

## *Cordylus minor*: A valid species of South African lizard (Reptilia: Cordylidae)

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Received 14 March 1989; accepted 19 June 1989

The taxonomic status of *Cordylus cordylus minor* FitzSimons 1943 is reconsidered. An analysis of variation in external morphological characters shows *minor* and *cordylus* to be two non-overlapping sets of organisms. A phylogenetic study shows the *minor-cordylus* set to be non-monophyletic, leaving no option than to consider *minor* a separate species.

Die taksonomiese status van *Cordylus cordylus minor* FitzSimons 1943 word heroorweeg. 'n Analise van variasie in uitwendige morfologiese kenmerke toon *minor* en *cordylus* as twee nie-oorsleutelende stelle organismes. 'n Filogenetiese studie wys dat die *minor-cordylus* versameling nie-monofileties is, wat geen ander uitweg laat as om *minor* as 'n aparte spesie te beskou nie.

FitzSimons (1943) was of the opinion that the girdled lizard species *Cordylus cordylus* consists of five races, namely *C.c. cordylus*, *C.c. minor*, *C.c. tasmani*, *C.c. pustulatus* and *C.c. rhodesianus*. Loveridge (1944), in his revision of the family Cordylidae, however, recognized 10 subspecies, adding to the list *C.c. rivae*, *C.c. tropidosternum*, *C.c. jonesii*, *C.c. angolensis*, *C.c. lawrenci* and *C. c.niger*. Ever since the work of Loveridge these 11 taxa almost without exception, presented a taxonomic problem in one way or another. We quote Broadley (1965) in this regard: 'The taxonomy of the forms treated as races of *C. cordylus* by Loveridge (1944) presents a formidable task to herpetologists attempting to apply a biological concept to this group'.

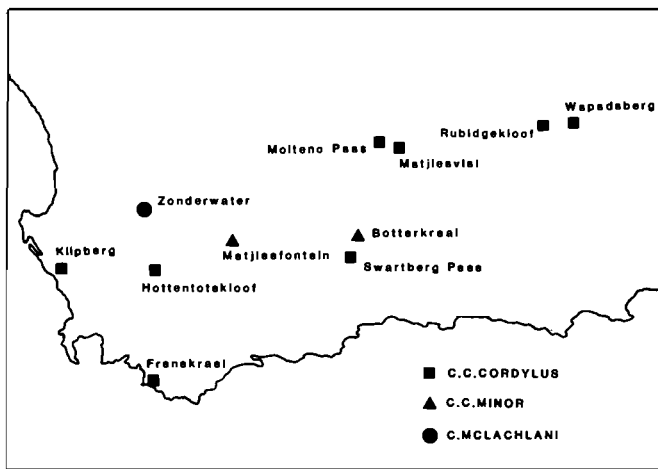
The general opinion today is that most of these races are species in their own right and in the latest checklists of the herpetofauna of southern Africa (Branch 1988a, b) all of the above-mentioned races, with the exception of *niger*, *angolensis* and *jonesii*, are listed as full species. In the mean time *niger* has also been elevated to full species (Mouton & Van Wyk, in press). With the exception of *niger*, however, no formal motivation for elevation to specific rank has been presented for any of these taxa. Broadley (1965, 1971) expressed his views that *rhodesianus*, *tropidosternum* and *tasmani* might be considered full species, *jonesii* as a race of *tropidosternum* and *angolensis* as synonymous with '*tropidosternum tropidosternum*'. Surely, however, it was not his intention that these views should, without further elaboration, be adopted in the formal taxonomic literature.

Likewise Visser (1967, 1971) suggested that *minor* may be specifically distinct, pointing out that *pustulatus*, *lawrenci*, *campbelli*, *namaquensis* and *minor* are 'structurally all very close with similar ecological preferences in the desertic areas occupied by all'. Although listing *minor* as a race of *cordylus*, Branch (1981) shares the opinion of Visser that *minor* shows affinities to *lawrenci* (attention is here drawn to Branch's recent misspelling of the name *lawrenci*, further citations for his '*lawrencei*' should be avoided). The views of Visser and Branch have never been investigated and no formal case for elevation to specific rank has been presented to justify

the subsequent listing of *minor* as a full species by Branch (1988a, b).

The original description of the dwarf girdled lizard, *C.c. minor*, by FitzSimons (1943) was based on six adult specimens collected from just north of Matjiesfontein in the Karoo. This taxon has until recently only been known from the type locality and its immediate environs (Visser 1967). We, however, collected similar *Cordylus* specimens on the farm Botterkraal 45 km to the east of Prince Albert (Figure 1) and the range of this eastern population was subsequently extended 15 km SE to Bruinrante near Meiringspoort by Branch (1988). This new population, as well as the recently described species, *Cordylus mclachlani* (Mouton 1986), provides interesting new material which may help to elucidate the taxonomic status of *C.c. minor*. The objective of our study is to reconsider the taxonomic status of the Matjiesfontein population, and also to consider the status of the new eastern population.

The composition of a species must be seen as a hypothesis and it is the task of the systematist to evaluate all hypotheses and to retain only the most likely one. In the case of allopatric populations critical evaluation of species limits must be done without the aid of the interbreeding criterion and in the past the criterion used in such cases was usually overall similarity. The latter, however, is today considered invalid as a grouping criterion of natural, non-overlapping sets of organisms (Wiley 1981). When no direct information on reproductive behaviour is available, further evaluation of species status can only come from analysis based on the phylogenetic criterion where hypotheses of species composition are based on distributions of synapomorphies (Eldredge & Cracraft 1980; Wiley 1981). If it can be demonstrated that a subset of a hypothesized species shares synapomorphies with another species, the hypothesized species is not monophyletic. Under such circumstances the subset should be removed from the original species and either referred to the other species, described as a separate species or all three taxa described as subsets of a single species. If reproductive isolation between two of the three taxa has been demonstrated the latter option is unavailable.



**Figure 1** Sample populations in the analysis of geographic character variation in the *minor-cordylus* set.

The taxonomic status of *minor* as a subspecies of *cordylus* as proposed by FitzSimons (1943), is based on overall similarity and as such needs re-evaluation. Accordingly, the objective of our study was to determine whether the species *Cordylus cordylus* (i.e. including subsets *minor* and *cordylus*) constitutes a monophyletic assemblage. If it can be demonstrated, in the absence of direct information on reproductive behaviour, that the *minor* subset shares synapomorphies with another species it follows that the *minor* and *cordylus* subsets are not sister taxa and that the hypothesized species is not monophyletic. The *minor* subset will then have to be described as a full species. If, however, the analysis shows the *minor* and *cordylus* subsets to be sister forms the status of *minor* as either full species or subspecies remains moot.

### Materials and methods

Demonstration of *minor* and *cordylus* as two non-overlapping sets of organisms is necessary before an evaluation of the taxonomic status of *minor* can be done. For this purpose 10 populations belonging to the *minor-cordylus* complex were selected (Appendix 1) for an analysis of 'intraspecific' variation in external morphological characters. The selected populations represent a large geographical area and include populations geographically in close proximity to the Matjiesfontein and Botterkraal populations (Figure 1). This facilitated the detection of possible clinal trends within the complex. A population of *C. mclachlani* was included in the analysis as a reference set.

Seventy-nine specimens from the 11 localities were investigated for 11 meristic and eight two-state characters (Appendix 2). In making scale counts the following considerations were followed:

- (1) All scales bordering the eye and in contact with the upper labials, with the exception of the anterior one (preocular), were considered as suboculars.
- (2) All scales bordering the upper lip, with the exception of the rostral, were counted as upper labials. In all cases the large labial below the posterior corner of the eye

were taken as the last upper labial. In many of the specimens examined, smaller scales bordering the upper lip sometimes occurred behind the large upper labial. Because of some confusion whether these scales should be considered as labials, as well as, in some cases, the presence of small granules, which complicate the issue even more, these scales were ignored.

(3) All scales bordering the lower lip, excluding the mental, were counted as lower labials. Any scales following the large posterior lower labial were not considered as labials.

(4) The transverse rows of dorsal scales were counted from immediately behind the occipitals to the base of the tail. The row of scales immediately anterior to the cloaca, when followed around to the dorsal side, was considered the posterior row of dorsal scales.

(5) The number of longitudinal rows of dorsals and laterals were counted more or less midway between the fore and hind limbs across the body. In all cases the first lateral row was easily distinguished from the smaller lateral scales separating the laterals from the ventrals.

(6) The transverse rows of ventrals were counted from axil to groin.

(7) The longitudinal rows of ventrals were counted midway between the fore and hind limbs. Care was taken to unfold the lateral fold when counting the longitudinal rows of ventrals.

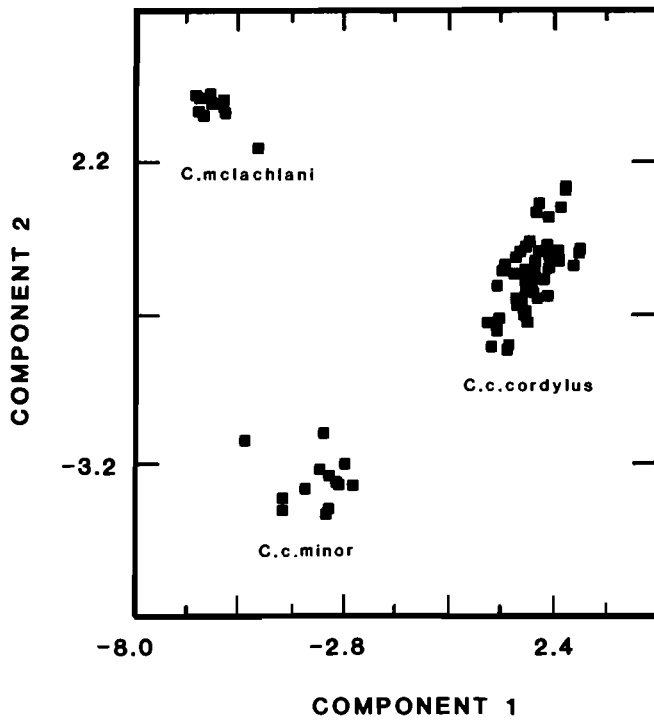
(8) The number of scales under the fourth digit of both the fore and hind limbs were counted from immediately behind the claw to the base of the digit.

Principal component analysis (PCA) (Sokal & Rohlf 1981), which is widely used in intraspecific studies of morphological variation, was used in this study. It was run on an R-mode correlation matrix of standardized data using the Statgraphics statistical package. PCA ordines ungrouped data and could therefore be used on individual specimens. All qualitative characters used in this analysis being two state characters, the states were coded as either 0 or +1 and were used in combination with the meristic characters.

Having demonstrated the *minor* subset to be a non-overlapping set of organisms, its taxonomic status, i.e. whether a separate species or a subspecies of *cordylus*, was considered in terms of the phylogenetic criterion. The program Phylogenetic Analysis Using Parsimony (PAUP) written by David Swofford (1985 version 2.4) was used in this regard. Four taxa were included in this analysis namely *C.c. cordylus*, *C.c. minor*, *C. mclachlani* and *Pseudocordylus capensis* (material investigated were specimens from the Hottentots Holland Mountains). Seventeen external morphological characters were used in the search for shared synapomorphies (Appendix 3).

### Results and discussion

A scatterplot of the first two principal components (Figure 2) which account for 70% of the variation, shows that the primary pattern of morphological variation within the *minor-cordylus* complex is categorical rather than clinal or mosaic in nature. The bottom aggregation includes only individuals of the Matjiesfontein and the



**Figure 2** Principal components analysis (PCA) of the total character set. Points are individual scores plotted on the first two principal components, which account for 70% of the variation.

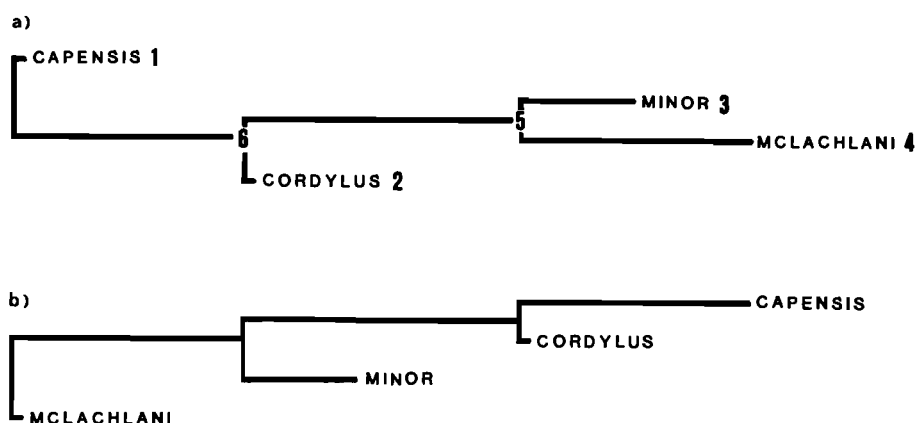
Botterkraal populations, suggesting that, although geographically more than 200 km apart (Figure 1), these two populations probably belong to the same gene pool or only recently separated ones. In terms of the available information there is no choice other than to refer the Botterkraal population to *C.c. minor* FitzSimons 1943. The Botterkraal locality is thus a considerable range extension for *C.c. minor*, previously only known from the type locality at Matjiesfontein. It also bears the implication that this taxon in all probability will be found at other localities in between these two known populations. Morphologically individuals of the two populations are very similar, the only differences being in the higher number of upper labials and the presence of a

**Table 1** Character state matrix prepared for PAUP with *P. capensis* as the designated ancestor (for characters see Appendix 3)

Taxon	Character																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
<i>P. capensis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>C. cordylus</i>	0	0	0	0	0	0	0	0	0	1	0	0	1	1	1	1	1
<i>C.c. minor</i>	1	1	1	1	0	1	0	0	1	1	0	0	1	3	2	2	1
<i>C. mclachlani</i>	1	1	1	1	1	1	1	1	1	2	1	1	1	2	1	1	1

**Table 2** List of character changes for cladogram (a). Nodes are numbered from 1–6 (see Figure 3a) (for characters see Appendix 3)

Character	Changed		Along branch	Consistency
	From	To		
1	0	1	6 → 5	1.000
2	0	1	6 → 5	1.000
3	0	1	6 → 5	1.000
4	0	1	6 → 5	1.000
5	0	1	5 → mclach	1.000
6	0	1	6 → 5	1.000
7	0	1	5 → mclach	1.000
8	0	1	5 → mclach	1.000
9	0	1	6 → 5	1.000
10	0	1	capens → 6	1.000
	1	2	5 → mclach	1.000
11	0	1	5 → mclach	1.000
12	0	1	5 → mclach	1.000
13	0	1	capens → 6	1.000
14	0	1	capens → 6	1.000
	1	2	6 → 5	
	2	3	5 → minor	1.000
15	0	1	capens → 6	1.000
	1	2	5 → minor	1.000
16	0	1	capens → 6	1.000
	1	2	5 → minor	1.000
17	0	1	capens → 6	1.000



**Figure 3** Cladograms obtained with PAUP with (a) *Pseudocordylus capensis* and (b) *Cordylus mclachlani* as the designated ancestor.

posterior interparietal scale in the Matjiesfontein population.

The middle aggregation (Figure 2) consists of all the individuals of the Klipberg, Franskraal, Hottentotskloof, Swartberg, Molteno Pass, Matjiesvlei, Rubidgekloof and Wapadsberg Pass populations (= localities) with very little interpopulation variation. What is important is the high degree of similarity between the western Cape and Karoo populations, bearing in mind that these populations are spread over a distance of more than 600 km. We conclude that the four Karoo populations are in no way separable from the western and southern Cape populations of *C. cordylus*, a possibility mentioned by Branch (1981).

Although the crude method used gives no true reflection of the degree of dissimilarity, the position of the *mclachlani* aggregation in the scatterplot (Figure 2) provides some perspective of the phenetic relationship

between *minor* and *cordylus*.

The character state matrix prepared for the phylogenetic analysis with PAUP is listed in Table 1. An exhaustive search, with *Pseudocordylus capensis* as the designated ancestor, produces only one minimum length tree with a consistency index of 1.000 for all character changes (Figure 3a). The list of character changes is given in Table 2. With *P. capensis* as ancestor *minor* and *mclachlani* share several synapomorphies implicating that they belong to a different subset than *cordylus*. Similarly, with *C. mclachlani* as the designated ancestor *cordylus* and *capensis* share synapomorphies, with *minor* excluded from this subset (Figure 3b). Thus whatever the character-state-transformation sequence *minor* fails to group with *cordylus*. In terms of the phylogenetic criterion *minor* can not be considered conspecific with *cordylus* when either *mclachlani* or *capensis*, depending on the transformation sequence, is excluded from the

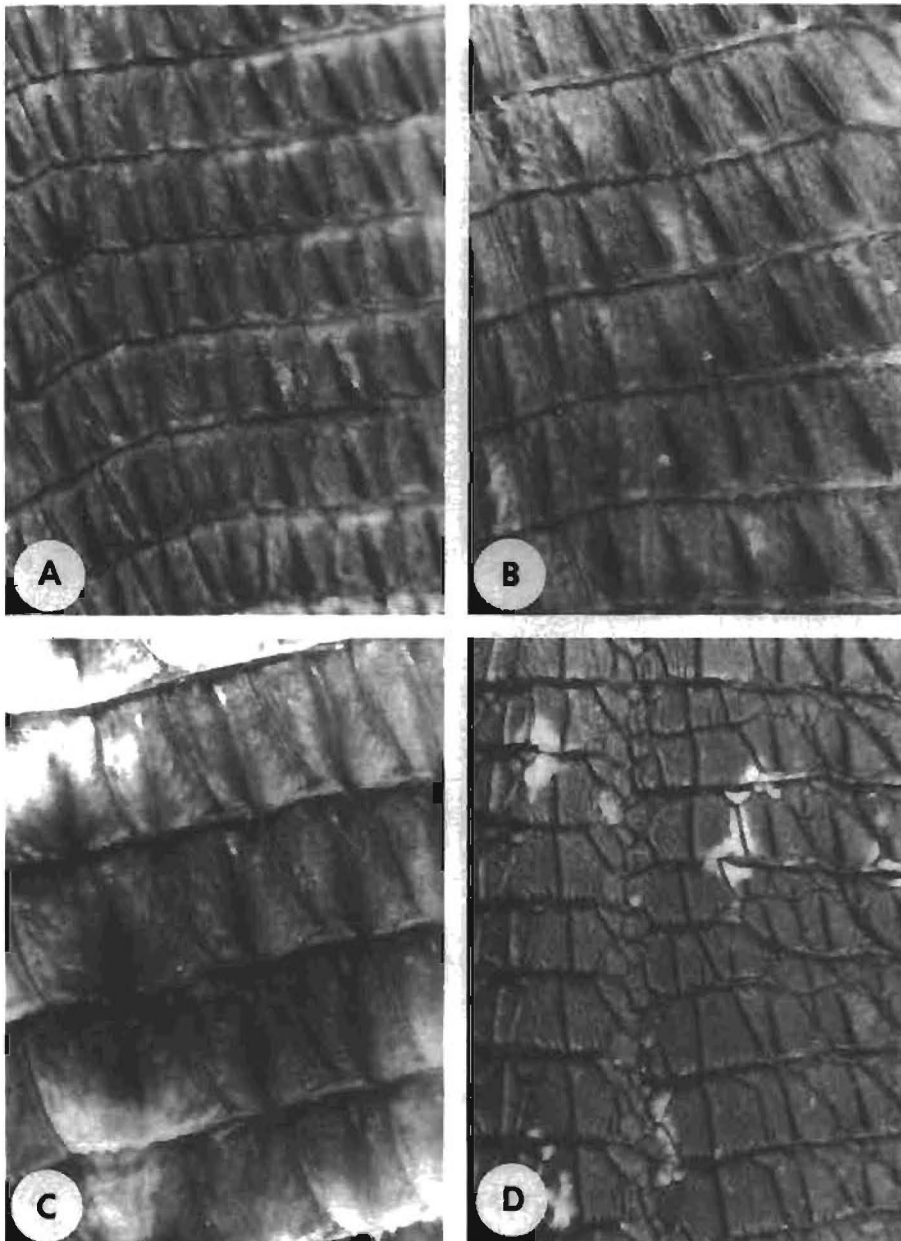


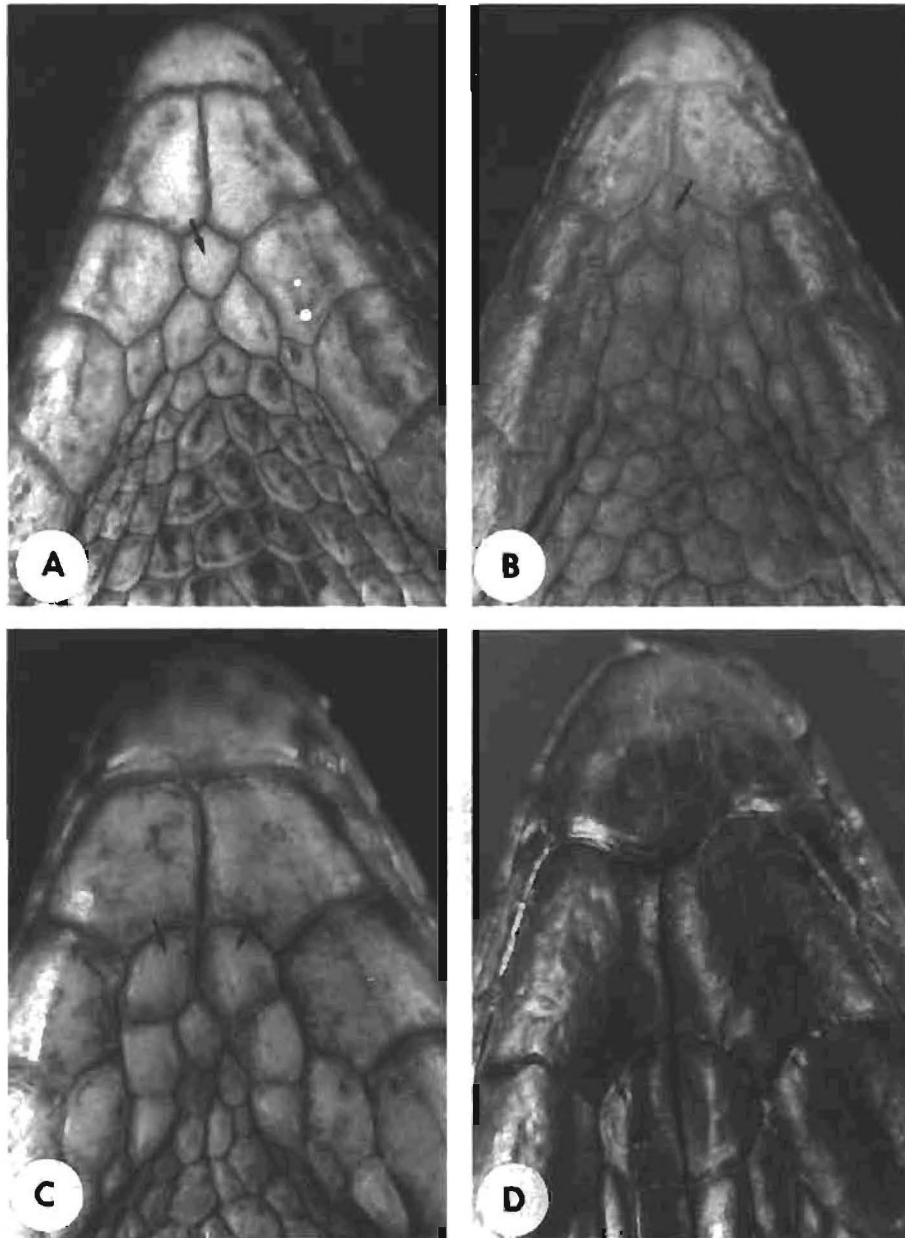
Figure 4 Dorsal scaling in (a) *C. minor*, (b) *C. mclachlani*, (c) *C. cordylus* and (d) *P. capensis*.

hypothesized species. *C. cordylus* and *P. capensis*, however, occur sympatrically at many localities as do *C. cordylus* and *C. mclachlani* (at Wupperthal (Mouton in prep.)) which means, in terms of the reproductive criterion, that neither *cordylus* and *capensis* nor *cordylus* and *mclachlani* can be conspecific respectively. It follows then that *minor* cannot be considered a subspecies of *cordylus*.

It must be pointed out that sister group relationship between *minor* and *mclachlani* is not implicated by the cladogram in Figure 3a, such a conclusion can only be reached when all known *cordylus* taxa are included in the analysis. *C. mclachlani* displays a whole set of autapomorphies, some of them unique to the genus (Mouton 1986), which renders the possibility that *mclachlani* and *minor* might be conspecific unlikely. Furthermore, in *mclachlani* femoral glands are absent in females while in

*minor* they are present. Although no direct evidence is available, there are some indications that the femoral glands might be involved in reproductive behaviour (Duvall 1979; Van Wyk in press) suggesting that *minor* and *mclachlani* might be reproductively isolated. With the information at hand the only valid option therefore is to describe *minor* as a full species.

We would like to point out a few shared character states between *mclachlani* and *minor* which might be useful in further taxonomic studies. In both these taxa the dorsal body scaling is similar, the scales being small, rectangular and keeled obliquely outward (Figure 4a & b). The two vertebral rows of dorsals are not or only slightly enlarged, trapezoid to rectangular in form and longitudinally keeled. Furthermore the dorsals are subequal in size to the laterals. In *cordylus*, on the other hand the dorsal scaling consists of large quadrangular to



**Figure 5** Ventral view of the head showing a single anterior sublingual in (a) *C. minor* and (b) *C. mclachlani* and two anterior sublinguals (chinshields) in (c) *C. cordylus* and (d) *P. capensis*.

squarish scales, longitudinally keeled, and with the inner sides rounded (Figure 4c). The two vertebral rows of dorsal scales are usually distinctly larger than the other dorsals and the laterals usually subequal in size to the dorsals.

Another shared character state worthy of mention is the character of the chinshields. In both *mclachlani* and *minor*, although the sublinguals are enlarged anteriorly, no distinct chinshields are discernable (Figure 5a & b). Furthermore the sublinguals terminate anteriorly in a single sublingual partly separating the first pair of sublabials. In *cordylus* and *P. capensis* on the other hand, chinshields are more readily discernable and the sublinguals (chinshields) terminate anteriorly in two sublinguals next to each other (Figure 5c & d). In addition, in both *mclachlani* and *minor* the posterior pair of parietals are invariably subequal in size to the anterior pair while in *cordylus* and *capensis* the anterior pair is subequal to the posterior pair. In both *mclachlani* and *minor* the dorsal head shields are strongly rugose and pitted both anteriorly and posteriorly. In *cordylus* the posterior head shields are normally rugose to some degree but the anterior shields are normally smooth to only feebly rugose.

### Acknowledgements

The authors thank B.W. Oelofsen who assisted with the collection of the Botterkraal specimens, W.D. Haacke of the Transvaal Museum, Pretoria, for the loan of the type specimens of *C. minor* and W.R. Branch of the Port Elizabeth Museum for *C. cordylus* material. This publication resulted from research done by the Cordylidae Research Group based at the University of Stellenbosch, an international effort to promote and coordinate research on the family Cordylidae.

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### Appendix 1 Material investigated in the analysis of variation in external morphological characters in the *minor-cordylus* set using PCA

- TM19563–19568, the six *C.c. minor* type specimens collected by FitzSimons (1943) from near Matjiesfontein in the Cape Province.
- JEM1486–1492, seven *Cordylus* specimens suspected to be *C.c. minor*, collected by the first author at the farm Botterkraal in the Prince Albert district in the Cape Province.
- JEM1860–1867, eight *C.c. cordylus* specimens collected by the first author in the Swartberg Pass near Prince Albert.
- JEM421–423, 654–662, twelve *C.c. cordylus* specimens from Klipberg in the Darling district.
- JEM1426–1428, six *C.c. cordylus* specimens from Franskraal near Gans Bay.
- JEM65, 66, two *C.c. cordylus* specimens from Hottentotskloof near Ceres.
- PEM-R1638, 1639, 1681, 1682, 1698, 1699, six *C.c. cordylus* specimens from Rubidge Kloof in the Graaff-Reinet district.
- PEM-R1644, 1645, 1674, 1677, 1700, 1701, 1703, 1704, eight *C.c. cordylus* specimens collected at Wapadsberg Pass in the Cradock district.
- PEM-R1646–1652, 1675, 1676, nine *C.c. cordylus* specimens from Molteno Pass in the Beaufort West district.
- PEM-R1635–1637, 1691, 1694, five *C.c. cordylus* specimens from the farm Matjiesvlei in the Beaufort West district.
- SAM47100–47109, the 10 *C. mclachlani* type specimens collected on the farm Zonderwater in the Koue Bokkeveld.
- (TM = Transvaal Museum, Pretoria; SAM = South African Museum, Cape Town; PEM = Port Elizabeth Museum; JEM = J. Ellerman Museum, University of Stellenbosch.)

**Appendix 2** External morphological characters used in the principal component analysis of external morphological variation within the *minor-cordylus* set

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**Meristic characters**

1. Number of supraciliaries.
2. Number of suboculars.
3. Number of upper labials.
4. Number of lower labials.
5. Transverse series of dorsals.
6. Transverse series of ventrals.
7. Longitudinal series of dorsals.
8. Longitudinal series of ventrals.
9. Number of scales under fourth toe.
10. Number of scales under fourth finger.
11. Number of femoral pores.

**Two-state characters**

1. Posterior parietal present or not.
  2. Laterals larger than dorsals or not.
  3. Dorsal scaling rectangular or oblique.
  4. Posterior parietals smaller or larger than anterior parietals.
  5. Supranasals present or not.
  6. Nasals swollen or not.
  7. Single anterior chinshield (sublingual) present or not.
  8. Headshields rugose both anteriorly and posteriorly or not.
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**Appendix 3** External morphological characters used in PAUP to determine the taxonomic status of *Cordylus cordylus minor* FitzSimons 1943

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1. Presence of a posterior parietal.
  2. Size of lateral scaling in comparison to dorsal scaling.
  3. Form of dorsal scaling.
  4. Size of posterior parietals in comparison with anterior parietals.
  5. The presence of femoral pores in both sexes.
  6. The presence or absence of a single anterior sublingual.
  7. Whether the nasals are swollen or not.
  8. Whether supranasals are present or not.
  9. The texture of the head scales.
  10. The number of supraciliaries.
  11. The number of suboculars.
  12. The number of upper labials.
  13. The number of transverse series of dorsals.
  14. The number of longitudinal series of dorsals.
  15. The number of longitudinal series of ventrals.
  16. The number of femoral pores.
  17. The number of lower labials.
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