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BURROWING BIOLOGY OF THE SCORPION *CHELOCTONUS JONESII* POCOCK (ARACHNIDA: SCORPIONIDA: SCORPIONIDAE)

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ABSTRACT

The burrowing biology of *Cheloctonus jonesii* Pocock from southern Africa is described. Pedipalpal burrowing is dealt with for the first time, and related to aspects of the ecology of this scorpion.

INTRODUCTION

Little has been reported on pedipalpal burrowing among scorpions and the subject remains controversial. Pocock (1896) suggested that members of the north African genus *Scorpio* L. and the southern African genus *Opisthophthalmus* C. L. Koch excavate their burrows with their pedipalps. Since then, Newlands (1972) has ascertained that *Opisthophthalmus* spp. do not burrow in this fashion, but use their chelicerae to loosen the soil which is then gathered by the first pair of legs. Cloudsley-Thompson (1955) suggested that the pedipalps of *Scorpio maurus* L. are especially adapted for excavating burrows, but Newlands (1969) believes that the enlarged chelae in this species provide a protective shield while the scorpion is inside the burrow.

The burrowing biology of *Cheloctonus jonesii* Pocock is described here. The scorpion *C. jonesii* occurs in Zimbabwe (Rhodesia), Swaziland, Mozambique and South Africa, and within South Africa is found mostly in the northeastern and eastern Transvaal and in Natal. It is very abundant in Zululand (Natal) where densities of about 2 burrows per $3m^2$ have been found (Newlands, pers. comm.). *C. jonesii* appears to be restricted to areas of high rainfall (about 801-1250mm/year) in conjunction with soils of high clay content. Newlands (1972) associates it with pelitic soils, such as black turf. This species is more abundant on plains than in valleys, preferring coarsely and sparsely grassed areas, where it constructs its burrows in open veld at the base of (or among) grass tufts or occasionally under rocks.

MATERIALS AND METHODS

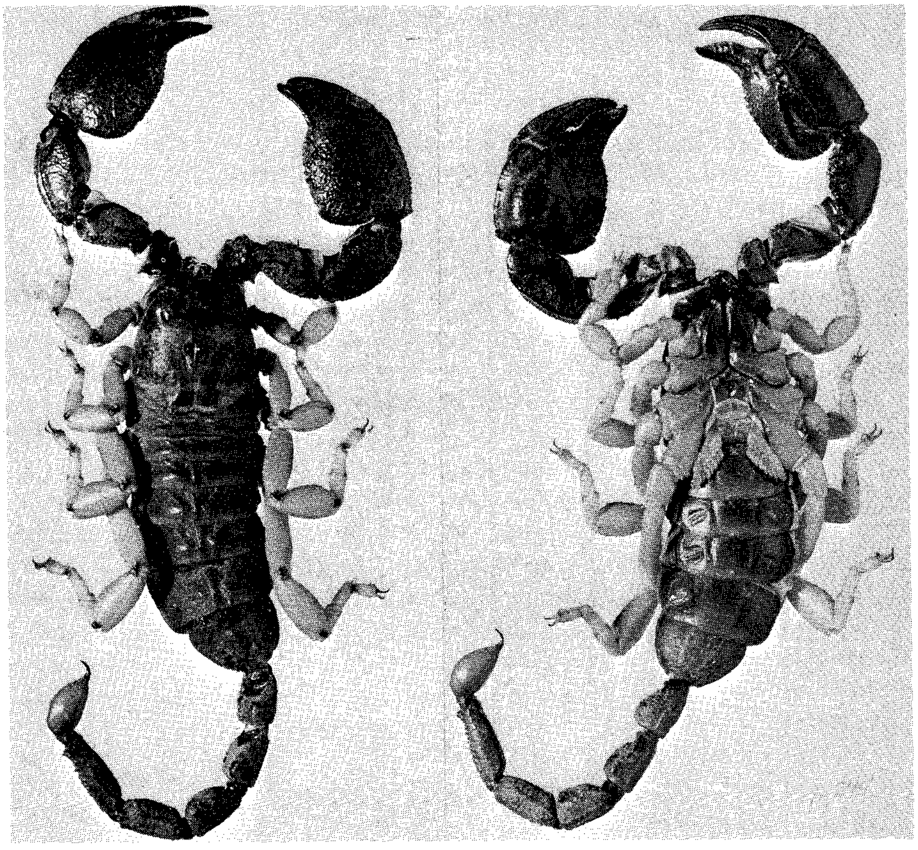
Field studies were carried out at Newington (eastern Transvaal), near Skukuza Kruger National Park), and at Pongola (in Zululand) in Natal Province, South Africa. Fifty burrows were carefully excavated, and occasionally plaster casts were made to obtain data on burrow structure.

Laboratory studies were performed in 40 liter terraria two-thirds filled with soil from the original habitat, and prepared to approximate natural conditions. Mature scorpions did not construct burrows in captivity, and observations were made on juvenile specimens. These scorpions did not excavate burrows during daylight hours, and all observations were made at night with the aid of visible red light.

OBSERVATIONS

Cheloctonus jonesii has the morphological traits commonly associated with fossorial habits in hard-packed soils. Among these are: heavy body; stout pedipalps with rounded chelae and broad, short fingers; relatively short metasoma (about 50% of total body length); and relatively short, stout legs with the tarsi armed ventrally with strong spines (Figs. 1 and 2).

Description of the burrow.—The burrow is generally found at the base of a tuft of coarse grass, or among two or three tufts. In the former case the tumulus is usually seen on one side of the burrow entrance only, while in the latter the tumulus is spread out



Figs. 1-2.—External morphology of *Cheloctonus jonesii* Pocock: 1, dorsal view; 2, ventral view (scale in mm).

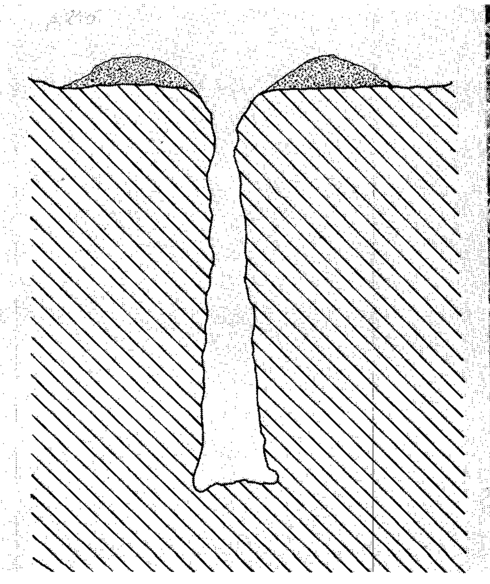
radially from the burrow entrance. The burrow is a simple tunnel with an oblong entrance (Figs. 3 and 4), penetrating the ground at about 70°-90° from the horizontal, and its diameter increases about one-third of the way down to about twice its entrance width. Burrow measurements taken in the field (Table 1) show little variability with the exception of depth as burrows of very young individuals are unusually shallow. Side tunnels are occasionally constructed, and in the Pongola region many of the excavated burrows had very short side tunnels (length less than about 3 cm). Exuviae, prey remains, and vegetal detritus were found in the short horizontal branches constructed from the terminal part of the main burrow. No second entrances to burrows were found.

Table 1.–Average measurements (in centimeters) of 42 burrows inhabited by *Cheloctonus jonesii* Pocock at Newington, Eastern Transvaal, South Africa (range in parenthesis).

	Males (n=10)	Females (n=17)	Immatures (n=15)
Entrance: width	2.8(1.5-3.5)	2.8(2.5-3.5)	2.2(1.5-3.3)
height	1.1(0.8-1.5)	1.3(0.8-2.5)	0.9(0.4-2.0)
Total depth:	18.5(14.0-22.0)	18.3(13.0-24.0)	15.6(4.0-22.0)

Digging behaviour.–Excavating the burrow is a lengthy process taking the scorpion two to three nights. Burrow construction in *C. jonesii* can be divided into three stages: (a) search for a suitable site, (b) soil loosening, and (c) soil transport.

Search. In apparent random behaviour the scorpion examines a large area before digging starts. The pectinal teeth are dragged continuously over the substrate, tending to support Carthy's (1968) suggestion that the sensory pegs on the teeth are mechano-



Figs. 3-4.–The burrow of *Cheloctonus jonesii* Pocock: 3, diagrammatic section of a burrow (about 20 cm deep); 4, typical burrow entrance (about 3 cm wide).

receptors involved in substrate selection. The pedipalps are also used occasionally by the scorpion to probe depressions and similar topographical features.

Soil loosening. The scorpion initiates this stage by extending and lifting the pedipalps. The trunk is arched dorsally, and is supported by the legs and the cauda. The metasoma is arched ventrally, and the ventral surfaces of segments 2 and 3 rest on the substrate. The pedipalps are then flexed (though not as strongly as in the resting position), and the chelae with slightly opened fingers are forced into the ground. The soil is loosened by forcefully wedging the chelal fingers almost vertically into the ground, and then flexing the chela. The convex external surfaces of the chelae function as fulcra after the initial 0.5cm of burrowing. Thus, the pedipalps are used much like "spades", and I consider the breadth, and relative shortness of the chelal fingers in *C. jonesii* to be an adaptation for excavation. Initially alternate pedipalps are used, but when burrowing has developed they are used simultaneously (Fig. 5).

Soil transport. Loose soil must be transported out of the vertical burrow shaft and away from its entrance. As in soil loosening, the pedipalps are the only appendages used for this purpose. One pedipalp is extended and then flexed, with the chela scooping loose soil and trapping it against the coxae, trochanters, femora and chelicerae. Similarly, the other pedipalp chela scoops more soil and traps it against the external face of the first chela (Fig. 6). Scooping and trapping of soil are done in one motion. Clods and small stones are taken between the chelal fingers, smaller ones by one chela and larger ones by both. Grass rootlets are grasped by both chelae and pulled loose, with an occasional thrust of the metasoma to snap the rootlet. The inner surfaces of the chelae are extensively granulated, providing friction against the slipping of collected soil.

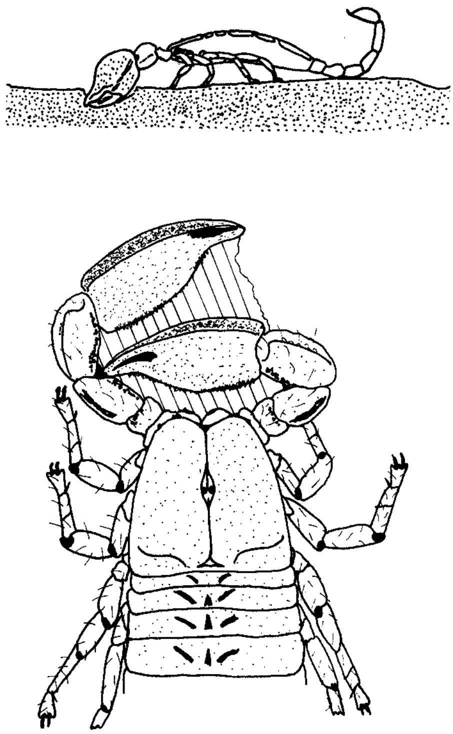
The "loaded" scorpion (with soil, a stone or a rootlet) backs up and out of the burrow. During this maneuver the first two pairs of legs push upwards while the last two pairs pull. During the climb the metasoma is flexed and the ventral surface of segment 5 (and sometimes 4) is pressed against the opposite burrow wall, acting both as a brace against slipping down and as a lever for moving up. The ventral keels on segment 5 are formed of posteriorly directed denticles; these denticles apparently function to facilitate vertical soil transport and not for tail-scraping as in many other fossorial scorpions. The rows of ventrolateral setae on caudal segment 5 found in most burrowing scorpionids are absent in *C. jonesii.* Upon reaching the burrow entrance the scorpion turns around and drops the load a few centimeters away. When the soil heaps up it is flattened and levelled by pushing with alternating pedipalps. Any soil particles caught between the chelal fingers are removed by the opposite chela after soil deposition.

Maintenance of the burrow consists of removing prey remains and unwanted soil, and is accomplished in a similar fashion to that described for soil transport. Examination of burrow tumuli and walls has shown that maintenance operations occur especially after rains (Fig. 4).

Interspecific interactions.—Much of the life of *C. jonesii* is centered in and around the burrow, and interspecific interactions are often conspicuous in this respect. My observations pertain to prey, predators and commensals.

Prey. The vertical burrow shaft of *C. jonesii* functions as a "pit-fall" trap for unwary prey. The remains recovered from excavated burrows consisted mainly of dung beetles and small tenebrionids.

Laboratory observations on scorpions feeding outside the burrow revealed that *C. jonesii* usually stings its prey. Stinging is done sideways rather than "overhead" (an action



Figs. 5-6.–Digging behaviour in *Cheloctonus jonesii* Pocock: 5, method of soil loosening; 6, method of soil transport.

that might be impeded inside the burrow). Prey are stung even where it is apparently unnecessary to subdue them.

Predators. Animals know to prey on *C. jonesii* are centipedes (*Scolopendra* sp.) and Lesser Red Musk Shrews (*Crocidura hirta* Peters) (collected in the field and fed in the laboratory). Studies by A. C. Kemp have shown that the hornbills *Tockus erythrorhyncus* (Temminck), *T. flavoristris* (Rüppell) and *T. nasutus* (Linnaeus) are predators of *C. jonesii*. The two former species are ground foragers and caught 95% of the total number of scorpions presented, while the latter is mainly arboreal and not an important predator (Kemp, pers. comm.). A large amount of *C. jonesii* remains were found among the tumuli of Bushveld gerbil (*Tatera leucogaster* Peters) burrows at Newington. In addition to this, chitinous remains were also found in gerbil faeces. These two observations suggest the Bushveld gerbil as a certain predator of *C. jonesii*. A well preserved whole scorpion was found in the faeces of the Cape porcupine, *Hystrix africae-australis* Peters (identified by I. L. Rautenbach), but since porcupines are vegetarians it is likely that the scorpion was ingested accidentally while on the surface (Rautenbach, pers. comm.).

The borrow of *C. jonesii* provides excellent protection from hornbills, shrews and gerbils as the entrance is too narrow to prevent access to the burrow. Centipedes are able to enter but probably stand little chance of overcoming the inhabitant unless it is young.

The narrow entrance and upper third of the burrow act to hinder the entrance of predators, while the wider lower two-thirds of the burrow provide ample maneuvering space for the scorpion. The massive chelae of *C. jonesii* serve not only to block access into the burrow for potential intruders, but also shield the front end of the scorpion from direct attack, and make it very difficult for potential predators to get a hold of the scorpion and pull it out of the burrow. If a potential predator succeeds in securing a grip of the pedipalp chela, the scorpion uses the legs to prevent itself from being dislodged, and could also use the metasoma to brace itself against the opposing burrow wall in a manner similar to that described for soil transport activities. Thus, most of the scorpions preyed upon are presumably taken outside the burrow (during maintenance operations or other surface activities).

Commensals. Crickets and terrestrial isopods were excavated from the terminal region of *C. jonesii* burrows. The terrestrial isopods presumably fell into the vertical burrow shafts and were unable to climb out, their distasteful and noxious properties preventing the scorpion from preying on them. The crickets might have wandered in or fallen in accidentally. Their means of escaping predation are not clear and permanent escape is probably rare. Lycosid spiders (*Lycosa* sp.) were found inhabiting the entrance and upper part in the majority of *C. jonesii* burrows at Newington and to a lesser extent at Pongola. These spiders were seen to leave the burrow, mainly during the night and occasionally during the day, presumably to hunt. Therefore they might not be actively competing for prey with the scorpion. If threatened, the spider retreats rapidly into the burrow, but rarely, if ever, ventures further than two-thirds of the way into the burrow. If coaxed with a blade of grass to penetrate deeper, they usually flee up and out. On one occasion, in the field, a spider fell into the terminal chamber and was seized by the scorpion. Apparent benefits to spiders occupying the upper part of *C. jonesii* burrows are effective protection against outside predators and dessication, and the burrows' role as a trap for prey.

DISCUSSION

Cheloctonus jonesii is the first confirmed pedipalpal burrower among fossorial scorpions. Most previously studied fossorial scorpions have burrows that are moderately inclined to nearly horizontal (Newlands 1969), and rely on their chelicerae, legs, and metasoma to loosen and transport soil from their burrows (Newlands 1972). Vertical burrows have been previously reported for the North American scorpion *Diplocentrus peloncillensis* Francke (Francke 1975), but nothing is known of the digging behaviour of this species. Morphologically, however, *D. peloncillensis* seems to be better adapted to dig with its legs since the last segments bear a pair of longitudinal rows of strong spines ventrally, and the pedipalp chelae are not as large and robust as in *C. jonesii*. An interesting ecological difference between these two species is that *D. peloncillensis* digs its vertical burrows under rocks, while *C. jonesii* does it in the open near or against tufts of coarse grass.

As mentioned earlier, the exposed burrow entrance of *C. jonesii* is valuable for prey capture, but the threat of flooding during rains could be serious. The evidence of burrow maintenance operations shortly after rains is an indication that flooding and subsequent deposition of soil in the burrows are not uncommon. Since *C. jonessii* occurs in areas of high rainfall it is possible that the vertical burrow and pedipalpal digging behaviour have evolved to cope with the main problems of flooding and deposition. Such flooding and deposition near the entrance of an inclined burrow could easily trap the scorpion and lead to suffocation, while in a flooded vertical burrow, material carried in by flooding would slide down the sides and raise the floor of the tunnel. Furthermore fossorial scorpions that rely on their chelicerae, legs, and metasoma to excavate probably do so poorly in mud. If so, they could not dig their way out of a collapsed flooded burrow efficiently and if they survived, maintenance operations or construction of a new burrow could not be performed for some time, exposing the scorpion to the elements and predators. *C. jonesii* on the other hand, being a pedipalpal burrower and occupying a vertical burrow could escape the perils mentioned above. It must be recognized, however, that other non-pedipalpal burrowers living in slanted burrows, for example, *Opisthophthalmus glabrifrons* Peters, can be found in the same areas as *C. jonesii*.

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