

BIRTH BEHAVIOR IN *DIPLOCENTRUS BIGBENDENSIS* STAHNKE (SCORPIONES, DIPLOCENTRIDAE)

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ABSTRACT

Four female *D. bigbendensis* gave birth in the laboratory. One parturition was normal and some of the young were reared to maturity, whereas the other three parturitions were abnormal and resulted in significant cannibalism of the newborn by their mothers. In the normal parturition 37 young were born during about 30 hours. The young emerged tail-first and upside-down, and were free of any "birth membranes." It is hypothesized that the tail-first emergence of the young is directly related to the katoikogenic type of embryonic development (in embryonic diverticula) that these scorpions undergo. The average birth lasted 6.9 ± 4.0 minutes, and the average interval between consecutive births was 44.4 ± 30.8 minutes. The relatively large standard deviation is due to the emergence of the young mostly in pairs separated by considerably longer intervals between pairs. It is hypothesized that the paired births are related to the bilateral symmetry of the female reproductive system.

INTRODUCTION

The reproductive biology of diplocentrid scorpions is poorly known. Certain aspects of the behavior of *Nebo hierichonticus* (Simon) (Nebinae), such as mating and parturition, were studied in Israel by Shulov et al. (1960) and by Rosin and Shulov (1963). The New World is inhabited by six genera of diplocentrids, all belonging to the subfamily Diplocentrinae. Williams (1969) observed parturition by *Diplocentrus whitei* (Gervais), but gave no specifics in his report. Thus, the only published observations on the reproductive biology of diplocentrine scorpions are those I made on *Diplocentrus spitzeri* Stahnke from Arizona (Francke 1981). My objectives here are to describe and analyze the birth behavior of *Diplocentrus bigbendensis* Stahnke from Texas.

MATERIALS AND METHODS

A sample of 27 *D. bigbendensis*, including seven adult females, were collected on 17 June 1974 in Big Bend National Park, Brewster Co., Texas. The specimens were placed individually in 11.5 X 10.5 X 7 cm plastic containers with a moist piece of paper towel on the bottom, and transported to Tempe, Arizona. There a 2-3 cm layer of soil was added to the containers, which were then kept in darkness at room temperature (approx. 25° C). The scorpions were offered live crickets and water once a week.

On 10 September 1974 one female was in the process of giving birth, and a second one had assumed a similar "parturition" posture. Following the initial disturbance with

"white" light a change was made to red light to minimize further disturbance. Four parturitions occurred in the laboratory, three in September and one in November 1974. One parturition (Female E) was observed without interruptions from start to finish and is considered to have been normal because (a) no apparent complications were detected, and (b) the young have been successfully reared to maturity (Francke, in preparation). Partial observations were made on the other three parturitions (Females A, B, and D), which are considered abnormal because in each case the mother attempted to cannibalize the young and prevented them from climbing upon her back. The normal parturition is described first, followed by remarks and comparisons with the three abnormal parturitions.

FEMALE E

Pre-partum behavior.—Sporadic observations from 10-17 September 1974 showed that this female was the most active, engaging in digging behavior frequently. Since this behavior has not been previously described for any diplocentrid scorpion, a summary follows.

Digging behavior consisted of two phases: digging with the legs and tail-scraping. Digging with the legs usually started with the front two legs on one side, flexed under the body, loosening soil with the ventral spines of tarsomere II and shoving it posterolaterally. As soil accumulated along the side of the mesosoma the third and fourth legs on that side were brought into action, kicking the soil backwards by forceful extension of the joints. Often the actions of the two ipsilateral pairs of legs were recurrently alternated so that a stroke of soil-loosening and shoving by legs I and II was immediately followed by a stroke of soil-kicking by legs III and IV. After one bout of 20-25 cycles a moderate pile of soil accumulated to one side of the female at the level of the basal segment of the metasoma. The female would cease digging, move forward slightly, and engage in tail-scraping. This phase started with the metasoma moderately curled and lying sideways on the side of the soil pile. The metasoma would then be lifted off the substrate, moved sideways beyond the pile of soil, returned to the substrate, and slightly extended while being returned to an axial position in a swiping motion. With each swipe the top layer of the soil pile was removed and shoved backwards and medially. Eight to ten swipes were required to level the soil, at which time the female resumed digging with the legs on the contralateral side.

Parturition.—On 18 September 1974 at 0931 hrs. female E assumed the parturition posture with her metasoma backed against a corner of the container. The prosoma was lifted off the substrate with the carapace forming an angle of approximately 30° to the substrate. The mesosoma was moderately arched, with sternites IV and V resting on the substrate. The metasoma was strongly flexed dorsomedially. The pedipalps were moderately flexed and the chelae were parallel to the body axis with the fingers wide open. The first pair of legs were strongly flexed under the prosoma, crossing each other medially and forming the birth basket. The second pair of legs were slightly flexed with the tarsi resting on the substrate submedially, and during the initial births did not form a functional part of the birth basket.

The female proceeded to give birth to 37 young during the following 27 hours. Table 1 is a chronological summary of the events and behaviors recorded during this parturition.

The posture of the female during the first few births was as described above, and only one change was noticed during the births of the young. Between births the female's

Table 1.—Chronology of parturition by *Diplocentrus bigbendensis* Stahnke, female E and behavior of the young. Times are reported using the 24-hour system. r = female's right side, l = female's left side.

ORDER	BIRTH			ASCENT TO FEMALE			
	DATE (Sept.)	TIME APPEAR	TIME DROP	RANK	DATE (Sept.)	TIME UP	SIDE UP
1	18	0937	0939	7	18	1615	r
2	18	0947	0951	2	18	1323	r
3	18	1012	1019	1	18	1230	r
4	18	1024	1026	31	19	1046	l
5	18	1029	1045	4	18	1426	r
6	18	1114	1127	3	18	1410	r
7	18	1209	1212	11	18	2007	l
8	18	1237	1245	5	18	1510	r
9	18	1259	1311	9	18	1800	l
10	18	1408	1412	17	19	0004	l
11	18	1452	1500	6	18	1605	r
12	18	1507	1516	8	18	1741	r
13	18	1547	1554	13	18	2015	l
14	18	1650	1655	18	19	0004	r
15	18	1709	1720	20	19	0035	r
16	18	1800	1809	10	18	1922	l
17	18	1819	1825	12	18	2010	r
18	18	1915	1918	22	19	0147	r
19	18	1925	1943	14	18	2156	l
20	18	2041	2043	15	18	2218	l
21	18	2046	2049	16	18	2305	r
22	18	2115	2122	23	19	0227	l
23	18	2224	2228	19	19	0035	r
24	18	2230	2233	24	19	0330	l
25	18	2321	2329	21	19	0046	l
26	19	0004	0008	37	19	1639	l
27	19	0026	0030	25	19	0437	r
28	19	0231	0236	36	19	1446	r
29	19	0317	0322	26	19	0520	r
30	19	0335	0343	32	19	1217	l
31	19	0426	0435	27	19	0600	l
32	19	0520	0522	29	19	0948	l
33	19	0642	0653	28	19	0835	r
34	19	0750	0758	34	19	1412	l
35	19	0844	0850	30	19	1016	r
36	19	1002	1013	33	19	1217	r
37	19	1215	1222	35	19	1446	r

pectines were held at an angle of about 15° to the body axis (or about 45° from the substrate). During births the pectines were extended, assuming a position perpendicular to the substrate. Thus, it was possible to anticipate the emergence of each young by the female's behavior.

At 1055 hrs., after five young had been born, the female's second pair of legs was recruited to form an intergral part of the birth basket. Shortly before the seventh birth, the female engaged in a short bout of pedipalp movement. The right and left pedipalps were alternately shifted back-and-forth. The pedipalp chelae were then moved from a

subparallel to a transverse position with respect to the body axis, and the fixed fingers almost touched along the midline in front of the carapace. A few minutes before the eighth and ninth births, respectively, the female briefly raised the pedipalps off the substrate while simultaneously "pushing" with the metasoma against the corner of the container. After the ninth birth the female assumed a more relaxed position: the body was not as strongly angled with the substrate, the pedipalp chelae were held convergently at about 45° to the body axis and the fingers were closed.

The parturition position, with pedipalp chelae transversely across the midline and the right and left fixed fingers almost touching, was resumed three minutes before the tenth birth. The tenth through twelfth births were preceded by pedipalpal and metasomal movements as described above; and three minutes after the twelfth birth the female reverted to a relaxed posture.

At 1536 hrs. stronger pedipalpal flexions occurred and the female resumed the parturition position. The mother showed a noticeable change in behavior as the thirteenth young emerged: the prosoma was suddenly and strongly arched backwards, and the pedipalps were extended and stretched up-and-back quite forcefully ("throwback" behavior). The female relaxed after the young emerged, and shortly before each of the following six births she resumed the parturition position after some pedipalpal and metasomal motion.

The movements by the female increased in frequency and intensity from the twentieth birth on. Prior to resuming the parturition posture the female would strongly arch backwards, raising the prosoma off the substrate. The pedipalps would be partially extended and raised off the substrate, and the female would then alternately twist the anterior half of the body first to one side of the midline and then to the other while stretching the pedipalps up-and-back in 3-5 consecutive cycles. The vigorousness of the female's motions, their timing with respect to the births, and their increase in intensity and frequency with progressively later births suggest that they may serve to stimulate and facilitate the passage of the young out of their respective ovariteral diverticula and forward along the ovariterus to the genital opening. The female also assumed a relaxed posture between births from about the twentieth birth on. The relaxed posture was characterized by having the pedipalp chelae fingers $\frac{1}{4}$ open, the chelae divergent from each other, the prosoma lowered, and the telson positioned over tergites III-IV. The parturition posture was usually assumed a few minutes before each birth: the pedipalp chelae fingers were wide open, the chelae were convergent to each other, the prosoma was raised (by strongly arching the mesosoma), and the telson was held over tergites V-VI.

The female abandoned the parturition position and "broke" the birth basket at 1448 hrs. on 19 September, approximately 29 hours after she had assumed it and 2.5 hours after the 37th birth. The average interval between consecutive births (time of initial appearance) was 44.4 ± 30.8 min. (mean \pm S. D., $n = 36$). The shortest interval was 5 min.; and the longest interval was 133 min. The elapsed time between the appearance of the first and the last young was 26 hrs. 38 min.; and the time from appearance of the first young until the last one had settled on the female's back (#26) was 31 hrs. 02 min.

On 19 September the female engaged in periodical bouts of throwback behavior until about 1930 hrs., or for about seven hours after the last birth.

Post-partum behavior.—The female fed on a live cricket on 20 September, and ate another one on 24 September. She also cannibalized four young before they could molt and disperse. The female died of unknown causes in March 1975.

Behavior of the young.—All the young were born tail first and free of any enclosing membranes. Two of the young appeared right-side up, and 35 appeared upside-down. The

emergence of each young, from the time the telson could be observed coming out to the time the young dropped into the birth basket, lasted 6.9 ± 4.0 min. ($n = 37$). The fastest were four births that required 2 min. each, and the longest one took 18 min. As they emerged the young would flex and stretch their appendages, and soon after being completely out, they could move on their own.

The side of the female along which a newborn climbs is apparently randomly determined: 21 young went up the female's right side and 16 went up her left side (Table 1). The time elapsed between completing emergence and setting on the mother's back was 295.6 ± 282.9 min. (Table 1). The fastest young (#11) took only 65 min., while the slowest (#4) required 24 hrs. 20 min.

On the night of 19 September 1974 the young, having just climbed upon their mother, were randomly positioned on her dorsum. Gradually the young shifted around with respect to each other, and by 3 October a definite pattern appeared. The young, 2-3 layers deep, were positioned transversely across the mother's dorsum, facing each other medially. A narrow gap was evident along the female's midline.

Three young were down on 4 October 1974 actively moving around in the vicinity of their mother. The young molted to the second instar on 6-7 October 1974, and the last one left the mother on 16 October. In order to molt the first-instar young assumed a characteristic posture unlike that seen in subsequent molts. The body is strongly arched dorsally, and the metasoma is nearly straight and pointing slightly ventrad due to the arching of the body. The pedipalps and legs are flexed and crossed under the body—perhaps aiding in arching it—and the chelicera are fully extended.

OTHER FEMALES

Three other females gave birth in the laboratory. None can be regarded entirely normal or successful, but each offers some glimpses of behavior that corroborate the patterns described for female E.

Female A.—On 10 September 1974 at 1540 hrs. this female was found to have assumed the parturition posture, and the telson of the first young was emerging from her

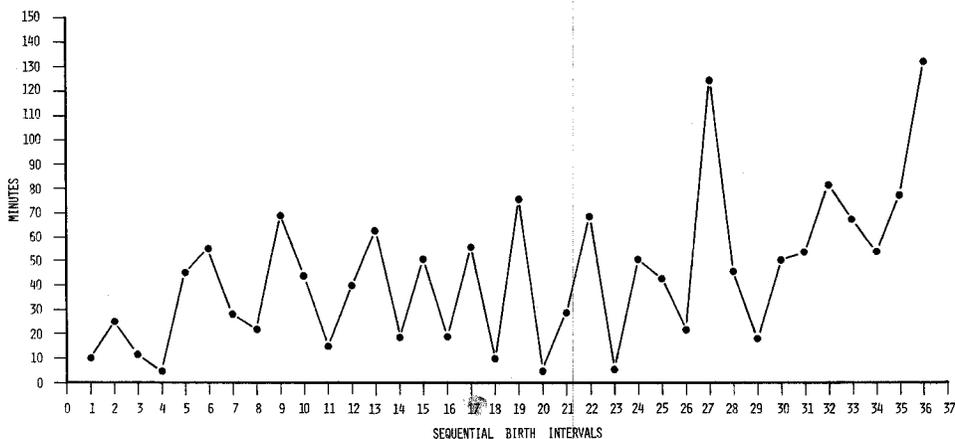


Fig. 1.—Interval (in minutes) between the initial time of appearance of consecutive births by *Diplocentrus bigbendensis* Stahnke female E in the laboratory.

genital opening. The posture assumed by female A was very similar to that described for female E, and the first young was emerging tail-first as those of litter E. The female was immediately transferred to a bigger container to facilitate observations and photography. The disturbance appeared to affect all subsequent events: the first young did not complete emergence until 25 hours later, and then eight additional young were born in less than 80 min. (1945 hrs. to 2105 hrs., 11 September). Three pairs emerged almost simultaneously; in each case one member of a pair emerged tail-first and the other emerged head-first. The nine young that were born in rapid succession were coated with a viscous substance and stuck to each other, thus being unable to stretch their appendages or to climb onto their mother's back. Eventually the female abandoned the parturition posture and attempted to cannibalize the young.

This female produced an additional 29 young over the next five days, as follows: 23 on 12 September, 4 on the 13th, none on the 14th, and one each on the 15th and 16th, respectively. Many of the births occurred late at night and were not observed; masses of young stuck to each other and on two consecutive mornings were found hanging from the female's genital opening. The births that were observed occurred mostly in pairs (i.e., two young born almost simultaneously followed by a time gap), and the newborn stuck to each other and to members of other pairs. Between the births of each pair of young the female engaged in bouts of throwback behavior.

To summarize the significance of these observations: female A had 38 young in six days (although 36 of them were born within a 36 hour period); the parturition posture and throwback behavior were similar to those observed in female E; and the majority of the births occurred in pairs. All the young died as first-instars, and the female died on 10 January 1975.

Female B.—On 10 September 1974 at 1540 hrs. this female was found in the parturition posture, carrying eight young on her back, and with 17 more on the ground under and near her. The female was cannibalizing one young, and the remnants of three others were found in the immediate vicinity (making a total of 29). Fearing that the sudden exposure to light had caused the female to move, thereby disrupting the birth basket for the young, I carefully placed all the young on the female's back and returned them to darkness.

During the next two days the female had at least four more young; and she cannibalized (or attempted to) several young, often knocking down those that would climb onto her back. In the early afternoon of 11 September I noticed 10 young arranged transversely across the female's back, facing each other medially. To prevent further cannibalism the first-instars were isolated and maintained at near saturation humidity levels. Six survivors began their first molt on 27 September: five died during or shortly after the molt, whereas the sixth survived to reach sexual maturity.

The significance of these observations is fourfold: (a) female B had 33 young (or more?), which compares favorably with the 37 and 38 young delivered by females E and A, respectively; (b) the pattern assumed by the young on their mother's back was very similar to that described for female and litter E; (c) the first molt occurred at an age of 17-20 days in both litters; and (d) the lone survivor represents, to my knowledge, the first scorpion successfully reared in isolation from shortly after birth.

Female D.—This female gave birth on 2-3 November 1974, about 1.5 months after the other three females. This female cannibalized the young a few hours after each one of them was born, and she moved around in her container between births, scattering the young as she went. Detailed observations were made on very few births, and in those the young emerged tail-first as did the young of female E.

DISCUSSION

The parturition posture of *D. bigbendensis* is very similar to that of *D. spitzeri*, differing only in the fact that in the latter the second pair of legs are an integral part of the birth basket from the beginning (Francke 1981), whereas in the former they are recruited into the birth basket after a few births have occurred. In *N. hierichonticus* the stance assumed by the gravid female is also similar to that of *Diplocentrus* spp., apparently differing only in that the pedipalp chelae are held parallel to the body axis during parturition, rather than transverse or oblique to it (Rosin and Shulov 1963:pl. 3; however, those photographs may picture a female during a "relaxed" phase, in which case there would be no significant differences between the two genera).

Throwback and twist behavior before each birth were not observed in *D. spitzeri*, but were very distinctive in *D. bigbendensis*. In *N. hierichonticus* conspicuous movements of the tail are reported (Rosin and Shulov 1963). In some cases tail movements were accompanied by elevation of the pedipalps, but it is difficult to determine if these pedipalpal elevations are homologous to the throwback behavior of *D. bigbendensis*.

The time from initial appearance to dropping into the birth basket was 6.9 ± 3.9 min. ($n = 37$) in *D. bigbendensis*, 61.6 ± 54.2 min. ($n = 8$) in *D. spitzeri*, and "10 minutes on the average" in *N. hierichonticus* (Shulov et al. 1960). The young of *D. spitzeri* are relatively larger at birth (second-instar is 35% of female size) than those of *N. hierichonticus* (25%) and *D. bigbendensis* (22-23%) (Francke 1981). The passage of young through the genital opening of the mother may be determined by the young's relative size: small young pass through considerably faster than larger young.

The young of *D. spitzeri* and *N. hierichonticus* emerge tail first, as did those of *D. bigbendensis* from the normal birth (female E). Shulov et al. (1960) indicate that "In another case of parturition of *N. hierichonticus* the neonati were observed to emerge mostly in pairs, one with the head first, the other with the tail first." Those authors did not indicate whether that was a normal and successful parturition or not; nonetheless, the same pattern occurred in *D. bigbendensis* female A births.

A possible explanation for the tail-first emergence of the young in normal births in diplocentrids relates to their position during embryonic development. Diplocentrid scorpions are katoikogenic, i.e., they develop in diverticula that arise perpendicularly from the main ducts of the ovariouterus. The embryos face the apices of the diverticula, and they literally have to back out (tail first) from the diverticula and make a 90° turn to enter the lumen of the oviduct. The path of least resistance would be to turn anteriorly with respect to the female because that is the direction towards the genital opening. Turning posteriorly would enable the young to enter the lumen, and then to move forward and be born head first. However, turning posteriorly where other young are awaiting their turn to come out would be mechanically more difficult than turning anteriorly. The relationship, if any, between abnormal births and some young emerging head first is unclear at this time.

The ovariouterus leads into paired oviducts which emerge into a common atrium at the level of the genital opening. Thus, it is possible for two young to move forward simultaneously, one heading for each oviduct, and emerge as a "pair." The pattern of two young being born in rapid succession occurs in normal as well as abnormal births (in the latter rapid succession becomes simultaneous, as reported for *D. bigbendensis* female A, and *N. hierichonticus* in one parturition). The intervals between consecutive births from litter E have been calculated from Table 1 and plotted in Fig. 1. The marked zig-zag

pattern, especially during the intermediate births, supports the explanation of two young moving forward at the same time.

In *D. spitzeri* the pattern of intervals between consecutive births provides an independent test for the explanation derived from *D. bigbendensis*. The intervals in *D. spitzeri* were 128, 207, 45, 1065, 43, 202, 1513, and 180 min. respectively (Francke 1981). The median is 191, and the pattern of runs with respect to it is: below—above—below—above—below—above—above—below, deviating from a zig-zag only once. Intervals between consecutive births are not known for *N. hierichonticus* (or any other katoikogenous scorpion) and thus further testing of the hypothesis presented above cannot be offered here.

In *D. bigbendensis* early births have shorter consecutive intervals than late births. The median in Fig. 1 is 44.5; in the first 12 births nine intervals are below the median, in the middle 12 births six intervals are below the median, and the last 12 births only three intervals are below the median. The pattern strongly suggests that the young nearest the genital opening, i.e., those that are in the anterior-most diverticula and have a shorter distance to travel in order to get out, are born first. The young farthest from the genital opening, which have to travel a greater distance to get out, are born last.

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