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# AFROTROPICAL *CULICOIDES: C. (AVARITIA) MIOMBO* SP. NOV., A WIDESPREAD SPECIES CLOSELY ALLIED TO *C. (A.) IMICOLA* KIEFFER, 1913 (DIPTERA: CERATOPOGONIDAE)

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ABSTRACT

MEISWINKEL, R., 1991. Afrotropical *Culicoides: C. (Avaritia) miombo* sp. nov., a widespread species closely allied to *C. (A.) imicola* Kieffer, 1913 (Diptera: Ceratopogonidae). *Onderstepoort Journal of Veterinary Research*, 58, 155–170 (1991)

*Culicoides (Avaritia) miombo* sp. nov. is described and illustrated from both sexes collected in northern Malawi. Two references in the literature have previously referred to this new species as either *C. brosseti* Vattier & Adam or *C. imicola* Kieffer. A further 4 references are discussed that most likely deal with *C. miombo* sp. nov. and not *C. brosseti. C. miombo* sp. nov. is apparently widespread in subtropical and tropical Africa and is now recorded from Zimbabwe, Botswana, South Africa, Nigeria and the Ivory Coast. There are also probable records from Angola, Burkina Faso, Zambia and eastern Madagascar. On the African mainland, both north and south of the equator, the pattern of distribution of *C. miombo* sp. nov. correlates strongly with that of drier Guineo-Congolian rainforest, and Sudanian and Zambezian woodlands, the latter known as miombo in southern Africa. These phytochoria and associated biota are sensitive to frost and experience relatively high temperatures and rainfall—3 factors that appear to limit the distribution of *C. miombo* sp. nov. to north of the 20–22 °C mean annual temperature isotherms in southern Africa. The new species is a member of the Imicola group which consists of 6 species confined to the Afrotropical (including Madagascar), Oriental and eastern Palaearctic regions. One species has in historic times spread to Australia. The worldwide distribution of each species is briefly discussed. It is suggested that the Imicola and Orientalis groups are separate lineages within the subgenus *Avaritia. Culicoides miombo* sp. nov. is compared with its closest African congeners *C. imicola, C. pseudopallidipennis* Clastrier and *C. bolitinos* Meiswinkel; 15 character states are used to separate *C. miombo* sp. nov. and *C. imicola.* The female antennal and palpal measurements of *C. miombo* sp. nov. are subjected to statistical analysis to highlight their taxonomic usefulness. The larval habitat of *C. miombo* sp. nov. is unknown.

## INTRODUCTION

This is the 4th in a series of papers dealing with the systematics of those *Culicoides* species belonging to the subgenus *Avaritia* Fox, 1955 in the Afrotropical region (Meiswinkel, 1987, 1989a, 1989b). These studies concern themselves mainly with the southern African fauna but are intended to form the basis of a future regional revision.

Worldwide the subgenus *Avaritia* comprises 60–70 species which fall into more than 10 discrete species groups (personal observations). The greatest expansion of *Avaritia* is tropical with more than half the world species found in the Afrotropical and Oriental regions. A number of species from the latter region also extend into the eastern Palaearctic (Kitaoka, 1985) and Australia (Wirth & Dyce, 1985). South America and the more temperate northern regions of north America, Europe and Asia are relatively depauperate in *Avaritia* species, possessing only the small Pusillus, Chiopterus, Andicola and very distinctive Obsoletus groups. Little is known about the diversity of the subgenus *Avaritia* in the Malagasy subregion.

One of the 10 groups that comprises the subgenus *Avaritia* is the Imicola group, which is endemic to the Afrotropical, Oriental and eastern Palaearctic regions. Its most noteworthy member is *C. imicola,* an important vector of the arboviruses of bluetongue in sheep and African horsesickness (Du Toit, 1944). This species also occurs outside the African continent, being found in some countries on the southern, northern and eastern sides of the Mediterranean, in the Middle East and India, and, going still further east, has recently been recorded from Laos (Howarth, 1985), Thailand and Vietnam (Wirth & Hubert, 1989). *Culicoides imicola* is also known from the islands of Madagascar and Reunion (Meiswinkel, 1989a).

It is becoming increasingly apparent, however, that *C. imicola* is only one of a discrete group of at least 6 allied taxa in Africa alone, hereafter referred to as the Imicola group. To date only 3 of these species have been named i.e. *C. imicola* Kieffer, 1913, *C. pseudopallidipennis* Clastrier, 1958 and *C. bolitinos* Meiswinkel, 1989. Outside the Afrotropical region a further 2 species of the Imicola group are found i.e. *C. brevitarsis* Kieffer, 1917, and *C. nudipalpis* Delfinado, 1961. The former is very widespread, occurring from India through the Oriental region and up into the eastern Palaearctic. In historic times *C. brevitarsis* has also established itself in Australia where its predilection for the dung of the water buffalo *(Bubalus bubalis)* and cattle as a larval habitat has seen it spread widely on that continent (Dyce, 1982). It also displays quite some importance as a vector of bluetongue (St. George & Muller, 1984) and Akabane viruses (Muller, Standfast, St George & Cybinski, 1982; Murray, 1987; Murray & Nix, 1987). I consider *Culicoides brevitarsis* to be the sister-species of the African *C. bolitinos.* The larvae of the latter species also develop exclusively in the dung of large herbivores such as the African buffalo *(Syncerus caffer)*, the blue wildebeest *(Connochaetes taurinus)* and cattle (Meiswinkel, 1989a). Little, however, is known about *C. nudipalpis,* both taxonomically and biologically. It in turn does appear to be the sister-species of *C. imicola,* and is at present only known to occur east of Huxley's modification of the Wallace line (Rosen, 1988) in Indonesia and the Philippines (Wirth & Hubert, 1989).

In a study on the *Culicoides* of Southeast Asia (Wirth & Hubert, 1989) 4 of the above-mentioned species i.e. *C. imicola, C. pseudopallidipennis, C. brevitarsis* and *C. nudipalpis* were placed within the Orientalis group of the subgenus *Avaritia.* More recently, while reviewing the *Culicoides* of Kenya, Glick (1990) contradicted this stance in not recognizing *Avaritia* and instead used the Imicola group and placed in it all species that rightly belong in the subgenus *Avaritia.* I disagree with both sets of opinions as their respective groups are clearly polyphyletic, and together contain 24 species that represent at least 8 different lineages within the subgenus *Avaritia.* I suggest rather that the Orientalis and Imicola groups be considered 2 separate lines within *Avaritia* and that each line has representatives in both the Afrotropical and Oriental regions. However, only in

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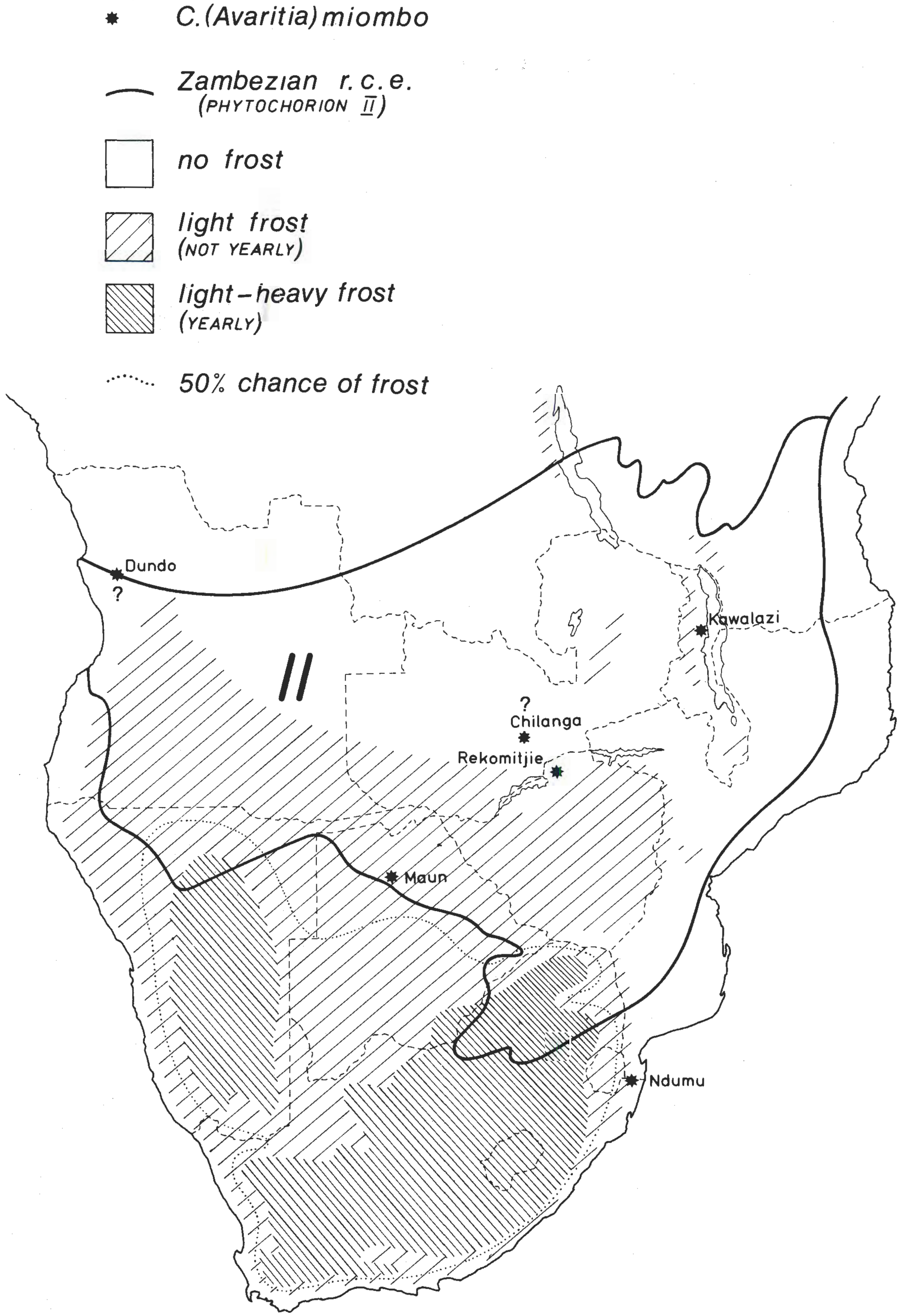


FIG. 1 Map of southern Africa detailing the extent of the Zambezian regional centre of endemism (r.c.e.) (phytochorion II), the prevalence of frost, and the localities where *C. (Avaritia) miombo* sp. nov. has been collected

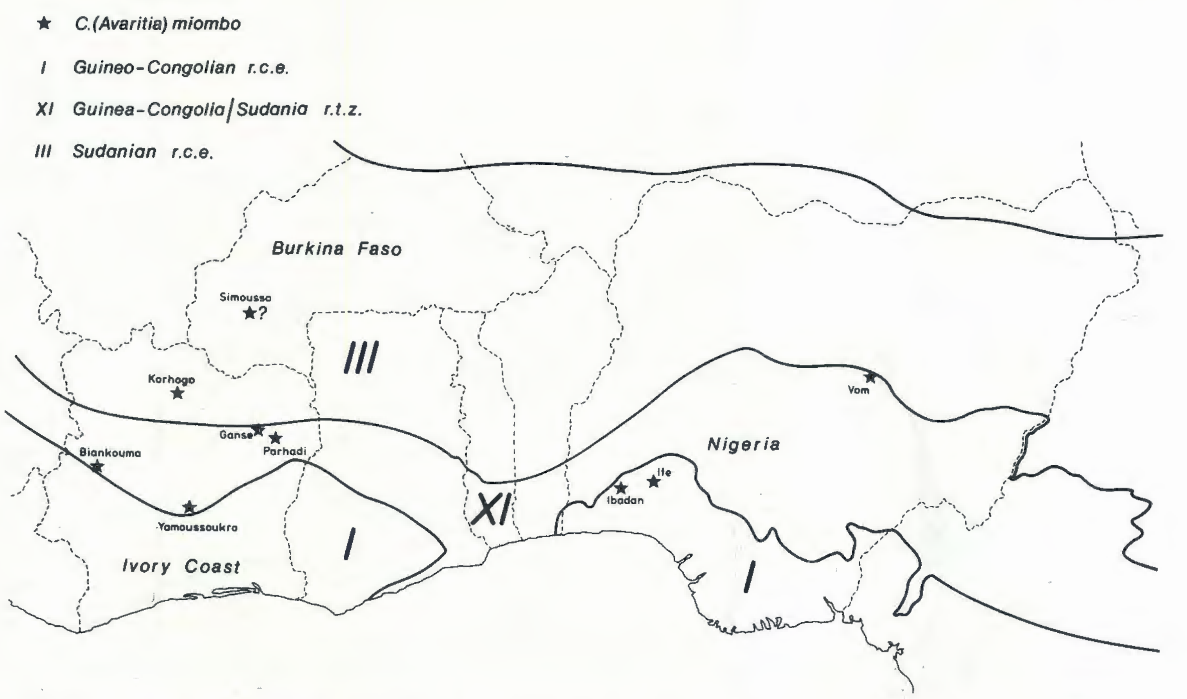


FIG. 2 Map of western Africa detailing the extent of the Guineo-Congolian and the Sudanian regional centres of endemism (phytochoria I and III); the Guinea-Congolia/Sudania regional transition zone (r.t.z.) (phytochorion XI), and the localities where *C. (Avaritia) miombo* sp. nov. has been collected

future studies, once further new species of the Imicola group have been described, will the respective monophylies of the Imicola and Orientalis groups be more fully explored.

In this paper some emphasis is placed on a numerical description of *C. miombo* sp. nov. so as to delineate more clearly the differences that exist between it and 2 of its congeners *C. imicola* and *C. bolitinos*. The new species is introduced with a brief description of the floristic composition and geographical extent of wetter Zambezian miombo woodland south of the equator and drier Guineo-Congolian rainforest and Sudanian woodland north of the equator. This is done to indicate the basic climatic preferences of *C. miombo* sp. nov. and, secondly, to initiate the exploration and definition of the ecozone preferences of various *Culicoides* species in Africa. It is the sympatric occurrence of various biota that will produce the patterns needed to elucidate the biogeography of this genus, a subject which has been almost wholly neglected in the region. Finally, the detailed mapping and description of the type locality of *C. miombo* sp. nov. is meant also to serve as a basis for the future description of other Ceratopogonidae from north-eastern Malawi.

## MATERIALS AND METHODS

All material of *C. miombo* sp. nov. examined was collected either by light- or truck-trap. Light-trapping was done using a commercially available modified New Jersey-type downdraught trap equipped with an 8-watt U.V. tube. Truck-trapping involved the use of a trap based on the design of Dyce, Standfast & Kay (1972). The descriptive format, style of illustration and ratios used are exactly as set out in Meiswinkel (1989a). Measurements are given in µm and were made at 400 × magnification.

### Statistical analysis

The lengths of each antennal and palpal segment of *C. miombo* were analysed by means of the parametric completely random design utilizing 25 randomly chosen measurements for each segment. Bartlett's test showed all variances to be homogeneous while comparisons of means were done using Bonferroni's multiple comparison test. For comparison of *C. miombo* to *C. imicola* and *C. bolitinos* the relevant numerical data for the latter 2 species were drawn directly from Meiswinkel (1989a). It must be noted, however, that in Meiswinkel (1989a) a 4 % error occurred during the transformation of the raw measurements data into µm. This has been corrected in Tables 5 and 6 of the present study. Finally the mean lengths for the antennal and palpal segments given in these tables will be seen to differ fractionally from those given in the text; this is because the latter means are derived from the measurement of many more (68–70) specimens.

## RESULTS

Africa, including Madagascar, is divided into 20 major phytochoria, which are further subdivided into 80 major vegetation units (White, 1983). *C. miombo* sp. nov. is for the present recorded from or very near to 14 of these units which fall into 6 of the major phytochoria; these 14 units form part of forest, forest transitions, woodlands and woodland transition zones. These phytochoria and vegetation zones are listed in Table 1 and then briefly discussed in the text to indicate the broad climatic preferences of *C. miombo* sp. nov. This is followed by a more detailed description of the topography, vegetation and climate of the type locality of the new species in Malawi.

### Phytochoria with which *C. miombo* sp. nov. is associated

The type locality of *C. miombo* sp. nov. in Malawi is dominated by *Brachystegia* woodland (Leguminosae: Caesalpinioideae) and falls into the mapping unit 25 of White (1983) classified as 'wetter Zambezian miombo woodland'. Wetter miombo, however, is only 1 of 20 vegetation types comprising the Zambezian regional centre of endemism. For a detailed account see White (1983).

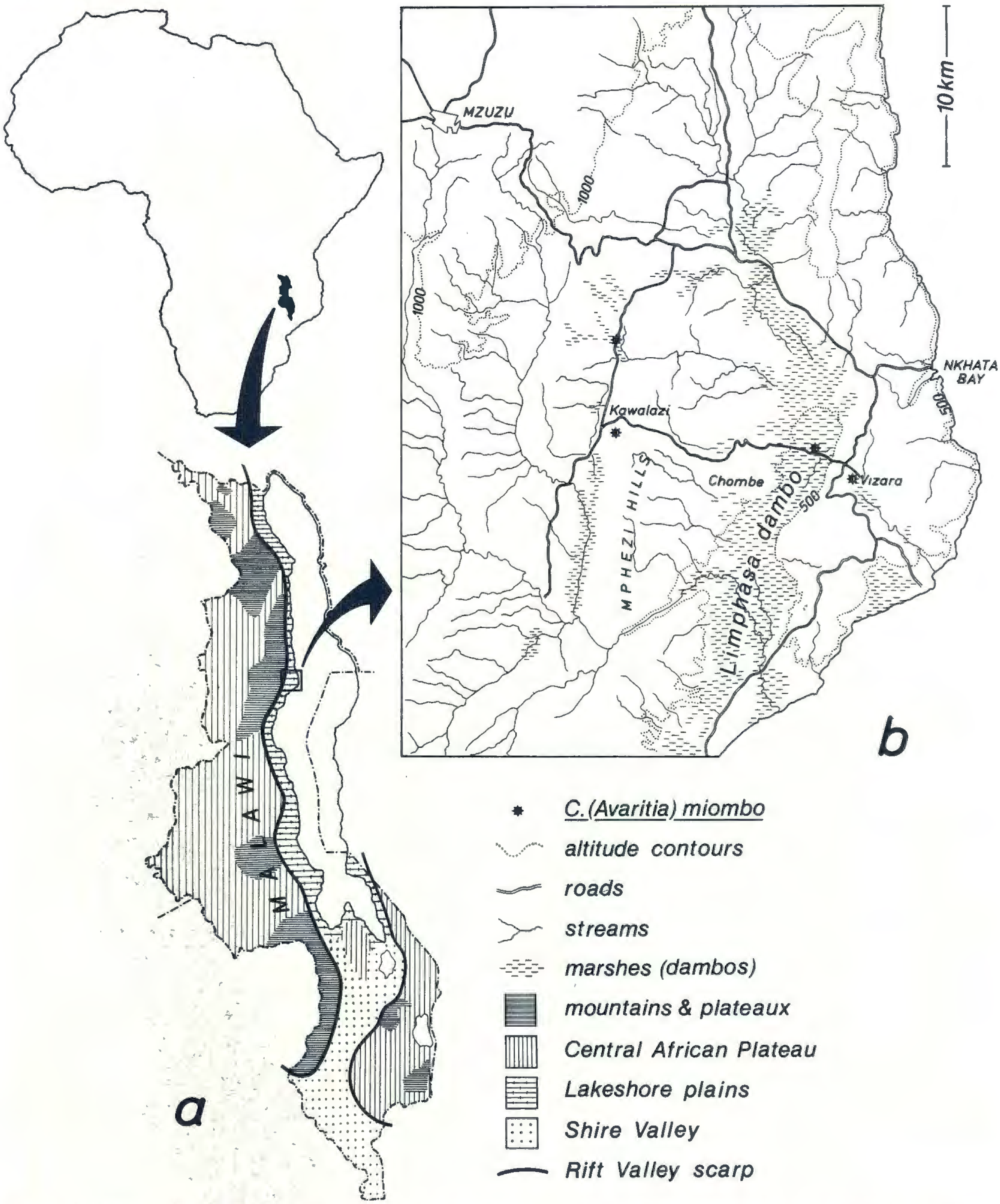


FIG. 3 (a) Map of Malawi showing 5 major landscape types, and (b) in greater detail, the topography of the type locality of *C. (Avaritia) miombo* sp. nov.

As to climate, almost the entire Zambezian region falls within the tropical summer rainfall zone. There is a single rainy season, chiefly from November to April with rainfall being between 500–1 400 mm/annum. Precipitation in general decreases from north to south but there are pronounced regional variations. Mean annual temperatures range from 18–24 °C. There are 3 seasons: 1. Wet season, November–April where rain falls mostly as thunderstorms and heavy showers, with a fair amount of sunshine. 2. Cool season, May–August where day temperatures are moderately high with continuous sunshine; night temperatures are low and ground frosts may occur in sheltered valleys. 3. Hot season, September–November where temperatures and atmospheric humidity progressively increase until the oppressive feeling in the air is relieved by the advent of rains.

On the African mainland south of the equator, *C. miombo* sp. nov. has been positively identified from 3 other localities i.e. Rekomitjie (16° 08′ S, 29° 24′

TABLE 1 List of 16 localities from which *C. (Avaritia) miombo* sp. nov. has been recorded in Africa and Madagascar with details of associated major phytochorion, vegetation unit, altitude, mean annual temperature, rainfall and incidence of frost taken from White (1983)

| Locality | Co-ordinates | Altitude (a.s.l.) | Major phytochorion | Vegetation unit | Mean annual temperature | Rainfall (mm per annum) | Frost/no frost |
|---|---|---|---|---|---|---|---|
| Ibadan, NIGERIA | 7° 17′ N, 3° 30′ E | < 500 m | Transition between Guineo-Congolian regional centre of endemism (I) and the Sudanian regional centre of endemism (III) | 2 | 26 °C | 1 200 | No frost |
| Ife, NIGERIA | 7° 28′ N, 4° 34′ E | < 500 m | | 2 | | | |
| Vom, NIGERIA | 9° 45′ N, 8° 46′ E | 1 220 m | (III) | 11a, 12 27,29a 32 | 24–28 °C | 1 400 | No frost |
| Simousso, BURKINA FASO | 11° 01′ N, 4° 03′ W | < 500 m | (III) | 27, 29a | 24–28 °C | 1 400 | No frost |
| Parhadi, IVORY COAST | 8° 27′ N, 3° 29′ W | 300–400 m | (III) | 11a | 25,5° C | 1 100 | No frost |
| Ganse, IVORY COAST | 8° 35′ N, 3° 54′ W | 100–200 m | (III) | 11a | 25,5 °C | 1 100 | No frost |
| Korhogo, IVORY COAST | 9° 27′ N, 5° 39′ W | 300–400 m | (III) | 27 | 26 °C | 1 300–1 400 | No frost |
| Yamoussoukro, IVORY COAST | 6° 49′ N, 5° 15′ W | 200–300 m | Guinea-Congolia/Sudania regional transition zone (XI) | 2,11a | 25,5 °C | 1 100–1 200 | No frost |
| Biankouma, IVORY COAST | 7° 45′ N, 7° 18′ W | 500–700 m | (XI) | 11a | 24,5 °C | 1 400–1 500 | No frost |
| Dundo, ANGOLA | 9° 46 ′ S, 14° 42′ E | < 500 m | Guineo-Congolia/Zambezia regional transition zone (X) | 29c | 21 °C | 700–900 | No frost |
| Kawalazi and Limphasa, MALAWI | 11° 37′ S, 34° 06′ E | 600–700 m | Zambezian regional centre of endemism (II) | 25 | 18–24 °C | 1 400 | Frost localized to above 1 200 m altitude and in depressions |
| Chilanga, ZAMBIA | 15° 54′ S, 28° 35′ E | 1 000 m | (II) | 26, 28 29c | 18–24 °C | 1 400 | Frost localized to above 1 200 m altitude and in depressions |
| Rekomitjie, ZIMBABWE | 16° 08′ S, 29° 24′ E | 200–1 000 m | (II) | 26,28 | 18–24 °C | 1 400 | Frost localized to above 1 200 m altitude and in depressions |
| Maun, BOTSWANA | 20° 01′ S, 23° 25′ E | 500–1 000 m | (II) | 28,35a | 18–24 °C | 1 400 | Frost localized to above 1 200 m altitude and in depressions |
| Ndumu, SOUTH AFRICA | 26° 55′ S, 32° 15′ E | 0–100 m | Tongaland-Pondoland regional mosaic (XV) of undifferentiated woodland in transition to bushland: 20% of woody plants are Zambezian linking species | 29e, 16c | 22 °C | 600–1 000 | No frost |
| Manakara, MADAGASCAR. | 22° 06′ S, 48° 00′ W | 0–100 m | East Malagasy regional centre of endemism (XIX) of lowland rain forest and secondary grassland | 11b | 23–25 °C | 2 000–3 000 | No frost |

E), north-western Zimbabwe; Maun (20° 01′ S, 23° 25′ E), northern Botswana, and Ndumu (26° 55′ S, 32° 15′ E), northern Natal, South Africa. The records of *C. brosseti* from Dundo (9° 46′ S, 14° 42′ E), north-western Angola by Kremer (1972) and the species labelled as A-1 and A-10 by Kitaoka & Zulu (1990) from Chilanga (15° 54′ S, 28° 35′ E), Zambia in all probability refer to *C. miombo* sp. nov. (Fig. 1).

North of the equator *C. miombo* sp. nov. has been recorded as *C. imicola* from Ife, Nigeria (Kitaoka, Kaneko & Shinonaga, 1984), and as *C. brosseti* Vat-

TABLE 2 Mean lengths (μm) of segments and mean distribution of sensillae on the female and male antennae of *C. (A.) miombo* sp. nov.

| *C. miombo* | Antennal segments | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | III | IV | V | VI | VII | VIII | IX | X | XI | XII | XIII | XIV | XV |
| Female | | | | | | | | | | | | | |
| Sens. coeloconica | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| Sens. chaetica | 5 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 0 | 0 | 0 | 0 | 0 |
| Sens. trichodea (blunt-tipped) | LL | LLc | LLc | LLc | LLc | LLc | LLc | LLc | — | — | — | — | — |
| Lengths of segments | 36,8 | 23,3 | 23,6 | 25,7 | 28,1 | 27,3 | 28,2 | 32,7 | 44,6 | 46,0 | 48,4 | 49,5 | 83,3 |
| Male | | | | | | | | | | | | | |
| Sens. coeloconica | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 2 |
| Sens. chaetica | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 2 | 0 |
| Sens. trichodea (blunt-tipped) | LL | LLc | LLc | LLc | Lc | Lc | Lc | c | — | — | — | — | — |
| Lengths of segments | 71,3 | 36,3 | 37,5 | 37,5 | 37,5 | 37,5 | 37,5 | 37,6 | 37,5 | 36,3 | 96,3 | 75,0 | 92,5 |

tier and Adam, 1966 from Ibadan and Vom, Nigeria (Boorman & Dipeolu, 1979). The record of *C. brosseti* from Simousso, Burkina Faso (Cornet, 1969) quite likely also refers to *C. miombo* sp. nov. It is now recorded for the first time from 5 localities in the Ivory Coast, i.e. Parhadi (8° 27′ N, 3° 29′ W), Ganse (8° 35′ N, 3° 54′ W), Korhogo (9° 27′ N, 5° 39′ W), Yamoussoukro (6° 49′ N, 5° 15′ W) and Biankouma (7° 45′ N, 7° 18′ W).

There are important parallels between the Sudanian phytochorion north of the equator and the Zambezian one south of the equator. Their climates are broadly similar especially with regard to rainfall. In the Sudanian, however, temperatures are appreciably higher (24–28 °C) and nearly constant year-round while frost is unknown; the dry season is more severe. Floristically, Sudanian *Isoberlinia* woodland (units 27, 30 and 32) can be regarded as an impoverished variant of miombo woodland.

Off the African mainland the single record of *C. brosetti* (Kremer & Brunhes, 1972) from Manakara, Madagascar is quite likely a misidentification of *C. miombo*. Manakara (22° 06′ S, 48° 00′ E) is on the eastern coast, an area that falls into White's major phytochoria XIX (the East Malagasy regional centre of endemism) and in vegetation unit 11b, a mosaic of lowland rainforest and secondary grassland.

Table 1 lists all these localities and briefly indicates the vegetation unit, alitude, mean annual temperature, rainfall and incidence of frost at these localities in western and southern Africa. Fig. 1 and 2 map the localities and the phytochoria they occupy. Localities accompanied by a question mark are those from which I have not seen specimens of *C. miombo*.

**Type locality (Fig. 3)**

*Description of the lakeshore plains of Malawi*

Malawi is a small landlocked country that lies partially in the southernmost extension of the great African rift valley. Where the rift runs through Malawi it is 40–90 km wide but much of it is under Lake Malawi (570 km long × 80 km wide). Broadly speaking Malawi comprises 5 major landscape types (Fig. 3a).

The type series of *C. miombo* sp. nov. consists of 142 specimens (74♀♀ 68♂♂) collected at Kawalazi (11° 37′ S, 34° 06′ E) and Limphasa (11° 38′ S, 34° 13′ E) in north-eastern Malawi (Fig. 3b). These locales are 12 km apart and lie 600–700 m a.s.l. between the towns of higher-lying Mzuzu (1 235 m; 11° 27′ S, 34° 01′ E) and lower-lying Nkhata Bay (481 m; 11° 36′ S, 34° 18′ E). This hot lowland area, with a mean maximum temperature in November of 35 °C, lies in the rift valley trough, known as the lakeshore plains; the trough runs along most of the central length of Malawi. The plains, in which isolated hills frequently arise, vary in extent but may be as wide as 25 km. In these wider sections, such as between Kawalazi and Nkhata Bay, the natural vegetation is lowland woodland with large and small swampy areas fed by numerous streams and rivers; these waters originate in the jumble of hills and ridges that make up the western escarpment. The very fertile red alluvial soils of the plains have been developed for large-scale agricultural projects, as well as subsistence agriculture. The escarpment, which forms the western border of the lakeshore plains, consists of a series of low terraces which represents old shorelines of the lake; most of these slopes are covered in *Brachystegia* woodland and are generally not highly populated. Rainfall and temperature data for Kawalazi are not available but during the years 1963–1977 higher-lying Mzuzu had a mean annual rainfall of 1 218 mm, a mean minimum temperature of 11,7 °C and a mean maximum of 17,8 °C. For the years 1955–1977 lower-lying Nkhata Bay had corresponding figures of 1 695 mm, 18,8 °C and 27,8 °C. The data for Kawalazi would be most similar to that of Nkhata Bay except for rainfall averaging nearer 1 400 mm per annum (Piet Verster, Kawalazi Estates, personal communication, 1990).

At Kawalazi the *Brachystegia* woodlands (miombo) are not in a pristine state but are under some pressure from man. Much of the area between Mzuzu and Nkhata Bay is cultivated with large tracts planted to *Hevea* rubber (Vizara estate), tea and coffee (Chombe and Kawalazi estates) and eucalyptus. Besides such corporate investments Malawians also clear smaller areas for fruit, cassava and grain crops. Because their protein intake largely comprises fish, not many cattle or other domesticated breeds are kept in this area. Between the cultivated

TABLE 3 Number and frequency of coeloconica present on each of female antennal segments III–XV of *C. (Avaritia) miombo* sp. nov.

| No. of coeloconica per segment of *C. miombo* | Antennal segments | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | III | IV–IX | X | XI | XII | XIII | XIV | XV |
| 0 | — | 70 | 70 | 69 | — | — | 1 | 1 |
| 1 | — | — | — | 1 | 70 | 70 | 68 | 69 |
| 2 | — | — | — | — | — | — | 1 | — |
| 3 | 69 | — | — | — | — | — | — | — |
| 4 | 1 | — | — | — | — | — | — | — |
| No. of antennae examined | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 |

TABLE 4 Number and frequency of chaetica present on each of female antennal segments III–XV of *C. (Avaritia) miombo* sp. nov.

| No. of chaetica per segment *C. miombo* | Antennal segments | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | III | IV | V | VI | VII | VIII | IX | X | XI | XII | XIII | XIV | XV |
| 0 | – | – | – | – | – | – | – | – | 68 | 70 | 70 | 70 | 70 |
| 1 | – | – | 1 | – | 1 | – | – | – | 2 | – | – | – | – |
| 2 | – | – | 69 | – | 69 | 4 | 70 | 3 | – | – | – | – | – |
| 3 | – | 69 | – | 69 | – | 64 | – | 66 | – | – | – | – | – |
| 4 | – | 1 | – | 1 | – | 2 | – | 1 | – | – | – | – | – |
| 5 | 70 | – | – | – | – | – | – | – | – | – | – | – | – |
| No. of antennae examined | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 |

sectors, however, fairly sizeable tracts of *Brachystegia* woodland still exist. At Kawalazi the light-trap was operated on the western slope of the Mphezi hills (Fig. 3b) in largely undisturbed *Brachystegia* woodlands with a moderate amount of foliage between the sparse field layer and the lower canopy at 5–8 m. A shaded, moist, and well-vegetated depression was located 100 m away from the light-trap and was fed by a small constantly running stream. No domesticated stock occurred in the immediate vicinity; game consisted of a small troop of baboons, smaller mammals and birds. Kawalazi was randomly monitored by light-trap over most months starting October 1987 through to April 1989; this revealed *C. miombo* sp. nov. to be entirely absent during the drier months of October and November. It was only after rains had commenced that *C. miombo* sp. nov. appeared but always in low numbers, for example in April 1989 only 54 specimens (0,9 %) of a total of 6 043 *Culicoides* collected were of this species.

Twelve km to the east of Kawalazi, near Vizara, is found the extremely large Limphasa dambo (Fig. 3b) or marsh that is some 30 km long and 1/2–3 km wide. It is thickly vegetated with 1 m high grasses and herbage, is saturated underfoot and fed by quietly flowing, meandering streams. Occasionally very large palms and associated bush trace an eccentric line through the dambo. Elsewhere small parts of the dambo are planted to rice. A number of small scattered villages have arisen on the low banks of the dambo; here some cattle are kept and spend their days grazing the drier parts of the marsh.

The collecting of *Culicoides* at Limphasa was done on 2 occasions, once only during each of the hot, dry months of October and November, 1987, by truck-trapping on a slightly elevated road that transected the dambo. On these 2 occasions a total of 4 females and more than 100 males of *C. miombo* sp. nov. was caught at dusk. The presence of so many males could have been the result of a mating swarm being captured which in turn suggests that the larval habitat of *C. miombo* was in close proximity.

One other site was sampled once by light-trap in November 1987 i.e. the cattle-kraal at the Vizara rubber estate 4 km east of Limphasa. Here only 2 ♀♀ of *C. miombo* sp. nov. were caught amongst 359 *C. imicola* and 71 *C. bolitinos*.

**Culicoides (Avaritia) miombo sp. nov. (Fig. 4–14; Table 2–7)**

*Culicoides brosseti* Vattier & Adam: Boorman & Dipeolu 1979: 17. Nigeria (misident.).

*Culicoides imicola* Kieffer: Kitaoka, Kaneko & Shinonaga 1984: 458. Nigeria (misident.).

*Female* (Fig. 4–8, 13, 14; Table 2–7)

Head. Eyes (Fig. 4); seemingly bare but mostly sparsely to moderately hairy but with hairs absent from a transverse band formed by the median 3–8 rows of facets; eyes contiguous for a distance of between 1 and 2 facets. Antenna (Fig. 5, 13; Table 2–5) slender, basal segments IV–IX barrel-shaped, distal segments X–XIV faintly vasiform narrowing perceptibly subapically, XV nearly parallel-sided only narrowing apically; mean lengths of antennal segments III–XV: 36,8–23,3–23,6–25,7–28,1–27,3–28,2–32,7–44,6–46,0–48,4–49,5–83,3 µm (n = 68); total length of antenna: 470,0–537,5 mean 505,2 µm (n = 36); widths of antennal segments III–XV: 28,1–20,0–17,5–16,3–15,0–15,6 –15,6–15,0–14,4–14,4–14,4–13,7–15,0 µm (n = 1); AR 1,09–1,25, mean 1,15 (n = 66); sensilla coeloconica present on segments III, XII–XV in 97 % of antennae examined (n = 70), see Table 3 for deviations from the norm; sensilla chaetica distribution on segments III–XV was 5-3-2-3-2-3-2-3-0-0-0-0-0 (n = 70) in 97,5 % of antennae examined, see Table 4 for deviations from the norm; sensilla trichodea distribution of the LLc type i.e. each of segments IV–X with 2 long and 1 short blunt-tipped trichodea, segment III with only 2 long blunt-tipped trichodea (n = 70); AtR 1,27–1,76, mean 1,54 (n = 68); segments XI–XIV each with 8–12 sharp-tipped sensilla trichodea of varying lengths and thicknesses distributed in a basal and subapical whorl; XV with 2 × as many trichodea these distributed in a basal, median and subapical whorl (Fig. 5); similarly the short blunt-tipped basiconica range from 2–7 on each of the distal flagellar segments XI–XV (Fig. 5); all antennal segments uniformly clothed throughout with fine spiculae.

The distributions of sensilla coeloconica, chaetica and trichodea are given in Table 2. Palp (Fig. 6,14; Table 6): of a moderate length, slender, light brown throughout, mean lengths of palpal segments I–V: 19,85–49,77–45,90–25,60–26,87 µm (n = 70); total length 147,5–177,5 µm, mean 162,6 µm (n = 70); palpal segment I with only 1 rather long chaetica (n = 70), II with 2–4 rather short chaetica mean 3,06 (91 % with 3 chaetica; n=70); III moderately long

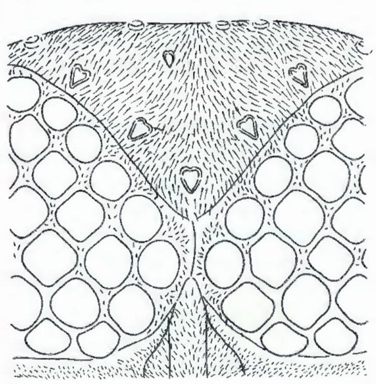

FIG. 4 *C. (Avaritia) miombo* sp. nov. Eyes, female (paratype Malawi 825)

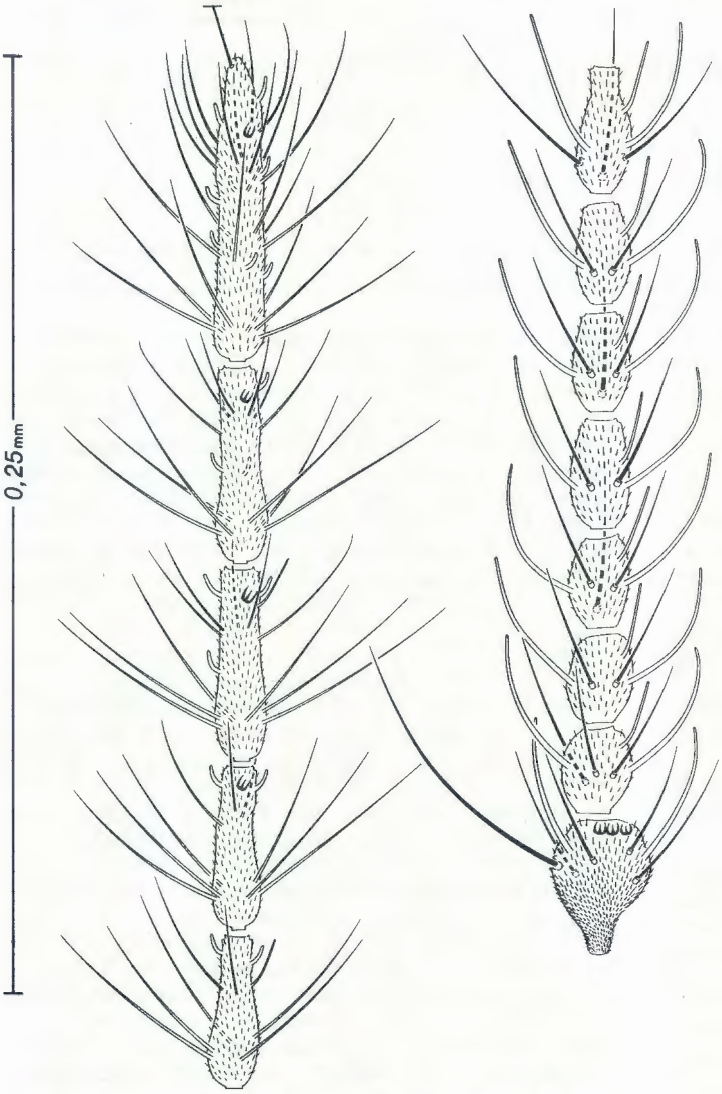


FIG. 5 *C. (Avaritia) miombo* sp. nov. Antenna, female: segments XI–XV on left, segments III–X on right (paratype Malawi 822)

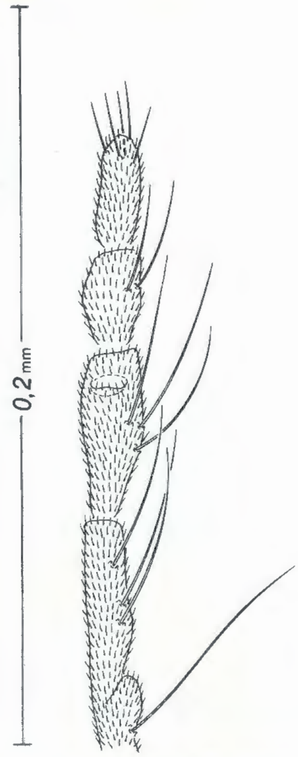


FIG. 6 *C. (Avaritia) miombo* sp. nov. Palp, female (paratype Malawi 813)

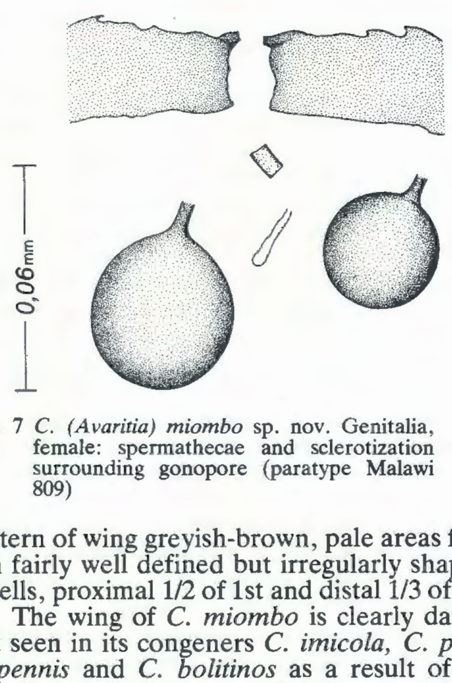


FIG. 7 *C. (Avaritia) miombo* sp. nov. Genitalia, female: spermathecae and sclerotization surrounding gonopore (paratype Malawi 809)

and slender carrying only 1–4 rather short chaetica, mean 2,87 (75 % with 3 chaetica; n=70), with a small, round and shallow subapical pit with opening about half the width of segment in diameter, margin of pit smooth but well-defined, IV with 1–4 chaetica, mean 2,44 (44 % with 3 chaetica; n=70), V with no chaetica on median portion of segment but does always bear 5 short erect bristles apically; these bristles appear to be different in form and function to those chaetica found on the basal segments and are thus dealt with separately; PR 2,44–3,00, mean 2,80 (n = 70); P/H ratio 0,91–1,17, mean 1,01 (n = 34); mandible with 13–18 fine teeth, mean 15 (n = 64).

Thorax. Legs: brown with all femora narrowly pale basally and with fore and middle femora indistinctly pale apically. All tibiae with a narrow well-defined basal pale band; remainder of fore and middle tibiae brown while apices of hind tibiae are pale; TR 1,51–1,84, mean 1,66 (n = 70); comb on apex of hind tibia with 5 spines, the 1st being the longest and only slightly longer than the 2nd (n = 70). Wing: (Fig. 8): length 0,83–1,01 mm, mean 0,94 mm (n = 66); breadth 0,41–0,51 mm, mean 0,46 (n = 66); CR 0,56–0,60, mean 0,58 (n = 66); macrotrichia scanty, confined to distal 3rd of wing in cells $R_5$, $M_1$ and $M_2$ only; microtrichia dense and coarse. Dark pattern of wing greyish-brown, pale areas faint yellowish fairly well defined but irregularly shaped; 2 radial cells, proximal 1/2 of 1st and distal 1/3 of 2nd cell pale. The wing of *C. miombo* is clearly darker than that seen in its congeners *C. imicola, C. pseudopallidipennis* and *C. bolitinos* as a result of the general reduction in the size of the pale areas. The most distinctive feature of the wing pattern is the elongate dark smudge which arises at the proximal base of the anal cell, cuts diagonally across the cell to terminate at the posterior wing margin well proximad of the apex of vein $Cu_1$. It is important to note that this smudge is divided into 2 by a fairly broad pale interruption subapically. Only in rare instances will these 2 dark areas be indistinctly and narrowly fused; only the smaller distal dark area is found in *C. imicola, C. bolitinos* and *C. pseudopallidipennis.* Other important species-specific wing pattern characters are: (i) pale costal spot 2 that straddles the r–m crossvein is reduced in size, slightly waisted medianally but expands to fairly broadly abut the

FIG. 8 *C. (Avaritia) miombo* sp. nov. Wing, female (holotype Malawi 820)

FIG. 9 *C. (Avaritia) miombo* sp. nov. Wing, male (paratype Malawi 951)

anterior wing margin, (ii) distal or 4th pale costal spot in cell $R_5$ abuts wing margin but in many specimens this spot is both reduced in size and isolated by a narrow dark strip that runs along the antero-distal wing margin; in rare dark forms this distal pale spot in cell $R_5$ almost disappears, (iii) proximal margin of this 4th pale costal spot rounded rather than sharply pointed, (iv) median 1/3 of anterior margin of vein

TABLE 5 Comparison of mean lengths (µm) of female antennal segments III–XV of 3 *Culicoides* species*

| Antennal segment | Species | | | F value |
|---|---|---|---|---|
| | *C. imicola* µm | *C. miombo* sp. nov µm | *C. bolitinos* µm | |
| III | 39,00 | 37,30 | 36,85 | 11,171 |
| IV | 25,45 | 24,00 | 23,35 | 20,261 |
| V | 25,20 | 24,08 | 23,45 | 12,500 |
| VI | 26,95 | 26,45 | 25,00 | 11,641 |
| VII | 28,23 | 28,63 | 26,35 | 14,755 |
| VIII | 28,08 | 27,63 | 26,18 | 9,656 |
| IX | 28,43 | 28,80 | 26,85 | 13,085 |
| X | 31,10 | 33,20 | 29,33 | 32,047 |
| XI | 43,00 | 45,75 | 40,75 | 26,595 |
| XII | 45,20 | 46,95 | 41,40 | 40,739 |
| XIII | 45,98 | 48,95 | 41,43 | 58,127 |
| XIV | 46,20 | 50,30 | 41,35 | 56,764 |
| XV | 73,78 | 85,25 | 69,60 | 63,220 |
| Total | 485,48 | 506,0 µm | 451,85 | 40,346 |

* All F values are significant at 5 %; means underlined are not significantly different at 5 %; n = 25 for each species

$M_1$ never entirely pale but brownish, (v) vein $M_2$ has both margins very broadly darkened for most of its length, does not have a preapical excision on the anterior margin only but instead can be fairly abruptly tapered on both margins near its apex; however, this tapering still leaves both margins at the apex of vein $M_2$ dark, while in some darker specimens the tapering may again flare into a more broadly brown apex. Scutum brown in alcohol but strikingly adorned with 2 fairly large yellow very narrowly separated admedian vittae; scutellum narrowly brown medianally, lateral margins broadly yellow; bearing 1 median bristle and 1 shorter bristle on each corner in 36/37 specimens, remaining specimen different in having 2 median bristles. Haltere knobs distinctly brown.

Abdomen (Fig. 7): 2 moderately sclerotized slightly unequal spermathecae present, measuring 40–50 × 35–41 µm and 34–44 × 29–35 µm (n = 20); both round and devoid of small hyaline punctations, with moderately long narrow pigmented necks; rather small narrow rudimentary 3rd spermatheca present measuring 14–21 × 4 µm; small sclerotized ring on common spermathecal duct cylindrical, smooth and parallel-sided, a little longer than broad, and about half the length of the rudimentary spermatheca; sclerotization surrounding the oviduct as shown in Fig. 7.

*Male* (Fig. 9–12; Table 2, 7)

Head. Eyes sparsely hairy between most facets. Antenna (Fig. 10, Table 2): plume rather sparse, fibrillae light brown, almost completely encircling medianally each of segments IV–XII in a regular whorl; these segments with very few spiculae, distal segments XIII–XV densely and evenly clothed with

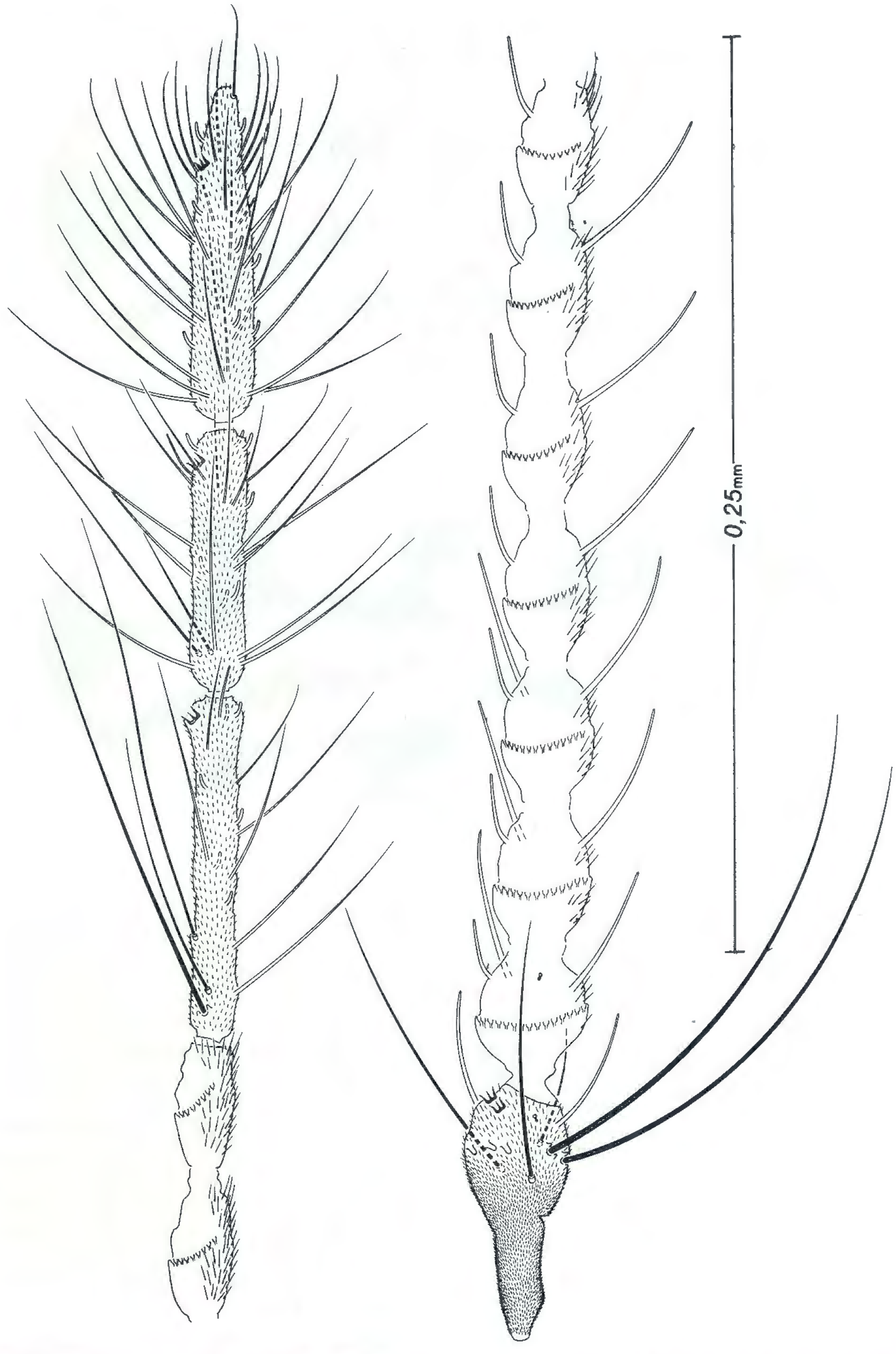


FIG. 10 *C. (Avaritia) miombo* sp. nov. Antenna, male: segments XI–XV on left, segments III–X on right (paratype Malawi 834)

spiculae; lengths of segments III–XV: 71,3–36,3–37,5–37,5–37,5–37,5–37,5–37,6–37,5–36,3–96,3–96,3 75,0–92,5 µm (n = 1); sensilla coeloconica distribution: 100 % with 2 on segment III, 100 % with 1 on XIII, 100 % with 1 on XIV and 92 % with 2 and 8 % with 1 on XV (n = 25); sensilla chaetica distribution: 5 of varying lengths and thicknesses on III, 2 basally (1st long and robust, 2nd shorter and weaker) and 1 medianally (being very slender and 1,5 × longer than segment) on XIII, 2 basally (both very slender but of different lengths, the one a little shorter than segment the other fractionally longer than segment) on XIV, none basally on XV only 1 apically ( n= 25); sensilla trichodea distribution on segment III–XII: III with 2 long blunt-tipped trichodea, segments IV–VI with 2 long and 1 short blunt-tipped trichodea, segments VII–IX with 1 long and 1 short blunt-tipped trichodea, segment X with 1 short blunt-tipped trichodea only, segments XI and XII lacking trichodea (n = 25). The only deviation from the norm noted was an extra long blunt-tipped trichodea in 2 antennae on segment VII; this extra trichodea was shorter than normal and obviously aberrant. The distributions of the sensilla coeloconica, chaetica and trichodea are identical to those found in *C. imicola* and *C. bolitinos* and appear in Table 2.

Wing: (Fig. 9). Genitalia (Fig. 11, 12), tergum 9 (Fig. 11) square, fractionally waisted medianally, finely spiculate throughout except for narrow strips of the anterior and posterior margins being bare, bearing 14–17 chaetica of different lengths, mean 15 (n = 25); apicolateral processes replaced by thin, hyaline flanges lacking tiny spiculae but each carry-

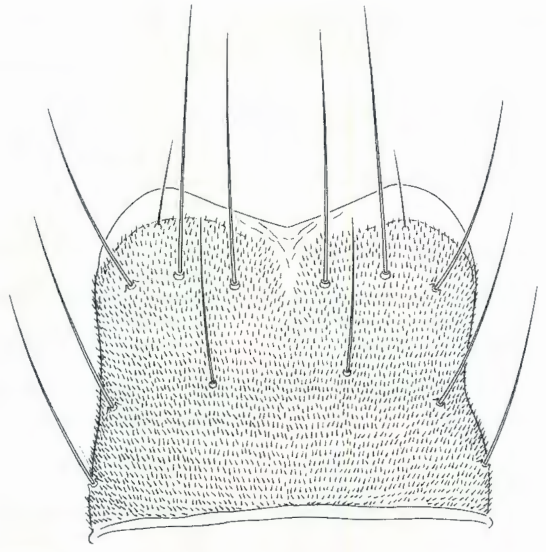

FIG. 11 *C. (Avaritia) miombo* sp. nov. Genitalia, male: tergum IX (paratype Malawi 161)

ing a single fine, rather short straight chaetica issuing from the interface that comprises the base of the flange and the adjoining spiculate fringe where the concave body of the tergum commences; posterior margin of tergum which separates these flanges gently concave lacking marked indentation or infuscation; 2 well-developed cerci (Fig. 12), each adorned with long spiculae and 2 long and 2 short chaetica apically; cerci protruding well beyond posterior margin of tergum; sternum 9 (Fig. 12) with a rather deep excavation , membrane within the excavated area always densely spiculate bearing 80–280 spiculae, mean 170 (n = 16); basimere with dorsal and ventral spiculae and chaetica as illustrated (Fig. 12), basimere 2,6 × as long as broad with basal infuscate collar and well developed dorsal and ventral roots of the form typical for the subgenus *Avaritia*. Distimere 0,8 × length of basimere, rather stout, gently curved and broadly blunt-tipped; basal half spiculate carrying 6–7 bristles of varying lengths and thicknesses, extreme apex with about 5 very short fine tactile sensilla. Aedeagus (Fig. 12) shield-shaped, slender, almost equal in length to the basimere; basal arch concave, only fractionally infuscate on lateral margins, distal margin of arch reaching to nearly 0,3 × length of aedeagus; lateral margins of aedeagus smooth and gently convex, darkly but narrowly infuscate and converging distad to end in a hyaline, round-tipped, parallel-sided terminal projection the base of which projects anteriorly into median area of aedeagus in the form of a raggedly infuscate "peg". Parameres (Fig. 12) separate, nearly touching medianally from where they diverge anteriad and posteriad at 45°, posterior halves as 2 convex almost hyaline blades initially stout but tapering smoothly to sharp, simple, erect tips.

Etymology. In southern Africa the widespread *Brachystegia* woodland is locally known as 'miombo'. Its distribution correlates strongly with that of the new species; both biota are sensitive to temperate conditions.

**Type material**

MALAWI: Holotype ♀ (slide Malawi 820), Kawalazi (11° 37′ S, 34° 06′ E) 20 km south-east of Mzuzu, northern Malawi, IV. 1989, P. & K. Verster, blacklight at homestead in *Brachystegia* woodland.

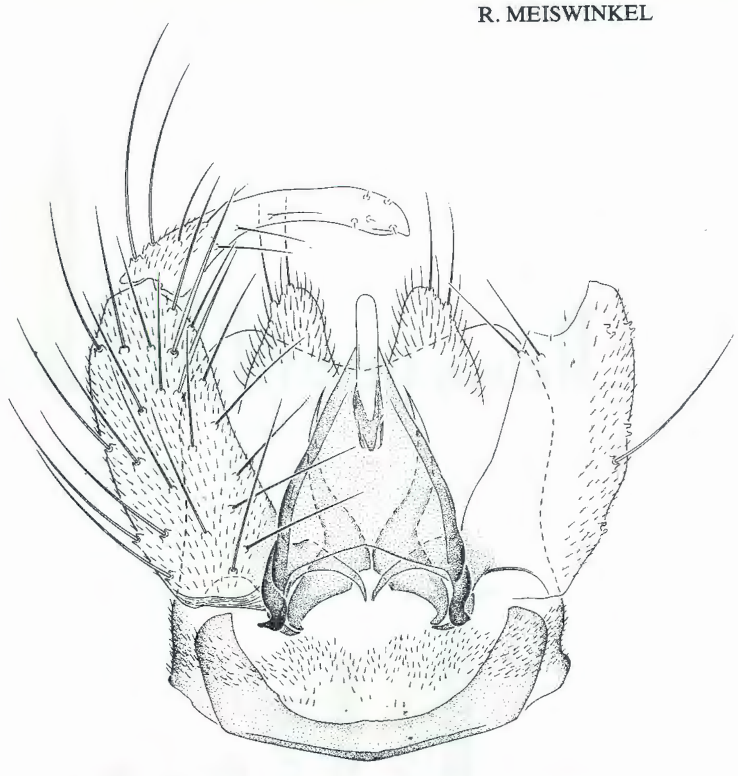

FIG. 12 *C. (Avaritia) miombo* sp. nov. Genitalia, male (paratype Malawi 161)

73 ♀♀ 68 ♂♂ paratypes, slides labelled and numbered to sex, the collection data as follows:

4 ♀♀, (slides Malawi 153–155, 166), Limphasa dambo, 8 km south-west of Nkhata Bay, 15. XI. 1987, R. Meiswinkel, truck-trap, dusk.

10 ♂♂, (slides Malawi 156–165), Limphasa dambo, 8 km south-west of Nkhata Bay, 15. XI. 1987, R. Meiswinkel, truck-trap, dusk.

5 ♀♀, (slides Malawi 208–212), Kawalazi, 20 km south-east of Mzuzu, northern Malawi, 14. II. 1988, P. & K. Verster, blacklight at homestead in *Brachystegia* woodland.

47 ♂♂, (slides Malawi 243–254, 267–270, 917–947), Limphasa dambo, 8 km south-west of Nkhata Bay, 26. X. 1987, R. Meiswinkel, truck-trap, dusk, 17h00–18h00.

1 ♂, (slide Malawi 60), Kawalazi, 20 km south-east of Mzuzu, northern Malawi, 14. XI. 1987, R. Meiswinkel, truck-trap in marshy and wooded area 5 km north of woodland light-trapping site, dusk.

TABLE 6 Comparison of mean lengths (µm) of female palpal segments I–V of 3 *Culicoides* species*

| Palpal segment | Species | | | F value |
|---|---|---|---|---|
| | *C. imicola* | *C. miombo* sp. nov | *C. bolitinos* | |
| I | 20,05 | 19,85 | 18,35 | 6,333 |
| II | 57,40 | 49,80 | 45,45 | 96,885 |
| III | 49,05 | 46,15 | 41,10 | 45,363 |
| IV | 29,65 | 25,70 | 24,90 | 54,368 |
| V | 27,45 | 27,25 | 24,55 | 14,207 |
| Total | 183,6 | 169,75 | 154,55 | 118,044 |

* All F values are significant at 5 %; means underlined are not significantly different at 5 %; n = 25 for each species

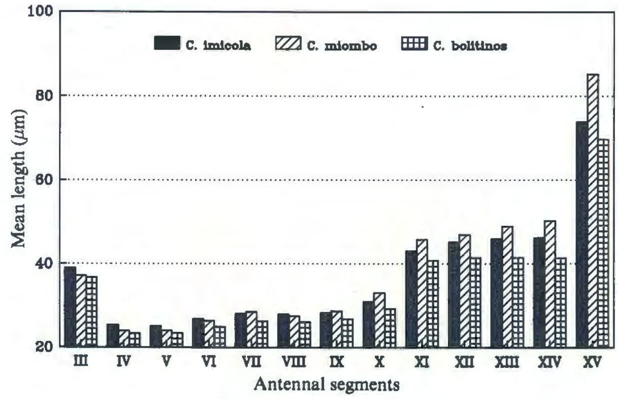


FIG. 13 Comparison of mean lengths (µm) of each of female antennal segments III–XV of *C. (Avaritia) imicola, C. (A.) miombo* sp. nov. and *C. (A.) bolitinos*

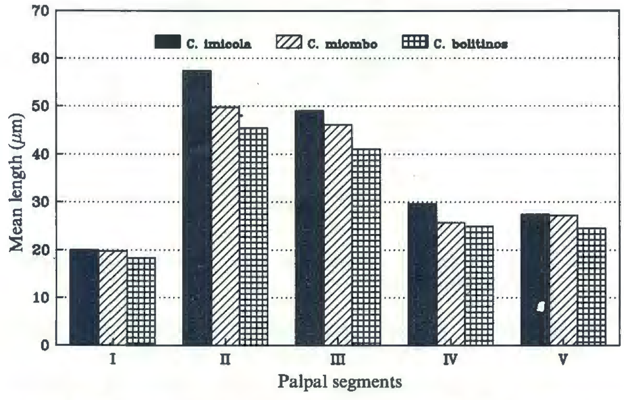


FIG. 14 Comparison of mean lengths (µm) of each of female palpal segments I–V of *C. (Avaritia) imicola, C. (A.) miombo* sp. nov. and *C. (A.) bolitinos*

14 ♀♀, (slides Malawi 854–856, 902, 904–907, 909–914), Kawalazi, 20 km south-east of Mzuzu, northern Malawi, II. 1989, P. & K. Verster, blacklight at homestead in *Brachystegia* woodland.

2 ♂♂, (slides Malawi 857, 915), Kawalazi, 20 km south-east of Mzuzu, northern Malawi, II. 1989, P. & K. Verster, blacklight at homestead in *Brachystegia* woodland.

6 ♀♀, (slides Malawi 837–842), Kawalazi, 20 km south-east of Mzuzu, northern Malawi, III. 1989, P. & K. Verster, blacklight at homestead in *Brachystegia* woodland.

1 ♂, (slide Malawi 858), Kawalazi, 20 km south-east of Mzuzu, northern Malawi, III. 1989. P. & K. Verster, blacklight at homestead in *Brachystegia* woodland.

44 ♀♀, (slides Malawi 801–819, 821–833, 843–853, 953), Kawalazi, 20 km south-east of Mzuzu, northern Malawi, IV. 1989, P. & K. Verster, blacklight at homestead in *Brachystegia* woodland.

7 ♂♂, (slides Malawi 834–836, 950–952, 976), Kawalazi, 20 km south-east of Mzuzu, northern Malawi, IV. 1989, P. & K. Verster, blacklight at homestead in *Brachystegia* woodland.

Paratype slides from this type series will be deposited in the following Museums:

1 ♀ 1 ♂; The Natural History Museum, London.

1 ♀ 1 ♂; United States National Museum, Washington, D.C.

1 ♀ 1 ♂; Muséum National d'Histoire naturelle, Paris.

TABLE 7 Fifteen morphological character states used to separate *C. imicola* from *C. miombo* sp. nov.

| | *C. imicola* | *C. miombo* |
|---|---|---|
| ♀ | – thorax entirely brown in alcohol | – thorax with 2 prominent yellow admedian vittae |
| | – scutellum entirely brown | – scutellum narrowly brown medianally and broadly yellow laterally |
| | – base of anal cell entirely pale | – base of anal cell with prominent brown streak |
| | – anterior margin of 2nd pale costal spot straddling the r-m crossvein with straight sides | – anterior margin strongly indented medianally on the level of the subcostal vein |
| | – proximal margin of distal pale spot in cell $R_5$ pointed | – this margin weakly pointed to rounded |
| | – median 1/3 of anterior margin of vein $M_1$ pale | – this area brownish |
| | – apex of vein $M_2$ broadly dark on both margins this preceded by a broad, pale and rather deep preapical excision on the anterior margin only; this excision usually touches and sometimes straddles vein $M_2$ | – apex of vein $M_2$ narrowly dark on both margins, this preceded by only a small, pale and indistinctly shallow preapical excision on both the anterior and posterior margins; these excisions do not touch or straddle vein $M_2$ |
| | – haltere knobs pale | – haltere knobs brown |
| | – palp slightly longer: 165,6–182,4 µm mean 176,1 µm (n=25) | – palp slightly shorter: 147,5–177,5 µm mean 162,6 µm (n=70) |
| | – P/H ratio 1,01–1,22 mean 1,07 (n=20) | – P/H ratio 0,91–1,17 mean 1,01 (n=34) |
| | – Antennal segments X–XV shorter (see Table 5) | – these segments longer (see Table 5) |
| | – AR 0,95–1,10 mean 1,01 (n=167) | – AR 1,09–1,25 mean 1,15 (n=66) |
| | – AtR 1,59–2,27 mean 1,86 (n=173) | – AtR 1,27–1,76 mean 1,54 (n=68) |
| | – eyes bare | – eyes sparsely to moderately hairy |
| ♂ | – membrane of sternum 9 with 8–145 spiculae, mean 47 (n=50) | – membrane with 80–280 spiculae, mean 170 (n=16) |

1 ♀ 1 ♂; Australian National Insect Collection, Canberra.

Holotype ♀ and remaining paratype ♀♀ and ♂♂ in the Onderstepoort collection.

Other slide material examined but not forming part of type series:

ZIMBABWE: 20 ♀♀ 10 ♂♂, (slides Zimbabwe 113–142), Rekomitjie Research Station (16° 08′ S, 29° 24′ E), north-western Zimbabwe, 16. III. 1988, R. J. Phelps, light-trap, warthog pen.

SOUTH AFRICA: 1 ♀, (slide Ndumu 11), Ndumu Game Reserve (26° 55′ S, 32° 15′ E), northern KwaZulu, Natal, 6. VI. 1988, R. & P. Meiswinkel, blacklight in camp.

BOTSWANA: 5 ♀♀, (slides Botswana 1–5) Mamalakwe river near Maun (20° 01′ S, 23° 25′ E), northern Botswana, 6. VI. 1988, H. V. de V. Clarke, light trap.

IVORY COAST: 5 ♀♀ 8 ♂♂, (slides Ivory Coast 1–13), Parhadi (8° 27′ N, 3° 29′ W), north-eastern Ivory Coast, 25. IX. 1990, R. Meiswinkel & J. C. Koffauth, blacklight at 15 cattle on edge of village in disturbed forest.

NIGERIA: 1 ♀ 1 ♂, Vom (9° 45′ N, 8° 46′ E), north-eastern Nigeria, 31. VIII. 1975, W. Taylor, at light.

**Unmounted material examined**

IVORY COAST: 125 ♀♀ 1 ♂, Yamoussoukro (6° 49′ N, 5° 16′ W), central Ivory Coast, 13. IX. 1990, R. Meiswinkel & L. E. O. Braack, blacklight at cattle kraal.

24 ♀♀, Ganse (8° 35′ N, 3° 54′ W), north-eastern Ivory Coast, 24. IX. 1990, R. Meiswinkel & G. J. Venter, blacklight at sheep and goats in village.

1 ♀, Biankouma (7° 45′ N, 7° 18′ W), western Ivory Coast, 28. IX. 1990, R. Meiswinkel & J. C. Koffauth, blacklight at 4 cattle in dense forest.

15 ♀♀, Parhadi (8° 27′ N, 3° 29′ W), north-eastern Ivory Coast, 25. IX. 1990, R. Meiswinkel & J. C. Koffauth, blacklight at 15 cattle on edge of village in disturbed forest.

23 ♀♀, Korhogo (9° 27′ N, 5° 39′ W), northern Ivory Coast, 26. IX. 1990, R. Meiswinkel & J. C. Koffauth, blacklight at 40 cattle in cultivated area adjoining ricefields.

## DISCUSSION

**Taxonomy**

*Culicoides (Avaritia) miombo* appears to have been dealt with six times previously in studies on Afrotropical *Culicoides*. Boorman & Dipeolu (1979) identified a Nigerian series as belonging to *C. (A.) brosseti* Vattier & Adam 'on account of the very prominent and extensive yellow markings on the anterior half of the mesonotum'. They did, however, note that their specimens differed in having a higher palpal ratio and lower costal ratio than were described for *C. brosseti* by the original authors Vattier & Adam (1966). I have examined a slide-mounted male and female of the Boorman & Dipeolu (1979) series collected at Vom and consider them to be *C. miombo*. Their photo of the female wing of *C. brosseti* is inseparable from the one figured above; especially characteristic is the dark streak at the extreme base of the anal cell. Boorman & Dipeolu erroneously described the male genitalia as having the 'tergite without lateral processes, posterior margin almost straight' and the membrane of sternum 9 as 'bare'. *Culicoides miombo* in fact has a very densely spiculate membrane and moderately developed apicolateral flanges, exactly as in the Vom male before me. *Culicoides brosseti* appears to be the only true cavernicolous species of *Culicoides* currently known from the Afrotropical region. However, *C. brosseti* is not a member of the Imicola group, but, as pointed out by Itoua & Cornet (1986), belongs to the Trifasciellus group which contains a 3rd species, *C. dubitatus* Kremer, Rebholtz-Hirtzel & Delecolle, 1976. The Trifasciellus group differs from the Imicola group in a number of morphological features involving the male genitalia and the distribution pattern of the long and short blunt-tipped sensilla trichodea on the antennae of both sexes. *C. brosseti*, like *C. miombo*, possesses prominent yellow admedian vittae on the anterior half of the mesonotum, and is likely the reason why *C. miombo* has been mistakenly identified as *C. brosseti* for the last 20 years.

The 2nd reference to *C. miombo* is one made by Kitaoka, Kaneko & Shinonaga (1984). Their wing photograph of a specimen of *C. imicola* from Ife, Nigeria is clearly that of *C. miombo*, the dark streak at the base of the anal cell once again being highly diagnostic.

The 3rd reference is that of Cornet (1969) who recorded a single female from Simousso, Burkina Faso. It is likely that he was dealing with *C. miombo* and not *C. brosseti*.

The 4th reference is that of Kremer (1972) who recorded 'très nombreux . . . femelles et mâles' of *C. brosseti* from Dundo, Angola. Though no taxonomic data was given it is likely that he too had *C. miombo* before him.

The 5th reference is the record of 16 ♀♀ and 1 ♂ of *C. brosseti* from Manakara, Madagascar (Kremer & Brunhes, 1972). As in the Angolan series no taxonomic data were given but as the 2 studies were published by Kremer in the same year the material examined was likely conspecific.

The final reference (Kitaoka & Zulu, 1990) deals with 2 unnamed species of *Culicoides* from Chilanga, Zambia and provisionally labelled as C. A–1 and C. A–10. These authors note that they are 'members of the *brosseti* subgroup of the subgenus *Avaritia* . . . which have two yellowish vittae on the thorax', and that together they comprised only 4% of nearly 10 000 *Culicoides* collected around a guinea-pig run. It is certain that these represent *C. miombo* sp. nov. and that their rarer C. A–10 is simply an abnormally dark variant.

I have not seen the above material discussed in the latter 4 references; their identification is thus tentative and for this reason a question mark is placed next to these records in Fig. 1 and 2.

**Differential diagnosis**

Fifteen character states that easily separate the 2 species *C. imicola* and *C. miombo* are summarized in Table 7. To differentiate *C. miombo* not only from *C. imicola* but also from *C. bolitinos*, statistical analyses were conducted on the antennal and palpal measurements of the 3 species. The mean measurement of each antennal and palpal segment, taken from 25 specimens of each species, was first tabulated and then tested for significant differences (Table 5, 6). It was found that *C. bolitinos* and *C. miombo* showed no difference in measurements between antennal segment III–V and palpal segment IV, while in turn a comparison of *C. imicola* and *C. miombo* showed antennal segments VI–IX and palpal segments I and V to be inseparable. It must be noted that heterogeneous variances occurred in the measurements of antennal segments IV and V but these were accepted as homogeneous mainly because the small size of these segments may have affected the accuracy of their measurements in all 3 species. Table 5 and Fig. 13 show that as a trio the 3 species are most easily separated by significant differences in the relative lengths of antennal segments X–XV. The same separation can be obtained using palpal segments II and III (Table 6, Fig. 14). Of the 15 character states that separate *C. miombo* and *C. imicola*, 6 are discussed in detail below. Three characters are very reliable for separating *C. miombo* and *C. imicola* under the dissecting microscope: The former has (a) prominent pale yellow admedian vittae on the scutum, (b) haltere knobs brown and (c) the prominent dark smudge at the base of the anal cell of the wing. The latter and 5 other character states are discussed in further detail below; where data is available these 2 species are also differentiated from *C. bolitinos* and *C. pseudopallidipennis*.

1. Female. Wing: The wing of *C. miombo* is distinctly darker than that seen in either *C. imicola*, *C. pseudopallidipennis* or *C. bolitinos*. The following wing characters more clearly define *C. miombo* as a good species:
   a. The 2nd pale costal spot is round where it straddles the r–m crossvein, is rather strongly waisted medianally only to expand and broadly abut the anterior wing margin. This spot is more quadrate and not waisted medianally in the remaining 3 species of the Afrotropical Imicola group.
   b. The shape of the distal pale spot in the apex of cell $R_5$: its proximal margin is weakly pointed to rounded; secondly this spot is quite often, especially in darker specimens indistinctly separated or isolated from the wing apex by a narrow dark strip that runs along the antero-distal wing margin; in still darker specimens the pale spot may almost vanish. In *C. imicola, C. pseudopallidipennis* and *C. bolitinos* this pale spot always broadly abuts the wing margin and is never isolated from the wing margin.
   c. The median 1/3 of the anterior margin of vein $M_1$ is more brown than pale; predominantly to entirely pale in *C. imicola, C. pseudopallidipennis* and *C. bolitinos*.
   d. Vein $M_2$ is broadly darkened for most of its length and does not have the very obvious preapical excision seen on the anterior margin in *C. imicola*. In *C. miombo* vein $M_2$ is near its apex moderately to fairly abruptly tapered on both margins; however, this tapering still leaves both margins of vein $M_2$ at the apex narrowly dark and never entirely pale as in *C. bolitinos*. Furthermore, in the majority of specimens of *C. miombo*, this preapical tapering once again 'flares' leaving the extreme apex of vein $M_2$ more broadly dark. No data is available for *C. pseudopallidipennis*.
   e. Extreme base of anal cell with a prominent long dark smudge; in *C. imicola, C. pseudopallidipennis* and *C. bolitinos* this area is entirely pale.
2. Female. Eyes: The extent of hairiness of the eyes in *C. miombo* is a deceptive character state that shows considerable variation. Firstly, the areas between the facets are at most only sparsely adorned with short hairs. These hairs will not be seen in specimens whose eyes are poorly cleared of dark pigment. Secondly, the median transverse band of 3–8 rows of facets are usually devoid of hairs with only the more lateral, and thus obscured, interfacetal areas weakly haired. The eyes of *C. miombo*, therefore, need to be carefully examined and the minute hairs will only be seen in that material which is properly prepared. *C. miombo* appears to be the only member of the Imicola group worldwide that possesses hairy eyes.
3. Female. Palps: The length of the entire palp in *C. miombo* (mean 169,8 µm; n = 25) is exactly intermediate between that of *C. imicola* (mean 183,6 µm; n = 25) and *C. bolitinos* (mean 154,6 µm; n = 25) as shown in Fig. 14. This is because the 3 species are quite easily separable on the mean lengths of palpal segments II and III. Although no data is available for *C. pseudopallidipennis* we do know that it has a moderately swollen 3rd palpal segment (Clastrier, 1958) as opposed to the slender one found in its 3 congeners.
4. Female. Antennae: As to the length of the entire antenna the converse is true; that of *C. miombo* is the longest (mean 506,0 µm; n = 25); with *C. imicola* intermediate (mean 585,5 µm; n = 25) and that of *C. bolitinos* again shortest (mean 451,9 µm; n = 25). As shown in Table 5 and Fig. 13 the 3 species are easily separable on the mean lengths of antennal segments X–XV. Those segments of inseparable length are underlined in Table 5.
5. Female. Antennae: The antennal trichodea ratio (AtR) gives an equally interesting result in that despite having the longest antennae of the 3 species *C. miombo* carries the shortest long blunt-tipped trichodea on antennal segment VI. These trichodea are longer but more or less equal in size in *C. imicola* and *C. bolitinos*. As illustrated by Clastrier (1958) these trichodea are rather short and unusually swollen in *C. pseudopallidipennis*.
6. Male. The males of the 3 species differ most significantly in the extent of spiculation on the membrane of sternum 9 of the genitalia. In *C. miombo* it is moderately to densely spiculate (80–280 spiculae, mean 170; n = 16), in *C. imicola* it is sparsely to moderately spiculate (8–145 spiculae, mean 47; n = 50) whereas in *C. bolitinos* it is normally bare occasionally carrying a few spiculae (0–18 spiculae, mean 2,56; n = 50). According to Glick (1990) this membrane is bare in *C. pseudopallidipennis*. There are subtle differences between the former 3 species in the shape of the posterior margin of tergum 9 but these are difficult to quantify.

**Larval habitat**

Unknown; suspected to be in well-vegetated marshy areas. The dung of cattle or any other large herbivore is thought not to be the larval habitat of *C. miombo* as none of nearly 400 specimens examined had the phoretic deutronymph stage of *Myianoetus* mites attached to its abdomen, an association that is commonly found amongst the adults of those *Avaritia* species whose immatures develop exclusively in animal dung.

**Vector status**

Unknown; however, one needs to re-examine the findings of Lee (1979) who assayed 270 000 *Culicoides* caught during the years 1967–1970 at the dairy herd of the University of Ibadan, Nigeria. Seventy isolates of 16 arboviruses belonging to 7 groups were made either from single *Culicoides* species pools or from multiple species pools that comprised at least 14 species. These quite likely included *C. miombo* sp. nov. as Lee reported *C. imicola* to be 1 of the 4 most abundant species taken during the study. The likelihood that *C. miombo* formed part of Lee's collection is supported by the statement made by Boorman & Dipeolu (1979) that *C. brosseti* (misidentification for *C. miombo*) was taken 'in large numbers with *C. imicola*' at Ibadan.

**Distribution**

In discussing biota that are strictly tropical in their occurrence (a subject admirably explored for certain sections of the southern African fauna by Stuckenberg, 1969) it is worthwhile to recall the words of Nix (1983) '. . . the available evidence indicates that the

20 °C isotherm encloses virtually all occurrences of tropical savanna on all continents' where 'annual mean rainfall ranges between 1 000 and 1 500 mm, annual mean air temperature exceeds 24 °C and mean minimum temperature of the coldest month is between 13–18 °C'. However, 'significant occurrences of tropical savannas are also found between the 8 °C and 13 °C isotherm for the coldest month and the absence of freezing temperatures', while the 8 °C isotherm 'coincides very approximately with the 50 % probability of a freezing temperature occurring in any one year'. Importantly Nix also notes that frost is a very 'meaningful boundary condition for living organisms'.

This definition fits *C. miombo* as in Table it can be seen that the new species appears to be restricted to those parts of Africa below 1 000 m in altitude, where frost is absent or very rare, and where the rainfall is relatively high (700–1 500 mm/annum), especially if this rainfall is distributed through all or most months of the year. It thus seems reasonable to predict that these ecological preferences will preclude *C. miombo* from ever becoming established in the more arid or cooler temperate areas of southern Africa, and likely explains why it occurs in such low numbers in Ndumu, South Africa; Maun, Botswana; Rekomitjie, Zimbabwe and Kawalazi, Malawi. All these localities are marginally embraced by the 8 °C minimum isotherm and thus experience frost occasionally (Fig. 1) and furthermore will have 4–6 months of the year hot and dry. For e.g. at Kawalazi, Malawi, during the hot dry months of October and November, *C. miombo* was rarely collected and then only near marshy areas. It was only found more widely once rains had commenced but even so remained uncommon, representing only 0,9 % of 6 043 *Culicoides* collected in the rainy month of April, 1989 (R. Meiswinkel, unpublished data, 1989).

In light of *C. miombo's* apparent need for fairly high temperatures and a high average rainfall it is pertinent to look north of the equator and repeat Boorman and Dipeolu's 1979 observation that *C. brosseti* (=*C. miombo*) occurred in large numbers in Nigeria. Here the mean minimum temperature of the coldest month is in the region of 18–22 °C, considerably higher than the 8 °C found in areas sampled for *C. miombo* in southern Africa. Similarly in the Ivory Coast *C. miombo* was always present in collections made in the northern half of the country (R. Meiswinkel, unpublished data, 1990) where at least some rain falls in each month of the year and frost is absent. Only once, however, was *C. miombo* the most abundant species in the Ivory Coast comprising 26,2 % of a subsample of 500 *Culicoides* caught at zebu cattle on the outskirts of Yamoussoukro. In the same collection *C. imicola* only constituted 0,8 % of the catch (R. Meiswinkel, unpublished data, 1990). It is important to note that not a single specimen of *C. miombo* was found amongst ± 10 000 *Culicoides* collected at 4 sites in the wetter southern half of the Ivory Coast. Although there is a paucity of data this suggests that *C. miombo* is virtually absent from the very high rainfall forested regions of equatorial Africa. When this is linked to the fact that no specimens of *C. miombo* have been collected in 30 years in the arid and temperate regions dominating South Africa the implication is strong that *C. miombo* evolved in the tropical woodlands immediately adjacent to the wetter rainforest block of equatorial Africa.

**Conclusions**

*Culicoides miombo* is a new member of the Imicola group that is widespread and can be common in the tropical woodlands of Africa. Because of its preference for high temperatures, good rainfall and frost-free regimes it is unlikely that *C. miombo* will ever become established in the more arid or temperate parts of southern Africa. It has until now been confused taxonomically with *C. brosseti* and *C. imicola* and as a result little to nothing is known about its host preferences, seasonal abundance and prevalence. Its larval habitat also remains undiscovered. Finally, *C. miombo* deserves mention as a potential vector of cattle viruses.

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