Boletín Sociedad Entomológica Aragonesa, nº **45** (2009) : 531−532. **NOTAS BREVES**

First report of random larval orientation in the genus *Vaejovis* C. L. Koch, 1836 (Scorpiones: Vaejovidae)

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Abstract: To date, female members of the North American scorpion genus *Vaejovis* C. L. Koch, 1836 have been reported to transport first-instar and pre-dispersal second-instars on their dorsa, with the young arranged in a longitudinal pattern of larval orientation. The current contribution reports the first observations of random larval orientation in the vaejovid scorpion *Vaejovis confusus* Stahnke, 1940, and synthesizes the known and previously unreported dorsal orientation patterns in members of the family Vaejovidae.
Key words: Scorpiones, Vaejovidae, *Vaejovis confusus*, larval orientation, dorsal transportation stage.

Primera observación de orientación larvaria aleatoria en el género *Vaejovis* C. L. Koch, 1836 (Scorpiones: Vaejovidae)

Resumen: Hasta el momento se había constatado que las hembras del género norteamericano de escorpiones *Vaejovis* C. L. Koch, 1836 transportan las crías del primer estadio y las del segundo estadio, antes de la dispersión, sobre el dorso, con las crías dispuestas según un patrón longitudinal de orientación larvaria. La presente aportación recoge las primeras observaciones de orientación larvaria aleatoria en el escorpión vaejóvido *Vaejovis confusus* Stahnke, 1940, y resume los patrones de orientación, conocidos y aún inéditos, en miembros de la familia Vaejovidae.
Palabras clave: Scorpiones, Vaejovidae, *Vaejovis confusus*, orientación larvaria, fase de transporte dorsal.

After giving birth, female scorpions transport their first-instar young on their dorsum (dorsal transportation stage) and continue to do so for a varying number of days after the young scorpions undergo their first molt to second-instar, after which the vagile second-instar young disperse from the maternal female and become free-living (Williams, 1969; Polis & Sissom, 1990; Lourenço, 2002). Maternal females carry their larvae in one of three patterns of orientation: random, transverse, or longitudinal (For a review see Savary, 1996). Random orientation in which offspring are stacked in multiple layers and exhibit a lack of group orientation occurs in 14 of the 18 extant scorpion families and is considered the basal pattern of orientation in scorpions (systematic classification follows Prendini & Wheeler, 2005; Levy, 2007; Volschenk *et al*., 2008). Transverse orientation in which the offspring are stacked in multiple layers and aligned at right angles to the midline of the maternal female, facing medially and leaving a distinct narrow gap along the female's midline has only been reported to occur in the diplocentrid scorpion *Diplocentrus whitei* (Gervais, 1844) (Francke, 1982). Longitudinal orientation in which the offspring are arranged in a single layer and aligned parallel to the midline of the maternal female, facing anteriorly with the frontal region of the prosoma in constant contact with the integument of the female appears to be limited to several taxa within the family Vaejovidae Thorell, 1876 (Williams, 1969; Savary, 1996). Larval orientation patterns for members of the family Vaejovidae are listed in Table I.

Five gravid females of *Vaejovis confusus* Stahnke, 1940 (Vaejovidae) were collected from excavated depressions under rocks in Yuma County, Arizona and sent to the author during the second week of August, 2006. An additional gravid female collected in northern Yuma County, Arizona was acquired by the author during the last week of May 2007. All females were housed in well ventilated 20 x 20 x 20 cm (15 L) glass enclosures with a dry 7.5 cm layer of sand for substrate and a large fragment of terracotta plant pot to provide shelter. Temperatures were maintained in the range of 26.6°C to 29°C during the day and 23.8°C to 25.5°C during the night. Common house crickets (Gryllidae: *Acheta domesticus* Linnaeus, 1758) were provided to each female every 10 days. All females were provided with drinking water by lightly misting a wall of each enclosure at or near substrate level during each feeding.

Females were checked during the morning and evening of each day for pre-parturition behaviors (*e.g.* stilting, birth basket formation) and births. Diurnal observations were conducted under natural lighting and nocturnal observations under a single low-intensity 60 watt red incandescent bulb (Machan, 1968) mounted in a 20 cm metal parabolic dome. All pre-parturition, parturition and post-parturition behaviors were recorded.

Random orientation of the first-instar young of *V. confusus* was observed in six laboratory maintained females between the periods of August 2006 to June 2007. The five gravid females acquired in August 2006 gave birth in August (n = 1), September (n = 1), October (n = 2) and November (n = 1) 2006. The five litters (n = 17, 34, 46, 60, 66) were observed from birth to dispersal in order to assess various behaviors, including orientation patterns, in the first- and second-instar offspring. The female acquired in May 2007 gave birth to a litter of 50 young on 04 June 2007. Additionally, multiple photographs of a captive female specimen of *V. confusus* with randomly oriented first-instar young were sent to the author by D. Dubose and K. Wilcoxen.

The apoikogenic young of *V. confusus* escaped the birth membrane and rested within the birth basket formed by the anterior pairs of walking legs of maternal females for a short period of time (<18-minutes), before ascending up the legs to the dorsum of the female. They remained there for a period of 8–12 days before molting to the second-instar and dispersing within 3–5 days. During the first-instar stage, offspring aggregated one to three layers deep in a random pattern of orientation upon the carapace, tergites, pleural membranes and metasomal segments I and II of maternal females. Unlike the first-instar young of the majority of other species of the genus *Vaejovis* C. L. Koch, 1836 (*e.g. Vaejovis bilineatus* Pocock, 1898) that exhibit longitudinal larval orientation, the active young of *V. confusus* did not remain in a stable position and only made occasional contact with the integument of the mother. Furthermore, first-instar specimens were observed to periodically descend from the dorsum of maternal females to the substrate. Specimens remained on the substrate for 8–22 minutes before re-ascending to the mother's dorsum. During this period, all observed offspring moved over the substrate and remained within 40 mm of their mothers.

Based on direct laboratory observations by the author and additional photographic depiction, it is hereby concluded that unlike the first-instar young of other *Vaejovis* species, the first-instar young of *Vaejovis confusus* exhibit the putatively plesiomorphic pattern of random larval orientation that occurs in 14 of the 18 extant scorpion families. The possible phylogenetic and adaptive significance of larval orientation patterns and dorsal transportation of young scorpions by females was reviewed by Savary (1996). In that presentation, both the transverse and longitudinal patterns of larval orientation were hypothesized to be apomorphic characters, with the longitudinal pattern of orientation restricted to and hence potentially apomorphic within the family Vaejovidae. Until a rigorous analysis of phylogenetic relationships within Vaejovidae is conducted, the phylogeny and evolution of larval orientation patterns will remain untested.

Table I. Larval orientation patterns in the family Vaejovidae Thorell, 1876 (Organized after Savary 1996).

TAXON	ORIENTATION	SOURCE
Paruroctonus becki (Gertsch & Allred, 1965)	Random	Pers. obs.
Paruroctonus boreus (Girard, 1854)	Random	Pers. obs. (Contrary to Tourtlotte, 1974)
Paruroctonus silvestrii (Borelli, 1909)	Random	Haradon 1972
Paruroctonus utahensis (Williams, 1968)	Random	Pers. obs.
Paruroctonus variabilis Hjelle, 1982	Random	Pers. obs.
Pseudouroctonus apacheanus (Gertsch & Soleglad, 1972)	Longitudinal	C. A. Brown, pers. com.
Pseudouroctonus iviei (Gertsch & Soleglad, 1972)	Longitudinal	Savary 1996
Pseudouroctonus minimus thompsoni (Gertsch & Soleglad, 1972)	Longitudinal	Savary 1996
Pseudouroctonus reddelli (Gertsch & Soleglad, 1972)	Longitudinal	Brown 1997
Serradigitus allredi Sissom & Stockwell, 1991	Longitudinal	Wm. Savary, pers. com
Serradigitus gertschi (Williams, 1968)	Longitudinal	Haradon 1972
Serradigitus wupatkiensis (Stahnke, 1940)	Longitudinal	Savary 1996
Smeringurus mesaensis (Stahnke, 1957)	Random	Pers. obs.
Syntropis macrura Kraepelin, 1900	Longitudinal	Hjelle 1974
Uroctonus mordax Thorell, 1876	Random	Haradon 1972; Francke 1976
Vaejovis bilineatus Pocock, 1898	Longitudinal	Sissom & Francke 1983
Vaejovis carolinianus (Beauvois, 1805)	Longitudinal	Taylor 1970
Vaejovis cashi Graham, 2007	Longitudinal	C. A. Brown, pers. com
Vaejovis coahuilae Williams, 1968	Longitudinal	Francke & Sissom 1984
Vaejovis confusus Stahnke, 1940	Random	Pers. obs.
Vaejovis intrepidus Thorell, 1876	Longitudinal	Pers. obs.
Vaejovis jonesi Stahnke, 1940	Longitudinal	Pers. obs.
Vaejovis punctatus variegatus Pocock, 1898	Longitudinal	Kovařik 2005
Vaejovis puritanus Gertsch, 1958	Longitudinal	Pers. obs.
Vaejovis spinigerus (Wood, 1863)	Longitudinal	Williams 1969
Vaejovis vorhiesi Stahnke, 1940	Longitudinal	Williams 1969
Vaejovis waueri Gertsch & Soleglad, 1972	Longitudinal	Sissom & Francke 1983

Acknowledgments
I want to thank Oscar F. Francke, Kari J. McWest, Warren E. Savary, Lorenzo Prendini, W. David Sissom, and an anonymous reviewer for critical reading of the manuscript and for their valuable comments and suggestions on its contents. Additional thanks are extended to Jillian Cowles and William Savary for providing unpublished photographs of Arizona scorpion species transporting first-instar young and Dawn Dubose and Kaylin Wilcoxen for additional photos of *Vaejovis confusus*, and a very special thanks to my wonderful wife Beth for her support, encouragement, and assistance in all things computer-related.

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