THE FRESHWATER DIAPTOMIDAE (CALANOIDA: COPEPODA) OF SOUTHERN AFRICA

by

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PREFACE

The taxonomic and systematic work described in this thesis was carried out in the Department of Zoology and Entomology, University of Natal, Pietermaritzburg, from January 1984 to October 1990, under the supervision of Professor J. Heeg.

These studies represent original work by the author and have not been submitted in any form to another university. Where use was made of the work of others it has been duly acknowledged in the text.

Nancy A. Rayner

signed: Nancy A. Rayner

"The essential basis of all biology is the accurate determination of species. This is not, and cannot be made, an easy matter; but it is intolerably difficult for any specialist in a small field, unless the work of such specialists, scattered in small papers through an infinity of periodicals, in all languages, can from time to time be brought together into some form of monograph. Such monographs are necessarily out of date almost as soon as they are written, but at least they serve for a time to make easier the task of those concerned primarily with general problems of biology. The work involved is very great, and perhaps incommensurate with its results, but it is justified by its necessity." (Gurney, 1931)

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ABSTRACT

Freshwater copepod taxonomy has been neglected in southern Africa for more than 50 years and this has placed a constraint on research on the biology and ecology of this important component of the freshwater invertebrate fauna. In this review of the calanoid family Diaptomidae of southern Africa, keys to the freshwater families, the African genera and southern African species are presented as well as diagnoses of the family Diaptomidae and the subfamilies Paradiaptominae and Diaptominae. The genus Lovenula has been revised. All available information on each species has been collated. This includes illustrations of the most important identifying characters, synonymies, a record of material examined and a map of distribution. The discovery of 11 new species, four Paradiaptomus, two Metadiaptomus and five Tropodiaptomus, indicates that the diaptomid fauna of southern Africa is more diverse than was previously envisaged. Biogeography and evolution of the group is discussed with reference to vicariance, dispersal and palaeoenvironments of the African continent. The Paradiaptominae (Lovenula, Paradiaptomus and Metadiaptomus) are endemic to Africa, while the Diaptominae have one endemic African genus Thermodiaptomus and the other, Tropodiaptomus, is not limited to the African continent. The latter genus has speciated throughout the warmer

regions of Africa, with more than 30 described species. Additional collections from isolated regions will, without doubt, substantially increase this number. Included in the account is a glossary of copepod terminology, an explanation of local limnological terms in current use, and a gazetteer. Biographical information on the pioneers of copepod research in southern Africa is included.

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CLASSIFICATION OF AFRICAN DIAPTOMIDAE

The type species for each genus is listed first, except for Tropodiaptomus. * Not recorded from southern Africa

Phylum: Arthropoda

Subphylum: Crustacea

Class: Copepoda

Order: Calanoida

Family: Diaptomidae

Subfamily: Paradiaptominae

Genus: *Lovenula*

Lovenula falcifera (Lovén, 1845)

Lovenula africana (Daday, 1908)

Lovenula excellens Kiefer, 1929

Lovenula simplex Kiefer, 1929

Genus: *Paradiaptomus*

Paradiaptomus lamellatus Sars 1895

Paradiaptomus alluaudi (Guerne & Richard, 1890) *

Paradiaptomus natalensis (Cooper, 1906)

Paradiaptomus greeni (Gurney, 1906) *

Paradiaptomus schultzei Douwe, 1912

Paradiaptomus similis Douwe, 1912

Paradiaptomus sp. nov. A

Paradiaptomus sp. nov. B

Paradiaptomus sp. nov. C

Paradiaptomus sp. nov. D

Genus: Metadiaptomus

Metadiaptomus transvaalensis Methuen, 1910

Metadiaptomus chevreuxi (Guerne & Richard, 1894) *

Metadiaptomus aethiopicus (Daday, 1908) *

Metadiaptomus capensis (Sars, 1907)

Metadiaptomus purcelli (Sars, 1907)

Metadiaptomus meridianus (Douwe, 1912)

Metadiaptomus colonialis (Douwe, 1914)

Metadiaptomus mauretanicus Kiefer & Roy, 1942 *

Metadiaptomus gauthieri, Brehm, 1949

Metadiaptomus vandouwei Kiefer, 1930 - incertae sedis

Metadiaptomus sp. nov. A

Metadiaptomus sp. nov. B

Subfamily: Diaptominae

Genus: Tropodiaptomus #

Tropodiaptomus schmeili (Kiefer, 1926)

Tropodiaptomus hutchinsoni (Kiefer, 1928)

Tropodiaptomus spectabilis (Kiefer, 1929)

Tropodiaptomus sp. nov. A

Tropodiaptomus sp. nov. B

Tropodiaptomus sp. nov. C

Tropodiaptomus sp. nov. D

Tropodiaptomus sp. nov. E

southern African species only

The genus is currently under revision

(see Dumont & Maas, 1987, 1988, 1989).

Genus: Thermodiaptomus

Thermodiaptomus galebi (Barrois, 1891) *

Thermodiaptomus galeboides (Sars, 1909) *

Thermodiaptomus mixtus (Sars, 1909) *

Thermodiaptomus congruens (Sars, 1927)

Thermodiaptomus yabensis (Wright & Tressler, 1928) *

Thermodiaptomus syngenes (Kiefer, 1929)

Thermodiaptomus ricardoae Harding, 1942 *

CHAPTER 1

INTRODUCTION

From 1904 to 1954, nine exploratory and collecting expeditions were organised from Europe and these yielded information on microcrustaceans from many parts of Africa (Dussart, 1980). Three such expeditions collected copepod material from southern Africa: the German South Polar Expedition of 1902-03 collection of freshwater Crustacea from the Cape Peninsula (described by Ruhe, 1914), G.E. Hutchinson's 1929 collection of freshwater Copepoda (identified by Kiefer, 1934) and Copepoda collected by the Swedish-South Africa Expedition of 1950-51 (identified by Brehm, 1958).

The first diaptomid species to be recorded from Africa was the large predatory calanoid Lovenula falcifera which was collected by J.H. Wahlberg from a saline pan in the Transvaal and described by Lovén in 1845 (see Fig. 1 for localities referred to in the text). Sars (1895, 1907, 1927), Cooper (1906), Daday (1908), Brady (1913), Gurney (1904), Methuen (1910), Douwe (1912b, 1914), Kiefer (1926, 1929), also described new species of freshwater copepods from material obtained from scientific expeditions or from enthusiastic collectors such as K.H. Barnard and W.F. Purcell of the South African Museum and J. Gibson, a magistrate from Richmond, Natal. Sars never visited South Africa, relying on his friend Purcell to send him specimens

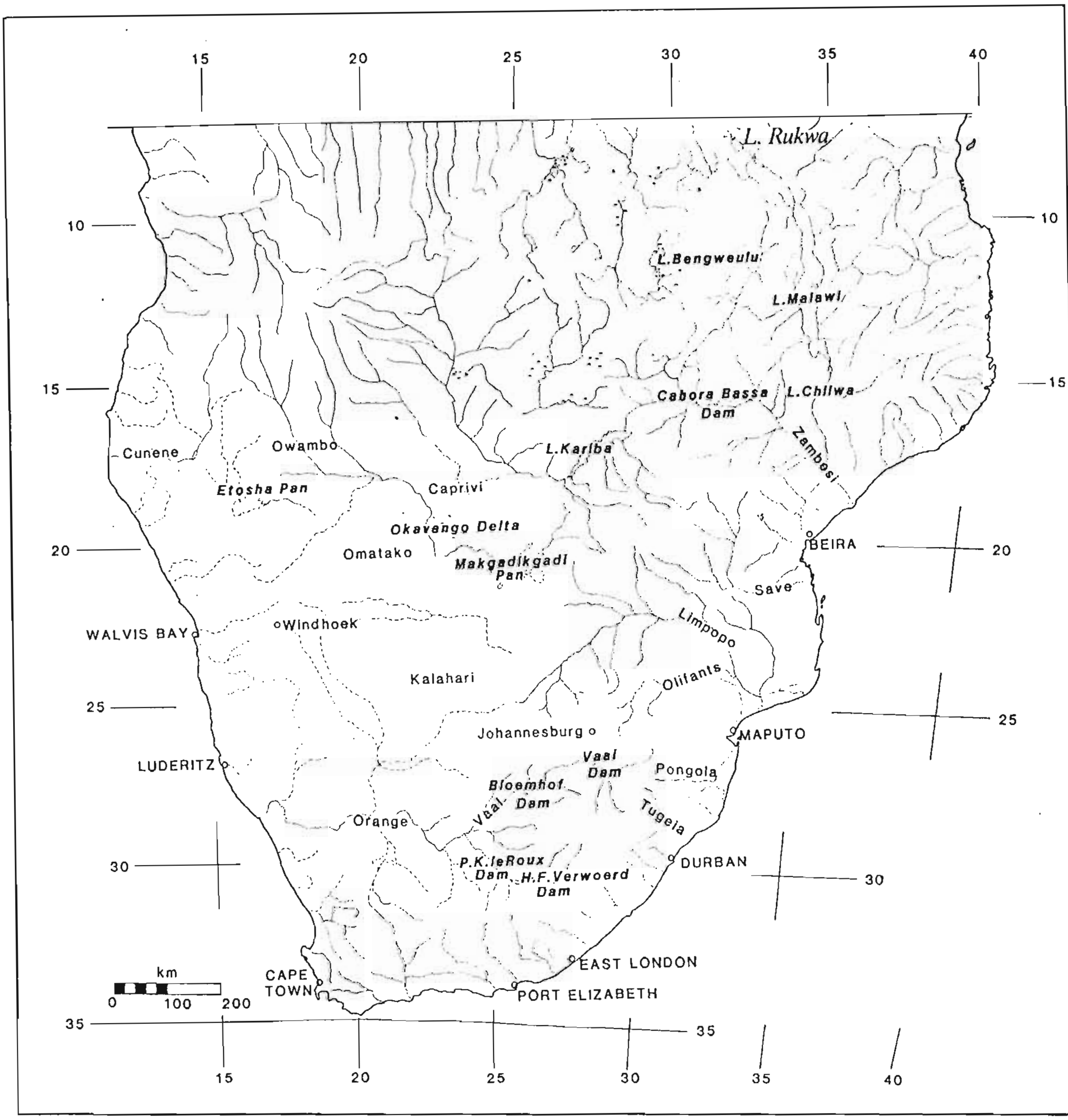


Fig. 1. Map of southern Africa showing countries, cities, major river systems, and some of the freshwater locations mentioned in the text (Gazetteer, Appendix 2). **Transparency** showing geo-political boundaries of southern Africa (except Lesotho and Swaziland) and the four provinces of South Africa (Cape, Natal, Orange Free State, Transvaal) is in pocket inside back cover.

and dried mud for hatching experiments. G.E. Hutchinson initiated the first limnological study in South Africa in 1929, when he surveyed the natural and impounded waters of the southern Transvaal and parts of the south-western Cape province (Hutchinson et al., 1932). This was described by the authors as the first attempt in southern Africa to correlate the planktonic organisms with the chemistry and physics of the environment. Included in this study is information on seasonal succession and factors limiting distribution of species as well as a comprehensive list of planktonic species. Kiefer (1934) identified the Copepoda for Hutchinson, some of which were recognised as new species. Kiefer, in addition to describing new species, made an invaluable contribution to the knowledge of South African freshwater Copepoda with his 1934 monograph. Since that date, although freshwater copepods have been collected in various surveys and in routine impoundment sampling, there has been no taxonomic research on South African freeliving freshwater Copepoda. For biographical notes on taxonomists and collectors associated with freshwater research in southern Africa, see Appendix 1.

The motivation for this study arose when it was realised from work on the zooplankton of Lake Midmar (Rayner, 1981) how poor was the knowledge of the freshwater invertebrate fauna in southern Africa. Initially, it was decided to study freshwater limnetic copepods with a view to mapping distribution and investigating their biology with particular reference to those species which occur in temporary pools in semi-arid areas. Kiefer's (1934) monograph and Sars' papers (1895, 1907, 1927) appeared to be comprehensive enough to use for identification of species. The first narrowing of the field of research arose when it was realised that the cyclopoid Copepoda were too complex a group of organisms to be included in the project. Many cyclopoid species in South Africa are thought to be cosmopolitan and literature is available for their study, but it was realised that some overseas specialist support would be required to undertake a work of this magnitude. When work began on the calanoids in earnest, the correct identification of species was basic to the study. This involved the dissection and analysis of many specimens of each species from different habitats and the checking of the species against the holotype or more often, a literature reference. Wherever possible, the original material used in the description, whether designated as a type or not, was obtained. All material used for species' descriptions early this century, had been sent overseas mainly to Sars (Norway), Kiefer (Germany), Douwe (Germany), and taxonomists at the British Museum (Natural History). The tracing of this material posed problems, with the exception of the material which had been returned by Sars to the South African Museum. With an increasing intensity of study of the local diaptomid species from material obtained locally or from overseas, it was realised that the taxonomy of the diaptomids of southern Africa was confused. The study thus narrowed further, with copepod biology being supplanted by diaptomid taxonomy. Some of the major problems were: misidentification of some of the most important species had become entrenched in the literature; a number of species had been "identified" from the literature with no reference to the type and were in fact new species; Tropodiaptomus kraepilini, while not occurring in South Africa, had been used as a blanket name for a number of undescribed Tropodiaptomus species. However, despite these problems, the efforts of taxonomists such as Sars, Douwe and Kiefer must be acknowledged, as they laid the foundations of copepod taxonomy in South Africa at a time when difficulties with communication alone would have been a major complicating factor. Limited collections and unfamiliarity with the physical geography of southern Africa through not having visited the subcontinent, also detracted from their otherwise excellent contributions to our knowledge of the Copepoda of the region. The expertise of Sars and Kiefer and especially Sars' magnificent illustrations, as well as the dedication of many of the early collectors and taxonomists, were an inspiration to me to continue taxonomic research on South African freshwater diaptomids, after a lapse of 50 years.

There are six families of calanoid copepods which have representatives in freshwater, coastal lakes and estuaries, or are relict marine species. The majority of freshwater calanoids belong to the family Diaptomidae which has a worldwide distribution. Sars (1903), created a new family for the Diaptomidae when he separated them from the Centropagidae. Kiefer (1932) established two subfamilies, the Afrotropical Paradiaptominae (Paradiaptomus, Lovenula, Metadiaptomus) and the Diaptominae (all the other diaptomid genera, including two which occur in southern Africa, Tropodiaptomus and Thermodiaptomus).

On the African continent, Dussart (1980) recorded 94 species or subspecies of calanoids in 16 genera and three families: Acartiidae, Pseudodiaptomidae and Diaptomidae. The two former families are found only in coastal lakes and estuaries. All the inland freshwater calanoid species in Africa are endemic diaptomids, some with a localised distribution. In southern Africa there are five genera with 19 described species, whose ranges, with few exceptions, are restricted to the Afrotropical subregion south of the Zambesi River. When the 11 new species have been described, the number of known southern African species will increase to 30. African species not recorded from South Africa are two Paradiaptomus, three Metadiaptomus, five Thermodiaptomus and some 30 Tropodiaptomus species.

CHAPTER 2

MATERIAL AND METHODS

Collection

Diaptomids were obtained from zooplankton samples from a wide range of freshwater habitats in southern Africa (see repositories and collectors listed below). Every attempt was made to trace holdings of copepod material, both in South Africa and Europe. A request for Brehm's material was graciously acknowledged but his 'heritage' appeared to have been lost. Letters to two institutions in Zimbabwe were ignored and attempts to contact museum authorities in Sweden, met with a refusal. A week was spent at the British Museum (Natural History) studying holdings of African Diaptomidae. Material was requested through the newsletter of the Limnological Society of Southern Africa. A good source of material came from requests by limnologists for the identification of freshwater zooplankton. Taxonomic decisions were made, and keys to genera and species were constructed, from analysis of dissected, preserved specimens.

Numbers have not been given under 'material examined' as sample vials invariably contained a large number of individuals from which some were selected for study. Details of material examined are presented in the following order: Museum catalogue number (where relevant), locality, collector's name, date, identification on the museum label (whether correct or not).

Repositories which provided material

South Africa:

Albany Museum, Grahamstown	AM
Albany Museum, general collection	AM-GEN
Albany Museum, Great Fish river survey	AM-GFR
Albany Museum, Vaal river catchment survey	AM-VAL
Natal Museum, Pietermaritzburg	NM
South African Museum, Cape Town	SAM
Transvaal Museum, Pretoria	TM

Other countries:

State Museum, Windhoek, Namibia	SMN
British Museum (Natural History)	BMNH
Zoological Museum, University of Hamburg	ZMUH
Hungarian Natural History Museum	HMNH

Names of Collectors

KHB - K.H. Barnard (S.A. Museum, 1911-1956)

FMC - F.M. Chutter

JAD - J.A. Day

AJCG - A.J.C. Gardiner

RCH - R.C. Hart

JMK - J.M. King

WFP - W.F. Purcell (S.A.Museum, 1896-1905)

MTS - M.T. Seaman.

Analysis of material

Specimens were preserved in 4% formalin or 75%

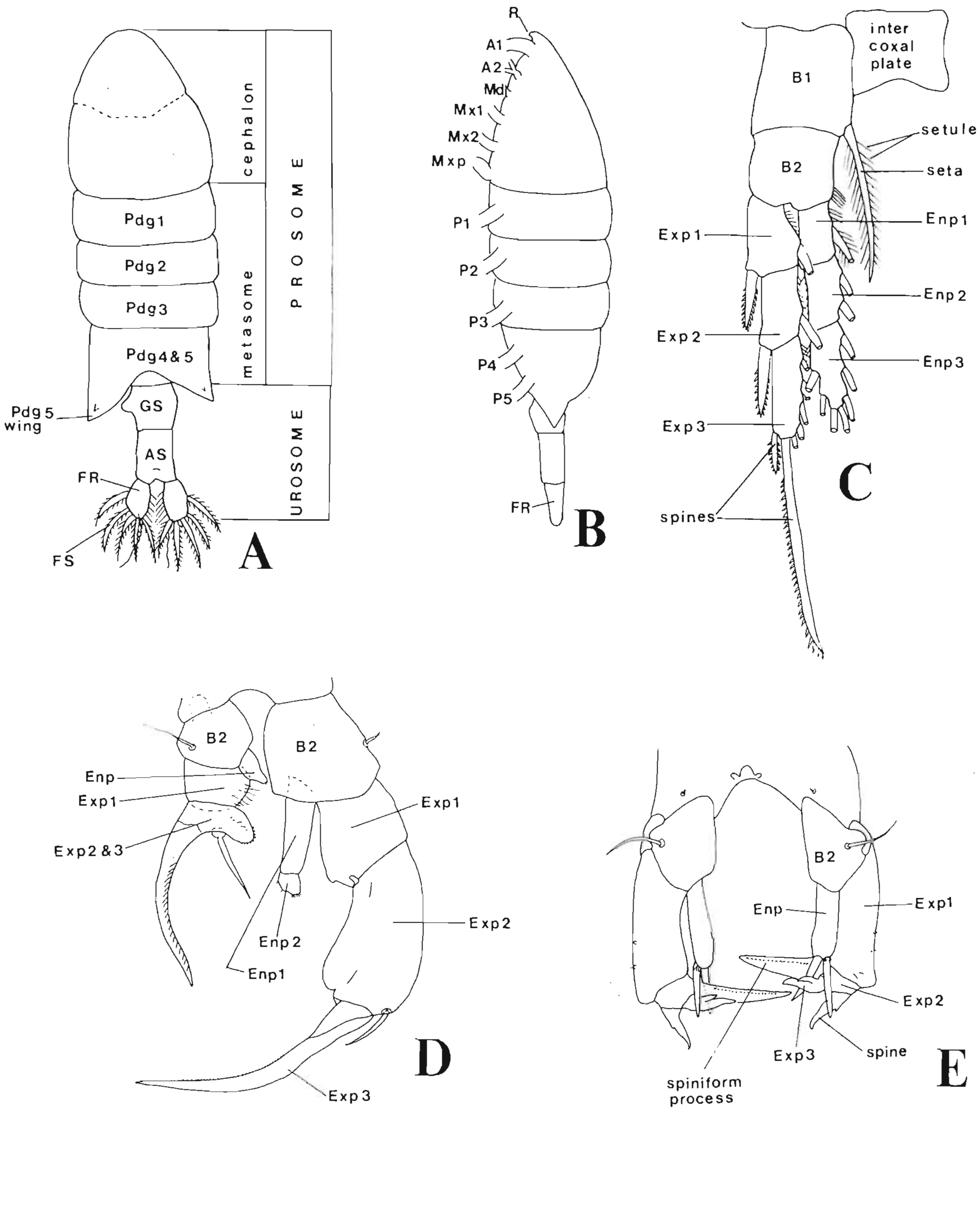
alcohol. Mounting was done in glycerine jelly sealed under cover slips with DPX. For more detailed examination of specimens, Phloxin B and Chlorozol Black E were used as stains. Cover slips on large whole mounts were supported at the four corners by "Prestick" so as to avoid crushing the specimen, and sealed in the usual way. A reference collection of 290 microscope slides and numerous wet specimens, was prepared. A Leitz Laborlux 12 microscope with a Wild Photoautomat MPS 45/51 and a camera lucida were used for identifying, measuring, dissecting, photographing and drawing specimens. All measurements are in millimetres, exclude furcal setae, and have been compiled from material examined, unless otherwise stated. The number of specimens measured varied, depending on the material available. Total length of individuals was a reliable measure for inter-specific comparisons, as well as comparisons between males and females within species. Prosomal length, although a slightly more accurate measurement, yielded less information in this respect. Measurements and coloration are affected by age and period of time of preservation of the specimen. Curvature of female antennae affects measurements relative to body length. Thoracic 'wings', shape of the tip of last segment of male right A1, and male P5 left exopodite (see Figs 36A, 36B) may be affected by orientation on the microscope slide. There is a tendency in some species for furcal setae to break, often in a consistent manner, and they have been illustrated accordingly (e.g. Fig. 16A).

The four Lovenula species have been illustrated in detail. For those described species for which literature is readily available, only the main identifying characters have been redrawn. The status of some species formerly classed as incertae sedis was resolved and these species have been illustrated in greater detail. The confusion in the literature, the lack of designation of type specimens and the unavailability of reference material, hampered progress. In the text, 'type locality' refers to the locality where the species was first collected, despite the fact that types were seldom designated. (The International Code of Zoological Nomenclature rules that the type locality is the locality where the name-bearing type was collected, so in some cases, the use of the term type locality is not correct). All African diaptomids, except some 30 Tropodiaptomus species, have been incorporated into the text, but no illustrations have been included for those species which have not been recorded from South Africa. Eleven new species will be described formally at a later date. Only those characters which distinguish a new species from others in the genus, have been illustrated.

Terminology and abbreviations

Fig. 2.

Note: Some of the terms are well known to copepodologists but have been included for non specialists, especially in southern Africa, who may be unfamiliar with


cephalon
metasome
PROSOME
UROSOME
Pdg1
Pdg2
Pdg3
Pdg4&5
Pdg5 wing
GS
AS
FR
FS
A
R
A1
A2
Md
Mx1
Mx2
Mxp
P1
P2
P3
P4
P5
FR
B
inter coxal plate
B1
B2
setules
seta
Enp1
Enp2
Enp3
Exp1
Exp2
Exp3
spines
C
B2
B2
Enp
Exp1
Exp2 & 3
Exp1
Exp2
Enp2
Enp1
Exp3
D
B2
Enp
Exp1
Exp2
Exp3
spine
spiniform process
E

copepod terminology.

C.V. = coefficient of variation (%). $\bar{x}$ = mean.

aesthetask: small rod-shaped sense organ on A1

anal somite (AS): somite proximal to furcae (Ur2 or 3 in female, Ur5 in male)

antenna 1 (A1): antennule, the first prosomal limb

antenna 2 (A2): antenna, the second prosomal limb

basis (B2): basal stem segment of endopodite and exopodite

body length (TL): total length excluding furcal setae

cephalon (cephalosome): head, including maxilliped somite

coxa (B1): the middle stem segment of a biramous limb

egg sac, brood sac: receptacle for eggs forming part of genital complex

endopodite (Enp): inner ramus of biramous appendage beginning with segment Enp1

exopodite (Exp): outer ramus of biramous appendage beginning with segment Exp1

furca (FR): caudal rami

furcal setae (FS): five spiny terminal setae and one slender "dorsal" seta arising from each furcal ramus

genital somite (GS): first urosomal double somite in female (Ur 1+2)

length : breadth (L:B): ratio maximum length to breadth of a structure

mandible (Md): the third prosomal limb

maxilla 1 (Mx1): maxillule, the fourth prosomal limb

maxilla 2 (Mx2): maxilla, the fifth prosomal limb maxilliped (Mxp): the sixth prosomal and first thoracic limb

metasome: pedigerous somites between cephalon and major articulation of the body

natatory legs (P1-P4): swimming legs, relating to pedigerous somites Pdg1-4

pediger (Pdg): a thoracic leg

pediger 5 (P5): modified swimming leg, relating to pedigerous somite Pdg5

precoxa (Pcx): the proximal stem segment of a biramous limb

prosome (Pr): complete body section anteriad to the major articulation (Head + Pdg1-5)

rostrum (R): a beak-like projection on anterior of the prosome

segment (Seg): fundamental division of a limb

seta: relatively long, flexible process, tapering to a point, generally with a double row of fine hairs (setules), giving the appearance of a feather

somite: fundamental body division

spermatophore : rod-shaped structure containing sperm, attached by male to female genital opening or urosome

spine: short, strong, more or less inflexible, usually armed on each side with a row of small denticles giving it a saw-like edge

spiniform process: an extension of a segment having the appearance of a spine

spinule: very small spine

thoracic somites (Pdg1-5): pedigerous thoracic somites thoracic 'wings' (Pdg5 wings): expansion of last prosomal somite in female to form wing-like processes

thorn: a hollow, usually pointed, extension of a limb segment

urosome (Ur): complete body section posteriad to the major articulation, the first somite being the non-pedigerous genital double-somite

Terms to be avoided: head, cephalosome, cephalothorax, mesosome, thorax, abdomen, cephalic somite, caudal rami, 'joint' and 'article' for segments, 'foot' instead of 'leg', telson.

Limnological terms of local origin

dam: a man-made impoundment. This term has become common usage in South Africa although in the northern hemisphere it relates to a wall which impounds a river.

pan: as defined by King (1951) "Pans, in the South African usage of term, are shallow depressions varying from a few square feet up to several square miles in area which occur typically along a belt stretching north-north-east from Calvinia, through the northern Cape and the western Orange Free State to the Transvaal. This belt is about 600 miles long and 100 miles wide, with a branch into South-West Africa and an outlying patch about Lake Chrissie in the Eastern Transvaal. After rain they may contain water; but often they are dry, broad floors of muddy and salty accumulation".

"Most pans are due to wind action. Fresh, brak, and salt pans more than a hundred yards wide are estimated to number about 9000 in the Kalahari south of the Okavango and Zambezi Rivers. The formation of very large pans, such as Etosha Pan and the panlands of Makarikari was induced by factors other than wind erosion. The Lake Chrissie pans are peculiar because they are relics of an ancient drainage system belonging to the Umpilusi River, from which the Vaal River has captured the headwaters. The flat channels, blocked by abundant sand from the quick-weathering local sandstones, have developed into pans, sometimes coalescing. Certain of the pans about Lake Chrissie are joined by a thread of outflow along the ancient channels". "The presence of pans possibly indicates a more arid climate in the past......nevertheless the situation of many does not lend support to the hypothesis".

The mean annual rainfall of South Africa is 475 mm compared with a world figure of 860 mm. In over 60% of South Africa and Namibia, the rainfall rarely reaches the sea. In most areas, run-off does not occur and the rains are absorbed immediately by the sandy soil. "Small rivulets have a short life and big floods are infrequent" (King 1951).

vlei: "The beds of intermittent rivers have in many cases been so choked by wind-drifted sand or silt that the original gradients have been lost, and a series of shallow lakes or "vleis" now appears after rains instead of a flowing river" (King 1951).

CHAPTER 3

KEYS TO FAMILIES AND AFRICAN GENERA OF FRESHWATER CALANOIDA

KEY TO FAMILIES

Adapted from Gurney (1931), Dussart (1967), Kiefer (1978a)

1 P1 endopodite with 3 segments,
P2-P4 endopodite with 3 segments....................2

1' P1 endopodite with fewer than 3 segments,
P2-P4 endopodite with 1-3 segments..................3

2 P5 in both sexes identical to P1-P4, with 3-segmented endopodite..........................F. Centropagidae

2' P5 modified in both sexes, female without endopodite*, male with one-segmented endopodite *..F. Pseudodiaptomidae

3 P1 endopodite 2-segmented,
P2-P4 endopodite 2- or 3-segmented..................4

3' P1 endopodite 1-segmented,
P2-P4 endopodite 1- or 2-segmented........F. Temoridae

4 P2-P4 endopodite 3-segmented,
P5 with endopodite in both sexes........F. Diaptomidae

4' P2-P4 endopodite 2-segmented,
P5 without endopodite in both sexes......F. Acartiidae

* some exceptions (Dr. T.C. Walter, Smithsonian Inst., Washington, D.C., U.S.A., pers. comm.).

Family Diaptomidae G.O. Sars, 1903

Family Centropagidae (partim)

Giesbrecht, 1892: 58

Schmeil, 1896: 5-6

Giesbrecht & Schmeil, 1898: 52

Douwe, 1909: 4

Thiebaud, 1915: 8

Family Diaptomidae

Sars, 1903: 83

Pesta, 1928: 27-28

Rylov, 1930: 78; 1935: 169

Gurney, 1931: 108

Kiefer, 1932a: 460; 1960/73: 23-24; 1978a: 70

Damian-Georgescu, 1966: 40

Dussart, 1967: 88

General description of the Diaptomidae

The cephalon is distinct from Pdg1. Pdg4 & Pdg5 are fused and often expanded in female to form 'wings'. Female urosome with two or three somites; urosome of male with five somites and may be asymmetrical. Genital somite of female is expanded laterally, sometimes with prominent asymmetrical lobes. Furcal rami are usually longer than broad, typically symmetrical in female, sometimes asymmetrical in male, with lateral setae on right furcal ramus sometimes modified in male. Female A1 and male left A1 are 25-segmented (for details of individual segments with setae, aesthetasks and sensory spines, see

Kiefer 1978a). Male right A1 has 21 or 22 segments, enlarged and modified from segment 13 to 18 with geniculation between segments 18 and 19. The 21-segmented A1 has three terminal, post-geniculate segments; the 22-segmented A1, has four. A2 has a 7-segmented exopodite which is longer than endopodite. P1 has a 2-segmented endopodite and 3-segmented exopodite, Exp2 lacks spine, Exp3 with one or two spines; P2-P4, endopodite and exopodite with three segments, Exp3 with one spine. P5 is non-natatory and biramous in both sexes. Female P5 has Exp2 produced mediad into a large, inner, spiniform process; Exp3 is reduced or absent or represented by one or two movable spines. Male P5, as well as basal segments of limb, highly asymmetrical, right leg much longer than left. Right leg has a lateral spine on Exp2; Exp3 is represented by a long, hinged, terminal blade-like claw. Male left P5 with Exp2 and Exp3 fused and variously modified, with sensory pads, spine-like outgrowths and setae. A single egg-sac in female, rod-shaped spermatophore in male.

Kiefer (1932a & b) split the Diaptomidae into two subfamilies, Paradiaptominae and Diaptominae.

Subfamily Paradiaptominae Kiefer, 1932a

P1, Exp3 with two outer spines; male right A1 with three post-geniculate segments, terminal segment usually with beak-like extension; male left P5, Exp2 with strong, well-developed lateral or medial spiniform process. There are three Paradiaptominae genera, <u>Lovenula</u> Schmeil, <u>Paradiaptomus</u> Sars and <u>Metadiaptomus</u> Methuen and they include some large predatory species which occur in temporary waters in drier regions and also in permanent waters. The majority of species are endemic to Africa.

Subfamily Diaptominae Kiefer, 1932a

P1, Exp3 with one outer spine; male right A1 with four post-geniculate segments, terminal segment without extension; male left P5 often with circular, serrated Exp2 and spine, if present, short and broad-based. The Diaptominae are cosmopolitan and include all the rest of the diaptomids, some 45 genera (Dussart & Defaye 1983).

KEY TO AFRICAN GENERA OF THE FAMILY DIAPTOMIDAE

Females

1 Urosome with two somites *............................2

1' Urosome with three somites (Fig. 25C)....Metadiaptomus

2 Body length usually > 2.0 mm,
Maxillipeds raptorial, with Enp with <5 segments......3

2' Body length seldom > 2.0 mm,
Maxillipeds not modified, with Enp with 5 segments....4

3 Body length 3.0-4.0 mm,
Maxillipeds scythe-shaped (Fig. 4I),
P5, Exp3 represented by two closely-applied spines, outer longer than inner, which project across large spiniform process of Exp2,
Furcal rami twice as long as broad, setae without bulbous bases (Fig. 3)......................Lovenula

3' Body length 2.0-3.5 mm,
Maxillipeds not as above,
P5 Exp3 represented by 2 small spines, outer shorter than inner, spines not projected across Exp2 spiniform process,
Furcal rami sometimes lamelliform, expanded distally, setae usually with bulbous bases (Fig. 15B)..Paradiaptomus

4 P5 endopodite with 2 terminal setae (Fig. 28B)...Tropodiaptomus

4' P5 endopodite without terminal setae (Fig. 39C)...Thermodiaptomus

* North African species Paradiaptomus alluaudi has three somites.

Males

1 Right A1, 21-segmented, geniculate between segments 18 and 19, no articulation between segments 20 and 21, diagnostic spiniform processes on segments 8, 10, 11, 13,
Left P5, Exp2 with spiniform process well-developed, lateral or medial.....................................2

1' Right A1, 22-segmented, geniculate between segments 18 and 19, articulation between segments 20 and 21, diagnostic spiniform processes on segments 10, 11, 13, 15,
P5, Exp2 without spiniform process...................3

2 Maxillipeds not raptorial, Enp with 5 segments,
Right P5, B2 expanded on inner margin and fringed with

small knobs, spines or setae (Fig. 18)................. ...._Metadiaptomus_

2' Maxillipeds raptorial, Enp with < 5 segments, Right P5, B2 not expanded and without knobs, spines or setae..4

3 Right P5, Exp2 parallel to long axis of body with lateral spine adjacent to Exp3 blade-like claw (Fig. 31D)..................................._Tropodiaptomus_

3' Right P5, Exp2 at right angles to long axis of body, with lateral spine separated from Exp3 blade-like claw (Fig. 40A)................._Thermodiaptomus_

4 Body length 2.5-4.0 mm
Maxillipeds scythe-shaped (Fig. 4I),
Left P5, Exp2 with strong, terminal spiniform process,
Setae of right furcal ramus modified with three lateral setae separated from two medial setae (Figs 3-4)..._Lovenula_

4' Body length 2.0-3.5 mm,
Maxillipeds not as above,
Left P5, Exp2 with short, lateral spiniform process,
No separation of setae on right furcal ramus but outermost seta may be enlarged (Figs 10E-F).............. ...._Paradiaptomus_

CHAPTER 4

REVISION OF THE GENUS LOVENULA SCHMEIL, 1898

INTRODUCTION

The known species of Lovenula are:

Lovenula falcifera (Lovén, 1845)

Lovenula africana (Daday, 1908)

Lovenula excellens Kiefer, 1929

Lovenula simplex Kiefer, 1929

Four Lovenula species are endemic to South, East and North Africa: Lovenula falcifera (Lovén), L. africana (Daday), L. excellens Kiefer and L. simplex Kiefer. All are comparatively large predators and the possession of well-developed raptorial maxillipeds is not only a striking morphological feature but also a highly-weighted taxonomic character. Broteas falcifer was collected by J. Wahlberg from a saline pan near the junction of the Crocodile and Apies Rivers in the Transvaal (Fig. 1), and deposited in the Swedish State Museum where it was described by Lovén (p. 206).

The taxonomy of the genus has been confused for nearly a century, mainly because research has been undertaken by scientists from European institutions, most of whom never visited South Africa. They relied on small samples of animals, or sediment from temporary waters, sent to them by colleagues. An outstanding contribution was made to the knowledge of South African freshwater micro-

Crustacea by G.O. Sars (p. 207), who described new species of Cladocera, Ostracoda and Copepoda from southern Africa. Although he did not designate types, he returned the material to the South African Museum in Cape Town, where it is still available for study. Other material collected in the early part of this century was housed in European museums and, in many cases, it has been lost or records are not traceable. Tribute must be paid also to Frederich Kiefer (p. 211), one of the greatest of all freshwater copepod taxonomists, who, together with Sars, laid the foundation of the taxonomy of freshwater micro-Crustacea in southern Africa. Kiefer (1934) reviewed the South African freshwater Copepoda and so provided a firm basis for current taxonomic research on copepods in southern Africa. In addition, the world list of calanoid copepods compiled by Dussart & Defaye (1983) is an important reference work.

The four closely related _Lovenula_ species are among the largest of the freshwater diaptomids and it is surprising that there has been so much confusion about the identity of these magnificent predatory copepods. However, the constant changes to the generic name, as well as the large number of synonyms, testify to the lack of any in depth study, and Kiefer (1934) was largely disregarded in his attempt to create stability. Sars (1899) redescribed '_L. falcifera_' from material sent to him from the Cape Flats by W.F. Purcell (p. 208) but the specimens used by Sars were _L. simplex_ (yet to be recognised as a new species by Kiefer, 1929). Rühe (1914) (p. 210) also did not recognise L. simplex as a new species when he identified it as Paradiaptomus falcifer. Although these two species are closely related taxonomically, the geographical separation of L. falcifera and L. simplex which is so obvious today (Fig. 6) would surely have been questioned by early taxonomists if more material had been available for study. Communication was also a problem as shown by Lovén (1845) giving the type locality of L. falcifera as the Magaliesberg (Transvaal) on the road to Port Natal. Douwe (1912a) suggested that Sars' (1899) redescription was not that of L. falcifera but related to a new species. However, despite Douwe's misgivings, Sars (1927) again recorded L. simplex as L. falcifera.

In his collecting expeditions in Ovamboland in the 1920's, K.H. Barnard (p. 210) had collected a species of Lovenula from temporary pools in this arid area of Namibia. Sars (1927), realising that this was a different species from his L. falcifera (i.e. L. simplex) named the new species L. barnardi. From this time onwards, L. simplex was known as L. falcifera and L. falcifera as L. barnardi, an error perpetuated by Harding and Smith (1967). In addition to the confusion over L. falcifera and L. simplex, there was a lack of authentic information on L. excellens, a Lake Chrissie species described by Kiefer (1929). Methuen (1910) failed to recognise it as a new species, identifying it as 'a local variety' of Broteas falcifer.

It is hoped that this revision will create stability in the genus Lovenula and lead to a reassessment of the Paradiaptominae of Africa. Dussart (1980) stressed the importance of revising, genus by genus, the African copepod fauna.

LOVENULA SCHMEIL, 1898

Broteas Lovén, 1845: 436 (non C.L. Koch 1839).

Broteas: Sars, 1899: 6-24.

Lovenula Schmeil in: Giesbrecht & Schmeil, 1898: 105.

Lovenula: Grochmalicki, 1913: 524. Kiefer, 1932a: 461; 1934: 108-110; 1978a: 74. Damian-Georgescu, 1966: 43. Dussart, 1967: 88. Dussart & Defaye, 1983: 54.

Paradiaptomus: Sars, 1907: 3 (partim).

Paradiaptomus: Stebbing, 1910: 531. Douwe, 1912b: 25; 1914: 96. Brady, 1913: 467. Lowndes, 1930: 164. Gurney, 1929: 581; 1931: 109. Barnard, 1935: 490 (partim).

Paradiaptomus subgenus Lovenula Dussart, 1989a: 32.

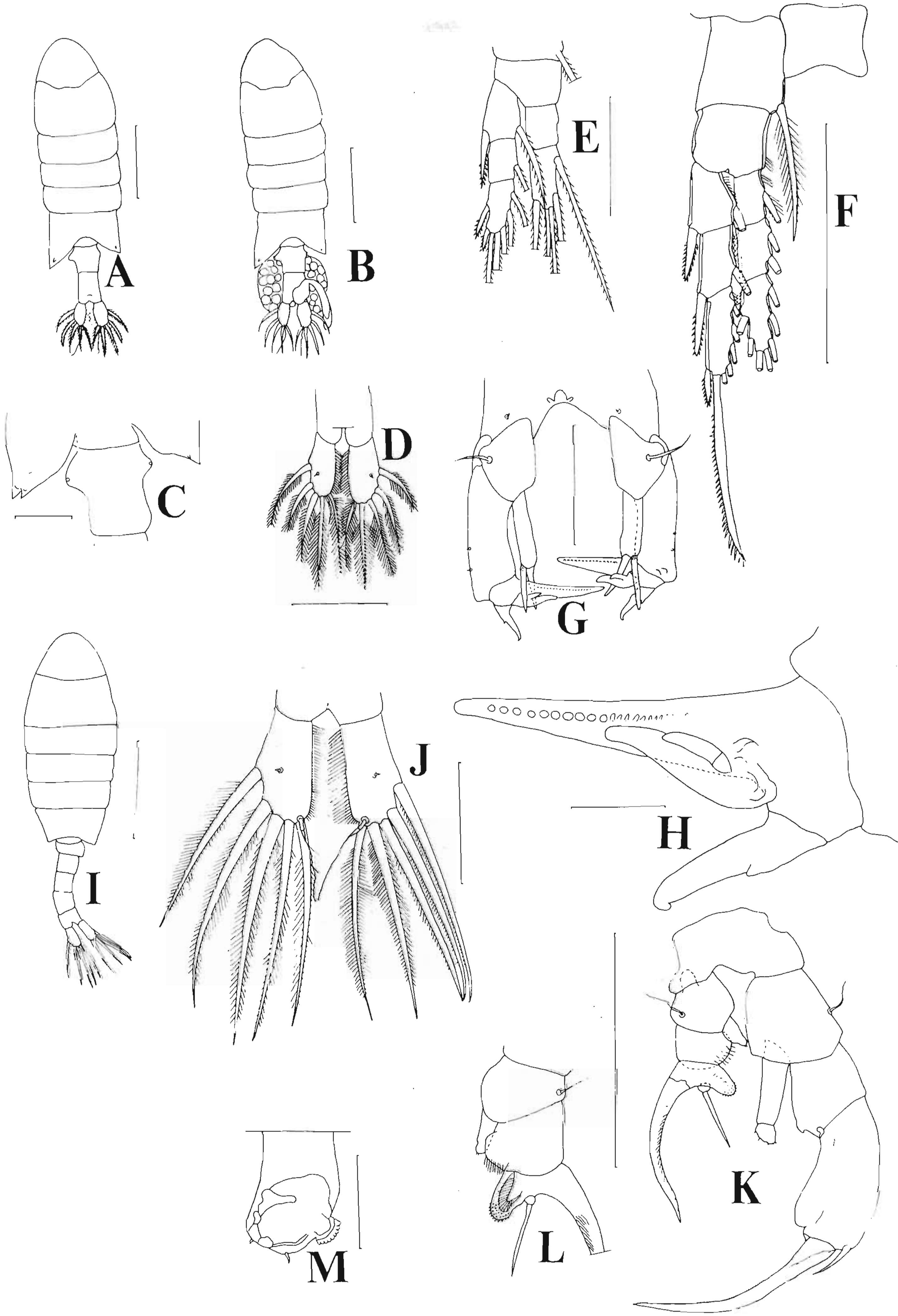
The generic name of this taxon was originally Broteas, assigned by Lovén (1845) when he described Broteas falcifer. Schmeil (1898) changed the name to Lovenula because Broteas was preoccupied by an arachnid genus. Sars (1895) described Paradiaptomus lamellatus, the type species of the genus Paradiaptomus. Sars (1907) gave the generic name Paradiaptomus to both B. falcifer and P. lamellatus as he considered them to be congeneric and also the name Paradiaptomus was older than Schmeil's Lovenula. Sars (1927) conceded that Lovenula and Paradiaptomus were two distinct genera but it was still a few years before the name Lovenula Schmeil gained full acceptance. The sinking of Lovenula under Paradiaptomus by Dussart (1989a) is discussed on page 59.

Characteristics of the genus

Length 2.5-4.0 mm, females more robust than males, prosome approximately 2/3 total length in both sexes (Table 1).

Prosome, urosome and furca: Female with 2 urosomal somites; last thoracic double-somite (Pdg4-5) of female expanded as 'wings' (Fig. 3A). Female genital somite expanded laterally, usually more pronounced on left (Fig. 3C). Male urosome of 5 somites, slender and cylindrical, often curving to the right or directed ventrally (Fig. 3I). Furcal rami in both sexes, asymmetrical, right slightly longer than left, each ramus with five strong apical setae and a slender 'dorsal' seta; a very small dorso-lateral seta on each furcal ramus (Fig. 3D); three outer setae on male right furcal ramus are spine-like, lack setules on outer margin and separate from two inner setae (Fig. 3J).

Antennae: Female A1 (Fig. 4A) and left A1 of male, 25-segmented with notably, two very short spines on segments 8 and 12. Male right A1 (Fig. 4B-D) 21-segmented, geniculate between segments 18 and 19, with terminal segment with a beak-like extension; longest diagnostic spiniform proc-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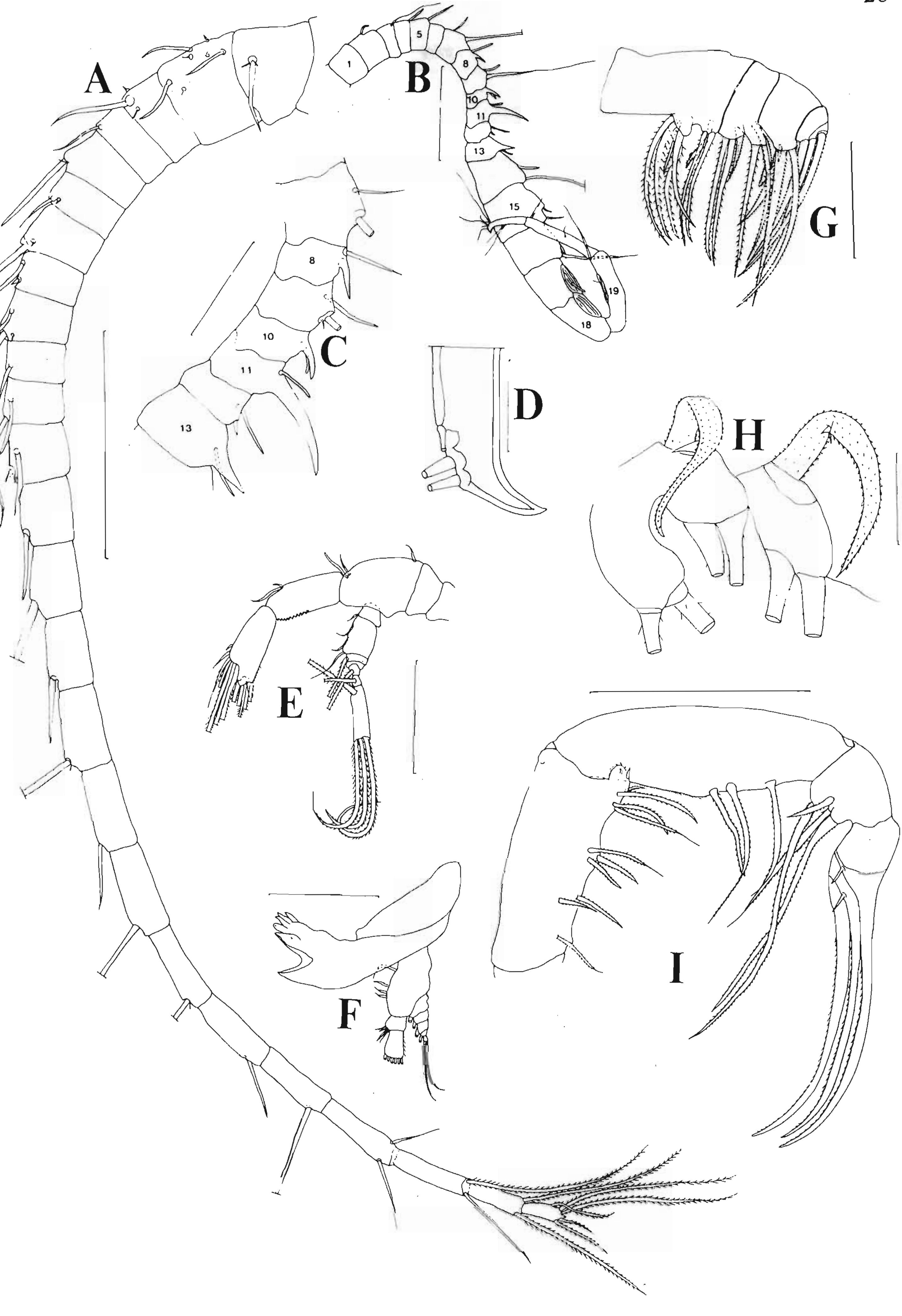
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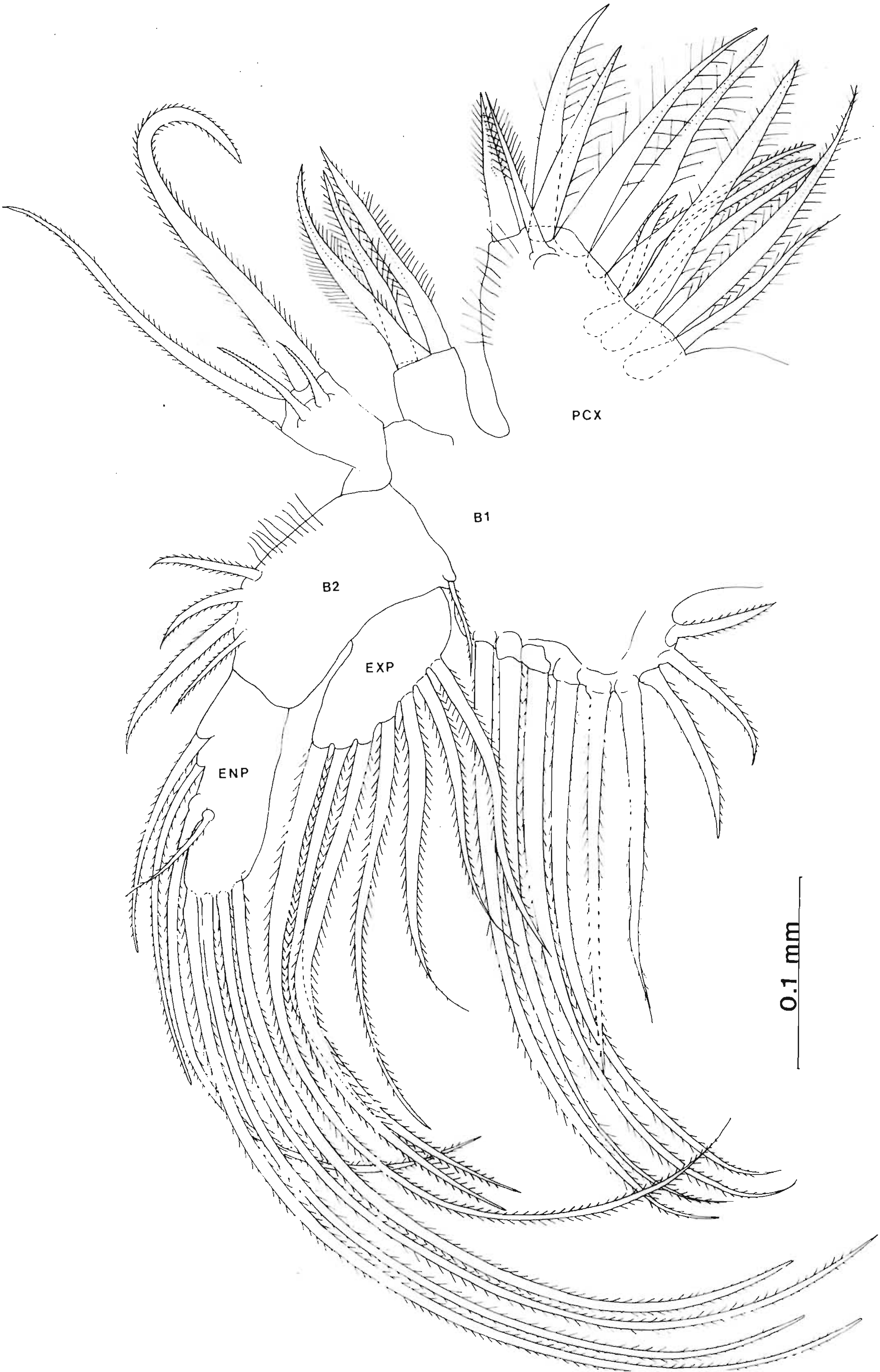
PCX
B1
B2
EXP
ENP
0.1 mm

ess on segment 11, with spiniform process on segment 10 shorter and curved in towards it; a strong, broad-based spiniform process on segment 13; the smallest process on segment 8. A2 biramous (Fig. 4E), with 2-segmented endopodite and 7-segmented exopodite; basis with 1 proximal, 2 distal setae; Enp1, 2 setae, lateral border denticulate distally; Enp2 with distal lobes with approximately 16 setae (not all shown on diagram); Exp2 and Exp7 long, Exp3-6 compacted; a single, strong seta arises from Exp3, Exp5, Exp6, and proximal end of Exp7; reduced Exp4 lacks a seta and Exp7 has 3 long, terminal setae.

<u>Mouthparts</u>: Mandible (Fig. 4F) consists of a large gnathobasal coxa with a single tooth and 5-6 smaller teeth separated by a v-shaped cutting edge; mandibular palp with four inner setae on basis, 2-segmented endopodite with 4 setae on Enp1, 6 on Enp2; 5-segmented exopodite with one inner seta on each of Exp1-4, 2 on Exp5. Maxilla 1 (Fig. 5) with precoxa with 13 spine-like setae with bristle-like setules; coxa with two lobes on inner border, one lobe with 3 strong setae, the other with 2 long, 2 short setae; basis with one proximal seta and 4 distal setae of different lengths; one-segmented endopodite with two lobes, with 3 short, 1 long seta and 4 very long setae, one-segmented exopodite with 7 long setae; 9 very long setae on outer border of coxa. Maxilla 2 (Fig. 4G) with coxa with 2 lobes with 5, 3 setae, basis with 3, 3, setae, Enp1 with 3 long, one very small, setae, Enp2-4 each with a spine-like seta; one seta on coxa, 2 on basis and one on Enp1 are

claw-like with fine bristles (Fig. 4H). Maxilliped (Fig. 4I) consists of precoxa, coxa, basis and 4-segmented endopodite; groups of 1, 2, 3, 4 inner setae on coxa and a spiny process at articulation with basis; basis with a fringe of small denticles on inner border with 2 and 1 strong setae; Enp1 with 2 long, 2 shorter setae; three terminal segments (Enp2-4) produced distally to form spiniform processes, smooth on outer margin, denticulate on inner.

Natatory legs: First natatory leg (P1) (Fig. 3E) with 2-segmented endopodite and 3-segmented exopodite (spine formula: 1,0,2); second, third and fourth natatory legs (P2-P4) (Fig. 3F) with endopodite and exopodite 3-segmented, spine formula of exopodite: 1,1,2; endopodites of P2-P4 same length; exopodites of P3 and P4 longer and sturdier than P2, length being achieved by extension of Exp1.

Non-natatory P5: Female P5 (Fig. 3G,H), endopodite one-segmented with two terminal setae, 5-6 sub-apical spinules at base of outer seta; Exp2 and Exp3 fused, Exp2 with an inner spiniform process and an outer broad-based spine; Exp3 represented by two closely-applied spines, outer spine longer than inner, both projecting across Exp2 spiniform process. Male P5 (Fig. 3K-M), right leg, Exp1 with an inner rounded process, Exp2 with an outer distal spine and Exp3 represented by a terminal, medially denticulate, blade-like claw; endopodite 2-segmented, the last segment ball-shaped with a semi-circular fringe of 6-8 spinules;

left leg with one-segmented endopodite, Exp2 produced laterally into a strong, medially denticulate spiniform process; on medial margin of Exp2, a triangular pad fringed with knobs or setae, and between outer spine and inner pad, a slender apical spine extending diagonally between the two structures.

Kiefer (1932a) divided the genus Lovenula into two subgenera, Lovenula s. str. and Neolovenula to accommodate Diaptomus alluaudi Guerne & Richard, 1890, a paradiaptomid which has some Lovenula affinities. This division is not supported by evidence presented later (see p. 56).

Lovenula falcifera (Lovén, 1845) - type species

Figs 3-5

Broteas falcifer Lovén, 1845: 436, pl. 6 (figs 1-16).

Broteas falcifer: Guerne & Richard, 1889: 118-121, figs 41-43.

Lovenula falcifera: Giesbrecht & Schmeil, 1898: 105, fig. 25. Daday, 1910b: 118. Kiefer, 1932a: 481, 484 (figs 6-8), 486; 1932b: 214-215, fig. 1; 1934: 110-115, figs 1-8; 1939: 324, figs 1-3. Hutchinson et al., 1932: 17-150. Brehm, 1958: 34. Löffler, 1961: 356; 1964: 187; 1968. Kok, 1974: 153-183. Dussart & Defaye, 1983: 54.

Lovenula mea Gurney, 1904: 300-1, pl.18 (figs 7-13) (partim)

Diaptomus bouvieri Daday, 1910a: 187, 188 (figs 1a & 1b), 195 (pl. 5, figs 1-11).

Paradiaptomus falcifer: Stebbing, 1910: 532. Tollinger, 1911: 189. Douwe, 1912a: 2, pl.1 (figs 1-5); 1912b: 29,31; 1914: 95-96. Brady, 1913: 468, pl. 35 (figs 7-10). Gurney, 1929: 582.

Paradiaptomus meus: Stebbing, 1910: 533 (partim).

Paradiaptomus gurneyi Tollinger, 1911: 188 (partim). syn. nov.

Lovenula barnardi Sars, 1927: 92, pl.6 (figs 6-9).

Lovenula barnardi: Kiefer, 1928: 8. Harding & Smith, 1967: 518.

Paradiaptomus barnardi: Lowndes, 1931: 1291; 1935: 308. Barnard, 1935: 490.

Lovenula furcata Brehm, 1958: 34, Fig. 29. syn. nov.

Lovenula excellens Brehm, 1958: 35-37 (figs 34-37). Hart, 1984: 1602-1607; 1985a: 151-178; 1985b: 17-26; 1986: 351-371; 1987: 287-318. (misidentification).

Paradiaptomus (Lovenula) falcifera: Defaye, 1988: 115, table 1, figs 13-16. Dussart, 1989a: 33-34, 126 (figs 20 & 71).

Paradiaptomus (Lovenula) furcata: Dussart, 1989a: 39-40, 130 (Fig. 24C).

Material examined

Figs 1, 6, & Appendix 2

BMNH-1904.9.21.23,24, **BMNH-1951.8.10.68,69**, wet specimens labelled Lovenula mea Gurney, 1904. No locality given. Identity of male: Lovenula falcifera, female: Paradiaptomus schultzei Douwe, 1912b; L. mea placed into synonymy with L. falcifera (see synonymy list above).

SAM-1501, Port Elizabeth, no details.

NM, pond, Harrismith, E. Warren, February 1908.

SAM-A3787, Kimberley, no details.

HM-K8896, Farm Frauenstein, near Neudamm, 50 km ENE Windhoek, Namibia, W. Michaelsen, 13.05.11.

HM-K8895, Farm Otjituezu, near Neudamm, 66 km NE Windhoek, Namibia, W. Michaelsen, 13.05.11.

SAM-A4791, Grootfontein, S.H. Haughton, August 1917.

SAM-A11573, Ukualonkathi, Ovamboland, KHB, March 1923.

SAM-A11574, Ongka, Ondangua, Ovamboland, KHB, February 1923.

SAM-A11575, Onambeke, Ovamboland, KHB, April 1923.

SAM-A11576, Ukualuthi, Ovamboland, KHB, April 1923.

SAM-A5915, Junction Marico & Crocodile rivers, R.W. Tucker, 1918.

SAM-A5943, Beaufort W., S.H. Haughton, August 1917.

SAM-A11581, Aliwal North, S.H. Haughton, 24.07.21.

SAM-A11582, Cornets Kop, Molteno, Beaufort W., S.H. Haughton, June 1921.

SAM-A11584, W. Gouritsrivier bridge, G.E. Hutchinson, 1927.

SAM-A11590, Lobatsi, Bophuthatswana, J.H. Power, 1927.

SAM-A11537, **SAM-A11538**, **SAM-A11539**, **SAM-A12446**, **SAM-A12448**, **SAM-A12449**, **SAM-A12450**, **SAM-A12451** - all these vials contain material from Ovamboland, identified in G.O. Sars' handwriting as "*L. barnardi*" and relate to SAM-A11573-6. Barnard sent this material for identification to Sars in 1925 (correspondence files, S.A. Museum).

TM-1225, 1 mile NE Tsotsoroga Pan, 23.06.30, Vernay-Lang Kalahari Expedition.

TM-1260, 1 mile NE Tsotsoroga Pan, 3.07.30, VLKE.

TM-1508, N'Kate Pan, 07.08.30, VLKE.

BMNH-1959.3.2.3-4, Dodoma, Tanganyika, H.J. de S. Disney, undated.

AM-VAL 907A, Vaal river catchment, Stn 3, stones-in-current, FMC, 11.11.59.

AM-VAL 912A, Vaal river catchment, Stn VD 17, stones-in-current, FMC, 10.11.59.

AM-GEN 591D, pan between Middleburg & Belfast, J. Agnew, 23.06.60.

AM-GEN 595B, Dewetsdorp, J. Agnew, 29.03.61.

AM-VAL 1379F, Vaal river catchment, Stn SV 9, stones-in-current, FMC, 14.04.64.

AM-VAL 1390B, Vaal R. catchment, Stn SV 9, marginal vegetation, FMC, 14.04.64.

Witbank dam, MTS, 02.03.78.

Welbedacht dam, MTS, July 1980.

Mazelspoort dam, MTS, August 1981.

P.K. le Roux dam, MTS, 04.07.81.

P.K. le Roux dam, RCH, 12.01.82.

SMN-50727, waterhole, E. Caprivi, Namibia, S. Bethune, 08.12.82.

SMN-50772, 65 km E. Windhoek, Namibia, C. Meyer, 23.01.84.

Greyvenstein dam, MTS, 11.05.84 & 15.06.84.

Omataku dam, Namibia, W.A. Smit, 20.09.84.

AM-GFR, Witmos, J. O'Keefe & F. de Moor, 19.02.85.

Sterkfontein dam, W. Dorgeloh, 13.03.85.

White Hill pan, 42 km from Hwange, Zimbabwe, A.J.C. Gardiner, July 1985.

Elandsdrift, Great Fish R., R.W. Palmer, 20.01.86.

Spioenkop dam, RCH, 09.09.87.

SMN-51328, Gautscha pan, Boesmanland, Namibia, B.A. Curtis, 17.03.88.

SMN-51330, Tjokwe pool, Boesmanland, Namibia, B.A. Curtis, 17.03.88.

Quaggaplaat, Sutherland, temporary pool under snow, JMK, 31.08.88.

D510/02, Brak river airfield, JMK, 31.08.88.

Nuweleeurivierdam, RCH, 18.01.89.

Quaggaplaat, JMK, 26.08.89.

Description

Measurements are given in Table 1 and abbreviations on p. 10.

Female.

Figs 3-5

Large, robust build (Fig. 3A); A1 extends to posterior border of GS; antennae and mouthparts (Fig. 4A, Fig. 4F-I, Fig. 5); thoracic wings markedly expanded and backwardly directed, left longer than right, two points on left wing, one on right with a small additional spine on each wing; GS expanded more on left than right, slightly shorter than AS (Fig. 3C); furca (Fig. 3D); P1 (Fig. 3E); P2 (Fig. 3F); P5 strongly developed, spiniform process of Exp2 often carried at right angles to Exp1; endopodite same

Table 1

Measurements (mm) of four Lovenula species

Abbreviations: p.10.

Species	Locality	Date	Sex	n	Total length (TL) x̄	Total length (TL) range	Total length (TL) C.V. %	Prosome (Pr) x̄	Prosome (Pr) range	Prosome (Pr) C.V. %	Pr L:B	Pr:TL
L. falcifera	Spioenkop dam)	09.09.87	♀	5	3.6	3.2 - 4.0	8.8	2.6	2.2 - 2.7	8.8	2.4	0.7
	" ")	" "	♂	6	3.3	3.1 - 3.5	5.2	2.3	2.2 - 2.5	5.0	2.7	0.7
	Sterkfontein dam	13.03.85	♀	10	3.1	2.6 - 3.4	7.7	2.2	2.1 - 2.4	6.2	2.1	0.7
SAM-A11573	Ovamboland	March 1923	♀	58	3.6	3.2 - 4.0	5.0	2.7	2.4 - 2.9	4.6	2.7	0.7
			♂	21	3.5	3.1 - 4.0	5.3	2.5	2.2 - 2.7	5.2	2.8	0.7
L. africana	Lake Rukwa)	1908	♀	11	2.4	2.1 - 2.6	5.3	1.8	1.7 - 1.9	5.0	3.0	0.7
Daday material	" ")		♂	13	2.4	2.2 - 2.9	7.6	1.6	1.4 - 2.0	8.2	2.8	0.7
BM(NH)1958.10.2.29												
	Makgadikgadi pan,)	04.05.57	♀	7	3.0	2.9 - 3.2	3.7	2.2	2.0 - 2.3	4.0	2.5	0.7
	Botswana)		♂	4	3.0	2.8 - 3.0	3.9	2.1	2.0 - 2.1	2.2	2.4	0.7
Syn. Paradiaptomus	Hora Keloli crater)	1926	♀	4	3.0	3.0 - 3.1	0.8	2.2	2.2 - 2.3	1.1	2.4	0.7
biramata Lowndes	lake, Ethiopia)		♂	4	2.6	2.4 - 2.9	8.3	1.8	1.7 - 2.0	7.2	2.4	0.7
BM(NH)1932.4.23.6-15												
L. excellens	Lake Chrissie)	01.06.60	♀	6	3.1	3.1 - 3.2	1.5	2.3	2.2 - 2.3	2.8	2.3	0.7
VAL1179D	" ")		♂	10	3.2	3.1 - 3.4	4.2	2.1	2.0 - 2.2	3.6	2.4	0.7
L. simplex	Groot Rondevlei	1981	♀	4	3.7	3.5 - 3.9	4.2	2.6	2.5 - 2.6	1.6	2.3	0.7
	"		♂	20	3.4	3.0 - 3.7	4.7	2.3	2.0 - 2.4	3.8	2.5	0.7
	Sirkelsvlei	1981	♀	3	3.1	3.0 - 3.2	4.6	2.1	1.9 - 2.2	6.0	2.3	0.7
	"		♂	14	2.8	2.5 - 3.0	6.0	1.8	1.6 - 2.0	7.0	2.5	0.6

length as Exp1, with two strong terminal setae, more than half length of endopodite; small process on outer margin of Exp2 lateral spine (Fig. 3G-H). Egg sac (Fig. 3B), details from three localities:

1. one female, ca 258 eggs, bilobed sac, L. 0.8 x B. 1.2 mm (SAM A4791, temporary pool, Grootfontein, 1917)
2. range 9-43 eggs, $\bar{x}$ = 21.6, P.K. le Roux dam, Hart (1987).
3. one female, ca 116 eggs, sac L. 0.85 x B. 1.0 mm (D560/02, Quaggaplaat, 1989)

Male

Figs 3-4

Slender build (Fig. 3I); right A1 strongly developed, segments 13-18 expanded and flattened (Fig. 4B-D); furca (Fig. 3J); P5, right leg, Enp2 spinules short and rounded; left leg endopodite well developed, with 2-3 apical spinules; Exp2 with strong, semi-circular spiniform process (Fig. 3K-M). Spermatophore length, range 0.75-0.95 mm.

Coloration

In freshly collected specimens, there may be indigo pigment deposited internally in appendages and furca. Dr. J.M. King, University of Cape Town (pers. comm.) noted that L. falcifera collected from a snow-bound pond at Quaggaplaat, near Sutherland, was blue-green in colour. Barnard (1935) recorded L. falcifera from near Tsotsoroga Pan, Kalahari, as having a sky blue body and anterior and posterior appendages bright red. Specimens collected by Warren in

1908 from a pond near Harrismith, were described as follows - " the body milky white, the antennae purple, the furca bright red round the base and purple terminally, the setae purple" (Brady, 1913). For further information on pigmentation in copepods see Ringelberg (1980).

Historical

Lovenula falcifera was collected by J. Wahlberg, from a salt pan in the Magaliesberg mountains, between the Crocodile and Apies rivers, Transvaal (Figs 1, 6). Lovén gave the specific name 'falcifer' - bearing a scythe or sickle, referring to the sickle-shaped, large raptorial maxillipeds. Swedish museum authorities declined to supply any information regarding types. However, Loven's illustrations show quite clearly the very characteristic fifth leg of the male *L. falcifera* and this fact, together with the locality, leave little doubt as to the identity of the species. With regard to those species placed into synonymy with *L. falcifera*: *L. mea* (*gurneyi*), *L. barnardi*, *L. excellens* (misidentified) were examined. *Diaptomus bouvieri* had been placed into synonymy with *L. falcifera* and this was justified by illustrations in Daday (1910a). Brehm (1958), in a short description with one illustration (the thoracic wings), indicated that *L. furcata* was a species of *Lovenula* with different shaped 'wings' from *L. falcifera*. The specimen figured appears to be ventral side uppermost, which would account for the difference. Copepod material from the Swedish-South Africa Expedition of 1950-51 was sent to Brehm for identification, and at-

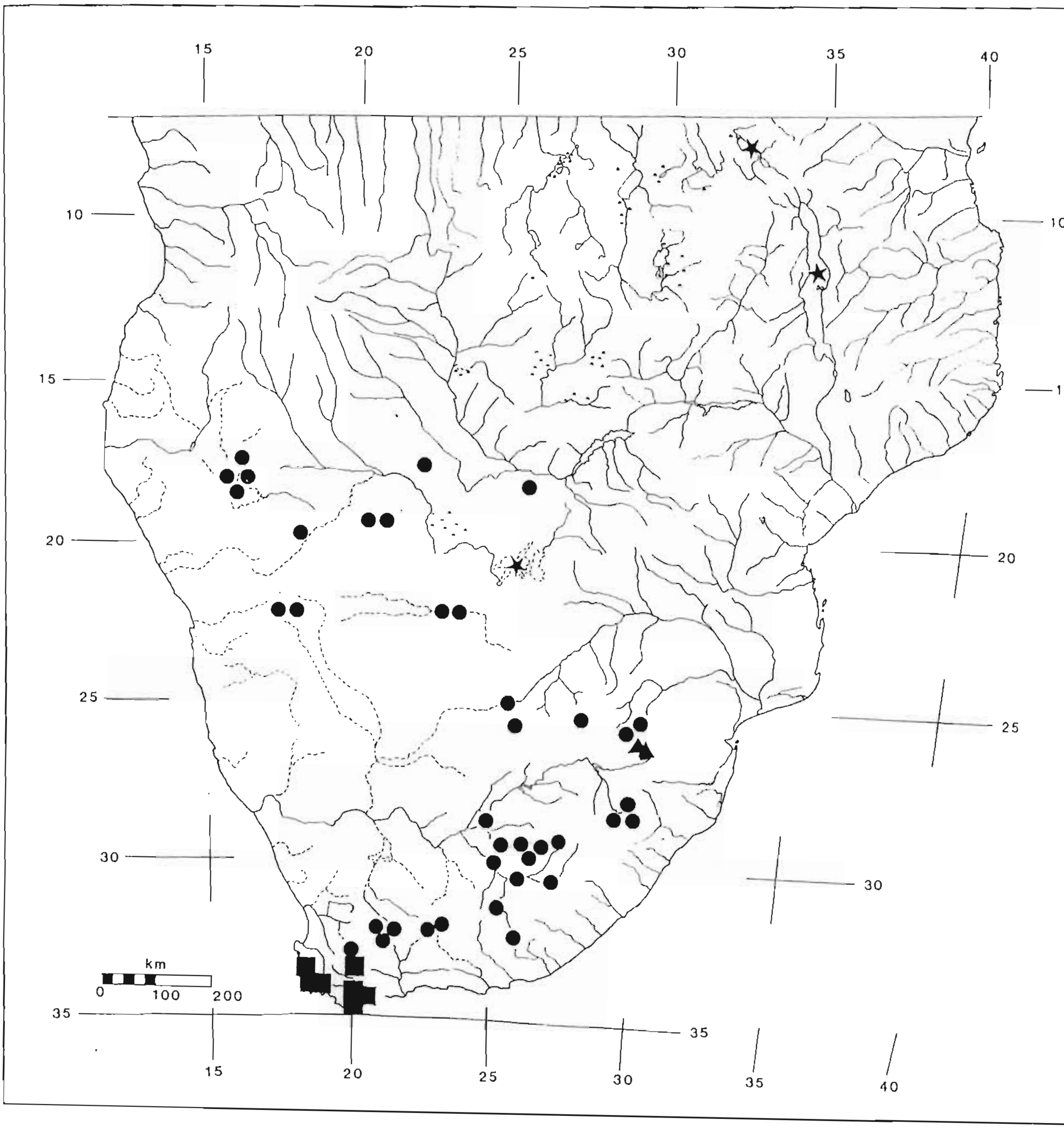

Fig. 6. Map of southern Africa showing distribution of ● Lovenula falcifera. ★ L. africana. ▲ L. excellens. ■ L. simplex.

tempts to trace this material, were to no avail. The decision to place L. furcata into synonymy with L. falcifera is justified, as no other species of Lovenula has been recorded from the area where it was collected. To create a species on the morphology of one thoracic wing (when this is a structure often affected by orientation on a microscope slide), is an ill advised procedure.

Distribution

Fig. 6

In South Africa, L. falcifera occurs in temporary, often saline, waters on the high veld, major impoundments on the Orange and Vaal Rivers; Ovamboland and other areas of Namibia; Kalahari (Barnard, 1935) (see material examined). Hutchinson et al. (1932) collected it in 1928 from Transvaal pans: Bothasrust, Brakpan 1 & 2, Eliazar, Florida Grass, Leeuw-kraal, Rietfontein 1 & 2, Weltevreden East & West; from O.F.S.: Morgenson farm dam; from E. Cape: Stormberg dam. Also, Kenya (Douwe, 1912a), Uganda (Lowndes, 1931), East African high mountain lakes (Löffler, 1964, 1968), Ethiopia (Defaye, 1988).

Lovenula falcifera is widely distributed, especially in drier areas in temporary pools but it also has the ability to colonise major man-made water bodies (Hart, 1984, 1985 a,b, 1986, 1987; Defaye, 1988). Despite its wide distribution, it has not been recorded from low-lying areas, vleis, coastal lakes or coastal plains (Fig. 6). It appears to be confined to the high plateau of Africa above 1000 metres, much of which lies in the pan belt (see p. 14), as well as in high mountain lakes in East Africa. It is obviously well adapted to the extreme temperature ranges of these regions.

Lovenula falcifera often co-occurs with a species of Metadiaptomus as prey species. It has been recorded as co-existing with M. meridianus (Witmos, Sterkfontein dam, P.K. le Roux dam, Greyvenstein dam, Mazelspoort dam, Quaggaplaat pan, Nuweleeurivier dam), M. colonialis (Spioenkop dam, White Hill pan in Zimbabwe, Omatako dam and Neudamm in Namibia) and M. transvaalensis (a pan between Middleburg and Belfast, TVL). In Witbank dam in the eastern Transvaal, L. falcifera was found to co-exist with Thermodiaptomus syngenes.

Remarks

In Southern Africa, the confusion of L. falcifera with L. simplex and L. excellens has detracted from correct interpretation of the biology of this important diaptomid.

Lovenula africana (Daday, 1908)

Fig. 7

Diaptomus africanus Daday, 1908: 45, 46 (figs 25a-e); 1910a: 111, pl. 5 (1-13).

Diaptomus africanus: Tollinger, 1911: 55. Cunnington, 1920: 559. Gurney, 1929 : 579-580.

Paradiaptomus biramata Lowndes, 1930: 163, pl. 1 (figs 1-

7), pl. 3 (figs 1-8); 1933: 308-9.

Lovenula africana: Daday, 1910b: 118. Kiefer, 1932a: 461, 486, 489 (figs 15-17); 1934: 119-122, figs 19-23; 1939: 324. Brehm, 1958: 37. Löffler, 1961: 356 (table 2), 363. Dussart & Defaye, 1983: 55. Green, 1986: 496-8.

Paradiaptomus africanus: Lowndes, 1936: 6, fig. 1 (A-H), fig. 2 (A,B). LaBarbera & Kilham, 1974: 461-464.

Paradiaptomus (Lovenula) africanus: Harding, 1942: 180.

Paradiaptomus (Lovenula) africana: Defaye, 1988: 112, table 1, figs 8-12. Dussart, 1989a: 37, 129 (figs 23A & 70).

Material examined

Figs 1, 6, Appendix 2

HMNH-1908, syntypes of Diaptomus africanus, Daday, Lake Rukwa.

BMNH-1932.4.23.6-15, syntypes of Paradiaptomus biramata, Lowndes, Hora Keloli, Ethiopia, J. Omer Cooper, 1926.

BMNH-1941.5.16.50-60, Lake Rukwa, E. Africa, C.K. Ricardo & R.J. Owen, undated.

BMNH-1958.10.2.29, Makgadikgadi main pan, Botswana, D.H. Eccles, 04.05.57.

Sowa pool, NE tip of Sowa pan, Makgadikgadi, Botswana, R.C. Hart, 10.07.90. Males and females with egg sacs and spermatophores.

Description

Measurements are given in Table 1 and abbreviations on p. 10.

Female

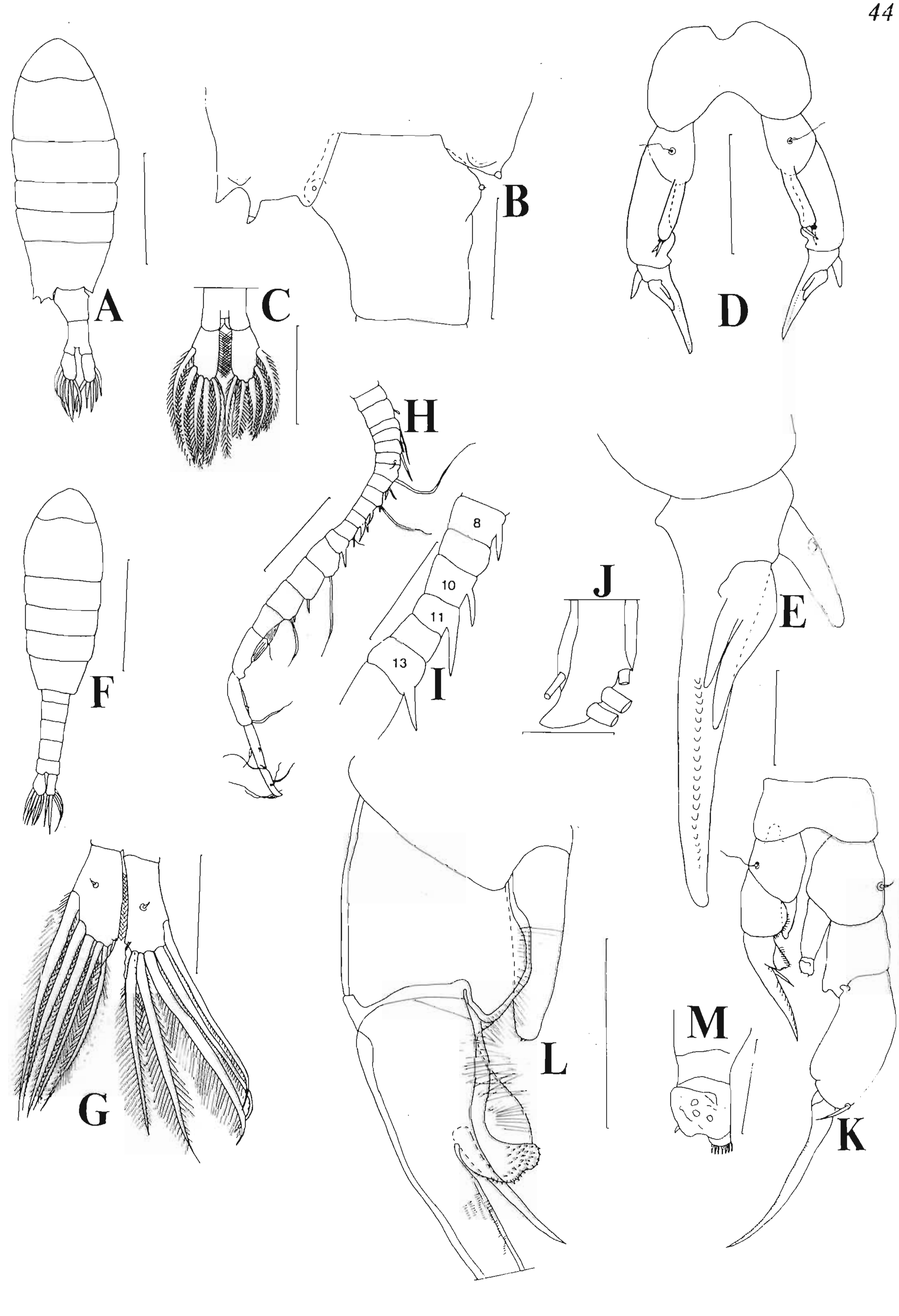
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Fig. 7 (A-E)

Moderate size (Fig.7A); A1 extends to posterior border of GS; thoracic 'wings' asymmetrical with three dissimilar processes on left side, outer process pointed, medial finger-like, inner rounded; GS slightly expanded, same length as AS (Fig. 7B); furca (Fig. 7C); P5, endopodite weakly developed, distinctly shorter than Exp1, spines small, 1/4 length of endopodite; spiniform process of Exp2 directed backwards; Exp2 lateral spine shorter than other species and with barely discernible process (Fig. 7D-E); egg sac, 13-14 eggs (Daday, paralectotype).

<u>Male</u>

Fig. 7 (F-M)

Moderate size (Fig. 7F); A1, moderately developed (Fig. 7H-J); furca (Fig. 7G); P5, right leg, Enp2 spinules slender and pointed; left leg endopodite well-developed, with 2-3 apical spinules; Exp2 produced to form a straight, backwardly-directed spiniform process (Fig. 7K-M).

<u>Type material</u>

Daday did not designate type material (Dr Lászlo Forró, Hungarian Natural History Museum, <u>pers</u>. <u>comm</u>.). Type locality, Lake Rukwa, Tanzania. Lectotype and paralectotypes designated from Daday's original material, deposited by author in 1989, with the Hungarian Natural History Museum, Budapest. Microscope slide Catalogue numbers: lectotype III/P-382; paralectotypes, male III/P-383, female III/P-384. Examination of syntypes of <u>Para-</u>

diaptomus biramata Lowndes (BMNH-1932.4.23.6-15) confirmed its synonymy with *L. africana* (Kiefer, 1934).

Distribution

Fig. 6

Only one southern African record, Makgadikgadi pan, Botswana; other African records: Lake Malawi (Cunnington, 1920); in Ethiopia: Hora Keloli, Hora Horeso (Lowndes, 1930); in Kenya: Lake Elmenteita, Rift Valley (Lowndes, 1935); crater lake, 2 miles W. Lake Naivasha (Lowndes, 1936); Lake Rukwa (Harding, 1942); in Kenya, Uganda, Tanzania, Rwanda: Lakes Big Momela, El Kekhotoito, Embagai, Eyasi, Kusare, Magad, Manyara, Mikuyu, Nakuru, Reshitani, Tulusia (LaBarbera & Kilham, 1974); in Ethiopia: Lakes Paulo, Bishoftu, Arenguade, Kilotes, Abijata, Langano, Arenguade (Green, 1986; Defaye, 1988).

Lovenula africana occurs in waters with high conductivity from Ethiopia through East Africa with the southernmost record being Makgadikgadi pan, Botswana. The conductivity range of 11 East African lakes was 3350-15000 μmhos cm-1 ($\bar{x}$ = 11439 -+ 5528), the highest conductivity range of any of 11 common species of copepods (LaBarbera & Kilham, 1974). This suggests that *L. africana* has an affinity for saline waters, confirmed by its occurrence in Makgadikgadi salt pan. The salt concentration in this pan may reach proportions such that flamingoes' legs are encrusted with salt deposits (R. Kennard, University of Natal, *pers. comm.*). *Metadiaptomus transvaalensis* has been recorded as the prey species of L. africana in Makgadikgadi pan. In Lake Bunyonyi, Metadiaptomus aethiopicus co-occurs with L. africana (Lowndes, 1936). Cunnington (1920) recorded two Tropodiaptomus species and Thermodiaptomus mixtus from Lake Malawi as well as L. africana, but in this large lake, there may have been spatial separation.

Lovenula excellens Kiefer, 1929

Fig. 8

Lovenula excellens Kiefer, 1929: 309-10 (figs 1-3).

Broteas falcifer Methuen, 1910: 159, pl. 16 (figs 45a,b) (misidentification).

Lovenula excellens: Kiefer, 1932a: 461, 487-8 (figs 12-14); 1934: 102, 106-7, 116-119 (figs 15-18). Hutchinson et al., 1932: 1-150; pl. 8 (fig. 2). Löffler, 1961: 356 (table 2), 363. Dussart & Defaye, 1983: 56.

Paradiaptomus excellens: Gurney, 1929: 582.

Paradiaptomus (Lovenula) excellens: Dussart, 1989a: 38-39, 130 (figs 24A & 70).

Material examined

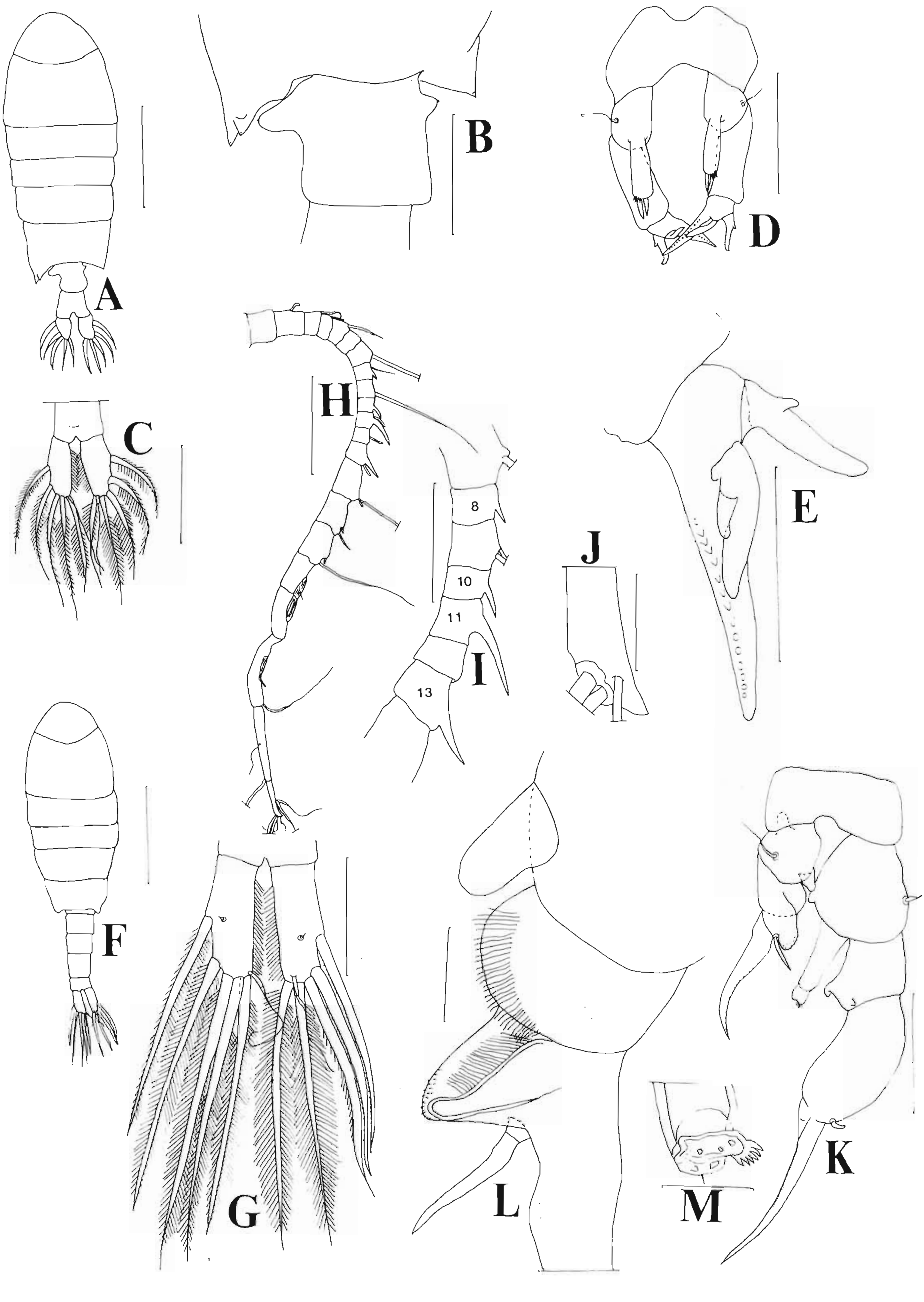
Figs 1, 6, Appendix 2

AM-VAL 676B, Lake Chrissie, bottom sediment, FMC, 10.12.58.

AM-VAL 720D, Vaal river catchment, Stn VD 2, Eckman grab, FMC, 10.12.58.

AM-VAL 1179D, Lake Chrissie, bottom sediment, FMC, 01.06.60.

Description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Measurements are given in Table 1 and abbreviations on p. 10.

<u>Female</u>

Fig. 8 (A-E)

Moderate size, robust build (Fig. 8A); A1 extends to posterior border of AS; thoracic 'wings' not markedly expanded, left slightly longer than right; GS with cone-shaped expansion on left side, AS slightly longer than GS (Fig. 8B); bases of FS widely separated, setae fine, long and tapering (Fig. 8C); P5, small, setae on endopodite, 1/4 length of endopodite, inner seta shorter; Exp2 lateral spine with well-developed process on outer margin (Fig. 8D-E); egg sac, unknown.

<u>Male</u>

Fig. 8 (F-M)

Slender build (Fig. 8F); right A1 slender (Fig. 8H-J); right FR, three outer FS shorter than inner two (Fig. 8G); P5, left leg, endopodite reduced, Exp2 spiniform process curved distally; right leg, Enp2 spinules sturdy and pointed; Exp2 lateral spine short, blunt; Exp3 claw not strongly developed (Fig. 8K-M); spermatophore length 0.62.

<u>Historical</u>

Type material was not designated. Kiefer's microscope slide numbers: 01154*, 01155*, 01156, 01165*, (* with diagram) (Dr Ulrich Franke, Landessammlungen für Naturkunde, Karlsruhe, Fed. Rep. Germany, <u>pers</u>. <u>comm</u>.). Material for description was obtained from alkaline pans (Avenue, Banagher 3, Blaauwater 1-5, Eilandspan, Liefgekosen, Magdalenasmeer North, Rietkuil) in Lake Chrissie area, E. Transvaal, South Africa, collected May 1928, by Hutchinson et al. (1932).

Distribution

Fig. 6

Lovenula excellens has been recorded only from pans in the Lake Chrissie area and upper Vaal River catchment. The Lake Chrissie pans are peculiar in that they are relics of an ancient drainage system belonging to the Umpilusi river, from which the Vaal river has captured the headwaters (King, 1951). L. excellens and Metadiaptomus transvaalensis were recorded as co-existing in Lake Chrissie (Methuen, 1910).

Remarks

This species posed a major problem in the resolving of the taxonomy of the Lovenula species. It was described by Kiefer (1929) from material collected by Hutchinson et al. (1932) in the Lake Chrissie area in the eastern Transvaal and was not mentioned again until its identity was queried by Kok (1974). Kiefer (1929, 1934) did not emphasise the main taxonomic differences between L. excellens and L. falcifera although Hutchinson et al. (1932) stated clearly that L. excellens was different enough from L. falcifera to be a good species. More recently, a misidentification of L. falcifera as L. excellens from the Orange River impoundments (Hart, 1984), almost entrenched the supposition that L. falcifera was a temporary-pool dweller and L. excellens a permanent-water species although the recent origin of man-made water bodies rules out this possiblity. The identity of L. excellens was confirmed by examination of material collected by Chutter (1963) in his 1958-60 survey of Lake Chrissie and the Vaal catchment. Kiefer's material was not seen, but reference to Kiefer (1929, 1934) confirmed without doubt, the identity of L. excellens.

Lovenula simplex Kiefer, 1929

Fig. 9

Broteas falcifer Sars, 1899: 6-24, pl. 1, figs 1-15.

Paradiaptomus falcifer: Rühe, 1914: 8-9, 29-32, fig. 10 a-f.

Lovenula falcifera: Sars, 1927: 86, pl.5 (figs 1-12).

Lovenula falcifera: Harding & Smith, 1967: 518.

Lovenula simplex Kiefer, 1929: 309-10, figs 1-3.

Lovenula simplex: Gurney, 1929: 582. Kiefer, 1932a: 461, 487 (figs 9-11); 1934: 105, 116-7 (figs 9-14), 123. Brehm, 1958: 37. Dussart & Defaye, 1983: 56. Gardiner, 1988: 181-229.

Paradiaptomus (Lovenula) simplex: Dussart, 1989a: 38, 129 (figs 23B & 69).

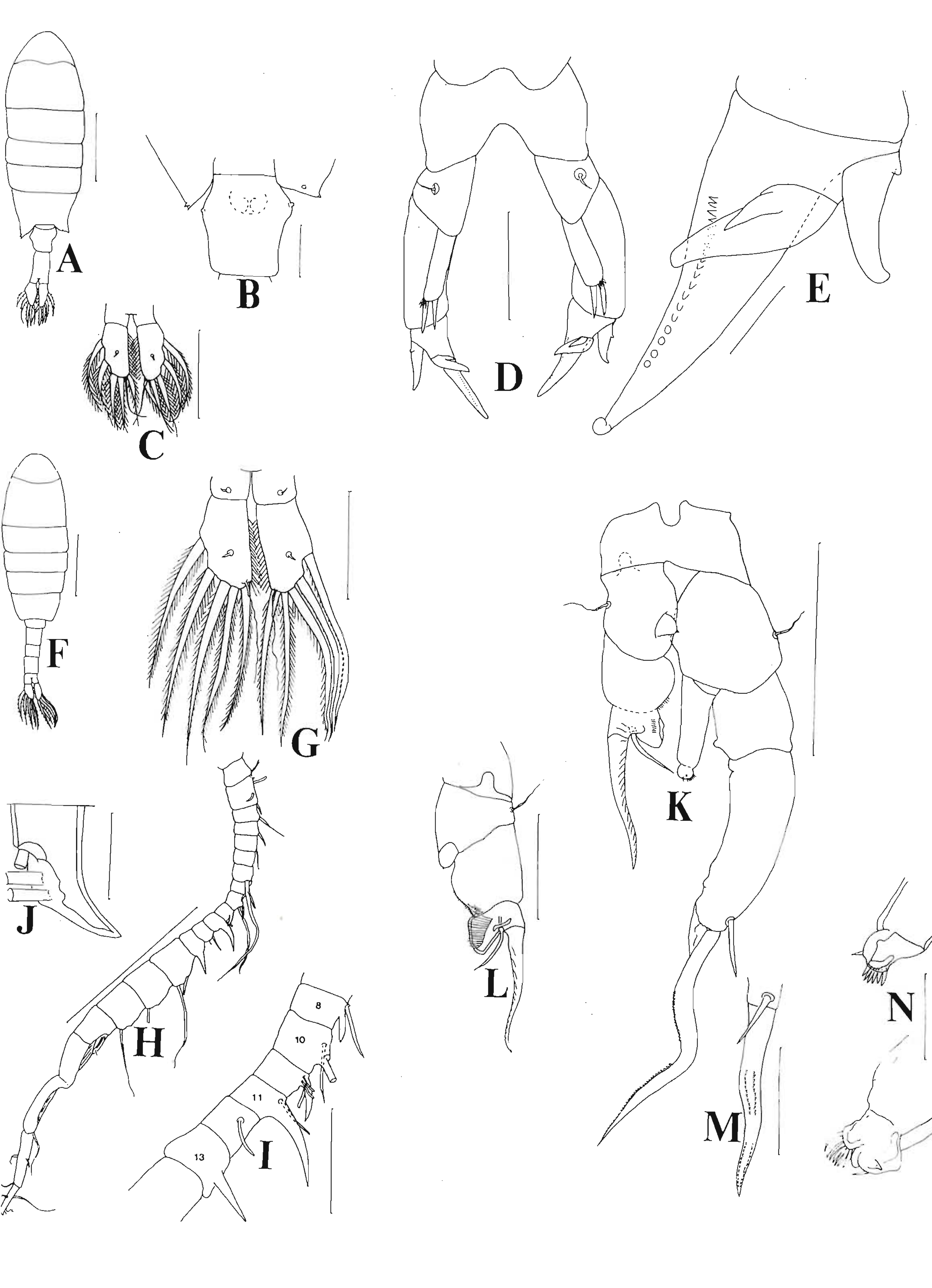
Material examined

Figs 1, 6, Appendix 2

SAM-A12440, ponds, Green Point common, Cape Town, WFP, 1898, labelled Lovenula falcifer.

SAM-A3788, Cape Flats, KHB, 1916.

SAM-A11534, Sars' writing, Broteas falcifer.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SAM-A11535, Sars' writing Broteas falcifer.

SAM-A11549, Green Point common, Paradiaptomus falcifer.

SAM-A11551, Touwsrivier, Paradiaptomus falcifer.

SAM-A11015, Diep river Quarry, Milnerton, E.G.H. Oliver, undated.

SAM-1503, Faure, near Seekoevlei, 1920?

SAM-A12468, **SAM-A12469**, **SAM-A12470**, very old, no details, late 1800's?

5 Si 1T, **9 Si 1T**, **9 Si 2T**, **10 Si 2T**, four different samples from Sirkelsvlei, AJCG, August 1981.

14 GR 2T, **16 GR 2T**, **17 GR 2T**, three different samples from Groot Rondevlei, AJCG, August 1981.

Gi 1T, Gillidam, AJCG, November 1981.

SWT-19A, Sirkelsvlei, JAD, 01.09.83.

SWT-27A, temporary pool, Noordhoek, JAD, August 1983.

SWT-17H, 10 km S.E. D.F. Malan Airport, Cape Town, JAD, 12.08.83.

De Hoop vlei, sites 1,3,4,5, JMK, 01.11.86.

G501/18, Wiesdrift, JMK, 11.05.89.

G501/18, Soetendalsvlei ditch, JMK, 12.05.89.

Description

Measurements are given in Table 1 and abbreviations on p. 10.

Female

Fig. 9 (A-E)

Large, robust build (Fig. 9A); A1 extends to posterior border of GS; thoracic 'wings' slightly expanded, left longer than right, an additional small spine on each wing; GS slightly expanded, AS twice length of GS (Fig. 9B); furca (Fig. 9C); P5, setae on endopodite, strong, about 1/3 length of endopodite; Exp2 spiniform process well-developed, directed backwards (Fig. 9D-E); egg sac, ca 87 eggs, L. 0.83 x B. 1.25 mm (SAM A11534); ca 113 eggs (SAM 1503).

Male

Fig. 9 (F-N)

Large (Fig. 9F); right A1 strongly developed, segments 8-13 expanded and flattened (Fig. 9H-J); urosome sturdy, right FR with three outer FS tapering distally (Fig. 9G); P5 long, right leg extending to posterior border of furca; left leg, endopodite reduced to a rounded process; Exp2 spiniform process straight and backwardly-directed (Fig. 9L); right leg, Enp 2 spinules sturdy and pointed (Fig. 9N); Exp2, outer spine, slender, 1/4 length of claw; Exp3 claw with slight S-shape (Fig. 9K, 9M); spermatophore length 0.65 mm.

Historical

Type material was not designated. Kiefer's microscope slide numbers: 01183, 01192*, 01193*, 01194* (* with diagram) (Dr Ulrich Franke, Landessammlungen für Naturkunde, Karlsruhe, Fed. Rep. Germany, pers. comm.). Kiefer's (1929) description related to material collected from Simonstown, Cape peninsula, by Rühe (1914) and housed in the Berlin Museum.

Distribution

Fig. 6

Lovenula simplex is restricted to the coast of the Cape Province where it has been recorded only from humic vleis (e.g. Gillidam, Sirkelsvlei and Groot Rondevlei), pools on the Cape peninsula and environs, and De Hoop vlei on the southern Cape coast. Gillidam is a small closed basin (35 m x 10 m) with dark brown water and large water level changes with pH 3.8-4.1, maximum depth 1.4 m, temperature range 10.5-29.0° C.. Sirkelsvlei is a closed basin (475 m x 90 m), with dark brown water and large water level changes with pH 6.3-6.7, maximum depth 1.4 m, temperature range 10.5-26.0° C. Groot Rondevlei is an open basin (420 m x 360 m), with brown water and moderate water level changes with pH 5.7-6.4, maximum depth 1.6 m, temperature range 11.0-26.0° C. (Gardiner, 1988). In the Cape province, Lovenula simplex co-occurs with Metadiaptomus capensis (Green Point common, De Hoop vlei, Sirkelsvlei, Varkensvlei, Vermont pan) and with Metadiaptomus purcelli (Cape Flats, Gillidam, Groot Rondevlei, Soetendalsvlei).

Remarks

Lovenula simplex has a very restricted distribution (Fig. 6), a fact which has been overlooked because of the confusion of this species with L. falcifera by Sars (1899, 1927), Rühe (1914) and by Harding & Smith (1967). Kiefer (1929, 1934) pointed out that it was not the same species as L. falcifera but his opinion was disregarded. Gurney (1929) noted that L. falcifera was "one variable species", not realizing in fact that there were two species involved. Although Kiefer's material was not seen, L. simplex presented no problems with identification, because of its restriced distribution, and good morphological characters which could be checked in Kiefer (1929, 1934).

SPECIES REMOVED FROM THE GENUS LOVENULA

(see also Chapter 5, p. 72)

Paradiaptomus alluaudi (Guerne & Richard, 1890)

Diaptomus alluaudi Guerne & Richard, 1890: 198-201.

Diaptomus unqviculatus Daday, 1891: 48, pl. 4 (figs 4-9).

Diaptomus lorteti Barrois, 1891: 277, figs 6-11.

Diaptomus alluaudi: Guerne & Richard, 1891: 213-217. Richard, 1893: 465-466, figs 32, 33. Poppe & Mrázek, 1895: 131. Schmeil, 1896: 177, pl. 14 (figs 7-9). Giesbrecht & Schmeil, 1898: 67, 93. Daday, 1910b: 118. Tollinger, 1911: 52, fig. P1. Gurney 1929: 576, 581. Gauthier, 1931. Lovenula (Neolovenula) alluaudi: Kiefer, 1932a: 461, 486, figs 18-20. Gauthier, 1933b: 128. Kiefer, 1934: 123; 1958: 158-160; 1978a: 74, 231 (pl. 13); 1978b: 494; Damian-Georgescu, 1966: 44. Dussart, 1967: 89, fig. 23. Dumont & Decraemer, 1977: 258. Dussart & Defaye, 1983: 56.

Paradiaptomus lorteti: Gauthier, 1933a: 64.

Neolovenula alluaudi: Gauthier, 1938: 116. Dumont & Verheye, 1984: 319. Löffler, 1961: 356 (table 2).

Paradiaptomus (Lovenula) alluaudi: Dussart, 1989a: 40-41, 130 (Fig. 24B).

Material examined

TM-uncatalogued slide of 2 males, labelled Neolovenula alluaudi, Ostrovan-See, Mazedonien, H.W. Schäfer, 09.12.41. **BMNH-1961.6.28.1**, wet specimens labelled Diaptomus alluaudi, Galatui Lake, near Calarasi, Roumania, A.D. Georgescu, undated.

Kiefer (1932a) created a subgenus, Neolovenula, for Diaptomus alluaudi and included it in the genus Lovenula as Lovenula (Neolovenula) alluaudi. Characters which this species has in common with Lovenula species are two external spines on last segment of P1, asymmetrical thoracic 'wings' of female, beak-like extension on last segment of male right A1 and shape of exopodite of male left P5. Characters not typical of Lovenula species are the small adult size and maxillipeds which are not characteristically scythe-shaped. In the female, the urosome has three somites, expansion of female genital somite is dorso-ventral not lateral, endopodite of female P5 is reduced and without terminal spines, outer Exp3 spine is shorter than inner and the spines do not project across Exp2. In the male, the right furcal setae are not modified, spine on segment 11 of male A1 is shorter than spine on segment 13, whereas in all other Lovenula species, it is longer, male P5 has no endopodite on left leg, and right P5 is atypical.

Paradiaptomus alluaudi is included in the Subfamily Paradiaptominae on the possession of two external spines on the last segment of the exopodite of the first swimming leg, although the proximal spine is reduced. It cannot, however, be included in the genus *Lovenula* even as a subgenus, as it lacks four of the most highly-weighted characters of the genus, namely, the massive raptorial maxillipeds, the modification of the right furcal setae in the male, and in the female, a urosome of two somites and the arrangement and projection of spines on the P5. Although *alluaudi* has been included in the genus *Paradiaptomus*, the possibility should be investigated of raising *Neolovenula* to generic status and placing *alluaudi* as a species in the monotypic genus *Neolovenula*.

Distribution

Paradiaptomus alluaudi is a circum-Mediterranean species not recorded south of the Sahara (Gauthier, 1933b; Dussart, 1967), with its type locality Lanzarote, Canary Islands. Lanzarote was originally part of the African continent. Other localities may be found in the synonymy list and 'material examined'.

Paradiaptomus natalensis (Cooper, 1906)

(see also Chapter 5, p. 73, Figs 12, 13)

Adiaptomus natalensis Cooper, 1906: 97-103, pl. 12 (figs 1-14).

Adiaptomus natalensis: Tollinger, 1911: 190, fig. Y5. Douwe, 1912b: 29, 31.

Diaptomus pictus Brady, 1913: 464, pl. 34 (figs 1-6).

Paradiaptomus natalensis: Gurney 1929: 582.

Lovenula natalensis: Kiefer, 1932a: 461; 1934:122-3. Dussart & Defaye, 1983: 55.

Paradiaptomus (Lovenula) natalensis: Dussart, 1989a: 36.

Metadiaptomus natalensis Dussart, 1989a: 128 (Fig. 22).

Material examined

Figs 1, 11, Appendix 2

AM-VAL 372F, males and females, ground pool, near Lindeque's drift, 8 km below Vaal river barrage, F.M. Chutter, 29.04.58.

Kiefer (1932), recognising this species as a paradiaptomid, placed it in the genus Lovenula although it is of small size and lacks both the large raptorial maxillipeds and the three spinous setae on the male right furcal ramus, two highly-weighted Lovenula characters. Also, the female has a dorsal keel on the last thoracic somite (Fig. 12B). The shape of the endopodite of the male right P5 (Fig. 13C) is a good Paradiaptomus character and the absence of important Lovenula characters justify placing this species in the genus Paradiaptomus. The shape and arrangement of spines on the male geniculate A1 (Fig. 13B) is almost identical to that of P. alluaudi, a fact which may indicate a relationship between these two species. Gurney (1929a) stated that A. natalensis was a typical Paradiaptomus and should be included in that genus. Kiefer (1934) noted that the status of this species could be decided only if the poor descriptions of Cooper (1906) and Brady (1913) could be checked against new material as no types were designated. It was 45 years before this rare species was collected again by Chutter (1963) in 1958, and examination confirmed that it ranks as a Paradiaptomus species.

SYSTEMATIC STATUS OF LOVENULA AND PARADIAPTOMUS

Gurney (1929) assessed the status of South African diaptomids, but his attempt to form two series, one for Lovenula and one for Paradiaptomus, was flawed by poor descriptions and misidentifications. Gauthier (1951), in describing Paradiaptomus rex, discussed the affinities of the two genera. He stated incorrectly that the only character which distinguishes the two genera is the massive raptorial maxillipeds of Lovenula. More recently, Dussart & Defaye (1983) indicated that Lovenula should be made a subgenus of Paradiaptomus so Defaye (1988) and Dussart (1989) established Paradiaptomus as the genus, with subgenera Paradiaptomus (s.str.) and Lovenula. However, the four Lovenula species have been shown to be closely related and current research leaves no doubt that they have enough characters in common and different from Paradiaptomus to retain generic status. These characters are the large size of the adult, the scythe-shaped raptorial maxillipeds, arrangement of spiniform processes and shape of the terminal segment of geniculate A1, exopodite of male left P5, the three outer spiny setae on the male right furcal ramus, and the relative sizes and arrangement of Exp2 spines of female P5. A comparision of the morphology of the mandible, maxillae 1 and 2 and maxilliped of the two genera gives a good indication that *Paradiaptomus* has retained more of the characters of its most recent common ancestor with *Lovenula*, than has *Lovenula*. It therefore, resembles the condition of that common ancestor more than *Lovenula* does. The importance of feeding-appendage morphology in diaptomid systematics cannot be over-emphasised.

Many of the early taxonomists interchanged the generic names *Lovenula* and *Paradiaptomus* but Kiefer (1932a, 1934) never had any doubts as to which species he placed in the genus *Lovenula*. He was the only taxonomist to study all four *Lovenula* species and he described two of them. Confusion arose because species of uncertain affinities such as *L. mea*, *L. furcata* and *L. natalensis* were included in the genus. A major factor also has been the lack of any in-depth study on the freshwater copepods of southern Africa and the tendency to think of southern Africa in isolation from the rest of the continent. This account of the Diaptomidae has shown that the wealth and diversity of freshwater diaptomids in southern Africa is such that their further study will have a major impact on interpretation of both the biogeography and systematics of the Diaptomidae in Africa. It seems inopportune therefore, at this stage, to reduce a now known stable genus (*Lovenula*) to subgeneric status in a genus (*Paradiaptomus*) which has as its type *Paradiaptomus lamellatus* Sars, 1895, a species which lacks all the main Lovenula characters. Also, with the recent discovery of at least four new, as yet undescribed species of Paradiaptomus in southern Africa, that genus will need to be reassessed.

KEY TO THE SPECIES OF LOVENULA

Figs 3-5, 7-9

Females

1 Genital somite strongly expanded on left side,
P5, Exp2 lateral spine with well-defined process on outer margin...2

1' Genital somite slightly expanded on left side,
P5, Exp2 lateral spine with very small process on outer margin...3

2 Body length 3.0-3.2 mm,
Genital somite with cone-shaped expansion on left side,
P5 endopodite with paired terminal setae 1/4 of its length, inner seta shorter than outer,
P5, Exp2 lateral spine with pronounced process on outer margin.............................*Lovenula excellens*

2' Body length 3.2-4.0 mm,
Genital somite with rounded expansion on left side,
P5 endopodite with paired terminal setae more than 1/2 its length, setae of equal length,
P5, Exp2 lateral spine with small process on outer margin.............................*Lovenula falcifera*

3 Anal somite twice length of genital somite,
Left thoracic 'wing' with two pointed

processes..............................*Lovenula simplex*

3' Anal somite and genital somite of equal length,
Left thoracic 'wing' with three dissimilar processes...
......................................*Lovenula africana*

Males

1 Body length 3.0-4.0 mm,
Geniculate (right) A1, combined length of last two segments twice length of ante-penultimate segment,
Left P5, Exp2 spiniform process curved,
Right P5, Exp2 lateral spine, short...................2

1' Body length 3.2-4.0 mm,
Geniculate (right) A1, combined length of last two segments slightly exceeds length of ante-penultimate segment,
Left P5, Exp2 spiniform process straight,
Right P5, Exp2 lateral spine, long....................3

2 Geniculate (right) A1 strongly developed with segments 13-18 flattened and expanded,
Left P5, Exp2 spiniform process semi-circular,
Right P5, Exp2 lateral spine, slender and pointed .....
...................................*Lovenula falcifera*

2' Geniculate (right) A1 less strongly developed with segments 13-18 slightly expanded,
Left P5, Exp2 spiniform process curved distally,
Right P5, Exp2 lateral spine very short and blunt..............................*Lovenula excellens*

3 Right P5, Exp3 blade-like claw with slight S-shape,
Exp2 lateral spine 1/4 length of claw,
Left P5 endopodite reduced to rounded process ....Lovenula simplex

3' Right P5, Exp3 with blade-like claw slightly curved,
Exp2 lateral spine 1/6 length of claw,
Left P5 endopodite well developed with 2-3 terminal spinules............................Lovenula africana

CHAPTER 5

GENUS *PARADIAPTOMUS* G.O. SARS, 1895

Note: This is not a revision of the genus. The four new species will be described to publication standards at a later date.

The known species of *Paradiaptomus* in Africa are:

Paradiaptomus alluaudi (Guerne & Richard, 1890)

P. lamellatus Sars, 1895 - type species

P. natalensis (Cooper, 1906)

P. schultzei Douwe, 1912

P. similis Douwe, 1912

The genus was established by Sars (1895) for *Paradiaptomus lamellatus*, and Douwe (1912b) described two species from Namibia, *P. schultzei* and *P. similis*. *Paradiaptomus natalensis* was first described by Cooper (1906) as *Adiaptomus natalensis* and subsequently included in the genus *Lovenula* by Kiefer (1932a). In this account, *L. natalensis* is transferred to the genus *Paradiaptomus* along with *Neolovenula alluaudi* which has some *Paradiaptomus* characters (see p. 56). *Paradiaptomus similis* was placed into synonymy with *P. greeni* (Gurney, 1906), a species which occurs in India and Sri Lanka, by Gurney (1931). Although the asymmetry of the genital somite is somewhat similar in both species, and the fifth legs of the male are very similar, there are other characters which show that the two species are not conspecific. *Paradiaptomus* similis is a valid species. Paradiaptomus rex is placed into synonymy with P. schultzei.

There are four new, as yet undescribed, southern African species of Paradiaptomus and this brings the total known species in Africa to nine, with eight of these endemic to southern Africa. Paradiaptomus schultzei has a wide distribution which extends from South Africa and Namibia to Ethiopia and Senegal.

There is a wide size-range in the genus, from P. natalensis, the smallest, to P. lamellatus, the largest, but generally they are among the larger diaptomids. Paradiaptomus species occupy a wide variety of habitats such as the low-lying vleis of the western Cape province, the montane Drakensberg region and the semi-arid areas of Namibia and East and North Africa. They have not been recorded from man-made lakes. The occurrence of P. greeni in India and Sri Lanka, as the only Paradiaptomus species occurring outside Africa, is as puzzling today as it was in Gurney's day. Paradiaptomus greeni has a much stronger claim as a species of Paradiaptomus than does P. alluaudi, whose link with the genus is tenuous.

Paradiaptomus G.O. Sars 1895

Broteas Lovén, 1845 (partim)

Paradiaptomus Sars, 1895

Broteas: Guerne & Richard, 1890: 200 (partim). Sars, 1899: 4.

Paradiaptomus: Giesbrecht & Schmeil, 1898: 95. Sars, 1907: 3. Tollinger, 1911: 187. Douwe, 1912a: 2; 1912b: 25; 1914: 96. Gurney, 1929: 572. Kiefer, 1932a: 462; Kiefer, 1934: 123; Kiefer, 1978a: 75. Defaye, 1988: 112. Dussart, 1989a: 28.

Lovenula: Grochmalicki, 1913: 524.

Characteristics of the genus

Generally robust, TL 2-3 mm; A1 short, seldom reaching to end of prosome; raptorial maxillipeds.

Female

Urosome with 2 somites (Fig. 15B) (P. alluaudi has 3 somites); GS may have asymmetrical lobes (Figs 14A-C); FR may be expanded distally and lamelliform, and FS may have swollen or bulbous bases (Fig. 15B).

Male

A1 with 21 segments, 3 of these postgeniculate, spiniform processes on segments 8, 10, 11 and 13, last segment of A1 not beaked (Fig. 10D); outer furcal seta of right FR may be enlarged (Fig. 16C); left P5, Exp2 with short, lateral spiniform process (Fig. 10F); right P5, Enp2, oval or oblate (Fig. 13C).

Paradiaptomus lamellatus Sars, 1895 - type species

Paradiaptomus lamellatus Sars, 1895: 46, pl. 7 (figs 1-7), pl. 8 (figs 1-10).

Broteas lamellatus: Sars, 1899.

Paradiaptomus lamellatus: Giesbrecht & Schmeil, 1898: 96. Stebbing, 1910: 532. Daday, 1910b: 118. Tollinger, 1911:

188, fig. V5. Douwe, 1912b: 29, 31. Rühe, 1914: 8-9, 27, fig 9 (a-d). Sars, 1927: 94, pl. 7, (figs 1-14). Gurney, 1929: 578, fig. 3 (12), 583. Kiefer, 1932a: 462, 488, 491, figs 21-22. Kiefer, 1934: 124-5, figs 24-28, 185. Brehm, 1958: 37. Harding & Smith, 1967: 518. Dussart & Defaye, 1983: 53. Dussart, 1989a: 29-30, figs 18A & 72.

As P. lamellatus has a localised distribution in the Cape province, the following records relate to incorrectly identified species:

Broteas lamellatus: Brady, 1908, 183 (Richmond, Natal).

Paradiaptomus lamellatus: Hutchinson et al., 1932: 17, 89 (Rietfontein pan, Transvaal).

Paradiaptomus lamellatus: Gauthier, 1938: 115, 117 (Sahara)

Paradiaptomus lamellatus: Oliff, 1960: 372 (source Tugela river, Natal, 3000 m).

Material examined

Figs 1, 11, Appendix 2.

SAM-A12441, pond, Cape flats, WFP, 1896, labelled Broteas lamellatus, "co-types" Sars.

SAM-A12445, P. lamellatus, Cape flats, WFP, undated.

SAM-A11540, P. lamellatus, Sars' writing.

SAM-A11541, P. lamellatus, Green Point common, Sars' writing.

SAM-A11542, **SAM-A11543**, P. lamellatus, Cape of Good Hope, Sars' writing.

SAM-A11544, **SAM-A11545**, P. lamellatus, Sars' writing.

SAM-A11546, **SAM-A11547**, **SAM-A11548**, P. lamellatus, Sars' writing.

SAM-A3788, Cape flats, KHB, 1916.

SAM-A3799, Stellenbosch, R.M. Lightfoot, September, 1916.

SAM-A11682, Valkenberg vlei, Miss E.L. Stephens, 15.07.22.

SAM-A11586, Kamieskroon, R.F. Lawrence & Hesse, October 1930.

AM-GBG 294D, Great Berg river, A.D. Harrison, 14.06.51.

AM-FRW 114D, western Cape province, A.D. Harrision & J. Agnew, 27.05.55.

BMNH-1978.26, 9 miles from De Doorns, K.G. McKenzie, September, 1970.

BMNH-1972.1.27, pond on Dwyka tillite, near Grahamstown airport, K.G. McKenzie, 1970?

SWT 26C, Taaiboskraal, SW Springbok, Namaqualand, temporary pool, JAD, 26.08.82.

SWT 12B, University of Western Cape, Bellville, temporary artificial vlei in plant nursery, JAD, 12.08.83.

SWT 15H, Garies, Namaqualand, temporary pool on clay, JAD, 22.08.83.

G501/18, Wiesdrift, JMK, 11.05.89.

G501/19, Soetendalsvlei ditch, JMK, 12.05.89.

G501/21, Peter's bog and farm, JMK, 12.05.89.

Characteristics

Female

Figs 10A-B, 15B.

Robust, Pr: 2.33 mm, TL: 3.58 mm; two urosomal somites; Pdg5 wings expanded, not markedly asymmetrical, posteriorly directed; GS expanded symmetrically, length GS, x2 AS; AS expanded distally, forming with GS, an "hour-glass" shape; furcae expanded distally, lamelliform, setae short with bulbous bases (Fig. 15B). A1 short, barely reaching posterior border of Pdg3; mandible with one large tooth and 2 rounded and 6 pointed molars (Fig. 10A); maxilla 1 similar to Lovenula but with 2-segmented Enp (Fig. 10B, cf. Fig. 5); maxilla 2 somewhat compacted, lacks clawed setae (cf. Fig. 5H); maxilliped raptorial with Enp2-3 each with a long seta associated with spiniform process, Enp4 with spiniform process with spine-like denticles on inner margin and 4 sensory setae. Egg sac (SAM-A11545): ca 95 eggs.

Male

Figs 10C-F.

Robust (Fig. 10C); Pr: 2.10 mm, TL: 3.46 mm. A1 short and segments 13-18 expanded (Fig. 10D); outer seta of right FR, enlarged (Fig. 10E); left P5 with well-developed endopodite, Exp2 spiniform process and medial spine of similar shape and length (Fig. 10F).

Historical

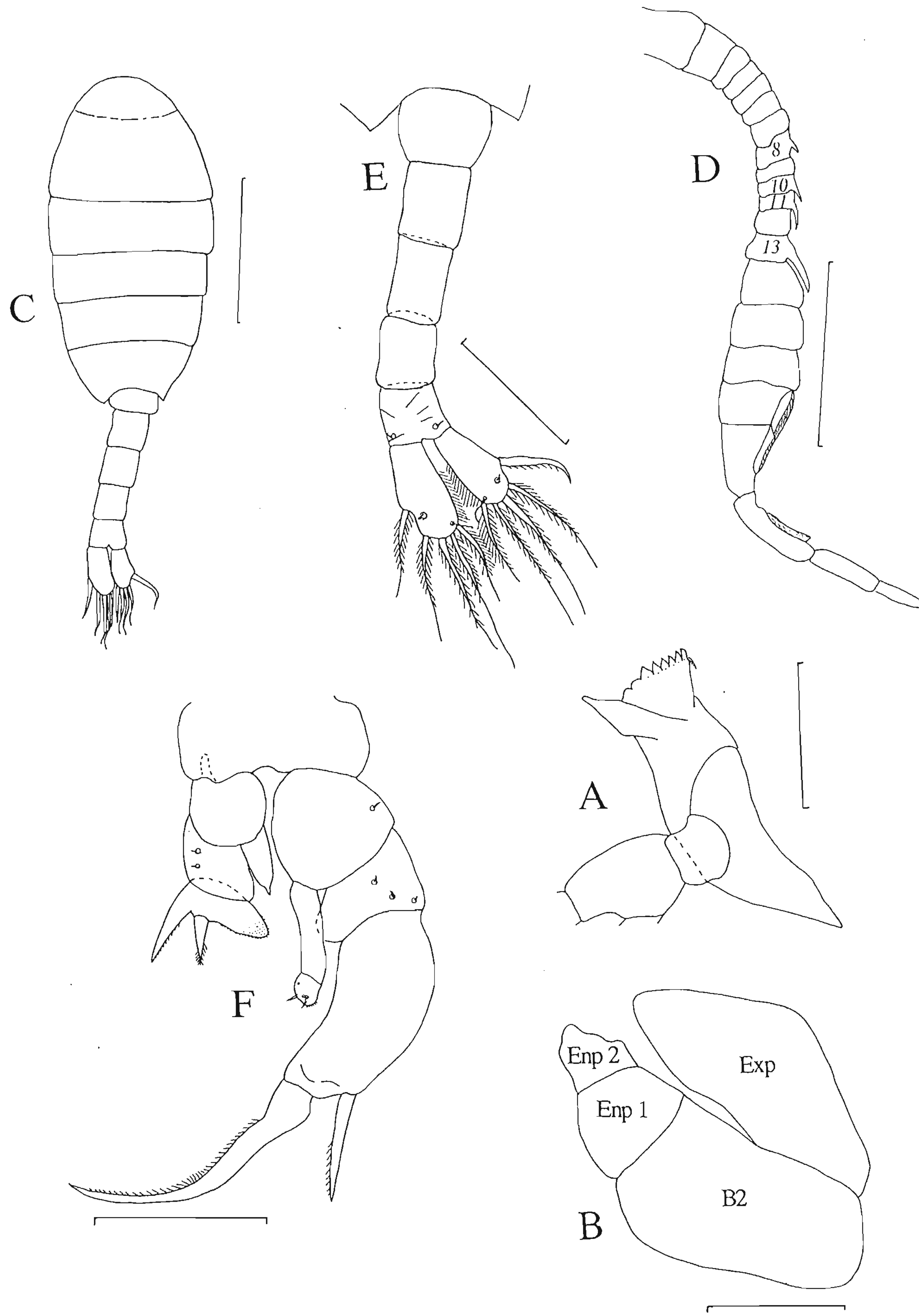
Paradiaptomus lamellatus was cultured by Sars from dried sediment from a Knysna swamp. Professor R. Collett sent the material from South Africa in 1890. The species was named for the large lamelliform furcae of the female. Sars did not designate types.

Distribution

Fig. 11

Paradiaptomus lamellatus has been recorded only

Fig. 10. <u>Paradiaptomus</u> <u>lamellatus</u>. Adult female: A. Mandible. B. Palp of maxilla 1. Adult male: C. Dorsal view. D. Right A1. E. Urosome, dorsal view. F. P5, posterior view. Bar scale in mm. A,B=0.05. C=1.0. D,E=0.5. F=0.25. Female urosome, see fig. 15B.


C
E
D
8
10
11
13
A
F
B
Enp 2
Enp 1
Exp
B2

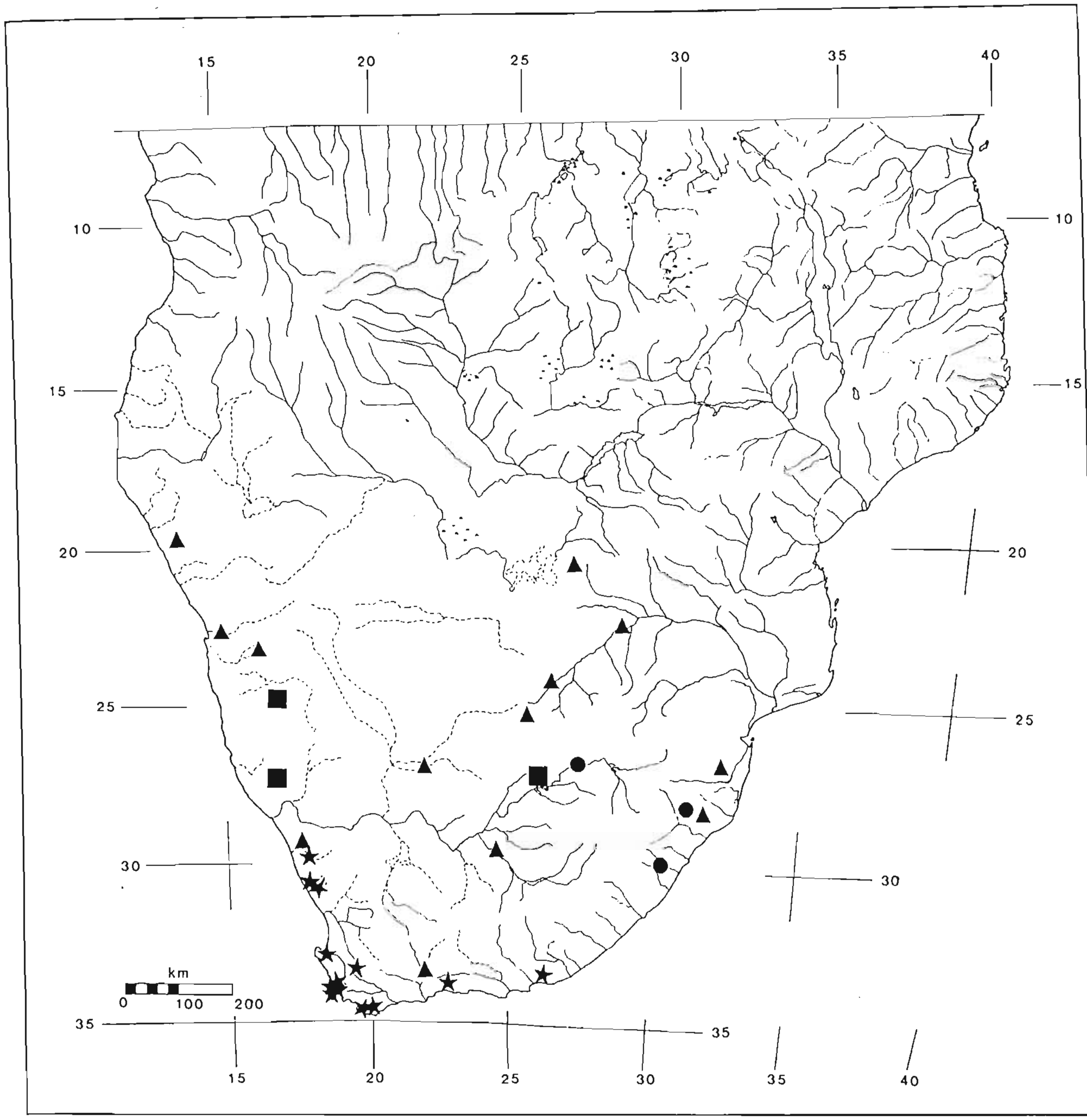


Fig. 11. Map of southern Africa showing distribution of ★ Paradiaptomus lamellatus, ● P. natalensis, ▲ P. schultzei, ■ P. similis

from freshwater coastal lakes and vleis of the western and southern Cape province.

Paradiaptomus alluaudi (Guerne & Richard, 1890)

Diaptomus alluaudi Guerne & Richard, 1890: 198-201.

Diaptomus ungviculatus Daday, 1891: 48, pl. 4 (figs 4-9).

Diaptomus lorteti Barrois, 1891: 277, figs 6-11.

Diaptomus alluaudi: Guerne & Richard, 1891: 213-217. Richard, 1893: 465-466, figs 32, 33. Poppe & Mrázek, 1895: 131. Schmeil, 1896: 177, pl. 14 (figs 7-9). Giesbrecht & Schmeil, 1898: 67, 93. Daday, 1910b: 118. Tollinger, 1911: 52, fig. P1. Gurney, 1929: 576, 581. Gauthier, 1931.

Lovenula (Neolovenula) alluaudi Kiefer, 1932a: 461, 486, figs 18-20. Gauthier, 1933a: 128. Kiefer, 1934: 123; 1958: 158-160; 1978a: 74, 231 (pl. 13); 1978b: 494. Damian-Georgescu, 1966: 44. Dussart, 1967: 89, fig. 23. Dumont & Decraemer, 1977. Dussart & Defaye, 1983: 56.

Paradiaptomus lorteti: Gauthier, 1933a: 64.

Neolovenula alluaudi: Gauthier, 1938: 116. Dumont & Verheye, 1984: 319. Löffler, 1961: 356 (table 2).

Paradiaptomus (Lovenula) alluaudi: Dussart, 1989a: 40, figs 24B & 71.

Material examined

TM-uncatalogued slide of 2 males, labelled Neolovenula alluaudi, Ostrovan-See, Mazedonien, H.W. Schäfer, 09.12.41. **BMNH-1961.6.28.1**, wet specimens labelled Diaptomus alluaudi, Galatui Lake, near Calarasi, Roumania, A.D. Georgescu, undated.

Measurements of BMNH material: Female: Pr: 1.28 mm, TL: 1.71 mm. Male: Pr: 1.03 mm, TL: 1.44 mm

This species is the least typical of all Paradiaptomus species and its status requires further investigation (see p. 56).

Paradiaptomus natalensis (Cooper, 1906)

Adiaptomus natalensis Cooper, 1906: 97-103, pl. 12 (figs 1-14).

Adiaptomus natalensis: Tollinger, 1911: 190, fig. Y5. Douwe, 1912b: 29, 31.

Diaptomus pictus Brady, 1913: 464, pl. 34 (figs 1-6).

Paradiaptomus natalensis: Gurney, 1929: 582.

Lovenula natalensis: Kiefer, 1932a: 461; 1934:122-3. Dussart & Defaye, 1983: 55.

Paradiaptomus (Lovenula) natalensis: Dussart, 1989a: 36, fig. 69.

Metadiaptomus natalensis: Dussart, 1989a: fig. 22.

Material examined

Fig 1, 11, Appendix 2.

AM-VAL 372F, males and females, ground pool, near Lindeque's drift, 8 km below Vaal river barrage, F.M. Chutter, 29.04.58.

Characteristics

Female

Figs 12A-C.

Small, robust (Fig. 12A); Pr: 1.12 mm, TL: 1.66 mm (n=5); A1 extending just beyond end of Pr; GS symmetrical; Pdg4-5 with dorsal keel and asymmetrical 'wings'; GS symmetrical, shorter than AS (Fig. 12B); P5 with Enp setae nearly as long as Enp (Fig. 12C); egg sac: 9, 10 eggs.

Male

Figs 13A-C.

Small, robust (Fig. 13A); Pr: 1.01 mm, TL: 1.50 mm (n=10); A1 with spiniform processes on segments 10 and 11 longer than that on segment 13 (Fig. 13B); left P5 with well developed endopodite, Exp2 spiniform process robust, curved, medial spine, slender; right P5, Enp2 elongated, Exp2 lateral spine, short, sturdy (Fig. 13C).

Distribution

Fig. 11

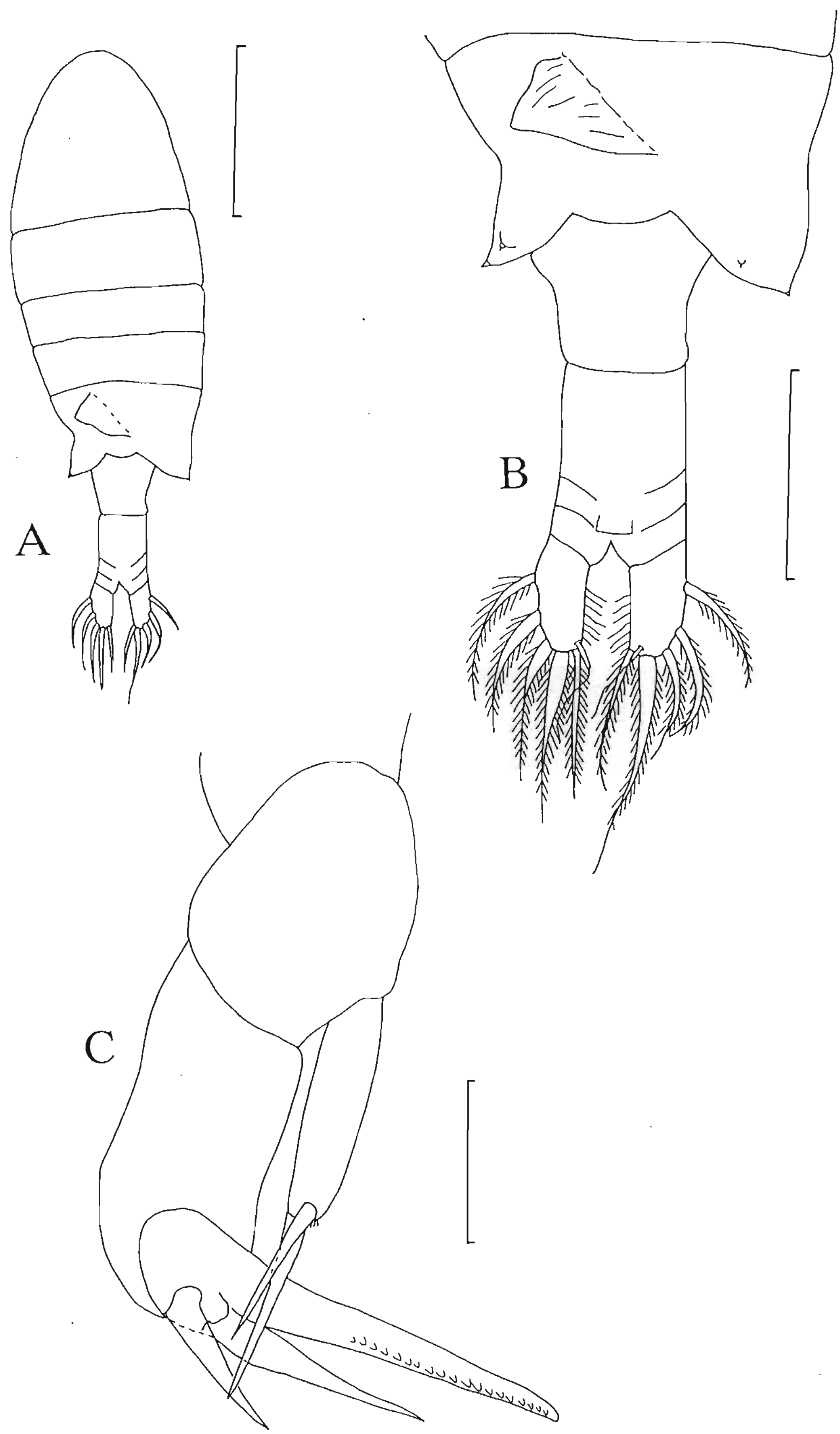
This species was first collected by J. Gibson, in November, 1905, from a marsh pool in Richmond, Natal. It was collected again by Gibson in 1913 from Mahlabatini, Zululand, and in the Vaal river catchment by Chutter in 1958. Its rarity may relate to the draining and destruction of many southern African wetlands.

The status of P. natalensis is discussed in Chapter 4, p. 58.

Paradiaptomus greeni (Gurney, 1906)

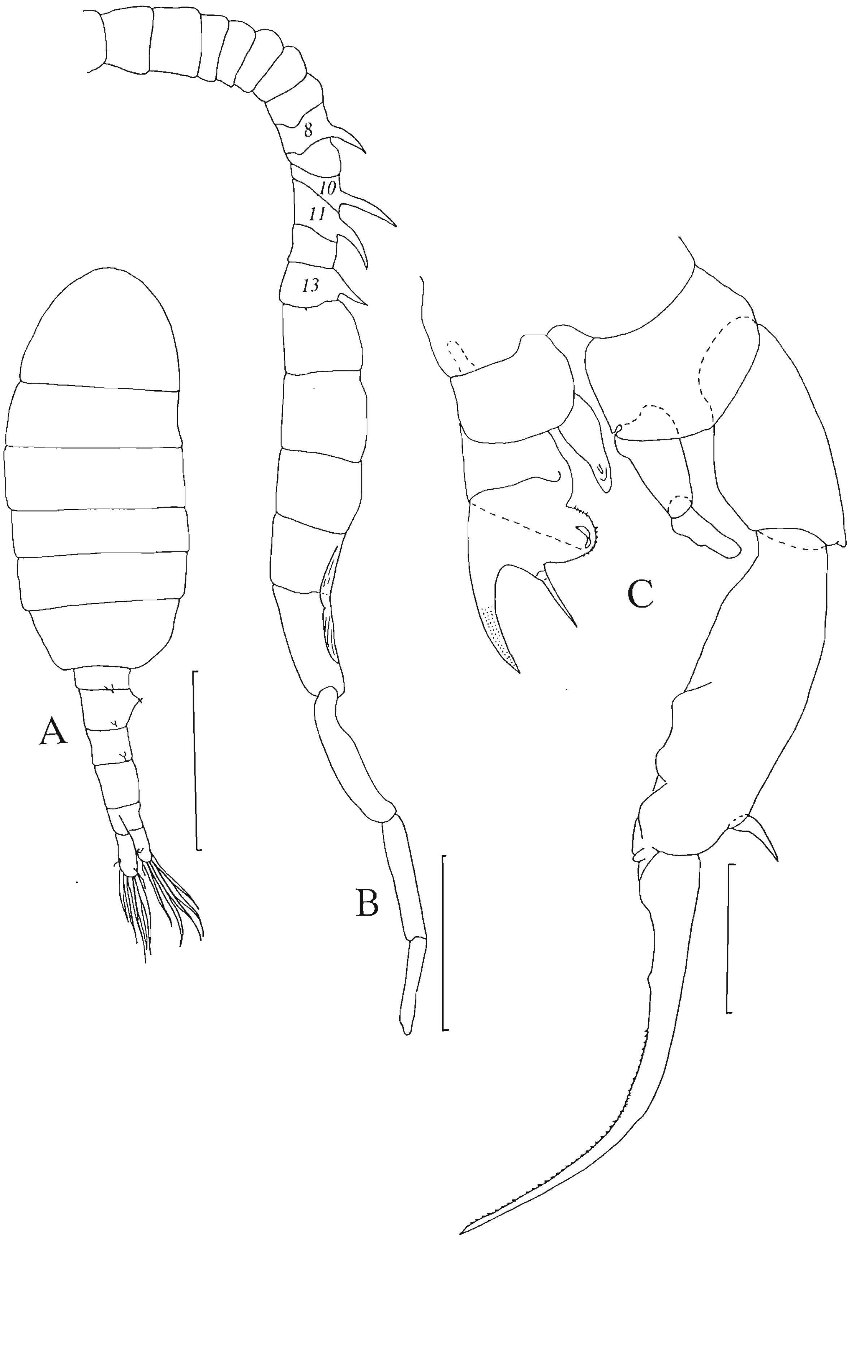
Diaptomus greeni Gurney, 1906: 129-132, pl. 2 (figs 1-9). Tollinger, 1911: 119, fig. F3.

Fig. 12. Paradiaptomus natalensis. Adult female: A. Dorsal view. B. Urosome, dorsal view. C. P5. Bar scale in mm. A=0.5. B=0.25. C=0.05.



A
B
C

Fig. 13. Paradiaptomus natalensis. Adult male: A. Dorsal-lateral view. B. Right A1. C. P5, posterior view. Bar scale in mm. A=0.5. B=0.25. C=0.05.


8
10
11
13
A
B
C

Paradiaptomus greeni: Gurney, 1931: 301-3, figs 1-5. Kiefer, 1939, 1958.
Paradiaptomus greeni: Brehm, 1953a; Rajendran, 1973; Song, 1975; Fernando, 1976, 1980 (these references quoted from Dussart & Defaye, 1983, and not seen in original). Kiefer, 1978a: 76, 230 (pl. 12B). Dussart & Defaye, 1983: 54.
Paradiaptomus (Lovenula) greeni: Dussart, 1989a, 35, figs 21 & 70.
Distribution: India, Sri Lanka, China.
Incertae sedis: Paradiaptomus greeni from Madagascar (Brehm, 1960).

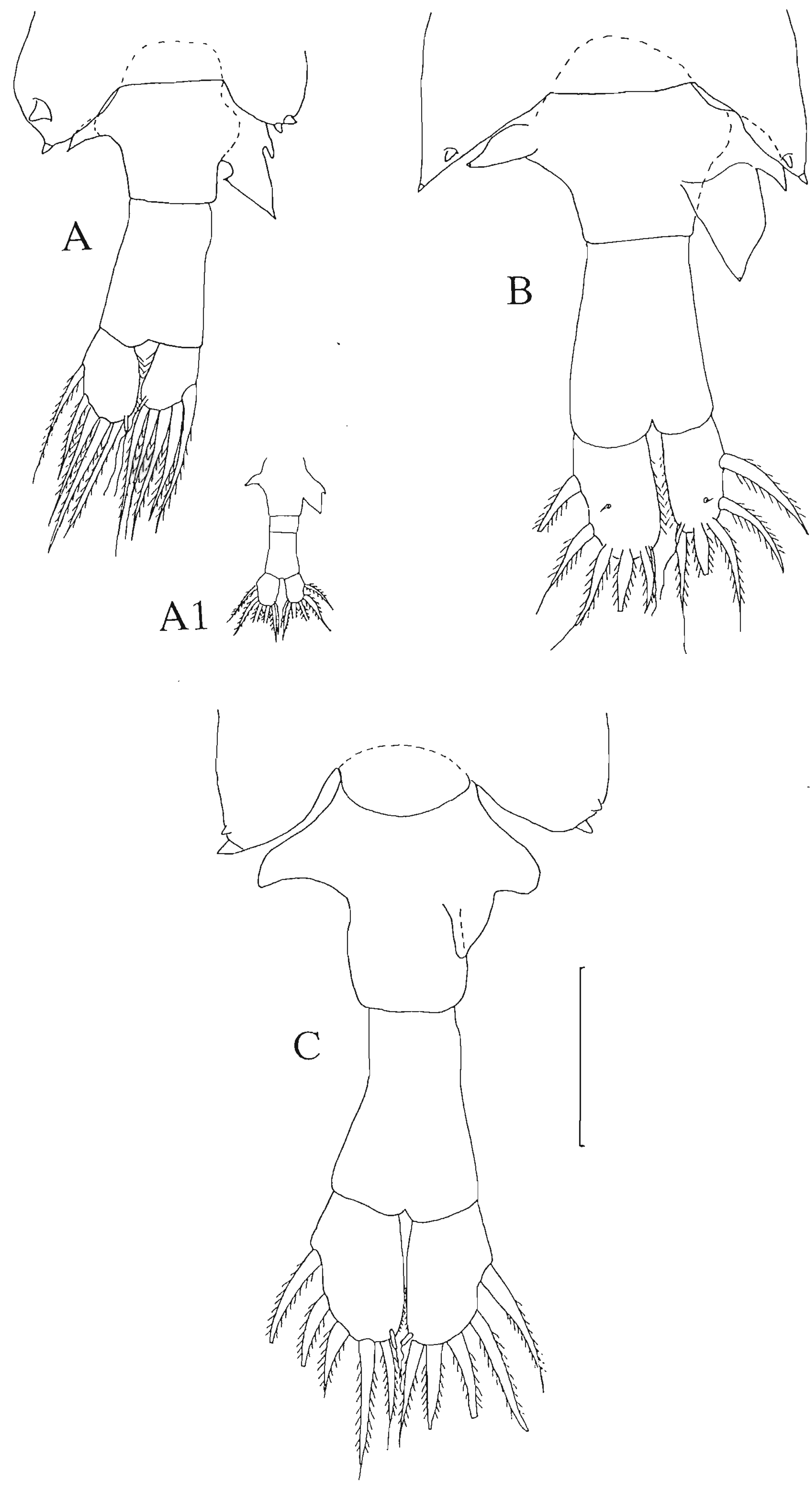
Material examined

BMNH-1957.11.16.153-73, microscope slides of female and male prepared from wet specimens from Lahore, South India, Collector, R. Gurney, undated (Gurney died in 1950). Measurements of Lahore specimens: Female: Pr: 1.41 mm, TL: 1.78 mm. Male: Pr: 1.33 mm, TL: 1.74 mm.

Remarks

This species does not occur in Africa. It was confused with P. similis, a morphologically similar species which occurs only in Africa, by Gurney (1931) (see figs 14A, 14A1, 14B). All records of Paradiaptomus greeni from Africa have been placed into synonymy with Paradiaptomus similis. Although the asymmetry of the genital somite is somewhat similar and the male fifth legs very alike, I consider P. greeni and P. similis to be good species (Figs 14A, 14B). The wide and discontinuous distribution of a

Fig. 14. Adult female urosome, dorsal view. A. *Paradiaptomus greeni*. Locality: Lahore, India, BMNH Cat. No. 1957.11.16.153-73. A1. Locality: Sri Lanka, after Gurney (1906). B. *Paradiaptomus similis*. C. *Paradiaptomus schultzei*. Bar scale, 0.25 mm.


A
A1
B
C

paradiaptomid species (Namibia and Sri Lanka/India) should immediately raise the possibility of there being more than one species. Recourse to Gurney's (1906) original diagrams of P. greeni (Fig. 14A1) and comparision of material from Namibia and India, confirmed, without doubt, the existence of two species, P. greeni and P. similis.

Paradiaptomus schultzei Douwe, 1912

Paradiaptomus schultzei Douwe, 1912b: 26, pl. 4 (figs 1-12), 29, 31.

Lovenula stolzmani Grochmalicki, 1913: pl. 53 (fig. 4).

Paradiaptomus schultzei: Douwe, 1914: 95, 96. Hutchinson et al., 1932: 27, 89, 150. Kiefer, 1932a: 462, 488; Kiefer 1934: 101, 125-6 (figs 31-32), 185. Brehm, 1958: 37. Colvin, 1971: 81, 83. Dussart, 1977: 829, fig. 2. Dussart & Defaye, 1983: 54. Dumont & Verheye, 1984: 318. Verheye & Dumont, 1984: 193, figs 2,3. Wodajo & Belay, 1984: 132. Defaye, 1988: 112, figs 5-7. Dussart, 1989a: 30-31, figs 19 & 72.

Paradiaptomus rex Gauthier, 1951: 94, pl. 24-25. syn. nov.

Paradiaptomus rex: Brehm, 1958: 37. Dumont & Verheye, 1984: 319. Dussart & Defaye, 1983: 54. Dussart, 1989a, 31-32, figs 18B & 72.

Material examined

Fig. 1, 11, Appendix 2.

ZMUH-K8631, Farm Frauenstein, near Neudamm, 50 km ENE Windhoek, W. Michaelsen, 13.05.11.

SAM-A1578, Kamanjab, Kaokoveld, KHB, January 1926.

SAM-A11583, Oudtshoorn, KHB, ca 1926.

SAM-A3787, Kimberley, KHB's writing, undated.

BMNH-1958.10.2.31, Plumtree, Zimbabwe, D.H. Eccles, February 1954.

BMNH-1978.27, Gamsberg Pass Road, NW Windhoek, K.G. McKenzie, October 1970, identified as P. lamellatus.

SM-147, Kharu-Gaiseb salt stream 20 km inland, Namibia, JAD, 20.01.83.

Makane's bridge, Zululand, hatched in laboratory on 11.10.84 from dried sediment, collected by D.M. Ward, 29.10.84.

Umfolozi Game Reserve, Lion pond, M. Hamer, 26.09.85.

Mala Mala Game Reserve, D.G. Hay, 23.11.85.

Characterisitics

Female

TL: 2.24 mm; A1 barely extending to end Pr; urosome with asymmetrical lobes; FS short, with bulbous bases (Fig. 14C); P5, Exp2 spiniform process with coarse denticles; egg sac: ca. 50 eggs.

Male

TL: 2.22 mm; right P5, Exp1 with 2 adjacent inner processes, medial process beaked; Exp3 claw, straight, curved distally.

Historical

Specimens were collected by Schultze from three places in the Kalahari: Letlake pan and Kanyane, central Kalahari, December 1904, and a rain pool in the veld north of Pitshane, eastern Kalahari, January 1905 and a watering hole near Steinkopf in Klein-Namaland. Type material unknown. Douwe named this species in honour of its collector, Dr Leonhard Schultze, Professor of Geography, University of Kiel.

Synonymy of Paradiaptomus rex

Careful consideration of Gauthier's (1951) description of P. rex leaves me in no doubt, even without examination of type material, that the species he described was P. schultzei. Inspection of a number of P. schultzei females showed that the third urosomal somite which Gauthier emphasised, is the anterior part of the long anal somite. The impression that there is a third somite arises from the telescoping of the anal and genital somites. The right side of the genital somite of P. rex female is not figured exactly as in P. schultzei, but some P. schultzei females appeared as in Gauthier's diagram, because of their orientation on the microscope slide. The female and male fifth legs of P. rex and P. schultzei are identical. The geniculate antennae of both species appear to be the same, and the slightly hooked tip of the spiniform process of segment 13, occurs in both species. The furcal setae of both males are exactly as figured by Gauthier, with the outer seta of the right furca curving away slightly. One point of non-agreement, is the bulbous bases of the furcal setae of P. schultzei when compared with the setae of P. rex. It is not known how much emphasis Gauthier placed on this character, or to what extent it may show variability.

Errata p.81. June, 1991

Subsequent examination of *Paradiaptomus rex* supplied b[illegible]

The fact that P. rex has been recorded only once, and P. schultzei has a wide distribution through the drier areas of Africa, is also important.

Distribution

Fig. 11.

South Africa, Namibia, East Africa (Grochmalicki, 1913), Senegal (Gauthier, 1951), Ethiopia (Defaye, 1988),

Paradiaptomus similis Douwe, 1912

Paradiaptomus similis Douwe, 1912b: 27-31, pl. 4 (figs 13-14).

Paradiaptomus similis: Gurney, 1929: 573, 574 (fig. 1), 575 (fig. 2); 1931: 301.

Paradiaptomus greeni: Gauthier, 1933a: 128, 130; 1938: 117. Kiefer, 1932a: 462, 488, 491 (fig. 23); 1934: 127-8, figs 33-35, 185; 1958: 159. Brehm, 1958: 29, fig. 30. Dumont, 1979. Dussart & Defaye, 1983: 54. Dumont & Verheye, 1984: 319. (misidentification).

Paradiaptomus (Lovenula) greeni: Dussart, 1989a, 35, figs 21 & 70. (misidentification).

Material examined

Figs 1, 11, Appendix 2.

HMNH-III-115, 116, Kangane, Kalahari, Daday collection, wet specimens, labelled "Lovenula greeni (Gurney, 1906)".

SAM-A11585, Wolmaranstad, C.S. Grobbelaar, 1929.

SMN-50736, Fredericksrust, Okahandja, Namibia, S. Bethune, 15.02.83.

SMN-51338, Maltahohoe, Namibia, rainpool, S. Bethune, 12.03.88.

Characteristics

Female

TL: 2.25 mm; A1 extending to end of Pr; urosome with asymmetrical lobes; FS short with bulbous bases (Fig. 14B); egg sac: ca. 18 eggs.

Male

TL: 2.00 mm; right P5, Exp1 with 2 adjacent inner processes, medial process rounded; Exp3 claw curved uniformly.

HMNH, Daday material, labelled P. greeni, Kalahari: TL: Female: 1.56 mm; Male: 1.50 mm; counts of four egg sacs: 9, 10, 11, 12 eggs per sac.

Distribution

Fig. 11

Kalahari, Namibia, and other areas in Africa as P. greeni. See comments under P. greeni, p. 77.

NEW SPECIES

Paradiaptomus sp. A

Material examined

Locality (Fig. 17): Bulwer, Natal, pan on a mountain top, E. Warren, January 1914; Natal Museum, uncatalogued.
Sample consists of 12 females and 13 males, preserved in corrosive sublimate (HgCl), some specimens with damaged antennae, furcae and appendages. Warren's label "corro-

sive, brilliantly coloured Diaptomus".

Characteristics

Female:

Robust. Pr: 1.99 mm, TL: 2.97 mm; A1 extending to posterior border Pdg3; Pdg5 wings and urosome almost symmetrical; length FR x2 length AS; FR with long setae (Fig. 15A). One female with egg sac, 0.56 x 0.64 mm, ca. 20 eggs.

Male

Robust. Pr: 1.84 mm, TL: 2.87 mm. P5, see Paradiaptomus key.

Paradiaptomus sp. B

Material examined

Locality (Fig. 17): Vryburg, J.S. Brown, undated ?1920 Mus. No.: SAM-A5937.

Characterisitics

Female

Robust. Pr: 2.17 mm, TL: 3.25 mm; A1 extending barely to end of Pr; Pdg5 wings and GS almost symmetrical; FR same length as AS; FS long, with bulbous bases of setae 1-4 set close together; dorsal seta of left FR enlarged (Fig. 15C).

Male

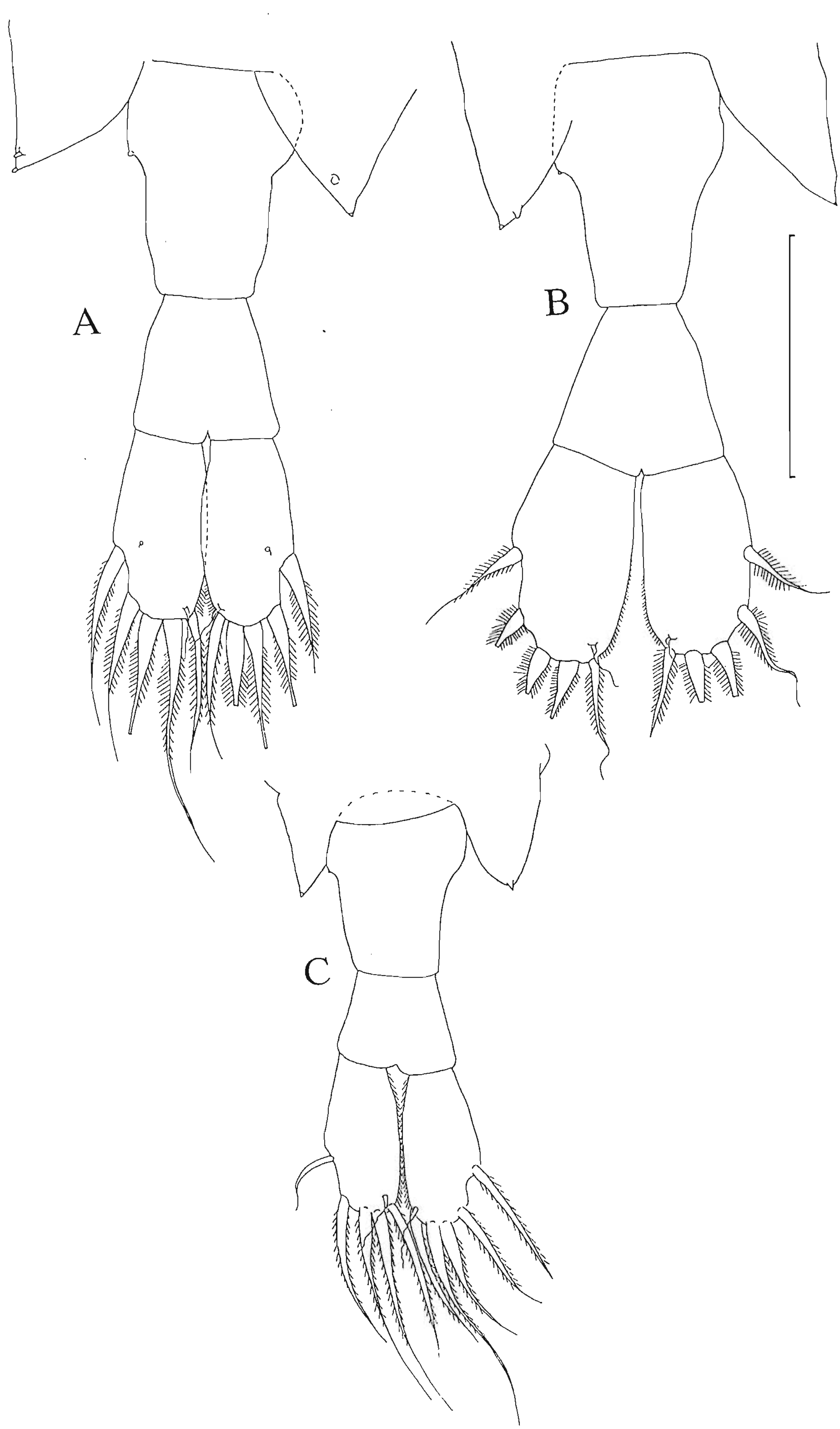
Robust. Pr: 2.03 mm, TL: 3.19 mm; for P5, see Paradiaptomus key.

Paradiaptomus sp. C

Material examined

Locality 1 (Fig. 17): Cape Point Nature Reserve, near

Fig. 15. Adult female urosome, dorsal view. A. *Paradiaptomus* sp. nov. A (Bulwer). B. *P. lamellatus*. C. *Paradiaptomus* sp. nov. B (Vryburg). Bar scale, 0.5 mm.


A
B
C

Roussouwskop, temporary blackwater, JAD, 25.08.83, Cat. No.: SWT 18B.

Locality 2 (Fig. 17): CPNR, 1 km S. Klaasjagersberg, temporary pool, JAD, 01.09.83, Cat. No.: SWT 14B.

Characteristics

Female

Robust. TL: 2.7 mm; A1 short, extending to Pdg3 posterior border; Pdg5 wings asymmetrical with 2 prominent spines on right wing; GS, AS, FR all of similar length; FS long (Fig. 16A).

Male

Robust. TL: 2.17 mm; outer seta of right FR enlarged; P5, see *Paradiaptomus* key.

Paradiaptomus sp.D

Material examined

Locality (Fig. 17): Rooipan (near Yzerfontein), 33° 20'S; 18° 10'E, alt: 2 m; area: 0.34 km^2; salinity: 52 °/oo; conductivity: 4250 mS/m; pH: 8.2; TDS: 26510 mg/l. Collector JMK, 02.08.88, Cat. No.: G201/10. Further details - Silberbauer & King, S. Afr. J. Aquatic Sci. (in press).

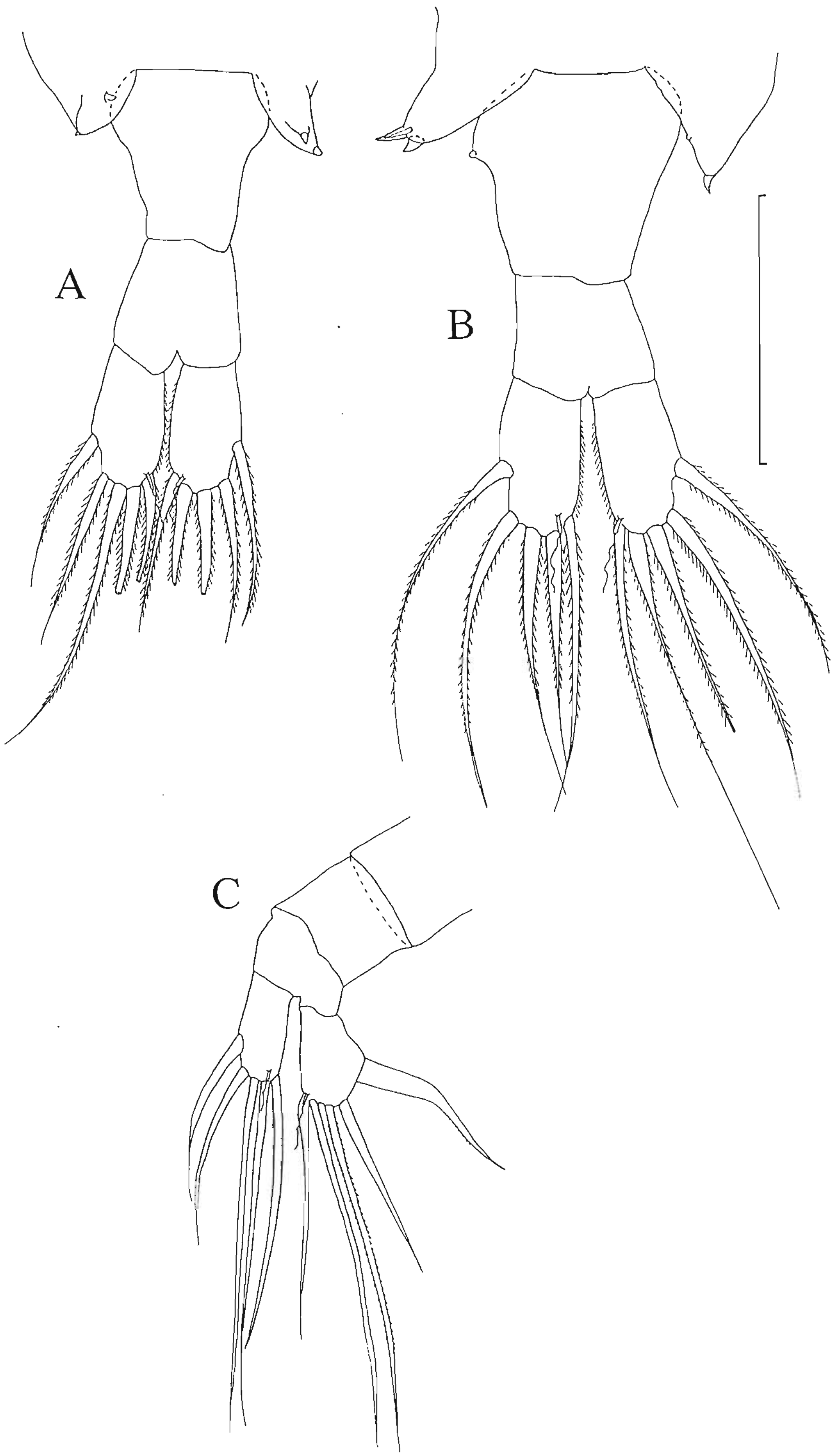
Characteristics

Female

TL: 3.08 mm; A1 extending beyond posterior border of Pdg3; Pdg5 wings with 2 prominent spines on left wing; FS very long (Fig. 16B).

Male

Fig. 16. A. _Paradiaptomus_ sp. nov. C. (Cape Point). Adult female urosome, dorsal view. B. _Paradiaptomus_ sp. nov. D (Rooipan). Adult female urosome, dorsal view. C. _Paradiaptomus_ sp. nov. D (Rooipan). Adult male urosome, dorsal view. Bar scale, 0.5 mm.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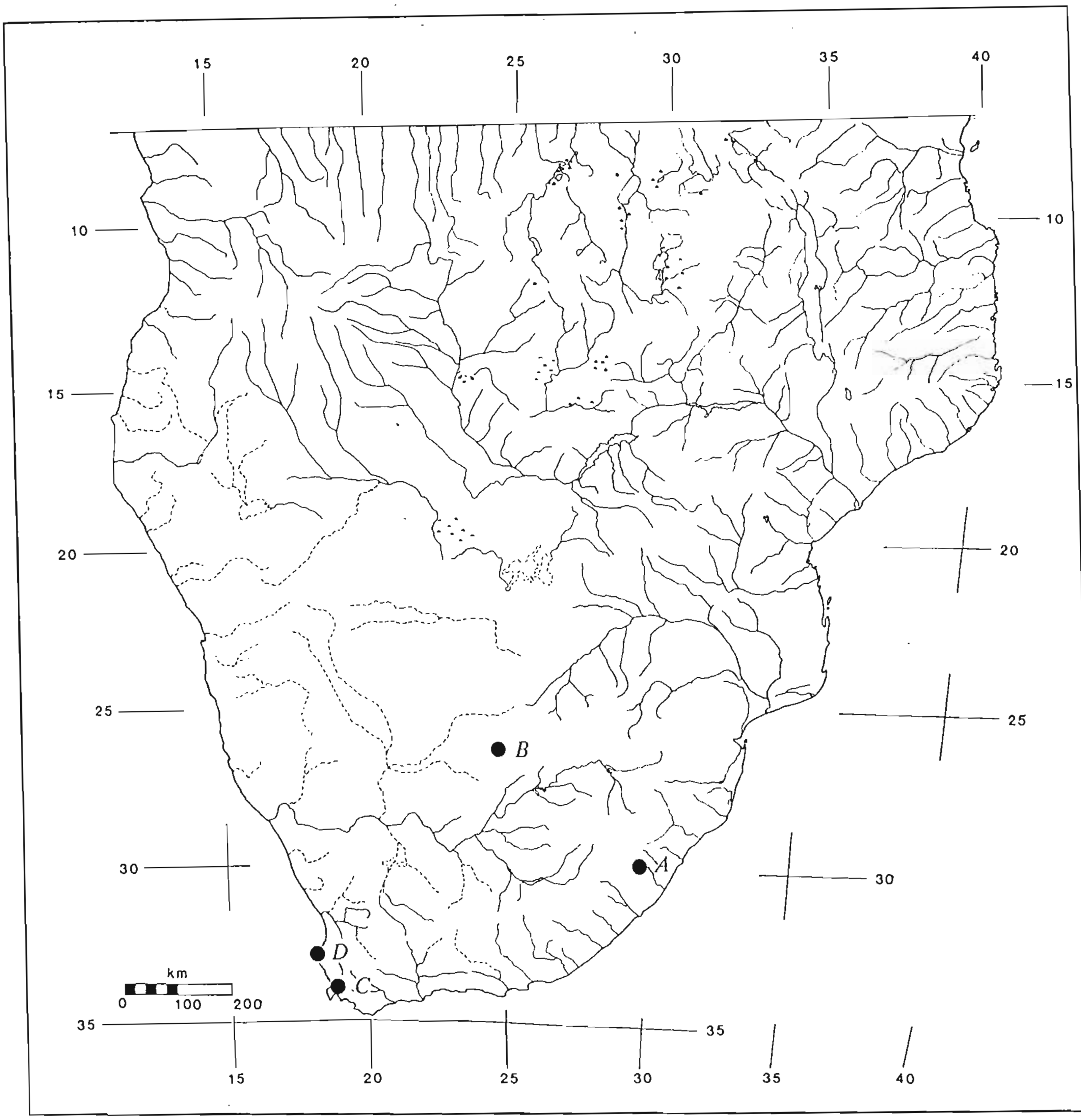


Fig. 17. Map of southern Africa showing localities of new species of Paradiaptomus. A. Bulwer; B. Vryburg; C. Cape Point Nature Reserve; D. Rooipan.

TL: 2.39 mm; AS and FR asymmetrical, with right FR with large spine-like, outer seta, other setae very long (Fig. 16C). Right P5 with endopodite broad-based, triangular.

KEY TO THE SPECIES OF *PARADIAPTOMUS*

Females

1 Urosome with 3 somites......................*P. alluaudi*

1' Urosome with 2 somites..............................2

2 TL < 2 mm,
Furcal setae without swollen bases....................3

2' TL > 2 mm,
Furcal setae with swollen bases.......................4

3 GS symmetrical,
Pdg 4-5 with dorsal keel (Fig. 12B).......*P. natalensis*

3' GS asymmetrically lobed,
Pdg 4-5 without dorsal keel (Fig. 14A)........*P. greeni*

4 GS asymmetrically lobed.............................5

4' GS almost symmetrical..............................6

5 GS with lobes as Fig. 14C.................*P. schultzei*

5' GS with lobes as Fig. 14B..................*P. similis*

6 Pdg5 wings symmetrical, long, directed backwards,
AS, width of posterior border x2 anterior border,
Furcal rami expanded distally.........................7

6' Pdg5 wings asymmetrical, shorter, laterally directed,
AS, width of posterior border slightly > anterior

border,

Furcal rami longer than broad..........................8

7 Furcal setae short, with widely-separated bulbous bases (Fig. 15B)..............................P. lamellatus

7' Furcal setae long, with swollen bases close together (Fig. 15C)...........Paradiaptomus sp. nov. B (Vryburg)

8 Furcal setae long = combined length GS + AS + FR, Left Pdg5 wing with 2 prominent spines (Fig. 16C)...... ....Paradiaptomus sp. nov. D (Rooipan)

8' Furcal setae length < combined length GS + AS + FR, Pdg5 wing with one small spine.......................9

9 Anal segment approx. same length as furcal rami (Fig. 16A)............Paradiaptomus sp. nov. C (Cape Point)

9 Anal segment approx. 1/2 length of furcal rami (Fig. 15A).................Paradiaptomus sp. nov. A (Bulwer)

Males

1 TL < 2 mm......................................2

1' TL > 2 mm......................................4

2 Right P5, Enp well-developed, Exp2 with constant width...3

2' Right P5, Enp reduced, Exp2 narrowed proximally........ ....P. alluaudi

3 Left P5, Exp2 with straight, slender spiniform process. ....P. greeni

3' Left P5, Exp2 with curved, robust spiniform process (Fig. 13C)................................*P. natalensis*

4 Right furcal ramus, outer seta enlarged...............5

4' Right furcal ramus, all setae similar.................7

5 Right furcal ramus asymmetrical with very enlarged seta (Fig. 16C)......*Paradiaptomus* sp. nov. D (Rooipan)

5' Right furcal ramus not asymmetrical, seta moderately enlarged..6

6 Right P5, length Enp1 = length Enp2, Exp2 lateral spine, length = 1/3 length Exp3 claw...... ....*Paradiaptomus* sp. nov. (Cape Point)

6' Right P5, length Enp1 = x3 length Enp2, Exp2 lateral spine, length = 1/2 length Exp3 claw (Fig. 10F).........................*Paradiaptomus lamellatus*

7 Right P5, Exp1 with 2 adjacent, inner processes.......8

7' Right P5, Exp1 without processes.....................9

8 Right P5, Exp1 medial process beaked, Exp3 claw straight, curved distally........*P. schultzei*

8' Right P5, Exp1 medial process rounded, Exp3 claw curved uniformly ....*P. similis*

9 Right P5, length endopodite = length Exp1, Length Exp2 lateral spine = 1/3 length Exp claw, Left P5, length Exp2 spiniform process = length Exp2 spine,

Exp2 spiniform process, denticulate distally...........
.....................*Paradiaptomus* sp. nov. A (Bulwer)

9' Right P5, length endopodite = 1 1/2 length Exp1,
Length Exp2 lateral spine = 1/2 length Exp3 claw,
Left P5, length Exp2 spiniform process slightly less than length Exp2 spine,
Exp2 spiniform process, uniformly denticulate..........
.....................*Paradiaptomus* sp. nov. B (Vryburg)

CHAPTER 6

GENUS METADIAPTOMUS METHUEN, 1910

Note: This is not a revision of the genus. The two new species will be described to publication standards at a later date.

The known species of Metadiaptomus in Africa are:

Metadiaptomus transvaalensis Methuen, 1910 - type species

M. chevreuxi (Guerne & Richard, 1894)

M. capensis (Sars, 1907)

M. purcelli (Sars, 1907)

M. aethiopicus (Daday, 1908)

M. meridianus (Douwe, 1912)

M. colonialis (Douwe, 1914)

M. mauretanicus Kiefer & Roy, 1942

M. gauthieri, Brehm, 1949

Incertae sedis - M. vandouwei (Kiefer, 1930)

The genus was established by Methuen (1910) for Metadiaptomus transvaalensis and some of his reasons for creating a new genus were not correct (e.g. 26-segmented A1). He omitted to emphasise one of the main characteristics of the genus, that of the female urosome with three somites. However, he did describe the characteristic morphology of the basipodite of the male right P5 and mentioned the curved claw or short spine on the exopodite of the left P5. These two characters, as well as the female urosome of three somites, are constant for the genus. All Metadiaptomus species are endemic to Africa or Madagascar (M. gauthieri), except the Asian species M. asiaticus (Ul'yanin, 1875). This species, first described in the genus Diaptomus, requires further investigation. Data collected in this study, indicate that some Metadiaptomus species can tolerate waters of high salinity, and some have the ability to colonise man-made lakes. Western Cape province species have a limited distribution, but other species such as M. meridianus and M. colonialis are widely distributed (Fig. 23). Six of the nine known species, as well as two undescribed species, occur in southern Africa.

Metadiaptomus Methuen, 1910

Metadiaptomus Methuen, 1910: 160.

Metadiaptomus: Kiefer 1932a: 462; 1934: 128; 1978a: 72. Dussart, 1989a: 16.

Characteristics of the genus TL ranges from < 1 mm to slightly > 2mm; females larger than males, with size dimorphism as high as 2:1 in some species (Table 2).

Female

Urosome with 3 somites; antennae extending beyond the Pr and often to FR ; Pdg5 wings usually symmetrical; GS symmetrical, or with asymmetry related to processes or spines (Fig. 25A); furcal rami and furcal setae symmetrical (Fig. 20A); P5 as in Fig. 22B with fine or coarse denticles on Exp2 spiniform process.

Male

A1, 21 segmented, geniculation between segments 18 and 19, diagnostic spiniform processes on segments 8, 10, 11, 13 (Fig. 24B); furcal rami and furcal setae symmetrical; right P5 with basipodite expanded and fringed with setae, knobs or small spinules (Figs 18A, 18B); left P5, Exp2 with lateral spine, usually extended (Fig. 18A).

Metadiaptomus transvaalensis Methuen, 1910 - type species

Metadiaptomus transvaalensis Methuen, 1910: 160-163, pl. 16 (figs 46 a-c), pl. 17 (figs 47-50), pl. 18 (figs 51-55).
Paradiaptomus transvaalensis: Kiefer, 1929: 14. Hutchinson et al., 1932: 32-62, 89-150, 185, pl. 7 (fig. 1).
Metadiaptomus transvaalensis: Kiefer, 1932a: 462-490, 491 (figs 24-25); 1934: 102, 129-31 (figs 36-42), 185. Löffler, 1961: 356 (table 2) 360, 363. Dussart & Defaye, 1983: 57. Dussart, 1989a: 17-18, figs 11, 68.

Material examined

SAM-A11832, Du Toit's pan, J.H. Power, 05.08.12, det. D.H. Eccles, 23.04.63.
BMNH-1958.10.2.34, Makgadikgadi main pan, Botswana, D.H. Eccles, 04.05.57.
VAL 676C, **VAL 683E**, Lake Chrissie, FMC, 10.12.58.
VAL 514H, Lake Chrissie, FMC, 15.01.59.
GEN 591D, pan between Middleburg & Belfast, J. Agnew, 23.06.60.
Welkom, Flamingo pan, OFS, E.R. Dempster, 8.12.88.
Souwa pool, Souwa pan, Makgadikgadi, Botswana, R.C. Hart, 10.07.90, breeding population.

Fig. 18. Adult male, P5, posterior view. A. *Metadiaptomus transvaalensis*. B. *Metadiaptomus meridianus*.

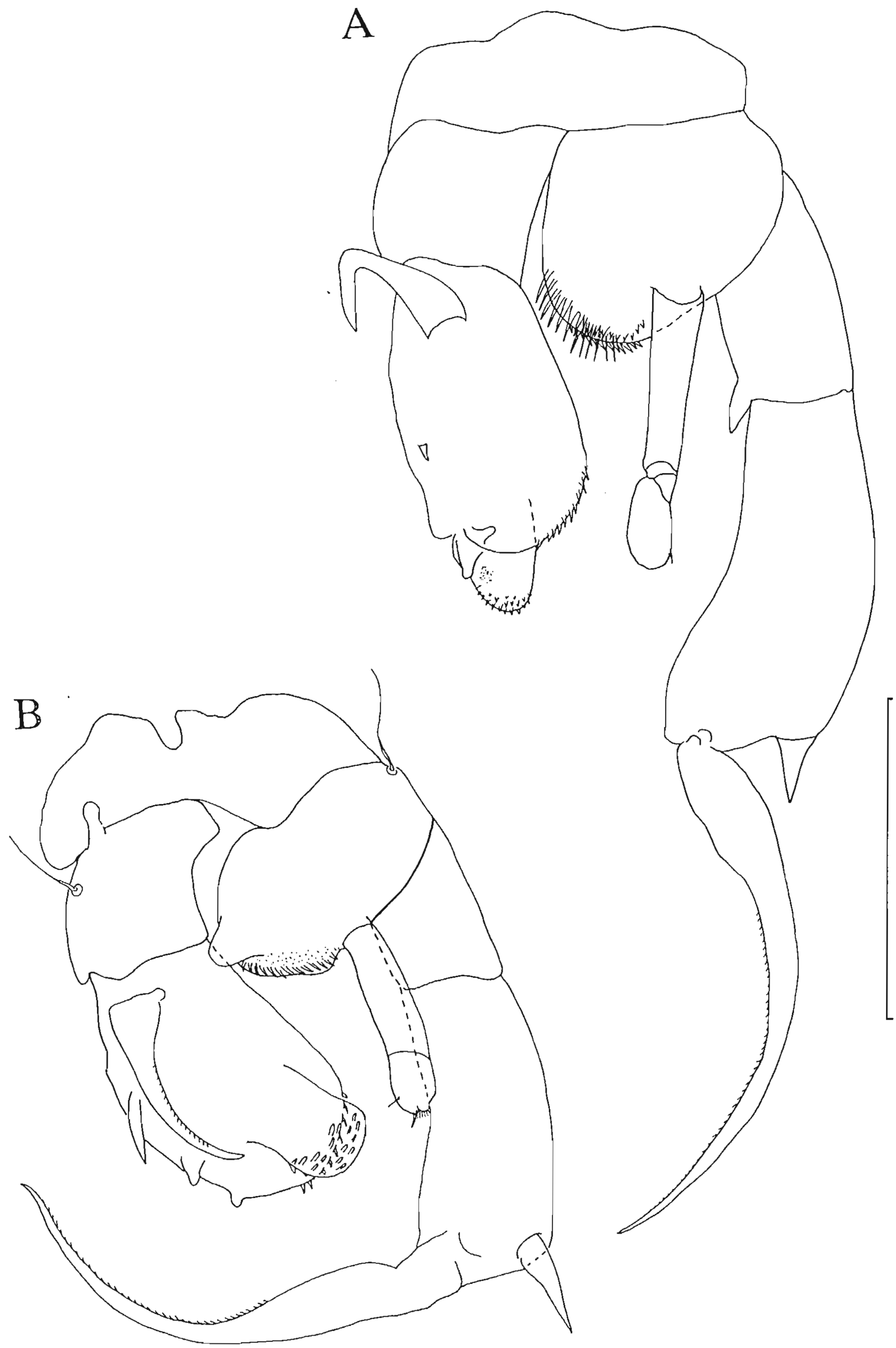


Table 2

Total length (mm) (excluding furcal setae) of 11 species of *Metadiaptomus*. * from Dussart (1989a).

Species	Female	Male
chevreuxi	2.7-3.1	2.5-2.7 *
capensis	2.07	1.02
purcelli	1.04	0.80
aethiopicus	1.7-2.0	1.5-1.8 *
transvaalensis	2.29	1.2
meridianus	1.64	1.12
colonialis	1.64	1.2
mauretanicus	1.5	1.2 *
gauthieri	1.13	0.95
sp. nov. A	1.83	1.45
sp. nov. B	1.68	1.58

Characteristics

Measurements, Table 2. Pr, female and male tapering anteriorly.

Female

A1 extending just beyond Pr; Pdg5 wings symmetrical, markedly extended posteriorly; GS symmetrical, length = length Ur2 + AS + FR; FR symmetrical with long FS; P5, Enp same length as Exp1, Enp setae = 1/2 length Enp.

Male

FR symmetrical, FS long; B2 fringed with long spinules; right P5, Exp1 with inner triangular process, Exp2 lateral spine, triangular; Enp slender, with ovoid Enp2; left P5, Exp2 lateral spine, recurved (Fig. 18A).

Distribution

Fig. 19

Metadiaptomus transvaalensis was twice recorded as co-occurring with Lovenula africana in Makgadikgadi salt pan (Figs 1, 6), and with L. falcifera in a pan between Middleburg and Belfast, Transvaal (23.06.60) (p. 45, Fig. 6).

Metadiaptomus asiaticus (Ul'yanin, 1875)

Diaptomus asiaticus Ul'yanin, 1875.

Diaptomus asiaticus: Guerne & Richard, 1889. Sars, 1903. Tollinger, 1911: 56, fig. T1. Gurney, 1929: 576, 578 (fig. 3 (6)).

Paradiaptomus asiaticus: Rylov, 1930.

Metadiaptomus asiaticus Kiefer, 1932a: 462; 1978a: 74, Fig. 12A. Brehm, 1958: 37. Löffler, 1961: 356 (table 2). Dussart & Defaye, 1983: 57.

Distribution

This species occurs in Asia, Turkey, northern China, western Mongolia, western Siberia, north east of Lake Baikal, lakes of the steppe region of the Volga. Its inclusion in the genus Metadiaptomus should be confirmed, especially as it is the only species in the genus outside

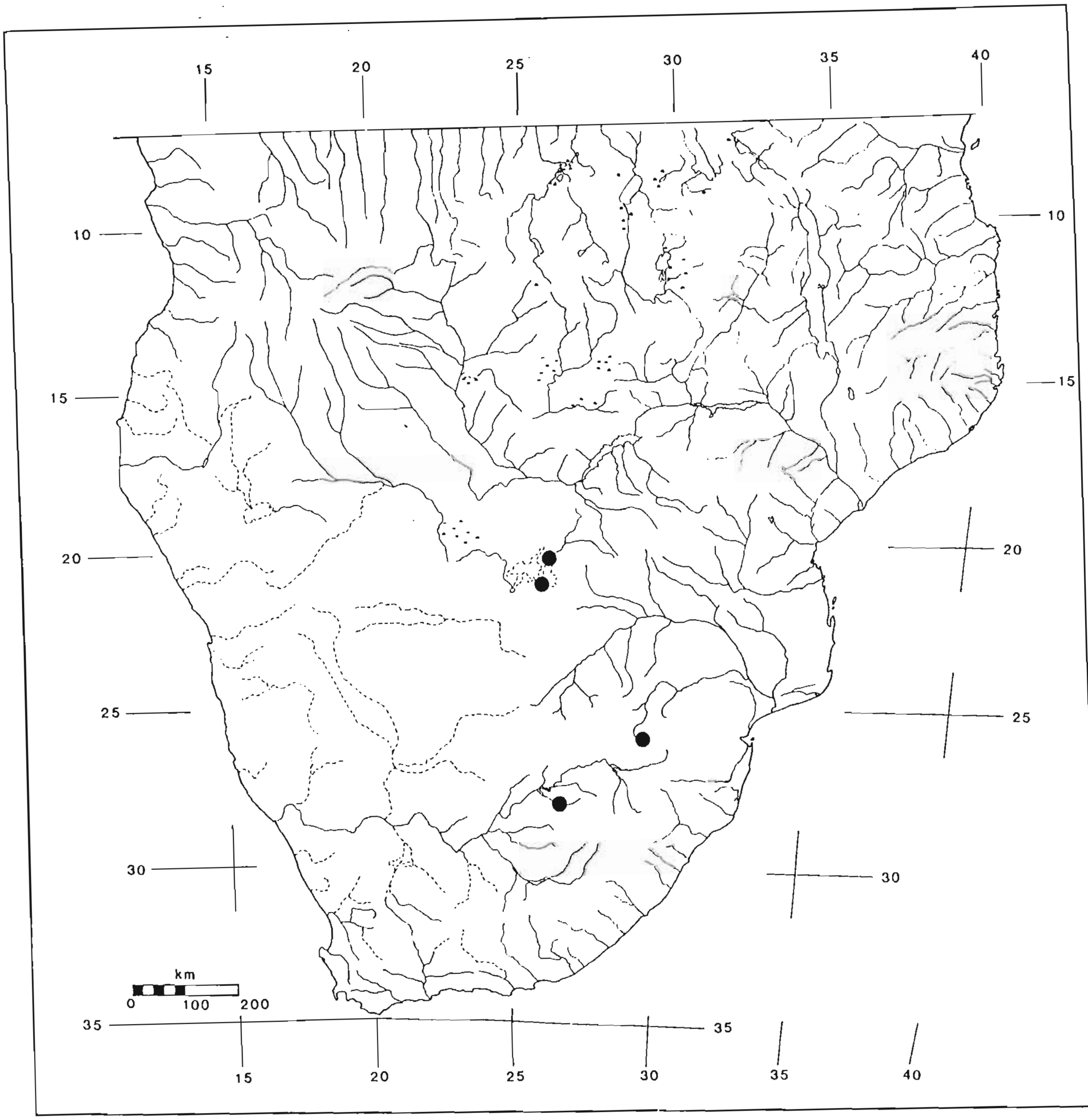


Fig. 19. Map of southern Africa showing distribution of *Metadiaptomus transvaalensis*.

Africa and Madagascar. No specimens have been examined.

Metadiaptomus chevreuxi (Guerne & Richard, 1894)

Diaptomus chevreuxi Guerne & Richard, 1894: 176-9, figs 1-5.

Diaptomus chevreuxi: Giesbricht & Schmeil, 1898: 94. Gurney, 1909; 1929: 576, 581. Daday, 1910b: 118. Tollinger, 1911: 52, fig. N1.

Metadiaptomus chevreuxi: Kiefer, 1932a: 462, 490; 1954; 1958: 159; 1978a: 72, 228 (pl. 10). Gauthier, 1933a: 64-5; 1938: 113. Brehm, 1958: 37. Dussart & Defaye, 1983: 57. Dussart, 1989a: 18-19, figs 12 & 67.

Distribution and comment

Dussart (1989a) recorded this species from temporary waters in North Africa: Algeria, Morocco, Tunisia, Iran, Iraq. This is the largest Metadiaptomus species and shares some unusual characters with Metadiaptomus sp. nov. A (Leeupan). The relationship between these two species is of particular interest as they are widely separated on the African continent and yet have synapomorphies.

Metadiaptomus capensis (Sars, 1907)

Diaptomus capensis Sars, 1907: 4, pl. 1 (figs 1-12), pl. 2 (figs 1-2).

Diaptomus capensis: Daday, 1910b: 118. Stebbing, 1910: 531. Tollinger, 1911, 57, fig U1. Rühe, 1914: 26, figs 8 (a-b). Sars, 1927: 98, pl. 8 (figs 1-12).

Paradiaptomus capensis: Hutchinson et al., 1932: 71, 89, 150.

Metadiaptomus capensis: Kiefer, 1932a: 462, 490; 1934: 103, 135-6, fig. 50. Harding & Smith, 1967: 520. Brehm, 1958: 37. Gardiner, 1988: Ch. 9, p. 6. Dussart & Defaye, 1983: 57. Dussart, 1989a: 19-20, figs 13A & 66.

Material examined

SAM-A5944, Green Point common, Cape Town, WFP, 14.10.1898.

SAM-A12442, Green point common, small pond, WFP, undated, labelled Diaptomus capensis.

SAM-A11559 to **SAM-A11566**, 8 vials, Green Point common, Sars' writing labelled D. capensis.

SAM-A11556, Salt river vlei (fresh), R.W. Tucker, 05.12.14, labelled D. capensis.

SAM-3800, **SAM-A11557**, **SAM-A11558**, Stellenbosch, R.M. Lightfoot, September 1916.

BMNH-1958.10.2.33, Namaqualand, 6 miles S. Garies, J. Balfour-Browne, 18.07.54.

Si 1T, Sirkelsvlei, AJCG, 1981.

SWT 15J, Garies, JAD, 22.08.83.

SWT 19B, Sirkelsvlei, JAD, 01.09.83.

SWT 20A, Yserfontein salt pan, JAD, 22.08.83.

De Hoop vlei, JMK, 01.11.86.

G247/01, Vermont pan, JMK, 23.05.88

G403/05, Diepte Gatt, JMK, 25.05.88.

G201/04, Rondeberg 718, JMK, 04.08.88.

G501/16, Melkbos pan, JMK, 10.05.89.

G501/20, Varkensvlei, JMK, 12.05.89.

Characteristics

Measurements, Table 2.

Female

Large, TL x2 TL male; A1 extending to end GS; Pdg5 wings symmetrical; GS expanded to right with short spine; GS with genital operculum; FR and FS symmetrical (Fig. 20A); P5, Exp2 spine = 2/3 length spiniform process, Enp slender, setae nearly 1/2 length Enp.

Male

Small, robust; B2 very pronounced medially, with fringe of small processes; right P5, large endopodite; Exp1 inner process 1/3 length Exp2; Exp2 long, boat-shaped, Exp2 lateral spine very small; Exp3 claw semi-circular; left P5, Exp2 spine short, stout (Fig. 20B).

Distribution

Fig. 21

Metadiaptomus capensis often co-occurs as prey species with Lovenula simplex (p. 54, Fig. 6).

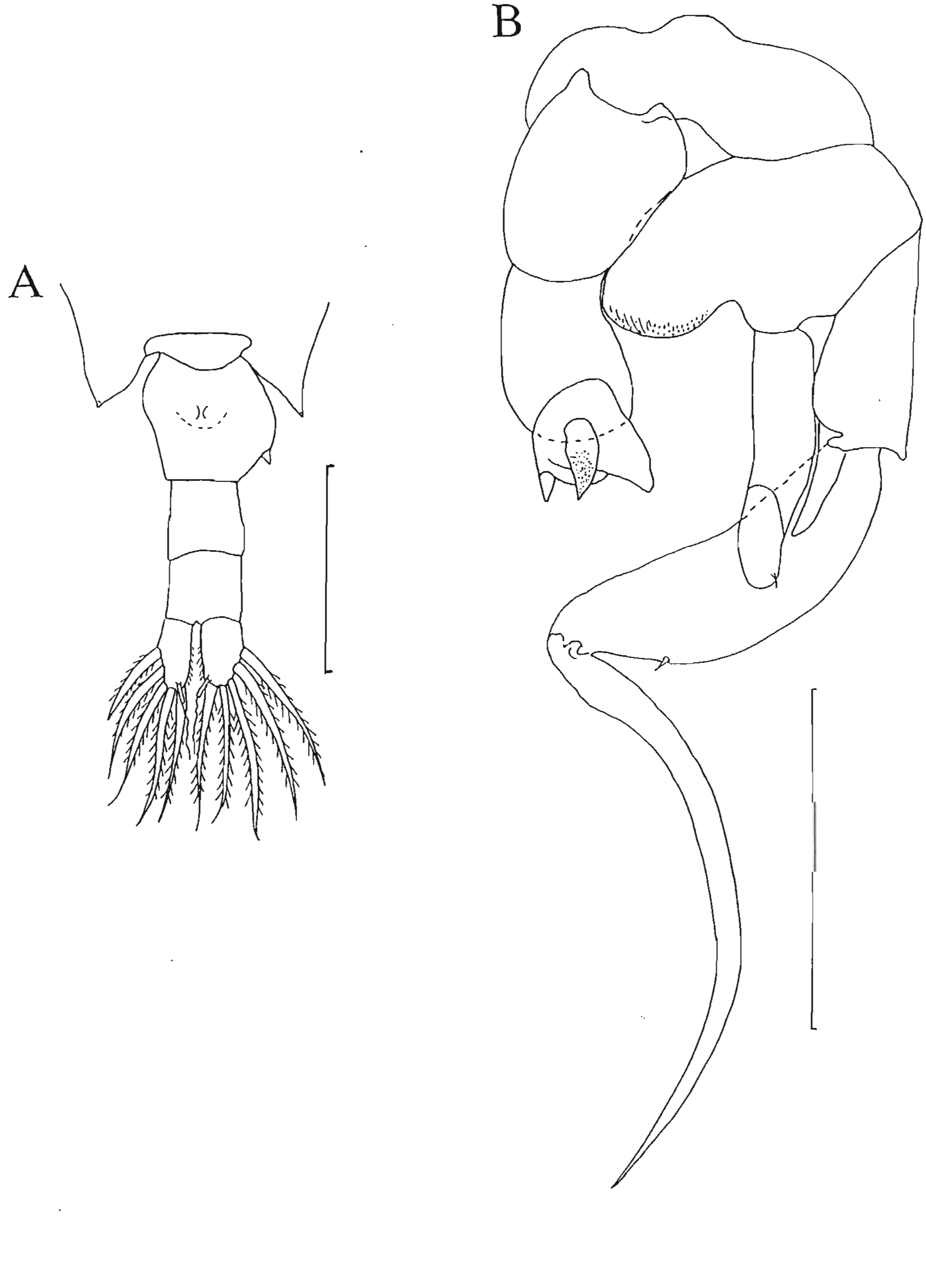
Metadiaptomus purcelli (Sars, 1907)

Diaptomus purcelli Sars, 1907: 12, pl. 2 (figs 3-10).

Diaptomus purcelli: Daday, 1910b: 118. Stebbing, 1910: 531. Tollinger, 1911: 57, fig. V1. Rühe, 1914: 8-9. Sars, 1927: 103, pl. 9 (figs 1-8).

Metadiaptomus purcelli: Kiefer, 1932a: 462, 490, 493 (fig. 31); Kiefer, 1934: 104-107, 135, 136 (figs 51-52), 185. Brehm, 1958: 32, 37. Harding & Smith, 1967: 520. Gardin-

Fig. 20. Metadiaptomus capensis. A. Adult female urosome, dorsal view. B. Adult male, P5, posterior view. Bar scale in mm. A=0.25. B=0.1.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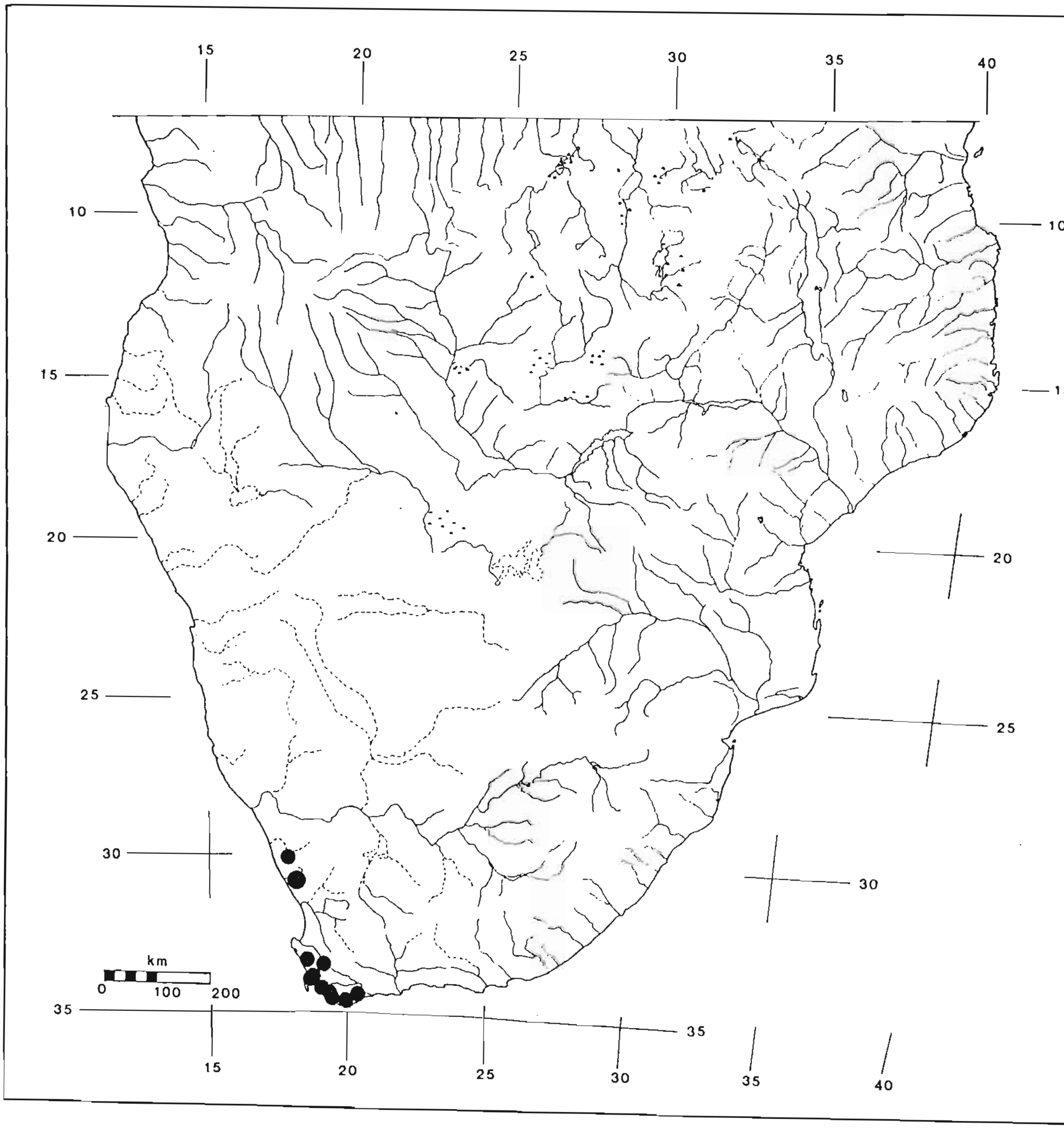


Fig. 21. Map of southern Africa showing distribution of <u>Metadiaptomus capensis</u>.

er, 1988: Ch. 9, p. 8. Dussart & Defaye, 1983: 57. Dussart, 1989a: 22-23, figs 15A & 68.

Paradiaptomus purcelli: Hutchinson et al., 1932: 84-89, 123, 150.

Material examined

SAM-12447, Cape flats, WFP, undated, labelled Diaptomus purcelli.

SAM-A11567-69, Cape of Good Hope, Sars' writing, undated, labelled D. purcelli.

SWT 3T, Stellenbosch-Cape Town road, Spoonbill pond, JAD, 09.10.79.

Gillidam, Groot Rondevlei, Groot Witvlei, 7 vials, AJCG, 1981.

SWTJ, Betty's Bay, temporary blackwater pool, 30 m diameter, JAD, 22.08.83.

SWT 14C, Cape Point Nature Reserve, 1 km S. Klaasjagersberg, temporary pool, JAD, 01.09.83.

G205/01A, Paardevlei, JMK, 17.12.84.

KR2, Kuilsrivier, JMK, 15.11.85.

Buffalo river, below Laing dam and below Bridledrift dam, R.W. Palmer, 13.06.86.

G203/01, Simonstown, Kleinplaats West, JMK, 22.12.87.

Palmiet river, Ariesdam, B. Byren, January & July 1988.

H101/03, Platdrif, JMK, 10.05.88.

G203/04, Groot Rondevlei, JMK, 27.01.88.

H101/01, Bokkekraal, WOR 378, JMK, 09.05.88.

H101/05, Verrekyker, Tulbagh, JMK, 11.05.88.

G203/12, Noordhoek soutpan, JMK, 15.06.88.

G203/13, Kenilworth Racecourse, pool, JMK, 13.07.88.

G501/14, Groot Hagel Kraal, JMK, 22.09.88.

H900/02, Gouriqua, JMK, 22.10.88

G501/08, Soetendalsvlei, JMK, 09.05.89.

E201/06, Driehoek, JMK, 27.05.89.

Characteristics

Measurements, Table 2.

Female

Small, robust; A1 with long seta on segment 1 (Fig. 22A), A1 extending to FR; dorsal expansion on AS (Fig. 22C); P5, Exp2 spiniform process with coarse denticles (Fig. 22B).

Male

Very small; A1 with long spiniform process on segment 13; B2 slightly expanded with fringe of spinules; right P5, Enp stout; Exp1 process well-developed with 'comma' shape; Exp2 lateral spine, short; left P5, Exp2 lateral spine, recurved (Fig. 22D).

Distribution

Fig. 23

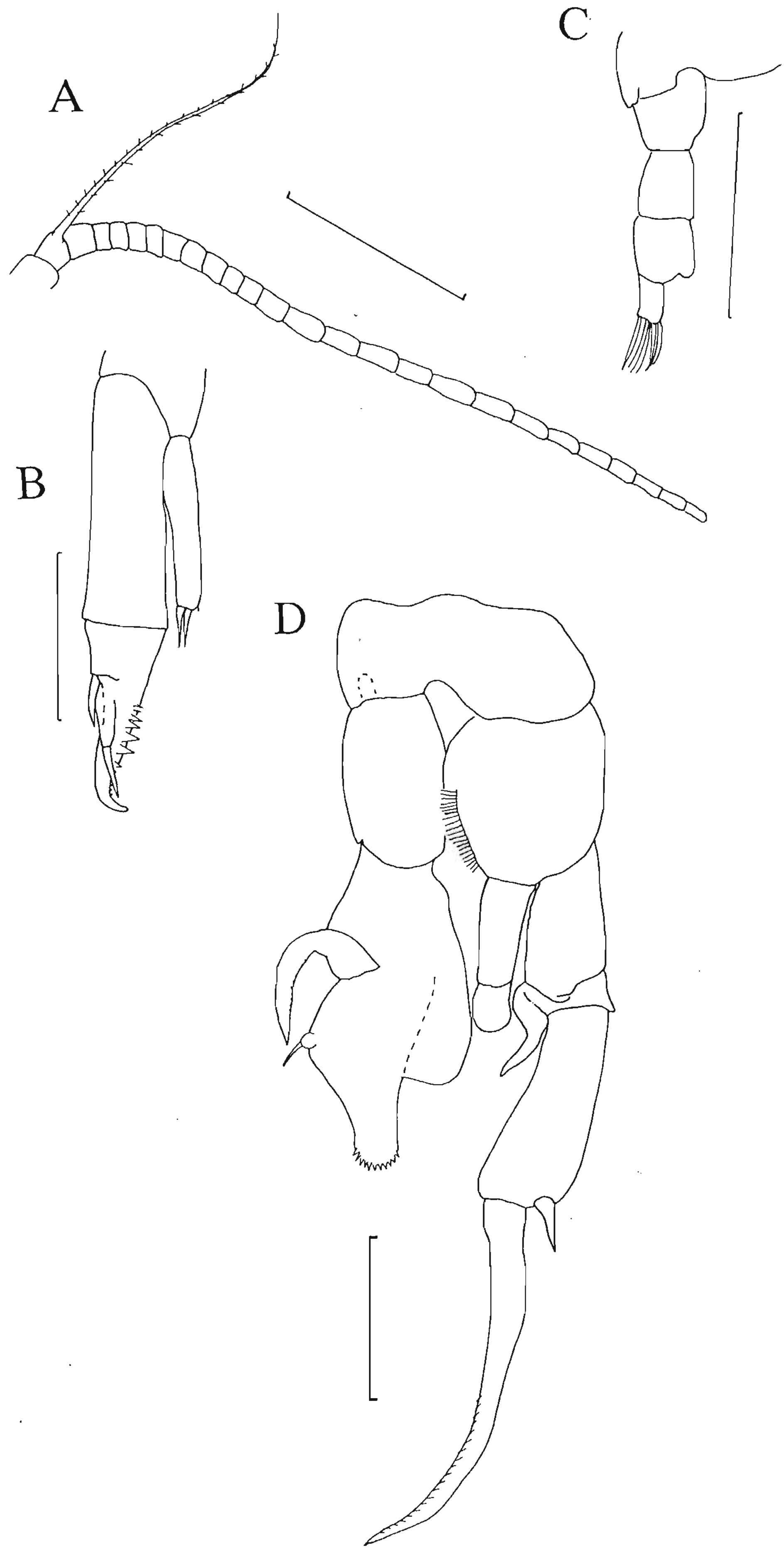
Co-occurrence with Lovenula simplex rare.

Metadiaptomus aethiopicus (Daday, 1908)

Diaptomus aethiopicus Daday, 1908: 49, 50 (fig. 26a-d). Daday, 1910b: 113, pl. 5 (figs 14-21, 26-27). Tollinger, 1911: 54, fig. Q1.

Diaptomus rehmanni Grochmalicki, 1913: 528, pl. 53 (fig.

Fig. 22. Metadiaptomus purcelli. Adult female: A. Antenna 1. B. P5. C. Urosome, lateral view. Adult male: D. P5. Bar scale in mm. A,C=0.25. B,D=0.05.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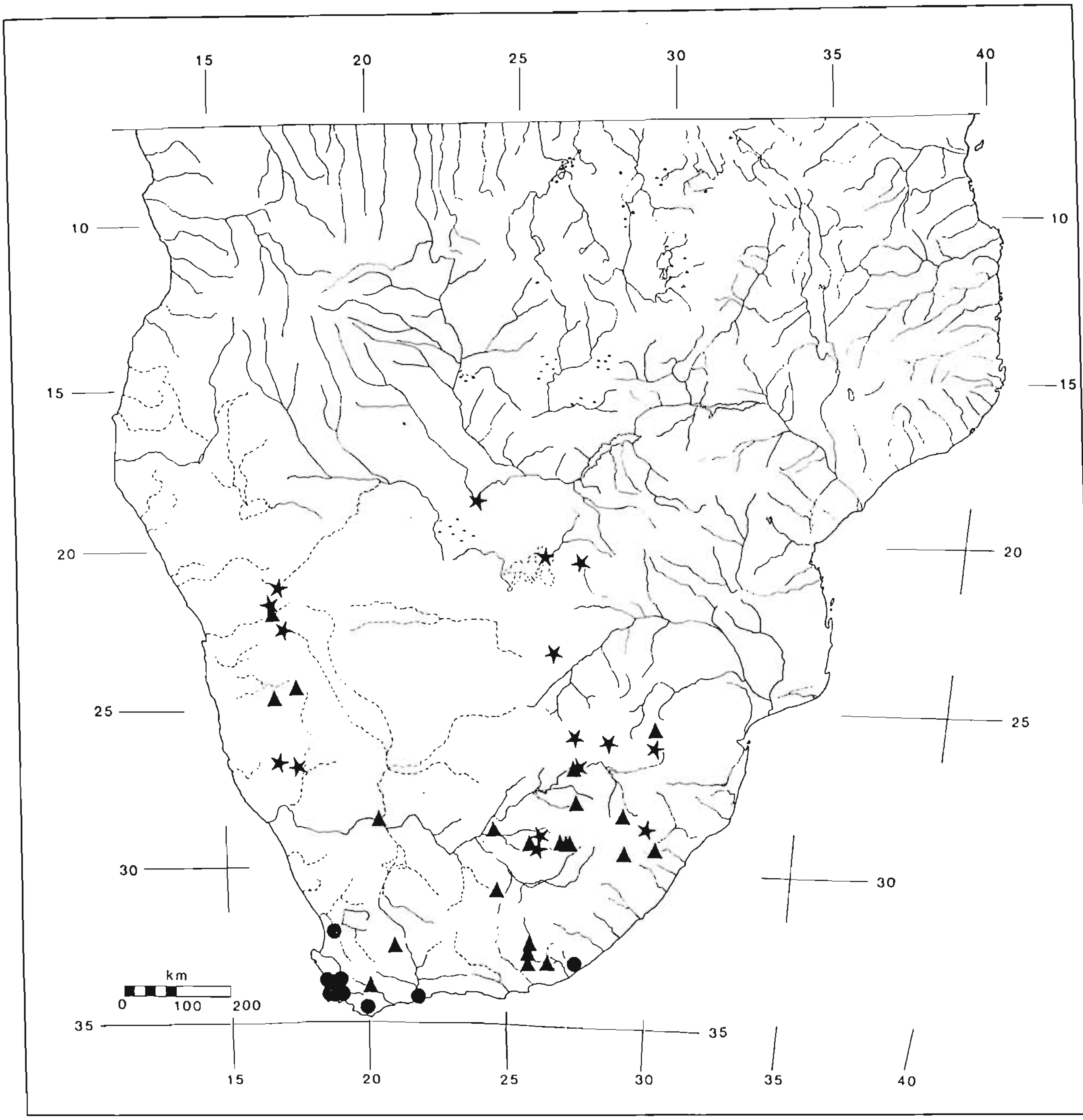


Fig. 23. Map of southern Africa showing distribution of ● <u>Metadiaptomus purcelli</u>, ▲ <u>M. meridianus</u>, ★ <u>M. colonialis</u>

5).

Paradiaptomus aethiopicus: Kiefer, 1930: 122.

Metadiaptomus aethiopicus: Kiefer, 1932a: 462, 490, 492 (figs 26-28); 1934: 135-138, 137 (figs 53-57). Lowndes, 1936: 11, figs 2c-k. Green, 1965: 388, 393-398; 1976: 433-435. Dussart, 1977: 829, fig 3(a-e). Dussart & Defaye, 1983: 58. Dussart, 1989a: 20-21, figs 13B, 66.

Material examined

BMNH-1939.4.18.267-276, Lake Bunyonyi, E.B. Worthington, 1936.

HMNH-III, Daday collection, Lake Rukwa-Ndjara, slide of female and male.

Distribution

East Africa

Metadiaptomus meridianus (Douwe, 1912)

Diaptomus meridianus Douwe, 1912b: 24, Pl. 4 (figs 15-19).

Diaptomus masculus Brady, 1913: 466, Pl. 35 (figs 2-6).

Diaptomus meridianus: Douwe, 1914: 95.

Diaptomus rigidus Sars, 1927: 101, Pl. 8 (figs 13-18).

Metadiaptomus meridianus: Kiefer, 1932a: 462, 490; 1934: 103, 106-7, 131-35 (figs 43-49), 185. Brehm, 1958: 32, 37. LaBarbera & Kilham, 1974: 461. Rayner, 1981: 88. Dussart & Defaye, 1983: 58. Hart, 1984; 1602-1607; 1985a: 151-178; 1985b: 17-26; 1986a: 351-371; 1986b: 401-426; 1987a: 67-82; 1987b: 579; 1987c: 287-318; 1988: 123-139. Dussart, 1989a: 23-24, figs 15B & 67.

Paradiaptomus rigidus: Hutchinson et al., 1932: 29-32, 82-95, 150.

Paradiaptomus meridianus: Kiefer, 1934: 103.

Metadiaptomus transvaalensis Harding & Smith, 1967: 520. King et al., 1986: 341-49 (misidentification).

Material examined

NM-uncatalogued, Van Reenen, sheep pond, E. Warren, 27.12.06.

SAM-A11588, Kimberley, J.H. Power, 01.06.12.

SAM-A11949, Kimberley, J.H. Power, September 1912.

SAM-A11570, Kimberley, J.H. Power, ca 1920, D. rigidus Sars' writing.

SAM-A11935, Kimberley, J.H. Power, undated.

SAM-A11579, Riemvasmaak, Molopo river, KHB, 1925.

SAM-A11589, Kimberley, J.H. Power, 30.03.31.

VAL 19A, Vaal river barrage, sandy mudbanks, FMC, 07.09.55.

VAL 563E, Vaal river catchment, stones-in-current, FMC, 14.10.58.

VAL 700A, Vaal river catchment, stones-in-current, FMC, 20.11.58.

VAL 665D, Vaal river catchment, stones-in-current, FMC, 09.12.58.

VAL 592D & VAL 595D, Vaal river catchment, marginal vegetation, FMC, 12.01.59.

VAL 661D, Vaal river catchment, stones-in-current, FMC, 14.01.59.

VAL 929J, Vaal river catchment, marginal vegetation, FMC, 22.09.59.

VAL 1157, Vaal river catchment, stony backwater, FMC, 08.08.60.

VAL 1381A, Vaal river catchment, marginal vegetation, FMC, 15.04.64.

RSU 6.6, Couran's drift, Sundays river, A.T. Forbes, 12.07.67.

Midmar dam, E.M. King, 02.06.81.

Mazelspoort dam, MTS, August 1981.

P.K. le Roux dam, R.C. Hart, 12.01.82.

SMN-50703 & SMN-50710, Van Rhijn dam, Namibia, S. Bethune, 27.04.82 & 14.08.82.

Greyvenstein dam, MTS, 05.03.84, 16.03.84, 23.03.84, 12.04.84, 25.05.84, 15.06.84, 17.08.84.

Tweespruit pan, MTS, 27.04.84.

Leeupan, MTS, 17.08.84.

SMN-50716-7, Hardap dam, no details.

GFR 11G, Witmos, J. O'Keeffe & F. de Moor, 19.02.85.

GFR 15F, Montague, J. O'Keeffe & F. de Moor, 19.02.85.

Sterkfontein dam, W. Dorgeloh, 13.03.85.

Grahamstown, quarry ponds, M. Aken, February 1986.

GFR, sites at Cookhouse, Dassiedeur, Drennan, railway bridge drift, R.W. Palmer, 20.01.86.

Buffalo river, Laing dam, R.W. Palmer, 13.06.86.

SMN-51338, Maltahohoe, rainwater pool, K. & S. Roberts, 12.03.88.

Sterkfontein dam, R.C. Hart, 17.01.89.

Nuweleeurivierdam, R.C. Hart, 18.01.89.

D560/02 A2, Sutherland, Quaggaplaat, JMK, 26.08.89.

Characteristics

Measurements, Table 2.

Female

TL, x1.5 TL male; A1 extending to mid-GS; Pdg5 wings symmetrical, not markedly extended; GS, AS and FR symmetrical; FS long; P5, Exp2 spiniform process long; Enp with long setae, 1/2 length Enp.

Male

Small; B2 very expanded with fringe of spinules and knobs; right P5, well-developed endopodite; Exp1 very small spiniform expansion on inner margin; left P5, Exp2 with long, curved spine, 3 characteristic processes, and larger, extended process with small spinules (Fig. 18B).

Distribution

Fig. 23

Metadiaptomus meridianus is widely distributed on the high plateau of southern Africa, and in East Africa. It often co-occurs with Lovenula falcifera (p. 41, Fig. 6).

Metadiaptomus colonialis (Douwe, 1914)

Diaptomus colonialis Douwe, 1914: 95-6, Pl. 3 (figs 1-11).

Paradiaptomus colonialis: Kiefer, 1928: 9-11, Figs 9-15. Hutchinson et al., 1932: 23-31, 61-89, 149.

Metadiaptomus colonialis: Kiefer, 1932a: 462, 490, 493 (fig. 30); 1934: 101-7, 139-141 (figs 59-67), 185. Brehm, 1958: 37. Löffler, 1961: 356 (Table 2). Harding & Smith, 1967: 520. Dussart & Defaye, 1983: 58. Defaye, 1988: 104 (Table 1), 115, 117 (figs 18-23), 145. Dussart, 1989a: 21-22, figs 14, 66.

Material examined

Type material in ZMUH

(i) **ZMUH-K8631 & ZMUH-K8896**, Farm Frauenstein, near Neudamm, 50 km ENE Windhoek, Namibia, M. Michaelsen, 13.05.11. Good specimens of M. colonialis and 3 male Lovenula falcifera.

(ii) **ZMUH-K8897**, Neudamm, 42 km ENE Windhoek, Namibia, W. Michaelsen, 10-15.05.1911, labelled D. colonialis Douwe, Typus, presented to ZMUH, 15.04.25. Paradiaptomus schultzei also in sample.

(iii) **ZMUH-K8895**, Farm Oujituezu, near Neudamm, 66 km NE Windhoek, Namibia, W. Michaelsen, 13.05.11, adult females and males of M. colonialis, one male L. falcifera.

(iv) **ZMUH-K14600**, Diaptomus colonialis Douwe, Cotypus; Kuibis, between Keetmanshoop & Luderitz on the Huibhoch plateau, Namibia, W. Michaelsen, 15.07.11, presented to ZMUH, 15.04.25. One damaged female, one male CV.

(v) **ZMUH-K14605**, Diaptomus colonialis Douwe, Cotypus; Seeheim, near Keetmanshoop, Namibia, W. Michaelsen, 19.07.11, presented to ZMUH, 15.04.25. Females and males, TL female: 1.48 mm, TL male: 1.24 mm, females with spermatophores attached to denticulate coupler on GS, no gravid females.

Other material examined

BMNH-1958.10.2.32, Plumtree, Zimbabwe, D.H. Eccles, February 1954.

VAL 559F, Vaal river catchment, 15.10.58.

VAL 714L, Vaal river catchment, oxbow, marginal vegetation, FMC, 18.11.58.

VAL 670B, Vaal river catchment, stones-in-current, FMC, 20.11.58.

VAL 701F, Vaal river catchment, marginal vegetation, FMC, 20.11.58.

VAL 679B, **VAL 684D**, Vaal river catchment, marginal vegetation, FMC, 08.12.58.

VAL 895M, Vaal river catchment, Ekman grab, FMC, 20.10.59.

VAL 932A, Vaal river catchment, marginal vegetation, FMC, 12.11.59.

Nooitgedacht dam, MTS, 13.09.73.

Buffelspoort dam, MTS, 27.06.75 & 07.01.76.

Lindleyspoort dam, MTS, 02.06.76.

Bronkhorstspruit dam, MTS, 15.12.77.

Olifantsnek dam, MTS, 22.12.77.

SMN-50748, Omataku dam, S. Bethune, 20.02.83.

Omataku dam, W.A. Smit, 07.02.84.

Von Bach dam, W.A. Smit, 06.12.84.

Zimbabwe, White Hill pan, near Hwange, AJCG, July, 1985.

Spioenkop dam, R.C. Hart, 09.09.87.

E. Chobe Game reserve, Nogatsaa waterhole, AJCG,

VAL 559F, Vaal river catchment, oxbow, FMC,

Sowa inflow, Sowa pan, Makgadikgadi, Botswana, R.C. Hart, 10.07.90, breeding population.

Characteristics

Measurements, see Table 2.

Female

TL, x1.3 TL male; A1 extending to end AS; Pdg5 wings and FR, symmetrical; GS with semi-circle of spines on right margin (Figs 24A, 24A1); GS length, slightly > length Ur2+AS; FS long; P5, Exp2 spiniform process, long; Enp, length 2/3 Exp1; setae, 1/2 length Enp.

Male

A1, with strong process on segment 13, last segment beaked (Fig. 24B); B2 strongly expanded, fringed with small knobs; right P5, Exp1 with well-developed inner process; Exp2 lateral spine, very small; Exp3 claw, long, semi-circular; left P5, Exp2 lateral spine small (Fig. 24C).

Distribution

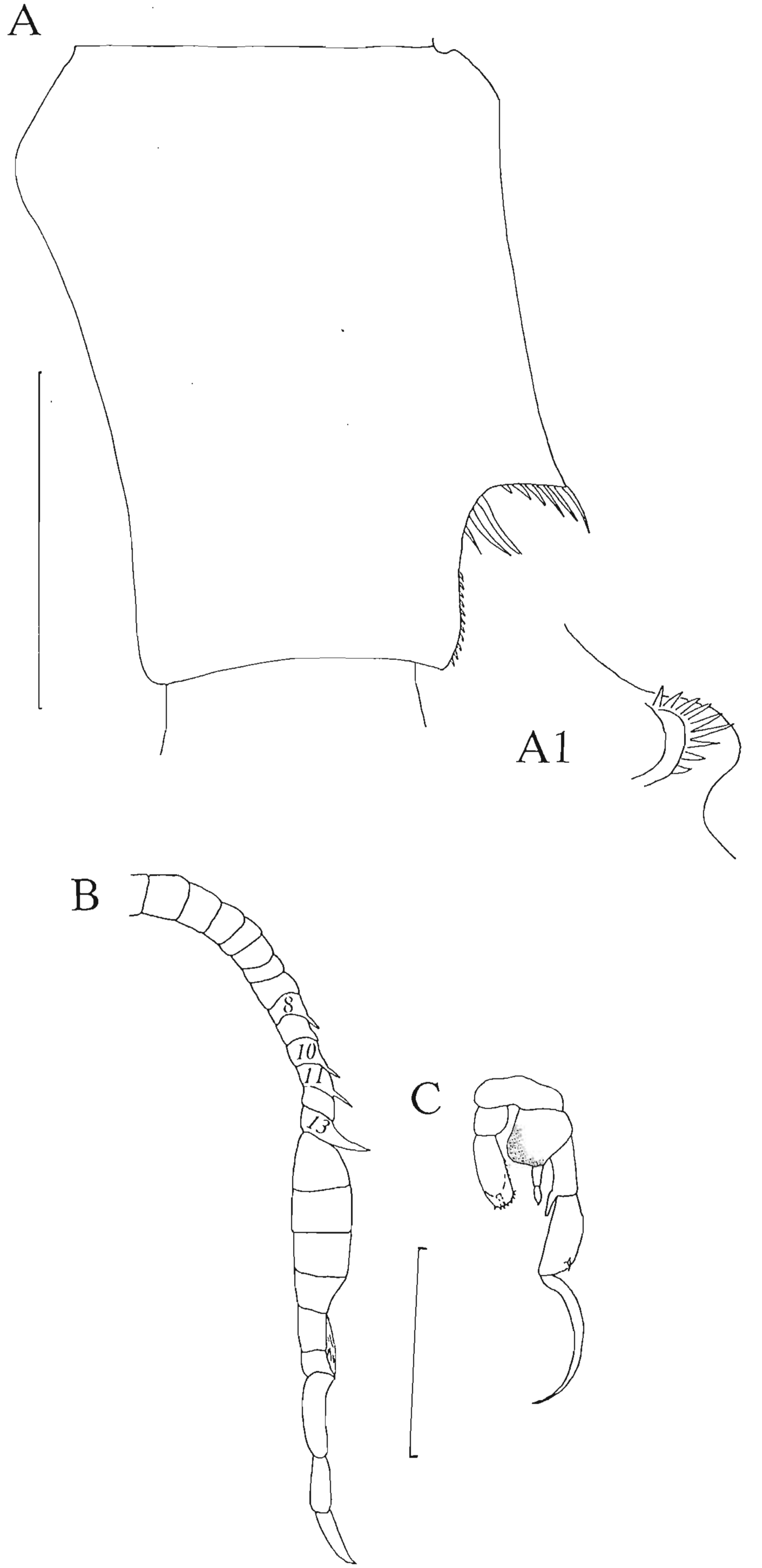
Fig. 23

Metadiaptomus colonialis has a wide ditribution from southern Africa to Ethiopia. It may co-occur with Lovenula falcifera (p. 41, Fig. 6).

Metadiaptomus mauretanicus Kiefer & Roy, 1942

Metadiaptomus mauretanicus Kiefer & Roy, 1942: 33-37, figs 1-11. Brehm, 1958: 37. Rzoska, 1961: 268. Kiefer, 1958: 159; 1978a: 73, 229 (Pl. 11); 1978b: 494. Dumont et al., 1981: 165, 180 (Fig. 13). Dussart & Defaye, 1983: 59. Dumont & Verheye, 1984: 319. Verheye & Dumont, 1984: figs 1a & b. Dussart, 1989a: 25-26, figs 16B & 67.

Fig. 24. <u>Metadiaptomus colonialis</u>. Adult female: A. Genital segment, dorsal view. A1. Detail of GS, spermatophore-coupler. Adult male: B. Right A1. C. P5. Bar scale in mm. A,A1=0.1. B,C=0.25.


A
A1
B
8
10
11
13
C

Distribution and comment

Metadiaptomus mauretanicus is a species of temporary waters, occurring in Mauretania, Algeria, Mali, Chad and Soudan (Dussart, 1989a). It shares some unusual characters with Metadiaptomus sp. nov. A (Leeupan) and the relationship of these two species, as well as M. chevreuxi, is of biogeographical and evolutionary interest because of their distribution and synapomorphies.

Metadiaptomus gauthieri Brehm, 1948

Metadiaptomus gauthieri Brehm, 1948:

Metadiaptomus gauthieri: Gauthier, 1951: 101, Pl. 26 (Figs A-H). Brehm, 1958: 37. Dussart & Defaye, 1983: 59. Dussart, 1989a: 26-28, figs 17 & 67.

Material examined

Locality (Fig. 27): Presumably Ovamboland, as the Museum number (**SAM-A11572**) is in the same series as K.H. Barnard's 1923, Ovamboland collection. Specimens are labelled Diaptomus No. 2, in Sars' writing, but with no other details.

Characteristics

Measurements, Table 2.

Female

Small, slightly longer than male; A1, long, extending to end of FR; Pdg5 wings expanded; GS symmetrical with 2 oval structures dorsally; Ur2 short; FR ovoid, with thickened FS arising symmetrically around FR (Fig. 25C); P5, Exp2 spiniform process, triangular, with coarse denticles; Exp3 spine nearly as long as spiniform process; Enp, 2 long setae, > 1/2 length Enp.

Male

TL < 1 mm; right A1 with strong broad-based spiniform process on segment 13; B2 strongly expanded, fringed with small spinules; right P5, Enp well-developed; Exp1, inner process well-developed; Exp3 claw long, exceeds combined length of right P5 and B2 (Fig. 25D).

Distribution and comment

Metadiaptomus gauthieri was described by Brehm (1948) from Madagascar, and again by Gauthier (1951) from Senegal. Gauthier was convinced that the Senegal species was identical to the Madagascar species, and this will have to be accepted until such time as types or new material can be compared. Characteristics of the species from Ovamboland (Namibia) agree perfectly with the description of Gauthier (1951). Another species to occur in both Namibia and Senegal is Paradiaptomus schultzei.

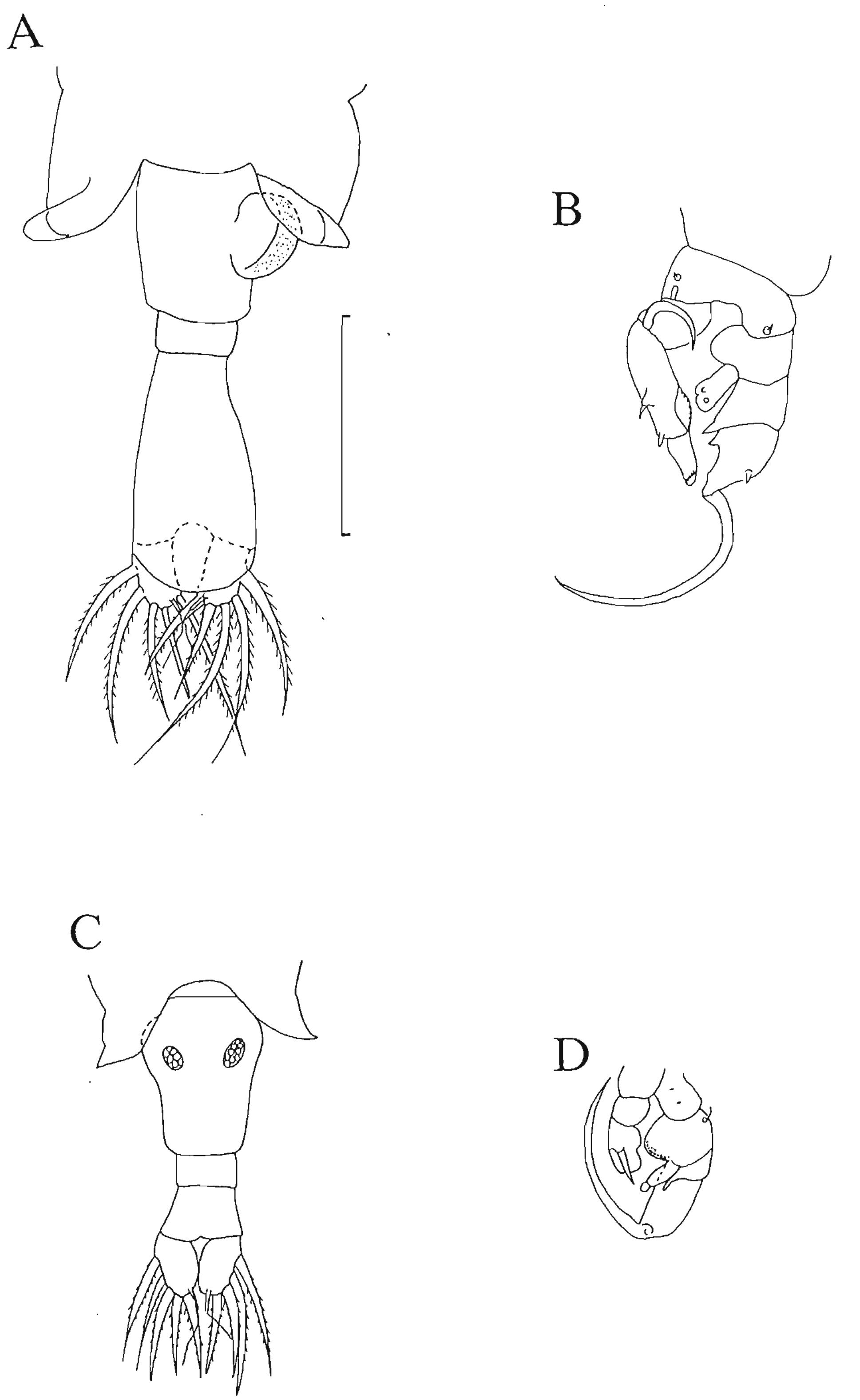
Incertae sedis - Metadiaptomus vandouwei (Kiefer, 1930)

Paradiaptomus vandouwei [sic] Kiefer, 1930:

Metadiaptomus vandouwei [sic]: Kiefer, 1932a: 462, 490, 493 (fig. 29); 1934: 138-9 (fig. 58). Brehm, 1958: 37. Dussart & Defaye, 1983: 58. Dussart, 1989a: 24-25, figs 16A & 68.

The name P. vandouwei was given to this species by Kiefer (1930) without any description. When reviewing

Fig. 25. <u>Metadiaptomus</u> sp. nov. A (Leeupan). A. Adult female urosome, dorsal view. B. Adult male P5, posterior view. <u>Metadiaptomus gauthieri</u> (Ovamboland). C. Adult female urosome, dorsal view. D. Adult male, P5, posterior view. Bar scale, 0.25 mm.


A
B
C
D

material of M. aethiopicus from East Africa, Kiefer had found material from South Africa in the Berlin Museum, containing female diaptomids which he considered to be similar to the female of M. aethiopicus but the thoracic wings were less extended and the genital somite more symmetrical (Kiefer, 1934). He was correct in not assigning these females to M. aethiopicus, but it is difficult to judge their true status. Metadiaptomus vandouwei has been recorded without any additional information in subsequent publications, and diagrams purported to be of M. vandouwei (Dussart, 1989a) appear to be a combination of Kiefer's (1934) vandouwei female urosome and Daday's (1910b) M. aethiopicus. Until more information is available (possibly from the Berlin Museum), M. vandouwei must remain incertae sedis.

NEW SPECIES

Metadiaptomus nov. sp. A

Locality (Fig. 27): Leeupan, OFS, 29°09' S; 25°43'E., salt pan, alt. 1362 m, area 10 ha (FSL), depth 0.9 m (FSL), conductivity range 775-7040 uS/cm; turbidity range 4-2750 JTU; water temperature range 4-25° C. Collector M.T. Seaman. Adult females and males collected on 04.05.84, 08.06.84, 22.06.84, 19.07.84, 17.08.84.

Characteristics

Measurements, Table 2.

Female

TL, x1.3 TL male; A1 extending to posterior border Pr;

Pdg5 wings lobed; GS with rounded process on right margin; very short Ur2; AS very long, expanded distally (observed `as a spermatophore-coupler); FR short, set apart; FS long, as a rosette (Fig. 25A); P5, Enp short, rotund, setae more than 1/2 length Enp; Exp2 spiniform process, triangular, Exp3 outer spine, 2/3 length Exp2 spiniform process.

Male

Right P5, Enp short, rotund; Exp1 with small, triangular inner process, Exp2 short, small lateral spine; Exp3 claw, long, bow-shaped; left P5, long, extending to end right P5, Exp2; Exp1 with long recurved spine.

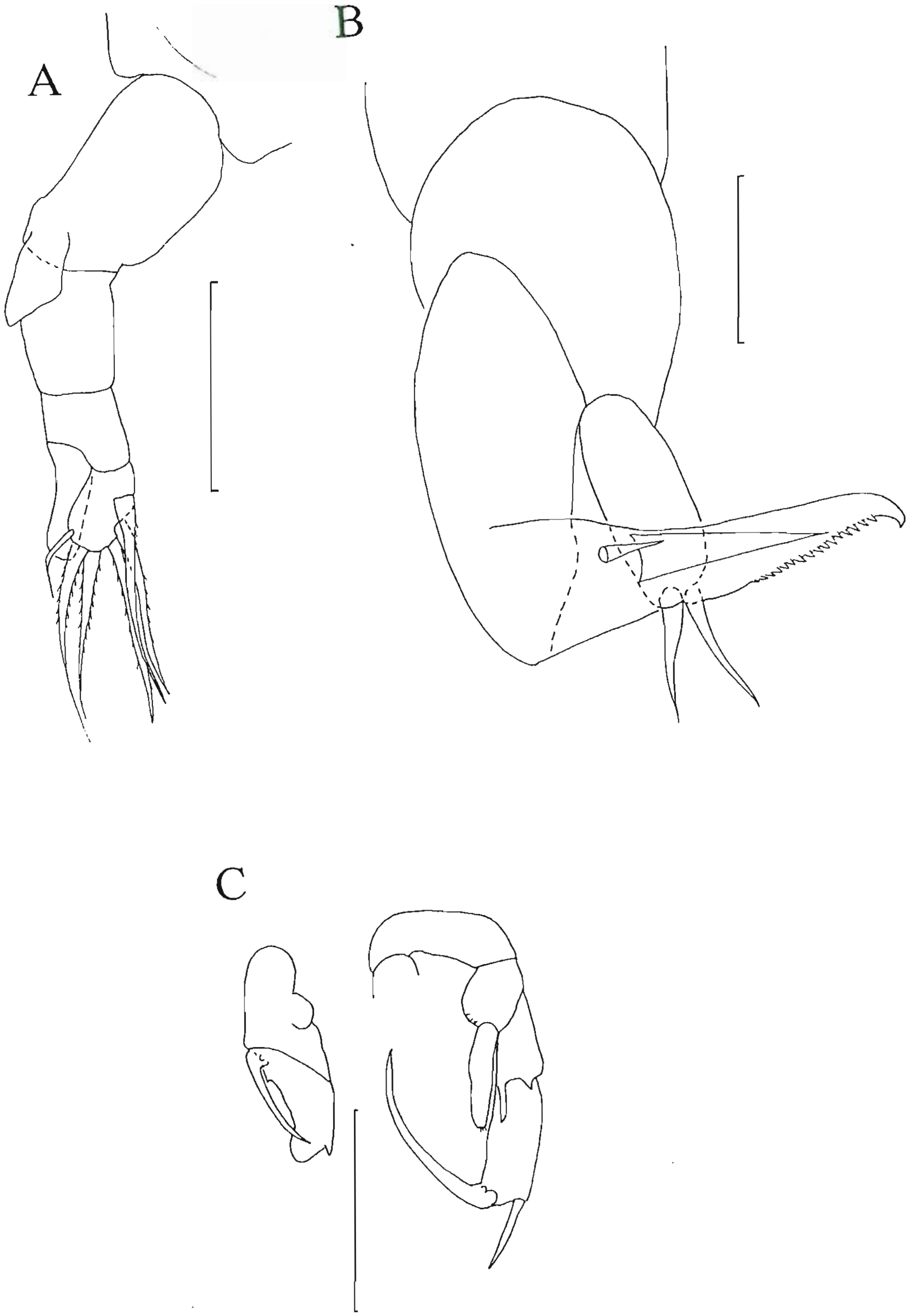
Remarks

Metadiaptomus sp. nov. A shares unusual apomorphic characters with *M. chevreuxi* and *M. mauretanicus*, two species which are geographically widely separated from it. In the female, the round lateral expansion of the genital somite (Fig. 25A) also occurs in *M. chevreuxi*, while the distally expanded anal somite is found in *M. mauretanicus*. In the male, the long left fifth leg is similar to that of *M. mauretanicus* and the short, rotund endopodite of the right leg, is not unlike that of *M. chevreuxi*. The evolutionary implications of these synapomorphies are of considerable interest.

Metadiaptomus sp. nov. B

Locality (Fig. 27): King William's Town, Gate. Collector K.H.Barnard, 15.01.35. Mus. No. SAM-A11908.

Fig. 26. Metadiaptomus sp. nov. B (King Williams Town). A. Adult female urosome, dorso-lateral view. B. Adult female P5. C. Adult male P5, left and right leg, posterior view, Bar scale in mm. A,C=0.25. B=0.05.


A
B
C

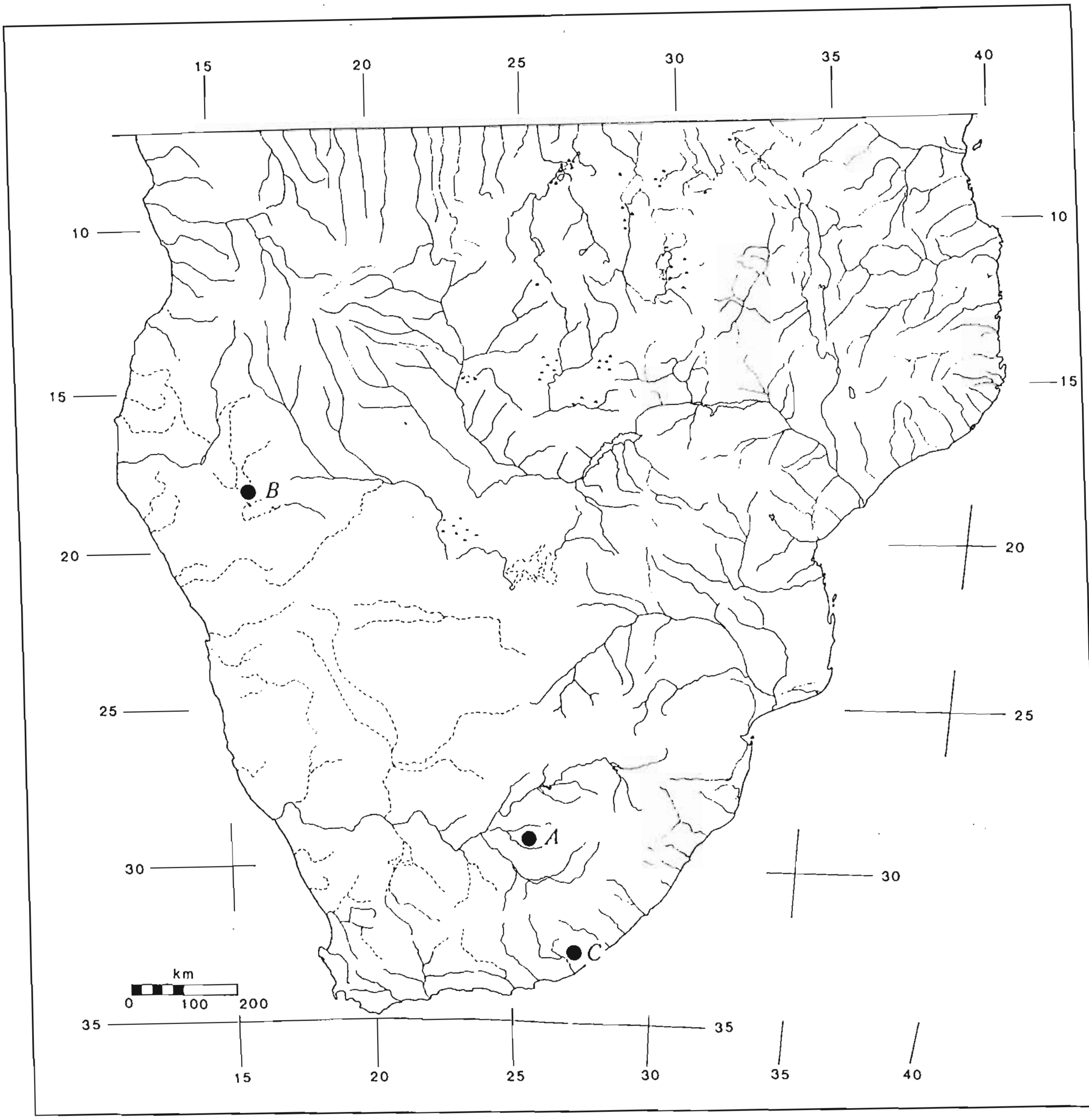


Fig. 27. Map of southern Africa showing localities of A. Metadiaptomus sp. nov. A (Leeupan); B. Metadiaptomus gauthieri (Ovamboland); C. Metadiaptomus sp. nov. B (King Williams Town).

Characteristics

Measurements, Table 2. Material in poor condition.

Female

A1 probably to end GS; keel on distal border of GS; FS long, with thick bases (Fig. 26A); P5, with short, rotund Enp, long setae; Exp2 spiniform process, coarse denticles, curved distally (Fig. 26B).

Male

B2, slightly expanded, fringed with a few small spinules; right P5, Enp broad, long; Exp1 with well-developed inner process; Exp2 lateral spine, slender, 1/4 Exp3 claw; left P5, Exp2 spine long, slender (Fig. 26C).

KEY TO THE AFRICAN SPECIES OF METADIAPTOMUS

Females

1 Genital somite asymmetrical............................2

1' Genital somite almost symmetrical, unadorned..........
....6

2 GS with expansion on right side.......................3

2' GS with dorsal keel on distal margin (Fig. 26A).......
......................*Metadiaptomus* sp. nov. B (KWT)

3 GS with large round expansion on right side......
....4

3' GS with spine, or half-circle of spines on right side
....5

4 AS not expanded, FR asymmetrical.........*M. chevreuxi*

4' AS with dorsal, distal expansion, FR symmetrical (Fig. 25A).........*Metadiaptomus* sp. nov. A (Leeupan)

5 GS with single spine on right side (Fig. 20A)........
....*M. capensis*

5' GS with half-circle of spines on right side (Fig. 24A, 24A1)...............................*M. colonialis*

6 GS symmetrical..7

6' GS with minor asymmetrical expansions...............8

7 TL, female:male, 2:1; Pdg5 wings markedly expanded posteriorly........................*M. transvaalensis*

7' TL, female:male, 1.5:1; Pdg5 wings not markedly expanded...............................*M. meridianus*

8 TL ca 1 mm,
A1, segment 1, with long seta (Fig. 22A)...........
....*M. purcelli*

8' TL > 1 mm,
A1 without seta................................9

9 GS with dorsal, distal expansion.....*M. mauretanicus*

9' GS without dorsal expansion.....................10

10 Pdg5 wings, symmetrical, curved outwards, one spine each wing (Fig. 25C)...................*M. gauthieri*

10' Pdg5 wings, asymmetrical, with multiple spines, both wings..............................*M. aethiopicus*

Males

1 TL > 2 mm,
Left P5, large, extending to mid Exp3 claw of right P5.....................................*M. chevreuxi*

1' TL < 2 mm,
Left P5, not extending beyond end of Exp2 of right P5...2

2 Right P5, Exp2 lateral spine very small or absent..3

2' Right P5, Exp2 lateral spine, well-developed......6

3 Right P5, Enp large, rotund,
Right P5, Exp2 reduced,
Left P5 extending to end right P5, Exp2 (Fig. 25B)..
..................*Metadiaptomus* sp. nov. A (Leeupan)

3' Right P5, Enp elongated,
Right P5, Exp2 not modified,
Left P5 extending to end right P5, Exp1............4

4 B2 markedly expanded medially,
Enp large (Fig. 20B)....................*M. capensis*

4' B2 not markedly expanded,
Enp moderate size...............................5

5 Left P5, Exp2, medial spine short, stout (Fig. 24C).
...................................*M. colonialis*

5' Left P5, Exp2, medial spine 1/2 length Exp2 (Fig. 25D)..............................*M. gauthieri*

6 B2 markedly expanded...........................7

6' B2 not markedly expanded.......................9

7 Right P5, Exp1 inner process well-developed ....
...................................*M. aethiopicus*

7' Right P5, Exp1 inner process reduced.............8

8 Right P5, Exp1 inner process triangular,
B2 fringed with long spinules,
Enp, slender with Enp2, ovoid (Fig. 18A)............
................................*M. transvaalensis*

8' Right P5, Exp1 inner process very small, B2 fringed with short spinules, small knobs,

Enp, stout (Fig. 18B)..................*M*. *meridianus*

9 B2 fringed with setae,

Right P5, Exp1 inner process, 'comma' shaped (Fig. 22D)...................................*M*. *purcelli*

9' B2 without setae,

Right P5, Exp1 inner process straight.............10

10 Right P5, Enp long, extending to mid Exp2,

Right P5, Exp3 claw, curved uniformly (Fig. 26C)........................... *Metadiaptomus* sp. nov. B (KWT)

10' Right P5, Enp extending to end Exp1,

Right P5, Exp3 claw, straight, curved distally..*M*. *mauretanicus*

CHAPTER 7

GENUS TROPODIAPTOMUS Kiefer, 1932

Note: This is not a revision of the genus. The five new species will be described to publication standards at a later date.

There are more than thirty described Tropodiaptomus species in Africa, three of these from southern Africa. A number of these species have been described and figured superficially and are subject to controversy (Verheye & Dumont, 1984). The genus is known from other parts of the world. The confusion over the non-African type species, Tropodiaptomus orientalis, was resolved by a redescription by Dussart et al. (1984) and Dussart (1989b). Brady (1908), who originally desribed Diaptomus orientalis from Sri Lanka (Brady, 1886), also recorded D. orientalis from Richmond, Natal. No illustations were included in Brady (1908), but examination of this material (BMNH-1951.8.10.476/7), confirmed the species as T. spectabilis. Research on the species of Tropodiaptomus in Africa is being continued actively by Dumont & Maas (1987, 1989, 1989), Verheye & Dumont (1984) and Defaye (1988). Speciation has taken place all through the warmer regions of Africa and there are probably many more species of Tropodiaptomus to be described, especially from areas which have been poorly collected. Of nine Tropodiaptomus species from East Africa and the Rift valley lakes, Dumont & Maas (1988) reported that most had restricted ranges and were often limited to one or two lakes. They noted that a few species were ill-described or in need of redescription. The number of endemic species in these lakes suggests a comparatively recent speciation. Over the years, many species were identified as *Tropodiaptomus kraepilini* before the extent of tropodiaptomid speciation was realised. This was particularly so in South Africa, where there are a number of closely related species which are very similar to *Tropodiaptomus kraepilini*. Differentiation of species in the *kraepilini*-complex is related mainly to morphology of the male P5 and endopodite of the female P5. Dumont & Maas (1988) listed a suite of reliable characters for *Tropodiaptomus* species' identification.

Tropodiaptomus Kiefer, 1932

Tropodiaptomus Kiefer, 1932a: 466.

Tropodiaptomus: Kiefer, 1934: 141. Defaye, 1988: 106. Dussart, 1989: 69-73.

Characteristics of the genus

In both males and females, total length rarely exceeds 2 mm.

Female:

Urosome with 2 somites (Fig. 31A); GS long; A1 long, extending to AS or FR; Pdg5 left wing expanded and squared-off (Fig. 33A); P5, Enp1 with one apical, 1 subapical seta (Fig. 28B).

Male:

A1 with 22 segments, 4 of which are post-geniculate, spiniform processes on segments 10, 11, 13, 15; right P5, Exp2 may have a second lateral spine or rounded process (Fig. 31C); left P5 Exp2 without spine, inner margin circular and denticulate, apical seta with fine terminal setules (Fig. 29).

Tropodiaptomus orientalis (Brady, 1886) - type species

Diaptomus orientalis Brady, 1886: 296, pl. 37 (figs 21-26), from Ceylon. "NON Sars, 1889: 59-68, pl. 7 (figs 12-16), pl. 8 (figs 1-4), from Australia".

The type species was redescribed by Dussart et al. (1984) and Dussart (1989b). Dumont & Maas (1987) mentioned a T. orientalis species group, and an ill-defined East African T. cf. orientalis. Verheye & Dumont (1984) and Dumont & Maas (1988) also recorded T. cf. orientalis from Africa.

The following old references to Diaptomus orientalis from Africa should be attributed to other Tropodiaptomus species: Stebbing, 1910: 531; Gurney, 1906: 131-2, table 1; Brady, 1908, 184; Kiefer, 1930: 120-122, figs 6-9; 1932a: 499, figs 53, 53a; Abu Gideiri, 1969: 372, 377.

Tropodiaptomus kraepilini (Poppe & Mrázek, 1895)

Diaptomus kraepilini Poppe & Mrázek, 1895: 129, pl. 1 (fig. 10), pl. 2 (figs 1-4).

Diaptomus kraepilini: Daday, 1908: 48; 1910b: 113. Tollinger, 1911: 46, fig. H1. Douwe, 1912b: 31. Cunnington, 1920: 559. Lowndes, 1930: 165, pl. 2 (figs 1-4), pl. 3

(figs 9-15). Pesta, 1937: 158.

Tropodiaptomus kraepilini: Kiefer 1932a: 467, 495, 499 (fig. 52); 1934: 106, 141-145, 142 (figs 68-72), 143 (fig. 73). Harding, 1942: 180. Fryer, 1957: 67-68. Brehm, 1958: 38. Abu Gideiri, 1969: 372, 377. Colvin, 1971: 41-65. Einsle, 1971: 23, fig. 1. Dussart & Defaye, 1983: 108. Verheye & Dumont, 1984: 202, fig. 10. Defaye, 1988: 106, 119 (figs 26-30). Dumont & Maas, 1987: 12, fig. 47; 1988: 419, fig. 1. Dussart, 1989a: 74, figs 1, 41, 78.

Historical

Type locality: Zanzibar, near Kibueni and Massingini.

Tropodiaptomus kraepilini has not been recorded from southern Africa, although the majority of species belong to the kraepilini species-complex. Tropodiaptomus kraepilini from the Linyante river, Botswana (Kiefer, 1934) is almost certainly not the species of Poppe & Mrazek (1895) but another species in the kraepilini species-complex.

Tropodiaptomus neumanni (Douwe, 1912)

Diaptomus neumanni Douwe, 1912a: 4, pl. 1 (figs 6-12).

Diaptomus neumanni: Lowndes, 1935: 308; 1936: 12, fig. 2L.

Tropodiaptomus neumanni: Kiefer, 1932a: 498; 1934: 185. Dussart & Defaye, 1983: 109. Verheye & Dumont, 1988: 210, fig. 14. Dussart, 1989b: 80, figs 44B, 81.

Distribution:

Lake Baringo, Lake Naivasha, Rift valley, Kenya highlands. Not recorded from southern Africa.

Tropodiaptomus schmeili (Kiefer, 1926)

Diaptomus schmeili Kiefer, 1926: 262-3, fig. 1a-c.

Tropodiaptomus schmeili: Kiefer, 1932a: 467, 498, 501 (fig. 59). Dussart & Defaye, 1983: 110. Dussart, 1989a: 84-85, figs 45B, 81.

Material examined

SMN-51302, Makuri, Bushmanland, Breeding population, B.A. Curtis, 13.03.88.

BMNH-1958.10.2.28, Plumtree, Zimbabwe, temporary pool, D.H. Eccles, Feb., 1954 (FWSR 10/15L). Wet specimens and 24 microscope slides, labelled T. spectabilis.

ZMUH-Type K8461, Diaptomus schmeili Kiefer, wet specimen, male. Locality: Susserwasserloch Kalkboden, Farm Neitsas, Grootfontein district, Namibia. Dr. med. G. Foch leg. 1907, det 20.11.1908. The type material was 19 years old when described by Kiefer and the male type specimen had dried up at some stage. There were no females in the type material, but females in SMN-51302, Bushmanland, are in perfect agreement with Kiefer (1926). The large size and unusual characters (Figs 28A, 28B, 29), allow easy identification of this species.

Characteristics

Female: TL: 2.34 mm; A1 extending to end of AS; Pdg5 wings asymmetrical, with spine on each wing; GS long, asymmetrical, with spine on each lateral margin; AS shorter than FR; Left FR longer and broader than right FR; setae on inner

Fig. 28. _Tropodiaptomus schmeili_. Adult female: A. Urosome, dorsal view; B. P5. Bar scale in mm. A=0.25. B=0.1.

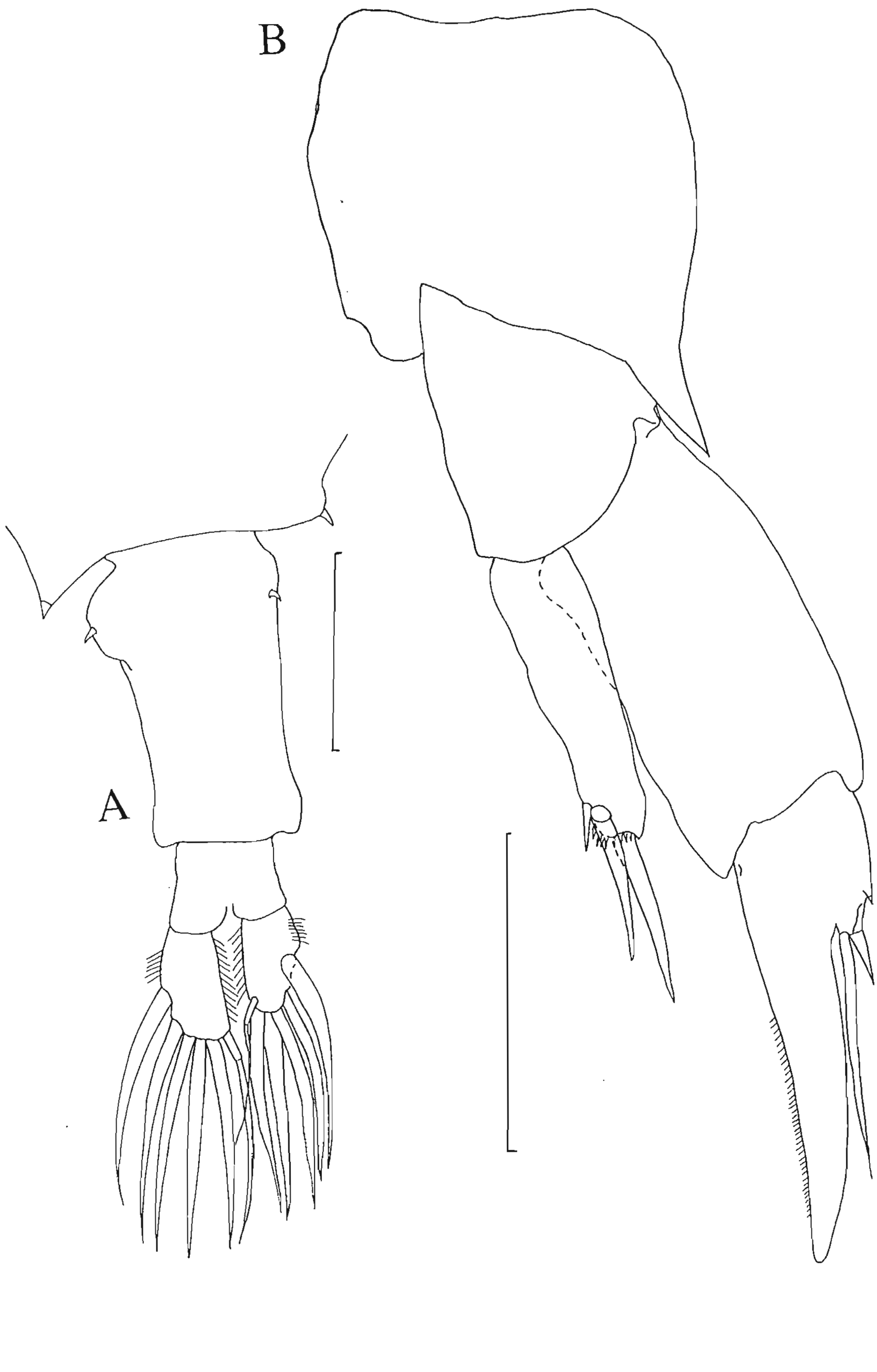
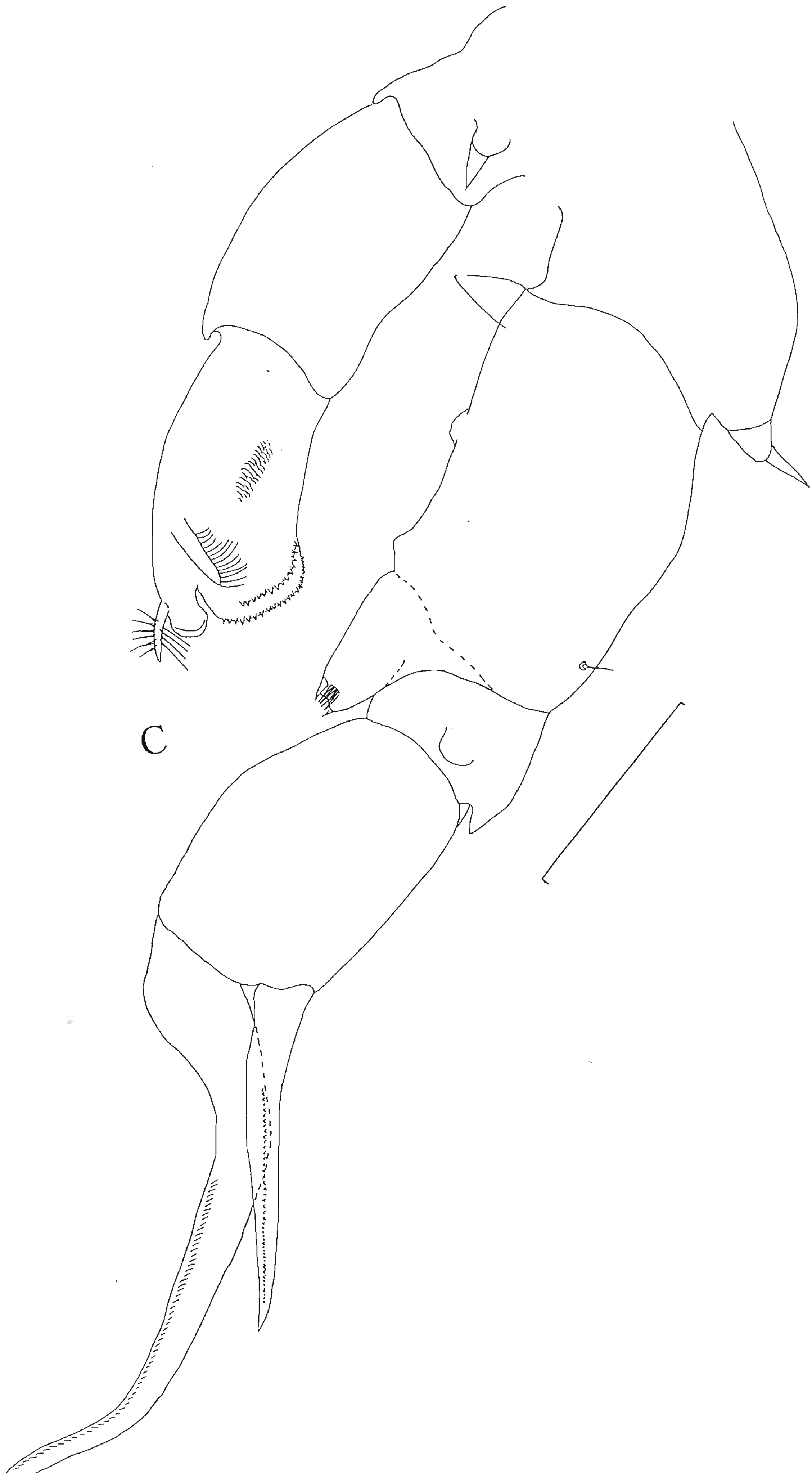

B
A

Fig. 29. Tropodiaptomus schmeili. Adult male P5, posterior view. Bar scale, 0.1 mm.


C

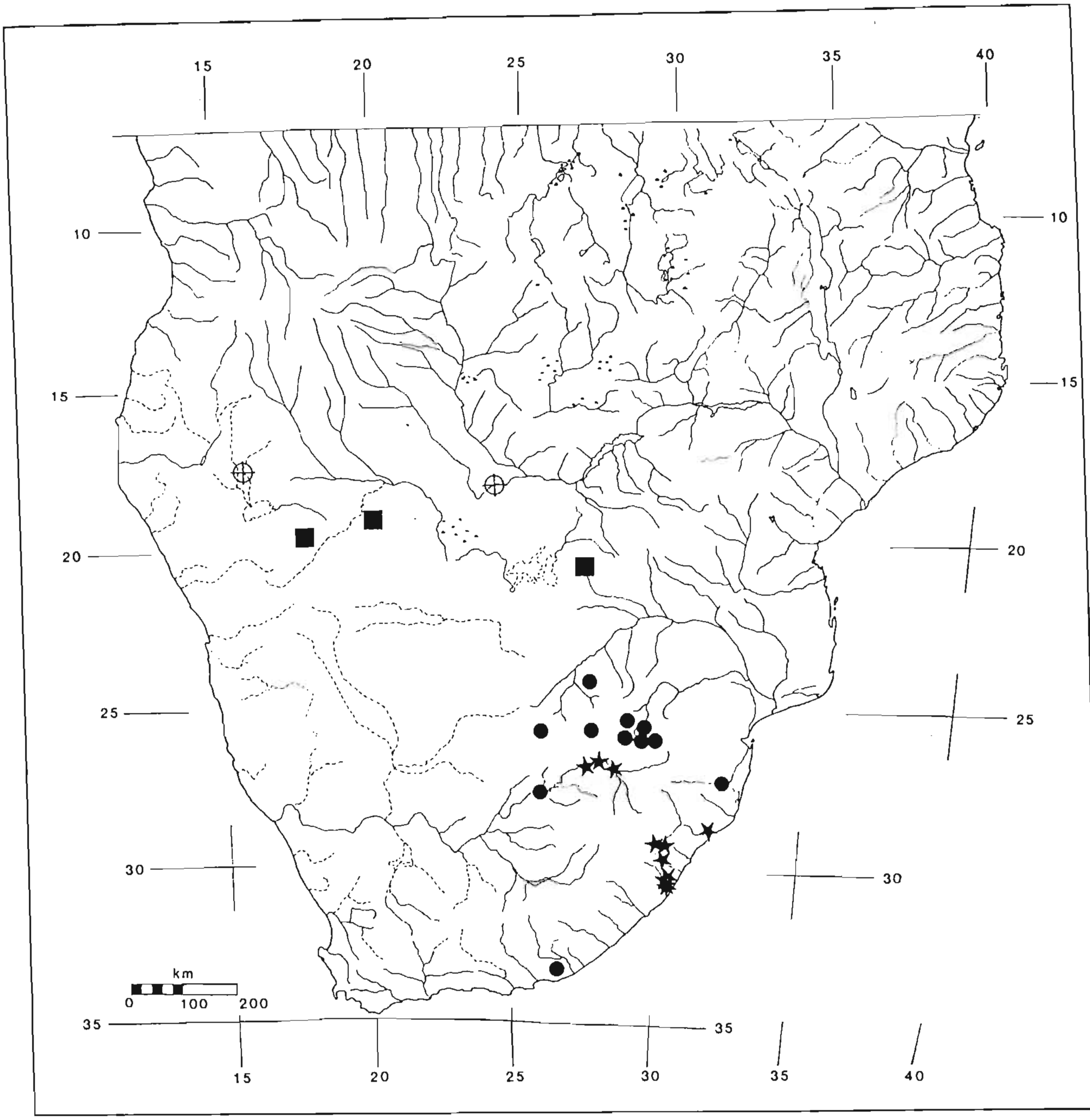


Fig. 30. Map of southern Africa showing distribution of ■ <u>Tropodiaptomus schmeili</u>, ★ <u>Tropodiaptomus spectabilis</u>, ⊕ <u>Thermodiaptomus congruens</u>, ● <u>Thermodiaptomus syngenes</u>.

and outer margins of both FR; FS long; dorsal seta on left FR long and enlarged (Fig. 28A); P5 (Fig. 28B); 2 egg sacs: 13, 11 eggs.

Male:

TL: Typus: 1.81 mm (shrunken); Makuri: 2.16 mm; P5 (Fig. 29).

Distribution

Namibia, Zimbabwe (Fig. 30).

Tropodiaptomus hutchinsoni (Kiefer, 1928)

Diaptomus hutchinsoni Kiefer, 1928: 11-12, figs 16-19.

Tropodiaptomus hutchinsoni: Kiefer, 1932a: 467, 500, 503 (fig. 60); 1934: 106, 145-147, 146 (figs 74-80), 147 (fig. 81). Dussart & Defaye, 1983: 110. Dussart, 1989a: 85-86, figs 47B, 84.

This species (type locality: Linyante river, Botswana) has not been recorded since it was collected in 1928 (Hutchinson et al., 1932).

Tropodiaptomus spectabilis (Kiefer, 1929)

Diaptomus orientalis: Brady, 1908: 184.

Diaptomus fuscatus Brady, 1913: 465, pl. 34 (figs 7-10), pl. 35 (fig. 1).

Diaptomus spectabilis Kiefer, 1929: 311-313, figs 5-6.

Diaptomus spectabilis: Hutchinson et al., 1932: 42, 46, 51-2, 95, 150.

Tropodiaptomus spectabilis: Kiefer, 1932a: 467, 498, 499 (figs 54-55); 1934: 106, 148, 149 (figs 82-88). Oliff, 1960: 372. Harding & Smith, 1967: 520. Colvin, 1971: 83. Rayner, 1981: 145-153, pl. 5 (figs a-d), pl. 6 (figs a-c). Dussart & Defaye, 1983: 110. King et al., 1986: 837-840, figs 3-4. Rayner & King, 1986: 837-840, figs 1-3. Rayner, 1988: 75. Dussart, 1989a: 87-88, figs 48B, 80.

The use of spectabilis contradicts the provisions of the ICZN as fuscatus takes priority. As the name has been used for 60 years, an application will be made to the Commission of Zoological Nomenclature to suppress fuscatus in terms of Articles 23 & 79, so that current usage of spectabilis is thus maintained.

Material examined

BMNH-1951.8.10.456 & **BMNH-1951.8.10.457**, slides, female and male types of Diaptomus fuscatus Brady, 1913, material remounted by BMNH in 1988; locality, Nkwifa (Equeefa), inland from Kelso, Natal. Female fragmented, male A1 and P5, perfect agreement with T. spectabilis (Kiefer, 1929) (Fig. 31D).

BMNH-1951.8.10.476 & **BMNH-1951.8.10.477**, slides, male and female of Diaptomus orientalis (Brady, 1908). These specimens were collected by J. Gibson from Somkala & Richmond, Natal, South Africa. Male A1 & P5 identical to T. spectabilis, a species known from the area. Tropodiaptomus orientalis Brady, 1886, does not occur in Africa (Dussart et al., 1984; Dussart, 1989b).

AM-VAL 681J, Vaal river catchment, oxbow, marg. veg., FMC, 09.12.58.

AM-VAL 614F, Vaal river catchment, Station VD8, marg. veg., FMC, 14.01.59.

AM-VAL 548S, Vaal river catchment, Station VD11a, FMC, 14.10.59.

Midmar dam, N.A. Rayner, 1977-1979.

Midmar dam, E.M. King, 21.04.81.

Vernon Crookes' Nature Reserve dam, J. Heeg, September 1984 & 1985.

Midmar dam, R.C. Hart, 22.03.88.

Albert Falls' dam, R.C. Hart, 22.01.89.

Wagendrift dam, R.C. Hart, 24.03.89.

Nagle dam hatcheries, R.C. Hart, 23.05.89.

Richards' Bay, Umhlatuze canal, Barringtonia swamp, P. Reavell, 08.07.89.

Characterisitics

Measurements (mm): **AM-VAL 614F:** TL: Female: 1.55, male 1.39. **Wagendrift dam** (24.03.89): TL: Female: 1.68, male 1.48. **Albert Falls dam** (22.01.89): TL: Female: 1.51, male 1.40.

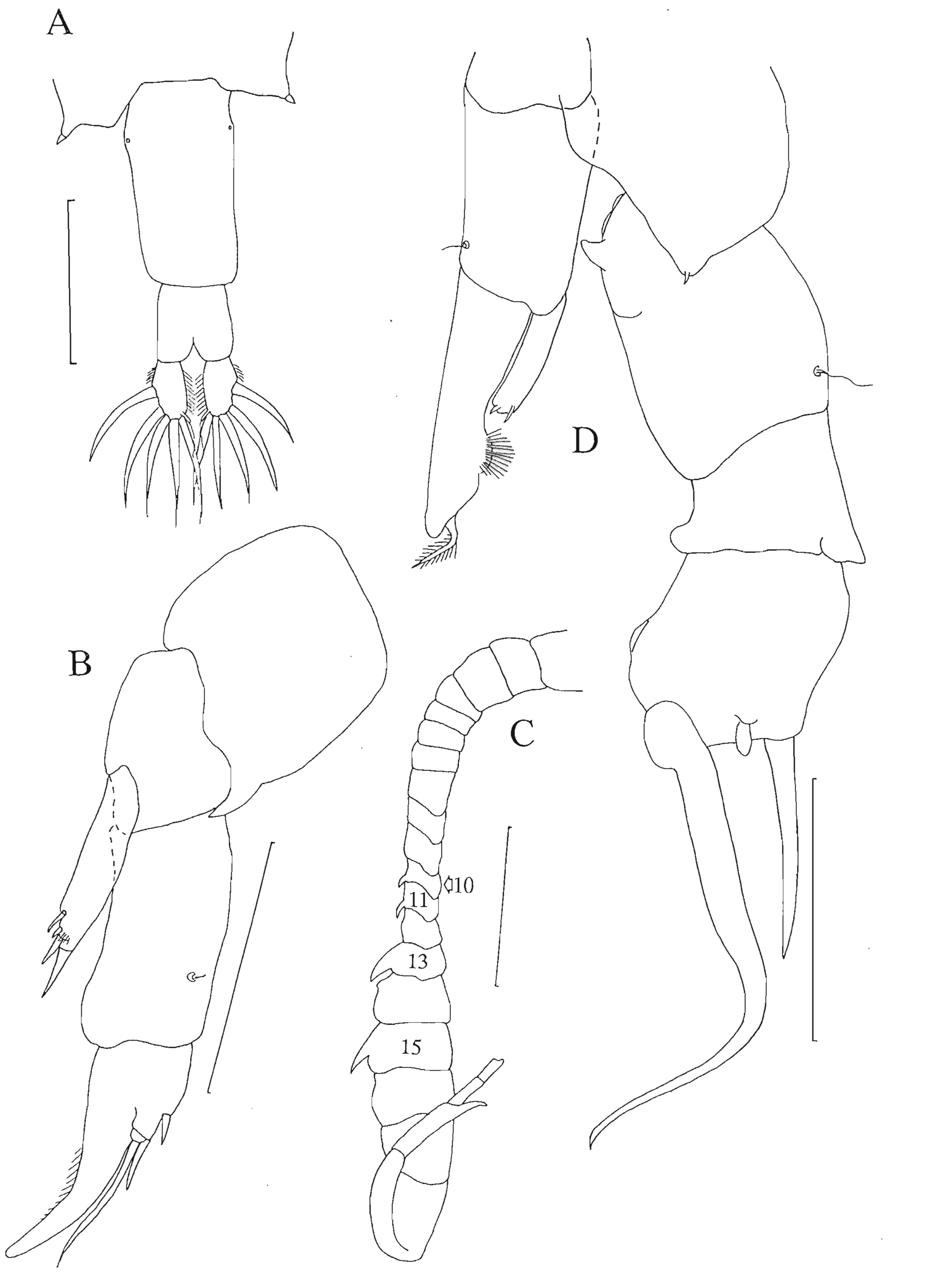
Female

A1 extending to posterior border of GS; GS long, > x2 length AS; setae on outer and inner margins of FR (Fig. 31A); P5 (Fig. 31B); egg sacs: 7, 8 eggs.

Males

A1 with segments 13-18 flattened and expanded, spiniform process on segment 13 broad-based and beak-like (Fig. 31C); right P5, Exp2 with long outer spine, medial rounded

Fig. 31. Tropodiaptomus spectabilis. Adult female: A. Urosome, dorsal view. B. P5. Adult male: C. Right A1. D. P5, posterior view. Bar scale in mm. A,C=0.25. B,D=0.1.



A
B
C
D
10
11
13
15

process; Exp3 claw, curved distally (Fig. 31D).

Distribution

Fig. 30

Coastal lowlands of Natal, Vaal river catchment.

Tropodiaptomus monardi Kiefer, 1937

Tropodiaptomus monardi Kiefer, 1937: 146-148, Figs 1-3.

Locality: Angola. This species has not been recorded from South Africa.

NEW SPECIES

Tropodiaptomus nov. sp. A

Locality (Fig. 38): Freshwater coastal Lake Bhangazi, Zululand, Natal. Breeding population collected by R.C. Hart, 03.05.89.

Female: Small; TL: 1.03 mm; A1 extending to end of FR; GS long, > x4 length AS; short AS and FR, FR separated (Fig. 32A); P5 very small (Fig. 32B); 2-4 large eggs (diam. 0.13 mm).

Male: Slightly smaller than female; TL: 0.98 mm; P5 (Fig. 32C).

Tropodiaptomus nov. sp. B

Locality 1 (Fig. 38): Waterhole, 15 km along Ndumu-Malopo road, E. Caprivi, Namibia. Breeding population collected by S. Bethune, 08.12.82. Mus. No.: SMN-50728.

Locality 2 (Fig. 38): Three rainwater pools at engravings, Okarukuvisa Kamp, Waterberg Plato Park, Namibia. Breeding population collected by S. Bethune, 19.02.83. Mus. No.:

SMN-50746.

<u>Female</u>: TL: 1.65 mm; A1 extending nearly to end of FR; dorso-lateral, distal expansion on GS; AS with lateral indentations; FS stout and long; FR dorsal setae with thick base, long (Fig. 33A); P5 (Fig. 33B); egg sac: ca 40 eggs.

<u>Male</u>: TL: 1.38 mm; right P5, Exp2 with very long lateral spine; Exp3 claw, long (Fig. 33C).

<u>Tropodiaptomus</u> nov. sp. C

Locality (Fig. 38): Mala Mala Game Reserve, Transvaal. Breeding population collected by D.G. Hay, 23.11.85.

<u>Female</u>: TL: 1.36 mm; A1 extending nearly to end of FR; GS long, x3 length AS; AS short with lateral indentations; FR with setules on inner and outer margins in female and male; FS stout, outer setae longer (Fig. 34A); P5, Exp2 spiniform process with separate small row of denticles (Fig. 34B); egg sac: ca 30 eggs.

<u>Male</u>: TL: 1.14 mm; right P5, Exp2, very long outer spine, Exp3 claw forming right angle (Fig. 34C).

<u>Tropodiaptomus</u> nov. sp. D

<u>Material examined</u>

Locality 1 (Fig. 38): Breeding population from Mhlolo pan, Pongolo floodplain, A.J.C. Buchan, 25.06.85; 20.01.86; 24.06.86.

Locality 2 (Fig. 38): Grahamstown, Quarry ponds, in macrophytes. Breeding population collected by M. Aken, Feb.,

Fig. 32. <u>Tropodiaptomus</u> sp. nov. A (Bhangazi). Adult female: A. Dorsal view, with egg-sac of 3 large eggs. B. P5. Adult male: C. P5, posterior view. Bar scale in mm. A=0.25. B,C=0.05.

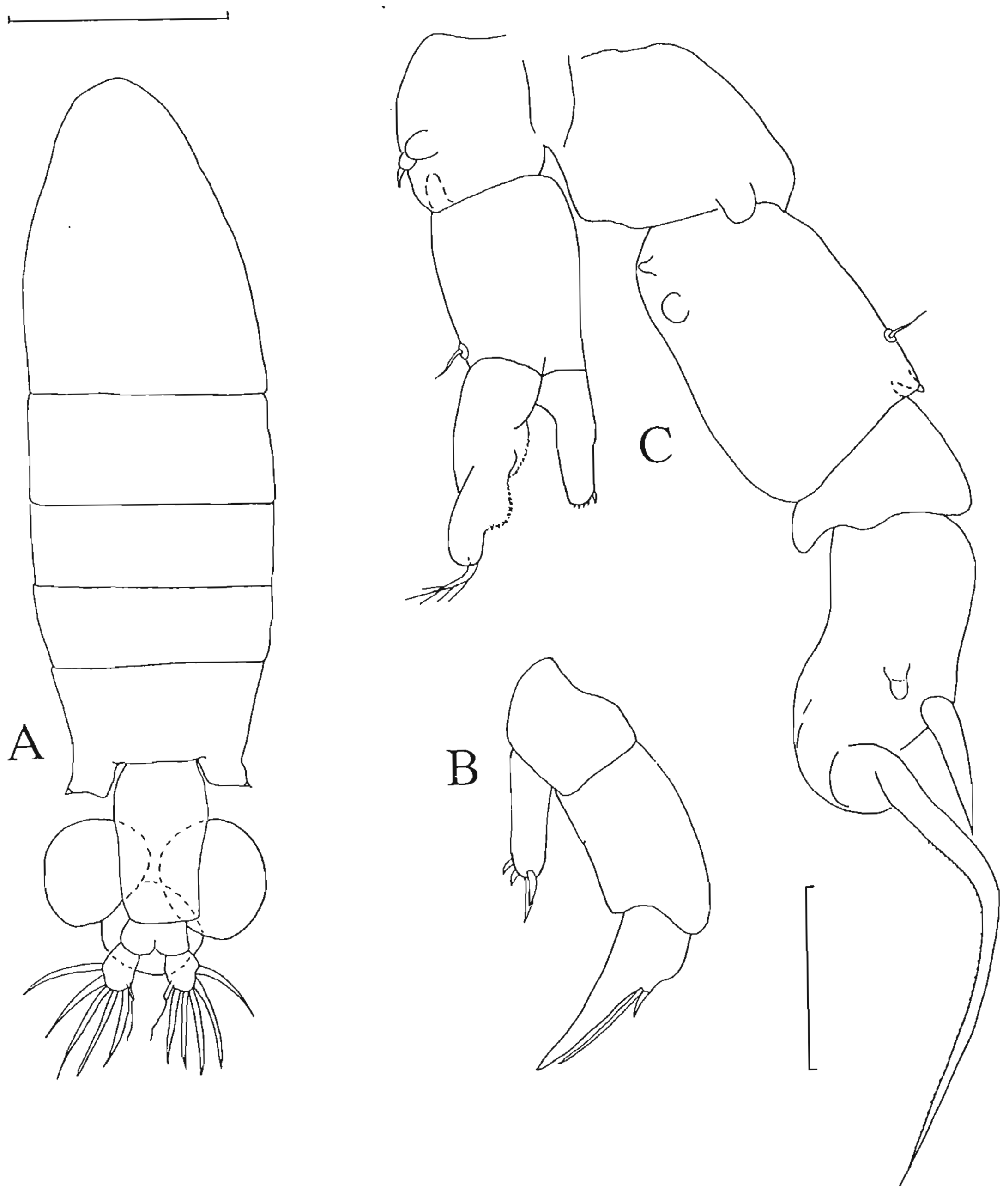

A
B
C

Fig. 33. Tropodiaptomus sp. nov. B (Caprivi). Adult female: A. Urosome, dorsal view. B. P5. Adult male: C. P5, posterior view. Bar scale in mm. A=0.25. B,C=0.05.

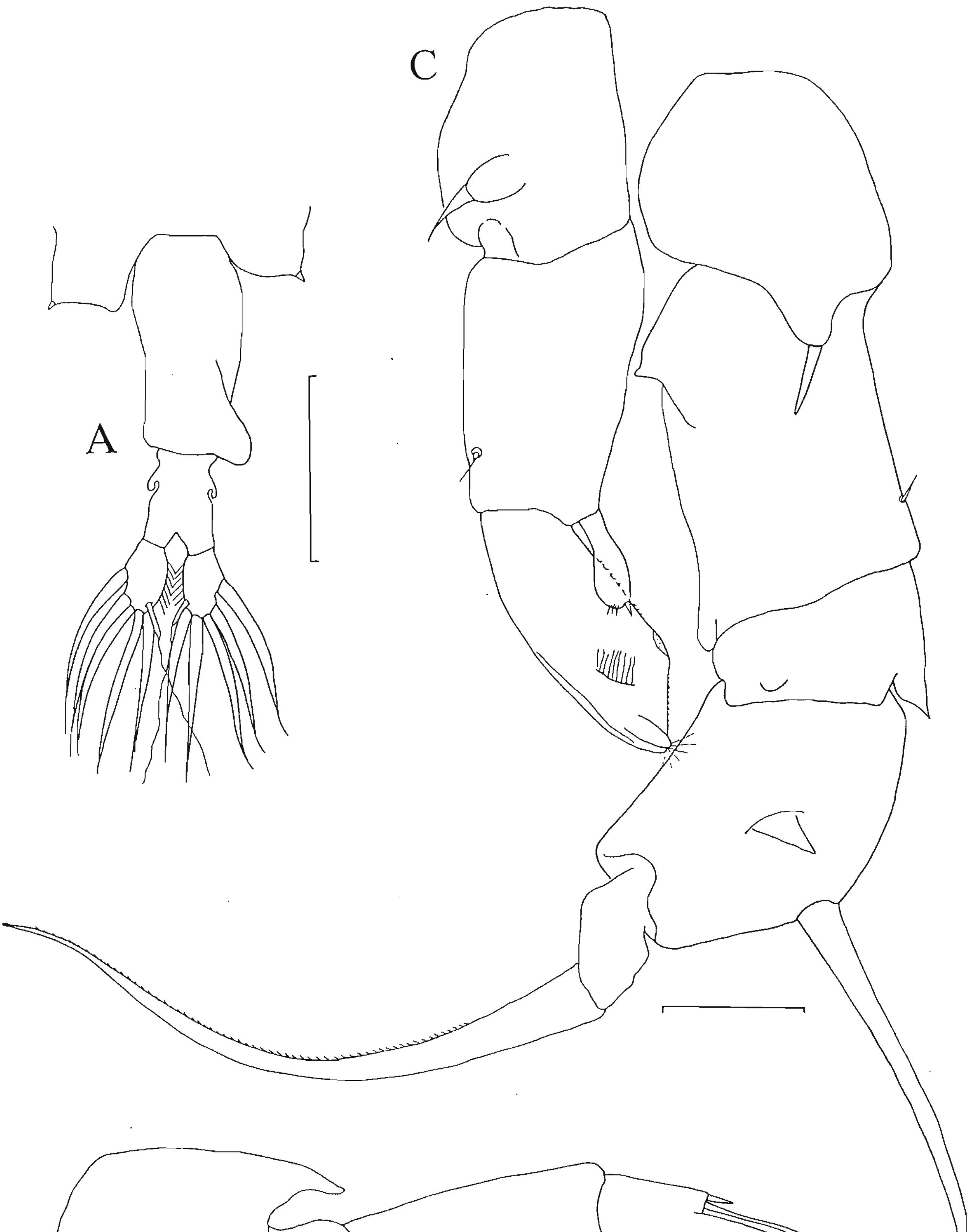

A
B
C

Fig. 34. Tropodiaptomus sp. nov. C (Mala Mala). Adult female: A. Urosome, dorsal view. B. P5. Adult male: C. P5, anterior view. Bar scale in mm. A=0.25. B,C=0.1.

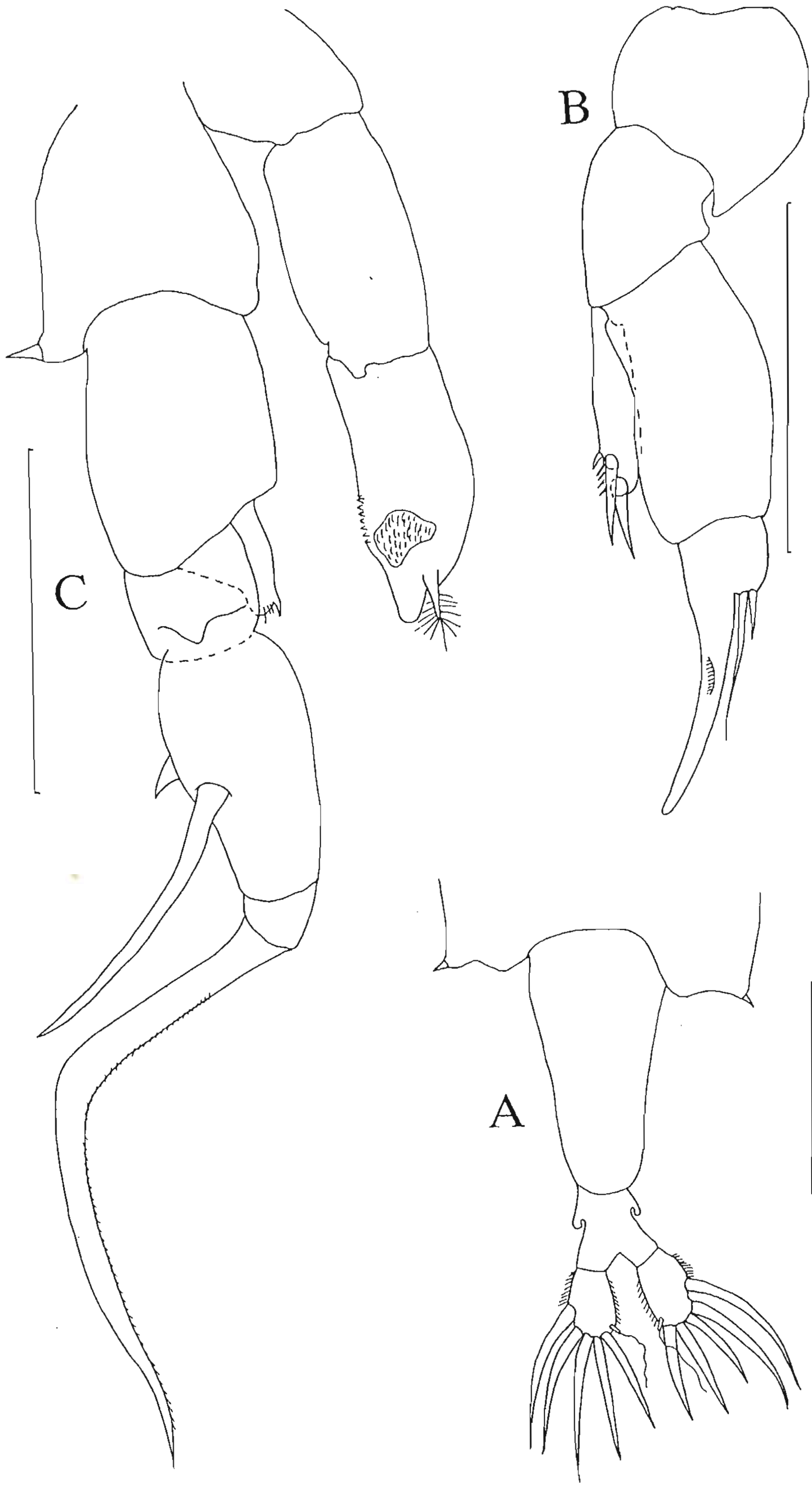

B
C
A

Fig. 35. Tropodiaptomus sp. nov. D (Mhlolo). A. Adult female urosome, dorso-lateral view. B. Female P5. Bar scale in mm. A=0.25. B=0.1.

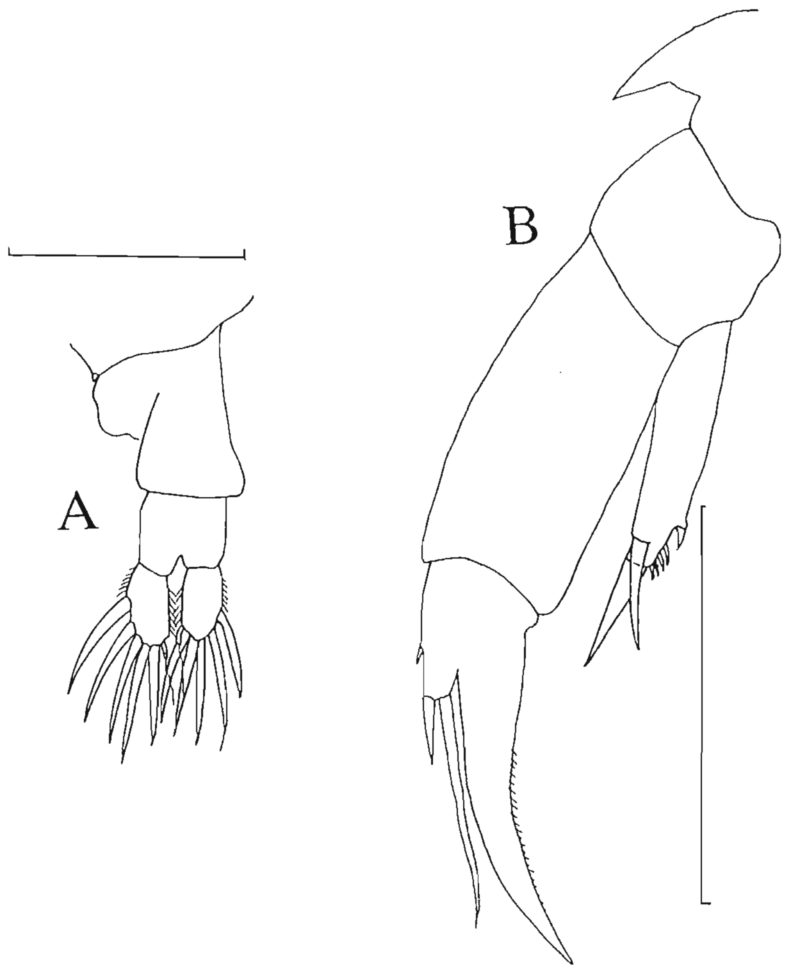

A
B

Fig. 36. _Tropodiaptomus_ sp. nov. D. Male P5, posterior view. A. Mhlolo Pan. B. Quarry Pond. Bar scale, 0.1 mm.

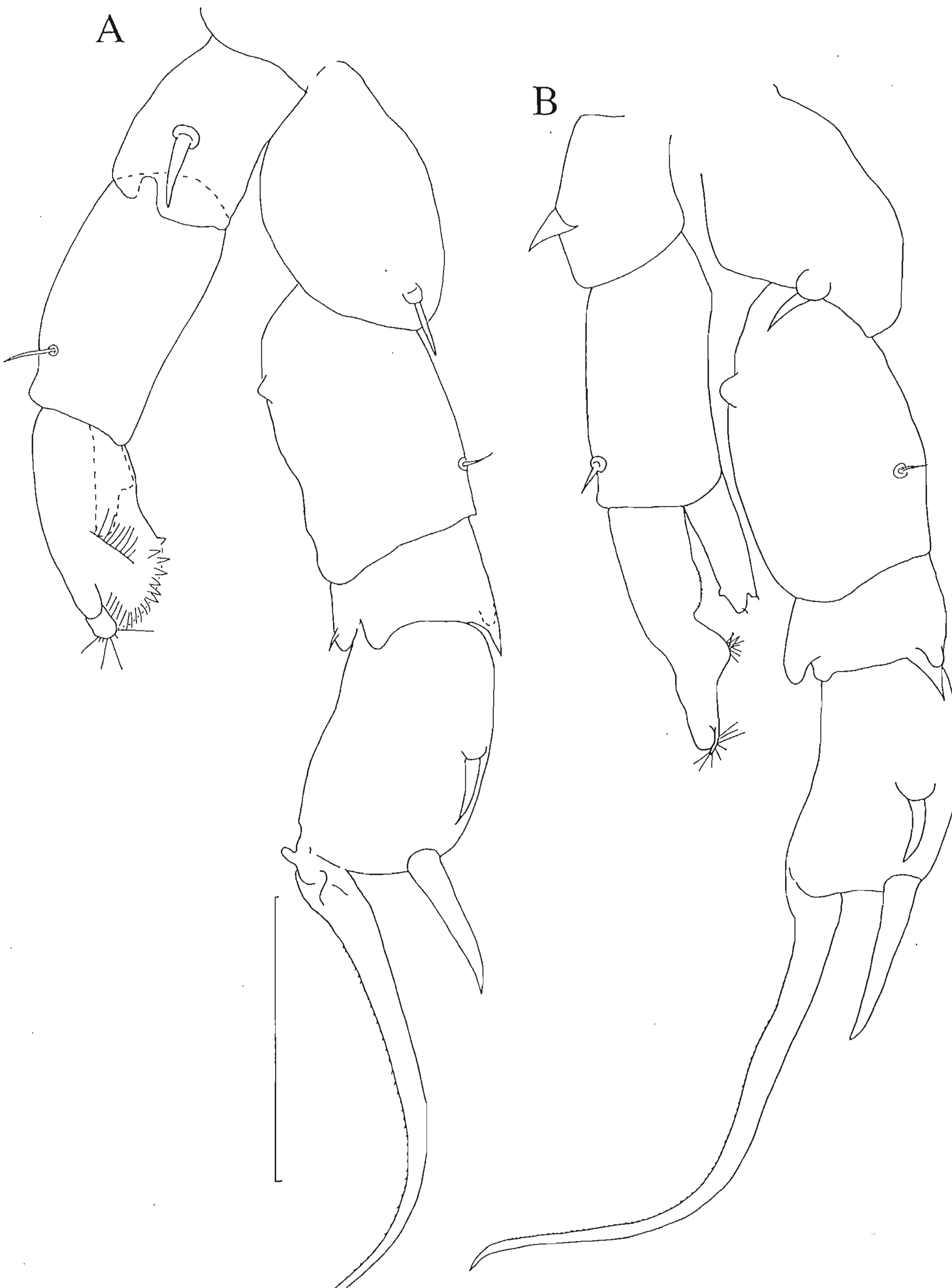
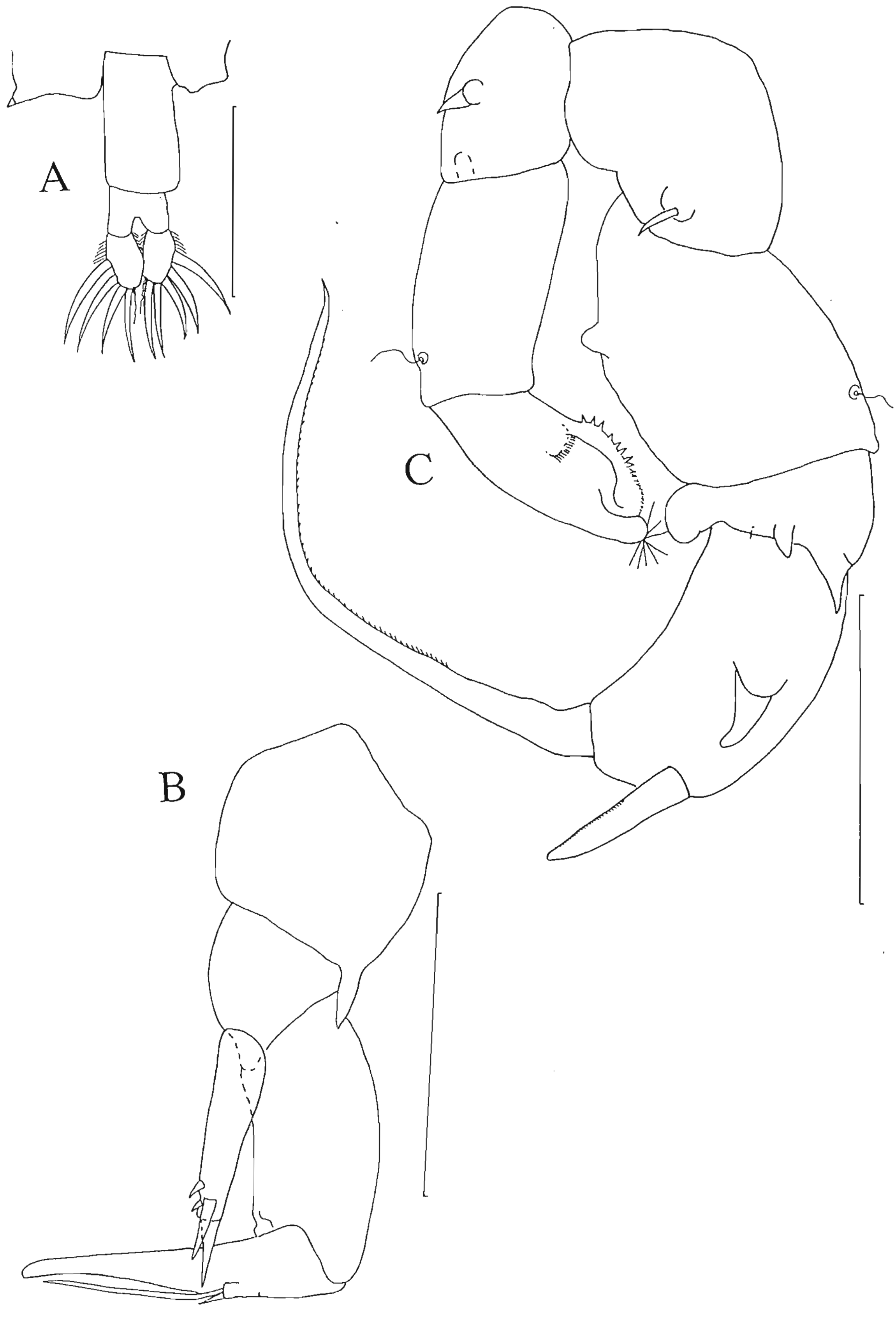


Fig. 37. <u>Tropodiaptomus</u> sp. nov. E (Chinde). Adult female: A. Urosome, dorsal view. B. P5. Adult male: C. P5, posterior view. Bar scale in mm. A=0.25. B,C=0.1.


A
B
C

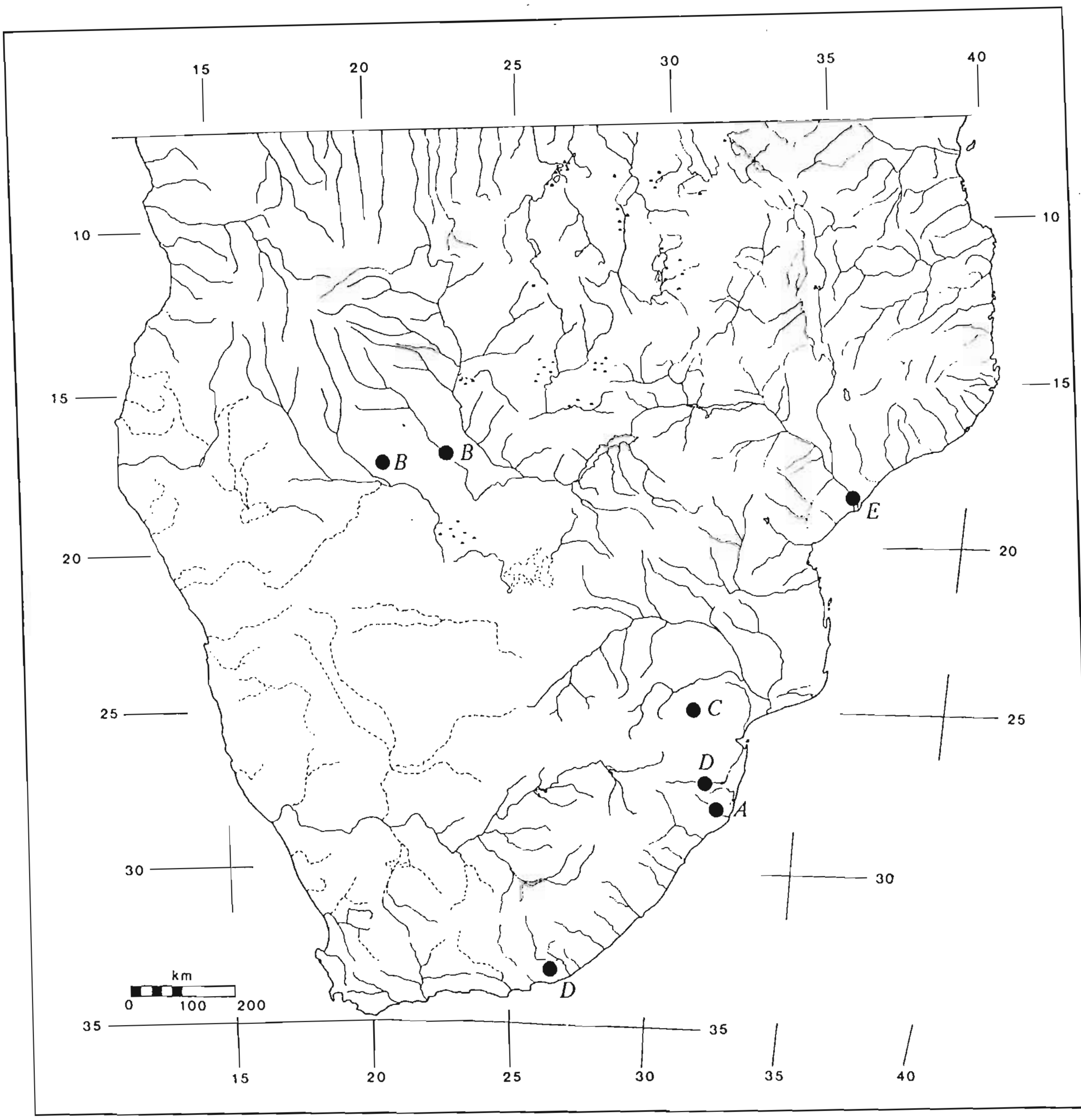


Fig. 38. Map of southern Africa showing localities of new species of <u>Tropodiaptomus</u>. A. Lake Bhangazi; B. Caprivi; C. Mala Mala Game Reserve; D. 1. Mhlolo pan, Pongolo floodplain, 2. Quarry ponds, Grahamstown; E. Chinde.

1986.

Female: TL: 1.40 mm; A1 very long, extending almost to end of FR; GS expanded ventrally (Fig. 35A); P5, Enp with one apical, one subapical seta, one spinule (Fig. 35B); egg sacs: 8, 8, 9, 10 eggs.

Male: TL: 1.32 mm; right P5, Exp2 with 2 lateral spines (Fig. 36A, 36B). The apparent difference in the left P5 in Figs 36A & B, is related to orientation of the leg.

This species is very similar to *T. kraepilini* of Verheye & Dumont (1984) but there are minor differences such as detail of the female P5 endopodite.

Tropodiaptomus sp. E

Locality (Fig. 38): Zambezi delta region, Pre-impoundment survey of Cahora Bassa dam, Sombo rice paddy, 10 km S. Chinde. Breeding population collected in channel taking water from river. Collector: B.R. Davies, 13.03.74, Mus. No. AM-CAB 24A.

Some specimens dark brown in colour.

Female: TL: 1.32 mm; A1 extending slightly beyond end of FR; Pdg5 left wing expanded; long GS, slightly expanded distally; short AS; setules on inner and outer margins of FR; FS robust (Fig. 37A); P5, Enp with one apical, one subapical seta, 2 spinules (Fig. 37B); egg sacs (3) with ca. 10 eggs.

Male: TL: 1.23 mm; right P5, Exp1 with prominent inner process, Exp2 with 2 stout, lateral spines, Exp3 claw very long (Fig. 37C).

KEY TO THE SOUTHERN AFRICAN SPECIES OF TROPODIAPTOMUS

Females

1 TL > 2 mm,
GS with pronounced lateral spines,
Left FR longer than right (Fig. 28A)..........
....................................*T. schmeili*

1' TL < 2 mm,
GS without lateral spines,
Left and right FR of similar length............2

2 TL ca 1 mm,
AS very short, 1/5 length GS (Fig 32A)..........
...........*Tropodiaptomus* sp. nov. A (Bhangazi)

2' TL > 1 mm, < 2mm,
AS not very short..............................3

3 AS with lateral indentations (Figs 33A, 34A)...4

3' AS without lateral indentations................5

4 GS without expansion,
FR with setules on lateral margin (Fig. 34A)....
...........*Tropodiaptomus* sp. nov. C (Mala Mala)

4' GS with dorso-lateral expansion on distal border (Fig. 33A),
FR without setules on lateral margin...........
.............*Tropodiaptomus* sp. nov. B (Caprivi)

5 TL > 1.5 mm,
P5 Exp2 outer spine well-developed (Fig. 31B)...
.................................*T. spectabilis*

5' TL < 1.5 mm.....................................6
P5 Exp2 outer spine very small or absent.......7

7 P5 Enp with 2 setae, 1 spinule (Fig. 35B).......
..............*Tropodiaptomus* sp. nov. D (Mhlolo)

7' P5 Enp with 2 setae, 2 spinules (Fig. 37B)......
..............*Tropodiaptomus* sp. nov. E (Chinde)

Males

1 TL ca 2 mm,
Right P5, Exp2 with one lateral spine (Fig.29)
.................................*T. schmeili*

1' TL < 2 mm,
Right P5, Exp2 with lateral spine and additional medial spine or process.......................2

2 P5, Exp2 with one lateral spine, one medial rounded process.............................3

2' P5, Exp2 with one lateral, one medial spine....4

3 TL < 1 mm,
Right P5, Exp2 lateral spine, 1/4 length Exp3 claw (Fig. 32C)..............................
............*Tropodiaptomus* sp. nov. A (Bhangazi)

3' TL > 1 mm,
Right P5, Exp2 lateral spine, 1/2 length Exp3 claw (Fig. 31D).................*T. spectabilis*

4 Right P5, Exp2, medial spine, narrow, pointed (Figs 36A, 36B)................................
.............<u>Tropodiaptomus</u> sp. nov. D (Mhlolo)

4' Right P5, Exp2, medial spine triangular........5

5 Medial spine with sharp point,
Lateral spine long, 1/2-2/3 length Exp3 claw...6

5' Medial spine with blunt end,
Lateral spine short, 1/4 length Exp3 claw (Fig. 37C).....................................
.............<u>Tropodiaptomus</u> sp. nov. E (Chinde)

6 Right P5, Exp2 L:B = 1,
Right P5, Exp3 claw uniformly curved (Fig.33C)..
............<u>Tropodiaptomus</u> sp. nov. B (Caprivi)

6' Right P5, Exp2 L:B = 2,
Right P5, Exp3 claw forming a right angle (Fig. 34C).......<u>Tropodiaptomus</u> sp. nov. C (Mala Mala)

CHAPTER 8

GENUS *THERMODIAPTOMUS* KIEFER, 1932

This genus, which is very closely related to *Tropodiaptomus*, was established by Kiefer (1932a). The *Thermodiaptomus* female P5 endopodite lacks setae (there is one apical and one subapical seta in *Tropodiaptomus*) and the exopodite of the male left P5 does not have the characteristic *Tropodiaptomus* shape. Also, the Exp2 of the male no right P5 exopodite has a different orientation, with the bases of the lateral spine and Exp3 claw, separated. Seven species are endemic to Africa, with two species occurring in southern Africa.

Thermodiaptomus Kiefer, 1932

Thermodiaptomus Kiefer, 1932a: 467.

Thermodiaptomus: Kiefer, 1934: 150. Defaye, 1988: 106. Dussart, 1989: 62-63.

Thermodiaptomus congruens (Sars, 1927)

Diaptomus congruens Sars, 1927: 106, pl. 9 (figs 9-13).

Diaptomus cyrtomaphorus Kiefer, 1928: 12-14, figs 20-24; 1934: 153, 154 (figs 95-99). syn. nov.

Thermodiaptomus acanthus Kiefer, 1937: 148-150, figs 4-7. Dussart, 1989b: 68, figs 37B, 77. syn. nov.

Diaptomus congruens: Seaman *et al*., 1978: 139, fig. 11.

Material examined

SAM-A11571, SAM-A11574, SAM-A11577, SAM-A11680, SAM-A11885,

Ongka, Ovamboland, KHB, February 1921.

Characteristics

Female:

TL: 1.86 mm; A1 extending to end of furcal rami; genital somite asymmetrical (Fig. 39B) with lateral spines (Fig. 39A); furcal setae stout, with strong setules only on last 2/3 of seta; setules on inner margin of furcal rami (Fig. 39A); P5 with setae on outer margin of Exp3 spiniform process (Fig. 40C).

Male:

TL: 1.59 mm; spiniform processes on urosomal somites 2 and 3 (Fig. 40A); P5 large (40B).

Distribution

Fig. 30

'Type locality': Ongka, Ovamboland (KHB).

Angola (Kiefer, 1937), Lake Liambesi (Seaman *et al*., 1978).

Remarks

Sars' original material from which he described this species was found in the South African Museum. It established the identity of *T. congruens* and *D. cyrtomaphorus* and, surprisingly, showed that Kiefer (1937) had made a mistake in not recognising *T. acanthus* as *D. congruens*. The new synonymies were justified with reference to illustrations of Kiefer (1928, 1937) and Sars (1927) and dissection of Barnard's Ovamboland material. The spiniform processes on urosomal somites 2 and 3 in the male are autapomorphic characters.

Fig. 39. _Thermodiaptomus congruens_. Adult female: A. Urosome, dorsal view. B. Urosome, lateral view; C. P5. Bar scale in mm. A,B=0.25. C=0.1.

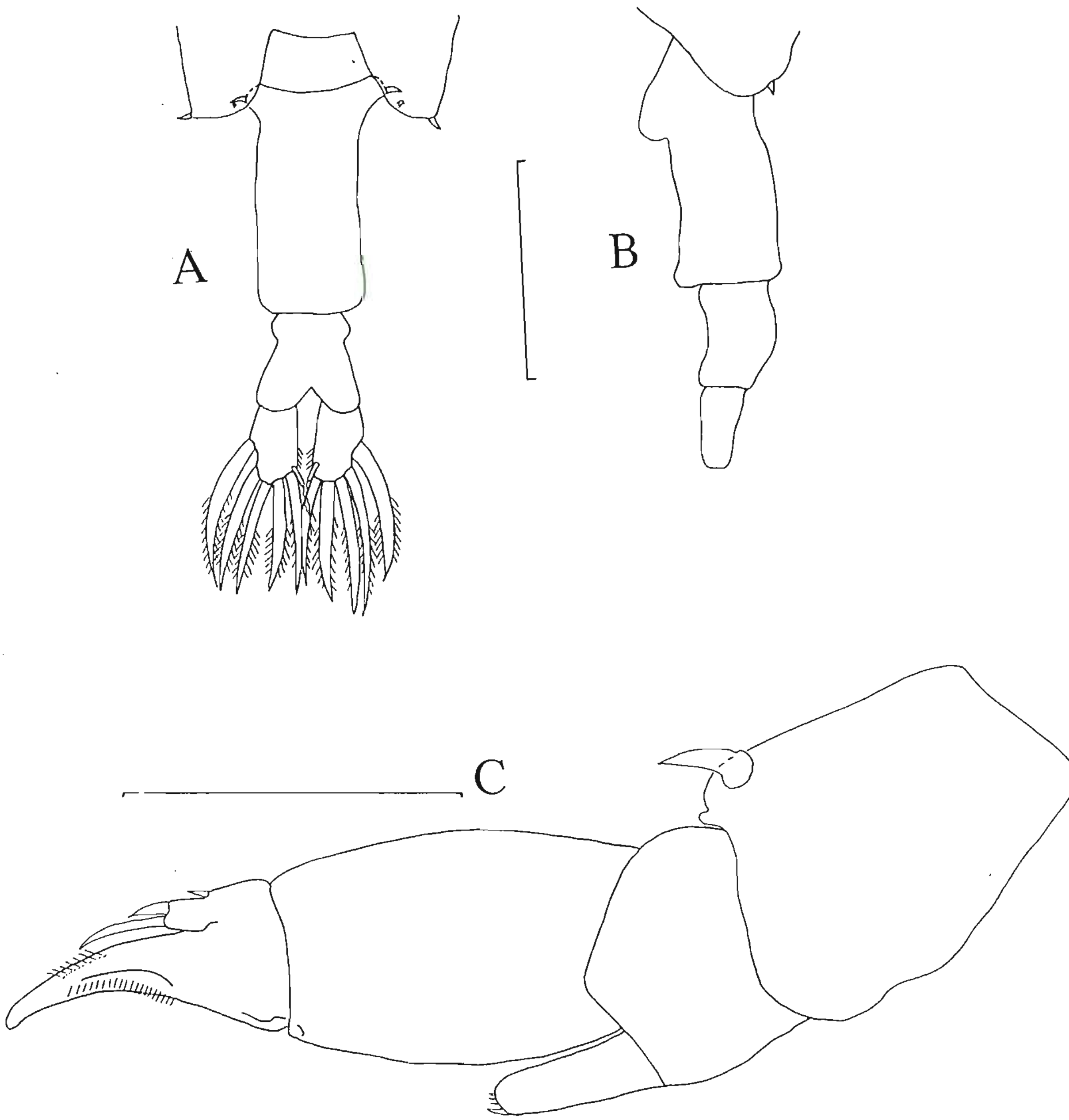

A
B
C

Fig. 40. <u>Thermodiaptomus congruens</u>. Adult male: A. P5, posterior view. B. Urosome, dorsal view. Bar scale in mm. A=0.25. B= 0.1.

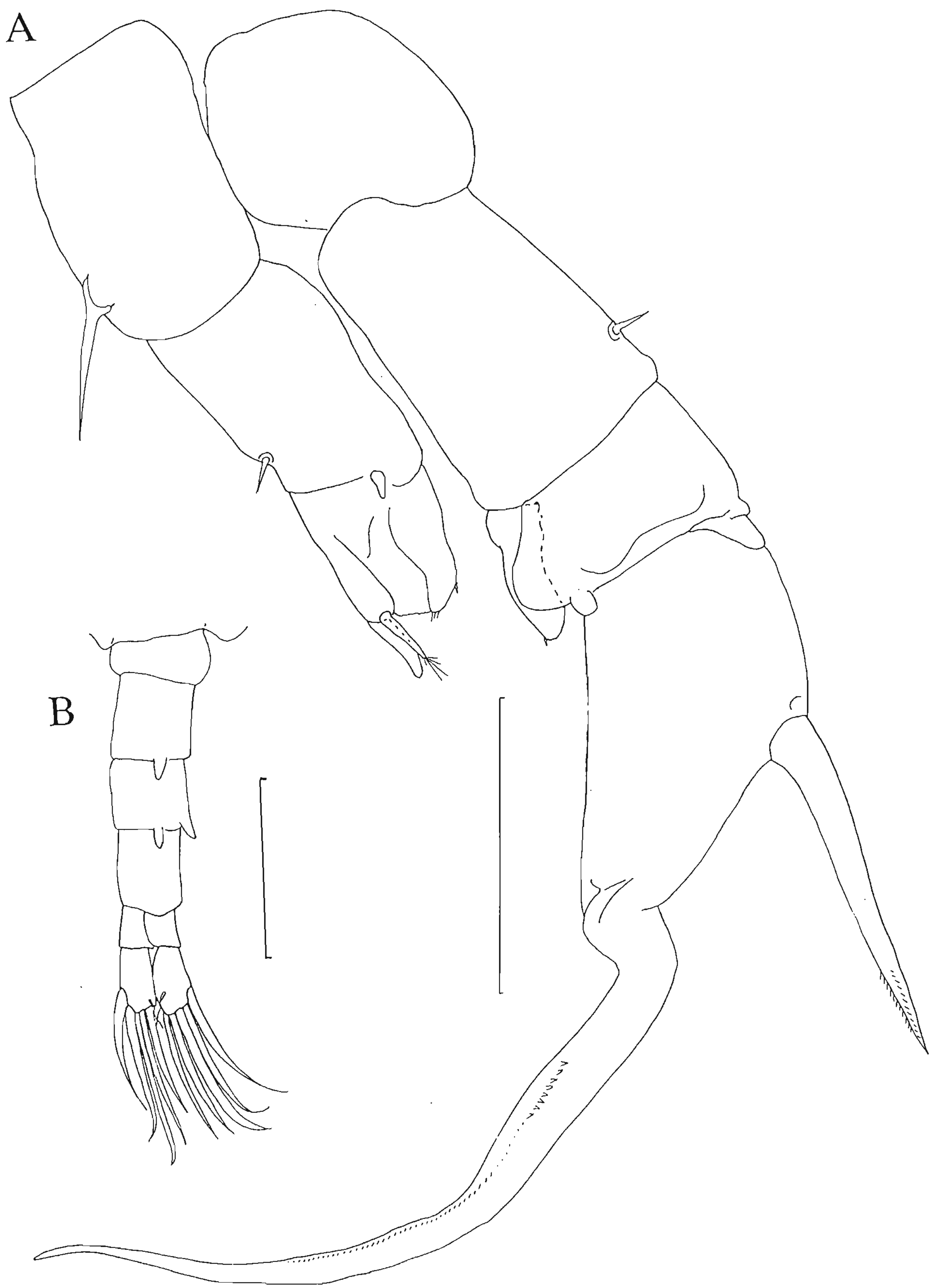

A
B

Fig. 41. <u>Thermodiaptomus syngenes</u>. Adult female: A. P5; Adult male: B. P5, posterior view. C. P5, posterior view, detail. Bar scale in mm. A,C=0.05. B=0.25.


A
B
C

Thermodiaptomus syngenes (Kiefer, 1929)

Diaptomus syngenes Kiefer, 1929: 313 (fig. 7).

Diaptomus syngenes: Hutchinson *et al*., 1932: 77, 93, 149.

Eudiaptomus sp. Harding & Smith, 1967: 520.

Thermodiaptomus syngenes: Kiefer, 1932a: 467-500, 503 (fig. 61); 1934: 150-2, figs 89-94. Abu Gideiri, 1967: 371. Colvin, 1971: 38-83. Dussart & Defaye, 1983: 106. Dussart, 1989a: 67-68, figs 38 & 76.

Material examined

Premier Mine dam, MTS, 12.09.73.

Roodeplaat dam, MTS, 14.09.73.

Lindleyspoort dam, MTS, 01.12.75 & 02.06.76.

Loskop dam, MTS, 07.01.78 & 11.07.78.

Witbank dam, MTS, 02.03.78.

Rust de Winter dam, MTS, 22.03.78.

Bronkhorstspruit dam, MTS, 21.06.78.

Bospoort dam, MTS, 29.06.78.

Pongolo flooplain, Mhlolo pan, A.J.C. Buchan, 25.06.85, 01.09.85 & 03.02.86.

Grahamstown, Quarry ponds, M. Aken, February 1986.

Characteristics

Female

TL: 1.23 mm; A1 very long, extending to end of FS; left P5, Exp3 seta very long (Fig. 41A). Egg sac: 4 large eggs.

Male

TL: 1.04 mm. P5 (41B, 41C).

Distribution

Fig. 30

'Type locality': Hartbeespoort dam. Other localities: Subtropical belt of northern and eastern Transvaal, Pongolo floodplain, Grahamstown. With the exception of Mhlolo pan on the Pongolo floodplain, all records are from man-made impoundments. Thermodiaptomus syngenes was recorded as co-occurring with Metadiaptomus colonialis in Lindleyspoort dam (02.06.76) and Bronkhorstspruit dam (1.06.78); with Tropodiaptomus nov. sp. D, in Mhlolo pan, Pongolo floodplain (25.06.85) and Quarry ponds, Grahamstown (February, 1986).

Other African species are:

Thermodiaptomus galebi (Barrois, 1891) - type species, recorded from North, East and Central Africa.

Thermodiaptomus galeboides (Sars, 1909) - Lake Victoria

Thermodiaptomus mixtus (Sars, 1909) - Lake Malawi

Thermodiaptomus yabensis (Wright & Tressler, 1928) - Nigeria, Niger, Haute-Volta, Mali

Thermodiaptomus ricardoae Harding, 1942 - Lake Young, East Africa

CHAPTER 9

DISCUSSION

There are many reasons why freshwater copepod research in southern Africa has been a neglected field of study for over 50 years. Firstly, the study of these organisms, along with many other invertebrate groups, has been initiated mainly by overseas institutions. Type material, on the rare occasions when it was designated, was not housed in South Africa and in many cases has been lost. The large number of copepod instars has always made copepod study difficult, and identification of freshwater copepods has posed a major problem for research workers in South Africa. The second World War and South Africa's political isolation further contributed to the fact that overseas scientists were unable or reluctant to become involved. Other contributing factors have been the lack of qualified manpower, lack of funding, and the tendency for postgraduate students to prefer the more active lifestyle associated with vertebrate research.

Material collected in South Africa is scattered in various museums, whereas it should be housed in the National Freshwater Collection at the Albany Museum. One of the reasons for this is that it is customary for museum personnel to expect that material described in museum publications be housed in their museum. A national register of freshwater invertebrates has been initiated by the Albany Museum but is only one of the activities of an already over-extended museum staff. Much of the copepod material is unsorted or unidentified, mainly because of lack of qualified personnel. The cyclopoid and harpacticoid material is virtually untouched.

TAXONOMY

The taxonomic work initiated by Sars, Douwe and Kiefer came to a halt in 1934 after Kiefer published his account of the freeliving copepods of South Africa. For many years this has been accepted as the definitive work, at least for the calanoids, with additional information available in Sars (1927) and Douwe (1912b; 1914). Taxonomic research on estuarine copepods of the Pseudodiaptomidae was undertaken by Grindley (1963).

There has been no research on southern African harpacticoids except for a few species described or mentioned by Sars (1927) and Kiefer (1934). The resurgence of interest in harpacticoid taxonomy worldwide has not as yet extended to South Africa. The prospect of embarking on harpacticoid taxonomy is not very appealing to most postgraduate students. In the forseeable future, there does not seem much possiblity of research in this field because of funding restrictions and the insignificant role of harpacticoids in freshwater habitats. The main concentration of harpacticoid species is in the vleis and inland waters of the western Cape province, while there are a few species associated with man-made impoundments.

Harpacticoids are invariably absent from temporary pools in semi-arid areas. Any future research would require a comprehensive collecting programme.

More information is available on cyclopoids. There are some well-known endemic species as well as a number of species which are probably cosmopolitan. There is a good diversity, the main genera being Mesocyclops, Thermocyclops, Eucyclops, Microcyclops and Paracyclops. As with the harpacticoids, there is no ongoing research on cyclopoids, but with interest emanating from some European institutions, it is possible that, if museum holdings were made available, an initial account of the cyclopoids could be undertaken. To collate all the material and make addi tional collections, would require researchers to visit South Africa.

Taxonomic research on freshwater calanoids appears deceptively easy. In South Africa, identification at the genus level is comparatively straightforward, although a reassessment of the genus Paradiaptomus is required. At species level, the availability of highly weighted characters varies from genus to genus and between males and females. There are some autapomorphies and apomorphies which facilitate species' identification but generally, a suite of characters is required. There is little variation in morphological characters and "variation" when recorded in the literature, is a good indication that more than one species is involved. Distributional data is important as it has high predictability for diaptomid identification.

Species of the genus *Lovenula* are set apart from all other diaptomids by their comparatively large size and the possession of very large raptorial maxillipeds. However, individual species of *Lovenula* are difficult to identify correctly, with the exception of *L. africana*. *Lovenula falcifera* and *L. simplex* have been confused since the days of Sars, and distributional data are critical for accurate identification: *Lovenula falcifera* has one of the widest distributional ranges of any African diaptomid, while *L. simplex* occurs only on the Cape peninsula and in the environs of Cape Town. *Lovenula excellens* is isolated in the Lake Chrissie area and superficially could be confused with *L. falcifera*. *Lovenula africana* has been recorded from Magadikgadi pan, Lake Malawi and Lake Rukwa, as well as other East African lakes of high conductivity.

Paradiaptomus species have conservative male morphological characters relating to the fifth pair of legs, and identification to species level using male characters may be difficult. Some females have aut apomorphies and specialised characters relating to the urosome and furca and these carry high weight for species identification. The decision to place *P. rex* into synonymy with *P. schultzei* improves the diagnosis of the genus, as it re moves the problematic three-somited urosome of *P. rex* from the taxon. *Paradiaptomus alluaudi* is the only *Paradiapto-*

mus species with this character and its affinity with the genus is so weak that consideration should be given to removing it from the taxon. Kiefer (1932a) gave P. alluaudi subgeneric status in the genus Lovenula but it would be better to designate it as Neolovenula alluaudi (Dumont & Verheye, 1984), with full generic status.

Generally, there appears to be a lamellatus species-complex, relating mainly to the south western Cape and montane species. This excludes P. schultzei and P. similis, known for their affinity for temporary waters in semi-arid regions.

In the genus Metadiaptomus, the male fifth pair of legs shows a small variation between species, usually relating to the armature of the basipodite of the right leg, and the presence or absence of the right leg Exp2 lateral spine. Interpretation of the conservative female morphology is aided by autapomorphies in M. colonialis, M. purcelli, M. capensis and Metadiaptomus sp. nov. A and B. The apomorphic characters which Metadiaptomus sp. nov. A (Leeupan) shares with both M. chevreuxi and M. mauretanicus provide interesting speculation as to the phylogeny of these three geographically, widely-separated species. A useful character in the genus is the relative size of male to female, as there is considerable dimorphism in size in some Metadiaptomus species.

The two Thermodiaptomus species in southern Africa are easily identifiable but T. congruens was poorly known because it occurs in Botswana and southern Angola, two inaccessible collecting regions. Tropodiaptomus species in southern Africa require much more study, as they can no longer be lumped together as in the past, as T. kraepilini or T. orientalis. The type-locality of T. kraepilini is Zanzibar and there is increasing tendency to refer to a T. cf. kraepilini complex of species to accommodate the many closely related species (Dumont & Maas, 1988). After many years of confusion, it has at last been established that T. orientalis does not occur in Africa (Dussart et al., 1984; Dussart, 1989b). Most Tropodiaptomus species in Africa are confined within narrow geographical ranges. The characters which differentiate the majority of Tropodiaptomus species are very fine and the group appears to be in a state of "explosive" speciation.

In South Africa, many errors in identification of diaptomid species were made in the past and these were compounded by being incorporated into the literature, over and over again. These problems would not have arisen if there had been ongoing taxonomic research. The early taxonomists contributed a great deal under the difficult circumstances of slow communication, distance and lack of material. The continuation of research on freshwater copepods depends on many factors, not the least being the importance of the group to South African limnology. It is hoped that the recent controversy on model descriptions of species (Monoculus newsletters Nos. 18-20, 1989-1990) will be resolved, and not deter future taxonomists from undertaking copepod research. It is appreciated that a description must give as much information as possible, as failure to do this adds to the confusion of those who follow. One of the major problems hindering taxonomic research has been non-designation of types and poor descriptions. However, there are limits to the amount of time which can be spent on diagrams, especially if there is a large number of species involved. It would be valuable to undertake a cladistic or phylistic analysis of the African diaptomids, but this would involve very careful selection of characters and decisions on evolutionary pathways. A cooperative effort with research workers from France and Belgium would be required if all African species were included.

BIOGEOGRAPHY

Dispersal and vicariance

One of the most important and controversial developments in biogeography during the 1970's was the rise of "vicarianism". To quote Briggs (1987), vicariance refers to the biogeographic patterns produced by a particular kind of allopatric speciation in which a geographic barrier develops so that it splits a formerly continuous population. This concept, propounded by Croizat *et al*. (1974), was considered to be different from Darwin's concept of allopatric speciation which results from dispersal from a centre of origin, and speciation as individuals cross barriers and colonise new areas. In the mid-1980's, it became accepted that vicariance and dispersal have both played a role in historical biogeogaphy. Briggs (1987) pointed out that barriers to migration are often not static and that, over time, most of them have been or will be changed. Sometimes the creation of a barrier will result in the interruption of the range of a species. For example, the tectonic uplift of a mountain range can constitute a barrier for lowland forms but simultaneously may present a migratory corridor for species of high-altitude biota. A good example of a combined vicariance and dispersal event was the closing of the Isthmus of Panama at about the end of the Pliocene. It separated the tropical marine biota of the New World into two parts, one inhabiting the Eastern Pacific and the other the Western Pacific. At the same time, the isthmus provided a dispersal corridor between North and South America for terrestrial and freshwater organisms.

On the African continent, both vicariance and dispersal have played a role in diaptomid distribution patterns. Vicariance events such as the uplift of the Cape Fold mountains and the formation of the Great Rift Valley have had an important effect in isolating dispersing organisms. The endemicity of the species of the Rift valley lakes and the western Cape province of South Africa, supports strongly the importance of these barriers to further dispersal.

Climate

Today, southern Africa is dominated by dry climates and strongly seasonal precipitation regimes (Deacon & Lancaster, 1988). The climates of southern Africa are strongly influenced by the latitudinal position of the subcontinent, which tapers southwards from 18 to 35^{o} South. The west coast is paralleled by the cold northward-flowing Benguela current, whilst the warm south-flowing Mozambique and Agulhas currents lie off the east and south-east coasts. Many areas of the subcontinent lie at elevations of over 1000 metres. This, together with the narrow width of the land mass, exerts a moderating influence on the climate (Schultze, 1972). Gondwanaland climatic reconstructions indicate that there were wet conditions in the late Carboniferous-early Permian but from the Triassic, only southern Africa still experienced wet conditions. By the Cretaceous, only the southern tip of Africa still had wet conditions and the rest of the continent was experiencing drier conditions. At no time during the Quaternary did glacial conditions prevail, although there is evidence of periglacial conditions at high elevations. Data on palaeoclimates of southern Africa, indicate that 25000-15000 BP was the coldest period of the last 130000 years, with a temperature reduction of 5-9^{o}. The last Glacial Maximum occurred at about 16000 BP. From 14000-10000 BP, southern Africa was wetter but from 12000 BP, drier conditions began to prevail. From 9000-4000 BP, most of southern Africa was much moister than today and temperatures were warmer. From 4000-0 BP there have been low level temperature fluctuations around the present mean with some wetter intervals (Tyson, 1986; Deacon & Lancaster, 1988). It appears, therefore, that from Gondwanian times there have been no catastrophic climatic events which might have caused diaptomid extinction, but changing climates together with tectonic events will have governed diaptomid distribution.

Evolution and distribution

Only under exceptional circumstances are Copepoda recorded as fossils, so any discussion regarding ancestral forms and evolution is speculative. A fossil parasitic copepod from a lower Cretaceous fish has provided strong evidence that copepods are probably much older than previously thought (Cressey & Boxshall, 1987). The ancestors of freshwater copepods were almost certainly marine but at what period the transition to inland waters occurred is not known. Regarding the evolutionary history of the Diaptomidae of Africa, there is no fossil evidence to relate them to any particular geological period. In addition, poor taxonomic knowledge has contributed to lack of interpretation of their distribution, as emphasised by Dumont (1980).

Harrison (1978) grouped the freshwater fauna of southern Africa into South Temperate Gondwanian and Pan-Ethiopian. He made no mention of the Copepoda. The Gondwanian fauna had its origins in Gondwanaland before continental drift occurred during the Jurassic. Most of the Pan-Ethiopian fauna is said to consist of groups which entered Africa from the north after the closing of the Tethys sea and after India became joined to the Asian mainland. The evolution of some invertebrate groups and many vertebrate groups in Africa is known from the fossil record. It is only in the past decade that interest has been shown in freshwater copepod distribution and attempts made to relate it to possible origins and evolution.

Many of the African diaptomids, in particular the Paradiaptominae, are arid-adapted species and belong to shallow or temporary pool communities. Contrary to the consensus view, Williams (1988) considered temporary waters to be the ancestral freshwater habitat because of the geologically ephemeral nature of lakes. Supporting evidence for a long geologial history for the Paradiaptominae can be extrapolated from another arid-adapted freshwater taxon, the Notostraca, which has two genera, Triops and Lepidurus. Triops granarius and T. cancriformis are both well known from Africa. The upper Triassic, Lepidurus stormbergensis occurs in fossil beds in South Africa. The group has a very long geological record as Notostracan carapaces have been recorded from the Permian. Forms from the Triassic in Europe, differ but slightly from modern day Triops (Longhurst, 1956). Triops granarius has been recorded in South Africa in temporary pools in association with arid-adapted species such as Lovenula falcifera and Paradiaptomus schultzei. It seems very likely then, that the arid-adapted diaptomids of Africa together with the Notostraca, are Gondwanian in origin. The centre of origin of the Paradiaptominae could well be East Africa with its proximity to the tropics. Centres of origin have large geographic size, heterogeneous topography, warm and relatively steady temperatures, maximum species diversity for the general part of the world in which they are located, and possession of the most advanced species and genera of those groups of organisms that are well represented (Briggs, 1987). With the exception of three species, Paradiaptomus alluaudi, P. greeni and Metadiaptomus asiaticus, all Paradiaptominae are endemic to Africa. Paradiaptomus alluaudi is a north African and circum-Mediterranean species, P. greeni occurs in India and Sri Lanka and M. asiaticus in Asia. If these three species (or their ancestral forms) dispersed from a centre of origin in Africa, they must have dispersed either before the break up of Pangea or as recently as the Miocene, when land bridges had been established.

African species of the Diaptominae are all endemic, with some 40 species: seven Thermodiaptomus and 33 Tropodiaptomus (Dussart, 1989). This does not include the five new species from southern Africa. Morphological characters suggest that the genus Thermodiaptomus shared a common ancestor with the genus Tropodiaptomus. Species of both genera are confined to more permanent wetlands in warmer areas of Africa and extend into southern Africa in Angola, the Caprivi, the Okavango, the eastern Transvaal and along the warm east coast of Natal as far as the eastern Cape coast. In southern Africa, Tropodiaptomus species are restricted in their distribution, and often confined within narrow geographical limits. One of the most interesting points to arise from the current study, is the realisation that not only Tropodiaptomus species, but most species of Diaptomidae, are very limited in their distribution. Dumont (1980) noted that there is a world-wide tendency for a limited distribution of freshwater calanoids, despite the fact that they may be subject to passive dispersal. Most species appear to lack the ability to colonise new water-bodies, probably because of precise physical and chemical requirements and the availability of a suitable niche. Only five of the 31 diaptomid species from southern Africa, have been recorded as colonising man-made lakes. These are Lovenula falcifera, Metadiaptomus meridianus, M. colonialis, Tropodiaptomus spectabilis and Thermodiaptomus syngenes.

It is unlikely that the Diaptominae are Pan-Ethiopian in origin because there are many Tropodiaptomus species in South America, Australia and New Zealand, New Guinea, Philippines, India, Sri Lanka, China and Madagascar, indicating a Gondwanaian distribution. Their centre of origin may have been the Zaire-Amazon basin with dispersal southwards to the Pacific and northwards to the East, before the break up of Gondwanaland. The remarkable speciation of the genus Tropodiaptomus in Africa is of interest, and subspeciation has been reported by Dumont & Verheye (1984). The diversity, and what appears to be explosive speciation of the genus Tropodiaptomus, may well be related to the warm temperatures of the present interglacial period with accompanying niche boundary changes.

In southern Africa, the diaptomids inhabit three ecological zones. These are a) the high plateau, often semi-arid, with temporary water bodies and wide temperature fluctuations; although of lower altitude, Namibia is also included. b) the freshwater coastal lakes and vleis of the Cape province c) the subtropical belt extending from Angola in the west to Zululand in the east and along the Natal coast. Although some species occur in coastal wetlands, a recent marine origin is excluded for these species because of their obvious close relationships to inland species.

DISTRIBUTION OF THE DIAPTOMIDAE

Distribution of genera and species

Lovenula falcifera ranges from Ethiopia, through East Africa to the high plateau of southern Africa, L. africana is known from lakes of East Africa with high conductivity and extends its range to Lake Malawi and Makgadikgadi pan in Botswana, L. simplex is restricted to the Cape west coast and L. excellens has been recorded only from the Lake Chrissie region in the Transvaal. The centre of origin of the genus Lovenula may have been East Africa, the ancestral form being closely related to either

L. africana or L. falcifera. Morphological evidence for this is the fact that L. falcifera and L. africana both have a well developed endopodite on the male left P5, the other two species showing reduction in this structure. Lovenula species evolved as a result of both dispersal and vicariance. Lovenula excellens appears to have been trapped in an ancient river system which was captured by the Vaal River and L. simplex was probably isolated by the emergence of the Cape Fold mountains at the break up of Gondwanaland. Lovenula falcifera is the most successful and widely dispersed Lovenula species. It occurs in both temporary and permanent waters, has a wide altitudinal range and a wide temperature tolerance, especially for lower temperatures. It has never been recorded from coastal or low-lying water bodies.

Species of the genus Paradiaptomus are found either in coastal vleis of the Cape province or in inland arid areas. They have not been recorded from man-made lakes, which may indicate that they have an obligate diapausal stage or resting egg. Supporting evidence for this comes from Paradiaptomus schultzei which has a wide distribution but has not been recorded from permanent waters. On the other hand, widely distributed species of Lovenula and Metadiaptomus have been recorded as colonizing man-made lakes. The two genera, Lovenula and Paradiaptomus, are closely related and there are strong indications that Paradiaptomus has retained more of the characters of its most recent common ancestor with Lovenula, than has Lovenula. Supporting morphological evidence stems from the derived nature of the mandible, Maxilla 1 and the maxilliped in Lovenula species. Isolation of the western Cape province paradiaptomines is probably related to the emergence of the Cape Fold mountains.

Many species of the genus Metadiaptomus are noted for their tolerance of waters of high salinity. Habitats range from inland waters in semi-arid areas to the coastal vleis of the Cape Province. The genus Metadiaptomus has a wide distribution through Africa and Madagascar, although there are only 11 species - 9 described, and two new species from South Africa. Eight of these 11 species occur in southern Africa. Metadiaptomus meridianus and M. colonialis have a wide distribution in drier areas, extending into East Africa and Ethiopia (M. colonialis). They also colonise man-made impoundments. Other southern African species are restricted in their distribution. Metadiaptomus species may occur as prey species with one of the Lovenula species, probably indicating many years of co-evolution.

The stability and success of the Paradiaptominae may be a result of their ability to survive low, fluctuating, temperatures and semi-arid conditions. Also, the stability of the African continent will have favoured diaptomid survival and it appears that past climates (see above), have not been so severe as to threaten their survival. Species which have a wide distribution e.g.

Lovenula falcifera, Metadiaptomus meridianus and M. colonialis, also have the ability to colonise man-made lakes within their overall range. This is in contrast to the majority of species which are limited in their distribution, often being confined to one water body. One of the most interesting questions to arise with respect to diaptomid distribution, is what governs a species' dependence on a particular water body. Why, in two impoundments on the same river system only a few kilometres apart, should there be two different species e.g. Tropodiaptomus spectabilis in Albert Falls dam and Metadiaptomus meridianus in Lake Midmar (Prof.R.C. Hart, University of Natal, pers. comm.)? Why does Lovenula falcifera co-occur with Metadiaptomus meridianus in Sterkfontein dam and a few kilometres away in Spioenkop dam, co-occur with M. colonialis?

It is not known how many of the rarer diaptomids have become extinct since their collection early this century. The draining and depredation of southern African wetlands must have had an effect. The arid-adapted species, because of their inhospitable habitat (to man), have a decided advantage in terms of long-term survival.

Co-occurrence of species

Hutchinson (1967) noted that it was rare to find more than two calanoid species in one body of freshwater. This holds true for the Diaptomidae in southern Africa where there is no record of more than two species co-occurring. Lovenula species and Paradiaptomus lamellatus often co-occur with a smaller species, usually a species of Metadiaptomus (pp. 41, 46, 54). In some water bodies there is only one diaptomid species which co-exists with a larger cyclopoid species such as Mesocyclops major.

There are very few records of southern African Paradiaptominae co-occurring with Diaptominae e.g. the Caprivi (Lovenula falcifera and Tropodiaptomus sp. nov. B, SMN50727, 08.12.82) and the eastern Transvaal (L. falcifera and Thermodiapomus syngenes, Witbank dam, 02.03.78). Tropodiaptomus sp. nov. D and Thermodiaptomus syngenes have been recorded together (Pongolo floodplain, 1985/86, Quarry ponds, Grahamstown, 1986). These two species are small, total length of females being less than 1.5 mm. Their co-occurrence is a reason for speculation as there is invariably a size difference in co-occurring freshwater calanoid species (Hutchinson, 1967). Also of interest is the fact that the only record of T. syngenes from a natural habitat is from the Pongolo floodplain. There are many records from man-made water bodies, including Hartbeespoort dam, the type locality.

The co-existence of two species of diaptomids follows a definite pattern and this is well illustrated by Lovenula species. They may co-occur with different species of a particular genus (Metadiaptomus in temperate regions, and Tropodiaptomus or Thermodiaptomus in subtropical regions) but they never co-occur with any other Lovenula species and only rarely with Paradiaptomus species (their closest relatives). Paradiaptomus lamellatus co-occurs with Metadiaptomus capensis and M. purcelli in the western Cape province but it is doubtful if it has a predatory role because of its smaller maxillipeds and less specialised mandibles. It is possible that high primary productivity allows food specialisation and reduced competition. The species which co-occur with smaller species are the largest diaptomids in Africa, the four Lovenula species and P. lamellatus.

Diamond (1975) explored the origin of differences in community structure with an hypothesis that, through diffuse competition, the component species of a community are selected and coadjusted in their niches and abundances, so as to fit with each other and resist invaders. Diamond's assembly rules for species communities of birds in New Guinea, apply equally well to freshwater diaptomids. Of all the combinations that can be formed from a group of related species, only certain of these combinations occur in nature. Some pairs of species never coexist, either by themselves or as part of a larger combination. Forbidden combinations do not exist in nature for a number of reasons, one of which is the rule of compatability, which bans the co-existence of closely related species. The recognition of assembly rules may help us to understand competitive effects on the spatial niche limits of a given species, and the puzzling tropical phenomenon of patchy distributions. Competition for resources and the minimize the unutilised resources available to potential invaders (Diamond, 1975).

Dispersal routes

Dispersal routes of fish often give an insight into the dispersal of zooplankton (Dumont & Verheye, 1984) as they may follow the same route. If it is assumed that the genus Tropodiaptomus (and Thermodiaptomus) had as a centre of origin the Zaire-Amazon basin, by what routes would dispersal into southern Africa have taken place? One of the main fish dispersal routes from the Zaire basin is via the upper Zambezi river, along the Zambezi to the east coast, and then south along the coast to the eastern Cape province of South Africa. There is also a minor inland route from the Zambezi to the Limpopo to the Vaal rivers, and another minor route from Zaire to the Cunene river and the Okavango swamp (Bell-Cross, 1982). Comparing the distribution of Tropodiaptomus species in southern Africa (Figs 30, 38) with possible invasion routes, there is a remarkable correlation, as all known Tropodiaptomus species occur within the subtropical area bounded or traversed by fish dispersal routes. The southern limit of their distribution coincides with the known southern limit of subtropical fauna.

The main fish dispersal route from east Africa is either on a direct line from the Rift valley to the Zambezi or a route following the coast to the Zambezi. The inland route would aid dispersal of the Paradiaptominae

The inland route would aid dispersal of the Paradiaptominae as they could have avoided the wetter coastal areas. The inland route would connect them with the Vaal river and hence the Orange river, which must have played a major role in the dispersal of arid-adapted diaptomids.

To summarise: Only in the present decade has interest been shown in copepod biogeography in Africa. As taxonomic revision proceeds, biogeographical knowledge will expand. Distribution has been governed by both vicariance and dispersal. Climatic conditions from Gondwanian times were not unfavourable to diaptomid survival. The two subfamilies of diaptomids probably had different centres of origin, although both were probably Gondwanian. Fish dispersal routes were available to the zooplankton but passive dispersal would have only been effective if niches were available. The rules of assembly of species communities as formulated by Diamond (1975) for birds, apply equally well to diaptomids. There is high endemicity in the African Diaptomidae. The few species which have a wider distribution have the ability to colonise man-made impoundments.

FURTHER STUDY

There are a number of new species of Paradiaptomus, Metadiaptomus and Tropodiaptomus requiring description. Unsorted material, especially at the Albany Museum, needs to be analysed. An attempt should be made to acquire material from Zimbabwe, Angola and Mocambique as very little is known of the freshwater fauna of these areas.

In South Africa, every opportunity should be taken to sample water bodies, especially in remote areas. Serious consideration should be given to enlisting the help of overseas researchers to study the harpacticoids and cyclopoids of southern Africa. A cladistic or phylistic analyses of the diaptomids of Africa should be undertaken, especially for the subfamily Paradiaptominae. Selection of characters would require careful consideration. Knowledge of diaptomid biogeography and evolution in Africa should advance with additional information from southern Africa.

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APPENDIX 1

BIOGRAPHICAL NOTES ON TAXONOMISTS AND COLLECTORS ASSOCIATED WITH FRESHWATER RESEARCH IN SOUTH AFRICA

Names are arranged chronologically. Despite enquiries and literature searches, no information could be found on Carl van Douwe, other than that he lived in Munich.

J. H. Wahlberg (died, 1856)

The study of entomology (and zoology) in South Africa began when pupils of Linnaeus, many of them from Scandinavian countries, came to South Africa to collect specimens. Thunberg (from 1770-03), Sparrmann (from 1772-76) and Walhberg (from 1838-45) sent many hundreds of specimens back to Europe for description and some of these bear names given them by Linnaeus himself. Wahlberg, primarily a hunter, was killed by an elephant in 1856, but before this managed to send 5000 specimens to Sweden to be described by Wallengren (Brown, 1977). The first fresh-water diaptomid to be described from southern Africa, *Lovenula falcifera*, was collected by Wahlberg and described by Lovén in 1845.

Sven Ludwig Lovén (1809-1895)

Lovén was a Swedish zoologist who published on marine fauna, especially hydrozoans, worms, crustaceans and on the distribution of birds in the Northern Hemisphere.

G. Stewardson Brady (1832-1921)

G.S. Brady, M.D., M.R.C.S., D.Sc., LL.D., F.R.S., C.M.Z.S. was professor of Natural History, Armstrong College, Newcastle-upon-Tyne, and consulting physician to the Sunderland Infirmary. He was one of the most famous crustacean taxonomists of all time. He became interested in microcrustaceans from Natal and described some new species, which were sent to him by James Gibson, a magistrate from Richmond, Natal. Brady published his descriptions of South African Entomostraca in the Annals of the Natal Museum in 1908 and 1913.

Georg Osian Sars (1837-1927)

From the age of 24 until his death, the Norwegian scientist, G.O. Sars, published 222 papers on Crustacea. In recognition of his many outstanding contributions, he was elected to 27 societies and organisations. On his eightieth birthday, he was named *princeps carcinologorum*, in a celebratory article (Frey, 1982). Sars made an outstanding contribution with his publications on freshwater microCrustacea from South Africa. Sars (1927) described a number of new species of freshwater Copepoda from the Cape province, and in so doing, laid the foundation of copepodology in southern Africa.

E. Daday (1855-1920)

E. Daday, a Hungarian scientist, worked on the systematics of nearly all groups of aquatic microfauna during his scientific career of over 40 years. About half of his works are studies on Crustacea, mostly microcrustaceans. He described three new species of diaptomids (Diaptomus africanus, D. aethiopicus and D. kilimensis) from the East African lakes, and D. Bouvieri from the Orange River in 1910, which was subsequently put into synonymy with Lovenula falcifera.

Arnold W. Cooper (died, 1926)

A.W. Cooper, J.P., F.R.M.S., was Chairman of Natal Museum Trustees 1904-1913, and on the Board from 1913 until his death in 1926. He was first president of the Natal Naturalists' Association and was a keen photographer and collector. He was a friend of Ernest Warren's and often went on collecting trips with him and is mentioned in early Annual Reports of the Natal Museum as having been involved in collecting invertebrates. In 1906, Cooper described Adiaptomus natalensis, a new species of diaptomid which he had collected in Natal.

William Frederick Purcell (1866-1919)

W.F. Purcell was educated at the South African College in Cape Town, obtained his doctorate at the Berlin University, and was an assistant at the South African Museum in Cape Town from 1896 to 1905 (Lawrence, 1977). He was instrumental in supplying Professor G.O. Sars in Norway with freshwater micro-Crustacea from the Cape Province, so laying the foundation for the first descriptions of South African freshwater Copepoda (also

Cladocera and Ostracoda).

Ernest Warren (1871-circa 1945)

Ernest Warren was born and educated in England and was an outstanding student of the University of London where he was awarded a D.Sc. in 1899. In 1903, he came to Natal as Director of the Natal Museum and from 1910, occupied concurrently the chair of Zoology at the then Natal University College. Warren placed great emphasis on the Museum collections and in 1908, he collected Entomostraca from the Drakensberg, Witzieshoek, and near Harrismith. Brady (1913) described these species but one of the diaptomids was incorrectly identified and is a new Paradiaptomus species. The material was located again in the Natal Museum after 80 years, and was found to be in an excellent state of preservation.

Robert Gurney (1879-1950)

Robert Gurney was a member of a Quaker family from Norfolk, England, and with no financial need to earn a living, he never held a professional zoological position, but worked from his own private laboratory. He was educated at Eton and Oxford and in 1902 published his first paper on decapod larvae and in 1904, his first paper on copepods. The study of decapod larvae and freshwater copepods was to dominate his research for the rest of his life. The crowning achievement of his freshwater work was the three volume monograph on the British Freshwater Copepoda, published by the Ray Society between 1931 and 1933.

He was awarded a D. Sc. by Oxford University in 1929, even before his monographic works appeared (Rice, 1989). Gurney published on the taxonomy of South African freshwater Crustacea in 1904, 1929 and 1931.

Keppel Harcourt Barnard (1887-1964)

K.H. Barnard was born in London, educated in Germany and Cambridge, and came to the South African Museum in Cape Town in 1911. He became one of South Africa's foremost scientists, mainly through his research on marine and freshwater Crustacea. He made extensive collecting expeditions and in 1921, 1923 and 1926 went to Ovamboland, the Kaokoveld and the then, South West Africa. During these expeditions he collected copepods, some of which were later described by Sars as new species. Barnard had the foresight to see that this material was properly curated and it is still available today for study. Barnard's publications on the freshwater crustacean fauna of temporary pools in southern Africa, still stand today as definitive works.

Freidrich Eduard Rühe (1888-1915)

Freidrich Rühe was an outstanding crustacean taxonomist, a member of the so-called Berlin School of Cladocerology at the Zoological Museum. Before his untimely death in World War II, he published 10 papers exclusively on Crustacea. In 1914, Rühe published an account of the freshwater Crustacea collected in the western Cape by the German South Polar expedition of 1901-03. This was a milestone, as it was the first comprehensive account in southern Africa, of crustacean species from a specific locality.

Frederich Kiefer (1897-1985)

Kiefer contributed over 280 publications (including several books) on freeliving freshwater Copepoda. He was born in Karlsruhe (West Germany) and in 1921 at the age of 24, published his first paper on copepods. He revised the diaptomids of the Old World in 1932 and with his other publications on cyclopoids and harpacticoids, established himself as a systematist of repute. He was asked to identify the copepods of the great limnological expeditions which were undertaken between 1927 and 1936 and became involved with South African copepods when asked to identify G.E. Hutchinson's 1929 collection. Kiefer was a schoolteacher for 45 years and did all his work in his spare time. He retired as professor of the Humboldt-Gymnasium at Konstanz in 1962. In 1951 he was awarded an honorary doctorate in natural sciences by Freiburg University. Kiefer's second major research interest was the limnology of Lake Constance (the Bodensee) and in 1963, he became honorary director of the Anstalt für Bodenseeforschung. He was still associated with the institute up to the time of his death.

G. Evelyn Hutchinson

G.E. Hutchinson, Emeritus Professor of Zoology at Yale University, U.S.A., was born in England in 1903. From 1926-28 he was senior lecturer in Zoology at the University of the Witwatersrand, Johannesburg. During his stay in South Africa he collected data on freshwater organisms which resulted in the first ever survey of pans and inland waters of South Africa (Hutchinson _et al_., 1932). Professor Hutchinson is a renowned limnologist, the recipient of many awards and honours. He has maintained his links with South Africa and has always been most supportive and helpful to local zoologists.

APPENDIX 2

GAZETTEER

(Fig 1, Transparency)

Cape province: CP. Natal: NTL. Orange Free State: OFS. Transvaal: TVL. Cape of Good Hope Nature Reserve: CGHNR

Albert Falls dam, NTL	30° 25' S; 30° 24' E
Aliwal North, CP	30° 40' S; 26° 40' E
Apies & Crocodile rivers, TVL	25° 50' S; 28° 10' E
Beaufort West, CP	32° 20' S; 22° 35'E
Betty's Bay, CP	34° 22' S; 18° 55'E
Belfast, TVL	25° 40' S; 30° 03' E
Bellville, Univ. W. Cape, CP	33° 52' S; 18° 38' E
Bergvliet, Constantia, CP	34° 03' S; 18° 27' E
Bhangazi, lake, NTL	28° 08' S; 32° 35' E
Boesmanland, Namibia	30° 15' S; 19° 00' E
Bokkekraal, CP	33° 40' S; 19° 24' E
Bospoort dam, TVL	25° 33' S; 27° 21' E
Brak river airfield, CP	32° 30' S; 20° 43' E
Bronkhorstspruit dam, TVL	25° 53' S; 28° 43' E
Buffalo river, below Bridledrift, CP	32° 59' S; 27° 43' E
Buffalo river, below Laing dam, CP	32° 58' S; 27° 29' E
Buffelspoort dam, TVL	25° 46' S; 27° 29' E
Bulwer, NTL	29° 48' S; 29° 46' E
Bunyonyi, lake, Uganda	1° 20' S; 29° 50' E
Bushmanland, Namibia	30° 15' S; 19° 00' E
Cape flats, CP	34° 04' S; 18° 38' E
Caprivi, Namibia	18° 05' S; 21° 45' E

Chinde, Moçambique	18° 40' S; 36° 30' E
Chrissie, lake, TVL	26° 20' S; 30° 12' E
Courans drift, Sundays river, CP	33° 30' S; 25° 45' E
De Doorns, CP	33° 29' S; 19° 40' E
Deelpan, TVL	29° 11' S; 25° 45' E
De Hoop vlei, CP	34° 27' S; 20° 23' E
Dewetsdorp, OFS	29° 35' S; 26° 40' E
D.F. Malan airport, CP	33° 58' S; 18° 37' E
Diep river, Milnerton, CP	33° 52' S; 18° 30' E
Diepte Gatt, CP	34° 21' S; 19° 20' E
Dodoma, Tanganyika	6° 00' S; 35° 40' E
Driehoek, CP	32° 27' S; 19° 10' E
Faure, CP	34° 02' S; 18° 45' E
Flamingo pan, Welkom, OFS	27° 55' S; 26° 45' E
Frauenstein farm, Neudamm, Namibia	22° 22' S; 17° 19' E
Fredericksrust, Okahandja, Namibia	21° 59' S; 16° 53' E
Gamsberg pass, NW Windhoek, Namibia	23° 16' S; 16° 15' E
Garies, Namaqualand, CP	30° 35' S; 17° 59' E
Gautscha pan, Boesmanland, Namibia	19° 00' S; 20° 00' E
Gillidam, CP	34° 18' S; 18° 26' E
Gouriqua, CP	34° 23' S; 21° 45' E
Gouritsrivier, CP	33° 40' S; 21° 40' E
Grahamstown, CP	33° 20' S; 26° 32' E
Great Berg river, CP	32° 53' S; 18° 15' E
Great Bruckkarossberg, Namibia	27° 15' S; 18° 45' E
Great Fish river, Cookhouse, CP	32° 44' S; 25° 48' E
Great Fish river, Dassiedeur, CP	32° 28' S; 25° 46' E
Great Fish river, Drennan, CP	32° 26' S; 25° 44' E

Great Fish river, Elandsdrift, CP	32^{o} 31' S; 25^{o} 45' E
Great Fish river, railway bridge, CP	32^{o} 31' S; 25^{o} 45' E
Green Point common, CP	33^{o} 54' S; 18^{o} 25' E
Greyvenstein dam, TVL	29^{o} 04' S; 26^{o} 09' E
Grootfontein, CP	31^{o} 28' S; 25^{o} 05' E
Grootfontein, Namibia	19^{o} 30 S; 18^{o} 10' E
Groot Hagel kraal, CP	34^{o} 40' S; 19^{o} 35' E
Groot Rondevlei, CP	34^{o} 14' S; 18^{o} 23' E
Groot Witvlei, CP	34^{o} 22' S; 18^{o} 53' E
Hardap dam, Namibia	24^{o} 30' S; 17^{o} 50' E
Harrismith, OFS	29^{o} 20' S; 29^{o} 08' E
Hartbeespoort dam, TVL	25^{o} 45' S; 27^{o} 40' E
Hora Keloli, Ethiopia	7^{o} 30' N; 38^{o} 30' E
Kamanjab, Kaokoveld, Namibia	19^{o} 40' S; 14^{o} 50' E
Kamieskroon, CP	30^{o} 27' S; 17^{o} 57' E
Kenilworth, CP	33^{o} 59' S; 18^{o} 29' E
Kharu-Gaiseb, salt stream, Namibia	19^{o} 52' S; 13^{o} 10' E
Kilimanjaro, Kenya	3^{o} 00' S; 37^{o} 30' E
Kimberley, CP	28^{o} 45' S; 24^{o} 45' E
King Williams Town, CP	32^{o} 53' S; 27^{o} 24' E
Klaasjagersberg, CGHNR, CP	34^{o} 14' S; 18^{o} 25' E
Knysna, CP	34^{o} 05' S; 23^{o} 05' E
Kuibis, Namibia	26^{o} 40' S; 16^{o} 50' E
Kuilsrivier, CP	34^{o} 02' S; 18^{o} 41' E
Leeupan, OFS	29^{o} 09' S; 25^{o} 43' E
Liambesi, lake, Namibia	17^{o} 55' S; 24^{o} 20' E
Lindeque's drift, TVL	26^{o} 45' S; 27^{o} 32' E
Lindleyspoort dam, TVL	25^{o} 29' S; 26^{o} 04' E

Lobatsi, Bophuthatswana	25^{o} 30' S; 25^{o} 35' E
Loskop dam, TVL	25^{o} 25' S; 29^{o} 21' E
Mahlabatini, NTL	28^{o} 14' S; 31^{o} 30' E
Makgadikgadi pan, Botswana	21^{o} 00' S; 26^{o} 00' E
Mala Mala Game Reserve, TVL	24^{o} 48' S; 31^{o} 32' E
Maltahohoe, Namibia	24^{o} 51' S; 16^{o} 59' E
Marico river, TVL	25^{o} 10' S; 26^{o} 25' E
Mazelspoort dam, OFS	29^{o} 02' S; 26^{o} 25' E
Melkbos pan, CP	34^{o} 43' S; 19^{o} 45' E
Middleburg, TVL	25^{o} 48' S; 29^{o} 27' E
Midmar dam, NTL	29^{o} 30' S; 30^{o} 12' E
Molopo river, Riemvasmaak, CP	28^{o} 28' S; 20^{o} 20' E
Molteno, near Beaufort W., CP	31^{o} 23' S; 26^{o} 20' E
Montague, CP	33^{o} 50' S; 20^{o} 09' E
Nagle dam, NTL	30^{o} 37' S; 30^{o} 37' E
Ndumu Game Reserve, NTL	26^{o} 55' S; 32^{o} 15' E
Neudamm, E. Windhoek, Namibia	22^{o} 30' S; 17^{o} 20' E
Nkwifa, NTL	30^{0} 20' S; 30^{o} 37' E
Nogatsaa waterhole, E. Chobe, Botswana	18^{o} 35' S; 24^{o} 15' E
Nooitgedacht dam, TVL	25^{o} 58' S; 30^{o} 05' E
Noordhoek, CP	34^{o} 07' S; 18^{o} 23' E
Nuweleeurivierdam, OFS	29^{o} 20' S; 27^{o} 08' E
Olifantsnek dam, TVL	25°47'S; 27°15'E
Omatako dam, Namibia	21^{o} 11' S; 17^{o} 12' E
Ombika (Onambeke), Namibia	19^{o} 20' S; 15^{o} 55' E
Ondangua, Namibia	17^{o} 55' S; 16^{o} 00' E
Ongka, Namibia	17^{o} 35' S; 15^{o} 50' E
Outdshoorn, CP	33^{o} 38' S; 22^{o} 12' E

Paardevlei, CP	34^{O} 05' S; 18^{O} 49' E
Palmiet river, Arieskraal, CP	34^{O} 13' S; 18^{O} 58' E
Peter's bog and farm, CP	34^{O} 37' S; 20^{O} 04' E
Pitshane, Botswana	25^{O} 10' S; 25^{O} 30' E
P.K. le Roux dam, CP	30^{O} 35' S; 24^{O} 50' E
Platdrif, CP	33^{O} 40' S; 19^{O} 18' E
Plumtree, Zimbabwe	20^{O} 30' S; 27^{O} 40' E
Pongolo river, Mhlolo pan, NTL	27^{O} 15' S; 32^{O} 15' E
Premier mine dam, TVL	25^{O} 50' S; 28^{O} 52' E
Quaggaplaat, CP	32^{O} 32' S; 20^{O} 57 E
Richmond, NTL	29^{O} 53' S; 30^{O} 17' E
Rietvlei dam, TVL	25^{O} 52' S; 28^{O} 16' E
Rondeberg, CP	33^{O} 26' S; 18^{O} 16' E
Roodeplaat dam, TVL	23^{O} 58' S; 27^{O} 43' E
Rooipan, CP	33^{O} 20' S; 18^{O} 10' E
Roussouwskop, CGHNR, CP	34^{O} 15' S; 18^{O} 26' E
Rukwa, lake, Tanzania	7^{O} 30' S; 32^{O} 30' E
Rust der Winter dam, TVL	25^{O} 14' S; 28^{O} 31' E
Seeheim, Namibia	26^{O} 45' S; 17^{O} 48' E
Simonstown, Kleinplaats W., CP	34^{O} 10' S; 18^{O} 23' E
Sirkelsvlei, CP	34^{O} 16' S; 18^{O} 25' E
Soetendalsvlei, CP	34^{O} 44' S; 19^{O} 58' E
Sowa pan, Makgadikgadi, Botswana	20^{O} 10' S; 26^{O} 10' E
Spioenkop dam, NTL	28^{O} 40' S; 29^{O} 30' E
Spoonbill pond, near Stellenbosch, CP	33^{O} 59' S; 18^{O} 55' E
Steinkopf, small Namaland, CP	29^{O} 15' S; 17^{O} 45' E
Stellenbosch, CP	33^{O} 53' S; 18^{O} 53' E
Sterkfontein dam, TVL	28^{O} 35' S; 29^{O} 04' E

Stormberg, CP	31° 25' S; 26° 40' E
Taaiboskraal, Namaqualand, CP	29° 48' S; 17° 50' E
Tamsu (Tamansu), Namibia	18° 35' S; 20° 36' E
Tjokwe pool, Boesmanland, Namibia	19° 00' S; 20° 00' E
Touwsrivier, CP	33° 20' S; 20° 03' E
Tweespruit dam, TVL	29° 14' S; 27° 04' E
Ukualonkathi, Ovamboland, Namibia	17° 45' S; 15° 40' E
Ukualuthi, Ovamboland, Namibia	17° 40' S; 15° 30' E
Umfolozi Game Reserve, NTL	28° 20' S; 31° 50' E
Vaal river and catchment, TVL	26° 45' S; 27° 30' E
Valkenberg vlei, CP	33° 52' S; 18° 28' E
Van Reenen, OFS	28° 21' S; 29° 22' E
Van Rhijn dam, Namibia	22° 00' S; 17° 00' E
Varkensvlei, CP	34° 49' S; 20° 01' E
Vermont pan, CP	34° 25' S; 19° 08' E
Vernon Crookes' Nature Reserve, NTL	30° 20' S; 30° 39' E
Verrekyker, Tulbagh, CP	33° 27' S; 19° 10' E
Von Bach dam, Namibia	22° 00' S; 16° 58' E
Vryburg, CP	26° 58' S; 24° 45' E
Wagendrift dam, NTL	29° 02' S; 29° 49' E
Waterberg Plato Park, Namibia	17° 15' S; 20° 30' E
Welbedacht dam, OFS	29° 54' S; 26° 52' E
White hill pan, Hwange, Zimbabwe	18° 20' S; 26° 35' E
Wiesdrift, CP	34° 40' S; 19° 55' E
Windhoek, Namibia	22° 35' S; 17° 05' E
Witbank dam, TVL	25° 53' S; 29° 18' E
Witmos, CP	32° 33' S; 25° 45' E
Wolmaranstad, TVL	27° 12' S; 25° 59' E

Yserfontein salt pan, CP 33° 20' S; 18° 09' E