

SCORPION SYMPOSIUM

DUE, Denise

THE BIOLOGY OF VAEJOVIS LITTORALIS WILLIAMS,
AN INTERTIDAL SCORPION FROM BAJA CALIFORNIA, MEXICO
Vanderbilt University

Vaejovis littoralis Williams is an intertidal scorpion inhabiting primarily the drift zone in the high intertidal of beaches in Baja California, Mexico.² Density within the drift zone averages approximately 2-4/m (island sites) to 12/m (mainland sites). Populations are aggregated into patches. Primarily juveniles exhibit diurnal activity. Nocturnally active juveniles tend to be spatially segregated from nocturnally active adults within the drift zone.

Diet of V. littoralis includes the isopod Ligia, V. littoralis, spiders, pseudoscorpions, centipeds, and beetles. Prey size is not a function of predator size. Centruroides exilicauda, V. littoralis, and Ligia were observed as predators on V. littoralis.

The adult sex ratio is skewed toward females (1 male: 2.1 females). Adult females are usually larger than adult males. Litter size ranges from 1-8. Limited data suggest that offspring size and litter size increase with maternal size.

Vaejovis littoralis exhibits cryptic coloration, small size, and lithophilic tarsal claws, all of which favor intertidal existence. Although V. littoralis is able to withstand up to 12 hours of submergence, it does not survive submergence significantly better than a comparable desert species. Field data suggest that V. littoralis does not exhibit an endogenous tidal rhythm.

FARLEY, Roger D.

INNERVATION AND PHARMACOLOGY OF THE HEART OF THE
DESERT SCORPION, PARUROCTONUS MESAENSIS STAHNKE
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The scorpion readily changes heart-rate in response to external stimuli, and this is probably important in supplying oxygen to its tissues as the animal abruptly alters its behavior. The pacemaker for the heart is a slender ganglion (15 mm long, 50-60 μ m diameter) in the dorsal midline of the heart. The largest nerve cell bodies (30-45 μ m in diameter) occur in clusters along the length of the ganglion.

The output of the pacemaker ganglion is regulated by nerve fibers in the dorsal branch of the segmental nerves from the subesophageal and first three abdominal ganglia. In perfusion experiments on the isolated heart and ganglion, octopamine was found to be the most effective cardio-accelerator (10^{-6} M), while gamma-aminobutyric acid reduced heart-rate. The effect of these agents on the heart was like that which occurred with electrical stimulation of the regulatory nerves.

In electron micrographs of the cardiac ganglion, nerve endings with electron-lucent vesicles 40-50 nm in diameter were most abundant. Bioamines such as octopamine have been associated with opaque granules in other studies, and such granules (170-250 nm diameter) are present in some nerve endings with and without vesicles were often seen in close apposition, suggesting chemical and electrical transmission. Possible gap junction particles and annular or double membrane vesicles were observed at some nerve-nerve junctions.

FRANCKE, Oscar F.
LIFE HISTORY STRATEGIES: INTER- AND INTRASPECIFIC TRENDS
Department of Biological Sciences
Texas Tech University

The consequences of viviparity and precocial young have on scorpion life histories are analyzed. The upper limits on size of young at birth are related to morphological maternal constraints during parturition: larger females can bear relatively larger young. The lower limits of size of young at birth are related to the number of molts required to attain adult size and sexual maturity: relatively smaller young require more molts. Litter size is in turn related to mother/young size relationships: a pregnant female can carry more relatively smaller young. The predicted relationships have not been demonstrated within any given species, but they are revealed in interspecific analyses. The anatomy of the female's ovariuterus (ten versus anastomoses), and the method of embryonic nutrition (apokogenic versus katoikogenic) do not affect the interspecific relationships in life history parameters indicated above.

GLEISSNER, Guenther
THE CIRCADIAN CLOCK OF THE SCORPION: A
CHALLENGE TO NEUROBIOLOGY
Zoologisches Institut der J.W. Goethe-Universitat

Our current knowledge on the neurobiology of the circadian clock of the scorpion Androctonus australis is to be described on the background of the visual system and the circadian change of sensitivity of the eyes. Tonic electrical activity in the

efferent neurosecretory fibers (ENSF) is the circadian signal, which induces the high sensitivity of the eyes during the night state. Octopamine most probably functions as a neuroregulator of the ENSF and a neuropeptide is possibly a cotransmitter. The ENSF show an extensive interlacing between the left and the right sides providing the anatomical basis of the tight bilateral coupling in the circadian system. These fibers, distributing a basic circadian signal among different neuropil centers, are an essential part of the clock. But it is still debatable whether they also belong to the frequency determining network. The clock functions as a multi-oscillator system with its component parts tightly coupled to each other. The oscillator driving the ERG rhythm seems to play an important role as a pacemaker for the clock system of the whole scorpion.

HADLEY, Neil F.

SCORPION CUTICLE: A STRUCTURE-FUNCTION ANALYSIS

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A key factor in the success of scorpions has been the development of a cuticle that provides mechanical support as well as serves as a barrier between the animal and its environment. Structurally, the scorpion cuticle follows the basic Arthropoda plan. Sclerotized cuticle (e.g., tergal sclerite) features a thin, outer epicuticle and an underlying, thicker procuticle that can be further divided into an exo- and endocuticle. The outer part of the exocuticle ("hyaline exocuticle") and the whole of the inner exocuticle are constructed of helicoidally arranged planes of chitin microfibrils. In the endocuticle, these microfibrils are arranged in bundles oriented horizontally and vertically. A complex series of interconnecting channels traverses the entire cuticle, connecting the epidermis with the surface of the epicuticle. These channels are believed to be the pathways by which lipids, which provide the principal barrier to transcuticular water flux, are transported from their site(s) of synthesis to the outer epicuticle. Intersegmental or soft cuticle (e.g., lateral pleuron) contains the same epicuticular sublayers as sclerotized cuticle; however, the exocuticle is absent, there are no pore canals, and the wax canals have a regular substructure in their walls that is apparently unique to scorpions. Intersegmental cuticle in this region is also compacted into many deep folds which, when expanded (e.g., gravid females), result in a greatly enlarged surface area. It is not known to what extent lipids are deposited in the epicuticle of intersegmental membrane, nor is it known if the composition of lipids in this region is similar to that for sclerite cuticle. We are presently attempting to measure cuticular permeability in Hadruirus arizonensis in vivo by attaching a miniature, ventilated capsule directly to either sclerite or intersegmental cuticle and monitoring water flux electronically. Preliminary data suggest that intersegmental

membrane is slightly more permeable than sclerite cuticle, but that water loss through the former also increases markedly when the surface is lightly rubbed with lipid solvents.

LOURENÇO, Wilson Roberto
SYSTEMATICS AND BIOGEOGRAPHY OF SOME NEOTROPICAL SCORPIONS
Laboratoire de Zoologie (Arthropodes)
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The systematics and biogeography of scorpions have progressed considerable in recent years; however, population-wide patterns of differentiation and distribution are rare. Some examples of different patterns are proposed and discussed, in particular for various elements of the family Buthidae from South America. Three major regions are analyzed: (1) Guyano-amazonian where three kinds of patterns are defined: (a) species exhibiting a great character stability throughout the population (e.g., Tityus cambridgei Pocock, 1897, and Tityus metuendus Pocock, 1897); (b) species with possible polytypic characters as (e.g., Tityus silvestris Pocock, 1897); (c) species with a clinal polymorphic character (e.g., Tityus gasci Lourenco, 1981). (2) Open vegetation formations (Caatinga, Cerrados and Chaco) of central South America, where almost all species of Tityus, Rhopalurus and Ananteris show a great stability of characters throughout the population. (3) Coastal Atlantic forests where Tityus costatus (Karsch, 1879) appears to form a mosaic polymorphic species.

MYERS, Christopher A.
BURROWING BIOLOGY AND SPATIAL DISTRIBUTION OF DESERT SCORPIONS
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The burrowing biology and spatial distribution of the desert scorpion Paruroctonus mesaensis was investigated. Individual P. mesaensis built their burrows into an incline and exhibited homing behavior. Light and temperature were found to act as environmental burrowing cues; there was no evidence of endogenous burrowing rhythms. First and second year P. mesaensis exhibited a significant association with areas of high vegetation cover and large perennials, while adults displayed a more random distribution. The implications of the observed spatial distribution, and various aspects of burrowing behavior are discussed. The burrowing biology of other scorpion species is also reviewed.

blind

Jump + light as cues to initiate

POLIS, Gary A.
COMPETITION AND PREDATION AMONG DESERT SCORPIONS
Department of Biology
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Interactions among four species of desert scorpion were analyzed over a nine-year period at two sites in the Coachella Valley, California. Although these species are potential competitors that feed on similar arthropod prey, they also eat one another. Such intraguild predation is frequent and forms 8 - 21.9% of the total diet of the various species. A size difference is the key determinate of scorpion-scorpion predation with larger individuals always the predator; thus each species is both predator and prey as it develops from small newborn to larger adult size. Intraguild predation occurs most frequently on males, moving individuals, and when food availability is low. Predation by the numerically dominant species (Paruroctonus mesaensis, 95% of all individuals), causes substantial mortality: 8% and 6% of two smaller scorpions (Paruroctonus luteolus and Vaejovis confusus, respectively) and 10% of all newborn Hadrurus arizonensis were observed being eaten by P. mesaensis. The impact of P. mesaensis on the success of these three species was assessed using a 29-month experiment during which 6000 P. mesaensis were removed from 300 (100 m²) quadrats. There were significant increases in the populations of P. luteolus and V. confusus (but not Hadrurus) in the removal quadrats as compared with control quadrats.

The hypothesis that exploitation competition for food was present and produced the experimental increases in density was also tested. Although there is extensive evidence that food limited feeding rates, growth, adult size, and reproduction, there was no evidence that food use by one scorpion depleted the availability of prey to other scorpions: neither the abundance of trapped prey, feeding rates nor body sizes were greater in the removal versus control quadrats.

We conclude that intraguild predation rather than exploitation competition is the major factor structuring the observed patterns of distribution and abundance of these scorpions. We suggest that aspects of foraging behavior and the spatial and temporal patterns of surface activity of smaller scorpion species and age classes have coevolved largely to avoid predation by P. mesaensis. Many assemblages of scorpion species exhibit intraguild predation, and we speculate that this process produces behavioral and activity patterns similar to those observed in this study.

ROOT, T. M.
THE NEURAL CONTROL OF SCORPION LOCOMOTION
Department of Biology, Middlebury College

Studies of invertebrate locomotion have helped us understand the neural basis of simple behaviors, and the scorpion Paruroctonus mesaensis has proven to be a particularly advantageous system to study because of the animal's relatively large size, simple nervous system, and transparent leg cuticle.

Cinematographic studies of walking scorpions have shown that the animal normally alternates the stepping of two sets of four legs, with quite constant latencies between the stepping of each leg. Removing one or two legs causes the animal to reorganize these stepping relationships, however, and changing the substrate texture or curvature generally increases the variability when each leg steps.

Electrical recordings from nerve cells, sensory receptors and muscles have helped us start to define the different components of the walking control system. The basic pattern of leg movements is generated by motor centers in the subesophageal ganglion on the brain, but how higher brain centers act to alter these patterns is currently unclear. Also, leg receptors such as slit sense organs, joint receptors and cuticular hairs are possibly involved in timing leg movements, but their exact role may be subtle, since experiments in which they are ablated seem to have little effect.

SISSOM, W. David
PHYLOGENY OF THE VAEJOVIDAE (ARACHNIDE: SCORPIONES):
PRELIMINARY SYNTHESIS
Department of General Biology
Vanderbilt University

The scorpion family Vaejovidae Thorell, 1876, is the source of considerable taxonomic confusion. The assignment of the subfamily Scorpionsinae and the genus Nullibrotheas to the Vaejovidae has already been questioned, but relationships among remaining taxa have largely been neglected.

Morphological evidence indicates that Syntropis and Vejovoidus are not closely related, and that the subfamily Syntropinae is not valid. This subfamily is defined by the possession of a single midventral metasomal keel on segments I-IV, rather than paired ventral submedian keels. Many other characters indicate important differences between Syntropis and Vejovoidus which clearly outweigh the carinal characteristic in significance.

The species groups of Vaejovis appear to belong to two distinct groups. One group contains the mexicanus, minimus, nitidulus, and wupatkiensis groups and can be defined by the possession of

a serrula on the cheliceral movable finger and a distinct white patch on the pedipalp chela fingertips. Uroctonus and Pseudouroctonus clearly belong in this group as well. The second group includes the eusthenura, punctipalpi, and intrepidus groups. Members of this group have trichobothria ib and it displaced distally on the fixed finger to the level of the sixth inter accessory granule and a spinule row on tarsomere II of the legs which terminates between three pair of small spines. Syntropis appears related to, if not subordinate to, this group. The relationships of other genera remain unclear.

STOCKWELL, Scott A., and FRANCKE, Oscar F.
THE SCORPIONS OF COSTA RICA
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Seventeen species of scorpion, representing four families and seven genera, are found in Costa Rica. Of these, two genera (Centruroides Marx and Didymocentrus Kraepelin) and eight species (Centruroides bicolor [Pocock], Centruroides gracilis margaritatus [Gervais], Centruroides thorelli [Kraepelin], and Didymocentrus concavimanus new species) are distinctly Central American in origin. Four genera (Ananteris Thorell, Tityus Koch, Chactas Gervais, and Opisthacanthus Peters) and eight species (Ananteris ashmolei Lourenco, Tityus championi Pocock, Tityus forcipula Pocock, Tityus pachyurus Pocock, Tityus dedoslargos new species, Tityus ocelatus new species, Chactas chrysopus Pocock, and Opisthacanthus valerioi Lourenco) are Amazonian in origin. Isometrus maculatus (de Geer) is pantropical in distribution (introduced) and has its origins in Asia.

Although Costa Rica has no endemic genera, C. koesteri and D. concavimanus, from the dry forests of Guanacaste Province, and T. ocelatus and T. dedoslargos, from eastern and southern Costa Rica, are known only from this country. Opisthacanthus valerioi is endemic to Cocos Island.

In the present work, Centruroides rubricauda (Pocock) is synonymized under Centruroides limbatus (Pocock) and three new species are described.

TOOLSON, Eric C.
REPRODUCTIVE BIOLOGY OF SCORPIONS
Department of Biology
University of New Mexico

In five species of scorpions from three families (Vaejovidae, Iuridae, and Buthidae), total dry mass of newborn progeny

represents $37.5 \pm 3.05\%$ of material dry mass. No dependence of clutch dry mass on maternal mass is evident in the data. Proportional investment in individual young decreases with female size, but the regression coefficient in Hadrurus arizonensis (Iuridae) is nearly an order of magnitude less than in the other families. The total number of young per clutch is positively dependent on maternal dry mass, but once again, the relationship is different in H. arizonensis. During embryogenesis, dry mass of embryos increases significantly in all species, but in Centruroides sculpturatus (Buthidae) embryonic growth is apparently completed by the time the median eye spots are pigmented; in the Vaejovidae and Iuridae, considerable mass increase occurs after this stage. In all species, embryonic scorpions accumulate relatively large stores of water. The adaptive significance of these data are discussed.

WARBURG, M. R.
HABITAT PARTITIONING BY SCORPIONS INHABITING THE
MEDITERRANEAN REGION OF NORTHERN ISRAEL
Department of Biology
Technion (Haifa, Israel)

Six scorpion species are known to occur in the Mediterranean region of northern Israel. Two of them are represented by two subspecies each. Some of these species can occur in the same habitat. their habitats range from dense oak-woodland with 900 mm rainfall to grassland bordering with arid region with 200 mm rainfall. Two species possess large pedipalps: a scorpionid, Scorpio maurus fuscus, and a large diplocentrid, Nebo hierichonticus weighing over 9 g. the smallest species, Compsobuthus spp. weighs less than 0.1 g. They also differ in their behavior, some species (the xeric ones) being more nocturnal than others. These xeric species, Leiurus quinquestriatus and Buthotus judaicus, are also capable of staying for longer periods at higher temperatures. the rate of water loss was lower in these species and did not increase markedly with rising temperatures or low humidities, as in the mesic species. Haemolymph osmolarity was high in all species (lower in winter than in summer), but only in the xeric ones did low humidity cause a lower concentration of haemolymph, the ions changed accordingly. Water content of the various compartments of the body varied between species and changed with season and moisture conditions. Thus, the various scorpion species occupy different microhabitats in time and space resulting from their anatomical and physiological adaptations.

oral secretion added to sac — known in terrestrial chthonids
spiders — graphocephala
zelotes
SPIDERS

BERRY, James W.
THE CONSTRUCTION AND MICROSCOPIC STRUCTURE OF THE EGG CASE
OF THE INTERTIDAL SPIDER, PARATHEUMA INSULANUS (DESIDAE)
Department of Zoology
Butler University

Paratheuma insulanus builds its egg cases in depressions on the underside of broken-up coral rock below the high tide line of the tropical Atlantic shores. After all the silk is added to the egg case, the spider adds a surface coating of oral secretions about 40 Å thick. Ruthenium red staining indicates the secretion is a glycoprotein. Individual fibers within the egg case are also surrounded with a similar-staining substance from the spinning apparatus. No function for the egg case coating has been established, but it may be important in waterproofing. Because of the location of the egg cases, it is likely that they are covered periodically by seawater sometime during the approximately 40 days between the egg laying and time of emergence of the young from the egg case. Preliminary experiments have shown that the adult spiders in their retreats can survive longer than 12 hours when submerged in seawater, but the effect of seawater on the egg case has not been investigated.

CANGIALOSI, Karen R., and UETZ, George W.
THE INFLUENCE OF ENVIRONMENT, HEREDITY, AND JUVENILE
EXPERIENCE ON THE SOCIAL STRUCTURE OF A COMMUNAL
TERRITORIAL ORB-WEAVING SPIDER
Department of Biological Sciences
University of Cincinnati

Metepeira spinipes, a communal/territorial orb-weaver from Mexico, shows considerable geographic variation and temporal flexibility in group size and social spacing. A series of laboratory studies was conducted to test whether the variation observed in the field is the result of behavioral plasticity, or the result of genetic mechanisms inherent in different populations. Spiders from source populations in desert and moist tropical habitats were collected as eggs and raised in the laboratory under identical controlled conditions. Measurements of three-dimensional spacing parameters in laboratory colonies (nearest neighbor distance, within-colony density) have shown significant differences in spatial organization between populations suggesting differences in genetic makeup. To test for the effect of experience on tolerance, experiments were conducted rearing tropical and desert spiderlings in isolation and in communal groups. Tropical spiders put together after isolation show spacing patterns and nearest neighbor distances similar to those seen in the communally reared groups. Desert

goods required in these remote towns are produced in the southern regions of Brazil where *Tityus serrulatus* is present.

This case of transportation by human agency is an isolated one. There should be no chance of permanent introduction of *Tityus serrulatus* into Amazonia, since it is only successful in modified environments and is selected negatively against the local species of the equatorial forest (Lourenço & Cloudsley-Thompson, 1996; Lourenço *et al.*, 1996).

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more, one for the new extant Pseudochactidae, another for the fossil Palaeopisthacanthidae. The last included information on Cretaceous taxa, most of which have been described by Wilson Lourenço. Despite this, high-level scorpion phylogeny and taxonomy are still basically unresolved, and the division of extant family groups is not yet settled. It is, however, to be hoped that this work will, for many years, serve the basic needs of taxonomists working on Scorpiones. Worth mentioning is that, following the example of the redoubtable Pierre Bonnet who summarised the rules 'De la nomenclature en sciences naturelles' in his '*Essai poétique*' (1948), Victor Fet concludes his own joint publication with 'An essay on scorpion'—in light-hearted verse written in the style of W. S. Gilbert.

Whilst on the subject of scorpions, it may be useful to add that, during the early 1960s, I worked, among other things, on the reproduction of the 'Omdurman scorpion' as *Leiurus quinquestriatus* (Buthidae) was called in Khartoum. Faysal Abushama was one of my research students in those days, and the same species formed the subject of his thesis. Neither of us was able to determine the sex of our specimens except by watching their reproductive behaviour or by dissecting them. A few years ago, the problem was solved for me by Wilson Lourenço, who pointed out that, in buthids, the male pectines are always larger than those of the female. Moreover, they usually overlap in their internal portions whereas the female pectines never overlap.

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Scorpion Taxonomy

by John Cloudsley-Thompson

Michael E. Sologlad and Victor Fet are to be congratulated on their latest publication: 'High-level Systematics and Phylogeny of the Extant Scorpions: (Scorpiones: Orthosterni)'. *Euscorpium. Occasional Publications in Scorpology*, No. 11, December 2003, 175 pp. This huge, comprehensive work on the taxonomy of all modern groups of scorpions includes a considerable amount of detailed character analysis. Many of these characters, such as tarsal spination, biogeography and cladistics, are described for the first time. Especially important is the analysis of a newly discovered relict genus, *Pseudochactas* from Central Asia. *P. ovchinnikovi* Gromov is most probably a Tethys relict. It is separated into its own family, superfamily and parvorder. It possesses a set of paired ventral median carinae on metasomal segment V, which is unique among recent scorpions so far described. One of the main issues for extant scorpion phylogeny has been its 'rooting' within fossil taxa. Many earlier authors had no reservations about deriving extant scorpions from Palaeozoic taxa. Some even derived present day genera from more than one fossil ancestor! Recent work by Sologlad & Fet, incorporated here, has been elaboration of the orthobothriotaxy of Max Vachon's three trichobothrial 'types' and the identification of two

With very best wishes
from
John