2 August 2014, 7 ♀, 2nd instars of RA 996.

Gender Identification

Gender identification of vaejovids based on external morphology usually involves examining the genital operculum. In males, the two sclerites are separated for most of their length, whereas in the female they are fused together for at least half their length. In genus *Serradigitus*, a member of subfamily Syntropinae, these sclerites are fused for their entire length (which is diagnostic of the subfamily). Also, in the male, genital papillae are present under the genital operculum, usually visible extending below the posterior edge of sclerites. These papillae are absent in the female. Of particular importance for members of tribe Stahnkeini, the basal teeth of the pecten in females are modified in their shape, sometimes their size, and always lack a sensorial area (one to three teeth depending on the species). This condition is diagnostic for tribe Stahnkeini, thus also found in genera *Stahnkeus*, *Wernerius*, and *Gertschius*.

Figure 1: *Serradigitus miscionei*, on a vertical sand flake in Walnut Gulch, Arizona (holotype locality; from Ayrey, 2011).

See Soleglad & Fet (2008) and Soleglad & Fet (2006: 14–19; figs. 12–32) for illustrations and a detailed discussion of the pectines of this tribe.

For *Serradigitus miscionei* discussed in this paper, the number of pectinal teeth and the lack of a sensorial area on the basal teeth (1 or 2) were used to determine that early instar specimens were indeed females. Ayrey (2011: 6) reports "…Pectinal tooth counts for adult females are, 13/13 (19), 14/13 (2) and 14/14 (1) with an average of 13.09 (44). …". The early instars examined in this paper exhibited a pectinal tooth count range of 12–13, clearly within the range reported by Ayrey (2011). Also, the basal tooth was reduced in size and lacked a sensorial area. See Figure 2 for illustrations of the sternopectinal area and single pectens for both early instars and adult specimens of *S. miscionei*.

Discussion

In the description of *Serradigitus miscionei* Ayrey, 2011 the author noted that of the 22 specimens collected, all were females. As more specimens were found and examined, it began to seem odd that no males were found. By the time the number of specimens examined reached 50, it seemed like there was something going on besides sampling error. At this writing, the author has examined 187 specimens, and all were females. The overwhelming numbers of females strongly suggests that this species reproduces by parthenogenesis.

With the birth of the most recent clutch of 3 first instars (15 October 2016) the author has decided that there is a definite possibility that *Serradigitus miscionei* is an all-female species of scorpions. Examination of 15 all-female captive broods, from wild-caught females, using the morphological criteria described above, revealed that all offspring scorpions were indeed females. This provides a strong evidence that this species reproduces by thelytokous parthenogenesus, i.e. has all-female broods.

Parthenogenesis in scorpions has been known since 1962 (Matthiesen, 1962). With one exception, all parthenogenetic species have been from the family Buthidae. The notable exception is *Liocheles australasiae* (Fabricius, 1775) (Hemiscorpiidae). Thelytokous parthenogenesis has been found in ten of the eleven known parthenogenetic species (Lourenço, 2008).

The author has raised several generations of parthenogenetic buthid scorpions (genus *Tityus*) that were kept individually from second instars. *Tityus serrulatus* Lutz et Mello, 1922 has been raised for three generations

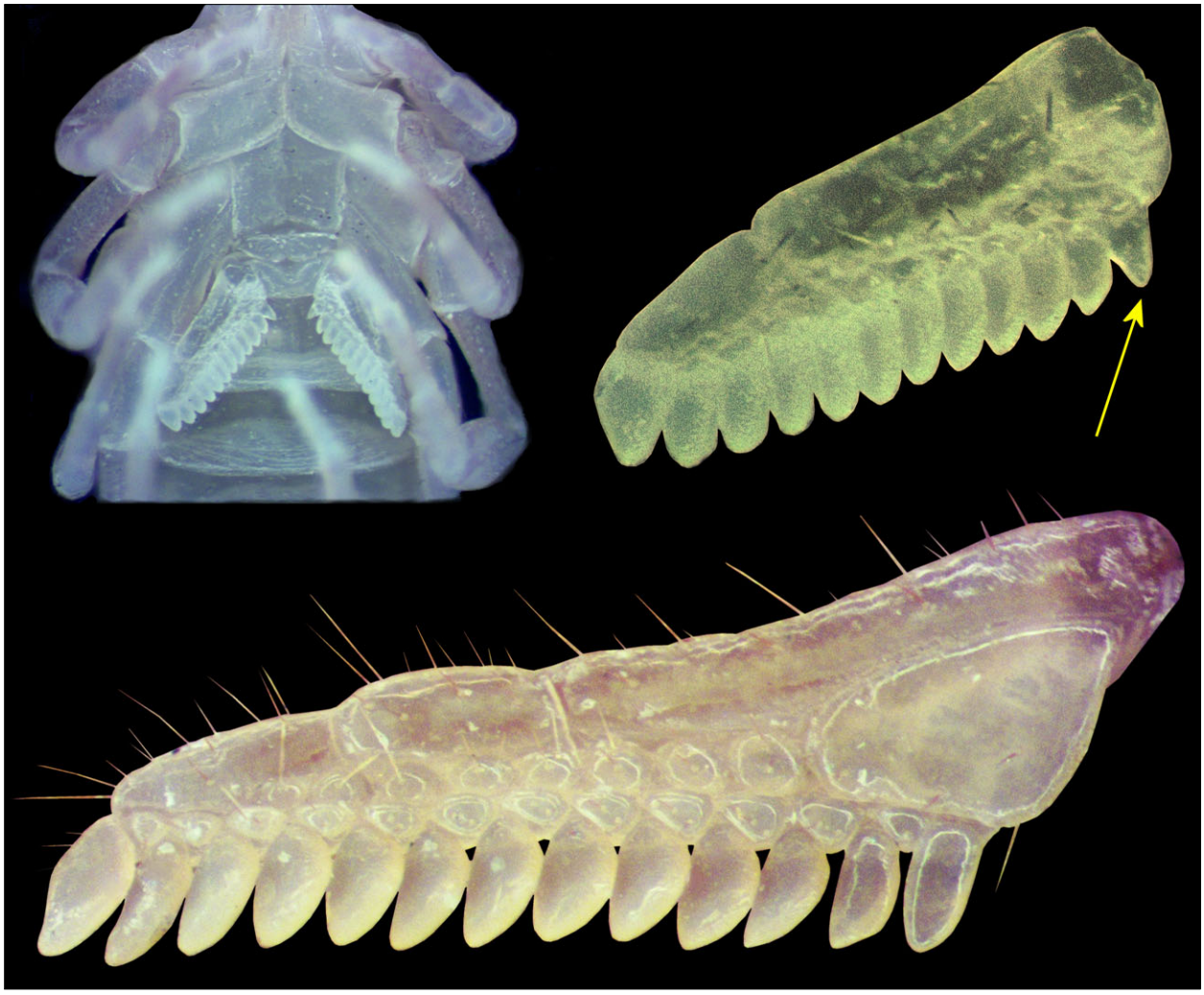

Figure 2: *Serradigitus miscionei*. **Top.** 1st instar juvenile female showing the sternopectinal area. Note, this female has 12 pectinal teeth on each pecten and both pecten's basal tooth is reduced in size and lacks a sensorial area (indicated by arrow). **Bottom.** Pecten of an adult female with 13 teeth.

(Figure 7) and *Tityus stigmurus* (Thorell, 1876) (Figure 8), for four generations.

Unfortunately, the small size of *S. miscionei* second instars (full adult size is approximately 25 mm) has made it difficult to successfully raise them to maturity in order to obtain the second generation (and with it, the direct proof of parthenogenesis). Several attempts have been made and additional attempts are planned.

It should be noted that parthenogenesis in scorpions could possibly be caused by intracellular endosymbiotic bacteria *Wolbachia* known to cause feminization in arthropods (Ferdy et al., 2016). *Wolbachia* in scorpions were first found in parthenogenetic species *Tityus serrulatus* (Buthidae) (Suesdek-Rocha et al., 2006), but then also in non-parthenogenetic Scorpionidae and Hemiscorpiidae. However, a recent study by Bryson (2014) detected no *Wolbachia* in any of the 40 studied species of Vaejovidae, which included *Serradigitus miscionei*.

Reproduction

The broods shown in Figures 3–5 exhibit the same non-random behavior as described for the *"vorhiesi"* group of the genus *Vaejovis* in Ayrey (2013). Examination of Figures 5–6 shows some variability with the 1st instars distributed randomly on the mothers back. This appears to be accounted for by the very small number of 1st instar offspring. It appears that when there is no pressure from additional siblings to fit on the mothers back, then the drive to line up in the classic formation is not there. The 1st instars in Figure 6 stayed in those positions until they molted into 2nd instars.

Figures 3–4: *Serradigitus miscionei* with 1st instar juveniles. **3.** From Walnut Gulch, Arizona. **4.** From Sahuarita, Arizona.

Figures 5–6: *Serradigitus miscionei* with 1st instar juveniles. **5.** From Sahuarita, Arizona. **6.** From Walnut Gulch, Arizona.

Figures 7–9: 7. *Serradigitus miscionei* from Walnut Gulch, Arizona with 1st instar juveniles. **8.** *Tityus serrulatus* with 1st instar juveniles. **9.** *Tityus stigmurus* with 1st instar juveniles.

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