VERTICAL ACTIVITY, HOST PREFERENCE, AND POPULATION STUDIES OF ADULT CULICOIDES (DIPTERA: CERATOPOGONIDAE)

by

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** - New to the state of Virginia.

* - New to Giles County, Virginia

I. INTRODUCTION

The genus Culicoides includes species of small blood-sucking gnats belonging to the family Ceratopogonidae (Diptera). They are often referred to as "punkies" or "no-see-ums".

In southwestern Virginia, these gnats have long been worrysome pests of hunters, fishermen, and campers. In addition they have become pests of livestock and have been incriminated as the vector of Blue Tongue Disease of sheep and cattle.

A number of Culicoides have been categorized as being either mammalophilic or ornithophilic. Culicoides are extremely small (they can enter screened windows), and they have short flight ranges (Jamnback, 1965). There has been a question as to how selective such an insect could be, since any type of blood meal might be difficult to obtain at times. Does a species which feeds in the forest canopy really prefer birds to mammals, or is it because there are more birds than mammals in the forest canopy? Does a species which feeds at ground level really prefer mammals to birds, or is it because there are more and larger mammals than birds at ground level? During the summer of 1969, the host preferences of several Culicoides species were investigated in the light of their vertical activity patterns.

Little has been demonstrated concerning the seasonal and daily abundance of adult Culicoides species in Virginia. There also have been differences of opinion concerning the best trapping method to collect a particular species or a wide range of species. During the summer of 1970, 3 trapping methods were employed simultaneously to investigate the seasonal and daily activity patterns of several Culicoides species and to determine the relative effectiveness of the 3 trapping methods. They were:

1) Goat-Baited Trap

2) Black Light Trap (Converted New Jersey Light Trap)

3) D-Vac® Vacuum Insect Net

The above traps were entirely different from each other in their methods of operation. The first trap used a potential host as an attractant. The second used a light source as a visual attractant. The third did not use any attractant at all, but merely sampled the air for flying Culicoides species. It was reasoned that a combination of results from 3 different types of traps would be more meaningful than results from any one of them alone.

II. LITERATURE REVIEW

A. Vertical Activity

Several studies on the vertical abundance and distribution of insects have been made, but only a few of them have included data on Culicoides species. Various collecting techniques have been employed including airplanes, light traps, adhesive paper traps, sticky panels, human bait, and animal-baited traps.

Glick (1939) used bi-planes to study the distribution of insects, spiders, and mites in the air. Interestingly enough, a few Culicoides were collected at all altitudes up to and exceeding 5,000 feet.

Williams (1955b) positioned light traps at 6, 25, and 40 feet on a 50-foot tower located in a wooded area of Georgia. Of his total catch, 44% were collected at the 6-foot level, 40% at the 40-foot level, and 15% at the 25-foot level. More C. arboricola were collected at 6 feet than at 40 feet. The opposite was true of C. venustus Hoffman and C. crepuscularis.

Carpenter (1951) used light traps and white adhesive paper traps to study C. furens in the Panama Canal Zone. He placed the adhesive traps in windows at elevations of 7, 23, and 35 feet on 3 floors of a building and caught Culicoides at each level in about equal

numbers. This indicated to him that the gnats would enter buildings at any height whenever human beings were inside to attract them. He also attached adhesive papers to both sides of boards which were placed in horizontal positions on stakes at heights of 8 to 68 inches in the jungle. He found no significant difference in the numbers collected at the different heights. In an attempt to determine the resting sites of adult C. furens (Poey), Bidlingmayer (1961) situated grease-smeared masonite panels on poles at 1, 2, 8, and 14 feet above the ground. Female C. furens preferred the 1 and 2-foot panels as resting sites, while 88% of the males were taken from the 8 and 14-foot panels.

Using ladders and block and tackle, Snow (1955) positioned men in trees for 1-hour exposures. Collections were made simultaneously at ground level and 30 feet in the forest proper and at ground level and 75 feet at the forest edge. He found that C. travisi exhibited a general preference for shrub and low vegetation rather than tree canopy levels. Distinct canopy preference was shown by C. guttipennis, C. haematopotus, and C. paraensis. Culicoides paraensis also was found to move up the tree trunks, spreading into the canopy during the day and moving back down in the evening.

Service (1969), using human bait, collected C. obsoletus (Meigen) at ground level, 10, and 19 feet in a tree. He found a very pronounced decrease in the biting rate with increase in height.

Bennett (1960), working in Ontario, Canada, was the first to make extensive use of animal-baited traps for collecting Culicoides. He hoisted 13 species of birds into trees at 0, 5, 10, and 20 feet.

After 20 to 30 minute exposure times the birds were brought down, covered, and the gnats aspirated from the animals. Culicoides sphagnumensis (Williams) was the predominate species, being collected mainly from the 5, 10, and 20-foot levels.

Fallis and Bennett (1961) collected more C. obsoletus from bird-baited traps at 5, 10, 15, 20, and 25 feet above the ground than at ground level.

Newton (1966) placed Fallis-Bennett traps, containing rabbits and chickens, side by side on platforms in trees. The platforms were situated at 5, 10, 15, and 20-foot levels in the trees. Although several problems were encountered, 7 species of Culicoides were collected. Culicoides guttipennis was collected at all 4 levels, and more were collected from the chickens than from the rabbits. However, the numbers collected were too small to warrant any definite conclusions.

Humphreys (1969) used Fallis-Bennett type traps, containing rabbits and turkeys, at ground level and at 25 feet. He found C. sanguisuga to be active at both levels. However, since the peak seasonal activity had already occurred by the time his studies were initiated, only small numbers of this species were collected.

B. Host Preference

Jamnback (1965) proposed a theory that host preference was correlated with the abundance of sensory pits on the antennae. He stated that the antennae of ornithophilic species had more antennomeres with olfactory pits than did mammalophilic species. Six species were listed as being known to prefer large mammals (C. furens, C. hollensis

(Melander & Brues), C. melleus (Coquillett), C. obsoletus, C. variipennis (Coquillett), and C. sanguisuga), and 6 species as being known to prefer birds (C. crepuscularis, C. downesi (Wirth & Hubert), C. haematopotus, C. scanloni, C. sphagnumensis, and C. stilobezzioides Foote & Pratt). Based on sensillar patterns only, 6 additional species were listed which could be expected to prefer mammals (C. bickleyi, C. chiopterus (Meigen), C. jamnbacki, C. spinosus (Root & Hoffman), C. stellifer, and C. venustus), and 9 species which could be expected to prefer birds (C. arboricola, C. baueri (Hoffman), C. biguttatus, C. guttipennis, C. niger (Root & Hoffman), C. piliferus, C. pseudopiliferus, C. travisi, and C. villosipennis Root & Hoffman).

Little is known of the host preferences of many Culicoides, especially species which feed on animals other than man. Since it is difficult to prove actual blood-feeding on hosts other than man, many reports of host preference are somewhat circumstantial. A summary of the reported host preferences of the 8 Culicoides species which were collected during the host preference studies is given in Table I.

C. Activity Time Period

Most Culicoides are crepuscular, showing peaks of activity at dawn and dusk. Jamnback and Watthews (1963) investigated the activity of C. sanguisuga in open meadows and in a shady bog. For their purposes, they considered all C. obsoletus group females to be C. sanguisuga. They found activity peaks to occur at about 1 hour after sunrise and

Table I. Reported host preferences (ornithophilic vs. mammalophilic) of 8 *Culicoides* species.

SPECIES	H O S T P R E F E R E N C E S
arboricola	Probably primarily ornithophilic (Wirth and Bottimer, 1956; Snow *et al.*, 1957; Jamnback, 1965; Messersmith, 1966; Battle, 1970). Also reported from man (Hair and Turner, 1968) and rabbits (Humphreys, 1969).
guttipennis	Not well known. Probably ornithophilic (Jamnback, 1965). Reported in large numbers from poultry (Messersmith, 1966). Also reported from mammals (Pratt, 1907; Malloch, 1915; Snow *et al.*, 1957; Murray, 1957: Hair and Turner, 1968; Humphreys, 1969).
hinmani	Not well known. Possibly mammalophilic (Hair and Turner, 1968). A few also reported from poultry (Messersmith, 1966).
mulrennani	Nothing known. Reported pest of man at Cranberry Glades, West Virginia (Battle, 1970).
paraensis	Not well known. Possibly mammalophilic. Reported from man (Snow, 1955; Hair and Turner, 1968) and rabbits (Humphreys, 1969). Also reported from poultry (Messersmith, 1966) and birds (Humphreys, 1969).
piliferus	Not well known. Probably ornithophilic (Jamnback, 1965). Reported from poultry (Messersmith, 1966; Humphreys, 1969). Also reported from mammals (Wirth and Hubert, 1962; Humphreys, 1969).
sanguisuga	Primarily mammalophilic, especially on large mammals (Jamnback, 1965). Also reported from birds as well as other mammals (Jamnback, 1965; Messersmith, 1966; Humphreys, 1969; Battle, 1970).
scanloni	Probably primarily ornithophilic (Jamnback, 1965). Reported from poultry (Jamnback, 1965; Messersmith, 1966).

again at sunset, after a steady rise in activity beginning at about 1½ hours before sunset. Activity at sunset reached higher peaks in the open meadow than in the shady bog area. Service (1969) observed maximum biting of true C. obsoletus at sunset. In England, Hill (1947) found that C. obsoletus reached its peak of activity at about 1 hour before sunset. Williams (1955a) suggested that the activity of C. obsoletus was greatest in the early evening before it was dark enough to use light traps.

Some Culicoides activity was found to continue during the day under certain conditions (Fallis and Bennett, 1961). One species, C. paraensis, was usually diurnal in its activity (Snow et al., 1957). Williams (1951) found C. obsoletus to be active in wooded areas of Alaska during cloudy days when the light intensity was approximately that which occurred at sunset. Humphreys (1969) found C. sanguisuga to be most active during dusk, which he determined to be from .5 to 11 foot candles. In laboratory tests, he found C. guttipennis to feed more at light intensities corresponding to dusk. Jamnback and Watthews (1963) observed no activity of C. sanguisuga in open meadows during the day, but they found some activity to continue during the day in a shady, moist, bog area protected from the wind. Service (1969) stated that a large local resting population of C. obsoletus would bite at any time in shaded situations.

Most crepuscular species were found to be somewhat active during the night (Williams, 1955a; Kettle, 1962). A few species were nocturnal, and one species, C. biguttatus, reached its peak after midnight. Snow et al. (1957) indicated that C. crepuscularis and C.

stellifer were the principal species active at night in the Tennessee River Basin. They also reported C. obsoletus feeding at night. Culicoides furens has been found to be both crepuscular and nocturnal, although its dawn and dusk activity was greater than its night activity (Linley and Davies, 1971).

Williams (1955b) found that the peak activity for all species he collected in light traps in Georgia occurred from 9:00 p.m. to midnight, regardless of the time of sunset. Similar results were obtained by Newton (1966), who used light traps equipped with timers to collect Culicoides at 2 hour intervals from 9:00 p.m. to 5:00 a.m. Nearly all species were most active during the 9:00 to 11:00 p.m. time interval. Culicoides sanguisuga and C. guttipennis were active throughout the night with the greatest activity occurring during both the 9:00 to 11:00 p.m. and 3:00 to 5:00 a.m. time intervals. Culicoides obsoletus was most active during the 11:00 p.m. to 1:00 a.m. interval. The least amount of activity for most species occurred during the 1:00 to 3:00 a.m. interval.

III. MATERIALS AND METHODS

A. 1969 Vertical Activity and Host Preference Studies

A series of 18 experiments was conducted at a wooded site on Big Stony Creek in the Jefferson National Forest of Giles County, Virginia. The experiments took place between July 10 and September 24, 1969 (Table II).

Specially designed animal-baited traps were used to permit unattended all-night collecting (Figure 1). Traps were designed for use with a large goat (110 pounds), small goat (75 pounds), large turkey (14 pounds), small turkeys (8 pounds), and large rabbits (8 pounds). The animals were placed in wire restraining cages over which the traps were placed. All traps were of the same basic design, with only dimensional changes to accommodate the shapes of the test animals. The basic frames of the traps were constructed from 1" x 1" fir boards covered with fine mesh "Saran®" plastic screening. Vertical slits $1\frac{1}{2}$" to 2" wide were cut in the "Saran®" on each side of the traps. Black muslin cloth was used to cover the tops of the traps and extended about a third of the way down all 4 sides. Plywood ($\frac{1}{2}$") was used to house funnel apparatuses, each of which was fashioned from 2 "Nalgene®" plastic funnels welded together with a Bunson burner. Lids from "Nalgene®" plastic jars were welded to the bottoms of the

Table II. Dates of 1969 vertical activity and host preference experiments in Giles County, Virginia.

DAYS	JULY	AUGUST	SEPTEMBER
1			
2			#15
3			
4		#7	
5			
6			
7		#8	
8			
9			
10	#1		
11		#9	#16
12			
13		#10	
14	#2		
15			#17
16	#3		
17			
18		#11	
19			
20		#12	
21			
22			
23	#4		
24			#18
25		#13	
26			
27		#14	
28			
29	#5		
30			
31	#6		

Figure 1. Animal-baited traps used to collect Culicoides spp. from goats, turkeys, and rabbits.

Figure 2. Culicoides spp. which have entered the collecting funnel of the Goat-Baited Trap.

second funnels so that "Nalgene®" jars, containing alcohol, could be changed periodically. The tops of the second funnels were covered with clear cellulose acetate which allowed light to enter the funnel apparatuses. Figure 2 is a top view of the second funnel into which Culicoides emerged from the goat.

Female Culicoides entered the traps through the vertical slits along the sides. After spending an undetermined amount of time on the animals, the gnats climbed up the front of the traps toward the collecting funnels which were always directed toward the setting or rising sun. After entering the funnels, the gnats found their way into the alcohol collecting jars.

On each of the 18 test nights, 3 rabbits and 3 turkeys were placed in their traps at approximately 2 hours before sunset. One trap containing a rabbit and another trap containing a turkey were hoisted, one after the other, up the side of a large poplar tree, by means of ropes and pulleys. A second rabbit and turkey were then hoisted up the opposite side of the same tree in like manner. A third rabbit and turkey were situated on opposite sides of the base of the tree. Thus, a rabbit and turkey were on opposite sides of the tree at 50 feet, 25 feet, and ground level (Figures 3 and 4). The traps were oriented with guy ropes so that the collecting funnels were facing the setting sun. Relative positions of the test animals were rotated on successive experiment nights.

In early tests it was found that nearly all Culicoides activity ceased before 3:00 a.m. Therefore, on 10 of the test nights the traps were brought down at about 3:00 a.m., the alcohol jars changed,

Figure 3. Animal-baited traps positioned at 25 and 50 feet in a poplar tree.

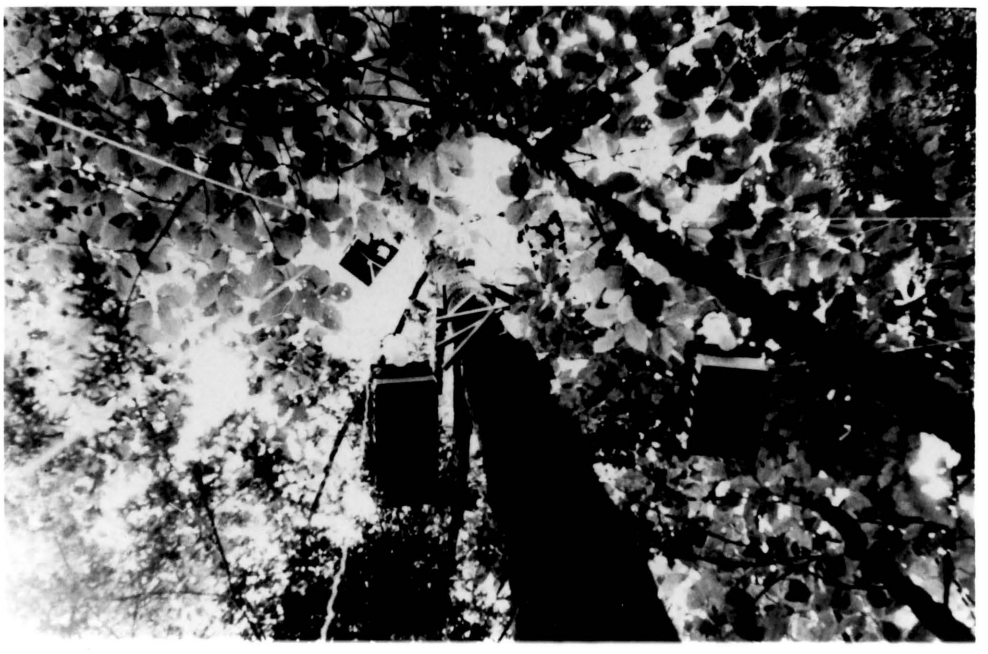

Figure 4. Bottom view of animal-baited traps positioned in poplar tree.

and the traps hoisted back into the tree and reoriented for the morning collection. At approximately 2 hours after sunrise, the traps were again brought down, and the experiment terminated.

During 15 of the vertical activity experiments, a trap containing a small goat (75 pounds) was located at the edge of a clearing, 25 feet from the base of the vertical experiment tree. Humphreys (1969) reported larger animals to be more attractive to C. sanguisuga than smaller animals. Therefore, the goat was used to provide a more sensitive index to Culicoides activity. On 3 of the test nights, a larger goat (110 pounds) and a larger turkey (14 pounds) were situated at 25 foot intervals from the small goat.

On July 29, the small goat trap was placed in its usual position, but without the goat. The purpose of this experiment was to see if the Culicoides were being attracted to the hosts or to the traps. No Culicoides were collected from the empty trap.

All Culicoides specimens were sorted and identified in the laboratory. Like Jamnback and Watthews (1963), all of the C. obsoletus group specimens were considered to be C. sanguisuga. Specimens which could not be identified in alcohol were mounted on slides for accurate identification. The identification of several species was confirmed by W. W. Wirth at the U. S. National Museum.

Paired t-tests were used in analyzing the number of Culicoides collected by the rabbit traps vs. the small turkey traps at the 3 elevation levels. Student's t-tests were used in analyzing the number of Culicoides collected on one side of the tree vs. the other side, regardless of the host involved. No differences were detected.

B. 1970 Population Studies

A series of 27 population studies was conducted at the same site as the 1969 host preference and vertical activity experiments. The studies took place twice weekly from May 13 to September 9, 1970 (Table III). Three trapping methods were used to collect adult Culicoides. These methods are discussed below.

Goat-Baited Trap

This trap was the same animal baited trap which was used in 1969. The trap was placed over a 75 pound male goat which was set in position 6 hours before sunset each day, with the collecting cones facing the direction of the setting sun. The trap remained in that position until 2 hours before sunrise, at which time the trap assembly was lifted off the goat, turned around, and replaced over the goat with the collecting cones facing the direction of sunrise. The trap remained in that position until 2 hours after sunrise when all experiments were terminated. Catches of Culicoides were divided into the number of adults collected during the following times:

Catch #1. The 4 hour period from 6 hours before sunset to 2 hours before sunset.

Catch #2. The 4 hour period from 2 hours before sunset to 2 hours after sunset.

Catch #3. From 2 hours after sunset to 2 hours before sunrise (overnight).

Catch #4. The 4 hour period from 2 hours before sunrise to 2 hours after sunrise.

Table III. Dates of 1970 population studies in Giles County, Virginia.

DAYS	MAY	JUNE	JULY	AUGUST	SEPTEMBER
1		#6	#14		
2		#7			#26
3					
4			n	#20	
5					
6				#21	
7			#15		
8		#8			
9			#16		#27
10		#9			
11				#22	
12					
13	#1		#17	#23	
14					
15					
16		#10			
17				#24	
18	#2				
19					
20	#3		#18		
21					
22		#11			
23					
24				#25	
25	#4	#12			
26					
27	#5		#19		
28					
29		#13			
30					
31					

From June 1 to September 9 (22 trap nights), Culicoides were aspirated out of the collecting cones and transferred to alcohol vials at ½-hour intervals during catch #2 and #2 and again during catch #4. The overnight collection (catch #3) was aspirated out of the cones at 2 hours before sunrise. The purpose of this procedure was to define better the activity time periods of the Culicoides. At each ½-hour time interval, temperature and relative humidity were recorded from a hygrothermograph which was callibrated by an electric psychrometer. Light intensity was measured at each ½-hour interval with a Gossen Luna-pro light meter.

Black Light Trap

A standard New Jersey Light Trap was modified by replacing the regular incandescent light bulb with a G. E. fluorescent BL (Black Light) tube (#F6T5-BL) which has a wave length of 360 nanometers. This type of trap has been reported to be a much more effective method of collecting Culicoides than the conventional New Jersey trap (Belton and Pucat, 1967; Rowly and Jorgensen, 1968). Hardware cloth (1/8" mesh) was placed around the outside of the trap to restrict large insects. The trap was run off of a 12 volt automobile battery (Figure 5).

The Black Light Trap was hung at a height of 5 feet in a small tree located across a clearing 200 feet from the Goat Trap. It was operated from 2 hours before sunset to 2 hours after sunset, and again from 2 hours before sunrise to 2 hours after sunrise on the same days the Goat-Baited Trap was operated. Thus, the Black Light Trap catches were comparable with the #2 and #4 Goat-Baited Trap catches. All Culicoides

Figure 5. Standard New Jersey Light Trap converted for use as Black Light Trap.

were collected into alcohol jars and brought into the laboratory for identification.

D-Vac® Vacuum Insect Net

The D-Vac is a vacuum insect sampling machine powered by a 2-cycle Tecumseh® gasoline engine strapped on the operator in back pack style. It is manufactured by the D-Vac Company, P. O. Box 2095, Riverside, California 92506. In this trap, insects are collected into a fine mesh nylon organdy bag which is attached to the open end of a flexible suction hose 8" in diameter and 6' 3" long (Figure 6).

Each D-Vac sample consisted of the operator walking a prescribed 15 minute course, down and back along the same side of a black top road that passed by the collection site. The open end of the suction hose was held 5' off the ground and was directed forward, parallel to the ground. All samples were taken in exactly the same manner, by the same operator, and over the same course. Thus the D-Vac provided comparative samples of the Culicoides which were flying in the air.

After each sample, the nylon organdy bag was removed from the suction hose and placed in an ice cooler until the specimens could be sorted and identified in the laboratory.

D-Vac samples were taken at the following times on the same days that the Goat-Baited Trap and Black Light Trap were in operation:

Catch #1. One hour before sunset.

Catch #2. Sunset.

Catch #3. One hour after sunset.

Catch #4. One hour before sunrise.

Catch #5. Sunrise.

Figure 6. D-Vac Vacuum Insect Net used to sample the air for flying *Culicoides* spp.

Catch #6. One hour after sunrise.

No samples were taken when it was raining, and some samples were missed due to mechanical difficulties.

IV. RESULTS AND DISCUSSION

A. 1969 Vertical Activity and Host Preference

The following 8 Culicoides species, listed in the order of their abundance, were collected from the 1969 animal baited traps:

1) C. sanguisuga - A ground breeding species.

2) C. arboricola - A tree hole breeding species.

3) C. paraensis - A tree hole breeding species.

4) C. guttipennis - A tree hole breeding species.

5) C. scanloni - A ground breeding species.

6) C. mulrennani - A ground breeding species.

7) C. piliferus - A ground breeding species.

8) C. hinmani - A tree hole breeding species.

Culicoides sanguisuga

General Host Preference:--This was by far the most abundant species (Table IV). The large goat (exposed on only 3 nights) attracted more C. sanguisuga per night than all the other animals combined. The relative attractiveness (number/night) of the animals to C. sanguisuga was as follows:

1) Large Goat

2) Small Goat

Table IV. Total number of Culicoides spp. collected from animal-baited traps at 0', 25', and 50 feet elevation in a tree.

	RABBITS[a]				SMALL TURKEYS[b]				SMALL GOAT[c]	LARGE GOAT[d]	LARGE TURKEY[e]
SPECIES	0'	25'	50'		0'	25'	50'		0'	0'	0'
	17 Nights	17 Nights	17 Nights	TOTAL	18 Nights	18 Nights	17 Nights	TOTAL	15 Nights	3 Nights	3 Nights
sanguisuga	163	55	33	251	298	55	74	427	3,327	1,822	235
arboricola	0	6	28	34	0	4	42	46	1	0	0
paraensis	1	0	3	4	3	4	13	20	9	0	0
guttipennis	0	0	7	7	0	1	8	9	7	2	1
scanloni	0	0	1	1	0	3	8	11	0	0	0
mulrennani	0	1	0	1	0	0	0	0	3	1	3
piliferus	0	0	0	0	0	0	3	3	0	0	0
hinmani	0	0	0	0	0	0	1	1	0	0	0

a/ - 8 pounds b/ - 8 pounds c/ - 75 pounds d/ - 110 pounds e/ - 14 pounds

3) Large Turkey

4) Small Turkeys

5) Rabbits

These results confirm the results obtained by Humphreys (1969).

This species has been reported to be primarily mammalophilic, especially on large mammals and the largest number of specimens came from the goats (Table I). However, it is interesting that more were collected from the small turkeys (24.1/night) than from the rabbits (14.7/night). It should be noted that the small turkeys were larger and bulkier than the rabbits even though they were the same weight.

Vertical Activity and Host Preference:--Culicoides sanguisuga was more active at ground level than at any other level in the tree. Generally it was less active with increased elevation. However, a few more were collected from the small turkeys at 50 feet (4.4/night) than from the small turkeys at 25 feet (3.1/night).

Although this species has been reported to be mammalophilic, significantly more were attracted to the small turkeys than to the rabbits at the 50-foot level (Table V). There was no significant difference in the number per night attracted to the rabbits vs. the small turkeys at ground level or at 25 feet.

Culicoides arboricola

General Host Preference:--This species is a tree hole breeder and is thought to be primarily ornithophilic (Table I). A total of 81 specimens was collected. Disregarding elevation in the tree, there was very little difference in the number collected from the rabbits (2.0/night) vs. the small turkeys (2.7/night).

Table V. Culicoides sanguisuga collected from animal-baited traps during 1969 vertical activity and host preference studies.

	SMALL GOAT	0'		25'		50'	
		RABBIT	TURKEY	RABBIT	TURKEY	RABBIT	TURKEY
TOTAL NUMBER	3,327	163	298	55	55	33	74
NUMBER PER NIGHT	221.8	9.6	16.6	3.2	3.1	1.9 a/	4.4 a/
PERCENT ENGORGED PER NIGHT	2.9%	6.8%	6.0%	9.1%	5.5%	6.3%	6.6%

a/ - Significant at the 5% level (paired t-test).

Vertical Activity and Host Preference:--*Culicoides arboricola* was collected only at the 25 and 50-foot levels, with the exception of 1 specimen collected from the small goat. This species exhibited a distinct preference for the forest canopy (Table VI). The number collected from the animals at 50 feet was 7 times that of the animals at 25 feet.

There was no significant difference in the number attracted to the small turkeys vs. the rabbits at either the 25 or 50-foot levels, but significantly more engorged on the small turkeys at 50 feet than on the rabbits at 50 feet (Table VI). However, several engorged specimens were collected from the rabbit at 50 feet.

Culicoides paraensis

General Host Preference:--This is a tree hole species whose host preference is not well known (Table I). Since it has only 4 antennomeres with sensory pits, it could be expected to be mammalophilic, according to Jamnback's theory (Jamnback, 1965).

A total of 33 specimens was collected. More were collected from the small turkeys (20 specimens) than from the rabbits (4 specimens). Nine were collected from the small goat.

Vertical Activity and Host Preference:--*Culicoides paraensis* was collected from all 3 levels in the tree. However, most of them (16 out of 20) were collected at the 50-foot level (Table VII).

Although more were collected on the turkeys than on the rabbits at all elevations, the collections were not large enough to permit statistical analysis.

Table VI. Culicoides arboricola collected from animal-baited traps during 1969 vertical activity and host preference studies.

	SMALL GOAT	0'		25'		50'	
		RABBIT	TURKEY	RABBIT	TURKEY	RABBIT	TURKEY
TOTAL NUMBER	1	0	0	6	4	28	42
NUMBER PER NIGHT	.07	0	0	.35	.22	1.6	2.5
PERCENT ENGORGED PER NIGHT	0	0	0	0	27.3% a/	10.7% b/	60.0% b/

a/ - 1 engorged specimen.

b/ - Significant at the 5% level (paired t-test).

Table VII. Culicoides paraensis collected from animal-baited traps during 1969 vertical activity and host preference studies.

	SMALL GOAT	0'		25'		50'	
		RABBIT	TURKEY	RABBIT	TURKEY	RABBIT	TURKEY
TOTAL NUMBER	9	1	3	0	4	3	13
NUMBER PER NIGHT	.60	.06	.17	0	.22	.18	.76
PERCENT ENGORGED PER NIGHT	21.7% a/	0	64.7% b/	0	0	0	0

a/ - 2 engorged specimens.

b/ - 2 engorged specimens.

Culicoides guttipennis

General Host Preference:--This is a tree hole species whose host preference is not well known (Table I). However, Jamnback (1965) suggested it may be primarily ornithophilic because of its preference for the forest canopy and its sensillar pattern (9 antennomeres with sensillae).

A total of 26 specimens was collected, and there was essentially no difference between the number collected from the rabbits (7 specimens) vs. the small turkeys (9 specimens). Seven specimens were collected from the small goat, and 2 were collected from the large goat.

Vertical Activity and Host Preference:--More C. guttipennis (15 specimens) were collected at the 50-foot level than at the lower levels (Table VIII). There was no difference in the number collected from the rabbits vs. the small turkeys at the 50-foot level.

Culicoides scanloni

This species is thought to be primarily ornithophilic (Table I). A total of 12 specimens was collected, and all but 1 were collected from the small turkeys (Table IV). One specimen was collected from the 50-foot rabbits. It was not collected from any of the ground level animals, and all but 3 specimens came from the 50-foot canopy level. Therefore, this species may prefer canopy feeding.

Culicoides mulrennani

Almost nothing is known about the host preferences of this species. It has been reported only from man (Table I). Only 8 specimens

Table VIII. Culicoides guttipennis collected from animal-baited traps during 1969 vertical activity and host preference studies.

	SMALL GOAT	0'		25'		50'	
		RABBIT	TURKEY	RABBIT	TURKEY	RABBIT	TURKEY
TOTAL NUMBER	7	0	0	0	1	7	8
NUMBER PER NIGHT	.47	0	0	0	.06	.41	.47
PERCENT ENGORGED PER NIGHT	14.9% a/	0	0	0	0	0	0

a/ - 1 engorged specimen.

were collected (Table IV). All but 1 specimen were collected from the larger animals (goats and large turkeys) at ground level. One specimen was collected from the rabbits at 25 feet. This little-known species may be a ground feeder with a preference for large animals.

Culicoides piliferus

The host preferences of this species are not well known (Table I). Jamnback (1965) suggested that it may be primarily ornithophilic. Only 3 specimens were collected, and these came from the small turkeys at 50 feet. This species may prefer feeding in the canopy.

Culicoides hinmani

The host preferences of this species are not well known. However, it has been collected mostly from man and other mammals (Table I). Only 1 specimen was collected during this study, and that was from the small turkeys at 50 feet.

B. 1970 Seasonal Distribution

A total of 49,192 Culicoides females representing 19 species were collected during the summer of 1970 (Table XI). The D-Vac collected 18 species; the Black Light Trap 12 species; and the Goat-Baited Trap 8 species. The Goat-Baited Trap was the most effective method of collecting C. sanguisuga and C. guttipennis. The Black Light Trap was the most effective method of collecting 10 of the species, including 2 new state records (C. alexanderi and C. jamnbacki). In addition, the Black Light Trap collected several species over a longer

Table IX. Summary of breeding sites and vertical activity preferences of 8 Culicoides spp. collected in 1969 from animal-baited traps at 0, 25, and 50 feet elevation in a tree.

SPECIES	BREEDING SITES	VERTICAL ACTIVITY PREFERENCES
sanguisuga	Ground	Primarily Ground - Although Collected At All Levels
arboricola	Tree Hole	Canopy
paraensis	Tree Hole	Probably Primarily Canopy - Although Collected At All Levels
guttipennis	Tree Hole	Canopy
scanloni	Ground	Probably Canopy
mulrennani	Ground	Possibly Ground
piliferus	Ground	Possibly Canopy
hinmani	Tree Hole	Possibly Canopy

Table X. Summary of host preferences of 8 Culicoides spp. collected in 1969 from animal-baited traps at 0, 25, and 50 feet elevation in a tree.

SPECIES	LITERATURE (See Table I)	RESULTS OF THIS STUDY (Mammal Vs. Bird)
sanguisuga	Primarily Mammalophilic	More On Turkeys But Not Significant Except On Turkeys At 50' [a/]
arboricola	Probably Primarily Ornithophilic (S.P.) [b/]	More On Turkeys But Not Significant Except For Engorgement On Turkeys At 50'
paraensis	Not Well Known - Possibly Mammalophilic (S.P.)	More On Turkeys But Not Significant
guttipennis	Not Well Known - Probably Ornithophilic (S.P.)	No Significant Difference
scanloni	Probably Primarily Ornithophilic (S.P.)	More On Turkeys But Not Enough Numbers For A Statistical Test
mulrennani	Nothing Known	More On All Larger Animals But Not Enough Numbers For A Statistical Test
piliferus	Not Well Known - Probably Ornithophilic (S.P.)	3 Specimens From The Turkeys At 50'
hinmani	Not Well Known - Possibly Mammalophilic (S.P.)	1 Specimen From The Turkeys At 50'

a/ - At the 5% level (paired t-test) b/ - Sensillar pattern

period than the other traps and generally provided a clearer picture of seasonal distribution. The D-Vac collected more species than the other methods and also collected C. alexanderi and C. jamnbacki. It collected several species not collected by the other traps, but most of these were represented by single specimens only. It should be kept in mind that the D-Vac was used to sample a greater area in less time than the other traps. The number of specimens collected was often rather low, but several species were collected in approximately the same proportions as in the Black Light Trap. The D-Vac differed most strikingly from the other traps in that no lights or animals were involved as attractants. It merely sampled Culicoides flying in the air and was probably the most unbiased method of collecting.

In Table XII may be seen the months of the summer in which the 19 species were collected. Three species (C. sanguisuga, C. haematopotus, and C. guttipennis) were collected each month, May through September. The remaining species were collected during 1 to 4 of the 5 months. More species were collected in June and July than in the other summer months. Nine species were collected in May; 16 species in June; 13 species in July; 6 species in August; and 5 species in September.

The seasonal distribution of the 19 species are discussed in the order of their abundance as follows:

Culicoides sanguisuga

This is a common ground breeding species in Virginia and has previously been reported from some 15 counties (Battle, 1970).

Table XI. Total number of Culicoides spp. females collected in 1970.

SPECIES	GOAT-BAITED TRAP	BLACK LIGHT TRAP	D-VAC	TOTAL
sanguisuga	31,484	14,120	1,513	47,117
bickleyi	0	790	98	888
alexanderi	0	579	72	651
jamnbacki	0	75	57	132
haematopotus	0	69	20	89
arboricola	6	55	2	63
mulrennani	4	39	14	57
guttipennis	45	6	1	52
stellifer	10	33	9	52
piliferus	0	36	7	43
travisi	0	20	5	25
biguttatus	0	7	2	9
snowi	4	0	1	5
testudinalis	1	0	3	4
crepuscularis	0	0	1	1
paraensis	1	0	0	1
pseudopiliferus	0	0	1	1
scanloni	0	0	1	1
variipennis	0	0	1	1
TOTALS	31,555	15,829	1,808	49,192

Table XII. Months (May to September, 1970) in which Culicoides spp. were collected.

SPECIES	GOAT-BAITED TRAP					BLACK LIGHT TRAP					D-VAC				
	M	J	J	A	S	M	J	J	A	S	M	J	J	A	S
sanguisuga	X	X	X	X	X	X	X	X	X	X	X	X	X	X	-
bickleyi						X	X	X			X	X	X		-
alexanderi						X	X				X	X	X		-
jamnbacki						X	X	X			X	X	X		-
haematopotus						X	X	X	X	X	X	X	X		-
arboricola	X	X				X	X			X	X			X	-
mulrennani		X	X				X	X				X	X		-
guttipennis	X	X	X	X	X		X	X					X		-
stellifer		X		X	X		X	X	X			X	X		-
piliferus						X	X	X				X	X		-
travisi						X	X	X				X			-
biguttatus						X	X	X				X			-
snowi	X	X										X			-
testudinalis		X									X	X			-
crepuscularis													X		-
paraensis				X											-
pseudopiliferus												X			-
scanloni												X			-
variipennis													X		-

The 3 trapping methods yielded a total of 47,117 adults over a period of 5 months from May to September (Figure 7). The population peak occurred in early June after a previous peak in middle to late May. Another peak occurred in early July, after which abundance tapered off with smaller peaks occurring in early July and early August. These results were in agreement with Jamnback (1965); Messersmith (1966); and Battle (1970), who reported the greatest populations to be in June and July.

The 3 trapping methods were approximately equal in their ability to assess the seasonal distribution of this species. However, the Goat-Baited Trap was the most effective method since it collected 12 times as many adults as the Black Light Trap, which in turn collected 9 times as many as the D-Vac.

Culicoides bickleyi

This is a ground breeding species which has been reported from the Virginia counties of Craig, Fairfax, and Montgomery (Battle, 1970).

The Black Light Trap and D-Vac yielded a total of 888 adults over a 3 month period from May to July (Figure 8). The population peak occurred in late May and early June, followed by a smaller peak in middle June. Slight peaks also occurred in early to middle July in the D-Vac collections. Only inadequate seasonal data have been previously available for this species in Virginia. Jamnback (1965) reported it to be an early spring species in New York State.

The Black Light Trap and D-Vac provided essentially the same seasonal information. However, the Black Light Trap collected 8 times

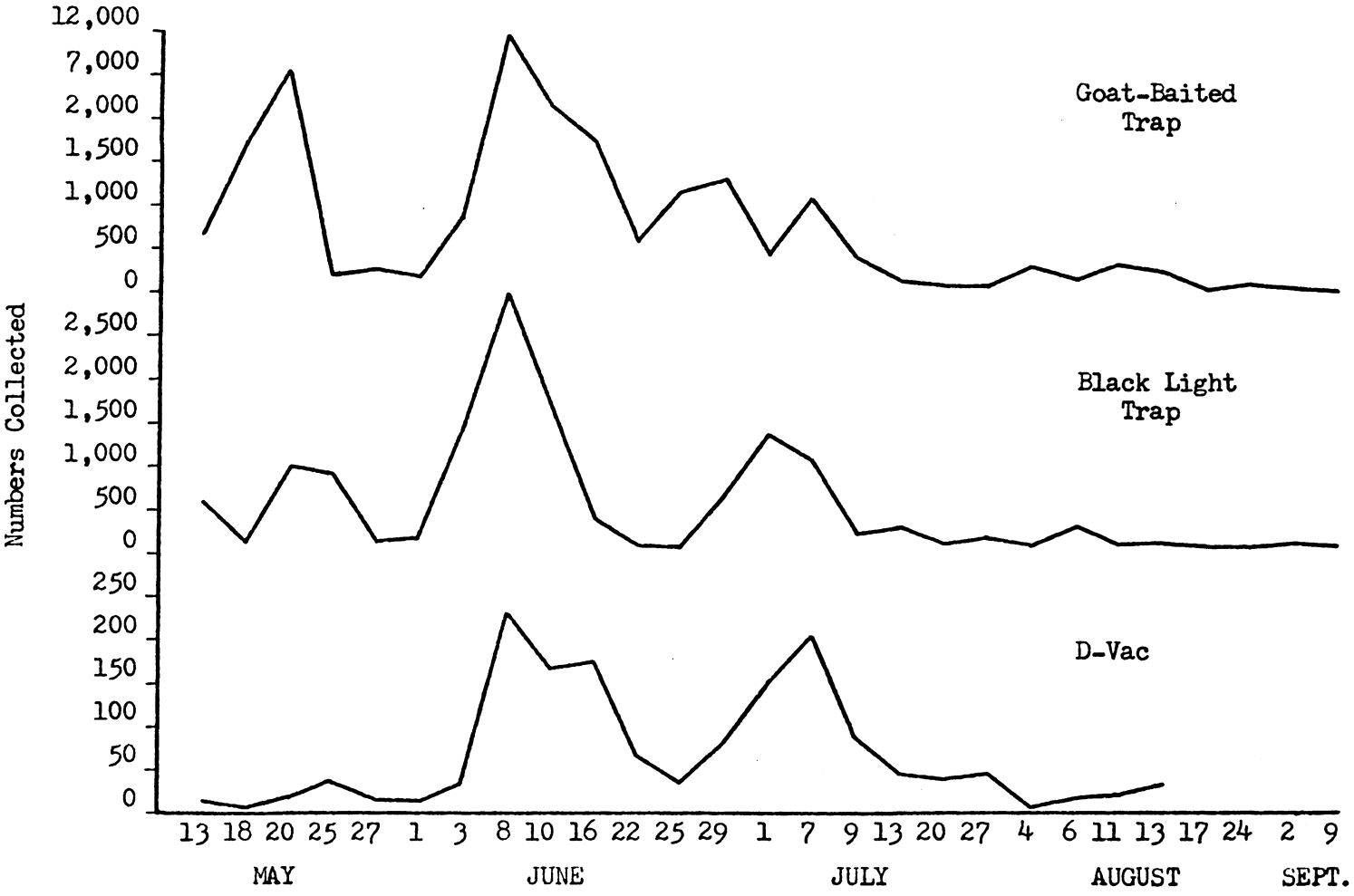

Figure 7. Seasonal distribution of Culicoides sanguisuga collected by Goat-Baited Trap, Black Light Trap, and D-Vac in 1970.

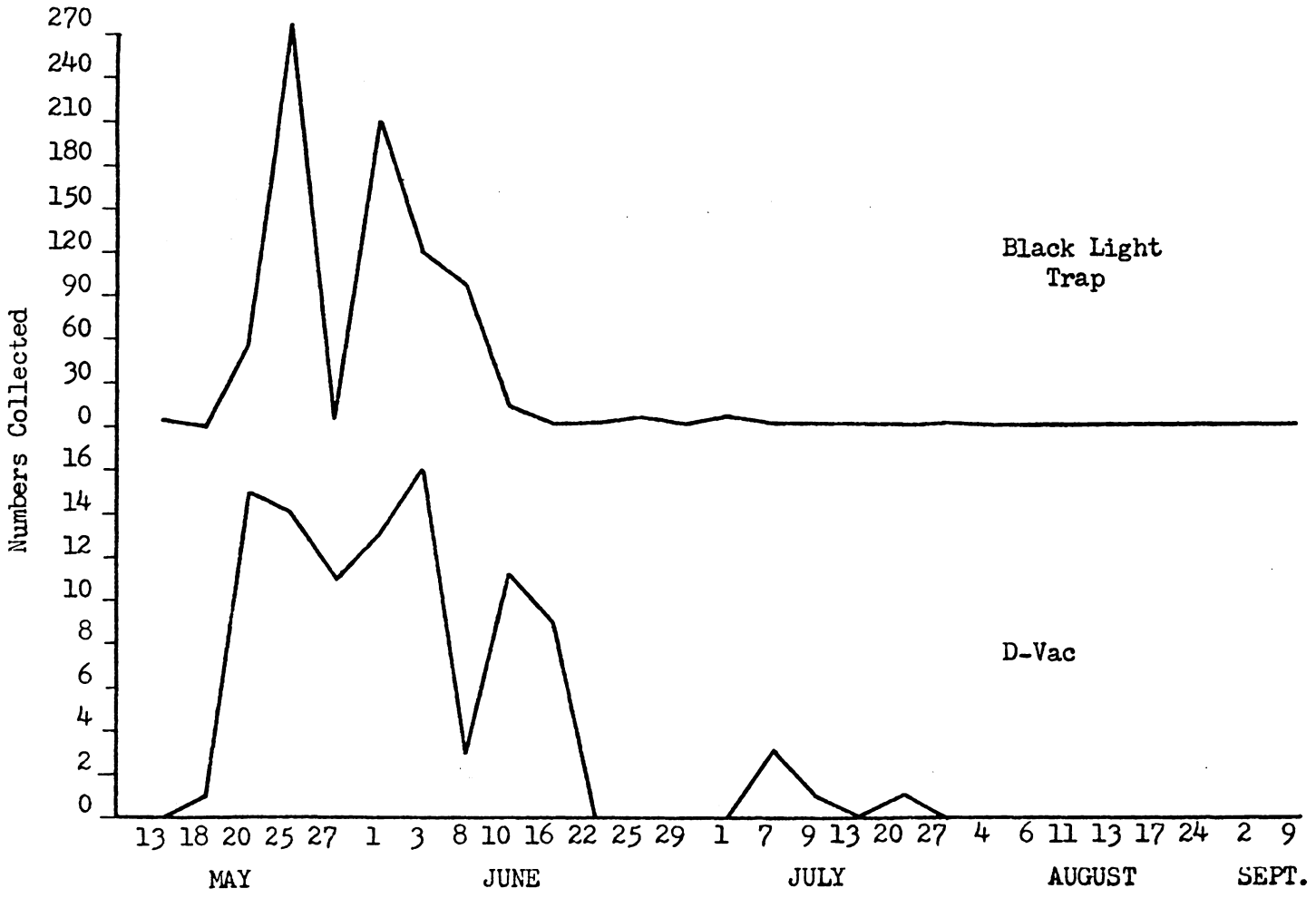

Figure 8. Seasonal distribution of Culicoides bickleyi collected by Black Light Trap and D-Vac in 1970.

as many adults as the D-Vac. It was interesting that no adults were collected from the Goat-Baited Trap, since Humphreys (1969) collected a number of them from goats.

At this point it might be well to make a few comments concerning this species and several others to follow which were collected in the Black Light Trap and/or the D-Vac, but not in the animal-baited traps. It is entirely possible that the trap assembly itself was a deterrent to the collection of some species. When Humphreys (1969) collected from animal-baited traps, the potential hosts were exposed for certain lengths of time after which the traps were placed over the hosts to confine any Culicoides already on the hosts. In this study, the traps covering the potential hosts were always in place, and Culicoides could enter the traps only through the slits in the sides. It is also possible that they entered the traps, fed on the hosts, and left the traps through the slits from whence they entered.

Culicoides alexanderi

Little is known about this species which has been collected only in Connecticut, Kentucky, Michigan, New York, Tennessee and Quebec (Jamnback, 1965).

The Black Light Trap and D-Vac collected a total of 651 adults over a 3 month period from May to July (Figure 9). As with C. bickleyi, no adults were collected from the Goat-Baited Trap. The population peak of this species in the Black Light Trap collections occurred in early June after a smaller peak in late May. Following the June peak, the numbers dropped considerably. The population peak in

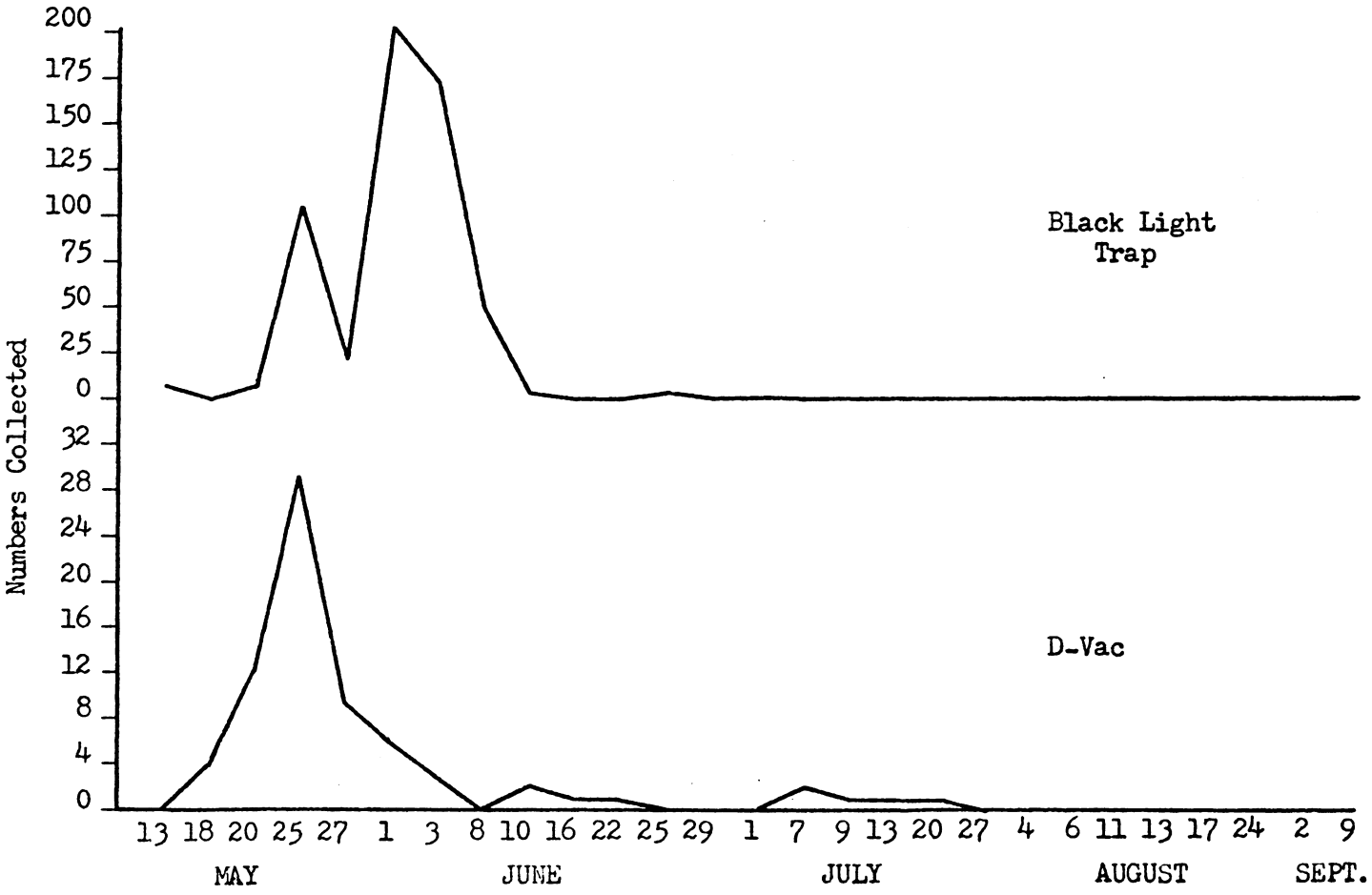

Figure 9. Seasonal distribution of Culicoides alexanderi collected by Black Light Trap and D-Vac in 1970.

the D-Vac collections occurred in late May, followed by low numbers in June and July. Apparently this species was still stimulated to fly to the Black Light Trap even after its normal flying activities, as measured by the D-Vac, had diminished. Very little has been previously known about the seasonal distribution of this species. Jamnback (1965) reported that adults had been collected only in the spring and early summer from April to June. Although the Black Light Trap did not collect any adults after July 1, the D-Vac continued to collect small numbers up to July 20.

Culicoides jamnbacki

This is a ground breeding species which has been reported only from Michigan, New York, and Ontario (Jamnback, 1965).

The Black Light Trap and the D-Vac collected a total of 132 specimens over a 3 month period from May to July (Figure 10). The peak, as collected by the Black Light Trap, occurred in early July after 2 smaller peaks in early June. The peak, as collected by the D-Vac, occurred in late May followed by 2 smaller peaks in early June. In Michigan, C. jamnbacki was found to be an early spring species, present in May and early June with small numbers collected in late June and July. In Ontario, small numbers were collected in late June (Wirth and Hubert, 1962; Jamnback, 1965). The D-Vac results were in agreement with these reports. The Black Light Trap results, however, indicated a definite peak in early July rather than in early spring. This was unusual since the data of previous reports were based on light trap collections. The problem could possibly be a taxonomic one, since the present keys to piliferus group species are in need of

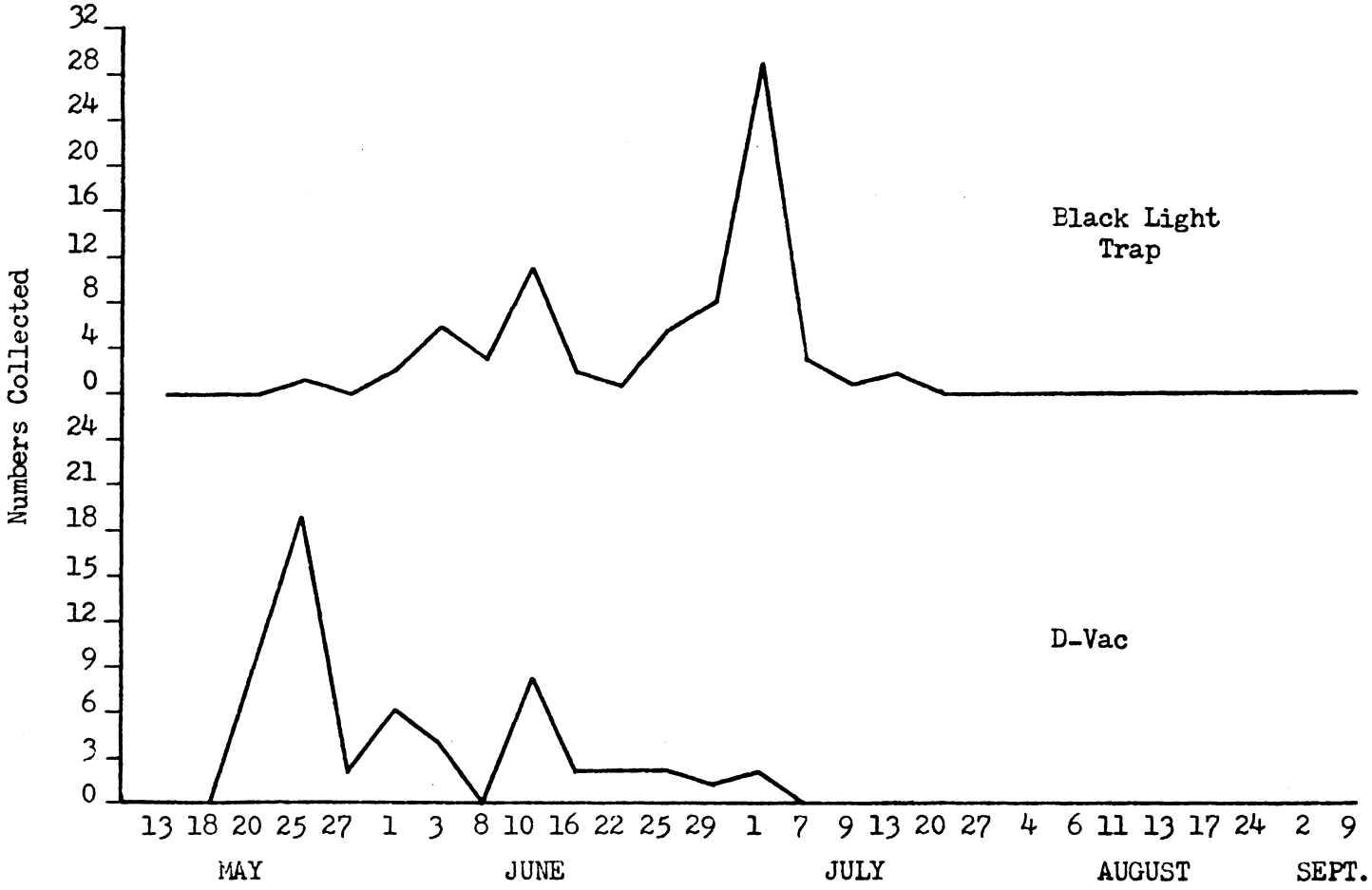

Figure 10. Seasonal distribution of Culicoides jamnbacki collected by Black Light Trap and D-Vac in 1970.

revision (Wirth, 1971 personal communication). The Black Light Trap and D-Vac collections might have represented 2 subspecies of C. jamnbacki. Also, since the D-Vac sampled a greater area than the Black Light Trap, it is possible that the two traps were sampling different populations.

The Black Light Trap collected only 1.3 times the number of adults collected in the D-Vac. Although C. jamnbacki has been presumed to be primarily mammalophilic (Jamnback, 1965), no specimens were collected in the Goat-Baited Trap.

Culicoides haematopotus

This is a common ground breeding species which has been reported from 39 Virginia counties (Battle, 1970).

The Black Light Trap and D-Vac collected a total of 89 specimens over a 5 month period from May to September (Figure 11). Numerous population fluctuations were noted throughout the summer. The largest of these occurred in late May and early June. The fluctuations may have been due to temporary population depletions resulting from sampling. These results agreed with Jamnback (1965) and Messersmith (1966) who found population peaks in late May and June.

The Black Light Trap collected 3.5 times more adults than the D-Vac, including a few specimens in August and September. The D-Vac did not collect any adults after July 13. None were collected from the Goat-Baited Trap.

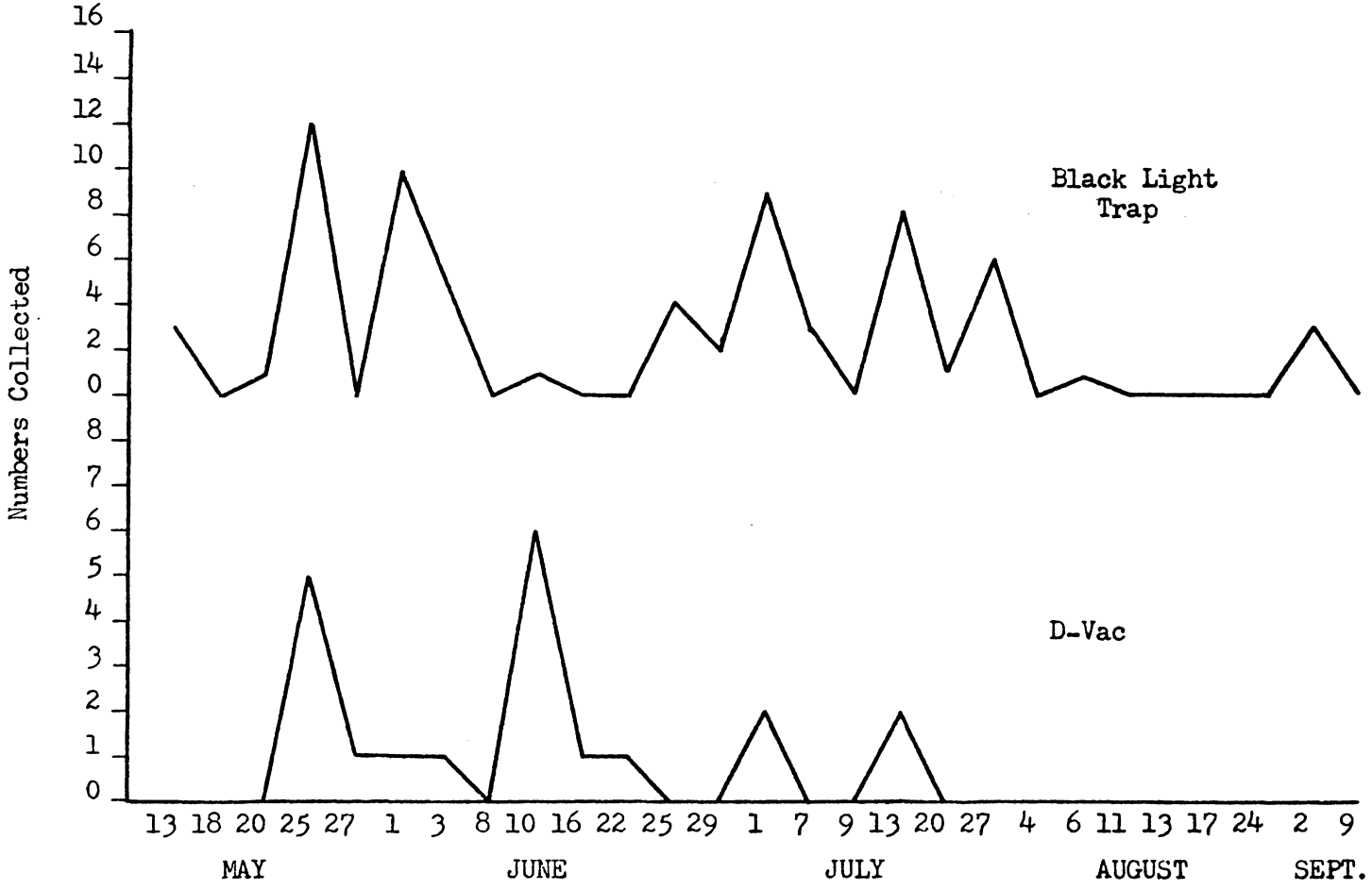

Figure 11. Seasonal distribution of Culicoides haematopotus collected by Black Light Trap and D-Vac in 1970.

Culicoides arboricola

This is a tree hole species that has been reported from 11 Virginia counties, including Giles County (Battle, 1970).

A total of 63 adults was collected in May, June, August, and September (Figure 12). Two nearly equal population peaks occurred in late May and early June, followed by a few adults in early September (Black Light Trap). The Goat-Baited Trap collected a few adults in May and June. The D-Vac collected only 2 adults (1 in early June, and 1 in early August). These results were not in agreement with Messersmith (1966) who collected adults in Virginia from July 2 to September 26, with a peak in August. His data were based on light trap collections mostly from inside poultry houses at Elkton and Ferrum, Virginia.

The Black Light Trap collected 7 times as many adults as the other 2 traps together, but the Goat-Baited Trap and the D-Vac collected a few specimens when the Black Light Trap did not.

Culicoides mulrennani

This is a ground breeding species which has been collected only from Blacksburg, Falls Church, and Vesuvius, Virginia (Battle, 1970).

A total of 57 specimens was collected during June and July (Figure 13). Population peaks occurred in late June through early to middle July, with a few specimens being collected in early June. The seasonal distribution of this species has previously been unknown.

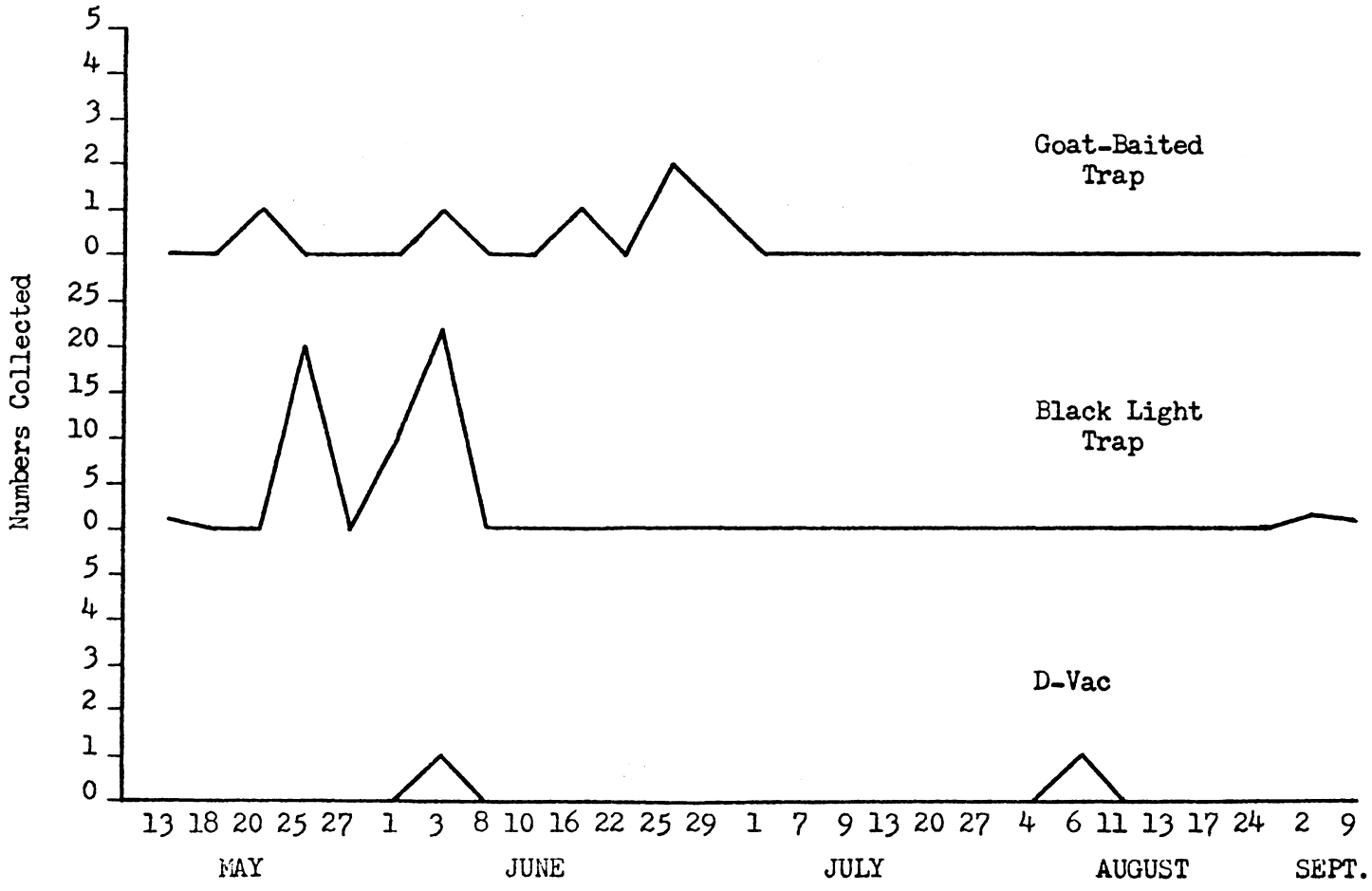

Figure 12. Seasonal distribution of Culicoides arboricola collected by Goat-Baited Trap, Black Light Trap, and D-Vac in 1970.

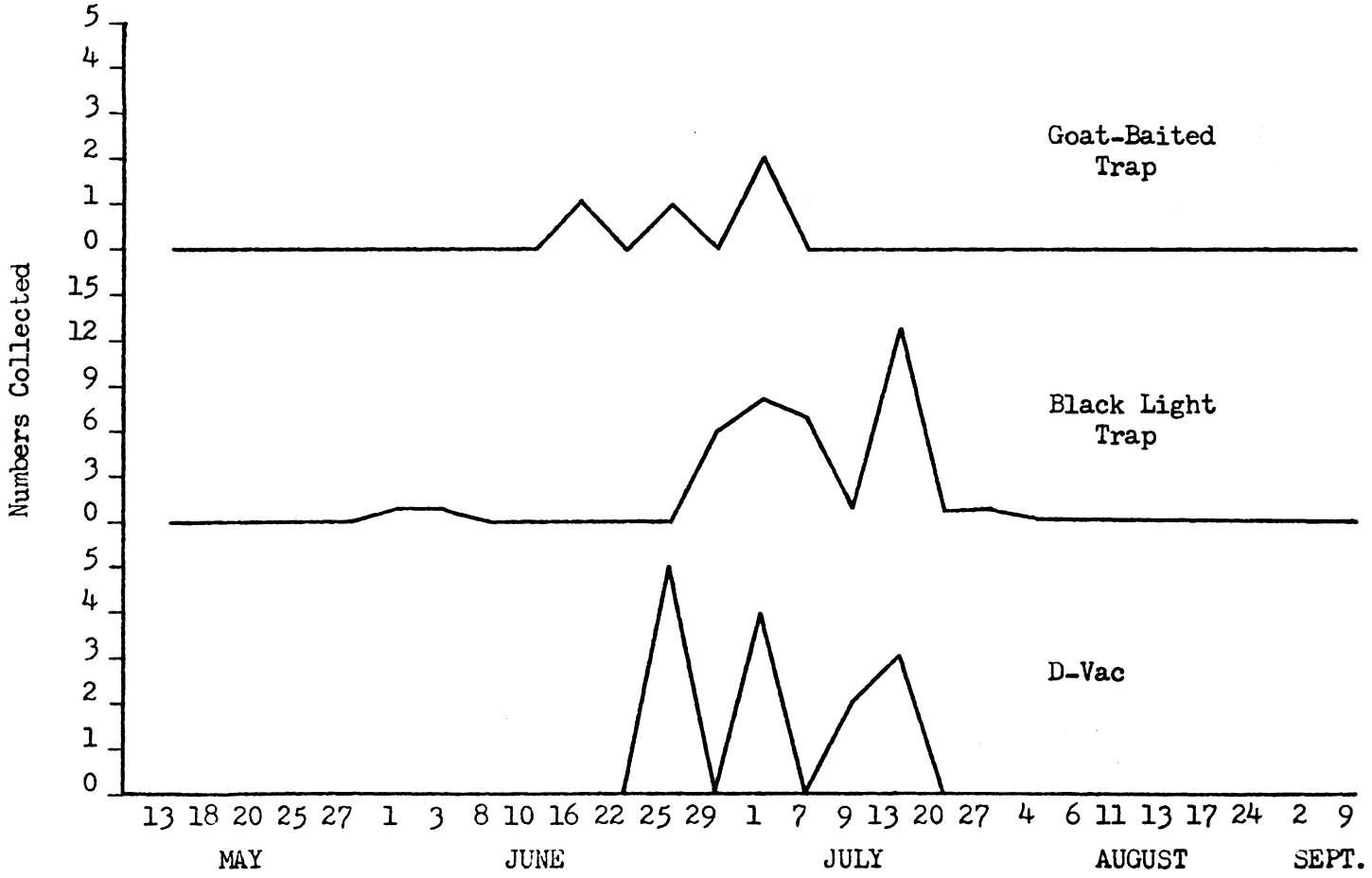

Figure 13. Seasonal distribution of Culicoides mulrennani collected by Goat-Baited Trap, Black Light Trap, and D-Vac in 1970.

The Black Light Trap and D-Vac gave better indications of seasonal abundance than the Goat-Baited Trap which collected only 4 specimens.

Culicoides guttipennis

This is a tree hole species which has been reported from 17 Virginia counties (Battle, 1970).

A total of 52 adults was collected over the entire 5 month period from May to September (Figure 14). The population peak occurred in early June, preceded by a few adults in middle May and followed by a fairly steady population through middle July. One specimen was collected in early August and another in early September. These results were in partial agreement with Messersmith (1966) who found adults from late April to middle September. However, he found the population peak to be in August.

The Goat-Baited Trap collected 6 times as many adults as the other 2 traps and provided the best picture of seasonal distribution.

Culicoides stellifer

This is a common ground breeding species which has been reported from 23 Virginia counties (Battle, 1970).

A total of 52 adults was collected over a 4 month period from June to September (Figure 15). The population peak occurred in early July, followed by a smaller peak in middle July. One specimen was collected in the Black Light Trap in early June; a few in August; and 1 in the Goat-Baited Trap in early September. These results were similar to those of Messersmith (1966) who found adults present from

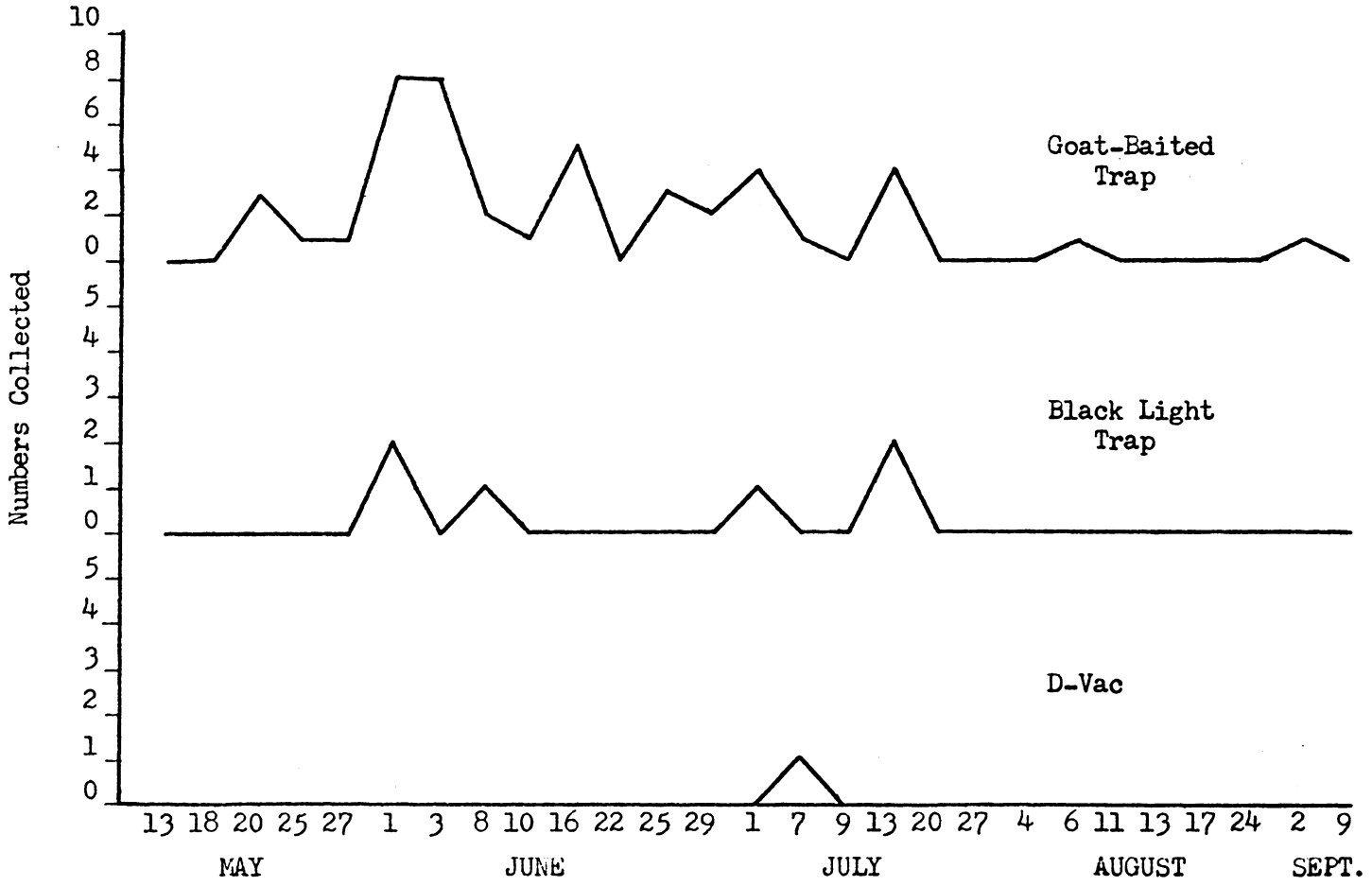

Figure 14. Seasonal distribution of Culicoides guttipennis collected by Goat-Baited Trap, Black Light Trap, and D-Vac in 1970.

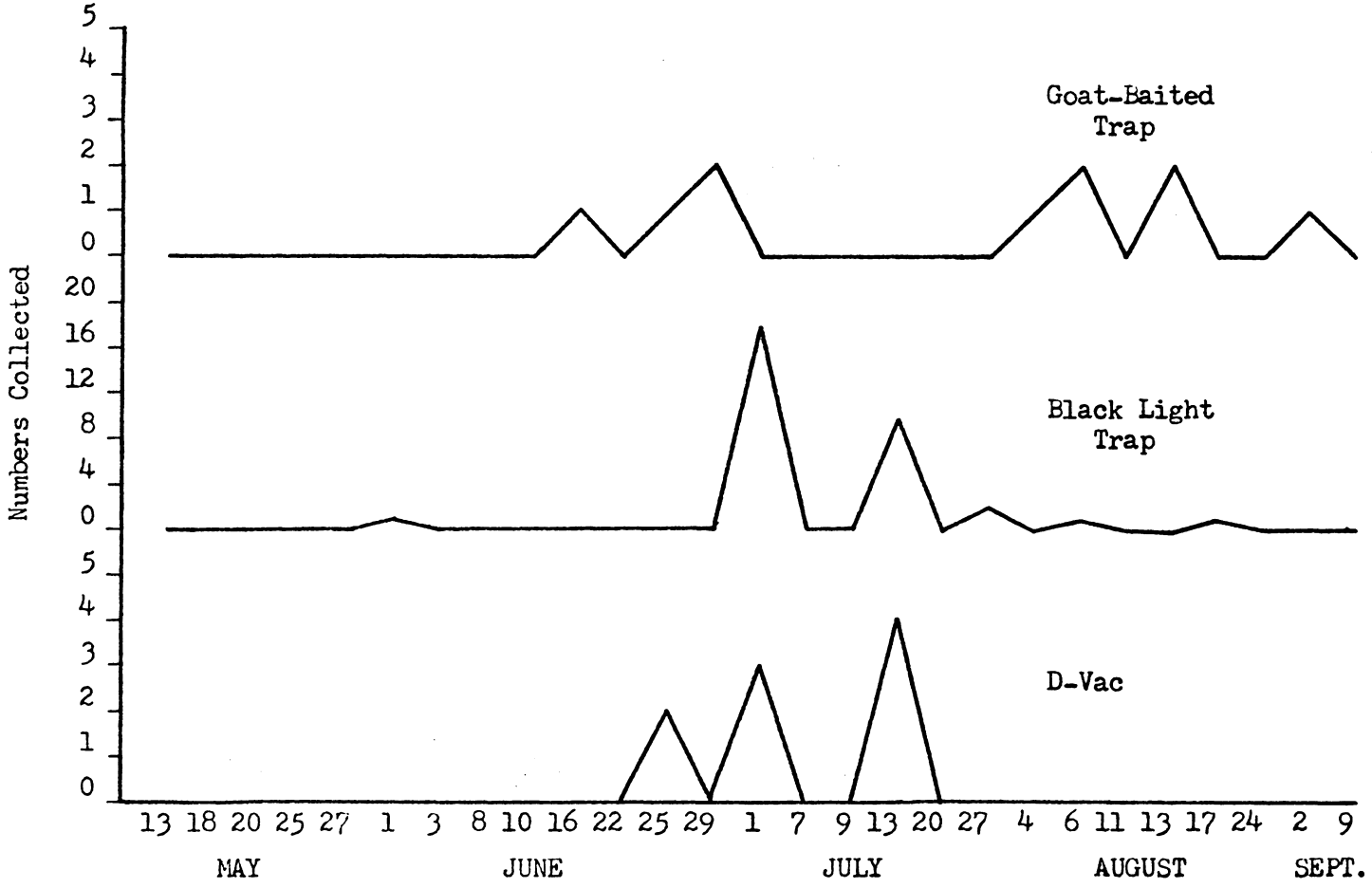

Figure 15. Seasonal distribution of Culicoides stellifer collected by Goat-Baited Trap, Black Light Trap, and D-Vac in 1970.

April to early September with a population peak in June. Jamnback (1965) reported that adults were most common in New York in early July.

The Black Light Trap collected more adults than the other 2 trap methods and provided a good picture of seasonal abundance. However, the Goat-Baited Trap and D-Vac collected a few specimens in middle and late June that the Black Light Trap missed. Also, the Goat-Baited Trap collected the only specimen collected in September.

Culicoides piliferus

This is a ground breeding species that has been reported from 14 Virginia counties (Battle, 1970).

The Black Light Trap and D-Vac collected a total of 43 adults over a 3 month period from May to July (Figure 16). The population peak occurred in early July. These results were in partial agreement with Messersmith (1966) who reported a population peak in July. However, he collected adults also in August and September.

The Black Light Trap collected all but 7 specimens and gave the best picture of seasonal distribution. No specimens were collected from the Goat-Baited Trap.

Culicoides travisi

This is a ground breeding species which has been collected in 11 Virginia counties (Battle, 1970).

The Black Light Trap and D-Vac collected a total of 25 adults over a 3 month period from May to July (Figure 17). The population peak occurred during late May to early June, followed by some activity on into early July. These results were in agreement with Messersmith (1966)

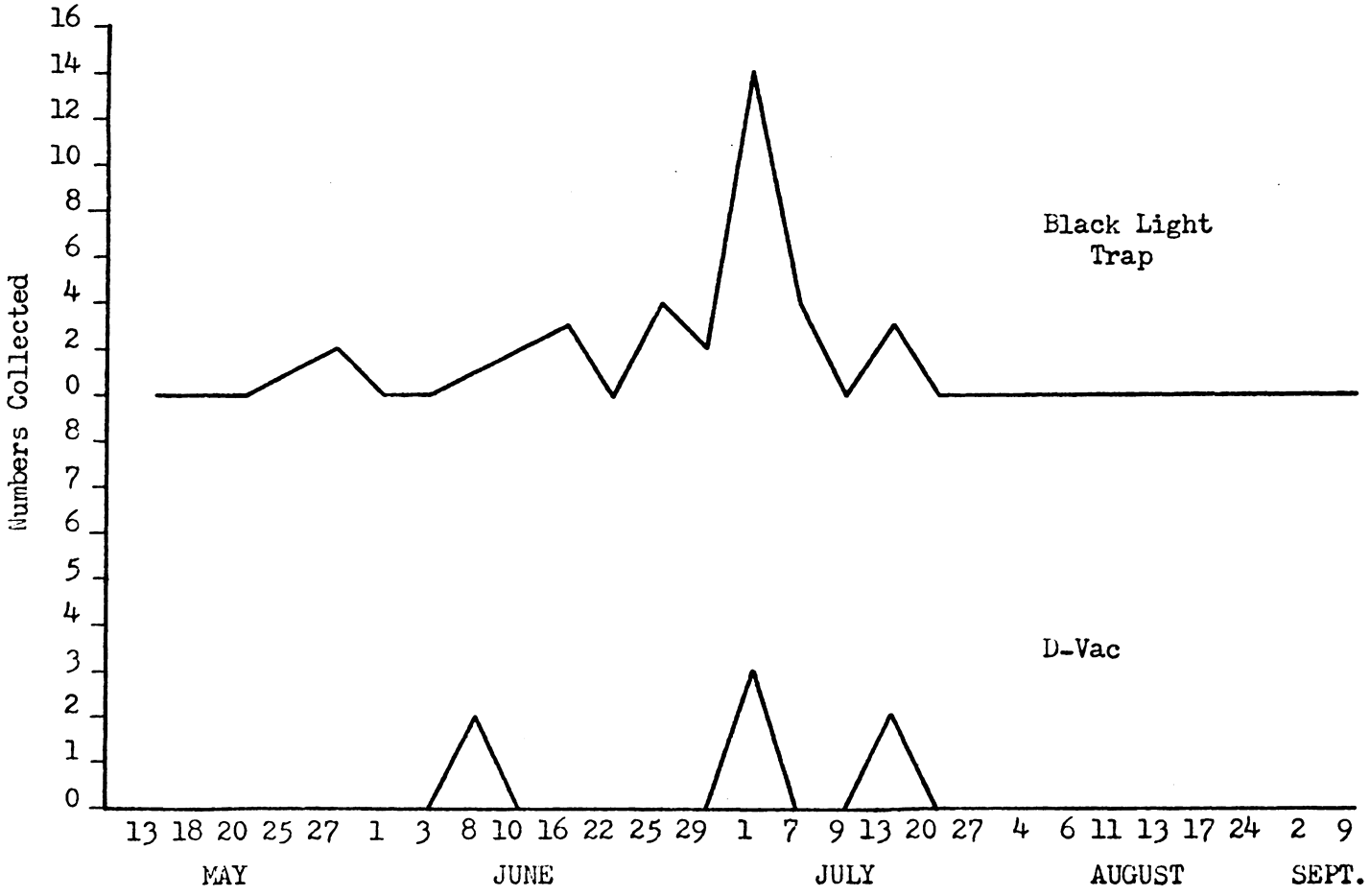

Figure 16. Seasonal distribution of Culicoides piliferus collected by Black Light Trap and D-Vac in 1970.

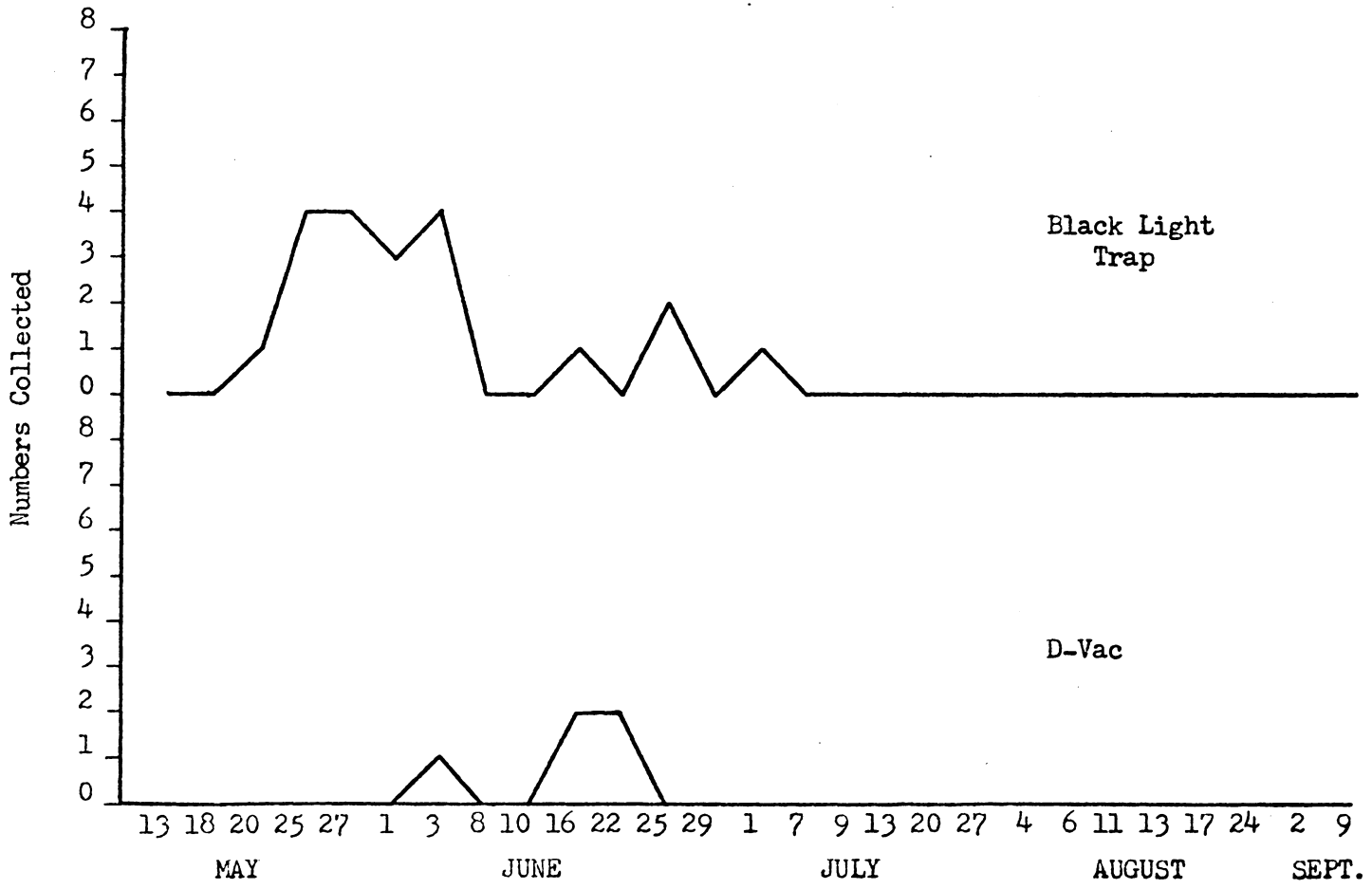

Figure 17. Seasonal distribution of Culicoides travisi collected by Black Light Trap and D-Vac in 1970.

who noted a numerical peak in June in Virginia. Battle (1970) stated that peak populations apparently occur in most areas in late springtime.

The Black Light Trap collected all but 5 of the adults and provided the best picture of seasonal abundance. No specimens were collected from the Goat-Baited Trap.

The following species were collected in numbers too small for definite conclusions, but their occurrence is reported below:

Culicoides biguttatus

This is a ground breeding species which has been reported from 10 Virginia counties (Battle, 1970).

The Black Light Trap and D-Vac collected only 9 adults from late May to early July. A slight population peak was observed in early July. Messersmith (1966) collected adults in Blacksburg, Virginia from middle April to late July with a population peak in June.

The D-Vac collected only 2 specimens, and the Goat-Baited Trap did not collect any.

Culicoides snowi

This is a tree hole species which has been collected only in the Virginia counties of Alexandria, Fairfax, and Rockingham (Battle, 1970).

The Goat-Baited Trap and D-Vac collected only 5 adults from late May to early June. Little has been known about the seasonal distribution of this species. It has been thought to be an early spring species, since most adult collections have been made in May or earlier (Battle, 1970).

The Goat-Baited Trap collected 4 specimens, and the D-Vac collected only 1 specimen. No adults were collected in the Black Light Trap.

Culicoides testudinalis

This is a ground breeding species which has been collected from Alexandria, Fairfax, Montgomery, and Rockbridge Counties in Virginia (Battle, 1970).

The Goat-Baited Trap and D-Vac collected only 4 adults in late May and early June. Jamnback (1965) reported this species to be most common in May and June. Messersmith (1966) collected 7 adults in July in Vesuvius, Virginia.

The D-Vac collected 3 specimens, and the Goat-Baited Trap collected 1. No adults were collected in the Black Light Trap.

Culicoides crepuscularis

This is a ground breeding species which has been reported from 21 Virginia counties (Battle, 1970).

The D-Vac collected only 1 adult on July 1. Messersmith (1966) collected adults in Bent Mountain, Blacksburg, Elkton, and Ferrum, Virginia from July 2 to September 26, with a peak in August.

No adults were collected from the Goat-Baited Trap or Black Light Trap.

Culicoides paraensis

This is a tree hole species which has been reported from 7 Virginia counties (Battle, 1970).

The Goat-Baited Trap collected only 1 adult on August 13. Messersmith (1966) collected 4 adults in Ferrum and Newport, Virginia in July.

No adults were collected in the Black Light Trap or D-Vac.

Culicoides pseudopiliferus

This is a ground breeding species which has been reported from the Virginia counties of Alexandria and Fairfax (Battle, 1970).

The D-Vac collected only 1 adult on June 1. Jamnback (1965) thought this to be a spring and early summer species. No seasonal data have been available from Virginia.

No adults were collected in the Goat-Baited Trap or Black Light Trap.

Culicoides scanloni

This is a ground breeding species which has been reported from 5 Virginia counties (Battle, 1970).

The D-Vac collected only 1 adult on June 1. Jamnback (1965) considered this to be an early spring species, but Messersmith (1966) collected 11 adults in July in Ferrum and Vesuvius, Virginia.

No adults were collected in the Goat-Baited Trap or Black Light Trap.

Culicoides variipennis

This is a ground breeding species which has been reported from a number of Virginia counties (Battle, 1970).

The D-Vac collected only 1 adult on July 1. Messersmith (1966) reported a June peak of this species in Rural Retreat, Virginia.

No adults were collected in the Goat-Baited Trap or Black Light Trap.

C. 1970 Activity Time Periods

The activity time periods of the species collected in 1970 will be discussed below in the order of their abundance. Culicoides sanguisuga, the most abundant species, will be discussed separately from the other species and will be followed by a discussion of pertinent meterological factors.

Culicoides sanguisuga

The activity time period of this species may be seen in Table XIII. The results from all 3 trapping methods were similar. Although a few more specimens were collected in the evenings than in the mornings, the differences were not great. These results were in agreement with Jamnback and Watthews (1963) and with Newton (1966). However, several workers indicated that evening activity was much greater than morning activity (Hill, 1957; Williams, 1955a; Service, 1969). Perhaps greater experimental attention has been given to the evening hours.

Since C. sanguisuga adults were aspirated from the 1970 Goat-Baited Trap at $\frac{1}{2}$-hour intervals from 2 hours before sunset and sunrise until 2 hours after sunset and sunrise, an accurate picture of nightly activity was obtained (Table XIV and Figure 18). A similar picture was obtained from the D-Vac results, even though the numbers were smaller (Figure 19). The activity distribution before and after

Table XIII. Activity of Culicoides sanguisuga during three time periods - 1970.

TRAPS	PM a/		OVERNIGHT b/		AM c/	
	No. Trap Days	Mean No. Collected	No. Trap Days	Mean No. Collected	No. Trap Days	Mean No. Collected
GOAT-BAITED	27	569.0	27	77.0	27	434.3
BLACK LIGHT	27	280.7	-	-	24	272.5
D-VAC	23	37.7	-	-	19	34.0

a/ - From 2 hours before sunset to 2 hours after sunset.

b/ - From 2 hours after sunset to 2 hours before sunrise.

c/ - From 2 hours before sunrise to 2 hours after sunrise.

Table XIV. Total Culicoides sanguisuga collected from Goat-Baited Trap at ½-hour time intervals before and after sunrise and sunset from June 1 to September 9, 1970 (22 trap days).

TIME INTERVAL	NUMBER COLLECTED	T O T A L S			
1	290				
2	608				
3	1,341	4,738			
4	2,549				
SUNSET				11,646	
5	3,247				
6	2,104				
7	984	6,858			
8	523				
					22,706
1	144				
2	251				
3	735	4,244			
4	3,114				
SUNRISE				11,060	
5	2,053				
6	1,729				
7	1,729	6,816			
8	1,305				

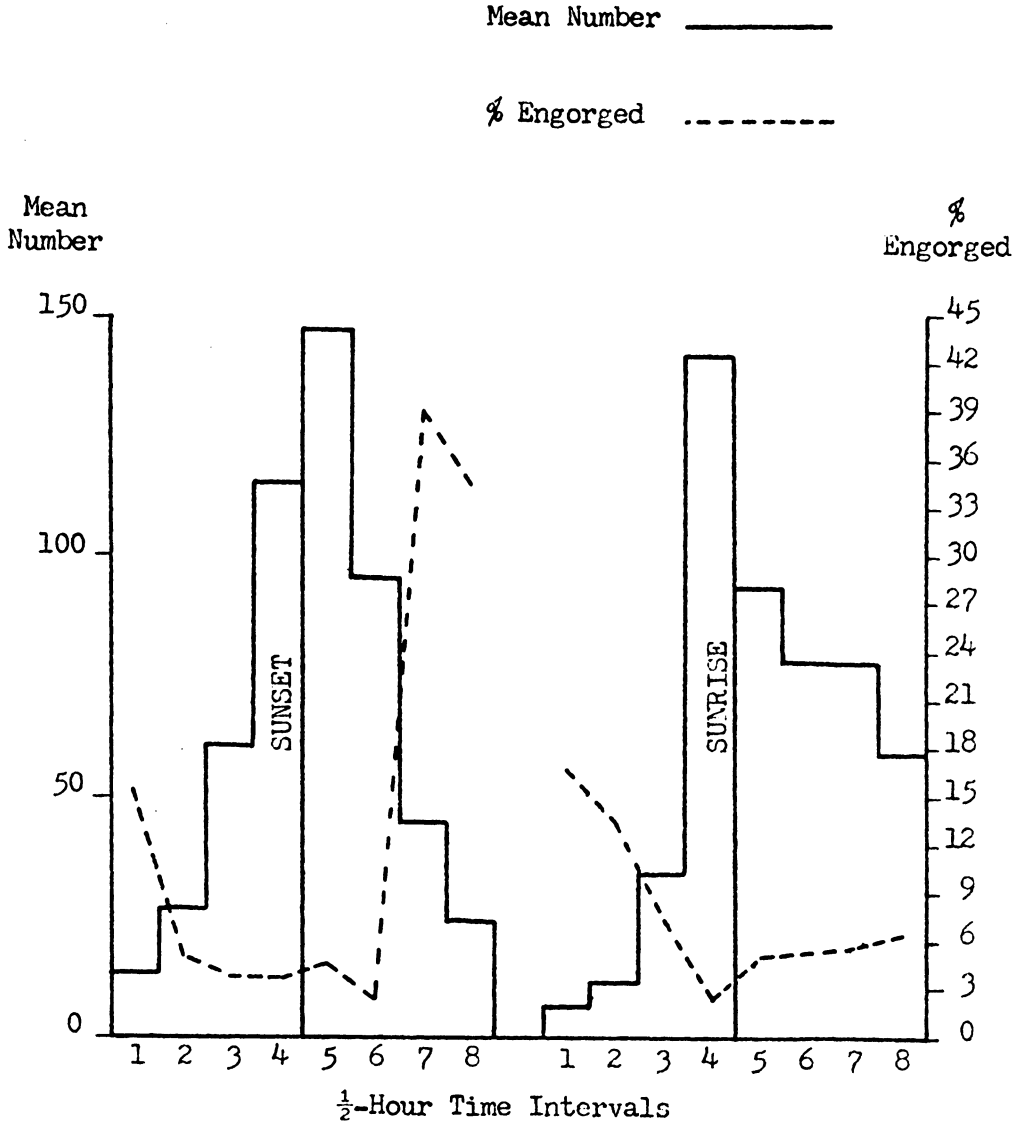

Figure 18. Mean number and percent engorged Culicoides sanguisuga collected by Goat-Baited Trap at ½-hour time intervals before and after sunset and sunrise (June 1 to September 9, 1970).

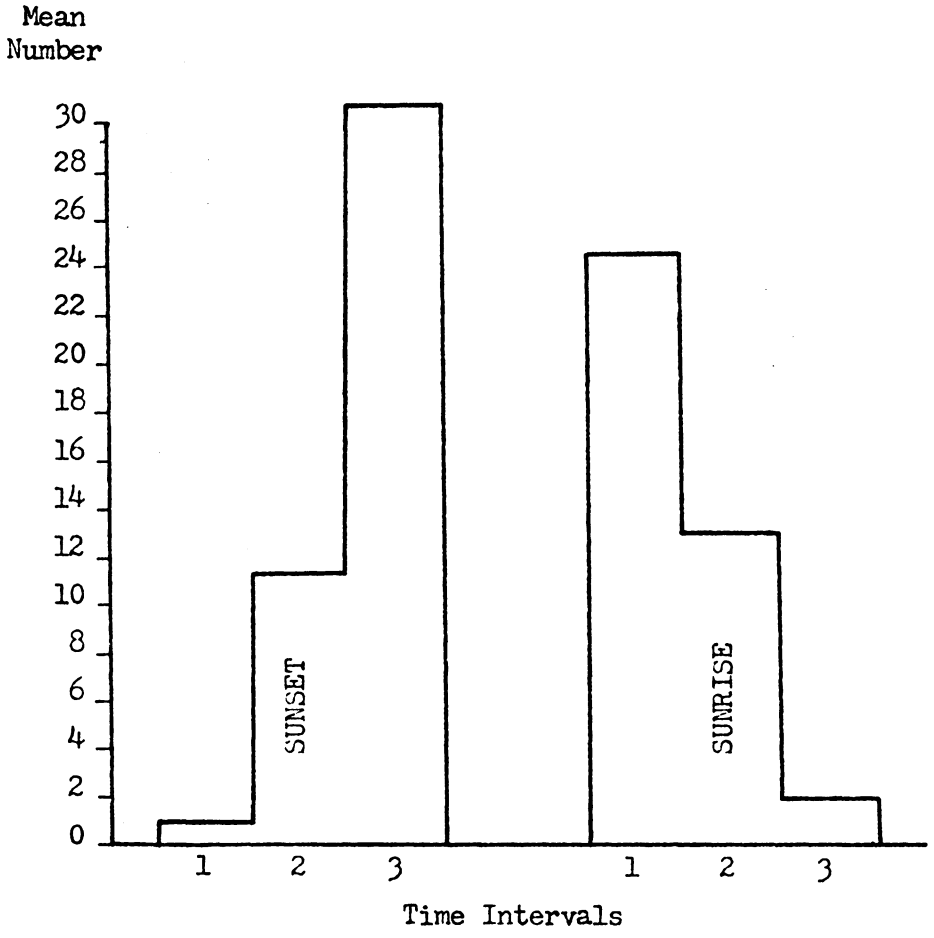

Figure 19. Mean number of Culicoides sanguisuga collected by D-Vac at 1-hour time intervals before and after sunset and sunrise (June 1 to September 9, 1970).

sunset was symmetrical, with the activity peak occurring during the ½-hour interval following sunset. At sunrise, the activity peak occurred during the ½-hour interval before sunrise. This peak was abrubt, and the mean number collected jumped from 33.4 to 141.5 a half hour. After the morning peak, the numbers collected did not decline as quickly as they did in the evening. The mean number collected at 2 hours after sunrise was 59.3, as compared with a 23.8 mean at 2 hours after sunset.

The percentage of engorged adults per ½-hour may be seen also in Figure 18. Percentage engorgement seemed to lag about an hour behind the total number collected. The most engorged females were collected during the third ½-hour interval after sunset. Presumably the engorged specimens were slow in coming off the goat due to time spent in engorgement. Jamnback and Watthews (1963) found that C. sanguisuga required a little more than 3 minutes, on the average, to engorge on human blood during landing rate experiments. However, the Goat-Baited Trap was a much different situation than the human arm. Several things might have contributed to a longer engorgement time: (1) Since a goat has a good deal more hair than a human arm, the time between landing and engorging would probably be increased. (2) The goat was not restrained within the wire cage and was often observed shaking, kicking, rubbing, etc., which would have been a deterrent to immediate feeding and engorgement. (3) After engorgement, the gnats were observed to crawl slowly up the front of the trap toward the collecting cones. They appeared sluggish and sometimes stayed in one spot for several minutes.

The percentage of engorged C. sanguisuga was much lower in the morning than in the evening and did not rise appreciably after the morning peak of activity (Figure 18). The somewhat higher percentage engorgement at the beginning of the morning collections was probably due to collecting adults which engorged during the night and came off the goat into the collecting cones in the morning. Although it is not reported in the figures, percentage engorgement for the overnight collections was 44.1%, which was higher than at any other time. Temperatures were lower in the morning than in the evening and might have had a negative influence on engorgement in the morning. Also, those members of the population which were ready to feed may have already fed during the previous evening.

Meterological Factors and Culicoides sanguisuga Activity

Mean light intensity dropped from 2,000 f.c. to 0 f.c. in the evenings and rose from 0 f.c. to 1,100 f.c. in the mornings. Light intensity seemed to show the best correlation with adult activity of C. sanguisuga (Figures 20). The light intensity in the evening changed most rapidly during the ½-hour time interval in which the most adults were collected. The same was true for the morning collections. Mean light intensity dropped 28.66 f.c. from 28.8 to .14 f.c. during the ½-hour of peak evening activity. It rose 19.148 f.c. from .052 to 19.2 f.c. during the ½-hour of peak morning activity. Thus, the greatest activity occurred when the mean light intensity was between .052 and 28.8 f.c. Humphreys (1969) found C. sanguisuga to be most active during dusk, which he determined to be from .5 to 11 f.c. In laboratory tests, Humphreys and Turner

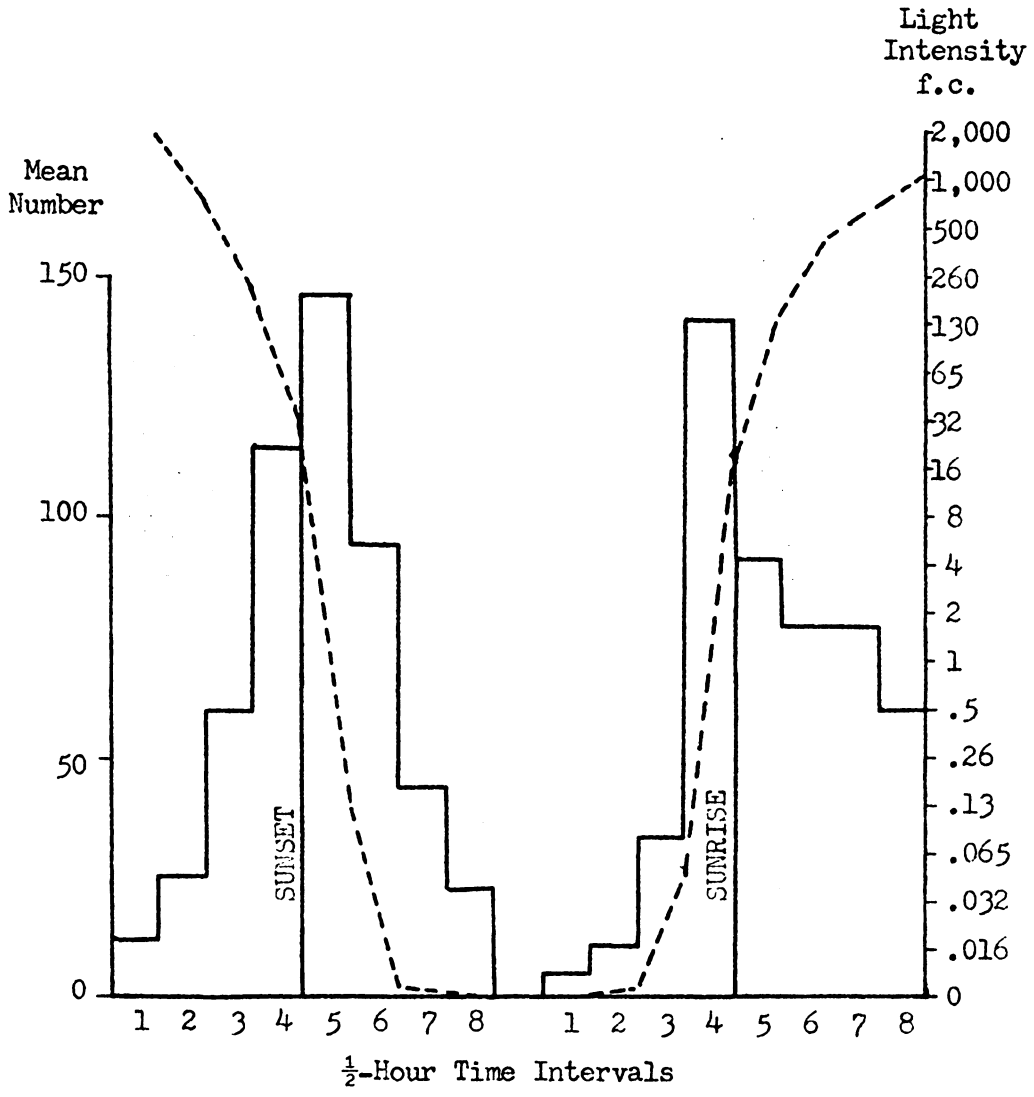

Figure 20. Light intensity (foot candles) and mean number of Culicoides sanguisuga collected by Goat-Baited Trap at ½-hour time intervals before and after sunset and sunrise (June 1 to September 9, 1970).

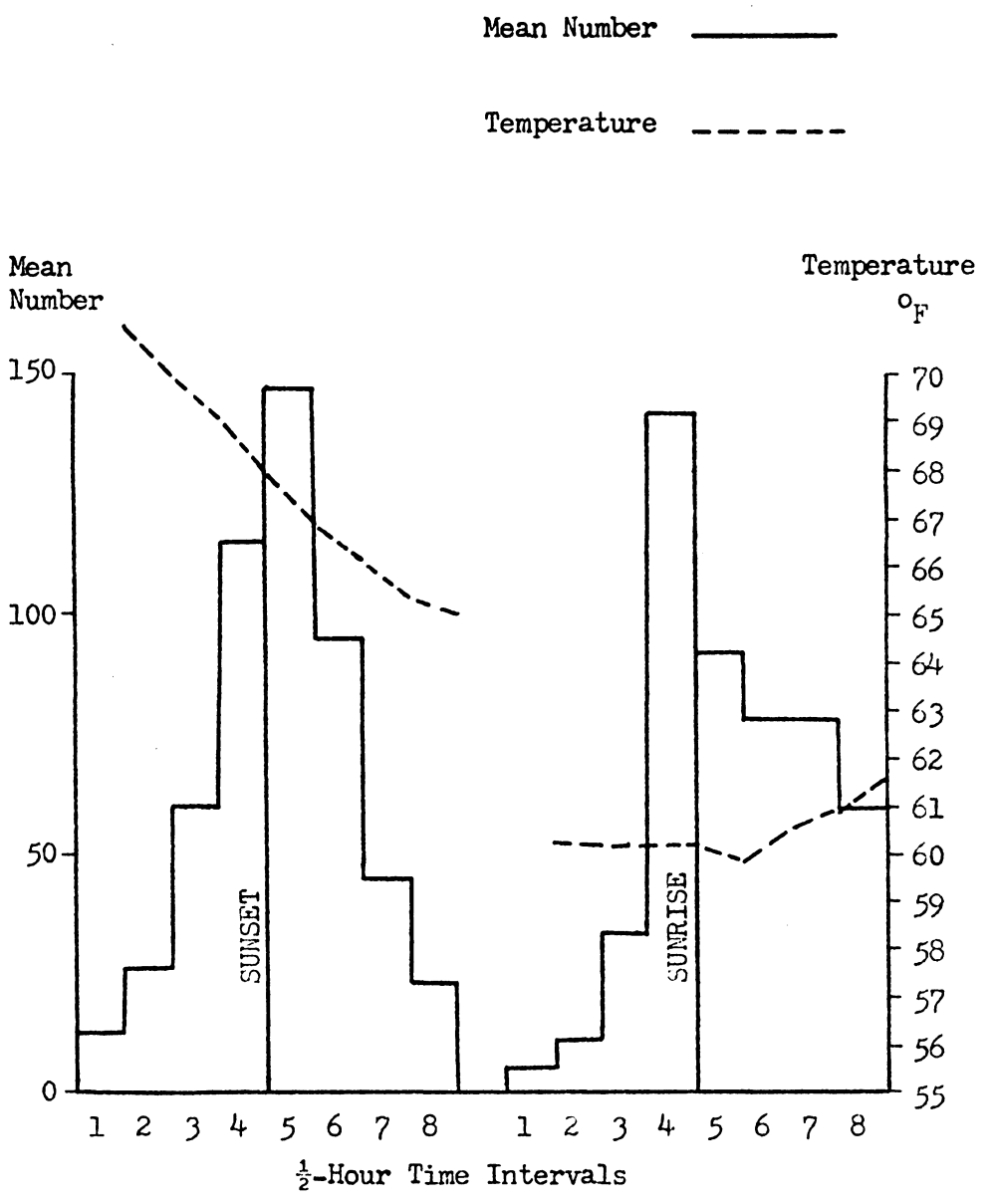

Figure 21. Temperature and mean number of Culicoides sanguisuga collected by Goat-Baited Trap at ½-hour time intervals before and after sunset and sunrise (June 1 to September 9, 1970).

(1971) found C. guttipennis to feed most rapidly at light intensities of 0.1 to 9.0 f.c. Jamnback and Watthews (1963) admitted a considerable degree of correlation between adult activity and light intensity, but they felt that a closer correlation existed between adult activity and evaporation rate.

Temperatures dropped an average of 11°F from 71°F to 65°F in the evenings, and rose an average of 1.7°F from 59.8°F to 61.5°F in the mornings (Figure 21). Morning temperatures did not start to rise until 1 hour after sunrise, which was 1½-hours after the morning peak of activity began. The 2 peaks of activity occurred during temperature of 60.2°F to 68°F. Since adult activity was nearly the same in both the evening and the morning, temperature alone probably had little effect on activity. However, as stated earlier, the lower morning temperatures may have inhibited the feeding response somewhat. Jamnback and Watthews (1963) found high landing rates of C. sanguisuga to occur during temperatures of 55°F to 81°F. Humphreys (1969) reported the optimum feeding activity of C. sanguisuga to occur between 60°F and 65°F.

Percent relative humidity rose 8.5% from 82% to 90.5% in the evenings and dropped 2.4% from 92.8% to 90.4% in the mornings (Figure 22). The 2 peaks of adult activity occurred during humidities of 88% to 92.6%. The numbers of C. sanguisuga per ½-hour in the mornings varied from 6.5 to 141.5, yet the humidity was always over 90%. Thus, relative humidity alone probably had little effect on adult activity within the range of 82% to 95%.

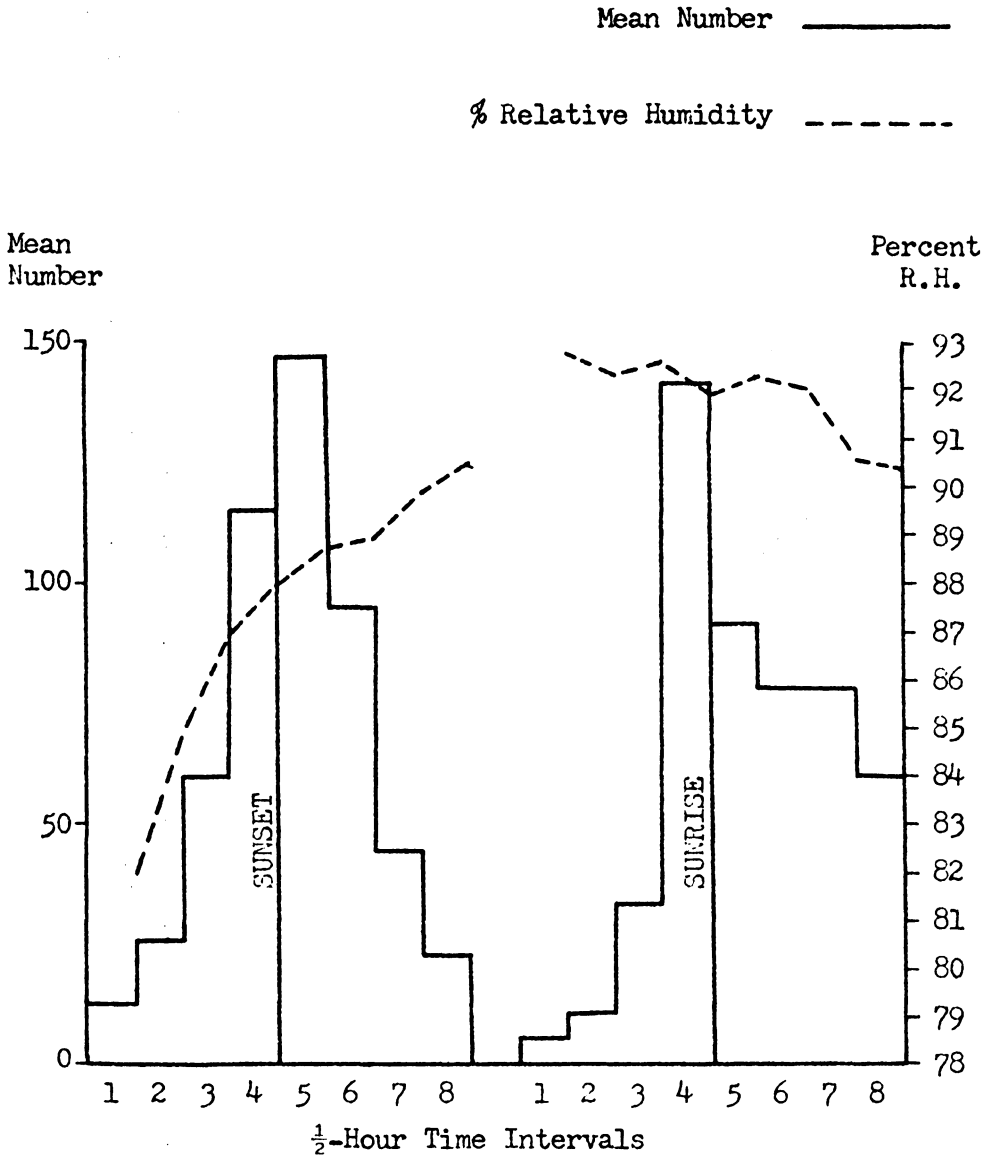

Figure 22. Percent relative humidity and mean number of Culicoides sanguisuga collected by Goat-Baited Trap at ½-hour time intervals before and after sunset and sunrise (June 1 to September 9, 1970).

Table XV. Activity of 10 Culicoides spp. during three time periods - 1970.

SPECIES	GOAT-BAITED TRAP						BLACK LIGHT TRAP				D-VAC			
	PM [a]		OVER-NIGHT [b]		AM [c]		PM		AM		PM		AM	
	Trap Days [d]	Mean No. [e]	Trap Days	Mean No.	Trap Days	Mean No.	Trap Days	Mean No.	Trap Days	Mean No.	Trap Days	Mean No.	Trap Days	Mean No.
bickleyi	(0)	0	(0)	0	(0)	0	(14)	47.6	(11)	11.3	(12)	7.8	(10)	.4
alexanderi	(0)	0	(0)	0	(0)	0	(10)	56.9	(8)	1.3	(13)	5.2	(11)	.5
jamnbacki	(0)	0	(0)	0	(0)	0	(13)	2.8	(11)	3.5	(11)	4.0	(9)	1.4
haematopotus	(0)	0	(0)	0	(0)	0	(15)	3.9	(13)	.9	(9)	2.0	(8)	.3
arboricola	(5)	1.0	(0)	0	(5)	.2	(7)	5.4	(6)	3.0	(2)	.5	(2)	.5
mulrennani	(3)	1.3	(0)	0	(0)	0	(9)	3.2	(8)	1.3	(4)	3.0	(3)	.7
guttipennis	(3)	.2	(3)	1.9	(3)	.9	(4)	1.3	(4)	.3	(1)	1.0	(0)	0
stellifer	(7)	1.4	(0)	0	(0)	0	(6)	5.0	(6)	.5	(3)	2.3	(2)	1.0
piliferus	(0)	0	(0)	0	(0)	0	(10)	2.7	(7)	1.3	(3)	1.7	(3)	.7
travisi	(0)	0	(0)	0	(0)	0	(8)	2.1	(6)	.5	(3)	1.7	(0)	0

a/ - From 2 hours before sunset to 2 hours after sunset.

b/ - From 2 hours after sunset to 2 hours before sunrise.

c/ - From 2 hours before sunrise to 2 hours after sunrise.

d/ - Days in which 1 or more specimens were captured.

e/ - Mean number per trap day in which 1 or more specimens were captured.

Other Species

In Table XV may be seen the activity time periods of the more abundant Culicoides species, other than C. sanguisuga, which were collected in 1970. Culicoides bickleyi and C. alexanderi were the 2 most abundant species other than C. sanguisuga. Evening collections of these species, both by the Black Light Trap and D-Vac, were considerably greater than the morning collections.

The following species were not collected in sufficient numbers to be able to draw definite conclusions, but indications of their activity time periods are presented (Table XV). Culicoides haematopotus, C. mulrennani, C. stellifer, and C. travisi were all collected predominantly in the evenings. Evening and morning collections of C. arboricola and C. piliferus were nearly equal, but more were collected in the evenings. As with the seasonal abundance studies, the Black Light Trap collections of C. jamnbacki did not agree with the D-Vac collections. In the Black Light Trap, the morning collections were somewhat greater than the evening collections. However, most of the D-Vac specimens were collected in the evenings. Again, as with seasonal abundance, the problem could possibly be a taxonomic one. Culicoides guttipennis, as collected by the Goat-Baited Trap, exhibited an unusual activity time period. More adults were collected during the nights than in the evenings or mornings. Evening collections of this species by the Black Light Trap and D-Vac were greater than the morning collections. Apparently this species is most active in the late evenings and throughout the nights. Humphreys (1969) collected more C. guttipennis adults after dark than at dusk. He did not make any morning collections.

V. CONCLUSIONS

A. 1969 Vertical Activity and Host Preference

Culicoides sanguisuga was the predominant species in this study. It was collected at all 3 levels in the tree, but more were collected at ground level than at either the 25 or 50-foot levels (Table V). This species has been considered to be mammalophilic, especially on large mammals (Table I). It was most interesting, therefore, to find that significantly more were collected from the small turkeys than from the rabbits of the same weight at the 50-foot level. At ground level more were also collected from the small turkeys, but this difference was not significant at the 5% level. At the 25-foot level, there was no significant difference between hosts.

At ground level, the greatest numbers of C. sanguisuga were collected from the large goat. Next in the order of their attractiveness were the small goat, the large turkey, the small turkeys, and the rabbits. Thus, C. sanguisuga tended to prefer larger animals, whether mammals or birds.

In the vertical activity experiments involving turkeys and rabbits, more specimens of each Colicoides species were collected from small turkeys than from rabbits, regardless of whether the

species had been considered to be mammalophilic or ornithophilic (Table X). It is my opinion that this occurred because the small turkeys were slightly larger and bulkier than the rabbits. However, this size difference was not great enough to make a significant difference with most species.

Two major factors emerge from this study as being important in determining a Culicoides blood meal. One factor is the vertical activity preference of the species (i.e., whether it feeds at ground level or in the canopy). The second factor is the size or bulkiness of the host, whether bird or mammal.

A species that prefers to feed at the canopy level will find more birds than mammals as potential hosts. In my opinion, this reflects host availability rather than host preference. It may be argued that a species feeds at the canopy level because of the greater abundance of avian hosts. However, when rabbits were introduced into the canopy, many so-called ornithophilic species were also attracted to these mammalian hosts.

It is possible that the differences in vertical activity habits of Culicoides species and the sizes of their potential hosts are more important in determining blood meals than whether the hosts are birds or mammals.

B. 1970 Seasonal Distribution

The conclusions from the 1970 seasonal distribution studies are as follows:

1. The D-Vac was the best method for collecting the greatest variety of species, even though several species were represented by only single specimens. This trap did not use animals or lights as attractants. It merely sampled Culicoides flying in the air, and for this reason it was probably the most unbiased collecting method. D-Vac collections were smaller than the other collections, but that was due to the shorter collection times (15 minute samples). Even though its collections were small, the seasonal distributions which resulted were remarkably comparable with results from the other 2 traps. If used more extensively, the D-Vac could be an excellent sampling tool.

2. The Black Light Trap generally provided the best picture of seasonal distribution for most species.

3. The Goat-Baited Trap provided the best picture of seasonal distribution for C. sanguisuga, the most abundant species.

4. Two species. C. alexanderi and C. jamnbacki, were collected for the first time in the state of Virginia.

5. Culicoides bickleyi, C. mulrennani, C. snowi, C. testudinalis, C. crepuscularis, C. pseudopiliferus, C. scanloni, and C. variipennis were collected for the first time in Giles County, Virginia.

6. More species of Culicoides were present during June and July than during the other summer months.

7. Culicoides sanguisuga, C. haematopotus, and C. gutti-pennis were most abundant in spring to mid-summer (May - July), but were present in each of the 5 months May to September.

8. Culicoides bickleyi, C. alexanderi, C. arboricola, and C. travisi were most abundant in spring and early summer (May - June).

9. Culicoides mulrennani, C. stellifer, and C. piliferus were most abundant in mid-summer (June - July).

10. More than 1 species or subspecies may be involved in C. jamnbacki, since its seasonal abundances as shown by the Black Light Trap and D-Vac were quite dissimilar (Figure 10).

C. 1970 Activity Time Period

Conclusions concerning activity time periods are as follows:

1. Nearly all species were active both in the evening and morning. However, in most cases adult activity was greater in the evening than in the morning.

2. Culicoides sanguisuga was by far the most abundant species collected and was therefore most suitable for activity studies. Nearly equal peaks of adult activity occurred during the ½-hour after sunset and the ½-hour before sunrise. Light intensities seemed to have the best correlation with these activity peaks. Mean light intensity dropped most rapidly (from 28.8 - .14 f.c.) during the evening peak and rose most rapidly (from .052 - 19.2 f.c.) during the morning peak. Thus, greatest adult activity occurred during light intensities of .052 - 28.8 f.c., which was a fairly narrow range, considering that light intensities varied from 0 to 2,000 f.c. during the experiments. Temperature and relative humidity during the experiments seemed to have less correlation with adult activity.

3. The activity time period of C. guttipennis was unusual. It was most active in the late evening and on through night and early morning.

VI. SUMMARY

During vertical activity experiments, 8 Culicoides species were collected from goats, turkeys, and rabbits in animal-baited traps at ground level, 25, and 50 feet in the forest canopy. The following factors were found to be important in Culicoides host selection:

1) Vertical activity patterns of the Culicoides.

2) Presence of a host (bird or mammal).

3) Size of the host.

The size of the host and its presence within the activity area of the Culicoides appeared to be more important than whether the host was a bird or a mammal.

During seasonal abundance and activity time period experiments, 19 Culicoides species were collected in the Goat-Baited Trap, Black Light Trap, and D-Vac. The Black Light Trap was the most effective trapping method for the largest number of species. The Goat-Baited Trap was selective for Culicoides and was the most effective method of collecting C. sanguisuga, by far the most abundant species. The D-Vac collected 18 of the 19 species, but several species were represented by only a few specimens. If the D-Vac were used extensively, it could prove to be very effective for a large number of species. It has the advantage of being able to sample a

large area in little time and with comparatively little trouble. Since it is an active sampling method, it is independent of attractancy to either a host or a light.

Two Culicoides species (C. alexanderi and C. jamnbacki) were collected for the first time in Virginia. Eight additional species were collected for the first time in Giles County, Virginia.

June and July were the best months to collect the most species of Culicoides. Three species were present each month May to September. Several species were most abundant in the spring and early summer (May and June), while other species were most abundant in mid-summer (June and July).

Most Culicoides species were found to be crepuscular, with their greatest activity occurring in the evenings. Other species were nearly as active in the mornings as in the evenings. One species, C. guttipennis, was unusual in being most active during the nights and in the mornings.

Nearly equal activity peaks of C. sanguisuga occurred during the $\frac{1}{2}$-hour time interval after sunset and during the $\frac{1}{2}$-hour before sunrise. Light intensities during those peaks were nearly identical, changed rapidly, and were more closely related to activity than were temperature or relative humidity factors.

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VERTICAL ACTIVITY, HOST PREFERENCE, AND POPULATION STUDIES OF ADULT CULICOIDES (DIPTERA: CERATOPOGONIDAE)

(Gary Dale Tanner)

Abstract

Automatic-collecting, animal-baited traps were used to investigate the vertical activities and host preferences of Culicoides species in a forest in Giles County, Virginia. Using ropes and pulleys, rabbit and turkey-baited traps were positioned at ground level, 25, and 50 feet elevation in a forest tree so as to give Culicoides choices of avian or mammalian hosts at each vertical level. Culicoides species generally exhibited preferences for one or more of the vertical levels. The size of the host and its presence within the normal vertical activity area of the Culicoides were found to be more important than whether the host was a bird or a mammal. Three trapping methods (Goat-Baited Trap, Black Light Trap, and D-Vac) were employed simultaneously to investigate the seasonal and daily activity patterns of Culicoides and to determine the relative effectiveness of the three methods. The Black Light Trap was the most effective method for most of the species. The Goat-Baited Trap was selective for Culicoides species and was most effective for collecting C. sanguisuga, the most abundant species. The D-Vac collected more species than the other methods, but several

species were represented by only a few specimens. Two species (C. alexanderi and C. jamnbacki) were collected for the first time in Virginia, and 8 more were new records for Giles County. Graphs were presented showing seasonal distributions for 11 species, and preliminary indications were given for 8 more. Most species were crepuscular in their activities, with the greatest activity usually occurring in the evenings. Some species were nearly as active in the mornings as in the evenings, and one species, C. guttipennis, was most active during the nights and in the mornings. Culicoides sanguisuga exhibited 2 nearly equal activity peaks during the $\frac{1}{2}$-hour time intervals after sunset and before sunrise. Light intensities were nearly identical during those times and were more closely related to activity than were temperature or relative humidity.