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A SURVEY OF THE MOSQUITO AND *CULICOIDES* FAUNAS AT TWO LOCALITIES IN THE KAROO REGION OF SOUTH AFRICA WITH SOME OBSERVATIONS ON BIONOMICS

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ABSTRACT

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The mosquito and *Culicoides* faunas were surveyed at Bethulie and Luckhoff in the arid Karoo region, southern Orange Free State, to determine which species occurred, their relative prevalence and the effects of rainfall. The feeding preferences of these insects were also investigated by means of baited catches.

Twenty-three mosquito species and 16 *Culicoides* species were collected. The commonest mosquito species, with their feeding preferences, if known, were as follows: *Culex* (*Culex*) *univittatus* Theo and *Culex* (*Culex*) *pipiens* Linnaeus, which are strongly ornithophilic and poorly anthropophilic; *Culex* (*Culex*) *theileri* Theo, which feeds on sheep and man avidly but is only moderately ornithophilic; *Aedes* (*Neomelaniconion*) *luridus* McIntosh, *Aedes* (*Neomelaniconion*) *lineatopennis* (Ludlow), *Aedes* (*Ochlerotatus*) *caballus* (Theo) and *Aedes* (*Ochlerotatus*) *juppi* McIntosh, all of which feed on sheep and man readily and which can aestivate as eggs for up to 20 months but only appear in numbers after rain; *Anopheles* (*Cellia*) *listeri* De Meillon, *Anopheles* (*Cellia*) *squamosus* Theo, *Culex* (*Culex*) *quinquefasciatus* Say and *Culiseta* (*Allotheobaldia*) *longiareolata* (Macquart). By far the commonest *Culicoides* at both localities was *Culicoides pycnostictus* Ingram & Macfie, which is strongly ornithophilic and also feeds on sheep. The following 5 species were also prevalent: *Culicoides similis* Carter, Ingram & Macfie, *Culicoides* spec. nov. 1., *Culicoides schultzei* (Enderlein), *Culicoides onderstepoortensis* Fiedler and *Culicoides nivosus* De Meillon. The last species is strongly ornithophilic.

Résumé

UNE ENQUÊTE DES FAUNES DE MOUSTIQUES ET DE CULICOIDES *DANS DEUX LOCALITÉS DE LA RÉGION DU KAROO EN AFRIQUE DU SUD AVEC CERTAINES OBSERVATIONS ÉCOLOGIQUES*

Des faunes de moustiques et de Culicoides *ont été recherchées à Bethulie et à Luckhoff dans la région aride du Karoo dans le sud de l'Etat Libre d'Orange pour déterminer quelles espèces survenaient, leur predominance relative et les effets des chutes de pluie. Les préférences alimentaires de ces insectes furent également investiguées au moyen de pièges à amorce. Vingt-trois espèces de moustiques et* 16 *espèces de* Culicoides *ont été rassemblées. Les espèces de moustiques les plus communes, avec leur préférences alimentaires, quand elles étaient connues, furent les suivantes:* Culex (Culex) univittatus *Theo et* Culex (Culex) pipiens *Linnaeus, qui sont fortement ornithophiliques et faiblement anthropophiliques;* Culex (Culex) theileri *Theo, qui s'alimente avidement sur le mouton et sur l'homme mais qui est seulement modérément ornithophilique;* Aedes (Neomelaniconion) luridus *McIntosh,* Aedes (Neomelaniconion) lineatopennis (*Ludlow*), Aedes (Ochlerotatus) caballus (*Theo*) *et* Aedes (Ochlerotatus) juppi *McIntosh, qui tous se nourrissent principalement sur le mouton et sur l'homme et qui peuvent estiver sous forme d'oeufs jusqu'à* 20 *mois mais apparaissent seulement en nombres apprès la pluie;* Anopheles (Cellis) listeri *De Meillon,* Anopheles (Cellis) squamosus *Theo,* Culex (Culex) quinquefasciatus *Say et* Culiseta (Allotheobaldia) longiareolata (*Macquart*). *De loin le plus, commun des* Culicoides *dans les deux localités fut* Culicoides pycnostictus *Ingram & Macfie, qui est fortement ornithophilique et qui s'alimente aussi sur le mouton. Les cinq espèces suivantes furent aussi prédominantes:* Culicoides similis *Carter, Ingram & Macfie,* Culicoides *spec. nov.* 1., Culicoides schultzei (*Enderlein*), Culicoides onderstepoortensis *Fiedler et* Culicoides nivosus *De Meillon. La dernière espèce est fortement ornithophilique.*

INTRODUCTION

In the past the mosquito and *Culicoides* faunas of the Karoo region have received little attention. However, it was feared that after the construction of dams and irrigation works on or along the Orange River in the arid Karoo region of the Orange Free State, there might be an increase in the populations of arbovirus vectors in this area. This in turn would probably increase virus transmissions and thus endanger the health of both humans and livestock. Studies were therefore conducted on the prevalence of these viruses in insects and sentinel avian hosts at 2 representative localities, Bethulie and Luckhoff (McIntosh, Jupp & Dos Santos, 1978; McIntosh & Jupp, 1979).

Mosquitoes, *Culicoides* and, to a lesser degree, Simuliidae were collected and assayed for virus over 4 summers, at Bethulie during 3 summers between December 1968 and March 1971 and at Luckoff during the summers of 1971 and 1976. The collection methods used were aimed primarily at securing large numbers of insects for virus assay and they tended to be somewhat biased towards the collection of *Culex* (*Culex*) *univittatus* Theo because of this mosquito's known importance as a vector of West Nile and Sindbis viruses. However, efforts were made to employ methods which would also show which species of mosquito and *Culicoides* were present in the 2 localities, their relative prevalence and the feeding preferences of the commoner species. One aspect of this survey, that is, on mosquitoes ovipositing in containers, has already been reported (Jupp, 1978). This paper reports the findings on the collections of adult insects.

STUDY LOCALITIES

Bethulie and Luckhoff, which are located about 150 km apart near the Orange River in the southern part of the Orange Free State, both have an altitude of 1 289 m and are situated in the semi-desert Karoo region where the vegetation is mainly xerophytic dwarf shrub. Both localities are in sheepfarming areas and insect collections were made on several such farms in the vicinity and, in the case of Bethulie, also near the dam in the town itself. Insect traps were usually set near dams, vleis or perennial streams on the farms.

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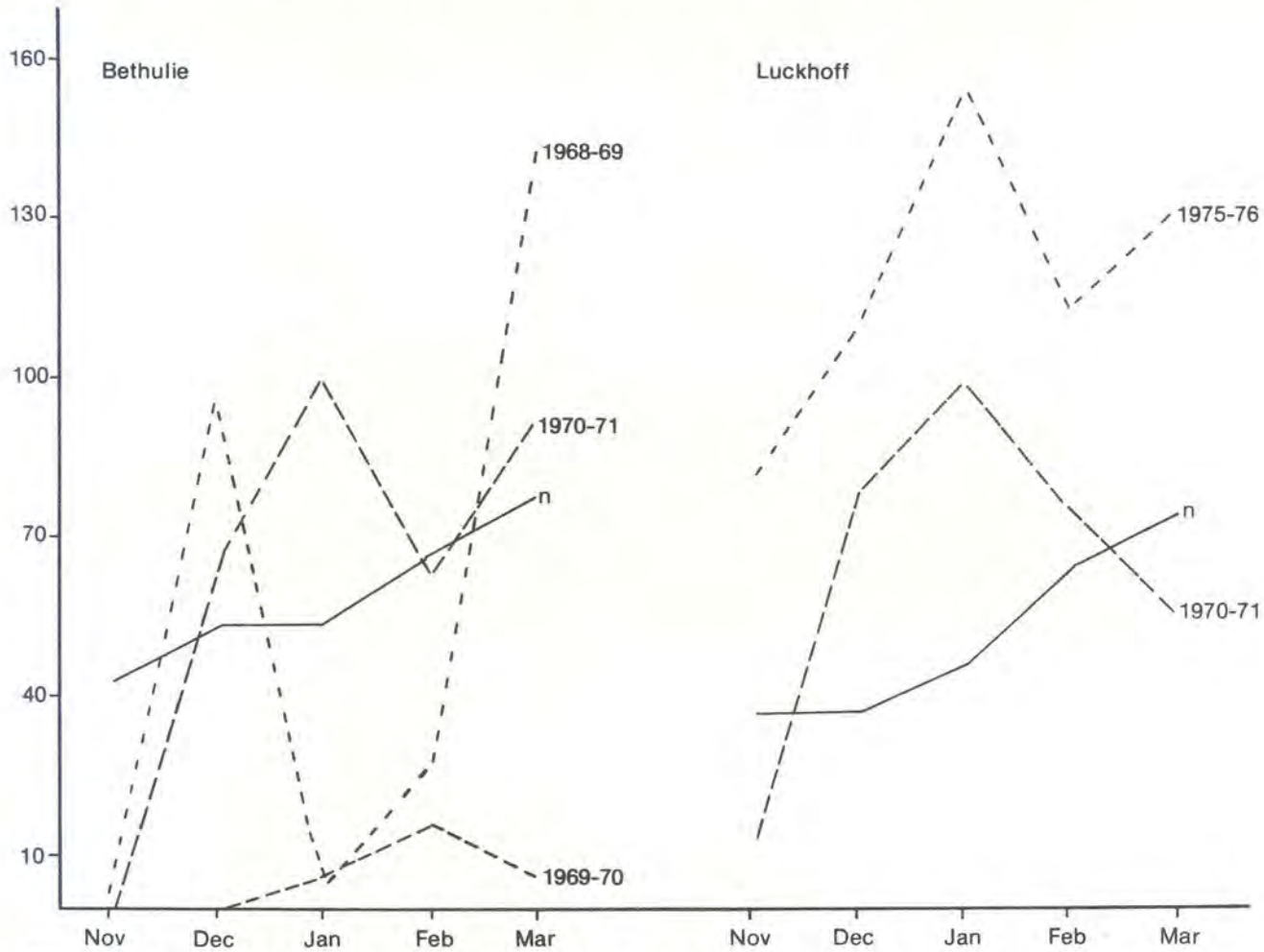

FIG. 1 Monthly rainfall (mm) at Bethulie and Luckhoff during summers when insects were collected. The normal (n) rainfall is shown for comparison.

The Karoo climate has very hot summers with a low rainfall and dry, cold winters. The mean annual rainfall for Bethulie is 439 mm and Luckhoff is somewhat drier with 379 mm. From November to March, when collecting was undertaken, the mean daily temperature varies from about 20–23 °C, the mean daily minimum being 11–15 °C while the mean daily maximum soars to about 28–31 °C. The normal monthly rainfall in summer at the 2 localities given in Fig. 1 shows that it is lower at Luckhoff for each of the 5 months. Monthly precipitation during the summers when the study took place is also shown. During the 1968–69 summer at Bethulie, rainfall was negligible during November, January and February but well above average in December and March, particularly in March, when it reached 143 mm. In 1969–70 there was a severe drought when very little rain fell the whole summer at Bethulie, while in 1971 precipitation was consistently above average at both study localities. Figures shown for the 1975–76 summer at Luckhoff reveal the abnormally high rainfall of that season.

Collection of mosquitoes and Culicoides

Five different collecting methods were used with traps operated overnight. In 3 of these methods the type of bait varied as follows:

(1) *Light trap:* This had an 8 watt suction motor and a 3 candle-power incandescent bulb powered by a 12 volt car battery. It was hung with its entrance about 1 m above the ground and insects were sucked downwards into a collecting cage made of organdie. The filter fitted over the entrance was either 5 mm wire mesh or nylon mosquito screen. The former prevented insects larger than mosquitoes from entering the trap while the latter prevented the entrance of these as well as mosquitoes, so that only *Culicoides* and similar small-sized insects were collected. In the summer of 1976 a few traps with the coarse filter were used with carbon dioxide as an additional attractant, as described previously (Jupp, McIntosh & Anderson, 1976).

(2) *Suction trap:* This consisted of the same motor unit as the light trap, without the light and filter, and was used in conjunction with either pigeon or sheep bait. When pigeons (*Columba livea*) were used the open end of the cylinder containing the motor unit was inserted into the bottom of a cage containing 2 sentinel birds about 2 m above ground level. Diptera attracted to the birds were sucked downwards into the collecting cage before they could feed. When used with sheep, the suction trap was mounted horizontally in the side of a wire-mesh cage containing the animal.

(3) *Lard-can type No. 6 trap:* This is based on the lard-can trap designed by Bellamy & Reeves (1952), but is smaller (Jupp, 1969). Each trap was baited with a pigeon enclosed in a cage of nylon mosquito screen which prevented mosquitoes from feeding. Traps were suspended 1,2–1,8 metres above ground level.

(4) *Net trap:* This trap, which was described by Jupp & McIntosh (1967), was baited either with about 2,5 kg of solid CO_2 inside a cardboard box, or with a sheep, penned in a wire cage within the net.

(5) *Human-baited catches:* These were undertaken at sunset with 2 or more catchers and lasted up to 1 hour. Each catcher operating outdoors alone, collected mosquitoes alighting on his legs with test tubes. Light was provided by an electric torch shaded with a red cloth cover.

The total number of trap-nights recorded with each method is listed below as well as the number of man-hours for the catches off human bait.

Light trap.....	(a) With coarse filter.....	145
	(b) With mosquito filter..	65
	(c) With coarse filter and CO_2 bait.....	8
Suction trap....	(a) Pigeon-baited.....	58
	(b) Sheep-baited.....	5
Lard-can trap...	Pigeon-baited.....	157
Net trap.....	(a) CO_2-baited.....	34
	(b) Sheep-baited.....	14
Human-baited catches.....		16½ man-hours

Mosquito and Culicoides *identification*

The nomenclature used for Anopheline mosquitoes follows that of Gillies & De Meillon (1968), and for culicines that of Knight & Stone (1977), except in the case of the 2 members of the *Culex pipiens* complex occurring in South Africa which are referred to as *Cx.* (*Culex*) *pipiens* L. and *Cx.* (*Cx.*) *quinquefasciatus* Say. The abbreviations used for generic and subgeneric names follow those suggested by Reinert (1975). Certain changes in nomenclature occurred in 2 aedine subgenera during the course of the study, 2 new species being named in the subgenus *Neomelaniconion* (McIntosh, 1971) and 1 in the subgenus *Ochlerotatus* (McIntosh, 1973), which were all found in the study area. It seems likely that the 2 *Neomelaniconion* species, *Ae. luridus* McIntosh and *Ae. unidentatus* McIntosh, were previously confused with *Ae. lineatopennis* Ludlow, and the *Ochlerotatus* species *Ae. juppi* McIntosh with *Ae. caballus*. Hence collections of *Neomelaniconion* and *Ochlerotatus* mosquitoes made prior to the recognition of these new species are referred to in the report as *lineatopennis* group and *caballus* group respectively.

The nomenclature used for *Culicoides* (*Cul.*) follows that of Fiedler (1951) with 3 exceptions as follows: Fiedler's *Cul. pallidipennis* Carter, Ingram & Macfie is referred to as *Cul. imicola* Kieffer and *Cul. babrius* De Meillon as *Cul. tropicalis* Kieffer according to the revision by Kremer (1972); while his *Cul. hirtius* De Meillon & Lavoipierre is referred to as *Cul. brucei* Austen after the revision by Khamala & Kettle (1971). One new *Culicoides* species with clear wings (*Cul.* spec. nov. 1.) and a second with spotted wings (*Cul.* spec. nov. 2.) were discovered during the study and are in the process of being described by Dr M. Cornet of ORSTOM and a co-author of this paper (E.M.N.).

Results

Traps

Mosquitoes were caught in all the traps used except in the light traps fitted with a mosquito filter, while *Culicoides* were collected only in suction and light traps. The pigeon-baited lard-can traps collected far fewer mosquitoes per trap night than suction traps, but they collected a higher proportion of *Cx. theileri*, as was also suggested during previous collections on the Highveld (Jupp, 1973). The net trap, baited with either CO_2 or a sheep, and the light trap, particularly when used with CO_2 bait, were found effective for collecting a wider range of mosquito species including the seasonal *Aedes*.

Species prevalence

A total of 22 798 adult female mosquitoes belonging to 23 species, divided among 4 genera, were caught at Bethulie and Luckhoff (Table 1). *Anopheles*, with 5 species, was represented by 852 insects and composed only 3,7% of the total catch. *Aedes*, with 9 species, totalled 8 931 insects (39,2% of catch). *Culex*, with possibly 8 species, totalled 12 709 insects and composed the largest proportion of the catch (55,7%). *Culiseta* was represented by a single species.

TABLE 1 Numbers of adult female mosquitoes collected at Bethulie and Luckhoff by all methods used over 69 nights during 4 summers (1968/69, 69/70, 71 & 76)

	No.	No. as % of total(c)
Anopheles (*An.*) *coustani*.....	8	
Anopheles (*An.*) *implexus*.....	1	
Anopheles (*Cel.*) *cinereus*.....	2	
Anopheles (*Cel.*) *listeri*.....	142	
Anopheles (*Cel.*) *squamosus*.....	693	3,0
Anopheles spp. undet.....	6	
Aedes (*Ad.*) *dentatus*.....	21	
Aedes (*Ad.*) *durbanensis*.....	1	
Aedes (*Ad.*) *hirsutus*.....	1	
Aedes (*Neo.*) *lineatopennis*.....	689	3,0
Aedes (*Neo.*) *luridus*.....	50	
Aedes (*Neo.*) *unidentatus*.....	4	
Aedes (*Neo.*) *lineatopennis* group(a).....	4 118	18,0
Aedes (*Och.*) *caballus*.....	981	4,3
Aedes (*Och.*) *juppi*.....	962	4,2
Aedes (*Och.*) *caballus* group (b).....	2 092	9,1
Aedes (*Stg.*) *aegypti formosus*.....	1	
Aedes spp. undet.....	11	
Culex (*Cx.*) *annulioris*.....	19	
Culex (*Cx.*) *pipiens*.....	2 379	10,4
Culex (*Cx.*) *quinquefasciatus*.....	54	
Culex (*Cx.*) *theileri*.....	4 108	18,1
Culex (*Cx.*) *tigripes*.....	1	
Culex (*Cx.*) *univittatus*.....	5 677	24,7
Culex (*Mai.*) *salisburiensis*(d).....	58	
Culex spp. undet.....	413	1,8
Culiseta (*All.*) *longiareolata*.....	306	1,3
Total Culicidae.....	22 798	

(a)=*luridus*, *lineatopennis* and *unidentatus*—see results
(b)=*caballus* and *juppi*—see results
(c)=In this and subsequent tables a blank indicates less than 1 %
(d)=Examination of larvae showed that both *salisburiensis* and the subspecies *naudeanus* occurred at Bethulie.

Among *Aedes*, the subgenus *Aedimorphus* was poorly represented, as was the subgenus *Stegomyia*, with only a single specimen. Three species of *Neomelaniconion* and 2 of *Ochlerotatus* were collected. Because 3 of these 5 species were discovered only during the study, collections prior to their discovery are referred to as the *lineatopennis* group and *caballus* group respectively. Collectively, these were a dominant part of the mosquito fauna of the region and in numbers collected accounted for 39,0% of the total catch, although active females were only plentiful after heavy rains. From collections in which species identifications were possible among *Neomelaniconion* mosquitoes, *Ae. luridus* was most prevalent at Bethulie and *Ae. lineatopennis* at Luckhoff, although all 3 species in this subgenus were prevalent at Luckhoff. In collections at Luckhoff in 1976 *Ae. caballus* and *Ae. juppi* were present in approximately equal numbers.

TABLE 2 Numbers of male and female *Culicoides* (*Cul.*) collected in 40 light-trap-nights at Bethulie and Luckhoff during 2 summers (1969/70, 1971)

	No.	No. as % of total
Cul. pycnostictus	2 314	46,6
Cul. similis	843	16,9
Cul. spec. nov. 1.(a)	720	14,5
Cul. schultzei	286	5,7
Cul. nivosus	275	5,5
Cul. onderstepoortensis	226	4,5
Cul. distinctipennis	63	1,2
Cul. neavei	55	1,1
Cul. tropicalis	49	
Cul. imicola	44	
Cul. bedfordi	36	
Cul. magnus	23	
Cul. brucei	15	
Cul. huambensis	2	
Cul. gulbenkiani	1	
Cul. spec. nov. 2.(b)	1	
Cul. spp. undet	11	

(a)=A clear-winged species
(b)=A species with spotted wings
Both species are being described by M. Cornet (ORSTOM) and E. M. Nevill

TABLE 3 Mosquitoes attracted to different animal baits and to man

	Pigeon (215)(a)		Sheep (19)(a)			Man(b)	
	No.	No. as % of total	No.	No. as % of total	Mean % fed(c)	No.	No. as % of total
An. coustani			5		0	3	
An. listeri			13		0		
An. squamosus	6		49	2,7	53	1	
Ae. caballus group	22		147	8,3	39	86	15,8
Ae. dentatus			2		0	11	2,0
Ae. luridus	9		3		0		
Ae. lineatopennis group	19		83	4,7	59	240	44,1
Aedes spp. undet			2		0		
Cx. annulioris	18						
Cx. pipiens	2 081	27,2	13		0		
Cx. quinquefasciatus	41						
Cx. salisburiensis	1						
Cx. theileri	405	5,3	1 381	78,4	75	202	37,2
Cx. univittatus	4 625	60,6	47	2,6	9		
Culex spp. undet	333	4,3	14		0		
Cs. longiareolata	63		2		0		

(a)=No. of trap-nights
(b)=16,5 man-hours collecting over 8 days
(c)=Arithmetic mean of percentage fed in each collection

Culex was dominated by 3 species, *Cx. univittatus*, *Cx. theileri* and *Cx. pipiens*, which between them accounted for 53,4% of the total catch. The presence of both *Cx. salisburiensis* and its subspecies *naudeanus* were established from larval identification. Even during the 1969–70 summer, when there was a severe drought (Fig. 1), appreciable numbers of *Cx. univittatus* (898) and *Cx. theileri* (727) were still collected.

Total catches of *Culicoides* and Simuliidae were not always recorded, partly because of the large numbers of *Culicoides* present. Random samples, consisting of a total of 16 031 *Culicoides* and 2 791 Simuliidae, were counted, and these figures are probably a fair representation of the relative numbers of these 2 groups of insects in the collections. In addition 16 species of *Culicoides*, collected in 40 light trap-nights, were identified and counted (Table 2).

Host preferences

The results of mosquito collections with the use of either pigeon, sheep or human baits are given in Table 3. While a variety of species were caught in pigeon-baited traps, these catches were dominated by *Cx. univittatus* and *Cx. pipiens*, with *Cx. theileri* also present in moderate numbers. Sheep-baited traps yielded largely *Cx. theileri*, but fair numbers of the *caballus* and *lineatopennis* groups were also caught. A high proportion of these mosquitoes was recorded as having fed on the sheep, as was also the case for *An. squamosus*. With the exception of *An. squamosus* the same species and species groups also predominated in the man-baited collections.

Table 4 gives the numbers of *Culicoides* species collected in pigeon-baited suction traps. *Cul. pycnostictus* and *Cul. nivosus* dominated these collections

at an even higher relative proportion than in light trap collections (Table 2). It therefore seems likely that these 2 species are attracted to and would feed on birds in the Karoo in significant numbers. Conversely, *Cul. similis*, *Cul.* spec. nov. 1., *Cul. schultzei* and *Cul. onderstepoortensis*, which were present in fair numbers in the light trap collections, were either poorly represented (*Cul.* spec. nov. 1.) or absent in the pigeon-baited collections, which indicates that probably none of these species are attracted to birds.

TABLE 4 *Culicoides* (*Cul.*) collected in 27 trap-nights in pigeon-baited suction traps

	No.	No. as % of total
Cul. pycnostictus	809	80,5
Cul. nivosus	149	14,8
Cul. neavei	18	1,7
Cul. spp. undet	17	1,6
Cul. spec. nov. 1	10	
Cul. imicola	1	

At Luckhoff in January, 1971, 39 *Cul. pycnostictus* were collected in sheep-baited suction traps during 5 nights, and in March, 1971, a suction trap set inside a sheep-baited net trap during 4 nights collected 11 of the same species. These results suggest that *Cul. pycnostictus* also feeds on sheep in the Karoo.

Collections made in pigeon-baited suction traps at Bethulie in 1971 indicated that some species of Simuliidae are strongly attracted to birds.

Discussion

Mosquitoes

Because of unavoidable variables resulting from individual trap bias, times which collections are made and siting of traps, it is extremely difficult to determine accurately the relative prevalence of species among a mosquito fauna. The numbers of the various mosquito species shown in Table 1 must therefore be assessed with this in mind. None the less, a variety of collecting methods were used during various climatic conditions over several years and the figures are meaningful in a particular context. They are the result of collections made for a specific purpose, namely, to investigate adult female mosquitoes as possible vectors of viruses. To some extent the vector species were known and the collecting methods were designed partly with these species in mind. Since our main interest was those species feeding on birds, domestic ungulates and man in a particularly arid region of the inland plateau in South Africa, a numerical presentation of the collections serves a useful purpose to this end.

The collections showed a considerable numerical predominance of *Cx. univittatus*, *Cx. theileri*, *Cx. pipiens* and certain members of the *Ae. lineatopennis* and *Ae. caballus* groups. All these species have in varying degrees been implicated as virus vectors during other studies (Gear, De Meillon, Le Roux, Kofsky, Rose-Innes, Steyn, Oliff & Schultz, 1955; Jupp & McIntosh, 1967; Jupp, 1976a, b; McIntosh, Jupp, Dos Santos & Meenehan, 1976). By revealing their prevalence in the Karoo, the present collections, indicate that they could act as vectors in this region. *Culex quinquefasciatus* and *Culiseta* (*All*) *longiareolata* were collected in only small numbers but, judging from the frequency with which they occurred in larval collections (Jupp, 1978), apparently both are prevalent species.

The difference in life histories among members of the *Aedes* and *Culex* genera has implications for their roles as vectors. *Aedes* pass through adverse climatic periods as drought-resistant eggs on the ground. In this form they remain viable for long periods as, for example, from April 1969 until December 1970, a period of 20 months, when the 1969–70 summer rains failed. Although adults of certain *Aedes* species appear in enormous numbers after sufficient rain has inundated the dormant eggs, the adults are short-lived and their ability to transmit viruses is correspondingly restricted in time. Despite this handicap, they possess great potential as vectors because they produce large populations, albeit for a short period. The collections showed that members of the *Ae. lineatopennis* and *Ae. caballus* groups belong to this category.

The eggs of *Culex* species are not drought resistant; these species survive adverse conditions as adults, pupae or larvae. They utilize permanent or semi-permanent ground pools for breeding and consequently the active adult female is present throughout the summer and autumn and their ability to transmit viruses extends over a longer period of the year. Where ground pools occur, *Culex* species will usually be found, as in the present study. The collections suggested that even during dry summers, virus transmission in the Karoo by *Cx. univittatus* and *Cx. theileri* would be possible. Since humans and domestic animals in an arid environment tend to cluster around permanent water, this habit of *Culex* species has obvious epidemiological implications.

Numbers of various mosquito species caught in the baited collections (Table 3) concurred with host preferences recorded in the Highveld region for those species common to both regions (Jupp & McIntosh, 1967; Jupp, 1973). In both regions *Cx. univittatus* and *Cx. pipiens* were strongly ornithophilic and poorly anthropophilic, while *Cx. theileri* was strongly attracted to ungulates and man besides being moderately ornithophilic. Members of the *Ae. lineatopennis* and *Ae. caballus* groups were shown to feed on sheep and man. Because of apparent differences in prevalence among species of these groups in the Highveld and Karoo, it seems that *Ae. luridus*, *Ae. lineatopennis*, *Ae. caballus* and *Ae. juppi* could be important vectors in the Karoo, whereas in the Highveld only *Ae. unidentatus* and *Ae. juppi* would assume this role.

Culicoides

Assuming the different *Culicoides* species are equally attracted to light traps, the numbers of the various species given in Table 2 are probably a fair representation of their relative abundance. *Cul. pycnostictus* probably dominates all other species in the Karoo and a further 5 species are fairly prevalent.

The predominance of *Cul. pycnostictus* on most of the farms at the 2 localities and the prevalence of bluetongue virus in the 2 areas suggest that this species could be the most likely vector of bluetongue virus in this region, particularly as the proven vector *Cul. imicola* is rare. In this connection it seems that *Cul. pycnostictus* does feed on sheep, judging by its collection in suction traps set near a sheep at Luckhoff. Its preference for birds shown here (Table 4) agrees with bloodmeal identifications for *Cul. pycnostictus* collected at Onderstepoort in the Transvaal

(Nevill & Anderson, 1972). *Cul. nivosus* was rare in the collections previously made at Onderstepoort by Nevill & Anderson (1972), but in the Karoo it was fairly common and apparently ornithophilic.

The densities of *Culicoides* were probably higher than is suggested by the study since trapping was mainly directed towards the collection of mosquitoes. *Culicoides* are probably better adapted to the arid Karoo than mosquitoes because their immature stages are less dependent on rainfall and it is their habit to develop in moist soil or dung rather than water. Thus it is that during droughts they are probably maintained at higher levels than mosquitoes. The collections showed that trapping sites, season and rainfall all influence catches of these midges.

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