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THE RELATIONSHIP BETWEEN THE NUMBERS AND DISTRIBUTION OF SOME ANTENNAL AND PALPAL SENSE ORGANS AND HOST PREFERENCE IN SOME *CULICOIDES* (DIPTERA: CERATOPOGONIDAE) FROM SOUTHERN AFRICA

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Abstract: The mean number of antennal pits and the number of antennomeres which bear pits were determined in samples from 12 *Culicoides* species from southern Africa. Those species which are known to prefer avian hosts had more pits and more pit-bearing antennomeres than did those known to prefer mammals. Preference for mammals is indicated by 6 or fewer pit-bearing antennomeres and for birds by 12 or 13. A few species fall between these ranges and, as yet, adequate host preference data are lacking for them. The incidence of the pits on the proximal antennomeres might be used where the above 2 parameters are intermediate. The mean numbers of antennal sensilla basiconica appear to show no host relationship. The mean number of bulb-shaped sensilla in the palpal pits demonstrated host preference relationship for those species examined.

Jamnback (1965) suggested that the number of antennal sensory pits, as represented by the number of antennomeres bearing them, is related to broad host preferences in *Culicoides*. He showed that a number of American species known to feed preferentially on large mammals had sensory pits on 4–6 antennomeres, while those known to feed preferentially on birds had pits on 8–13 antennomeres. Chu et al. (1975), in a study of the antennal and palpal sense organs of 1 of the mammalophilic species mentioned by Jamnback, *Culicoides furens* (Poey), found that sensory pits were present on 5 of the 13 antennomeres of the antennal flagellum and also that 10 pits were present on each antenna. Rowley & Cornford (1972) showed that the relationship holds in 4 other American species. The abundance of bulb-shaped sensilla in the palpal pits was also regarded as important in indicating possible host preference by Rowley & Cornford (1972).

Some information on the numbers and distribution of the sensory pits of the antennae of *Culicoides* found in southern Africa appears in taxonomic descriptions. The present work involved a study of the distribution of the sensory pits and their numbers in 12 *Culicoides* species which occur in southern Africa. Counts and measurements of the palpal sensilla were also carried out on some of the species. The advantage in epidemiological studies of a preliminary indication of the broad host preferences of *Culicoides* species is considerable, especially in those species such as *C. nivosus, C. tropicalis* and *C. gulbenkiani* which are usually collected in too small numbers for adequate blood meal precipitin testing.

MATERIALS AND METHODS

The *Culicoides* were collected in the Salisbury (17°50′ S, 31°03′ E) area. The antennal sensilla were examined in specimens mounted on slides in Swan's modification of Berlese's medium. It was necessary to employ scanning electron micrographs to count and measure the sensilla in the palpal pits. Specimens intended for scanning electron microscopy were subjected to critical point drying and coated with gold/palladium alloy.

Measurements were made with a Wild eyepiece micrometer on a Wild M5 microscope. The diameters of the bulb and stalk of the palpal sensilla were measured on 2 sensilla from a single pit for each specimen. The foreshortening on most micrographs made length measurements on the sensilla of questionable value, and these were not carried out.

RESULTS AND DISCUSSION

Antennal sensory pits. [See Chu et al. (1975) for description and discussion of function; see also McIver & Siemicki (1975).]

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TABLE 1. Mean numbers and distribution of antennal pit sensilla in ♀ of some *Culicoides* species, based on the present study (n = 10).

SPECIES OF *Culicoides*	NO. OF ANTENNOMERES WITH PITS	ANTENNOMERE													NO. OF PITS PER ANTENNA	
		3	4	5	6	7	8	9	10	11	12	13	14	15	$\bar{x}$	SE
C. schultzei (Enderlein) gp.*	4	2.0	.	.	.	.	1.0	1.8	2.1	.	.	.	.	.	6.9	0.31
C. sp. nr. *glabripennis* Goetghebuer	5	3.0	.	.	.	.	.	.	.	.	1.0	1.0	1.0	1.0	7.0	0
C. imicola Kieffer**	5(6)	3.0	.	.	.	.	.	.	.	0.1	1.0	1.0	1.0	1.0	7.1	0.10
C. gulbenkiani Pais Caeiro	6(5)	2.9	.	.	.	.	.	.	.	1.0	1.0	1.0	1.0	0.9	7.8	0.40
C. milnei Austen	6	2.7	.	.	.	.	.	.	.	1.0	1.1	1.0	1.3	2.0	9.1	0.31
C. fulvithorax (Austen)	6	3.0	.	.	.	.	.	.	.	1.0	1.0	1.0	2.0	2.0	10.0	0
C. brucei Austen***	6	3.0	.	.	.	.	.	.	.	1.0	1.0	1.0	2.0	2.2	10.2	0.20
C. zuluensis de Meillon	6	2.9	.	.	.	.	.	.	.	1.0	1.1	1.0	2.0	2.2	10.2	0.20
C. tropicalis Kieffer	8	3.5	1.0	1.8	1.8	2.0	2.3	2.2	2.5	.	.	.	.	.	17.1	0.50
C. distinctipennis Austen†	13	6.2	2.2	2.8	1.9	2.2	1.6	1.9	0.9	1.0	1.0	1.0	4.4	1.0	28.1	1.10
C. pycnostictus Ingram & Macfie	12	7.5	3.1	2.4	2.7	2.5	2.6	2.7	2.4	1.0	1.0	1.0	5.2	.	34.0	0.58
C. nivosus de Meillon	12	7.2	2.8	2.9	2.6	2.8	2.4	2.4	1.9	1.9	1.3	2.0	5.1	.	35.3	0.63

* According to M. Cornet (pers. commun.), this new species is common in Africa and designated *C. schultzei* (Enderlein) by most authors.

** (=*C. pallidipennis* Carter, Ingram & Macfie).

*** (=*C. hirtius* de Meillon & Lavoipierre).

† "praetermissus" form.

The number and distribution of the antennal sensory pits were determined in 10 specimens each of 12 species (TABLE 1). The same ranking of species may be obtained whether the number of pits or the number of pit-bearing antennomeres is recorded. The counting of pit-bearing antennomeres is quicker and would thus seem preferable whatever the physiological importance of either might be.

The results may be compared with those in various taxonomic works of other authors. Information on the distribution of antennal pits of many African *Culicoides* species appears in the descriptions in Khamala & Kettle (1971). Additional information is brought together in TABLE 2. Descriptions of species referred to in the text which are not dealt with in TABLE 1 and 2 may be found in Khamala & Kettle (1971). *C. babrius* as referred to by Khamala & Kettle (1971) is, according to M. Cornet (pers. commun.), a different species from the *C. babrius* de Meillon which M. Cornet believes to be a synonym of *C. tropicalis*. This view appears to be borne out by the fundamental difference in antennal pit distribution between *C. tropicalis* (3–10) and *C. babrius* (3, 7–10). The less important discrepancy in *C. pycnostictus* results (3–14; 3–15) may be due to small sample sizes.

TABLE 3 shows available data on host range or preference based on precipitin tests. Comparison with TABLE 1 shows that *C. milnei, C. zuluensis, C. brucei, C. imicola, C. fulvithorax* and *C. shultzei* gp., which feed mainly on large mammals, have pit sen-

TABLE 2. Numbers and distribution of antennal pit sensilla in ♀ *Culicoides* according to various authors.

SPECIES	ANTENNOMERE NO. (NO. SENSILLA)	NO. PIT SENSILLA PER ANTENNA	NO. ANTENNOMERES BEARING PITS	AUTHORITY
C. milnei	3(3), 11–14(1), 15(2)	9	6	Cornet et al. 1974
C. zuluensis	3(3), 11–13(1), 14–15(2)	10	6	Cornet et al. 1974
C. kerichoensis Khamala & Kettle	3(3), 11–13(1), 14–15(3, rarely 4)	12–14	6	Cornet et al. 1974
C. isiolensis Cornet, Nevill & Walker	3(3–5), 11–13(1), 14–15(2)	10–12	6	Cornet et al. 1974
C. glabripennis	3(3), 12–15(1)	7	5	Kremer et al. 1975a
C. kibatiensis Goetghebuer	3(3), 11–15(1)	8	6	Kremer et al. 1975a
C. trifusciellus Goetghebuer	3(3), 11–15(1)	8	6	Kremer et al. 1975a
C. dubitatus Kremer, Rebholtz-Hirtzel & Delecolle	3(3), 11–15(1)	8	6	Kremer et al. 1975b

TABLE 3. Host range and preferences of *Culicoides* species, based on precipitin tests.

SPECIES	HOST RANGE AND PREFERENCE* IF KNOWN	AUTHORITY
C. milnei	horses*, cattle, sheep, birds	Walker & Davies 1971; Nevill & Anderson 1972; Walker & Boreham 1976; Braverman & Boreham, in prep.
C. zuluensis	sheep, goat, horse, birds	Walker & Boreham 1976; Braverman & Boreham, in prep.
C. ciliodentatus Khamala & Kettle	bovid	Walker & Boreham 1976
C. magnus Colaco	sheep, cattle	Walker & Davies 1971
C. brucei	bovid*, birds	Walker & Boreham 1976
C. imicola	cattle*, horses, sheep, poultry	Walker & Davies 1971; Nevill & Anderson 1972; Walker & Boreham 1976; Braverman et al. 1977; Braverman & Boreham, in prep.
C. grahami Austen	bovid, sheep	Walker & Davies 1971, Walker & Boreham 1976
C. fulvithorax	horse, pig	Braverman & Boreham, in prep.
C. dekeyseri Clastrier	birds*	Walker & Boreham 1976
C. distinctipennis	birds*	Nevill & Anderson 1972, Braverman et al. 1977
C. pycnostictus	birds*	Nevill & Anderson 1972
C. cornutus de Meillon	cattle, sheep	Walker & Davies 1971, Walker & Boreham 1976
C. schultzei gp.	cattle*, sheep, goats	Nevill & Anderson 1972, Walker & Boreham 1976, Braverman et al. 1977

silla on 4–6 antennomeres and means of 6.9–10.2 pits per antenna. *C. distinctipennis* and *C. pycnostictus*, which feed on birds, have equivalent values of 12–13 and 28.1–34.0. On the basis of these results, it seems that the predictive usefulness in epidemiological work of the 2 parameters should be considerable, at least at the preliminary level. Of the remaining species in TABLE 1, *C.* sp. near *glabripennis* and *C. gulbenkiani* may be predicted to belong to the mammal-biting group and *C. nivosus* to the bird-biting group. It would be interesting to know the host preference of *C. tropicalis*, which falls intermediate between the ranges of the 2 groups (8 antennomeres with pits; mean number of 17.1 pits). The difference in incidence of the pits on the proximal antennomeres, particularly, in the 2 groups (TABLE 1) is very striking. With the exception of *C. schultzei* gp., none of the mammal-biting species has pits on antennomeres 4–10, while all bird-biting species have pits on these antennomeres. *C. tropicalis*, too, has no pits on antennomeres 11–15.

For other species from various parts of Africa (TABLE 2; Khamala & Kettle 1971), the relationship between the number of pit-bearing antennomeres and host preference again holds. Information on mean pit number is generally not available. *C. ciliodentatus*, *C. grahami* and *C. cornutus* normally have 4–6 pit-bearing antennomeres and appear to be mammal-biters, while *C. dekeyseri* with 12 is a bird-biter. TABLE 4 shows the predictions, based on number of pit-bearing antennomeres, for some African *Culicoides*. The general validity of the relationship will be tested by the extent to which these predictions are found to be correct, as more information on host preferences becomes available.

Jamnback (1965) suggested that presence of 8 or more pit-bearing antennomeres indicates a preference for birds. A tentative host range for only 1 species, *C. magnus*, in the 7–11 pit-bearing antennomere group is known. Evidence so far indicates that this species, which has 8 pits, is a mammal-biter. Fortunately, the number of species exhibiting this intermediate condition is small (TABLE 1, 2; Khamala & Kettle 1971). More data on host preference are necessary before any further conclusions can be drawn for these few species.

Antennal sensilla basiconica. [See Chu et al. (1975) for description.]

Sensilla basiconica were found in the 12 species on only the 5 distal antennomeres. These sense organs, which are probably hygroreceptors (Chu et al. 1975), were counted in the samples used for antennal pits. The results are given in TABLE 5. The mean numbers of sensilla basiconica bear no detectable relationship to host preference in these species. This is as might be expected for probable hygroreceptors, which are most likely concerned in some other aspect of behavior. There is also no obvious similarity in numbers between closely related species (following Khamala & Kettle 1971) in these samples, and sensilla basiconica numbers

TABLE 4. Predicted host preferences of some African *Culicoides* species, based on number of pit-bearing antennomeres.

MAMMALS (4–6 pit-bearing antennomeres)	BIRDS (12–13 pit-bearing antennomeres)
C. accraensis Carter, Ingram & Macfie	*C. arenarius* Edwards
C. adersi Ingram & Macfie	*C. bedfordi* Ingram & Macfie
C. albovenosus Khamala & Kettle	*C. gambiae* Claustrier & Wirth
C. austeni Carter, Ingram & Macfie	*C. hirtsutus* Khamala & Kettle
C. babrius de Meillon (sensu Khamala & Kettle)	*C. kaimosiensis* Khamala & Kettle
C. bwambanus de Meillon	*C. nivosus*
C. citroneus Carter, Ingram & Macfie	
C. dubitatus	
C. eriodendroni Carter, Ingram & Macfie	
C. expectator Clastrier	
C. giganteus Khamala & Kettle	
C. glabripennis	
C. sp. nr. *glabripennis*	
C. gulbenkiani	
C. hortensis Khamala & Kettle	
C. inornatipennis Carter, Ingram & Macfie	
C. isiolensis	
C. kanagai Khamala & Kettle	
C. kerichoensis	
C. kibatiensis	
C. kingi Austen	
C. latifrons Khamala & Kettle	
C. moreli Clastrier	
C. neavei Austen	
C. ovalis Khamala & Kettle	
C. parvulus Khamala & Kettle	
C. punctithorax Carter, Ingram & Macfie	
C. quinquelineatus Goetghebuer	
C. rhizophorensis Khamala & Kettle	
C. similis Carter, Ingram & Macfie	
C. stercorarius Khamala & Kettle	
C. sylvicola Khamala & Kettle	
C. tororoensis Khamala & Kettle [regarded by M. Cornet (pers. commun.) as a synonym of *C. gulbenkiani* Pais Caeiro]	
C. translucens Khamala & Kettle	
C. trifasciellus	
C. vitshumbiensis Goetghebuer (=*C. africanus* Clastrier)	

TABLE 5. Mean numbers of antennal sensilla basiconica in ♀ of some *Culicoides* species

SPECIES	PARAMETERS* n	$\bar{x}$	SE
C. gulbenkiani	5	14.0	1.22
C. brucei	5	19.0	1.38
C. sp. nr. *glabripennis*	10	21.9	1.08
C. imicola	5	24.6	0.60
C. milnei	7	24.6	1.19
C. fulvithorax	5	28.8	0.97
C. zuluensis	7	29.4	1.63
C. schultzei gp.	10	30.6	1.48
C. pycnostictus	5	31.2	2.03
C. distinctipennis	6	34.3	2.40
C. nivosus	5	35.8	2.52
C. tropicalis	5	36.0	1.52

* n = no. specimens; $\bar{x}$ = mean no.; SE = standard error.

TABLE 6. Numbers of bulb-shaped sensilla in palpal pits of some *Culicoides* species.

SPECIES	♀ n*	$\bar{x}$**	SE	Range	♂ n	Range
C. schultzei gp.	2	10	—	9–11	—	—
C. imicola	8	10.4	1.02	7–13	4	6–7
C. zuluensis	1	—	—	11	1	8
C. gulbenkiani	10	13.6	0.48	12–17	3	7–11
C. milnei	2	15	—	14–16	—	—
C. brucei	10	20.3	0.65	17–24	2	5–8
C. tropicalis	6	36.0	0.77	34–38	—	—
C. distinctipennis	2	—	—	33+, 50+	—	—
C. pycnostictus	1	—	—	50+	—	—
C. nivosus	6	—	—	48+, 75+	1	8

* n = no. specimens; $\bar{x}$ = mean no.; SE = standard error.
** Where sample number is very small or only a minimum count of sensilla possible, only ranges are given.

TABLE 7. Bulb and stalk diameters of palpal bulb-shaped sensilla in ♀ of some *Culicoides* species.

Species	Bulb diameter (μm)			Stalk diameter (μm)		
	n*	x̄	SE	n*	x̄	SE
C. imicola	8	1.8	0.10	7	0.8	0.06
C. gulbenkiani	5	1.6	0.04	5	0.8	0.01
C. brucei	10	1.9	0.03	10	0.7	0.03
C. nivosus	6	3.0	0.06	5	0.9	0.03

* n = no. specimens (2 sensilla measured from each specimen); $\bar{x}$ = mean no.; SE = standard error.

might, therefore, be useful for distinguishing difficult pairs of closely related species.

Palpal sensilla. [See Rowley & Cornford (1972) and Chu et al. (1975) for description.]

According to Rowley & Cornford (1972), species with smaller numbers of bulb-shaped sensilla in the palpal pits feed on mammals, while species with larger numbers feed on birds. Since carefully orientated electron micrographs are necessary for the count, this system would be much more time-consuming in routine use than would the use of the antennal characters. Counts were carried out on 10 species, though in some cases on very small samples. The results are given in TABLE 6.

As shown by Rowley & Cornford (1972), males have fewer bulb-shaped sensilla. Comparison of TABLE 3 and 6 shows that the relationship postulated by these authors appears to hold. It is noteworthy that both antennal pit number and distribution and palpal sensilla number place *C. gulbenkiani* among the mammal-biters and *C. nivosus* with the bird-feeders (TABLE 1, 6). Bluetongue virus has, in fact, been isolated from *C. tororoensis* (regarded by M. Cornet, pers. commun., as a synonym of *C. gulbenkiani*) in Kenya (Walker & Davies 1971). Once again, *C. tropicalis* is difficult to place. An explanation might lie in an unusual host range or aspect of feeding behavior in this species.

During the counts, it was possible to determine the stalk and bulb diameters of the bulb-shaped sensilla in 4 species where number and viewing angle made the measurements worthwhile (TABLE 7). The dimensions are very similar to those quoted by Rowley & Cornford (1972). *C. nivosus* has a relatively much larger bulb than the other 3 species.

CONCLUSIONS

The number of antennal pits and host preference show a striking relationship in the *Culicoides* species examined from southern Africa. This provides support from a geographically distant sample of species for the relationship postulated by Jamnback (1965), working on American species. The present work demonstrates that number of pit-bearing antennomeres is a satisfactory indicator of the total number of sensilla on the antenna, although both values fail to reflect the remarkable difference in the incidence of pits on the proximal antennomeres between most of the mammal-biting species and the bird-biting species in the samples examined. The numbers of bulb-shaped sensilla in the palpal pits also show the host preference relationship, but are much harder to count. The numbers of sensilla basiconica on the antenna show no such relationship.

A preliminary indication of the probable preference of a *Culicoides* species for bird or mammal hosts is, thus, relatively simply arrived at by a count of the number of antennomeres which bear sensory pits. Such indications provide a useful tool in epidemiological studies. This information is often already available in the literature, owing to the importance of the antennal pit distribution in the taxonomy of *Culicoides*.

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LITERATURE CITED

Braverman, Y., P. F. L. Boreham, R. Galun & M. Ziv. 1977. The origin of blood meals of biting midges (Diptera: Ceratopogonidae) and mosquitoes (Diptera: Culicidae) trapped in turkey runs in Israel. *Rhod. J. Agric. Res.* **15:** 101–04.

Chu, I-W., R. C. Axtell & D. L. Kline. 1975. Antennal and palpal sensilla of the sand fly *Culicoides furens* (Poey) (Diptera: Ceratopogonidae). *Int. J. Insect Morphol. Embryol.* **4:** 131–49.

Cornet, M., E. M. Nevill & A. R. Walker. 1974. Note sur les *Culicoides* (Diptera: Ceratopogonidae) du groupe de *C. milnei* Austen, 1909, en Afrique orientale et australe. *Cah. O.R.S.T.O.M. Ser. Entomol. Med. Parasitol.* **12:** 231–43.

Jamnback, H. 1965. The *Culicoides* of New York State (Diptera: Ceratopogonidae). *N.Y. State Mus. Sci. Serv. Bull.* **399:** 1–154.

Khamala, C. P. M. & D. S. Kettle. 1971. The *Culicoides* Latreille (Diptera: Ceratopogonidae) of East Africa. *Trans. R. Entomol. Soc. London* **123:** 1–95.

Kremer, M., C. Rebholtz-Hirtzel & J. C. Delecolle. 1975a. Etude des types de *Culicoides* (Diptera, Ceratopogonidae) de Goetghebuer et des autre *Ceratopogonidae* déposés au Musée de Tervuren. *Rev. Zool. Afr.* **89:** 769–820.

1975b. Description d'une espèce nouvelle: *C. dubitatus* n. sp. (Diptera, Ceratopogonidae) de la Region Ethiopienne. *Cah. O.R.S.T.O.M. Ser. Entomol. Med. Parasitol.* **13:** 233–36.

McIver, S. & R. Siemicki. 1975. Palpal sensilla of selected anopheline mosquitoes. *J. Parasitol.* **61:** 535–38.

Nevill, E. M. & D. Anderson. 1972. Host preferences of *Culicoides* midges (Diptera: Ceratopogonidae) in South Africa as determined by precipitin tests and light trap catches. *Onderstepoort J. Vet. Res.* **39:** 147–52.

Rowley, W. A. & M. Cornford. 1972. Scanning electron microscopy of the pit of the maxillary palp of selected species of *Culicoides*. *Can. J. Zool.* **50:** 1207–10.

Walker, A. R. & P. F. L. Boreham. 1976. Blood feeding of *Culicoides* (Diptera, Ceratopogonidae) in Kenya in relation to the epidemiology of bluetongue and ephemeral fever. *Bull. Entomol. Res.* **66:** 181–88.

Walker, A. R. & F. G. Davies. 1971. A preliminary survey of the epidemiology of bluetongue in Kenya. *J. Hyg.* **69:** 47–60.