

Observations on the life history of *Uroctonus mordax* Thorell (Scorpionida, Vaejovidae)

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Summary

One *Uroctonus mordax* male was raised in captivity from birth to its death at 579 days of age, by which time it had reached the fifth instar. Analyses of the rate of increase in dimensions per moult (growth factor) for a number of structures are used to predict the dimensions of subsequent instars. Adult, field caught, males have dimensions that agree with those predicted for seventh instars, strongly suggesting that *U. mordax* normally undergoes six moults during its post-embryonic development.

Introduction

Studies on scorpion life histories are few in number, and to this date none have been published on members of the family Vaejovidae. Two species of the family Scorpionidae have been raised under laboratory conditions from birth to sexual maturity: *Palamnaeus longimanus* (Herbst) from the Philippine Islands (Schultze, 1927), and *Pandinus gambiensis* Pocock from Africa (Vachon et al., 1970). One species of the family Chactidae, *Euscorpium italicus* Herbst from southern Europe, was successfully raised to reproductive age by Angerman (1957). Finally, the following species of the family Buthidae have been reared in captivity: *Buthus occitanus* Amoreux of southern Europe (Auber, 1963); the cosmopolitan *Isometrus maculatus* (de Geer) by Probst (1972); and two Brazilian species, *Tityus bahiensis* (Perty) by Matthiesen (1961, 1970), and *Tityus serrulatus* Lutz & Mello by both Matthiesen (1961, 1962, 1971) and San Martin & Gambardella (1966). Life history data on members of the families Bothriuridae and Chaerilidae are completely absent. My own studies on one member of the family Diplocentridae are near com-

pletion and will be the subject of a future contribution.

My objective here is to present the scant information I have been able to obtain on the life history of the vaejovid scorpion *Uroctonus mordax* Thorell. One laboratory-reared specimen moulted four times in captivity, and the morphometric data obtained from the exuviaë are used to predict the number of instars required by *U. mordax* to attain sexual maturity.

Observations

Uroctonus mordax is a widespread species in temperate, moist habitats of California and Oregon, ranging from 5 m to 2,000 m in elevation (Hjelle, 1972; Gertsch & Soleglad, 1972). Specimens have been captured during every month of the year, but larger and more numerous samples originate from the summer months. This suggests that the species might be largely inactive during colder months, but so are the collectors and thus it is not possible to draw any conclusions about seasonal activity patterns of *U. mordax* at this time.

Three adult females and two adult males of *U. mordax* were collected under the bark of Coast Live oak (*Quercus agrifolia* Nee) logs 1 mile west of Woodacre, Marin Co., California, on 16 March 1974. The specimens were placed in individual plastic bags with some soil and litter from the collecting area, and transported to Tempe, Arizona where I received them six days later.

In the laboratory the specimens were maintained individually in 11 x 11 x 7 cm plastic containers with a 2-3 cm deep layer of sterilized soil. They were watered and offered live crickets at irregular intervals which did not exceed two weeks. This regimen was maintained until 15 May 1974 when I undertook a five-week field trip, and during those five weeks (ending 23 June 1974) the scorpions were neither fed nor watered. Upon my return, I found that the three females had given birth in my absence (28, 31 and 34 young), and the first instars were occupying the mothers' dorsum. Parturition has not been observed in the field, but one female carrying first instars on her dorsum was captured on 30 August 1965 (Hjelle, 1972), and parturition in captivity has been previously recorded in the first two weeks of September (Haradon, 1972). I suspect that *U. mordax* females

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give birth in late summer under natural conditions, and that the early summer observations reported herein reflect the effects of laboratory conditions. Birth behaviour activity in *U. mordax* has previously been described by Haradon (1972), and my observations on the number of young per litter, as well as on the position assumed by the first instars on the female's back agree with his. Both Williams (1969), and Haradon (1972) report that young *U. mordax* are born enclosed in a "birth membrane", which is shed before they ascend to the female's back. The first moult for all three litters was completed by 3 July 1974, and soon afterwards the young descended from the mothers' backs. The mothers were transferred to freshly prepared containers soon thereafter, and each litter was kept together in the original containers.

The second instars were watered periodically in order to maintain a fairly high relative humidity in the containers. Food was offered to them at least twice a week, consisting of either newly emerged crickets or vestigial-winged fruit flies. Although a considerable number of second instars were observed drinking and feeding on numerous occasions, mortality among them was very high and by 1 December 1974 only three of them, from the same litter, remained alive. On 24 January 1975 one of them moulted into the third instar, and the remaining two second instars died shortly thereafter, one of undetermined causes and the other during ecdysis. The sole survivor was fed immature crickets and watered at irregular intervals until its death in the fifth instar at the age of 579 days.

The adult females, after being removed from their respective litters, were re-started on the feeding-watering regime described earlier, and fared as follows: the mother of the scorpion that survived to the fifth instar died of unknown causes on 29 April 1975, as did another female on 3 August 1975; while the third female is still alive (as at 15 November 1976) but has neither moulted nor produced more young.

Results

The chronology of the post-embryonic development of the single *U. mordax* male raised in captivity is presented in Table 1. The birth-date is unknown, but Haradon (1972) reported the duration of the first instar in this species to be 14-15 days; thus, through extrapolation I have inferred that birth occurred approximately on 18 June 1974. The fifth instar individual died of unknown causes before attaining sexual maturity.

Morphometric data for the single male of *U. mordax* reared are presented in Table 2. The exoskeleton of first instar scorpions is weakly sclerotized and the limits between sclerites and intersegmental membranes are not clearly demarcated, consequently no measurements are available for this stage in the life history. The short lasting first instar should be considered to be the last stage of embryonic development in *U. mordax*, rather than the first stage of post-embryonic development because (a) first instar scorpions do not feed, and (b) many "adult-like" external

	Date	Age in days	Duration of stage
Birth	18 June 1974	0	
1st instar			14-15*
Moult 1	3 July 1974	15	
2nd instar			205
Moult 2	24 January 1975	220	
3rd instar			87
Moult 3	21 April 1975	307	
4th instar			91
Moult 4	21 July 1975	398	
5th instar			181
Death	18 January 1976	579	

*Data from Haradon (1972)

Table 1. Chronology of the life-history of one *Uroctonus mordax* (Thorell) male maintained in captivity.

morphological characters do not appear until the second instar. The first instar in *U. mordax* is completely surrounded by a thin, transparent membrane (not to be confused with the "birth membrane" mentioned earlier) that (1) prevents the chelate appendages (cheliceræ and pedipalp chelae) from opening and thus from operating properly; (2) covers the tarsal claws, appearing as a soft pad which might be useful in permitting the newborn to secure a hold on the mother's dorsum; (3) covers the sensory organs, such as the pectines and the trichobothria, and renders the newborn insensitive to most external stimuli; and (4) covers the aculeus so that any attempts to sting potential prey or predators become futile.

The significance of the data presented in Table 2 is that they can be used to calculate the growth factor per moult (i.e., the relative amount of increase in

dimensions between succeeding instars) for each and all characters measured. This growth factor can be used, by extrapolation, to predict the measurements of subsequent instars not observed in this study. The predicted measurements can then be compared with actual measurements obtained from adult specimens, and in this manner it is possible to determine the number of instars required by *U. mordax* to complete its post-embryonic development. Six structures have been analyzed with this technique, and the results are presented in Table 3. The data so obtained are presented graphically in Figs. 1-3, where they are also compared with published measurements of *U. mordax* males (Hjelle, 1972; Gertsch & Soleglad, 1972). These graphs show a close correspondence between the predicted seventh instar measurements and the observed adult measurements, which is a strong

	2nd instar (exuvia)	3rd instar (exuvia)	4th instar (exuvia)	5th instar	Adult* male
Carapace length	2.00	2.60	3.45	4.50	7.30
Anterior width	1.10	1.50	1.95	2.40	—
posterior width	2.05	2.85	3.80	4.65	7.30
Metasoma length	7.20	9.80	14.05	18.60	35.45
I length	0.80	1.00	1.40	1.90	3.80
width	0.95	1.30	1.80	2.35	3.50
II length	0.90	1.20	1.70	2.25	4.60
width	0.90	1.15	1.60	2.05	3.10
III length	0.95	1.30	1.85	2.45	4.85
width	0.80	1.05	1.50	1.90	2.95
IV length	1.10	1.45	2.15	2.80	5.40
width	0.75	0.95	1.40	1.75	2.70
V length	1.65	2.40	3.45	4.60	8.60
width	0.70	0.90	1.30	1.65	2.50
Telson length	1.80	2.45	3.50	4.60	8.20
Vesicle width	0.70	0.90	1.30	1.75	2.95
depth	0.55	0.80	1.20	1.45	2.70
Pedipalp length	5.50	8.45	11.40	14.70	26.10
Femur length	1.60	2.05	2.75	3.60	6.70
Tibia length	1.60	2.10	2.95	3.80	6.50
Chela length	3.30	4.30	5.70	7.30	12.90
width	1.00	1.45	2.10	2.90	5.40
depth	0.90	1.30	1.90	2.50	4.30
Movable finger	1.80	2.35	3.00	4.00	7.55
Fixed finger	1.50	1.80	2.35	3.00	5.00
Pectinal teeth	12-12	12-12	12-12	12-12	13-12

*Data from Gertsch & Soleglad (1972), included here for comparative purposes.

Table 2. Measurements (in mm) of the stages observed in the post-embryonic development of one *Uroctonus mordax* male. (Measurements obtained with the aid of a calibrated ocular micrometer at 20x magnification)

	Observed				Mean Growth Factor	Predicted	
	2nd	3rd	4th	5th		6th	7th
Carapace length	2.00	2.60	3.45	4.50		5.90	7.70
Growth factor		1.30	1.33	1.30	1.31		
Metasoma V length	1.65	2.40	3.45	4.60		6.49	9.14
Growth factor		1.45	1.44	1.33	1.41		
Pedipalp chela length	3.30	4.30	5.70	7.30		9.35	11.95
Growth factor		1.30	1.32	1.28	1.30		
Pedipalp femur length	1.60	2.05	2.75	3.60		4.70	6.10
Growth factor		1.28	1.34	1.31	1.31		
Chela fixed finger length	1.50	1.80	2.35	3.00		3.75	4.70
Growth factor		1.20	1.31	1.27	1.26		
Telson length	1.80	2.45	3.50	4.60		6.30	8.63
Growth factor		1.36	1.43	1.31	1.37		

Overall mean 1.33

Table 3. Morphometrics of the stages in the life history of *Uroctonus mordax* males, based on one individual raised in captivity to the fifth instar (measurements in mm)

indication that *U. mordax* undergoes six moults in the course of its post-embryonic development and that sexual maturity is attained by the seventh instar.

Discussion

Growth Factor

The data presented in Table 3 indicate that in one *Uroctonus mordax* male the maximum increase in dimensions observed between succeeding moults was 45% (growth factor of 1.45), the minimum increase was 20% (growth factor of 1.20) and the average ($n = 18$) observed was 33% (growth factor of 1.33).

The two studies on the life history of scorpions belonging to the family Scorpionidae (Schultze, 1927; Vachon et al., 1970) do not provide measurements on any of the instars observed, and the growth factor in this family is still unknown.

The published studies on the life history of members of the family Buthidae provide some morphometric data which can be used to calculate the growth factor for those species. Probst (1972) in his detailed studies on *Isometrus maculatus* calculated an average growth factor of 1.3 for all the structures measured, i.e., a mean increase of 30% in dimensions between succeeding moults. Auber (1963) presented graphical

data on the pedipalp chela length of each instar of *Buthus occitanus*, and only the minimum and maximum dimensions observed among six males and six females reared to maturity can be extracted from the graph. If we assume that the specimen with the smallest dimensions at one instar moults into the specimen with the smallest dimensions in the succeeding instar, the average increase in size throughout the life history (i.e. six moults) is 26%. Similarly, if we assume that the specimen with the largest dimensions at one instar retains that size advantage in succeeding instars, then the average increase in size for all instars is 27% for males and 32% for females. In the unlikely possibility that the smallest individual at one instar becomes the largest individual in the succeeding instar, the average size increase for all moults is 55%; and the reciprocal permutation, from largest to smallest in one moult, gives an average increase in size of 3% per moult for males (zero growth in the moult from fifth to sixth instars, and negative growth in the following moult!), and 8% for females (zero growth in the moult from fifth to sixth instars). Finally, Matthiesen's (1970) data on *Tityus bahiensis* reveal an average increase in size of 22% between succeeding instars.

One study on the life history of members of the family Chactidae has appeared. Angermann (1957)

presents data on the carapace length of the different instars of *Euscorpis italicus* and from his raw data I have calculated an average increase in size of 25% per moult for *E. italicus*.

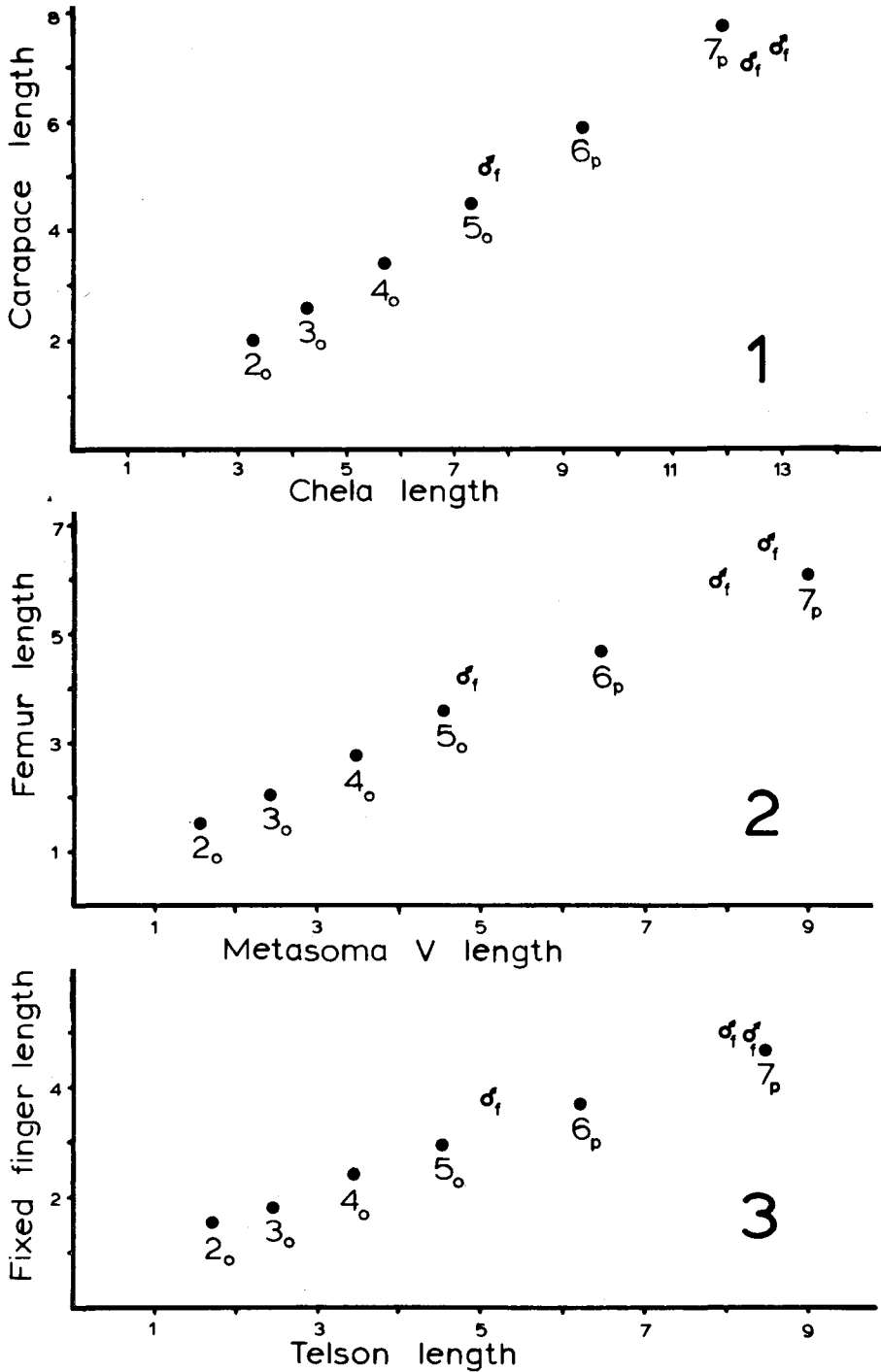
The scant amount of information available on scorpion growth has been summarized above, and it appears that a 25-35% increase in dimensions between succeeding instars is a reasonable expectation for scorpions in general. Larger increases in size are unlikely to occur because the exoskeleton is an effective limiting factor on the amount of somatic growth that can take place between moults, and because the respiratory organs of scorpions, i.e. the book-lungs, are not likely to play as significant a role in post-ecdysial volumetric expansion of the exoskeleton as is the case with arthropods possessing tracheal respiratory systems. Increases in size between moults of less than 25% are possible, but unlikely in view of the following evolutionary considerations: (a) the newly emerged scorpion is defenceless against predators because the cuticular exoskeleton, particularly on the stinger and the pedipalp chelae, is too soft to be useful during agonistic encounters, and even locomotory ability to escape seems to be impaired under these conditions; (b) newly moulted scorpions experience higher rates of water-loss due to cuticular transpiration than do intermoult specimens with tanned cuticles (Hadley, 1974), and this might result in detrimental physiological stresses that affect survival; and (c) ecdysis itself is a complicated process that is not always successfully completed by immature scorpions. Under laboratory conditions about one-third of the scorpions entering ecdysis die in the process (personal observations). Thus, for a given species of scorpion, optimization of the life history (to maximize evolutionary fitness) should lead to a reduction in the number of moults required to achieve sexual maturity. If this interpretation is valid, I do not expect to find scorpions moulting under unfavourable circumstances which would tend to reduce the growth factor per moult, and thus (a) result in smaller individuals that experience a decrease in mating success due to intraspecific competitive interactions and/or sexual selection, or (b) require an additional number of moults before sexual maturity is achieved. To this date the minimum overall increase in size per moult observed is approximately 20%, and this might well be the lower limit imposed by evo-

lutionary constraints in scorpions.

Number of Instars to Maturity

Our present knowledge of scorpion life-histories indicates that the postulated seven instars required by *U. mordax* to complete its post-embryonic development do not represent an excessive number. *Palamnaeus longimanus* undergoes seven moults before becoming sexually mature, i.e. adults represent the eighth instar (Schultze, 1927), while its relative *Pandinus gambiensis* attains sexual maturity at either the seventh or eighth instars (Vachon et al., 1970). *Euscorpis italicus* usually reaches sexual maturity in the sixth instar, although one female required an additional moult to complete its post-embryonic development (Angermann, 1957). Finally, among members of the family Buthidae we find that *Buthus occitanus* matures in the seventh instar (Auber, 1963); *Tityus serrulatus* completes its post-embryonic development after the fifth moult, and sixth instar females can reproduce parthenogenetically (Matthiesen, 1962; San Martin & Gambardella, 1966); *Tityus bahiensis* reaches sexual maturity at either the fifth or sixth instars (Matthiesen, 1970); and in *Iso-metrus maculatus* sexual maturity is usually achieved by the seventh instar, although 5-10% of the females become reproductive as sixth instars (Probst, 1972). It should also be pointed out that post-maturation moults have never been recorded in scorpions.

Life history data are now available for eight species of scorpions, belonging to seven genera in three different families, and the maximum number of instars recorded is eight. However, Auber (1959) speculated, on the basis of preserved museum specimens, that the chactid *Belisarius xambeui* Simon reaches sexual maturity in the 10th and/or 11th instars. In that study no specimens were reared to maturity in the laboratory to support that interpretation, and the scant morphometric data presented to support it indicate that only a 10-15% increase in size per moult was allowed for. The data presented above for other scorpion species suggests that this is an unreasonably low growth factor, in which case I expect that *B. xambeui* can reach reproductive size after only six or seven moults, and does not deviate significantly from other species in the number of instars required to complete its post-embryonic development.



Figs. 1-3: Morphometrics of the post-embryonic developmental stages of *Uroctonus mordax* Thorell (measurements in mm). Instars 2-7, o = observed in laboratory (this study, p = predicted, f = field caught males (from Hjelle, 1972, and Gertsch & Soleglad, 1972).

Acknowledgments

The research for this contribution was carried out during my graduate student career at Arizona State University, and was supported by a Graduate College Fellowship from that institution. I express my gratitude to the following friends who contributed in one way or another: Dr Laurie Vitt collected the specimens in California at my request, and his cooperation is much appreciated; Mr Charles Moss took care of the specimens during January and February, 1975, and Mr Edwin Minch performed the same task during January 1976 while I was out of the country on both occasions. Mr Fred Wagner of Texas Tech read the manuscript and his criticisms are equally acknowledged.

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