ISSN 0304–0798

PRINTED IN THE REPUBLIC OF SOUTH AFRICA BY THE RUSTICA PRESS (PTY.) LTD., WYNBERG,

IN DIE REPUBLIEK VAN SUID-AFRIKA GEDRUK DEUR DIE RUSTICA-PERS (EDMS.) BPK., WYNBERG, Ann. Natal Mus. Vol. 23(3) Pages 497–784 Pietermaritzburg December 1979

The Scorpions of Namibia (Arachnida: Scorpionida)

by

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SYNOPSIS

All the taxa of scorpions previously described or recorded from Namibia (South West Africa) are revised and a monographic account presented. Namibia is treated as a subregion of the Afrotropical (= Ethiopian) zoogeographical region and with limits of this subregion coinciding broadly with the political borders. All the characters used are defined and illustrated. Many characters previously unstudied are investigated, including trichobothria distributions and detailed structures of the hemispermatophores, and in a few species disc electrophoresis of the haemolymph. Ecological factors are extensively described and discussed. The nature of the substratum, taken in its broadest possible context, is found to be the most important single factor determining species distribution. 74 subgeneric taxa are revised, 46 of which are retained as valid and two as dubious while 10 new species are described, bringing the number of recognised species to 56. These are distributed among seven genera as follows: *Buthotus*, two species; *Karasbergia*, one species; *Parabuthus*, 14 species; *Uroplectes*, 10 species; *Hadogenes*, three species; *Lisposoma*, two species; *Opisthophthalmus*, 24 species. Keys are provided for all levels of taxa.

New species: *Parabuthus gracilis, P. namibensis, P. nanus, Uroplectes tumidimanus, Lisposoma josehermana, Opisthophthalmus coetzeei, O. gibbericauda, O. lornae, O. penrithorum, O. pygmaeus.*

New synonyms: *Buthus conspersus aeratus* Lawrence, 1927 = *Buthotus conspersus* (Thorell, 1877); *Parabuthus cristatus* Pocock, 1901 = *P. brevimanus* (Thorell, 1877); *Buthus fulvipes* E. Simon, 1887, *Parabuthus granulatus fuscus* Pocock, 1901, *P. granulatus bergeri* Werner, 1916 = *P. granulatus* (Hemprich & Ehrenberg, 1828); *Parabuthus ibelli* Werner, 1916. *P. laevifrons australis* Hewitt, 1918 = *P. laevifrons* (E. Simon, 1887); *Parabuthus laevifrons militum* Hewitt, 1918, *P. laevifrons concolor* Hewitt, 1918 = *P. stridulus* Hewitt, 1913; *Uroplectes alstoni* Purcell, 1901, *U. carinatus mediostriatus* Kraepelin, 1908 = *U. carinatus* (Pocock, 1890); *Uroplectes karrooicus* Purcell, 1901 = *U. schlechteri* Purcell, 1901; *Hadogenes lawrencei* Newlands, 1972 = *H. tityrus* (E. Simon, 1877); *Opisthophthalmus longiceps* Lawrence, 1941 = *O. adustus* Kraepelin, 1908; *O. gaerdesi* Lawrence, 1961, *O. carinatus scabriceps* Lawrence, 1966 = *O. brevicauda* Lawrence, 1928; *O. histrio* Thorell, 1877 = *O. carinatus* (Peters, 1861); *O. setiventer* Lawrence, 1969 = *O. intercedens* Kraepelin, 1908; *O. scabrifrons* Hewitt, 1918, *O. opinatus bradfieldi* Hewitt, 1931 = *O. opinatus* (E. Simon, 1887); *O. undulatus* Kraepelin, 1908, *O. laevicauda* Roewer, 1943 = *O. schultzei* Kraepelin, 1908; *O. vivianus* Lawrence, 1969, *O. pictus nigrocarinatus* Lawrence, 1969 = *O. setifrons* Lawrence, 1961; *O. luciranus* Lawrence, 1959 = *O. ugabensis* Hewitt, 1934; *O. wahlbergi gariepensis* Purcell, 1901, *O. wahlbergi nigrovescicalis* Purcell, 1901 = *O. wahlbergi* (Thorell, 1876).

New combination: *Opisthophthalmus jenseni* (Lamoral, 1972), ex *Protophthalmus*.

New status: *Uroplectes carinatus gracilior* Hewitt, 1913 raised to *U. gracilior; Uroplectes schlechteri* Purcell, 1901 lowered to *U. carinatus schlechteri* by Hewitt, 1918: 118, raised back to its original status; *Opisthophthalmus intercedens fitzsimonsi* Hewitt, 1935 raised to *O. fitzsimonsi; Opisthophthalmus gigas haackei* Lawrence, 1966 raised to *O. haackei; Opisthophthalmus undulatus ugabensis* Hewitt, 1934 raised to *O. ugabensis.*

Dubious species: *Hadogenes bifossulatus* Roewer, 1943; *Opisthophthalmus werneri* Lamoral, 1975.

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INTRODUCTION

The Namibian scorpion fauna is known mainly through publications by the following workers: Karsch (1879); Simon (1887); Thorell (1876–7); Peters (1861); Kraepelin (1897, 1899 & 1908); Purcell (1898–1901); Hewitt (1913–35) and Lawrence (1927–69). Hewitt (1918) published the first monograph on and key to the fauna of South Africa including species described from Namibia. Lawrence (1955) produced a comprehensive checklist of the southern African fauna (including Namibia) and updated Hewitt's 1918 key. Lamoral & Reynders' (1975) catalogue includes all the species described from Namibia up to December 1973.

Seven extant families of scorpions are recognised in the world. Representatives of two, Buthidae (genera *Buthotus, Karasbergia, Parabuthus* and *Uroplectes*) and Scorpionidae (*Hadogenes, Lisposoma* and *Opisthophthalmus*) occur in Namibia.

Of the 175 infrageneric taxa listed from southern Africa (south of the 17° latitude) in the 1975 catalogue, 74 (42%) are reported from Namibia. As Namibia covers approximately 25% of the surface area of southern Africa a large proportion of the fauna is concentrated in this area. On the assumption that the proportion of invalid taxa will be found to be approximately the same for the whole of southern Africa, it is suggested that the above percentage will remain more or less the same when the fauna of southern Africa has been completely revised.

Motivations

The decision to revise the scorpion fauna of Namibia was based on several considerations, the more important of which were: 1. The taxonomy of the group was in dire need of revision with many suspected synonymies causing problems in phylogenetic appraisals. 2. Virtually all previous publications are of a purely taxonomic nature, containing little or no biological information and are mostly based on few specimens and consequently lack information on intraspecific variation. 3. No comprehensive treatise or illustrated key to species exists for the fauna of this vast subregion. 4. Preliminary findings indicated that a very large proportion of the fauna was endemic and that consequently Namibia represents a major subregion of the Afrotropical Region (Afrotropical Region = Ethiopian faunal region, Crosskey & White, 1977). 5. Namibia was poorly sampled although supporting a large number of species.

Aims, limitations and results

The present study was initiated as an attempt to overcome the deficiencies outlined above and to present as complete a monographic account as possible.

Only taxa recorded within the political borders of Namibia are revised as these borders were found to coincide broadly with the biogeographic limits of this subregion.

This publication is based on the greater portion of my Ph.D. thesis (Lamoral, 1978). Interspecific affiliations recorded are those arrived at in the thesis as a consequence of the phylogenetic and biogeographic discussions and conclusions derived in terms of current concepts in systematic zoology which include cladistics and historical biogeography. Work on cladograms incorporating all the species within these genera is still in progress.

The following general conclusions are, however, offered here on the basis of phylogenetic, palaeogeographic, palaeoclimatic and biogeographic considerations discussed in my thesis:

1. The scorpion fauna of Namibia is derived from elements that originated in Laurasia during Pangean times. These elements migrated overland to the north African region of Gondwanaland and ultimately to southern Africa in the wake of the southward shift of the warm tropical belt, resulting from the drifting of landmasses which led to the present configuration of continents and climates. Some of those elements gave rise to genera now widespread in the Afrotropical and Oriental regions (*Buthotus* and *Uroplectes*), others to genera endemic to the Afrotropical region (*Parabuthus*) or subregions thereof, such as southern Africa (*Opisthophthalmus* and *Hadogenes*) and Namibia (*Karasbergia* and *Lisposoma*).
2. The spatial restriction of groups of taxa, such as an entire genus, distinct groups of species within a genus, or single species, is the result of vicariance, which has led to endemicity and a limited scope for contemporary dispersal. In many instances, the proposed vicariance agents are either still in existence (as in the case of the Kalahari sand system, or the Central Highlands of Namibia), or testable evidence is available for their past existence, and these thus provide a high degree of congruence with disjunct distribution patterns. In other instances, however, the inferred agents of vicariance are, at this stage, only speculative. Psammophilous species, however, most probably evolved as a result of dispersal from within Namibia into any one of the adjacent sand systems rather than as a result of vicariance. As a matter of fact, phylogenetic deductions from the genus *Opisthophthalmus* indicate that the psammophilous species are the most advanced ones (i.e. the *wahlbergi* group) and consequently the most recently evolved. It follows that psammophilous species must have evolved *after* the sand systems had become well-established and that the most likely way in which speciation could have taken place was through dispersal into an ecosystem which previously constituted a barrier.
3. Taking possible vicariance and dispersal into consideration, no affinities could be found between the scorpion fauna of either Namibia or southern Africa and South America. This lack of affinity was found to prevail from generic to subfamily levels for the family Buthidae and to family level for the Scorpionidae. Except for the controversial status of species of the genus *Opisthacanthus* in the Neotropical Region (see Newlands, 1973 and Francke, 1974) members of the family Scorpionidae are totally absent from the New World and it is concluded that the family evolved in post Cretaceous times after the continents of the New World had drifted away from Laurasia and Gondwanaland respectively.
4. All the genera of the family Scorpionidae occurring in Namibia and in southern Africa for that matter (excepting the genus *Opisthacanthus* in the latter instance) are endemic to southern Africa and with the probable

exception of Lisposoma, represent the more advanced taxa of scorpions in the subcontinent.

5. The nature of the substratum, taken in its broadest possible definition, is probably the most important single factor that has determined and still determines the distribution of scorpions. The nature of the substratum is affected to a greater or lesser extent by vegetation which is in turn partly the result of prevailing climatic conditions.
6. Since the Pliocene, the Kalahari sand system has operated as an agent of vicariance preventing migration of scorpion species along the north-east to south-west 'drought corridor' described by Balinsky (1962).
7. *Buthotus arenaceus* and *B. conspersus* are endemic to the Namibia subregion and represent the only two species of this genus occurring therein.
8. Because of the contradictory nature of the similarities between *Karasbergia methueni* and various other genera studied, no clearcut affiliation is possible at this stage. One can but suspect that *K. methueni* is probably a relic of a former forest-dwelling fauna that survived the advent of aridification by adopting a semi-endogean existence prior to its present infralapidicolous one.
9. The 14 valid species of *Parabuthus* occurring in Namibia represent three main groups of species, namely: (i) the '*brevimanus* group', composed of *brevimanus, kuanyamarum, gracilis* and *nanus*; (ii) the '*granulatus* group', composed of *granulatus* and *kalaharicus*; (iii) the '*villosus* group', composed of the remaining eight species. The *villosus* group is further divisible into two subgroups, namely the '*raudus*' (*villosus, brachystylus, raudus* and *schlechteri*) and '*laevifrons*' (*stridulus, laevifrons, kraepelini* and *namibensis*) subgroups. The *granulatus* group is a sister group of the *villosus* group while both of these form a large sister group to the *brevimanus* group.
10. The 10 valid species of *Uroplectes* occurring in Namibia represent four main groups of species, namely: (i) the '*planimanus* group', consisting of *teretipes, tumidimanus* and *planimanus*; (ii) the '*vittatus* group', composed of *vittatus* and *otjimbinguensis*; (iii) the '*pilosus* group', comprising *pilosus, longimanus, schlechteri* and *gracilior*; (iv) the '*carinatus* group', represented by only one species in Namibia, namely *carinatus*, whose sister species *variegatus* (C. L. Koch, 1845*a*) is distributed in the south-western regions of the Cape Province of South Africa. The *carinatus* group is a sister group of the *pilosus* group and both are sister groups of the *vittatus* group of which all three form a large sister group of the *planimanus* group.
11. No phylogenetic appraisal of the three valid Namibian species of *Hadogenes* is possible at this stage as they form only a minor group in comparison with the 24 species described from outside Namibia, the taxonomy of which is chaotic.
12. Because of the uncertainty of its phylogenetic relationship with other taxa of the family Scorpionidae, one can but suspect that the endemic genus *Lisposoma* represents a relic of a formerly tropical forest-dwelling ancestral element that survived the onset of aridification by resorting to a semi-endogean existence. The fact that *L. josehermana* still occupies a euedaphic

habitat tends to lend support to this suggestion. Adaptation to an infralapidicolous habitat by *L. elegans* must have contributed greatly towards its present fairly wide distribution.

13. The 24 valid species of *Opisthophthalmus* occurring in Namibia represent three main groups of species, namely: (i) the '*carinatus* group', composed of *gigas, haackei, brevicauda, carinatus, ugabensis, litoralis* and *cavimanus*; (ii) the '*opinatus* group', composed of *opinatus, coetzeei, gibbericauda, intercedens, fitzsimonsi, lornae, schultzei, adustus* and *setifrons*; (iii) the '*wahlbergi* group', composed of *wahlbergi, chrysites, penrithorum, flavescens, pygmaeus, concinnus, holmi* and *jenseni*. The *carinatus* group is a sister group of the *opinatus* group while both of these form a large sister group to the *wahlbergi* group.
14. In the distinctly tapered and fusiform distal crests of the distal lamina of their hemispermatophores, *Opisthophthalmus holmi* and *O. jenseni* share a character state uniquely derived in this genus. It was felt at some stage that such uniqueness provided sufficient distinctness to retain *holmi* and *jenseni* within Lawrence's (1969: 105) genus *Protophthalmus*. The existence of several synapomorphies between the *holmi-jenseni* sister species and other species within the *wahlbergi* group has, however, prompted me not to reinstate the genus *Protophthalmus* as anticipated previously (Lamoral & Reynders, 1975: 569). The *wahlbergi* group is endemic to the Namibia subregion and there are no extralimitrophe species that fall within this group.

Material

The material studied was obtained as follows: 1. about 3 500 specimens collected during five field expeditions to Namibia in 1969, 1970, 1972, 1973 and 1976; 2. about 1 600 specimens collected by staff members of the State Museum in Windhoek in support of this project; 3. about 300 specimens sent for study by various institutions; 4. approximately 300 specimens examined in the collections of the Musée national d'Histoire naturelle in Paris and the British Museum (Natural History) in London.

Thus approximately 5 700 specimens were examined altogether. Previously published records for the species revised here are available from Lamoral & Reynders' (1975) catalogue and have not been duplicated.

Methods

In accordance with current approaches in systematics, no formal subspecific names are used. Previously described subspecies were found to be either inseparable from their typical form or to exhibit diagnostic differences warranting species status.

Character states described in the diagnosis as well as those comprehensively described in the literature are in most cases not repeated in the detailed description of each species which as a result only contains new or corrected information.

A fairly large proportion of the type material examined is deposited overseas institutions and consequently not readily available. Whenever possib I have designated a homotype for such types. Mayr *et al* (1953: 239) give t following definition for homotype: 'A specimen compared by another than t author of a species with the type and determined by him to be conspecific wi it.' Homotypes are not recognised as types in the Code of Zoological Nome clature but designation of such typical specimens is certainly useful.

Colour descriptions for all the species treated are given using the ISCC-NI Colour Designation (Kelly & Deane, 1965) which consists of the standard colo name followed by its number. Although Munsell Renotations are supplied Kelly & Deane, these are not quoted in colour descriptions of the species, they are too lengthy and can in any case be looked up in the tables provided these authors.

In the lists of material examined, only the first of a series of collectors mentioned while other data are often abbreviated to save space.

Subadult and juvenile are abbreviated to subad and juv respectively.

A gazetteer of all the localities listed for the material examined during t present survey is supplied.

Field work was planned to include visits to as many type localities as possib in an attempt to collect topotypes.

Field methods. The use at night of two portable ultra-violet light units during r last three expeditions to Namibia greatly improved collecting yields. It has be known for some time that scorpions fluoresce when subjected to U-V light b this technique had never before been used in southern Africa. The use of a ra on sandy substrata under shrubs and other small plants often yielded go results during daytime collecting. Pitfall traps set in the ground yielded compa tively poor results. Other collecting methods included digging out burrov looking under stones, rocks, bark of trees and, generally, inspecting any potent shelter.

Laboratory methods. Measurements were taken using either a sliding mic meter or a microscope measuring eyepiece, and most of the drawings we prepared using a camera lucida. In most instances, measurements of typic specimens are not provided in the description of species as these are read available from figures.

Abbreviations for research institutes

AM—Albany Museum, Grahamstown, South Africa.
ANG—Museu do Dundo, Luanda, Angola.
BM—British Museum (Natural History), London, England.
GNM—Göteborgs Naturhistoriska Museet, Göteborg, Sweden.
LUZM—Lund University Zoology Museum, Lund, Sweden.
MCZ—Museum of Comparative Zoology, Cambridge, Massachusetts. Unit States of America.
MNHP RS—Museum national d'Histoire naturelle, Paris.
NM—Natal Museum, Pietermaritzburg, South Africa.
NMS—Natur-Museum Senckenberg, Frankfurt, Germany.

NMW—Naturhistorischen Museum, Wiesbaden, Germany.
NRS—Naturhistoriska Riksmuseet Stockholm, Sweden.
SAIMR—South African Institute for Medical Research, Department of Entomology Collection, Johannesburg, South Africa.
SAM—South African Museum, Cape Town, South Africa.
SMN—State Museum, Windhoek, Namibia (South West Africa).
TM—Transvaal Museum, Pretoria, South Africa.
WUS—Wiener Universität Sammlung, Vienna, Austria.
ZMB—Zoologisches Museum Berlin, DDR Berlin, Germany.
ZMH—Zoologische Staatsinstitut, Zoologische Museum Hamburg, Germany.

Acknowledgements

I wish to express my gratitude to the following for their assistance in the course of this investigation.

For their mentorial support: Professors J. Heeg and J. A. Meester. For financial support of field work: The Council for Scientific and Industrial Research, The Council of the Natal Museum and Total Petroleums S.A. (Pty) Ltd. For permission to work in areas under their jurisdiction: The Department of Nature Conservation and Tourism of Namibia, the Department of Plural Administration of Namibia, the Namib Desert Research Unit at Gobabeb. The Consolidated Diamond Mines of Namibia Ltd, Imcor Zinc (Pty) Ltd at Rosh Pinah and Ochta Diamonds (Pty) Ltd. For help with many general aspects and for collecting numerous specimens: Mr C. G. Coetzee, the Director of the State Museum in Windhoek, and staff members Dr M-L. Penrith and Mr M. Penrith, Dr P. Olivier and Mr S. Louw. For their hospitality and in most instances, permission to camp and work on their properties, all the owners of farms or land listed under material examined. In this regard I am particularly indebted to: Mr & Ms H. Erni, Mr A. Port, Mr J. Botha, Dr M. Seely and Dr H. Ebedes. For their congenial participation in field work during the various expeditions: 1969, Dr R. Day; 1972, Mr A. Bannister; 1973, Messrs L. Raw and K. Porter; 1976, Ms L. Ferguson and Mr & Ms J. Alfers. For the loan of material and various facilities provided: The Director and staff members of all the Research Institutes listed under abbreviations for Research Institutes. For the hospitality provided while working in their Research Institutes: Dr C. K. Brain (Director), Messrs G. Newlands and W. Haacke and staff members, Transvaal Museum, Pretoria; Dr T. Barry (Director) and staff members, South African Museum, Cape Town; Professor M. Vachon (Director) and colleagues, Laboratoire des Arthropodes, Museum national d'Histoire naturelle, Paris; Professor P. L. G. Benoit (Director) and staff members, Section des Invertébrés (non Insectes), Musée royal de l'Afrique centrale, Tervuren; Mr F. Wanless and Dr B. Parry, Department of Arachnology, British Museum (Natural History), London. For discussions on and laboratory facilities for haemolymph electrophoresis and related aspects: Dr M. Goyffon, Museum national d'Histoire naturelle, L.E.R.A.I., Paris; Professor G. Quicke and Dr I. Dreosti, Department of Biochemistry, University of Natal, Pietermaritzburg, and Dr Barry Bredenkamp, Institute of Parasitology, Durban.

For the conscientious typing of the manuscript of this publication: Ms P. Jerling. For executing a few of the drawings and for her moral support: Ms L. Ferguson. For her help with the preparation of photographs: Ms A. Seymour. For some drawings: Ms S. Britz. For discussions on the manuscript: Drs J. Londt, B. Stuckenberg, R. Miller and D. Brothers. For permission to reproduce one of his maps: Dr W. G. Coaton. For her help with the translation of Werner's German description of *O. pilosus*: Ms H. Colenbrander.

BIONOMICS

Habitat

Desert and semi-desert biomes, such as found in well over half of the Namibian region, are the least complex of all terrestrial biomes and offer a smaller selection of potential habitats than any other.

The scorpions of this region have successfully adapted to virtually the full range of potentially compatible terrestrial habitats and the degree of their success in colonising these is reflected in the ubiquitous nature of these animals.

A broad analysis of the Namibian scorpion fauna according to habitat preference appears in Table 1. More detailed information on the habitats of individual species is given in the section on systematics. Table 1 shows that 89,5% of the fauna is hemiedaphic, 8,9% epigeic and 1,8% euedaphic. Some of the species which have a preference for a particular habitat in one region are often found in a different habitat in another region if their preferred habitat is not available. *Buthotus conspersus*, for instance, can be found either under rocks or under the bark of trees, but the former is the preferred habitat where both are available. No species is unselective in its choice of habitat, but a few species can be found wandering from one habitat to another when searching for prey. Also, *Uroplectes gracilior* has often been found moving about at night on shrubs, occasionally on trees and in rock crevices in the same locality, although it normally rests under rocks on the ground during its diurnal inactive period and its normal habitat during the nocturnal active period is on the ground. *Uroplectes otjimbinguensis*, by contrast, is always epigeic on vegetation ranging from trees to large shrubs and is very seldom found on the ground.

As seen from Table 1, 42,8% of the scorpions of Namibia are fossorial and the surface and underground configuration of their burrows is of interest.

There is very little variation in the external configuration of burrows in all species and the occasional discrepancies observed are due entirely to local topographical adaptations and not to definite intraspecific patterns. The surface configuration of burrows of *Opisthophthalmus wahlbergi* and *O. holmi* is shown in Figs 1 and 2 respectively. The burrow entrances of scorpions are oval in cross-section and enable one to distinguish them from those of other fossorial arthropods, which in the majority of cases are round in cross-section. In addition, a fan-shaped mound radiating away from the entrance and consisting of the soil that has been excavated and pushed out is always found at the mouth of freshly dug or deepened burrows.

Data on the underground configuration of burrows were collected for most

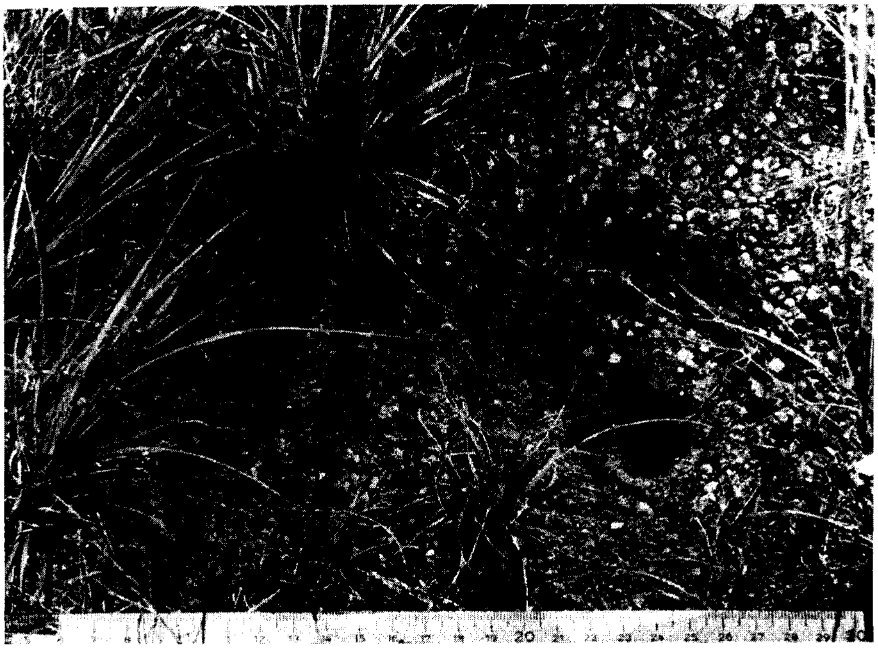


Fig. 1. Entrance to burrow of *Opisthophthalmus wahlbergi* on farm Kangas 371.

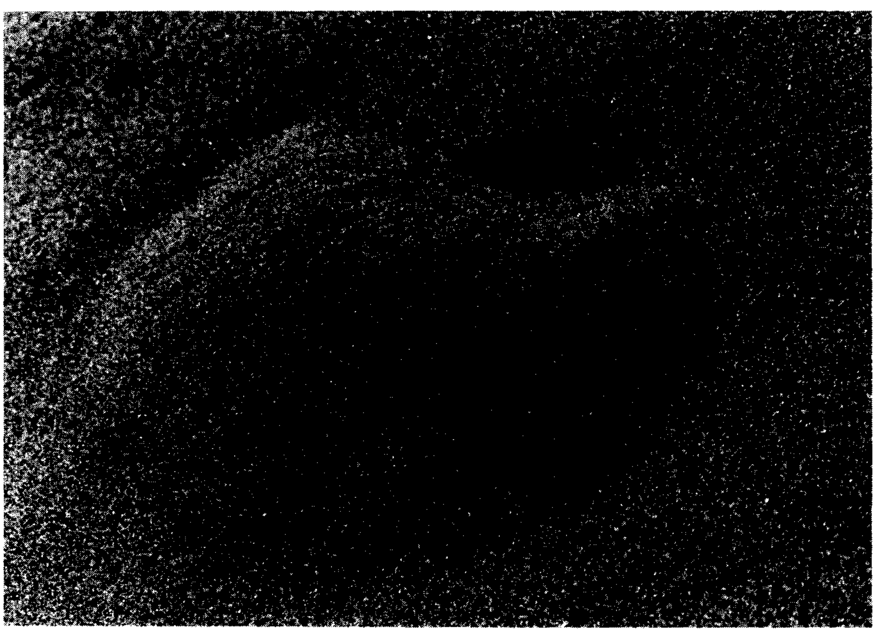


Fig. 2. Entrance to burrow of *Opisthophthalmus holmi* on slanting side of sand dune shown in Fig. 9.

fossorial species. A study of these revealed that there were no significant interspecific differences and that no single configuration represented an intraspecific characteristic. The average configuration of a burrow is as follows. At a point about 10–20 cm from the entrance, the burrow spirals vertically down for one to three turns and thereafter follows a random downward path to the bottom of the burrow which is enlarged into a chamber big enough to enable the scorpion to turn around.

Morphological adaptions

The scorpions of Namibia display an interesting range of morphological adaptations to their habitats. These are described, whenever relevant, under the individual species treated. The following is a generalised description of the different adaptations to the habitats listed in Table 1.

All Namibian fossorial species use their chelicerae to loosen soil particles and their anterior two pairs of legs to scrape and rake soil out of the burrow. Fossorial species burrowing in hard soils have powerful chelicerae and short robust legs provided with rows of stout, spine-like setae distributed laterally and distally so as to improve the efficiency of burrowing.

Ultrapsammophilous and to a lesser extent psammophilous species have long legs with long claws, a pad of numerous fine setae on the ventral surface of all telotarsi, and comb-like rows of long setae on the anterior and posterior edges of tibia, basitarsi and telotarsi of legs I and II (Figs 22–23). The latter adaptation is particularly well-developed in burrowing ultrapsammophilous species such as *Opisthophthalmus holmi.*

Infrasaxicolous, lithoclasicolous (habitat illustrated in Fig. 3) and infracorticicolous species tend to have greatly dorso-ventrally compressed bodies and appendages, long and slender tails, and short, stout spine-like setae on the ventral surfaces of telotarsi I–IV which operate in conjunction with the greatly curved claws to provide the legs with a vice-like grip on rough surfaces such as rocks and trees. This adaptation efficiently enables such scorpions to move rapidly in any spatial plane of their habitat.

Ecological factors

The selection of habitats and distribution of scorpions, as in other animals, is governed by an interaction of various ecological factors. The following sections on soils, vegetation, climate, topography and geology serve as a summary of available information on these broad ecological factors. The importance of such factors and their possible effects on distribution and range of species are dealt with elsewhere.

Soils: All scorpions of the genus *Opisthophthalmus* find shelter by digging burrows in the ground. It was found (Lamoral, 1978) that in Namibian species of this genus, habitat selection, distribution and range are directly correlated with soil hardness, and, to a much lesser and variable extent, texture, but not specific geological composition. Arbitrary categories of soil hardness were designated (Lamoral, 1978, Table 1) with the first and last categories representing the softest and hardest burrowing substrata investigated. Each category is delimited by a

Fig. 3. Crevice in a large boulder; typical habitat of lithoclasicolous species such as those of *Hadogenes*.

range of soil hardness expressed as the penetration force in kg cm^{-2} required to break up the soil. These arbitrary soil categories have, for convenience, been reproduced here as Table 2. Examples of the relevant soil categories for each Namibian species of *Opisthophthalmus* can be found in the sections dealing with bionomics in the main systematic section of this paper.

Vegetation: The characterisation of Namibian vegetation was necessary in the present study and I found that I was able to categorise the vegetation (Fig. 4) into the fourteen types described and delimited by Coaton & Sheasby (1972). Figs 5–17 are illustrations of a selection of these vegetation types. Notes on the correlation of scorpion species with vegetation appear in the relevant parts of the systematic section of this paper.

Climate: Taking into account such aspects as temperature, rainfall, wind and solar radiation, Barnard (1965) and Köppen (1931) divided Namibia into the climatic regions shown in Fig. 18 and Table 3. Symbols, such as BW kln, used as abbreviations for the different climatic regions, are those used by Köppen and are internationally accepted by geographers. A comparison of Figs 18 and 19 correlates climate with altitude.

Topography and geology: A broad impression of the topography of Namibia is given in Fig. 19. Namibia is roughly divisible into three major topographical zones: 1. the coastal zone delimited by the 900 metre contour; 2. the interior plateaux with altitudes ranging from 900 to 1 200 metres; 3. the interior highlands composed of the highland plateaux (1 200–1 500 metres) and mountains (1 500

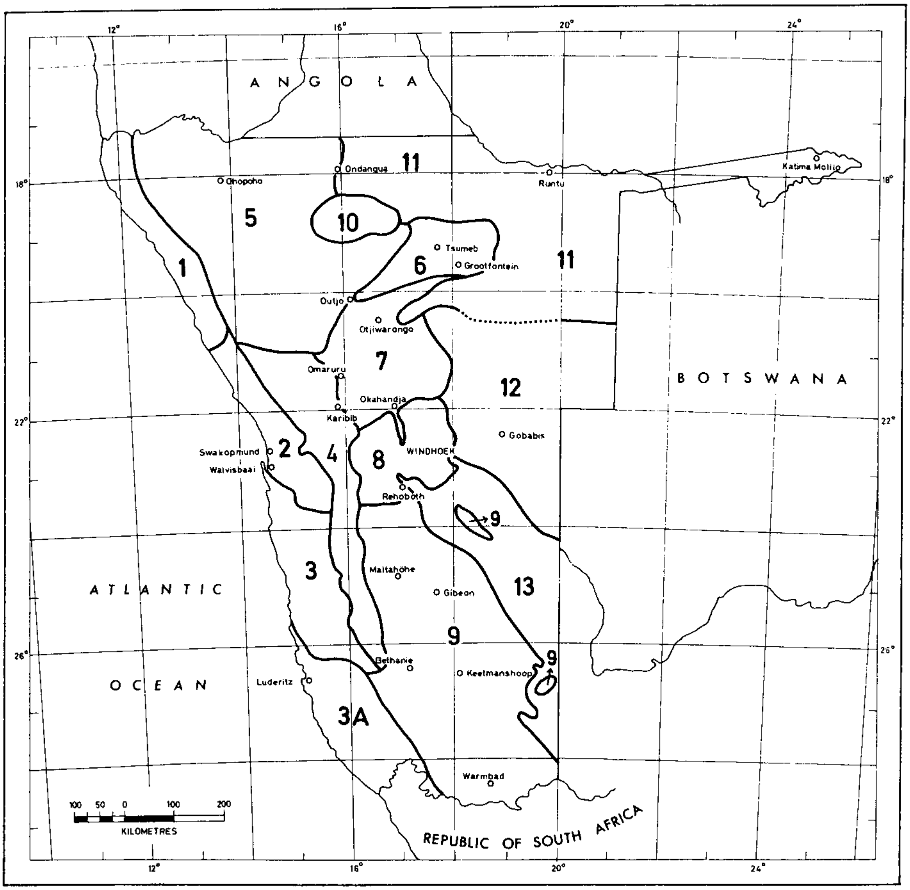


Fig. 4. Delimitation of the 14 vegetation types of Namibia. (After Coaton & Sheasby 1972).

1 Northern Namib (Desert)
2 Central Namib (Desert)
3 Southern Namib (Desert)
3A Desert and Succulent Steppe (Desert & Steppe)
4 Semi-desert and Savanna Transition (Savanna)
5 Mopane Savanna (Savanna)
6 Mountainous Savanna and Karstveld (Savanna)
7 Thornbush Savanna (Savanna)
8 Highland Savanna (Savanna)
9 Dwarf Shrub Savanna (Savanna)
10 Saline Desert with Dwarf Shrub Savanna Fringe (Desert & Transition)
11 Woodland and Forest Savanna: Northern Kalahari (Woodland Savanna)
12 Camelthorn Savanna: Central Kalahari (Savanna)
13 Mixed Tree and Shrub Savanna: Southern Kalahari (Savanna)

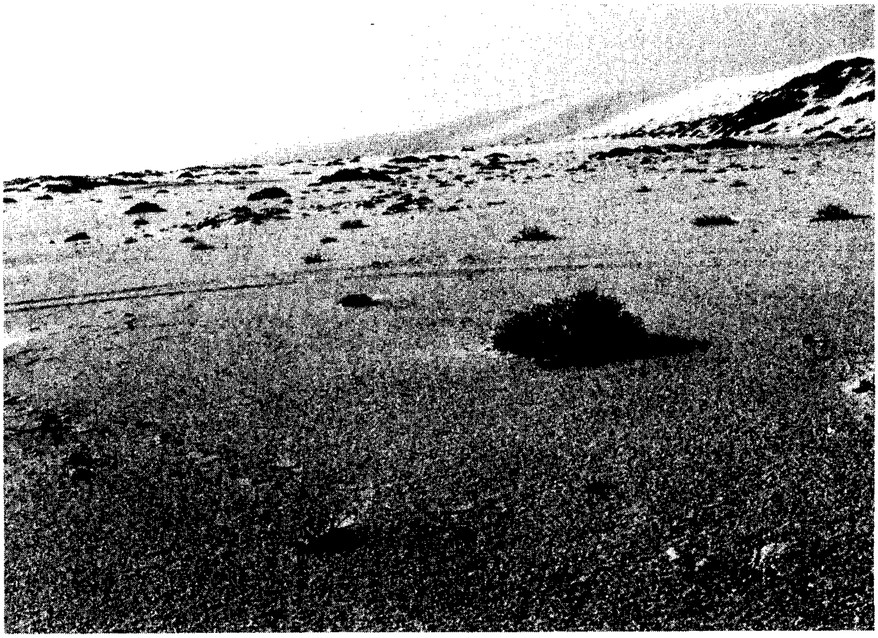


Fig. 5. Vegetation type 1, Northern Namib. Showing high white sand dune in the right background with bushes of *Acanthosicyos horrida* and small dunes on gravel plains elsewhere. Area shown is 8 km NE of Möwebaai, Skeleton Coast.

Fig. 6. Vegetation type 2, Central Namib. North-western region. Coastal strip north of Cape Cross. The small dunes (less than 90 cm high, 2–3 metres in diameter) are covered with perennial small shrubs belonging to the genus Trianthema. Typical habitat of *Parabuthus stridulus*.

Fig. 7. Vegetation type 2, Central Namib. South-eastern region. Gravel plains near Zebra Pan, in Namib Desert Park.

Fig. 8. Marginal zone between vegetation types 2, Central Namib and 3, Southern Namib. Looking north. The beginning of the sand dune system of the southern Namib is seen in the foreground. The Kuiseb river bed and banks with numerous *Acacia* sp. trees runs across the centre and the beginning of the Central Namib gravel plains is seen beyond that. Area near Homeb.

Fig. 9. Vegetation type 3, Southern Namib. Northern region. Habitat of *Opisthophthalmus holmi* showing tufts of *Stipagrostis sabulicola* on small dunes in one of the valleys between the large dunes near Suidrivier, 10 km west of Gobabeb, Namib Desert Park. The large dune in the background is partly misted over by incoming Namib fog.

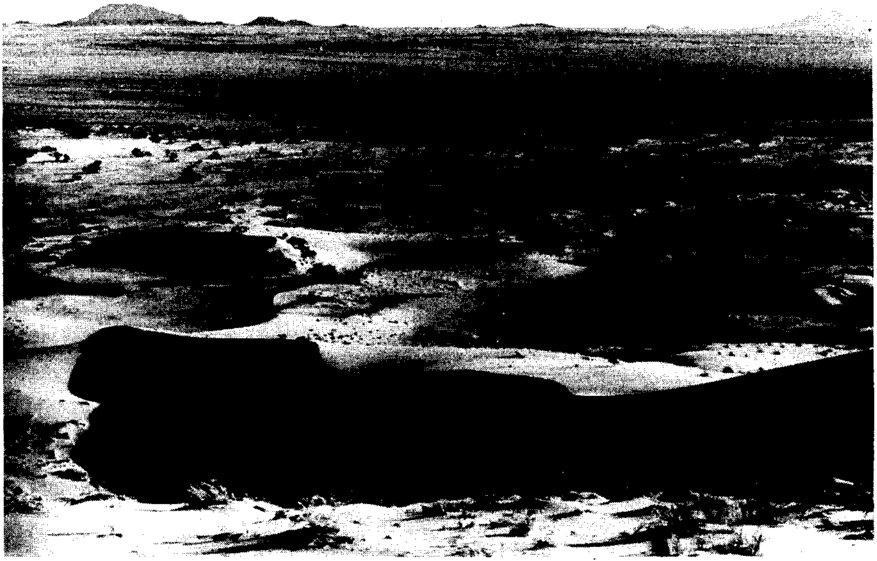


Fig. 10. Marginal zone between vegetation types 3, Southern Namib and 3A, Desert and Succulent Steppe. Looking South. The beginning of the high sand dune system of the Southern Namib is seen in foreground. The Koichab river bed and banks with numerous *Acacia* sp. trees runs across the upper centre and the beginning of the Desert and Succulent Steppe is seen beyond that. Area photographed is approximately 65 km NNW of Aus.

Fig. 11. Vegetation type 3A. Succulent Steppe, on farm Tsirub 13, 35 km SW of Aus. Typical habitat of *Opisthophthalmus adustus*.

Fig. 12. Vegetation type 4, Semi-desert and Savanna Transition. East of the Brandberg Mountains (seen in the distant background).

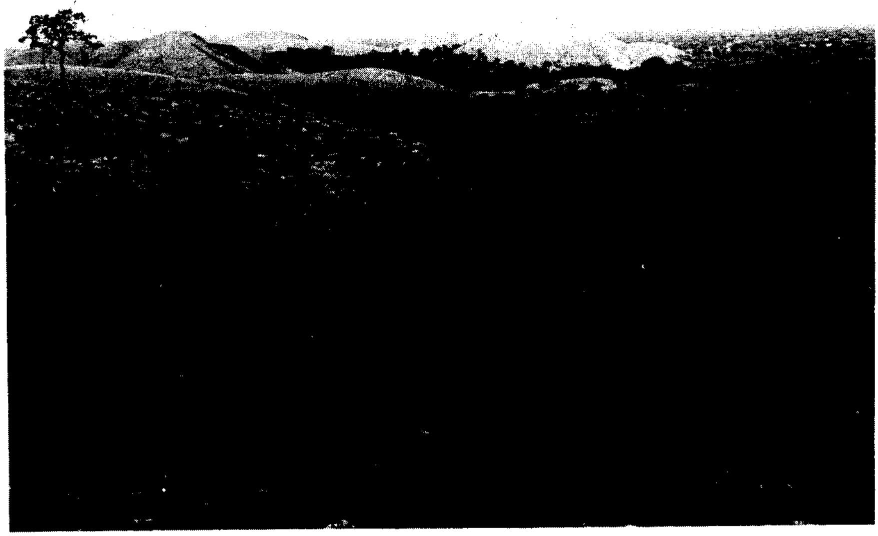


Fig. 13. Vegetation type 5, Mopane Savanna. Area NW of Sesfontein. *Buthotus conspersus* and *Lisposoma elegans* were found among the rocks seen in the foreground and centre left area of this photograph.

Fig. 14. Vegetation type 8, Highland Savanna. Broken terrain in the Khomas Hochland on farm Bergkranz.

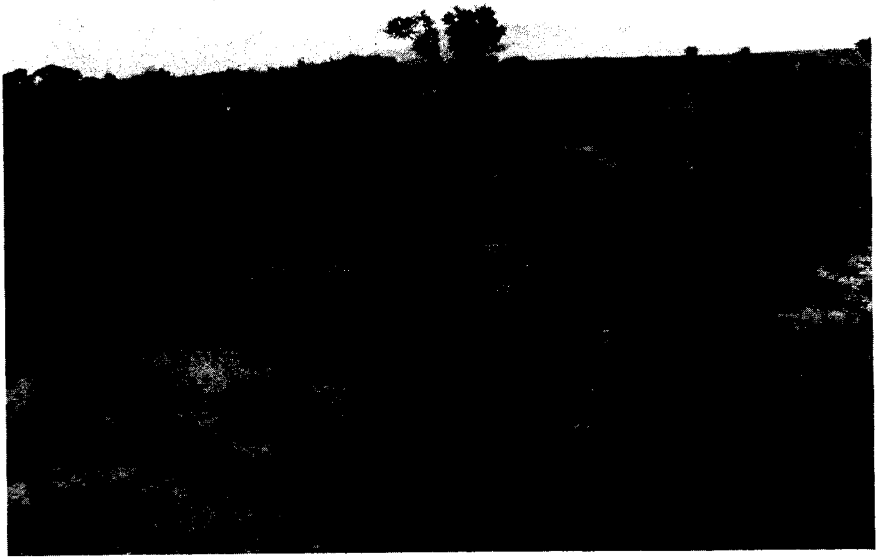


Fig. 15. Vegetation type 9, Dwarf Shrub Savanna. On sandy substratum 8 km south of Berseba. The mountain in the distance is Bruckaros.

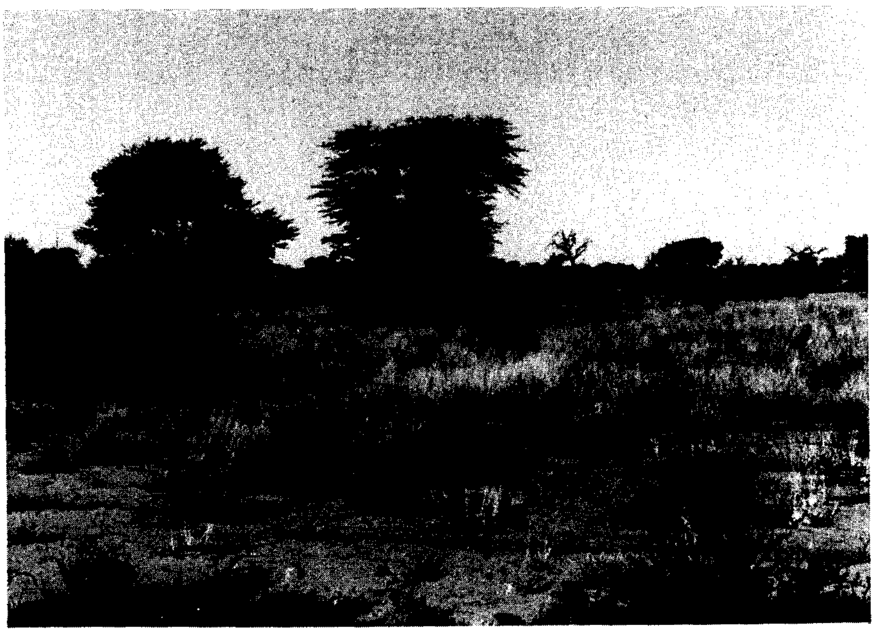


Fig. 16. Vegetation type 12, Central Kalahari. On Kalahari sand, north of Leonardville.

Fig. 17. Vegetation type 13, Southern Kalahari. Auob river west of Mata Mata, showing transition from river bed in foreground to calcrete banks in upper middle and Kalahari sand dunes in the background.

metres plus). The highland plateaux and mountains have been shaded in Fig. 19. The large central highland block stretching from north-east of Tsumeb to west of Bethanie forms an important geographical barrier to the distribution of several scorpion species. Other interior highlands of interest are the Aus and Karasberge plateaux in the south, the Brandberg and Erongo mountains in the west and the highlands of the Kaokoveld in the north-west.

Two geological systems have a determining influence on the distribution of Namibian scorpions. These are the Namib and Kalahari sand systems (Fig. 20) which are well-separated by a very wide non-sandy corridor with varying geological, topographical and vegetational characteristics. This region effectively acts as a barrier to the migration of psammophilous and semi-psammophilous species and is of particular significance to fossorial species.

MORPHOLOGICAL TERMINOLOGY

The morphological terminology used in this work is largely that currently recommended by Vachon (1952–73) and that tabulated by Stahnke (1970, Table 1: 309–312). In some cases, I have selected a terminology differing from that in Stahnke's table. A list of the preferred terms follows: genital aperture (of genital operculum I) for gonotreme; in caudal segments I to V, dorso-lateral keels for superior laterals and ventro-lateral keels for inferior laterals; in caudal segments I to IV, ventral keels for inferior medians; in caudal segment V, ventro-median

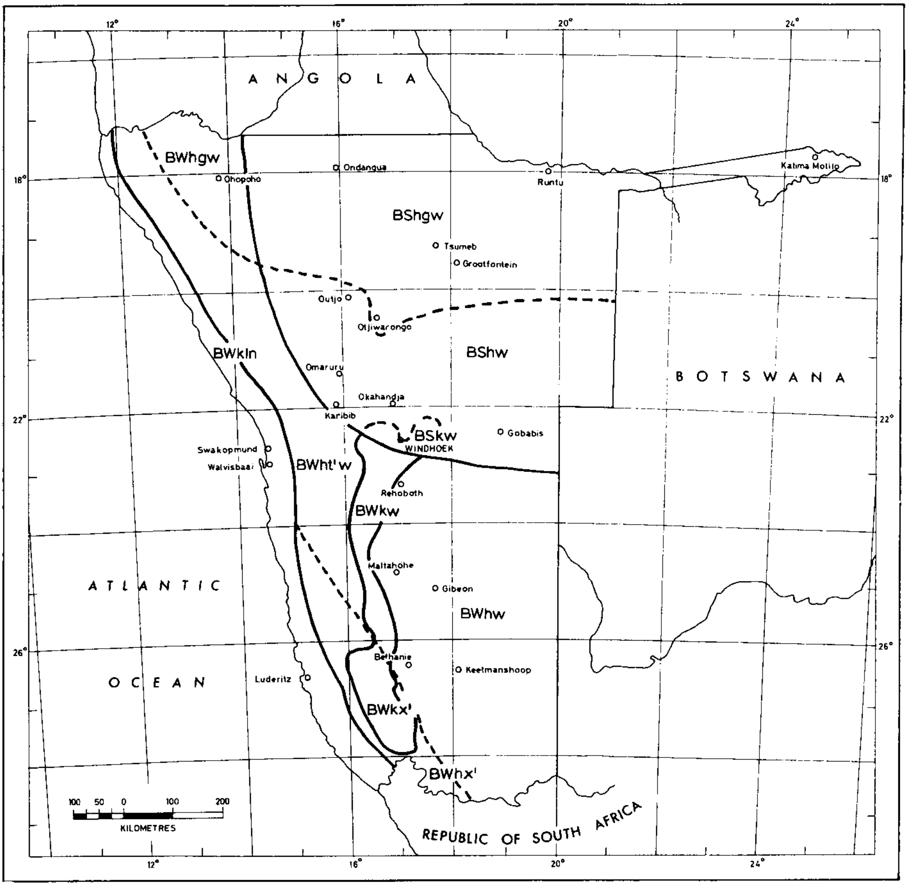


Fig. 18. Delimitation of the climatic regions of Namibia listed in Table 3.

for inferior median; in pedipalps; tibia instead of patella; in chelicerae chelae, hand for manus; in pedipalp chelae, hand for manus, fixed finger for tibia finger and movable finger for tarsus; in cutting edges of pedipalp fingers, rows of teeth for rows of granules; in keels of pedipalp hand, dorso-internal or dorsal crest for interior marginal of superior surface, finger keel for digital keel, dorso-external for exterior marginal of superior surface, ventro-external for exterior marginal of inferior surface, ventro-internal for interior marginal of inferior surface; in walking legs, basitarsus for tarsomere I, telotarsus for tarsomere II, apotele for pretarsus.

The leg segments terminology used follows that recommended by Couzijn (1976) in his extensive review of the subject.

Some species of the genus *Parabuthus* have a short accessory crest situated medially on the inner side of the dorsal crests of caudal segments IV and V. These unusual crests are not listed in Stahnke's table and are termed dorsal accessory crests in this publication.

Vachon's (1973) trichobothrial nomenclature is used instead of Stahnke's (1970).

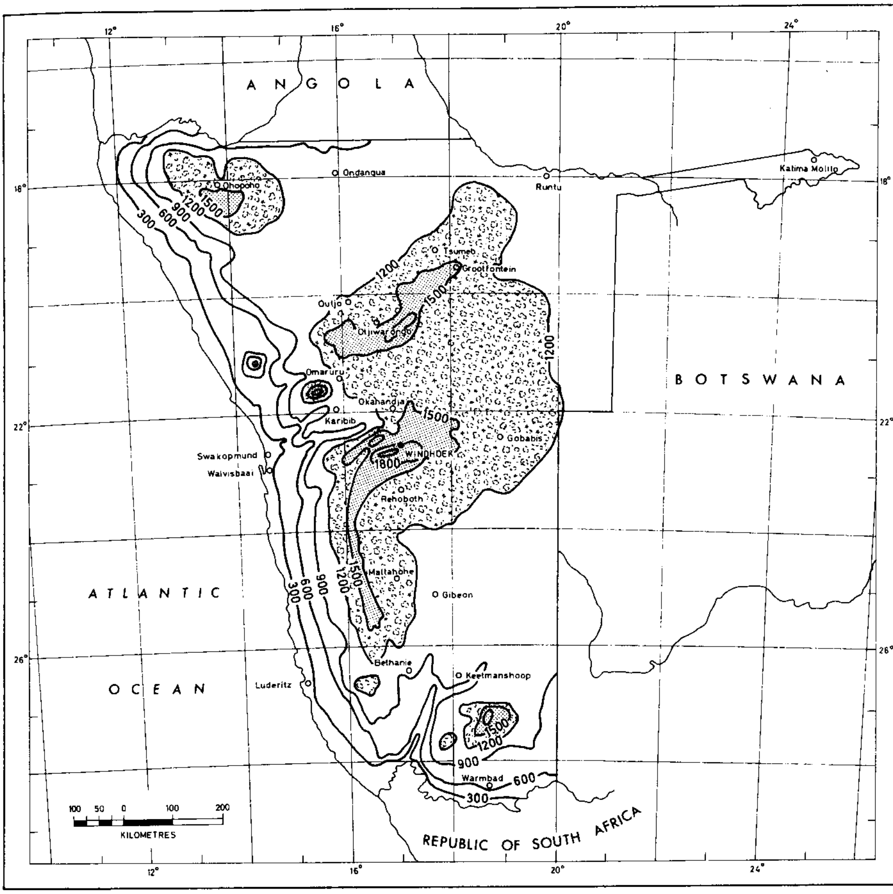


Fig. 19. Broad topography of Namibia with contours at 300 metre intervals.

MORPHOLOGICAL CHARACTERS

The aim of this section is to clarify and illustrate the interpretation of characters used in the taxonomic section.

Not all of these characters are described; only those that have previously been inadequately described or ambiguously interpreted, those that represent new contributions and those hitherto treated in languages other than English. Examples of the latter are Vachon's (1973) treatment of trichobothriotaxy and San Martin's (1969) work on hemispermatophores. The use of trichobothriotaxy and comparative studies of hemispermatophores are of topical significance because this is the first instance of application to taxa in the Afrotropical faunal region.

Colour

Owing to intraspecific, maturation stage and clinal variations, colour is often of limited diagnostic significance. This is particularly so in the case of colour shades but less in that of colour patterns. Consequently the importance of colour should be viewed critically and colour should be used as a diagnostic character only in cases where a large number of samples is available.

Of greater and more reliable significance is the consistent presence or absence of certain colour patterns such as the 'blackening' of caudal segments in *Uroplectes teretipes*.

To ensure uniformity and to avoid subjective interpretation all colour designations are based on the ISCC–NBS Colour Designation used by Kelly & Deane (1965).

Trichobothria (τ)

The symbol (τ) is used extensively in this work to refer to trichobothria. It is derived from the first letter of the Greek word $\tau\rho\iota\chi o\sigma$ used in the etymology of trichobothrium.

Trichobothria are found only on the femur, tibia and chelae of pedipalps (not on movable fingers). Newlands (1972*c*: 42) states that 'The pedipalps and caudal

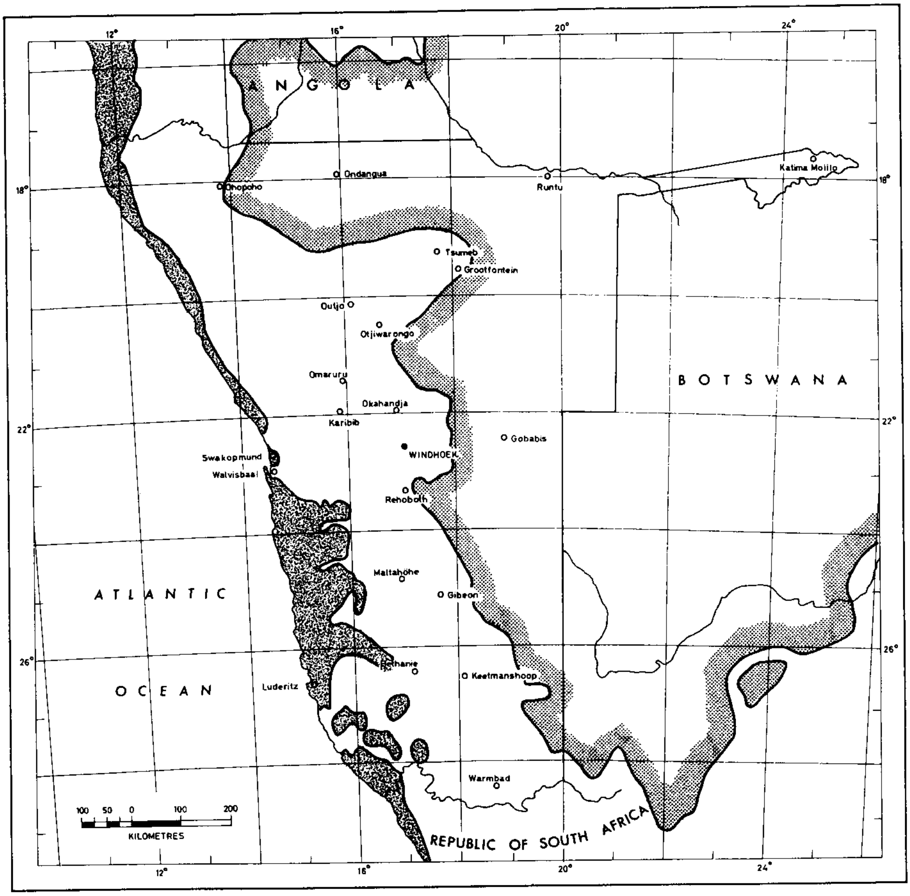


Fig. 20. Distributions of the Namib sand system (hatched) and the Kalahari sand system (edges stippled).

segments of *Hadogenes* are richly endowed with trichobothria . . .' and (p. 44) that '*Cheloctonus* has relatively few palpal and caudal trichobothria compared to *Hadogenes* and *Opisthacanthus*'. Careful examination of the cauda of various species of the genera listed by Newlands has failed to confirm the presence on any τ on the cauda, so I presume that he misidentified microsetae as τ.

Trichobothria are highly sensitive mechanoreceptors which are readily distinguished from normal setae, from which they very likely evolved. The characteristic and distinguishing features of τ and setae are shown in Fig. 21. Vachon (1973) gives a full account of the current use of τ in systematics and stresses their great diagnostic importance. He defines *trichobothriotaxy* as the study of the number and relative distribution of τ; Vachon proposes the terms *orthobothriotaxy* to describe the basic or fundamental number of τ for any given group of taxa studied, for example at the family level, and *neobothriotaxy* as any departure from this basic number. Increases and decreases in the basic numbers are called increasing (+) and decreasing (−) neobothriotaxies respectively. The absence of τ d_2 on the tibia of *Karasbergia methueni* and the presence of 28 τ instead of 13 on the external surface of the tibia in *Protophthalmus holmi* are examples of (−) and (+) neobothriotaxies respectively.

Vachon (1973) designated three fundamental types of orthobothriotaxies, namely type A for all the taxa of the family Buthidae, type B for Chaerilidae and type C for Scorpionidae and the remaining four families. The fundamental τ of types A and C appear in Table 4.

Vachon (1973) points out that although the position of single τ or groups of τ can often vary intraspecifically, this variation occurs within definite limits which he calls territories. I indicate such territories by the use of a broken line (Fig. 26). The frequency of such variations is higher in cases of marked (+) neobothriotaxies reaching levels where the trichobothriotaxies of certain segmental surfaces cease to be of interspecific value, e.g. the external τ of the tibia in *Protophthalmus holmi* and the ventral τ of the tibia in species of *Hadogenes*.

Certain τ occupy very stable positions with minimal intraspecific variation and these are known as 'pilot τ', e.g. esb_1 and et_1 on the external surface of the tibia (Fig. 26). The spatial stability of pilot τ provides points from which the variable positions of adjacent τ can be assessed and facilitates the delimitation of territories. In addition, a line drawn through pilot τ of different territories (Fig. 26) provides a stable reference line to determine the positions of all other τ and group territories. In all the species studied in this work, territory *em* is always positioned on the right-hand side of the reference line.

While τ have proved to be of diagnostic value in many taxa, trichobothriotaxy must be used with caution. Its value varies from group to group and both intra- and interspecific variation needs to be studied.

Setae

The only other movable projections occurring on cuticular surfaces of scorpions are setae. These are classified as macrosetae (forming the bulk of the vestiture) and microsetae. This classification is arbitrary, the main criterion being size. Macrosetae are robust, stiff, coloured setae varying considerably in length and diameter. They may be long and thin or short, squat, spine-like setae. Microsetae (Fig. 21) are small, fine whitish bristles attached to poorly developed areolar cups. In both kinds of setae, the bristle is much thicker basally than apically and the base almost completely fills the inner space of the areola; the bristle is stiff, brittle and readily breaks off in preserved specimens.

The short, robust, macrosetae which occur on the distal leg segments of some scorpions have sometimes been incorrectly described as spines. A similar situation prevails in taxonomic papers on solifuges and I have pointed out (Lamoral, 1973: 85–86) that this practice should be abandoned as very few true spines are found in these groups. A spine is an immovable cuticular process whereas a seta contains an extension of its underlying trichogen cell and is located in a basal socket formed by tormogen cells. All setae are linked to the cuticle by a membranous joint which allows movement to a greater or lesser extent, depending on their function.

The distribution and number of setae are of diagnostic importance in certain species of scorpions, but in most cases chaetotaxy is unreliable.

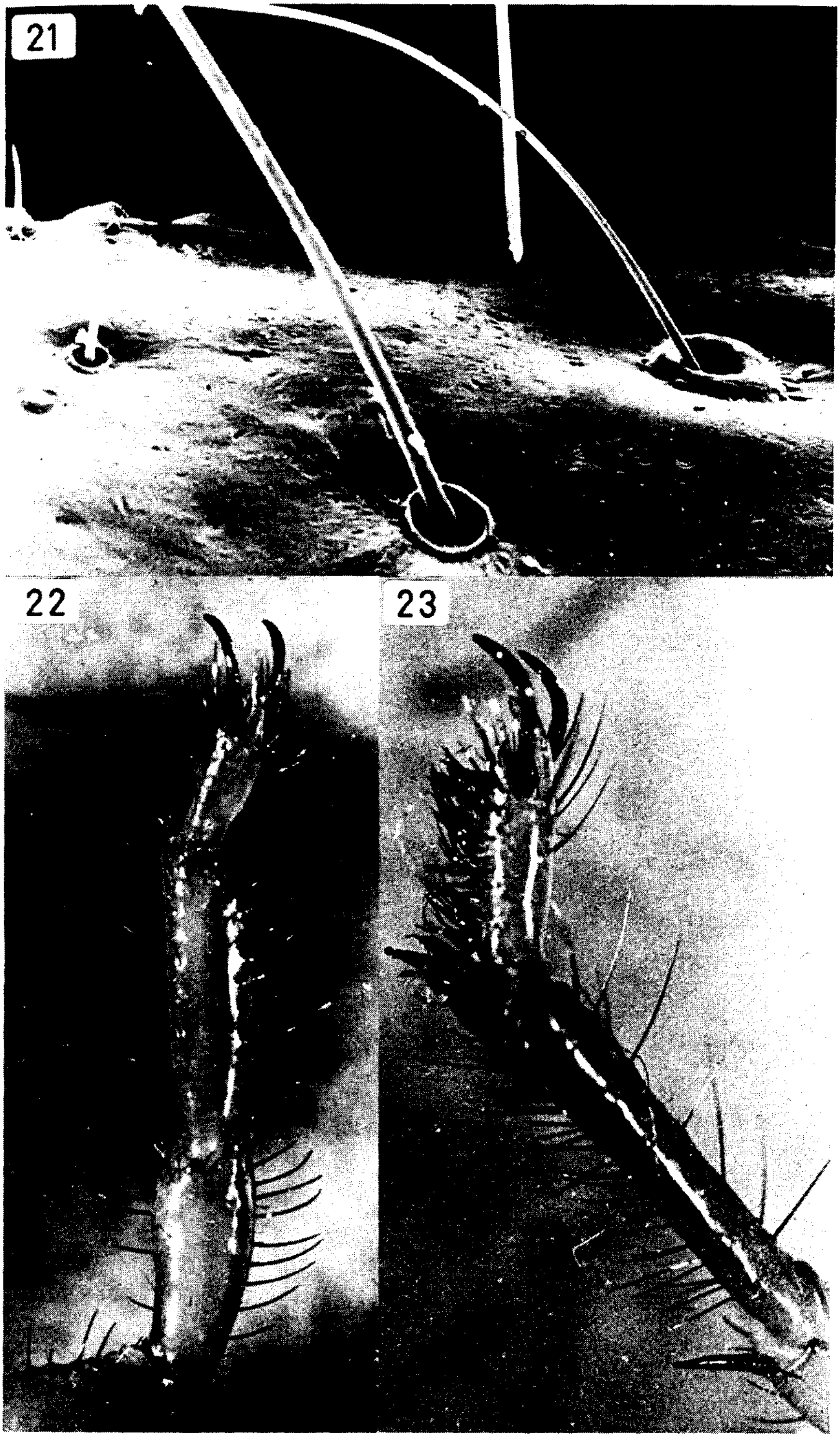
The presence of pads made up of numerous fine setae on the ventral surface of the tarsi of all legs and comb-like rows of long stiff setae (Figs 22–23) on the anterior and posterior edges of tibiae, basitarsi and telotarsi of legs I and II, is a good indicator of a psammophile habit.

The number and distribution of setae on the pedal spurs and the dorsal side of the pectines is usually fairly stable and does not exhibit much interspecific variation. In the few instances where this is not the case such setae may have diagnostic value.

Paraxial organ and hemispermatophore

The male genital system has been described by various authors including Vachon (1952*b*), Alexander (1957, 1959) and San Martin (1969). The terminology used to describe the various parts of the paraxial organ (Vachon & San Martin) or half spermatophore sac (Alexander) is basically that of Alexander (1957, 1959). Alexander's terminology for the hemispermatophore of *Parabuthus* and *Opisthophthalmus* was altered and added to by San Martin (mainly 1969) and is now applicable to other families. The terminology here used for the hemispermatophore (Fig. 27) is therefore basically that of San Martin, with amendments brought about by language differences, and with many additions necessitated by taxonomic differences.

Figs 21–23. 21, S.E.M. of basal portion of fixed finger in *Opisthophthalmus lornae* showing trichobothrium *esb* (middle right), a normal seta (centre foreground) and a microseta (middle left). The cutting edge of the finger appears as a transverse ridge in the background (150X). 22–2e, *Parabuthus stridulus*. 22, dorsal aspect of distal four segments of right leg I showing comb-like rows of long stiff setae on anterior and posterior edges of tibia, basitarsus and telotarsus and the long ungues, all indicating a psammophile habit; 23, posterior aspect of tibia (distal part), basitarsus and telotarsus of left leg IV, showing tibial and pedal spurs. The long ungues and pads of numerous long setae on the ventral side of the telotarsus, and to a lesser extent the basitarsus, indicate a psammophile habit.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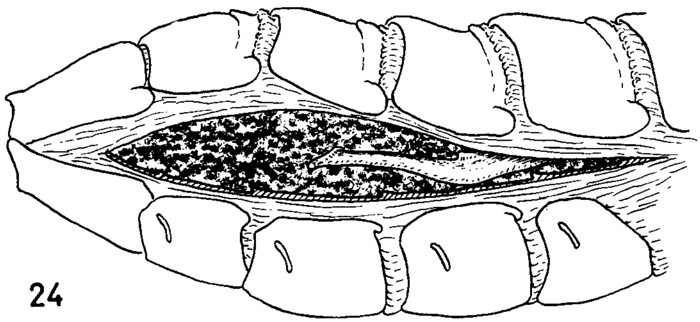
The paraxial organ exhibits a few characters which are diagnostic at family and sometimes generic level. The hemispermatophores, produced by and enclosed in the paraxial organs of sexually mature males prior to extrusion and mating, however, provide many stable specific characters in many genera of Afrotropical scorpions. The relative importance and stability of intergeneric and interspecific characters used are discussed in the systematic section of this paper.

Two dissections are necessary to obtain a hemispermatophore. These are not difficult but should be performed with great care in order to avoid mutilation. Unless otherwise stated, all paraxial organs and hemispermatophores illustrated come from the right-hand side of the donor.

The first dissection consists of the removal of one of the two paraxial organs from the mesosomal cavity. First the lateral pleural membrane is cut open by a longitudinal incision starting at the level of tergite VI and ending approximately at the level of tergite I (Fig. 24). Lifting the dorsal integument then reveals the distal portion of the paraxial organ imbedded in, and on occasions partially obscured by, digestive glands (Fig. 24). Fig. 25 shows the position of the two paraxial organs in relation to body segmentation. Bearing in mind this configuration, the next step consists of freeing the paraxial organ from surrounding tissue; moving from the distal to the proximal end until the common chamber can be seen. The paraxial organ should then be cut off at its base, as close as possible to the common chamber and transferred immediately to a small dish containing a preserving fluid, preferably 70% ethanol, for subsequent dissection.

During the second dissection the tissues of the paraxial organ which enclose the sclerotised hemispermatophore are removed. This is best done by working with two pairs of fine forceps and gently teasing and tearing the paraxial organ tissues apart, taking care not to damage delicate components. Once the hemispermatophore has been completely freed, it should at all times be kept in preserving fluid as dehydration leads to irreversible distortion. The dissected hemispermatophore should be stored in a micro- vial, preferably containing the specimen's accession number, and at all times kept in the same container as the specimen.

The hemispermatophores of Buthidae and Scorpionidae consist of three regions, basal, median and distal (Figs 27–32). The basal region comprises the foot, its stalk and the basal portion which is long and slender in Buthidae but broad, thin and ventrally concave in Scorpionidae. The median region is composed of four lobes, basal, median, outer and inner (Figs 27, 28, 33). A survey of available literature shows that there is a difference in lobe terminology for some of the families. The differences appear to have originated from allocation of lobe terminology on a positional basis rather than from functional and histological homologies. This has given rise to a situation where the lobe bearing the hook has been termed 'distal lobe' in Bothriuridae by San Martin (1969, Fig. 1) and Maury & San Martin (1973); 'internal' and 'median lobe', in two different figures, by Vachon (1952*b*, Figs 484 & 485) in Scorpionidae; 'median lobe' by Vachon (1952*b*, Fig. 86) and Maury (1969, Fig. 7) in Buthidae. As pointed out by Alexander (1959), the anatomical details and functional aspects of scorpionid and



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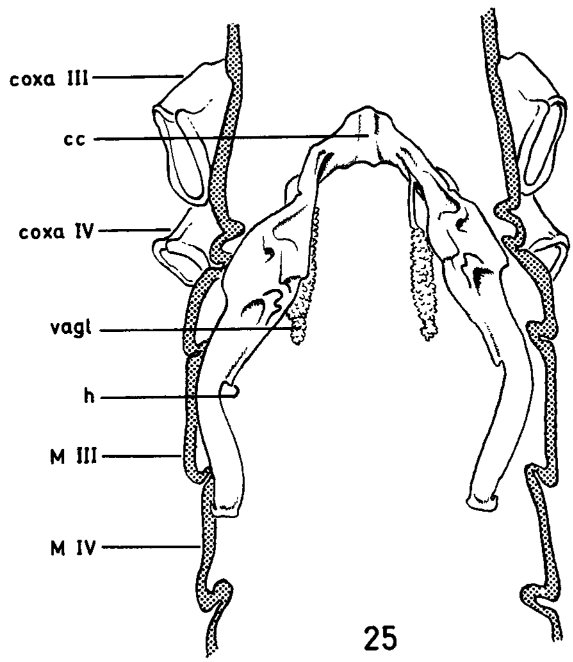

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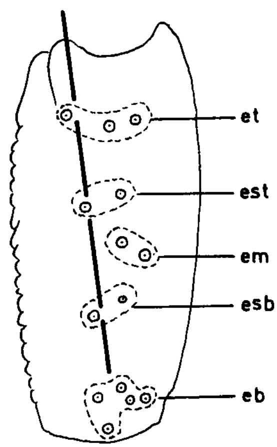

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Figs 24–26. 24, right side of a male mesosoma showing incision made in the pleural membrane to gain access to the paraxial organ; the distal end of the right paraxial organ is visible; 25, semi-diagrammatic dorsal aspect of male paraxial organs of *Opisthophthalmus carinatus in situ*; the testis network and associated glands of the paraxial organs are not shown (cc, common chamber; h, hook; M, mesosomal segments; vagl, ventral annex gland); 26, (+ 1) neobothriotaxic trichobothria on the external surface of the pedipalp tibia in *Opisthophthalmus*.

buthid spermatophores differ greatly, but there is a basic similarity. While it might be suggested that the similarities are a result of convergence, these similarities are, however, too great to substantiate such a hypothesis and it is more probable that the great dissimilarities are a result of extensive divergence from a plesiomorphic state, in which there was no rotation of the hemispermatophores during extrusion.

These considerations are undoubtedly the reasons for the difficulty experienced in homologising the hemispermatophore lobes of scorpionids with those of buthids. Unpublished data have led me to the following preliminary conclusions: 1. it is possible to homologise the various anatomical components of the spermatophores of buthids and scorpionids on the basis of functional, and histological features; 2. the spermatophores of these two families are not the result of evolutionary convergence but rather of marked anatomical modification of components caused by extensive divergence.

Examples of the application of these criteria to a few spermatophore characters are: the distal portions of the hemispermatophore, termed distal lamina in scorpionids and flagellum in buthids, are not homologous structures because the former is an extensive axial outgrowth of the hook-bearing median lobe while the latter is an outgrowth of the inner lobe as illustrated in Figs 27, 28, 33; the inner lobe of buthids encapsulates the sperm mass and the lobe performing the same function in scorpionids is its homologue and should accordingly be termed the 'inner lobe' (Fig. 27), and not basal lobe as used by Vachon (1952*b*, Fig. 485) for Scorpionidae and Maury & San Martin (1973, Fig. 3) for Bothriuridae.

The lobe terminology proposed in this work is the result of deductions similar to those explained above and is derived from that used for the Buthidae in the majority of publications.

The distal region of the hemispermatophore in Buthids is an extension of the inner lobe; it is long, whip-like (called the flagellum) and is divided into three parts, *pars recta*, *pars reflecta* and *pars bireflecta* (Fig. 33). The distal region in scorpionids is an extension of the median lobe and consists of a long, flattened and ventrally concave structure called the distal lamina which bears a proximal, lateral process known as the hook (Fig. 27).

The terms used in this text to describe positional aspects of the hemispermatophore refer to the normal position of the various surfaces inside the body cavity, prior to any dissection and removal. Thus, dorsal and ventral are the surfaces facing those respective regions of the body. Ectal refers to the surface or side normally facing the outer lateral region of the body, and ental, that facing the inner region.

The following are useful and stable parameters which in many cases serve as primary indicators of interspecific diagnostic differences in scorpionid hemispermatophores (Fig. 27). 1. The distance between the hook apex (ha) and the basal scallop (bsh) as a percentage of the distance between the hook apex (ha) and the waist (w) i.e.: $\%\ \mathrm{ha} \rightarrow \mathrm{bsh} = \mathrm{ha} \rightarrow \mathrm{bsh} \times 100/\mathrm{ha} \rightarrow \mathrm{w}$. 2. The distance between the hook apex (ha) and the waist (w) as a percentage of the distance between the distal crest (dcr) and the waist (w) i.e.: $\%\ \mathrm{ha} \rightarrow \mathrm{w} = \mathrm{ha} \rightarrow \mathrm{w} \times 100/\mathrm{dcr} \rightarrow \mathrm{w}$.

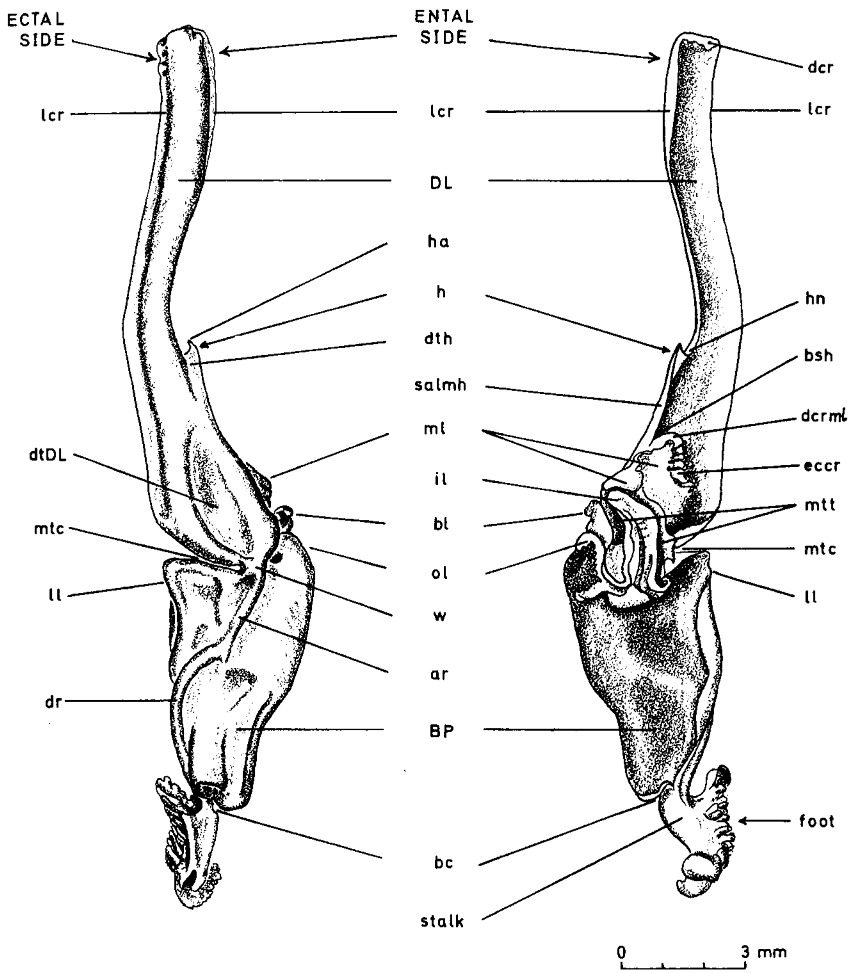
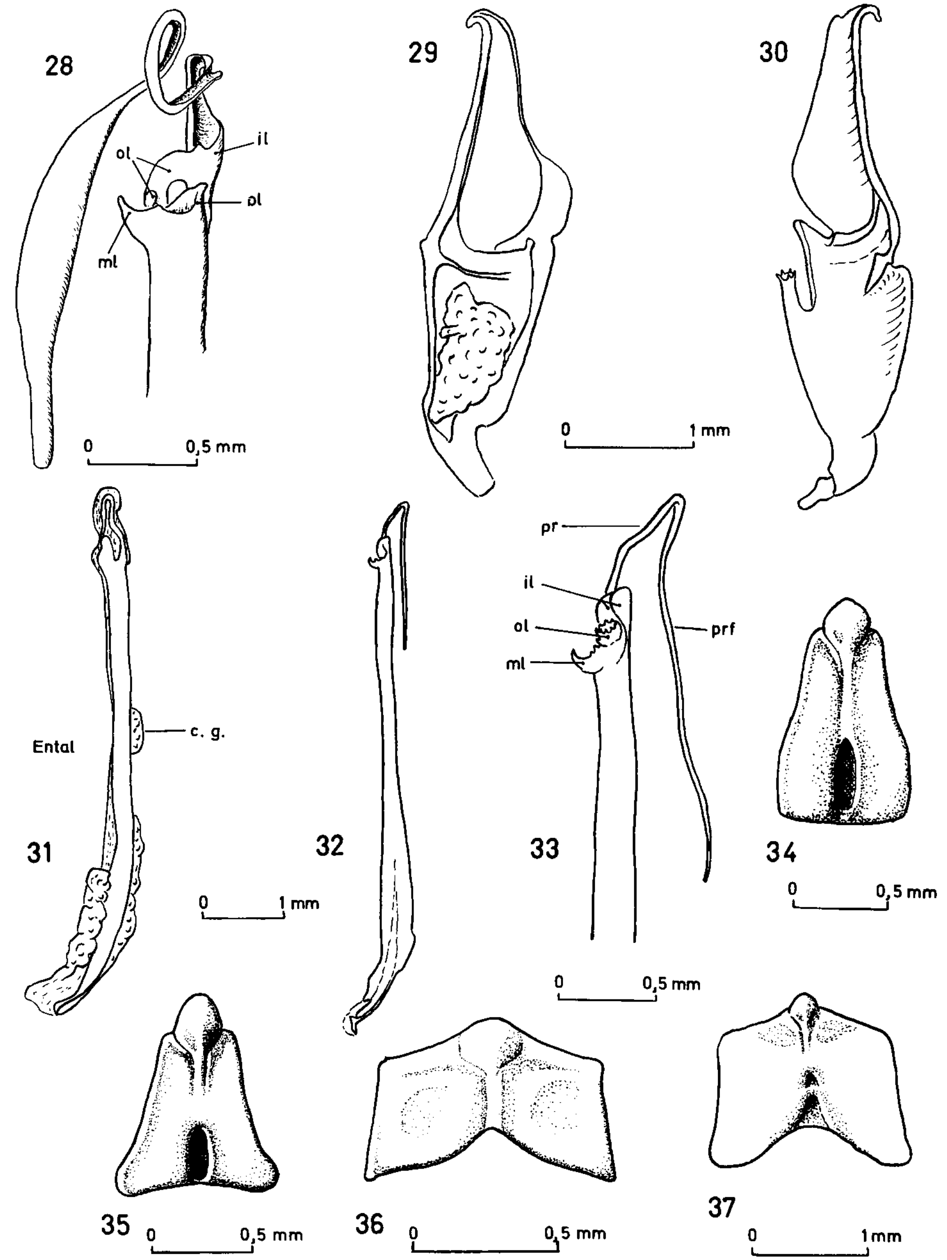


Fig. 27. Right hemispermatophore of *Opisthophthalmus carinatus* (SMN 11). Left, dorsal aspect; right, ventral aspect.

Abbreviations:
ar, axial rib
bc, basal cleavage
bl, basal lobe
BP, basal portion
bsh, basal scallop of hook
dcr, distal crest of distal lamina
dcrml, distal crest of median lobe
dl, distal lobe
DL, distal lamina
dr, diagonal rib
dtDL, dorsal trough of distal lamina
dth, dorsal trough of hook
eccr, ectal crest of median lobe
h, hook
ha, hook apex
hn, hook notch
il, inner lobe
lcr, lateral crest
ll, lateral lobe
ml, median lobe
mtc, median transverse cleavage
mtt, median transverse trough
ol, outer lobe
pbrf, *pars bireflecta*
pr, *pars recta*
prf, *pars reflecta*
salmh, sub-apical lateral margin of hook
w, waist



Figs 28–37. 28, *Parabuthus villosus*, distal ventral aspect of right hemispermatophore; 29–30, *Euscorpius carpathicus* (Linné, 1767), family Chactidae; 29, ventro-ectal aspect of left paraxial organ; 30, ventro-ectal aspect of right hemispermatophore; 31–33, *Uroplectes otjimbinguensis* (NM 10029); 31, right paraxial organ, ventral aspect; 32, right hemispermatophore, ental aspect; 33, enlarged distal portion of Fig. 32; 34–37, sterni of various taxa; 34, *Uroplectes carinatus* ♀; 35, *Parabuthus brevimanus* ♀; 36, *Superstitionia donensis* Stahnke ♂ (Chactidae); 37, *Euscorpius carpathicus* (Linné) ♀ (Chactidae).

Other formulae have occasionally provided useful diagnostic indicators within small groups of species and these are explained in the relevant sections of this paper.

Several attempts were made to prepare hemispermatophores for study using scanning electron microscopy. Although this proved useful in the interpretation of anatomical homologies, it was found that, because of their very fragile nature, they require a great deal of care in preparation, which is too time-consuming for routine purposes.

MORPHOMETRIC CHARACTERS

Several of the diagnostic characters used consist of measurements, ratios, or percentages of measurements, or other mathematical combinations. Such measurements or mathematical combinations are supplied as the arithmetic mean of each set followed by the range in brackets. Frequency is determined by the number of specimens of each species available for study and can be obtained from the lists of specimens examined. In addition measurements of typical adult specimens are given for each species. Total body length is taken from anterior margin of the carapace to tip of telson. Figs 38–41 illustrate the manner in which some of the key measurements were taken. The following list explains some of the main ratios used:

Carapace ratios. Several ratios used are functions of carapace length. This is based on the fact that carapace length is not subject to allometric growth discrepancies and is therefore a stable character irrespective of specimen age. The absence of a regression in graphs involving carapace length versus any other measurement indicates that the other measurement is also not subject to allometric growth, and thus confirms its diagnostic reliability. The following ratios are often used (Figs 39–40): lc/x or lc/y; lc/pwc; pwc/aw; hcs/lcs or width caudal segment/lcs plotted against carapace length. Width sternite V/carapace length is a good indicator of overall slenderness, often characterising sexual dimorphism.

Chela ratios (Fig. 38). Ratio lmf/lhb is an important diagnostic character and is not affected by allometric growth while lhb/lch and whb/lhb are other useful ratios.

Telson ratios (Fig. 41). The following are often used: la/lt or lv/lt; hv/lv; and width vesicle/height vesicle.

Pecten ratio. Pecten length/dentate margin length is often a good indicator of sexual dimorphism as well as interspecific differences.

PHYSIOLOGICAL CHARACTERS

Haemolymph electrophoresis

In the study of certain closely related taxa, the diagnostic importance of a large proportion of the key morphological characters proved of limited value. This suggested the possible occurrence of clinal variation, subspeciation, or sibling speciation. An electrophoretic analyses of the haemolymph proteins in such groups was therefore undertaken in order to obtain additional diagnostic characters. A combination of the methods described by Davis (1964) and Goyffon *et al.* (1970 for disc electrophoresis was employed with minor modifications in the composition of the stock and working solutions.

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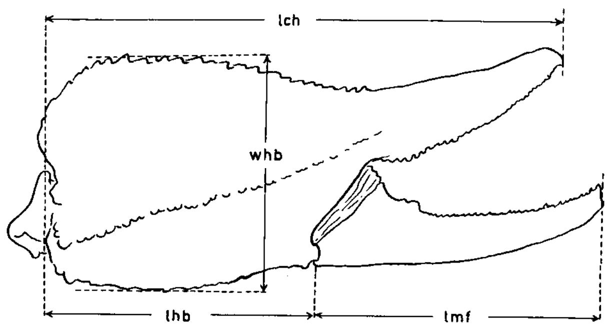

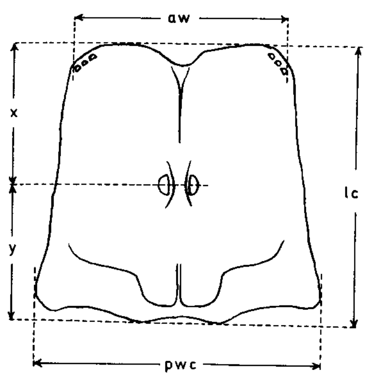

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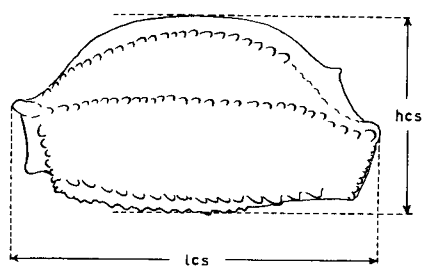

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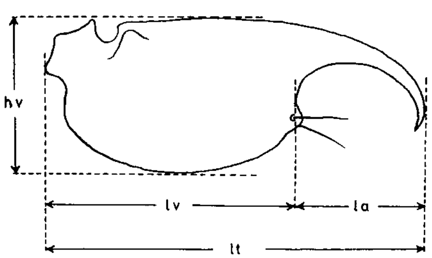
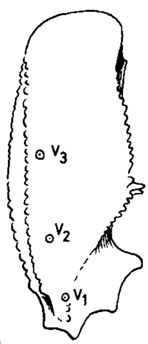


41



42

Figs 38–42. 38–41, diagrammatic representation of some measurement parameters; 38–39, *Opisthophthalmus* species; 38, right pedipalp chela; 39, dorsal aspect of carapace; 40, *Parabuthus* species, left lateral side of cauda IV; 41, *Uroplectes* species, left lateral side of telson; 42, ventral aspect of right pedipalp tibia in *Opisthophthalmus* species showing trichobothria v_1–v_3. *Abbreviations:* aw, anterior width carapace; hcs, height caudal segment; hv, height vesicle; la, length aculeus; lc, carapace length; lch length chela; lcs length caudal segment; lhb, length handback; lmf, length movable finger; lt, length telson; lv, length vesicle; pwc, posterior width or greatest width carapace; whb, width handback; x and y, distance from median eyes to anterior and posterior margins respectively.

KEYS TO TAXA

Unless otherwise mentioned, the character states used in keys apply to adult ♂ and ♀. In most cases the key also works for subadults and juveniles, bearing in mind that in many species juveniles exhibit colour patterns and infuscations of the appendages and caudal segments which do not occur in adults. In adults and juveniles the presence or absence of any structure such as keels is to be determined by the actual presence of the said structure and not darkening of the area concerned. Trichobothrial character states are ontogenically stable and are therefore applicable to all developmental stages.

KEY TO NAMIBIAN FAMILIES, SUBFAMILIES AND GENERA

1\. Pedipalp tibia without ventral trichobothria (Fig. 50); legs III and IV ventrally with a tibial spur (Fig. 23) between tibia and basitarsus; arising from the ventral region of the intersegmental membrane between the basitarsus and telotarsus of each leg a pair of pale but dark-tipped spurs, the anterior of which is usually bifurcate (Fig. 23); hand round to ovoid in cross-section, usually very slender, very seldom with keels, its upper surface never separated by a distinct keel into inner and outer portion (except faintly so in *Buthotus conspersus*). **Buthidae** (Buthinae) 2

— Pedipalp tibia with from three to numerous ventral trichobothria (Fig. 42); legs III and IV without a tibial spur; only one spur (the anterior one) between basitarsus and telotarsus of each leg; hand large and flattened, higher than broad, with upper region usually divided longitudinally by a keel (finger keel) into distinct inner and outer portions. **Scorpionidae** 5

2\. Two teeth on ventral proximal margin of fixed finger of chelicerae (Fig. 59) 3

— No such teeth 4

3\. Dorsal surface of caudal segments I, and to a lesser extent II, with a stridulatory area composed of fine to coarse granules, sometimes forming transverse ridges; abdominal tergites with one weakly developed median keel; carapace without keels .... **Parabuthus**

— Dorsal surface of caudal segments I and II without a stridulatory area; abdominal tergites with three well-marked longitudinal granular keels; carapace with conspicuously symmetrical granular keels .... **Buthotus**

4\. Trichobothria Eb_3 of hand much smaller than Eb_2 or missing (Fig. 74), $\tau\ d_2$ of tibia (Fig. 78) and femur (Fig. 79) missing; granular rows of movable finger of pedipalp with an inner but no outer flanking series (one species, *K. methueni*) .... **Karasbergia**

— Trichobothria Eb_3 of hand only slightly reduced in size and always present; $\tau\ d_2$ of tibia and femur always present; granular rows of movable finger of pedipalp with an inner and an outer flanking series .... **Uroplectes**

5\. Leg telotarsi with rounded lateral lobes distally (Scorpioninae) .... **Opisthophthalmus**

— Leg telotarsi with truncated lateral lobes distally 6

6\. Carapace with an anterior median furrow (Ischnurinae) .... **Hadogenes**

— Carapace without an anterior median furrow (Lisposominae) ... **Lisposoma**

KEY TO NAMIBIAN SPECIES OF *BUTHOTUS*

1. Cauda I, Fig. 56: width/length ratio 1,01 (0,95–1,05) for ♂, 1,08 (1,03–1,14) for ♀. Cauda V, Fig. 52: x/y ratio 0,85 (0,80–0,90). Cauda V, Fig. 53: area bounded by dorso-lateral and ventro-lateral keels, elongate subrectangular **arenaceus** (Purcell)

— Cauda I, Fig. 56: width/length ratio 1,31 (1,22–1,42) for ♂, 1,37 (1,28–1,47) for ♀. Cauda V, Fig. 54: x/y ratio 1,15 (1,10–1,20). Cauda V, Fig. 55: area bounded by dorso-lateral and ventro-lateral keels, elongate sub-oval....... **conspersus** (Thorell)

KEY TO NAMIBIAN SPECIES OF *PARABUTHUS*

1. Cauda IV, dorsal keels obsolete to absent, lateral and ventral surface finely to coarsely granular and without distinct granular keels (Figs 94–96)..... 2

— Cauda IV, with 8 or 10 distinct granular to costate keels 5

2. Caudal segments, Fig. 94: cauda V, distal half of ventro-lateral keels composed of distinctly lobate processes; cauda IV, antero-ventral margin demarcated by a transverse row of 5–6 strongly elevated, crescent-shaped tubercles; cauda II–III, distal section of ventro-lateral keels and postero-ventral margin composed of strongly elevated crescent-shaped tubercles, forming a broad U-shaped pattern; cauda III, lateral and ventral intercarinal surfaces smooth and shiny. Pedipalp femur, Fig. 93: $\tau\ d_2$ on proximo-dorsal side of dorso-internal keel .... **brevimanus** (Thorell)

— Caudal segments, Figs 95–96: cauda V, distal half of ventro-lateral keels composed of weakly to well developed subspinose processes; cauda IV, antero-ventral margin either smooth or demarcated by a transverse row of isolated round granules; cauda II–III, without any crescent-shaped tubercles on postero-ventral margins; cauda III, with at least distal one third of lateral and ventral intercarinal surfaces granular; Pedipalp femur, Fig. 116: $\tau\ d_2$ on proximo-internal side of dorso-internal keel 3

3. Caudal segments, Fig. 95: cauda III–V, proximal one-third of lateral and ventral surfaces smooth and shiny, antero-ventral margins smooth; cauda II–III, postero-ventral margins not demarcated by a transverse row of isolated round granules; cauda II–III, ventral and ventro-lateral keels costate; cauda I–II, lateral intercarinal surfaces lightly granular and shiny, ventral intercarinal surfaces smooth and shiny. Pedipalp femur, Fig. 147: $\tau\ e_1$, transversely halfway between d_4 and d_5; $\tau\ d_2$ distal to i_1 .... **kuanyamarum** Monard

— Caudal segments, Fig. 96: cauda III–V, lateral and ventral surfaces granular and matt, antero-ventral margins demarcated by a transverse row of isolated round granules; cauda II–III, postero-ventral margins demarcated by a distinct transverse row of isolated round granules; cauda II–III, ventral and ventro-lateral keels composed of isolated round granules; cauda I–II, lateral and ventral intercarinal surfaces granular and matt. Pedipalp femur, Fig. 116: $\tau\ e_1$ transversely either level with or distal to $\tau\ d_5$; $\tau\ d_2$ proximal to i_1 ... 4

4. Pedipalp hand, Figs 111–112: movable finger length/handback length ratio 1,25 (1,17–1,33) for ♂, 1,55 (1,46–1,61) for ♀. Pedipalp tibia, Fig. 114: $\tau\ d_2$

absent. Sternum: length almost double of greatest width ..... **gracilis** sp. n.
— Pedipalp hand, Figs 166–167: movable finger length/handback length ratio 2,00 (1,93–2,08) for ♂ & ♀. Pedipalp tibia, Fig. 170: τ d_2 present and small. Sternum: length equal to greatest width .... **nanus** sp. n.
5. Cauda II, dorsal stridulatory area not reaching posterior margin 6
— Cauda II, dorsal stridulatory area reaching posterior margin 10
6. Caudal segments, Figs 117–118: cauda IV, median lateral keel obsolete to absent; adult ♂ and ♀ telson width 67% (61–72%) of cauda V width; cauda V distal half of ventro-lateral keels with distinctly enlarged sub-lobate processes, accessory dorsal crest absent. Pedipalp femur, Fig. 123: τ d_2 on proximo-dorsal side of dorso-internal keel 7
— Caudal segments: cauda IV, median lateral keel present and well developed; adult ♂ & ♀, telson width percentage of cauda V width, not less than 75% and up to 101%; cauda V, distal half of ventro-lateral keels with moderately enlarged, laterally compressed sub-spinose processes, accessory dorsal crest present, composed of blunt to spiniform tubercles. Pedipalp femur: τ d_2 either on dorso-internal keel axis or on proximo-internal side of dorso-internal keel 8
7. Pedipalp chela, Figs 119–120: movable finger length/handback length ratio 2,00 (1,95–2,05) for ♀, 1,55 (1,50–1,60) for ♂; τ *dt* distal to *et*. Tergites I–VI, median keel present .... **granulatus** (H. & E.)
— Pedipalp chela, Figs 127–128: movable finger length/handback length ratio 1,60 (1,55–165) for ♀, 1,15 (1,10–1,20) for ♂; τ *dt* distinctly proximal to *et*. Tergites I–VI, median keel absent .... **kalaharicus** Lamoral
8. Caudal segments: cauda I–V and telson, densely pilose; cauda I–IV progressively decreasing in width, cauda IV 9% (8–10%) narrower than I; cauda I longer than wide, width percentage of length 97% (95–99%); cauda II to IV, dorsal aspect of dorso-lateral keels subparallel. Pedipalp chela, Figs 200–201: τ *eb* distal to basal dentate margin of fixed finger ..... **villosus** (Peters)
— Caudal segments: cauda I–V and telson, sparsely pilose; cauda I–IV either all almost the same width or progressively increasing in width; cauda I wider than long, width percentage of length 113% (104–123%); cauda II–IV, dorsal aspect of dorso-lateral keels convex. Pedipalp chela: τ *eb* proximal to basal dentate margin of fixed finger 9
9. Caudal segments, Figs 181–182: cauda IV width percentage of length 93% (87–98%); cauda V in adults, ventral aspect of ventro-lateral keels subtrapezoidal, tapering anteriorly, anterior width 9% (3–15%) narrower than posterior width; cauda I–IV progressively increasing in width, cauda IV 14% (8–20%) wider than I; cauda II and III wider than long, width percentage of length 105% (103–107%); cauda II–III, distal granule of ventral and ventrolateral keels, distinctly enlarged, obtuse and elevated; cauda V, dorso-lateral keel well-developed throughout .... **schlechteri** Purcell
— Caudal segments, Figs 173–174: cauda IV, width percentage of length 73% (67–78%); cauda V in adults, ventral aspect of ventro-lateral keels subtrapezoidal, tapering posteriorly, posterior width 6% (3–10%) narrower than anterior width; cauda I–IV all almost the same width, cauda IV as wide as I,

seldom slightly wider; cauda II and III narrower than long, width percentage of length 93% (90–97%); cauda II–III, distal granule of ventral and ventro-lateral keels, not enlarged and elevated; cauda V, dorso-lateral keel almost obsolete medially .... **raudus** (E. Simon)

10. Caudal segments: cauda I–V and telson, densely pilose; cauda IV, accessory dorsal crest present .... **brachystylus** Lawrence

— Caudal segments: cauda I–V and telson, at most sparsely pilose; cauda IV, accessory dorsal crest absent 11

11. Pedipalp chela: movable finger length/handback length ratio less than 1,65 for ♀ and 1,30 for ♂. Pedipalp tibia, τ *esb*$_2$ proximal, level or slightly distal to *esb*$_1$. Caudal segments: lateral and ventral intercarinal surfaces of cauda I–III and lateral surfaces of IV–V, smooth and shiny, rarely with a few scattered granules; cauda IV, median lateral keel poorly developed; cauda V, accessory dorsal crest obsolete to absent 12

— Pedipalp chela: movable finger length/handback length ratio greater than 2,0 for ♀, and 1,40 for ♂. Pedipalp tibia, τ *esb*$_2$ distinctly distal to *esb*$_1$. Caudal segments lateral and ventral intercarinal surfaces of cauda I–III and lateral surfaces of IV–V, matt, lightly to moderately and evenly granular; cauda IV, median lateral keel well-developed; cauda V, accessory dorsal crest present, composed of distinct blunt tubercles 13

12. Caudal segments, Fig. 188: telson vesicle very distinctly and deeply excavated along longitudinal half of dorso-proximal surface; cauda II, Fig. 191, stridulatory surface composed largely of transverse ridges some of which, particularly in the posterior half, extend across the surface. Pedipalp chela, Figs. 192–194: τ *dt* distal to *et*; τ *db* medial between *esb* and *est* ....
stridulus Hewitt

— Caudal segments, Fig. 148: telson vesicle shallowly excavated and not more so than in other species; cauda II, stridulatory surface composed largely of granules, occasionally including short transverse ridges posteriorly, none of which extend more than halfway across the surface. Pedipalp chela, Figs 150–151: τ *dt* proximal to or rarely level with *et*; τ *db* much closer to *esb* than *est* .... **laevifrons** (E. Simon)

13. Caudal segments, Fig. 155: cauda I, antero-median surface of stridulatory patch gently inclined to the anterior descending portion; cauda slender; cauda IV, V and telson strongly infuscated. Pedipalp chela, Figs 157–159: τ *eb* level with or slightly distal to base of dentate margin. Legs IV long and slender, reaching posterior end of cauda III. Pectinal teeth, ♀ 40–41, ♂ 42–47 per pecten .... **namibensis** sp. n.

— Caudal segments, Fig. 133: cauda I, antero-median surface of stridulatory patch sharply inclined to the anterior descending portion; cauda robust; cauda IV, V and telson same colour as I and II. Pedipalp chela, Figs 135–136: τ *eb* proximal to base of dentate margin. Legs IV, not reaching further than posterior end of cauda I. Pectinal teeth, ♀ 29–32, ♂ 33–36 per pecten .... **kraepelini** Werner

KEY TO NAMIBIAN SPECIES OF *UROPLECTES*

1. Pedipalp femur, Fig. 274: $\tau\ d_2$ on proximo-dorsal side of dorso-internal keel. Pecten, Fig. 230: first proximal tooth of ♀ falciform and much longer than adjacent teeth 2

— Pedipalp femur, Fig. 215: $\tau\ d_2$ on proximo-internal side of dorso-internal keel. Pecten, Fig. 229: first proximal tooth of ♀, much wider than but never longer than adjacent teeth, rarely completely unmodified 4

2. Caudal segments, Figs 233, 283–284: cauda III and IV, deeply infuscated to black; cauda IV, ventral keels obsolete to absent; cauda V, ventro-median keel distinct, composed of fine granules. Pedipalp hand, Fig. 285: $\tau\ Esb$ distal to or level with *Est*. Pectines: ♀ 36–40 and ♂ 40–44 teeth per pecten . . . . **teretipes** Lawrence

— Caudal segments, Figs 231–232, 267–268: cauda III and IV same colour as other segments, never blackened; cauda IV, ventral keels either costate or granular; cauda V, ventro-median keel indistinct. Pedipalp hand, Figs 269, 271: $\tau\ Esb$ distinctly proximal to *Est*. Pectines: ♀ 17–26 and ♂ 24–28 teeth per pecten 3

3. Pedipalp hand, Figs 269–271: almost apilose; movable finger length/hand-back length ratios 1,80 (1,70–1,90) in ♀, 1,55 (1,50–1,60) in ♂. Caudal segments, Figs 232, 267–268: cauda IV, ventro-lateral and ventral keels poorly developed, consisting of shallowly costate rows of fine granules; cauda V, ventro-lateral and ventro-median keels as in cauda IV; cauda V, ventro-lateral keels moderately diverging from each other; telson vesicle ventrally agranular and moderately punctate, sub-oval in lateral outline **planimanus** (Karsch)

— Pedipalp hand, Figs 292–294: distinctly pilose; movable finger length/hand-back length ratios 1,50 (1,45–1,55) in ♀; 1,40 (1,35–1,45) in ♂. Caudal segments, Figs 231, 290–291: cauda IV, ventro-lateral and ventral keels well-developed, consisting of elevated rows of distinct granules; cauda V, ventro-lateral and ventro-median keels as in cauda IV; cauda V, ventro-lateral keels sub-parallel to each other; telson vesicle ventrally, moderately granular, sub-circular in lateral outline . . . . **tumidimanus** sp. n.

4. Caudal segments: cauda II–V, median-lateral, ventro-lateral and ventral keels completely absent, dorso-lateral and dorsal keels almost completely absent, represented only by a distal granule and sometimes in cauda II–III by a row of small granules. Pedipalp hand, Figs 253–255: $\tau\ eb$ extremely basal in position and almost level with *Et*; $\tau\ Eb_3$ always proximal to Eb_2; $\tau\ Eb_2$ much closer to Eb_1 than Eb_3 5

— Caudal segments: cauda II–V, ventro-lateral, dorso-lateral and dorsal keels always present and ranging from poorly to well developed. Pedipalp hand, Figs 245, 246: $\tau\ eb$ never extremely basal in position or almost level with *Et*; $\tau\ Eb_3$ either level with or distal to Eb_2; $\tau\ Eb_2$ much closer to Eb_3 than Eb_1 6

5. Telson vesicle without a subaculear tooth. Pectines: ♀ 14–15, ♂ 15–17 teeth per pecten. Tergites I–VII, with a dark median band . . . .
otjimbinguensis (Karsch)

— Telson vesicle with a distinct subaculear tooth. Pectines: ♀ 19–20, ♂ 20–22 teeth per pecten. Tergites I–VII, with a pale median band flanked by a dark lateral band on either side .... **vittatus** (Thorell)

6. Pedipalp hand, Figs 210–212: movable finger length/handback length ratio 1,55 or less in adult ♀ and ♂. Pedipalp tibia, Fig. 214: length/external width ratio 2,55 in ♀, 3,2 in ♂. Caudal segments of adults: short and wide, length/width ratio for cauda I 1,05 (1,0–1,10) in ♀, 1,30 (1,25–1,35) in ♂. Tergites I–VII and posterior region of carapace, Fig. 208, with a dark median band; tergites I–VI with reticulate dark markings laterally between the lateral keels and lateral margins, almost forming a continuous band. Carapace: interocular surface with a dark triangular marking .... **carinatus** (Pocock)

— Pedipalp hand, Figs 237–239: movable finger length/handback length ratio 1,90–2,30 in ♀ and 1,80–2,00 in ♂. Pedipalp tibia, Fig. 241: length/external width ratios 4,0–4,3 in ♀ 4,1–4,5 in ♂. Caudal segments of adults: varyingly elongated, length/width ratio for cauda I 1,25–1,60 in ♀, 1,70–1,90 in ♂. Tergites I–VII and posterior region of carapace: median and lateral keels infuscated in some species, but without median and lateral bands as in *carinatus*. Carapace: interocular surface very seldom with a dark triangular marking 7

7. Caudal segments, Figs 227–228, 235–236, 275–276: cauda I–V sparsely pilose; cauda III–IV, ventro-lateral and ventral keels moderately to well-developed, always distinguishable. Pedipalp tibia, Figs 240–241, 280–281: dorso-internal keel moderately to well-developed along entire length; *τ est, et & em* triangular in distribution. Pedipalp femur, Figs 242, 282: dorso-internal and dorso-external keels well-developed along entire length, consisting of enlarged granules 8

— Caudal segments, Figs 234, 243–244, 259–260: cauda I–V densely pilose; cauda III–IV, ventro-lateral and ventral keels obsolete to poorly developed or indistinguishable from adjacent granules. Pedipalp tibia, Figs 247–248, 264–265: dorso-internal keel, proximal one quarter absent, remaining length obsolete; *τ est, et* and *em* falciform in distribution. Pedipalp femur, Figs 249, 266: dorso-internal and dorso-external keels poorly developed 9

8. Caudal segments, Figs 227, 235–236: cauda V, ventro-median keel indistinct from adjacent granules, ventro-lateral keels granular; cauda IV, ventral keels clearly defined in anterior half only, ventro-lateral keels granular and distinctly recurved in posterior half; cauda IV, adults, length/width ratios 1,90 (1,75–2,05) in ♀, 2,45 (2,35–2,55) in ♂; cauda II–III, ventro-lateral and ventral keels granular. Pedipalp hand, Figs 237–239: *τ eb* level with mesial base of fixed finger; distance *τ et–dt* > *est–et*. Pedipalp tibia, Fig. 240: distance $\tau\ d_1–d_2$ equal to half of distance $\tau\ d_3–d_4$. .... **gracilior** Hewitt

— Caudal segments, Figs 228, 275–276: cauda V, ventro-median keel distinct, consisting of a slightly elevated twin row of small granules, ventro-lateral keels consisting of small costate granules; cauda IV, ventral and ventro-lateral keels costate granular, the latter not distinctly recurved in posterior half; cauda IV, adults, length/width ratios 2,5 (2,4–2,6) in ♀, 3,20 (3,10–3,30) in ♂; cauda II–III, ventro-lateral and ventral keels costate. Pedipalp hand, Figs 277–279: *τ eb* distinctly distal to mesial base of fixed finger; distance *τ et–dt*   *est–et*. Pedipalp tibia Fig. 280: distance $\tau\ d_1–d_2$ equal to one quarter of distance $\tau\ d_3–d_4$. . . . . **schlechteri** Purcell

9. Pedipalp hand, Figs 245–246: movable finger length/handback length ratio 2,30 in adult ♀ and ♂; *τ it* level with first outer distal flanking tooth; *τ dt* and *et* separated by two outer flanking teeth; *τ est* halfway between 5th and 6th outer flanking teeth. Pedipalp tibia, Fig. 248: *τ est* distinctly proximal to *et*; *τ em* level with *et*. . . . . **longimanus** Werner

— Pedipalp hand, Figs 261–263: movable finger length/handback length ratio 1,95 (1,90–2,00) in ♀ and ♂; *τ it* proximal to first outer distal flanking tooth; *τ dt* and *et* separated by one outer flanking tooth; *τ est* level with 6th outer flanking tooth. Pedipalp tibia, Fig. 265: *τ est* level with *et*; *τ em* proximal to *et*. . . . . **pilosus** (Thorell)

KEY TO NAMIBIAN SPECIES OF *HADOGENES*

1. Cauda Figs 298–299: cauda I distinctly higher than wide, greatest height/greatest width ratios 1,15 (1,10–1,20) in ♀, 1,22 (1,20–1,24) in ♂; entire cauda 1,2 (1,1–1,3) times as long as trunk in ♀, nearly twice as long in ♂ . . . . **phyllodes** (Thorell)
2. Cauda, Figs 308–311: cauda I distinctly wider to slightly wider than high, greatest height/greatest width ratio at most 0,95 in ♀ and ♂; entire cauda at most subequal to trunk length in ♀, at most one and a half times as long as trunk in ♂ 3
3. Sternite VII, Figs 304–305: lateral margins slightly convex, posterior margin truncated; with distinct postero-lateral oval depressions; median keels present. Cauda, Figs 308–309: entire cauda subequal to trunk length in ♀, nearly one and a half times as long in ♂ . . . . **taeniurus** (Thorell)

— Sternite VII, Figs 302–303: lateral margins strongly convex, almost forming a half-circle with posterior margin; without any postero-lateral oval depressions; median keels absent. Cauda, Figs 310–311: entire cauda only two-thirds as long as trunk in ♀, three-quarters as long in ♂. . **tityrus** (E. Simon)

KEY TO NAMIBIAN SPECIES OF *LISPOSOMA*

1. Carapace: anterior margin sublinear, with a small but distinct median projection. Pedipalps: dentate margin of movable finger with an inner longitudinal row of 6 isolated teeth (Fig. 322); handback, suboval in cross-section; dorso-posterior keel of tibia absent. Caudal segments: I–IV, dorsal keels obsolete to absent except for a single distal granule, dorso-lateral keels absent; I–IV without ventral or ventro-lateral keels in adults . . . . **elegans** Lawrence

— Carapace: anterior margin sublinear, without a distinct small median projection. Pedipalps: dentate margin of movable finger with an inner longitudinal row of 10–16 isolated teeth; handback round in cross-section, distinctly globose; dorso-posterior keel of tibia granular. Caudal segments, Figs 333–

334: I–IV, dorsal and dorso-lateral keels granular; I–IV, with distinct, granular ventro-lateral keels in adult, these less well-developed in subadults and juveniles .... **josehermana** sp. n.

KEY TO NAMIBIAN SPECIES OF *OPISTHOPHTHALMUS*

1. Carapace, Figs 341–348; anterior median furrow with a distinct longitudinal suture usually but not always bifurcating anteriorly; median ocular furrow with a longitudinal suture. (These sutures occasionally not clearly visible on external inspection become apparent on dissected carapace) 2
— Carapace, Figs 349 & 358: anterior median furrow without a bifurcating longitudinal suture; median ocular furrow without a longitudinal suture . 17
2. Pedipalp chela: upper surface of handback, agranular and smooth to very shallowly reticular*; finger keel distinctly costate to predominantly costate. Telson vesicle: ventral surface smooth (seldom, with very few scattered small granules in ♂) 3
— Pedipalp chela: upper surface of handback, either with scattered granules or with rounded to flattened tubercules (these occasionally anastomosing); finger keel granular, occasionally costate distally. Telson vesicle: ventral surface always lightly to heavily granular (except in *O. adustus* where this surface is smooth but telson is lightly to deeply infuscated)............. 9
3. Carapace, Figs 343–344: median eyes distinctly posterior in position with carapace length over anterior distance of median eyes ratio (lc/x) falling between 1,30 to 1,45. Adults very large in size and with telson width distinctly greater than posterior width of cauda V 4
— Carapace, Figs 341–342, 345–346, 354: median eyes postero-medial in position with carapace length over anterior distance of median eyes ratio (lc/x) falling between 1,60 to 1,90. Adults large to moderately large in size and with telson width equal or subequal to cauda V posterior width 5
4. Pedipalp chela, Figs 451–452: outer ventro-lateral keel of handback predominantly costate; ventral surface of handback with 4 V τ. Pedipalp tibia, Figs 454–455: with 14 e τ and 3 v τ (very rarely 4) .... **gigas** Purcell
— Pedipalp chela, Figs 459–461: outer ventro-lateral keel of handback predominantly granular; ventral surface of handback with 5 V τ. Pedipalp tibia, Figs 463–464: with 20–23 e τ and 9–12 v τ .... **haackei** Lawrence
5. Pedipalp tibia, Figs 373, 377 & 380, with 9–13 v τ. Pedipalp chela, Fig. 570, τ V_3 distinctly medial on outer longitudinal axis 6
— Pedipalp tibia with 3 v τ (rarely 4). Pedipalp chela, τ V_3 within proximal half on outer longitudinal axis 7
6. Pedipalp tibia, Fig. 371–373: τ esb with an accessory τ; τ v_1 with an outer accessory τ forming a basal pair; τ d_2 approximately equidistant from τ i and d_1. Hemispermatophore, Fig. 374: hook notch shallowly excavated; position

* *Footnote:* South-eastern populations of *O. carinatus* have the upper surface of handback very shallowly granular. Specimens from these populations could mistakenly be carried through to couplet 9 on this character state alone. The next two character states in this part of couplet 2 should ensure that such specimens are carried through to couplet 3.

of hook apex almost halfway of total distal lamina length, with percentage ha→w distance of dcr→w distance 46% (44–48%). .. **brevicauda** Lawrence

— Pedipalp tibia, Figs 375–380, 571–573: *τ esb* without an accessory *τ*; v_1 without an outer accessory *τ*; *τ* d_2 distinctly closer to *τ i* than d_1. Hemispermatophore, Fig. 574: hook notch deeply excavated; position of hook apex distinctly proximal on total distal lamina length, with percentage ha→w distance of dcr→w distance 35% (33–37%) .... **ugabensis** Hewitt

7. Caudal segments: II, ventro-lateral keels shallowly costate; III, ventral and ventro-lateral keels shallowly costate; IV, ventral and ventro-lateral keels costate granular; V, ventro-lateral keels composed of distinctly elongated, spiniform granules. Carapace: interocular surface smooth to occasionally only very sparsely granular. Legs: telotarsi median dorsal lobe subequal to lateral lobes in length 8

— Caudal segments: II to IV, ventral and ventro-lateral keels absent, ventral surfaces with transverse ridges in ♂, smooth in ♀; V, ventro-lateral keels composed of short spiniform granules. Carapace: interocular surface lightly to strongly granular. Legs: telotarsi median dorsal lobe distinctly much shorter than lateral lobes .... **cavimanus** Lawrence

8. Pedipalp chela, Figs 383–384: outer ventro-lateral keel of handback predominantly costate; *τ est* distinctly distal to *dst*; distance between *τ est* and *esb* approximately equal to half that between *esb* and *eb*. Pedipalp tibia, Figs 385–387: *τ* d_2 approximately equidistant from d_1 and *i*; *τ* v_2 distinctly closer to v_1 than v_3. Legs: posterior surface of basitarsi I and II with a row of 3 to 4 short spine-like setae; lateral claws short, strongly curved and of equal length .... **carinatus** (Peters)

— Pedipalp chela, Figs 495–497: outer ventro-lateral keel of handback predominantly granular; *τ est* slightly distal to or level with *dst*; distance between *τ est* and *esb* approximately equal to that between *esb* and *eb*. Pedipalp tibia, Figs 498–500: *τ* d_2 distinctly closer to *i* than d_1; *τ* v_2 approximately equidistant to v_1 and v_3. Legs: posterior surface of basitarsi I and II with scattered long stiff setae; lateral claws long, distally curved and of unequal length .... **litoralis** Lawrence

9. Telson vesicle: lateral surfaces lightly to heavily granular 10

— Telson vesicle: lateral surfaces always smooth and shiny 11

10. Pedipalp tibia, Fig. 518: *τ* d_2 approximately equidistant from d_1 and *i*. Caudal segments: I, ventral keels obsolete to absent, ventro-laterals shallowly costate; II–III, ventral keels shallowly costate, ventro-laterals costate; IV ventral and ventro-lateral keels costate granular in ♀ and ♂; telson vesicle, posterior upper lateral surfaces with few to many spiniform granules but never including numerous minute spicules. Total body and carapace lengths of adults varying according to regions listed in Table 8 **opinatus** (E. Simon)

— Pedipalp tibia, Fig. 415: *τ* d_2 distinctly closer to *i* than d_1. Caudal segments: I–II, ventral and ventro-lateral keels absent; III ventral and ventro-lateral keels obsolete to absent; IV ventral keels obsolete to absent, ventro-lateral keels obsolete in ♀ and ♂, but occassionally very shallowly costate granular in ♂; telson vesicle, posterior upper lateral surfaces with a moderate number of spiniform granules interspersed with numerous minute spicules. Total body length of adults not exceeding 65 mm (carapace 10,5 mm). Distribution range confined to western central and central regions of Namibia .... **coetzeei** sp. n.

11. Sternite VII and ventral surfaces of cauda I and II rasp-like, covered with large, non anastomosing crescent-shaped granules. Carapace: anterior bifurcation very distinct and long, occupying almost one-quarter of total carapace length .... **setifrons** Lawrence

— Sternite VII and ventral surfaces of cauda I and II smooth or covered with small round granules, these never large or rasp-like but occasionally anastomosing to form shallow transverse ridges. Carapace: anterior bifurcation obsolete to distinct, short and not occupying more than one-sixth of total carapace length 12

12. Caudal segments: IV, ventral and ventro-lateral keels distinct, costate granular or granular; III, ventro-lateral keels shallowly costate 13

— Caudal segments: IV, ventral keels absent, ventro-lateral keels absent to occasionally very weakly costate; III, ventro-lateral keels absent 14

13. Pedipalp chela: outer ventro-lateral keel of handback granular. Caudal segments: IV, ventral and ventro-lateral keels costate granular, distal spine of dorsal keels moderately enlarged. Legs: lateral claws of I and II of unequal length .... **intercedens** Kraepelin

— Pedipalp chela: outer ventro-lateral keel of handback distinctly costate. Caudal segments: IV ventral and ventro-lateral keels granular, distal spine of dorsal keels not enlarged. Legs: lateral claws of I and II of equal length .... **fitzsimonsi** Hewitt

14. Cauda V: ventral surface evenly granular throughout; ventral keel absent and not distinct from adjacent granules; ventro-lateral keels subparallel to each other; each of lateral halves of ventral surface with a mid-lateral seta not flanked by any enlarged granules. In ♂, sternites III–VII and ventral surfaces of cauda I–III evenly granular to shallowly wrinkled. Habitus of ♀ unknown. .... **lornae** sp. n.

— Cauda V: ventral surface sparsely and unevenly granular; ventral keel distinct and granular; ventro-lateral keels either divergent or convergent posteriorly; each of lateral halves of ventral surface with a mid-lateral seta flanked by 1–3 distinctly enlarged granules. In ♂ sternites III–VII and ventral surfaces of cauda I–III smooth and agranular 15

15. Caudal segments, Figs 359–360, 545–546: IV, lateral profile of ventral surface sublinear, entire segment normally developed; V, ventro-lateral keels posteriorly predominantly divergent to each other. Pedipalp chela, Figs 362, 548, 553: outer ventro-lateral keel of handback, predominantly granular 16

— Caudal segments, Figs 441–442: IV, lateral profile of ventral surface arcuate, entire segment unusually globose; V, ventro-lateral keels, posteriorly convergent. Pedipalp chela, Fig. 444: outer ventro-lateral keel of handback predominantly costate .... **gibbericauda** sp. n.

16. Caudal segments II–IV, Fig. 365: distal spines of dorsal keels distinctly elongated and spiniform. Telson vesicle, Fig. 365: ventral surface smooth; entire telson lightly to strongly infuscated. Legs: basitarsi I and II, posterior surface with a comb-like row of long stiff setae; telotarsi III and IV without a ventral anterior row of spine-like setae; telotarsi lateral claws of unequal length, long and distally only slightly curved .... **adustus** Kraepelin
— Caudal segments II–IV: distal spines of dorsal keels only slightly larger than preceding ones. Telson vesicle: ventral surface lightly granular; telson not infuscated. Legs: basitarsi I and II, posterior surface with a row of three spine-like setae; telotarsi III and IV with a ventral anterior row of 1–2 spine-like setae; telotarsi lateral claws of equal length, short and strongly curved .... **schultzei** Kraepelin
17. Carapace: median eyes antero-medial to anterior in position with carapace length over anterior distance of median eyes ratio (lc/x) falling between 2,10 to 2,50. Caudal segments: cauda II, dorsal keels obsolete to absent; cauda III, ventral surface either lightly to distinctly granular or punctate; cauda V, dorsal keels absent, ventro-lateral keels posteriorly convergent 18
— Carapace: median eyes postero-medial to posterior in position with carapace length over anterior distance of median eyes ratio (lc/x) falling between 1,50 to 1,90. Caudal segments: cauda II, dorsal keels present and distinct; cauda III, ventral surface smooth, agranular and not punctate; cauda V, dorsal keels either partially developed or distinct along entire length, ventro-lateral keels either posteriorly divergent or subparallel to each other 21
18. Pedipalp chela Figs 469, 487: ventral surface of handback with 16–20 $V\tau$ 19
— Pedipalp chela Figs 422, 539: ventral surface of handback with 4 $V\tau$ ... 20
19. Pedipalp chela, Fig. 468: handback of ♂ and ♀ moderately wide, with width handback/carapace length ratio 0,53 (0,48–0,58); upper marginal keel of handback granular, composed of granules only slightly larger than those of upper surface of handback. Carapace, Fig. 358: median eyes distinctly anterior in position with carapace length over anterior distance of median eyes ratio (lc/x) falling between 2,35 to 2,50. Caudal segments: cauda III, dorsal keels present and distinct; cauda IV, ventro-lateral keels absent to obsolete; cauda V, lateral profile of ventral surface sublinear to shallowly convex .... **holmi** (Lawrence)
— Pedipalp chela, Figs 486, 488: handback of ♂ (♀ unknown) distinctly wide, with width handback/carapace length ratio (0,70; upper marginal keel of handback composed of blunt spiniform tubercules which are distinctly much larger and longer than those of upper surface of handback. Carapace: median eyes antero-medial in position, with carapace length over anterior distance of median eyes ratio (lc/x) 2,15. Caudal segments: cauda III, dorsal keels absent to obsolete; cauda IV, ventro-lateral keels costate granular; cauda V, lateral profile of ventral surface shallowly concave ....
jenseni (Lamoral)

20. Pedipalp tibia, Figs 541–542: with 14 *e* τ and 3 *v* τ. Pedipalp femur, Fig. 543: τ *d* distinctly distal to τ *i*. Caudal segments: cauda III and IV ventral and ventro-lateral keels absent to obsolete; cauda IV, ventral surface smooth and agranular; cauda V, ventro-lateral keels subparallel to each other. Legs: lateral claws equal in length within each pair; telotarsi median dorsal lobe distinctly shorter than lateral lobes .... **pygmaeus** sp. n.

— Pedipalp tibia, Figs 424–425: with 21–25 *e* τ and 10–13 *v* τ. Pedipalp femur, Fig. 426: τ *d* distinctly proximal to τ *i*. Caudal segments: cauda III, ventral and ventro-lateral keels costate granular; cauda IV, ventral keels granular, ventro-laterals costate granular; cauda IV, ventral surface granular; cauda V, ventro-lateral keels posteriorly convergent. Legs: lateral claws unequal in length within each pair; telotarsi median dorsal lobe length at least equal to that of lateral lobes .... **concinnus** Newlands

21. Carapace, Fig. 349: median eyes posterior in position, with carapace length over anterior distance of median eyes ratio (lc/x) falling between 1,50 to 1,60; carapace, medially with a distinct oval-shaped depression anterior to the median eyes; lateral and posterior surfaces coarsely granular. Caudal segments: cauda IV, dorsal keels distal spine distinctly enlarged and spiniform. Legs: lateral claws long and distally sublinear; telotarsi median dorsal lobe at least as long as lateral lobes, unusually broad and tumescent **flavescens** Purcell

— Carapace: median eyes postero-medial in position, with carapace length over anterior distance of median eyes ratio (lc/x) falling between 1,70 to 1,95; carapace without a distinct depression anterior to the median eyes; lateral and posterior surface lightly to moderately granular. Caudal segments: cauda IV, dorsal keels distal spine at most moderately enlarged. Legs: lateral claws short or long but distally curved; telotarsi median dorsal lobe either distinctly shorter or subequal to lateral lobes and not tumescent . 22

22. Pedipalp chela: upper surface of handback granular. Pedipalp tibia, Fig. 407–408, with 20–23 *e* τ and 7–9 *v* τ. Caudal segments: cauda V, ventro-lateral keels spiniform, dorsal keels present and distinct along entire length, lateral profile of ventral surface shallowly concave. Legs: telotarsi median lobe length subequal to lateral lobes .... **chrysites** Lawrence

— Pedipalp chela: upper surface of handback smooth and agranular. Pedipalp tibia with 14 *e* τ and 3 *v* τ. Caudal segments: cauda V, ventro-lateral keels granular, dorsal keels obsolete or only partially present, lateral profile of ventral surface either sublinear or convex. Legs: telotarsi median lobe distinctly shorter than lateral lobes 23

23. Telson: ventral surface of vesicle granular. Pedipalp chela, Fig. 581, with τV_2 close to the inner margin of the ventral surface of handback. Pedipalp tibia, with τd_2 closer to d_1 than *i*. Caudal segments: cauda III, ventral and ventro-lateral keels costate; cauda IV, ventral keels granular, ventro-laterals costate granular. Legs: telotarsi III and IV without a ventral anterior row of spine-like setae .... **wahlbergi** (Thorell)

— Telson: ventral surface of vesicle smooth and agranular. Pedipalp chela, Fig. 532, with $\tau\ V_2$ submedial. Pedipalp tibia, with $\tau\ d_2$ closer to i than d_1. Caudal segments: cauda III and IV with ventral and ventro-lateral keels absent to obsolete. Legs: tarsi III and IV with a ventral anterior row of 2–3 spine-like setae . . . . **penrithorum** sp. n.

SYSTEMATICS

Family Buthidae E. Simon, 1879

Subfamily Buthinae Kraepelin, 1899

Genus *Buthotus* Vachon, 1949*b*

Type species: *Buthus judaicus* E. Simon, 1872, by original designation.

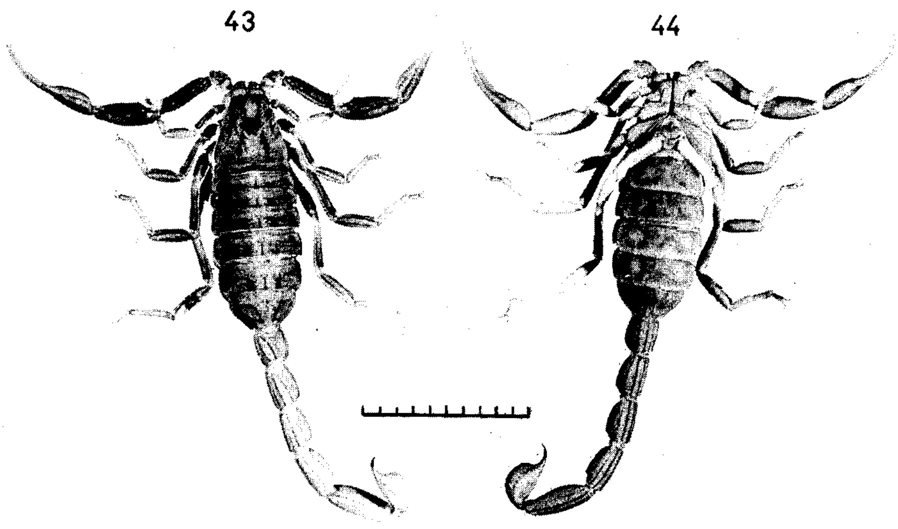
Diagnosis: Vachon (1949*b*: 143–145; 1952*b*: 229–231) and Vachon & Stockmann (1968: 89) diagnose this genus in detail.

Distribution: Angola, Namibia, northern Cape and northern Transvaal of South Africa. East Africa northwards to Ethiopia and Sudan. West Africa, North Africa, Arabia, Iran, Pakistan and India.

Buthotus arenaceus (Purcell, 1901). Figs 43–53, 56–61

Buthus arenaceus Purcell, 1901: 137–139

Diagnosis: A small species (greatest body length of adult ♂ 3,2 cm of ♀ 4,3 cm) which is most closely related to *B. conspersus* but can be distinguished from this species by having a clear halo around each trichobothrium on infuscated surfaces.



Figs 43–44. *Buthotus arenaceus*, largest ♀ from Schwarzkuppen farm (NM 10372). Scale in mm.