

LARVAL BEHAVIOR AND PHYLOGENETIC RELATIONSHIPS AMONG SCORPIONS

Alberto Ugolini and Marco Vannini

Istituto di Zoologia dell'Università
via Romana 17
50125 Firenze, Italia

ABSTRACT

The larvae of two species of *Euscorpium* (Chactidae) were each allowed to settle on the backs of immobilized adults of 8 species of scorpions belonging to 4 families. The percentage of larvae still present after 12 hours was recorded. A significant correlation appeared between these results and the phylogenetic relationship, as suggested by Lamoral (1980), between *Euscorpium* and the other families.

INTRODUCTION

The larvae of *Euscorpium carpathicus* (L.) and *E. flavicaudis* (Geer) settle on the backs of congeneric adult scorpions regardless of their species, sex or reproductive phase (Vannini et al. 1978, Vannini and Ugolini 1980). The mother-larva bond is regulated not only by specific behavior of both the larva and the mother but also by tactile (Angermann 1957, Vannini et al. 1978) and chemical (Vannini and Ugolini 1980) cues. The reaction of two species of *Euscorpium* larvae to adults belonging to different families is the object of this paper.

Table 1.—Species tested.

| Family | Species | Locality |
|----------------|--|----------|
| Chactidae | <i>Euscorpium carpathicus</i> (L.) | Italy |
| | <i>Euscorpium flavicaudis</i> (Geer) | Italy |
| Scorpionidae | <i>Scorpio maurus fuscus</i> (Hemprich & Ehrenberg) | Israel |
| | <i>Pandinus pallidus</i> (Kraepelin) | Somalia |
| Diplocentridae | <i>Nebo hierichonticus</i> (Simon) | Israel |
| Buthidae | <i>Buthotus polystictus</i> (Pocock) | Somalia |
| | <i>Buthotus judaicus</i> (Simon) | Israel |
| | <i>Leiurus quinquestriatus</i> (Hemprich & Ehrenberg) | Israel |
| | <i>Androctonus crassicauda</i> (Olivier) | Israel |

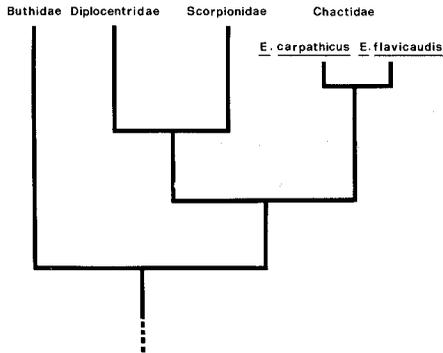


Fig. 1.—Cladogram of the scorpion families, adapted from Lamoral (1980). Three families not tested in our experiments have been omitted.

MATERIALS AND METHODS

Gravid *E. carpathicus* and *E. flavicaudis* females were collected in the vicinity of Florence and raised in the laboratory. Upon birth the larvae were placed in groups of ten on the backs of live, immobilized (see Vannini et al. 1978) adult scorpions (8 species representing 4 families: Table 1). None of these adults gave birth before or after the experiments. The number of larvae still present on the back of each adult was recorded 12 hours later. Each group of larvae was tested once. All the experiments were conducted in complete darkness, at room temperatures and RH, in September-October 1981.

RESULTS AND DISCUSSION

The number of *Euscorpilus* larvae available daily was irregular and unequal for both species. Thus, the results of Table 2 are somewhat unbalanced.

A preference hierarchy for both species of *Euscorpilus* was obtained (Table 2, columns P_c and P_f). Applying the Spearman rank correlation test to these hierarchies shows a high correlation between the two species ($r_s = 0.983$; $P < 0.01$). Pooling the data of both species gives their average preference hierarchy for the adults of other families (Table 2, column P_a).

Table 2.—Number of larvae still on the back of adults of various species after 12 h: in brackets, number of adults; N_c and N_f , number of larvae tested; P_c and P_f , percentage of settled larvae; P_a , average percentage.

| | | <i>Euscorpilus carpathicus</i> | | <i>E. flavicaudis</i> | | | | |
|------|-----|--------------------------------|-------|-----------------------|-------------------------------------|-------|-------|-------|
| | | | N_c | P_c | | N_f | P_f | P_a |
| E.f. | (4) | 10 9 10 10 10 | 50 | 98.0 | 9 10 9 9 10 10 9 10 10 9 10 9 10 | 130 | 95.4 | 96.1 |
| E.c. | (4) | 10 10 8 9 9 10 10 10 | 80 | 95.0 | 8 10 10 9 9 9 9 | 70 | 91.4 | 93.3 |
| S.m. | (3) | 10 9 6 9 9 9 | 60 | 86.7 | 10 6 10 6 10 9 8 10 9 8 | 100 | 86.0 | 86.2 |
| P.p. | (1) | 8 10 6 5 | 40 | 72.5 | 9 5 10 | 30 | 80.0 | 75.7 |
| N.h. | (3) | 2 2 5 9 5 7 | 60 | 50.0 | 6 9 9 1 8 10 1 5 10 10 | 100 | 69.0 | 61.9 |
| B.j. | (2) | 0 5 4 10 9 8 | 60 | 60.0 | 7 10 7 8 10 9 9 4 1 0 | 100 | 65.0 | 63.1 |
| B.p. | (3) | 0 10 10 2 7 3 | 60 | 53.3 | 5 5 0 8 5 0 0 0 1 0 | 100 | 24.0 | 35.0 |
| L.q. | (3) | 0 0 0 3 | 40 | 7.5 | 0 0 8 2 0 0 0 0 1 0 0 0 | 120 | 9.2 | 8.7 |
| A.c. | (1) | 1 0 0 | 30 | 3.3 | 0 1 0 0 0 0 5 2 0 | 90 | 8.9 | 7.5 |

Table 3.—Comparison between hierarchy of phylogenetic relationship (Fig. 1) and settling preference (Table 2, P₈).

| Species | Family | Number of Branchings | Rank | Settling Preference |
|-----------------------------------|----------------|----------------------|------|---------------------|
| <i>Euscorpis</i> (homospecific) | Chactidae | 0 | 1 | 1 |
| <i>Euscorpis</i> (heterospecific) | Chactidae | 1 | 2 | 2 |
| <i>S. maurus fuscus</i> | Scorpionidae | 2 | 4 | 3 |
| <i>P. pallidus</i> | Scorpionidae | 2 | 4 | 4 |
| <i>N. hierichonticus</i> | Diplocentridae | 2 | 4 | 6 |
| <i>B. polystictus</i> | Buthidae | 3 | 7.5 | 7 |
| <i>B. judaicus</i> | Buthidae | 3 | 7.5 | 5 |
| <i>L. quinquestriatus</i> | Buthidae | 3 | 7.5 | 8 |
| <i>A. crassicauda</i> | Buthidae | 3 | 7.5 | 9 |

The hierarchy of settling preference derived from our experiments (Table 3, $r_s = 0.879$; $P < 0.01$) agrees with the cladogram proposed by Lamoral (1980) for the various families of scorpions (Fig. 1). The slight discrepancies in behavior of the two species of *Euscorpis* could be due to experimental error. Of interest is the fact that, after considering congeneric affinities, the larvae showed a distinct preference for the Scorpionidae ($z = -1.97$; $P < 0.025$; Mann-Whitney U test) although these and the Diplocentridae show the same cladistic distance from the Chactidae. Among the Buthidae, the larvae preferred *Buthotus* to the two other genera ($z = -5.98$; $P < 0.001$; Mann-Whitney U test).

It has already been demonstrated that prolonged permanence of scorpion larvae on the mother's back is based on chemical and physical grounds (Vannini et al. 1978, Vannini and Ugolini 1980, 1981). A chloroform extract of the mother's cuticle prepared on blotting paper proved to be attractive to the larvae (Vannini and Ugolini 1980). It is possible that the relationship between phylogenetic position and settling preferences shown by the larvae is due to the differences in the wax making up the epicuticular layer, which is partially removable in chloroform and chloroform:methanol (see Hadley and Jackson 1977, Toolson and Hadley 1977, 1979, Vannini and Ugolini 1980).

In strictly taxonomical terms our methods are rather approximate and therefore we cannot expect a precise relationship between settling preference and taxonomical position. However, since there appears to be a general correlation between the two, at least at the family level, our technique does provide a positive and integrative contribution to present taxonomical knowledge of scorpions, especially if reciprocally experiments were to be carried out (i.e. Buthidae, Diplocentridae and Scorpionidae larvae on Chactidae adults), and extended to other families.

Torres and Heatwole (1967) used a similar technique to discover the factors regulating settling on maternal back, and their results do not seem in contrast with a general applicability of the method. They tested Buthidae larvae on Diplocentridae, Scorpionidae and Buthidae females. Although the larvae settled almost exclusively on conspecifics, it should be noted that the adults were not immobilized, only a small number of larvae were used, and some of the offspring were tested in the nymphal stage.

ACKNOWLEDGMENTS

We wish to thank Dr. W. Lourenço (Museum d'Histoire Naturelle, Paris) for having identified the somalian scorpions, Prof. M. R. Warburg (Technion, Haifa) for his help in

collecting and identifying the Israeli specimens, and Dr. B. H. Lamoral (Natal Museum) and Prof. L. Pardi (University of Florence) for their critical reading of the manuscript. The somalian scorpions were collected during an expedition of the Centro di Studio per la Faunistica ed Ecologia Tropicali del C. N. R.

LITERATURE CITED

- Angermann, H. von. 1957. Über Verhalten, Spermatophorenbildung und Sinnesphysiologie von *Euscorpium italicum* Hbst. und verwandten Arten (Scorpiones, Chactidae). Z. Tierpsychol., 14(3): 276-302.
- Hadley, N. F. and L. L. Jackson. 1977. Chemical composition of the epicuticular lipids of the scorpion, *Paruroctonus mesaensis*. Insect Biochem., 7(1):85-89.
- Lamoral, B. H. 1980. A reappraisal of suprageneric classification of recent scorpions and of their zoogeography. 8. Internationaler Arachnologen-Kongress, Wien, 439-444.
- Toolson, E. C. and N. F. Hadley. 1977. Cuticular permeability and epicuticular lipid composition in two Arizona vejovid scorpions. Physiol. Zool., 50(4):323-330.
- Toolson, E. C. and N. F. Hadley. 1979. Seasonal effects on cuticular permeability and epicuticular lipid composition in *Centruroides sculpturatus* Ewing 1928 (Scorpiones, Buthidae). J. comp. Physiol., 129:319-325.
- Torres, F. and H. Heatwole. 1967. Factors influencing behavioral interaction of female parent and offspring in scorpions. Carib. J. Sci., 7:19-22.
- Vannini, M. and A. Ugolini and C. Marucelli. 1978. Notes on the mother-young relationship in some *Euscorpium* (Scorpiones, Chactidae). Monitore zool. ital. (N. S.), 12:143-154.
- Vannini, M. and A. Ugolini. 1980. Permanence of *Euscorpium carpathicum* (L.) larvae on the mother's back (Scorpiones, Chactidae). Behav. Ecol. Sociobiol., 7:45-47.
- Vannini, M. and A. Ugolini. 1981. Parental care in *Euscorpium* (Arachnida, Scorpiones). 17th International Ethological Conference, Oxford.

Manuscript received September 1982, revised January 1983.