# INVESTIGATIONS ON THE SENSORY BEHAVIOUR AND ECOLOGY OF BLACK FLIES SIMULIIDAE: DIPTERA IN THE WHITESHELL FOREST RESERVE, MANITOBA

A

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ABSTRACT

This study of Simuliidae was carried out in the Whiteshell Forest Reserve and near La Salle, Manitoba in 1959 and 1960. The "helio-thermal" trap originally designed to capture Tabanidae (Thorsteinson, 1958) and improved by Bracken (1960) was further improved and used to monitor seasonal and diurnal activity of black flies and their response to motion. The diurnal activity of black flies was studied in relation to such meteorological factors as wind, light intensity, temperature, relative humidity and the time of day. It was found that flying conditions were optimal when it was calm or nearly so, cloudy with temperatures at about 70°F., and 75% relative humidities. On the average the greatest flying activity occurred between 7 and 9 in the morning.

Seasonal activity was monitored by counting the black flies captured at two locations in two traps maintained from May to September, 1960. The peak of seasonal activity occurred on May 31 near La Salle and on June 15 in the Whiteshell Forest Reserve.

The orientation to objects of various shapes and "degrees of brokenness" of contours was studied. It was found that black flies were attracted more to objects with solid contours. Black flies could recognize different shaped objects only by their differential "degree of brokenness" of contours. A stationary body suspended from underneath the trap increased the efficiency of the trap more than a moving body underneath the trap. Spheres were painted black, blue, red, yellow and green. It was found that the black, blue and red spheres attracted many more flies

than the yellow and green ones. However when wooden sticks were painted various colours and placed into the current, the flies laid more eggs on the yellow and green sticks than on any of the others.

Attempts were made to rear black flies from the egg stage in the laboratory by means of artificially circulated and aerated water.

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## CHAPTER I

## INTRODUCTION

### Importance of Study

In five outbreaks of black flies prior to 1948 more than 1,000 head of livestock were killed in the area of the South Saskatchewan River in Central Saskatchewan. *Simulium arcticum* was the chief species causing the deaths. Beginning in 1948 DDT was applied to the South Saskatchewan River at a rate below the toxic level for fish. Black flies were thus controlled over a distance of 115 miles downstream (Fredeen, 1956). Species of Simuliids are particularly troublesome to man in Canada's far northern regions and Alaska. Since swarms of these insects may travel as far as 140 miles with a favourable wind (Fredeen, 1956), chemical control is very difficult indeed in these northern regions. Officials in resort areas such as the Whiteshell Forest Reserve do not apply DDT to the rivers. They fear harm would be done to the fish, not only through the direct action of the chemical, but also because the larvae seem to be an important source of food for game fish. The author has seen young lake trout (*Cristivomer namaycush* Walbaum) readily eating larvae. Therefore it is hoped to control the pest species of Simuliidae by means other than the use of insecticides. An increase in our knowledge of the life cycles, sensory physiology and behaviour of the noxious black fly species may lead to development of non-insecticidal control measures.

### The Scope of the Study

The present study is concerned mainly with some aspects of behaviour of certain Simuliid species occurring in the Whiteshell Forest Reserve in South Eastern Manitoba. Much of the information was obtained through the use of traps. The numbers of Simuliids captured in various types of traps provided information regarding the orientation behaviour of these insects as well as a picture of the seasonal abundance in the Whiteshell Forest and at La Salle, Manitoba. Only a small part of the material was identified to species.

## Organization of the Thesis

The topics and experiments in this thesis are diverse. Therefore only a short outline of the literature available on black flies and a general account of the materials and methods used are given at the beginning of the thesis. At the beginning of each chapter dealing with a particular experiment or investigation, a detailed review of the literature and a description of the pertinent materials and methods is presented, followed by the results and discussions.

## General Review of Literature

The literature on Simuliidae is largely restricted to works on taxonomy and life cycles, damage done to cattle and poultry and their annoyance to man. A few papers deal with the trapping of black flies and their responses to specific stimuli. Cameron (1918, in Davies and Peterson, 1956) describes the black flies attacking cattle. Twinn (1936) gives a very thorough account of the species occurring in Eastern Canada. Davies and Peterson (1956) investigated the habits, ecology and physiology of many species occurring in Algonquin Park, Ontario. Many papers from all parts of the world, such as Rubtzov (1939) in Russia, Smart (1945) and Edwards (1921, in Davies and Peterson, 1956) in England, Nicholson (1950) in Minnesota, to mention only a very few, show the world wide importance of many members of this hematophagous family of flies. Two papers deal with the trapping of black flies in light traps (Williams, French and Hosni, 1955; Williams and Davies, 1957). Davies studied the landing ratio of black flies on different coloured cloth (1951) and the seasonal abundance and diurnal activity (1952). Wolfe and Peterson (1960) also made observations on the diurnal activity of Simuliids. Hocking (1960) provided a survey of literature on biting flies which includes Simuliidae.

## Materials and Methods in General

The experiments were carried out in 1959 and 1960. In each of three locations one permanent trap was set up to monitor seasonal activity. This trap, which in its modifications was also used in other investigations, will be described in detail later. One of these was located near La Salle, Manitoba; the other two in the Whiteshell Forest Reserve in Southeast Manitoba. The same general type of trap, the silhouette of which was presumed to function as a visual dummy of a potential host, was used to obtain data on the orientation responses of Simuliidae. Silhouettes were suspended underneath the canopies of the traps. They were painted various colours and compared. The comparative efficiency of stationary and moving silhouettes underneath the traps was investigated with respect to the number of black flies captured. The perception of form by black flies was studied with shapes made from corrugated cardboard with the smooth side facing out. These were painted black and smeared with tangle foot. Any black fly which touched the form became entangled in the sticky substance and could thus be counted. Oviposition behaviour on different coloured objects was studied by placing coloured, wooden sticks into the current of the river and weighing the eggs oviposited on them. The orientation of black flies to a filtered point source of light provided information on spectral sensitivity of black flies. A study of diurnal activity of black flies was made by collecting the trap catches every two hours for several days and keeping records of meteorological changes on these same days.

## CHAPTER II

## PRELIMINARY EXPERIMENTS AND MODIFICATIONS OF THE "HELIO-THERMAL TRAP"

### A. Visual Factors

#### Review of Literature

Two papers deal with the nocturnal trapping of black flies in light traps. Williams (1955) compared a 125 watt ultraviolet bulb with an ordinary 200 watt white bulb. The ultraviolet bulb proved to be more attractive. Williams and Davies (1957) report that they captured gravid and engorged female black flies in an ultraviolet trap of the Rothamsted type. Morris and Morris (1949) describe a trap used successfully to trap another group of hematophagous insects, the species of the genus *Glossina*. The tse-tse flies are diurnal insects and the trap design was based on such visual factors as shape, size, colour and type of material. A cylindrical shape of the trap was found to be very important. The efficiency of this trap was compared to the number of tse-tse flies that landed on and were caught by a negro boy. The fly boy was more attractive to anthropophilic species. Species previously known to prefer livestock and wild mammals were more attracted to the trap. Only one species was more attracted to moving than to stationary traps.

#### Materials and Methods

The traps used in this study were modifications of the type described by Thorsteinson (1958) (Figure 1 A). The large black funnel underneath the trap with a collecting jar screwed onto the narrow end

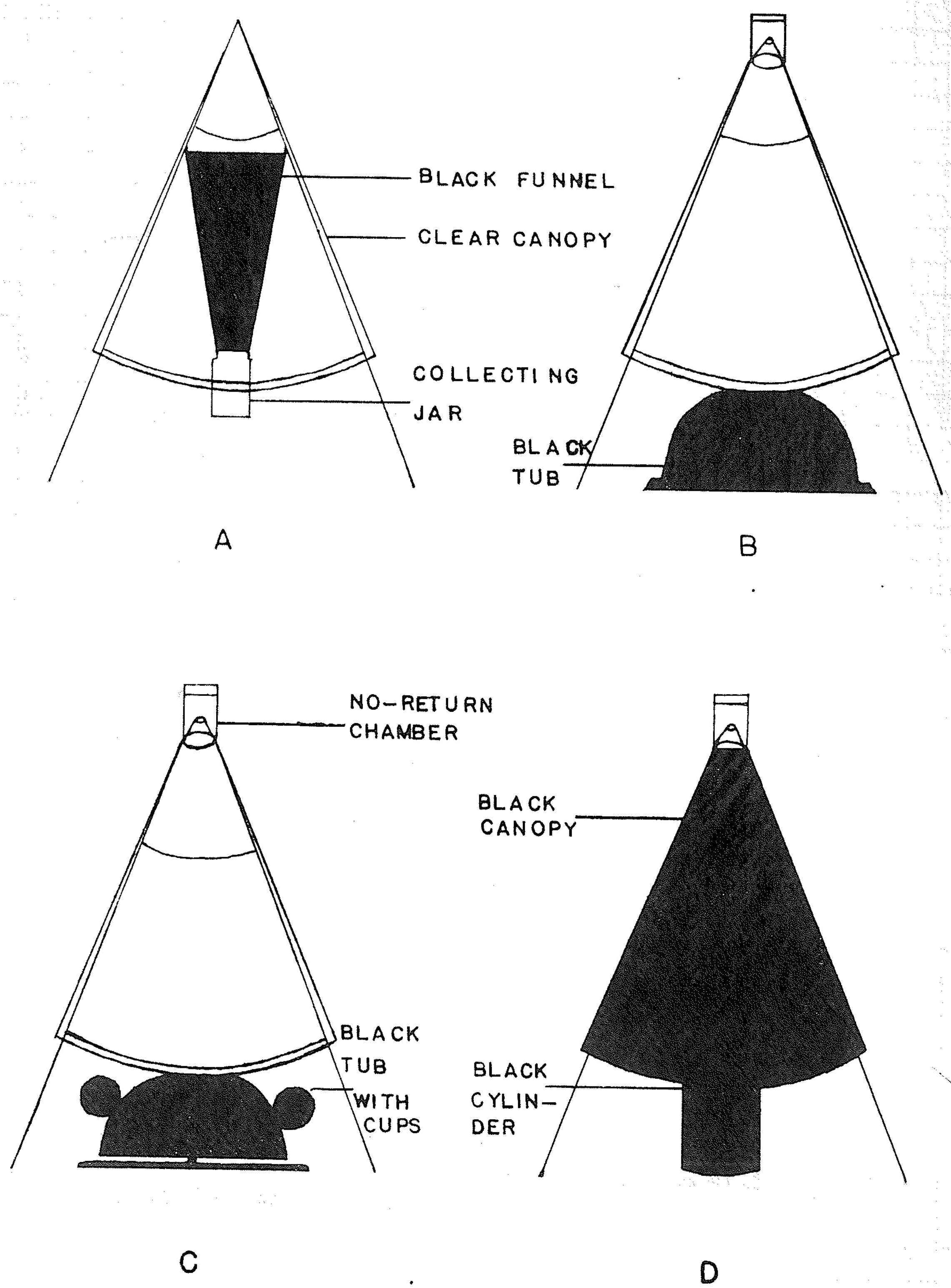
Figure 1. Modifications of the "Helio-thermal Trap"

A. The 1957 variety with a large funnel and a collecting jar underneath a clear canopy.

B. The 1958 variety with a black tub on the ground underneath the trap. The tub was raised to the same level as the one in C. A no-return chamber replaced the large black funnel. Clear canopy.

C. The 1958 variety with a black tub fitted on a central shaft and a bicycle front wheal bearing. Four cones were mounted to the sides. Clear canopy.

D. In 1959 the black tub was replaced by a black cylinder (45 x 61 cm.) suspended on a string from underneath the trap. The black cylinder could swing freely in any wind. The clear canopy was replaced by a black, opaque one.


BLACK FUNNEL
CLEAR CANOPY
COLLECTING JAR
A
BLACK TUB
B
NO-RETURN CHAMBER
BLACK TUB WITH CUPS
C
BLACK CANOPY
BLACK CYLIN-DER
D

was replaced by a no-return chamber fitted to the apex of the trap by Bracken (1960). This improved the trap considerably.

In the summer of 1959, two experiments were carried out to determine whether the black flies reacted to visual objects:

Experiment 1. Two traps had been set up about eight meters apart near Caddy Lake in the Whiteshell Forest Reserve. To start with, a black metal tub was placed upside down underneath one trap (Figure 1 B). Another black tub was placed underneath a second trap (Figure 1 C). This latter tub differed in that it was mounted on a central shaft, fitted with the front wheel bearing of a bicycle. Four cones were fastened to the side of the bucket like the cups of an anemometer. These cones were painted black on the outside and white on the inside. They were intended to catch the wind to rotate the tub, but because of a faulty bearing the tub did not actually rotate, so there was only a difference in shape and colour markings between the two tubs. Bracken (1960) had developed this rotating device but in his case it actually rotated. Both tubs were raised to the same height. On July 14, the positions of the traps were interchanged. On July 22, the simple black tub was replaced by a black cylinder (diameter 45 cm., height 60 cm.). It was suspended from underneath the trap and swayed in the wind (Figure 1 D). On July 29, a black cylinder with several vertical white stripes about 3.75 cm. wide replaced the rotating black tub. On August 4, the trap with the black and white stripes was moved into the shade of trees a few yards into the forest.

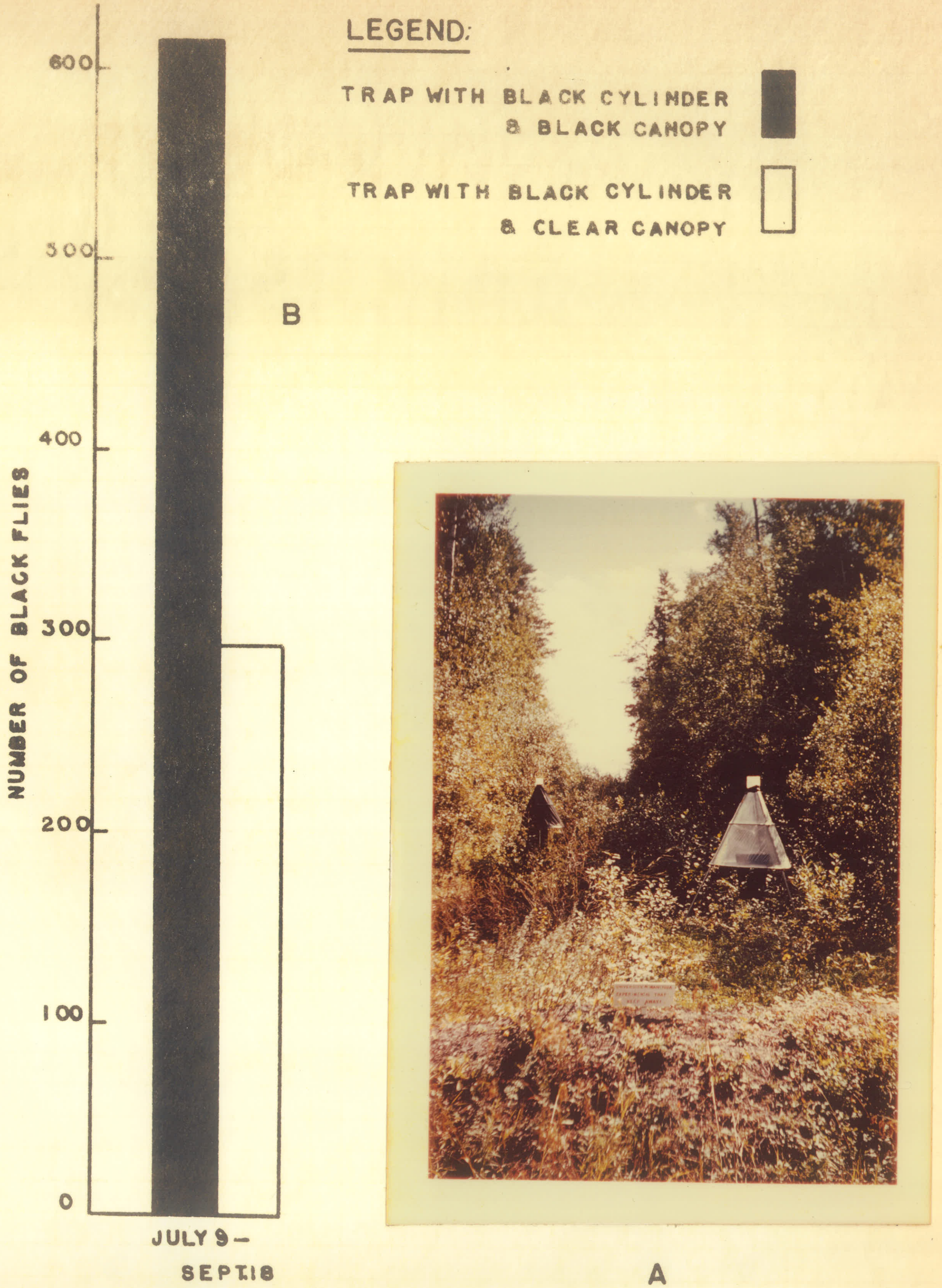
Experiment 2. Another experiment was carried out with two traps near Rennie, also in the Whiteshell Forest (Figure 2 A). On July 9, one trap was fitted with a transparent colourless canopy, the other one with an opaque, black one. A black cylinder (45 x 60 cm.) was suspended from underneath both traps. On July 15, after emptying both traps their positions were interchanged.

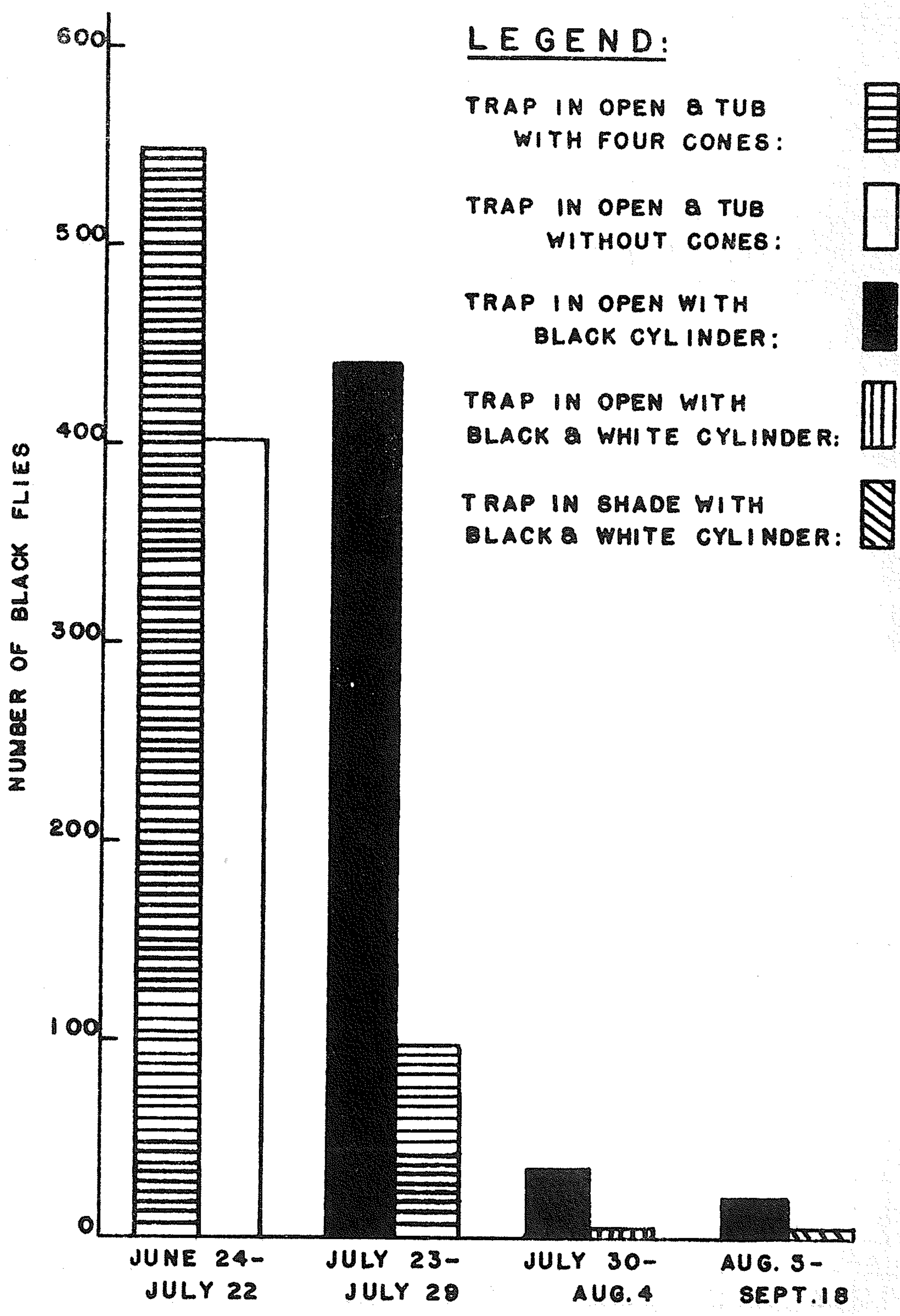
## Results and Discussion

Experiment 1. Figure 3 shows that the changes definitely affected the black fly catches. The tub with the anemometer underneath the trap caused larger captures than the tub without the cups. The large black cylinder suspended underneath the trap improved the catches even more. The trap with the solid black cylinder and situated in the open proved superior to the trap with the black and white cylinder, whether the latter was placed in the open or in the shade of the forest. This result may be interpreted in terms of the studies of silhouette contour which are described later in the thesis.

Experiment 2. The results of the second experiment are illustrated in Figure 2 B. The highest number of black flies were captured in the trap with the black canopy regardless of the location. In this respect the Simuliidae reacted similar to the Tabanidae.

Although the data do not permit a precise evaluation of the relative roles of shape, colour and movement in the attractiveness of silhouettes it appears clear that these visual stimuli were important. This agrees well with the findings of Morris and Morris (1949) that the tse-tse fly trap had to be clearly visible to be most effective. Therefore


LEGEND:
TRAP WITH BLACK CYLINDER & BLACK CANOPY
TRAP WITH BLACK CYLINDER & CLEAR CANOPY
NUMBER OF BLACK FLIES
0
100
200
300
400
500
600
JULY 9 - SEPT. 18
B
A


LEGEND:
TRAP IN OPEN & TUB WITH FOUR CONES:
TRAP IN OPEN & TUB WITHOUT CONES:
TRAP IN OPEN WITH BLACK CYLINDER:
TRAP IN OPEN WITH BLACK & WHITE CYLINDER:
TRAP IN SHADE WITH BLACK & WHITE CYLINDER:
NUMBER OF BLACK FLIES
600
500
400
300
200
100
0
JUNE 24- JULY 22
JULY 23- JULY 29
JULY 30- AUG. 4
AUG. 5- SEPT. 18

the swaying black cylinder and the black canopy were adopted as essential features of an improved black fly trap.

## B. Introduction of Cyanide to the No-return Chamber

### Materials and Methods

Specimens captured in the no-return chamber were often too mutilated to permit identification on account of moisture, spider webbing inside the chamber and large insects, particularly moths, damaging the small ones by fluttering about. Therefore sodium cyanide in "egg" form was introduced to kill captured insects instantly. Since sodium cyanide has a very strong and penetrating odour it was feared that black flies might be repelled. To test this, two traps, one with cyanide and one without, were set up side by side for 28 days and emptied nine times. After each collection the positions of the traps were interchanged to exclude position effects.

### Results and Discussion

In Table I the catches are shown. The ratio of catches for cyanide and no cyanide is very variable, but the trap with cyanide was always superior. The total for the cyanide trap was three times higher than for the non-cyanide trap. The quality of the specimens was invariably much improved.

Two explanations may be offered to explain the superiority of the poisoned trap. The first one is that some flies escaped again from the unpoisoned chamber. The second is that the odour of the cyanide attracted additional flies. The author considers the first explanation more probable but no critical evidence for or against the second hypothesis is as yet available.

TABLE I

COMPARISON OF CATCHES IN A TRAP WITH CYANIDE AND WITHOUT CYANIDE

| Collection | Trap with Cyanide | Trap without Cyanide |
|---|---|---|
| 1 | 10 | 0 |
| 2 | 156 | 27 |
| 3 | 141 | 84 |
| 4 | 3 | 2 |
| 5 | 35 | 11 |
| 6 | 7 | 6 |
| 7 | 2 | 1 |
| 8 | 75 | 4 |
| Total | 429 | 135 |

# CHAPTER III

## EFFECT OF MOVEMENT

### Review of Literature

There is no account of the reactions of black flies to movement. But this factor, along with others, was investigated by Sippel and Brown (1953) on mosquitoes. They placed a mouse into a box to study the attractiveness of smell, sight and movement by providing a transparent or opaque, perforated or tight cover. They found that smell is a stronger attractant than sight unless the sighted object moved. The movement factor was analysed by putting a living, mobile mouse into one box and an anaesthetized one into the other. They found that sight and smell were more attractive if combined than when tested individually. As mentioned previously movement attached to the tse-tse fly trap improved the catches for one species (Morris and Morris, 1949). Thorsteinson (1958) reports that Tabanidae already entered the "heliothermal trap" when it was being assembled. Bracken (1960) reports that traps equipped with a moving body were more attractive to Tabanidae than those with stationary silhouettes.

### Materials and Methods

Two experiments were conducted. In the first, eight identical traps of the type described above (Chapter 2 B) were set up in a wide circle of about 25 m. in diameter. Each of four traps were equipped with a cylinder, left swinging underneath the trap. Each of the four other traps had stationary cylinders suspended underneath. A trap with a moving cylinder always alternated with one whose cylinder was stationary. By emptying all traps twice eight replicates were obtained for each type of trap. After the first collection the traps were rotated to reduce the effects of position (Figure 4).

In a second experiment seven traps were used with the following modifications of the suspended silhouettes:

1. One black sphere, about 21 cm. in diameter, loose.
2. One similar balloon but stationary.
3. One similar balloon but weighted.
4. One black loose cylinder (27 x 48.8 cm.).
5. One black stationary cylinder (27 x 48.8 cm.).
6. One black loose plaque (54 x 48.8 cm.).
7. One black stationary plaque (54 x 48.8 cm.).

The balloons and the cylinders had about equal surface areas. Due to the action of the paint base on the rubber of the balloons the spheres began leaking air when exposed to the heat of the sun. However they shrank at about equal rates. After the third replication, they were replaced by plastic balloons of 22 cm. diameter. These plastic substitutes had a 20% larger surface area than the rubber balloons and the cylinders. However the change did not seem to effect the catches significantly. The positions of the traps were interchanged after each collection to conform to the requirements of a Latin square design.

## Results and Discussion

In experiment 1 the traps with the tethered cylinders were found significantly more effective than the traps with the loose cylinders

Figure 4. Arrangement and types of traps used to study response of black flies to movement under the trap.

(Table II). The 5% level of significance is quite low in view of the fact that the stationary trap totalled a 3.3 times higher catch than the moving trap. The cause of the low level of significance lies in the high variability of the individual ratios. This can be explained by the fact that the black flies were active mostly in the evening, particularly in the last two weeks of July 1960 when the experiments were conducted and very few thunderstorms occurred. Since generally the atmosphere in the evening is calm, the loose cylinders did not always sway in the wind when the black flies were most active. Therefore the two kinds of traps were different only when there was some wind. In the second experiment the results from experiment 1 were essentially confirmed (Table 3). Because of the high variability of the catches the original figures were transformed to percentages of the maximum catch for each of the seven individual totals. Then these percentages were transformed to degrees [percentage (p) = $\sin^2$, Hayes, Immer and Smith, (1955)] .

Traps equipped with loose and weighted spheres appeared to be more attractive in the first replication but this was not confirmed in the other replicates. The loose balloon showed only a slow swinging motion and the weighted balloon moved even less. The loose cylinder swayed more than the loose balloon, but the loose plaque swung violently and erratically in even a slow breeze. It is interesting to note that the total differences between the moving and stationary cylinders were less than the differences of the two plaques. This is in accordance with the fact that movement in general caused smaller catches. Therefore

TABLE II

COMPARISON OF CATCHES IN THE NON-MOVING TRAPS AND IN THE MOVING TRAPS

| Collection | Moving Cylinders | Non-moving Cylinders |
|---|---|---|
| 1 | 3 | 68 |
| 2 | 9 | 13 |
| 3 | 10 | 38 |
| 4 | 4 | 9 |
| 5 | 9 | 9 |
| 6 | 4 | 39 |
| 7 | 17 | 52 |
| 8 | 17 | 15 |
| Total | 73 | 243 |

TABLE III

COMPARISON OF CATCHES IN MOVING AND STATIONARY TRAPS OF DIFFERENT TYPES

| Collection | Balloons Loose | Balloons Weighted | Balloons Stationary | Cylinders Loose | Cylinders Stationary | Plaques Loose | Plaques Stationary | Total Counts |
|---|---|---|---|---|---|---|---|---|
| 1 | 51 | 52 | 27 | 26 | 23 | 3 | 21 | 203 |
| 2 | 3 | 4 | 3 | 2 | 14 | 9 | 15 | 50 |
| 3 | 6 | 6 | 3 | 2 | 6 | 7 | 6 | 36 |
| 4 | 7 | 3 | 3 | 2 | 1 | 0 | 11 | 27 |
| 5 | 2 | 4 | 5 | 0 | 3 | 1 | 3 | 18 |
| 6 | 3 | 3 | 1 | 0 | 8 | 2 | 2 | 19 |
| 7 | 2 | 11 | 5 | 5 | 7 | 1 | 5 | 36 |
| Total | 74 | 83 | 47 | 37 | 62 | 23 | 63 | 389 |

Level of significance of differences in all experiments: P 0.05

Moving vs. stationary plaque: P 0.05

Moving vs. stationary cylinder: P 0.05

Moving plaque and cylinder vs. stationary plaque and cylinder: P 0.01

the plaque showing the greatest movement caught the fewest flies. In spite of these results one is tempted to speculate that the moving silhouettes should attract black flies more from afar than stationary forms. It is a well known fact that in nature predators generally discover moving prey more readily than stationary prey. More specifically Sippel and Brown (1953) reported that moving mice are more attractive than stationary ones. If movement is attractive to black flies as it is to many other animals of prey, then the moving silhouette underneath the trap prevented the flies from entering the no-return chamber.

CHAPTER IV

# INVESTIGATIONS OF THE EFFECT OF SHAPE

## Review of Literature

It was mentioned previously that Morris and Morris (1949) found that the round sides of a cylindrical trap were better than flat sides. They also had reasons to conclude that the dimensions two feet long, two and one-half feet high and seven inches wide were more effective than these dimensions doubled. The designers of the trap related the most efficient shape and size to the body contours of the natural host animals of the tse-tse fly.

Sippel and Brown (1953) offered two cubes to caged mosquitoes of *Aedes aegypti* and observed the landing ratio on both. One cube was solidly black, the other was painted in a black and white checker board pattern thus providing increased contours. In successive tests the contours on the one cube were increased by decreasing the size of the squares. Thus the relative amount of black and white surface area was kept equal. The results showed that the solidly black cube was most attractive. Among the black and white cubes, landing ratios increased with the lengths of the contours.

The perception of shape was also studied on some non-blood sucking insects such as *Musca domestica* (Smirnow and Chuvakkina, 1958) and on bees (von Frisch, 1950). Smirnow reports that *Musca domestica* was attracted more to a sweet lure when small pieces of black paper on a white background were placed on the lure. Square pieces were more attractive than rectangular ones of the same surface area and broad rectangles more than long ones. He concludes that the black pieces simulated other flies already attracted to food which in turn induced more flies to land. von Frisch (1950) found that bees can differentiate shape on the basis of the "degree of brokenness" of the figures. Solid patterns such as a circle, a triangle or a square could not be distinguished from each other but they could be distinguished from a cross or a Y. The cross and the Y again could not be differentiated from each other by the bees.

## Materials and Methods

### A. Two dimensional objects

For the investigation of the relative attractiveness of two dimensional objects we used similar patterns as those used by von Frisch (1950) to study the perception of form by bees. Six designs were made, divided into two categories: (1) solid patterns, (triangle, circle and square) and (2) broken patterns, (Y, X and the outline of a square consisting of four bars). These patterns were made of corrugated cardboard with the smooth side facing out, painted black and smeared with tanglefoot. They were hung up about two meters apart (Figure 5) and interchanged in position after each count so that the experiment could be analysed according to a Latin square design. The individual counts for each design were very variable and included some zero values. Therefore the original data were converted by the formula $y = \sqrt{x + 1}$ and then analysed (Snedecor, 1956).

### B. Three dimensional objects

In two experiments the forms were constructed of corrugated

cardboard again, painted black and smeared with tanglefoot. In the first experiment a cube was used with a surface area of 5011.3 cm.$^2$, a rectangle (area, 5023.8 cm.$^2$) and a cylinder (area, 5027.5 cm.$^2$). With these small differences in surface area it was assumed that any difference in the catches were due to shape. To hold up the forms we used the insect trap which was stripped of canopy and no-return chamber for this purpose (Figure 6 A). The positions of the forms were interchanged after each count, twelve times in all. The three shapes were compared twice in each of the six possible arrangements in order to reduce position effects. A second experiment with three dimensional bodies was conducted. Again these were fastened into insect trap skeletons and smeared with tanglefoot (Figure 6 B). The purpose of this experiment was mainly to test for differences between vertical and horizontal cylinders. The following forms were tested.

| Form | Height | Width | Surface Area |
|---|---|---|---|
| 1. Cylinder, vertical | 49 cm. | 32 cm. | 6531.5 cm.$^2$ |
| 2. Cylinder, vertical | 49 cm. | 32 cm. | 6531.5 cm.$^2$ |
| 3. Cylinder, horizontal | 49 cm. | 32 cm. | 6531.5 cm.$^2$ |
| 4. Cylinder, vertical | 61 cm. | 30 cm. | 7159.2 cm.$^2$ |
| 5. Cylinder, horizontal | 61 cm. | 30 cm. | 7159.2 cm.$^2$ |
| 6. Rectangular box, vertical | 50 cm. | 25.9 cm. | 6515 cm.$^2$ |

The six bodies were arranged in one row and interchanged in position after each count as required by a Latin square design.

Figure 6. Arrangement and Types of Objects Used to Study Differentiation of Three Dimensional Shapes by Black Flies.

A. Three dimensional objects

B. Three dimensional objects, particularly horizontal and vertical cylinders

A

B

Results and Discussion

The results from the experiment with two dimensional objects are shown in Figure 7. It can be concluded that black flies are more attracted by solid patterns and that different patterns can only be recognized by their "degree of brokenness". In the case of von Frisch's experiments the bees recognized their own hive on the bases of the above six and two similar patterns. They were not attracted to them as the black flies were. However, it can be concluded that black flies as well as bees can distinguish between the two types of patterns. Broken outlines present a greater optomotor stimulus than solid figures. Considered in this way these observations conform to the results obtained in the study of stationary and moving silhouettes.

Table IV gives the results of the experiment with the cube, rectangle and cylinder. Again there was a large variability within the twelve replications of each shape and the data were again transformed to degrees based on percentages before being analysed as a randomized block design. The differences were not found to be significant.

Table V gives the results obtained for the third experiment on three dimensional objects. The statistical analysis of results indicated that the various shapes did not differ significantly in attractiveness. The flies landed at about equal rates on the squat cylinders whether they were horizontal or vertical. However there is a suggestion that the tall cylinders were more attractive when presented in a vertical as compared with a horizontal position although this difference did not quite reach the five per cent level of statistical significance. There

Figure 7. Black fly catches on two dimensional objects. Level of significance for the difference of all patterns = $p$ 0.05

Solid patterns vs. broken patterns = $p$ 0.01

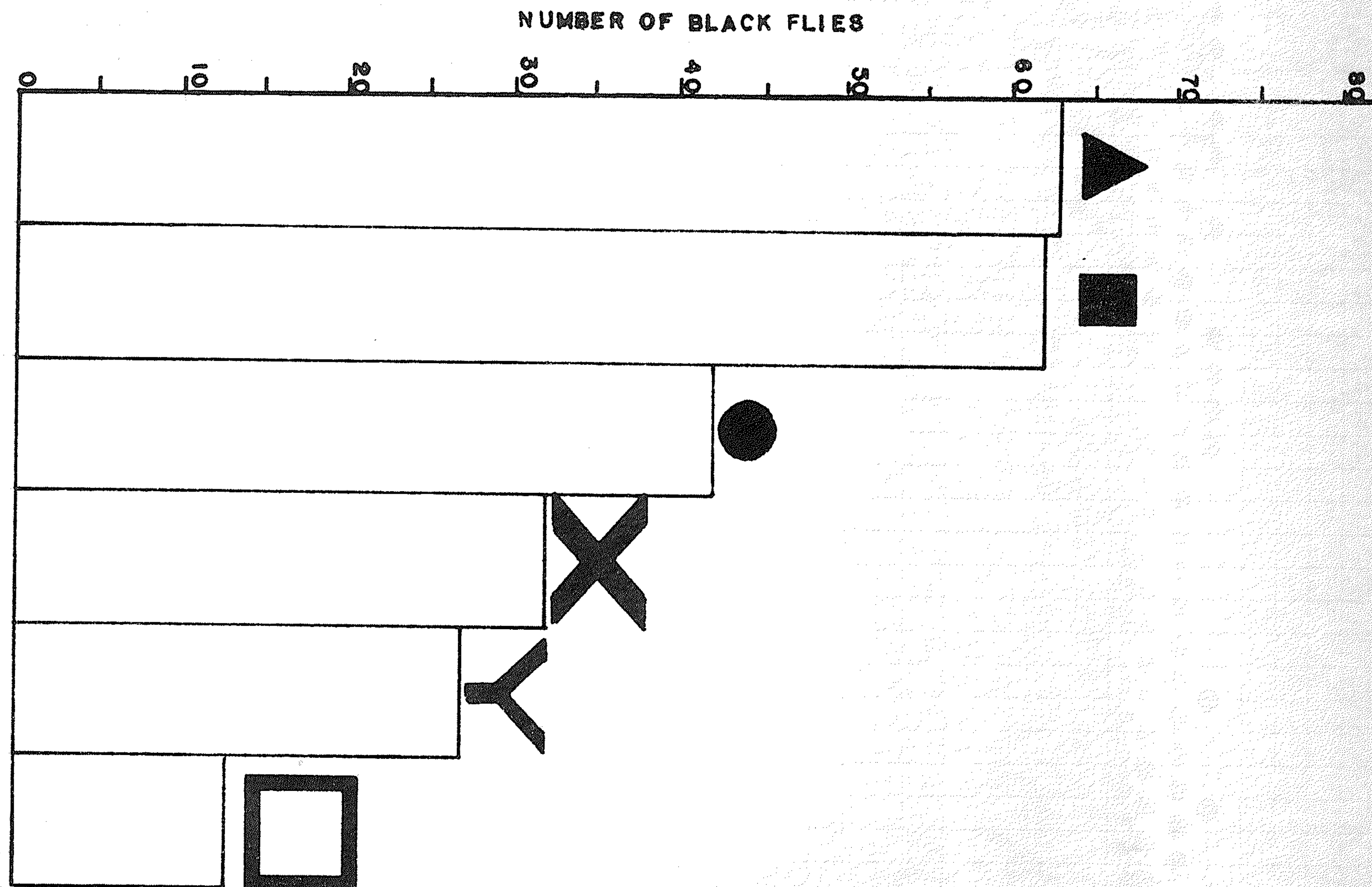

NUMBER OF BLACK FLIES
0
10
20
30
40
50
60
70
80

TABLE IV

BLACK FLY CATCHES IN TRAPS FITTED WITH THREE DIMENSIONAL SILHOUETTES OF THE SAME SURFACE AREA

| Cube<br>28.9 x 28.9 cm.<br>Surface area 5011.3 cm.$^2$ | Rectangle<br>44.6 x 22.5 cm.<br>Surface area 5023.8 cm.$^2$ | Cylinder<br>48.8 x 27 cm.<br>Surface area 5027.5 cm.$^2$ |
|---|---|---|
| 5 | 5 | 6 |
| 6 | 11 | 11 |
| 14 | 17 | 11 |
| 17 | 12 | 38 |
| 7 | 18 | 15 |
| 21 | 15 | 24 |
| 10 | 12 | 9 |
| 6 | 10 | 6 |
| 7 | 8 | 12 |
| 8 | 6 | 12 |
| 12 | 11 | 20 |
| 24 | 23 | 19 |
| 137 | 148 | 183 |

TABLE V

BLACK FLY CATCHES IN TRAPS FITTED WITH HORIZONTAL AND VERTICAL THREE DIMENSIONAL SILHOUETTES

| Tall Cylinder 61 x 30 cm. Surface area 7159.2 cm.$^2$ | | Squat Cylinder 49 x 32 cm. Surface area 6531.5 cm.$^2$ | | | Rectangle 25.9 x 25.9 x 50 cm. Surface area 6515 cm.$^2$ |
|---|---|---|---|---|---|
| Vertical | Horizontal | Vertical | Vertical | Horiz-ontal | Vertical |
| 6 | 2 | 1 | 6 | 1 | 11 |
| 11 | 3 | 6 | 5 | 1 | 6 |
| 2 | 7 | 2 | 2 | 4 | 6 |
| 6 | 3 | 3 | 5 | 4 | 3 |
| 10 | 5 | 7 | 6 | 10 | 1 |
| 5 | 4 | 2 | 3 | 3 | 2 |
| 40 | 24 | 21 | 27 | 23 | 29 |

is a fairly large difference among replications of each shape, suggesting quite large positional differences. It is believed that with more even counts a significant difference could have been obtained between vertical and horizontal cylinders. Many Tabanidae also became entangled on the objects and they favoured consistantly and markedly the three horizontal cylinders, which supports the findings of Bracken in his experiments of this summer (Personal communications). The results of the experiments with three dimensional bodies show some conformity to those with two dimensional bodies. In the latter the black flies recognized shape by the "degree of brokenness" of the contours. Shapes of similar "degrees of brokenness" could not be differentiated. The three dimensional bodies have a very similar "degree of brokenness" of silhouette outline.

# CHAPTER V

## EXPERIMENTS WITH COLOURED OBJECTS AND A MONOCHROMATIC SOURCE OF LIGHT

### Review of Literature

The exploration of colour vision in insects is difficult because insects may react differently to various intensities of colours as well as to different hues. To confuse the issue more, there is an objective physical intensity of reflected light, which may be measured in foot candles (ft.-c.) or lux and a subjective or physiological intensity which is often different for different insects because of "differential wave length absorption by the photosensitive substance and other pigments that exist in the retina" (Dethier, 1950 from Weiss, 1946). This means that if an insect prefers blue over yellow that this blue may appear of lower physiological intensity to the insect and it prefers the lower intensity rather than the colour. Thus to give proof that an insect can distinguish colours, the test colours have to appear with equal brilliance to the insect. Von Frisch was the first to show that at least one insect, the honey bee could distinguish colours. He trained the bees to come to a source of food on a blue substrate. Then he placed the blue in the form of a small square among many graded shades of grey between black and white in a checker board design. The bees ignored all grey squares and gathered at the blue one (Dethier, 1953 from von Frisch, 1914). Had they been attracted by a certain intensity, they would have confused the blue colour with one or more greys similar to it in reflectance. The bees could not distinguish between yellow orange and yellow green and blue violet and blue purple. They could not distinguish red from grey at equal reflectance. Subsequently it was shown that many insects can perceive light through the spectral range 2537 Å - 7000 Å. All these wavelengths are not equally stimulating. For most insects the regions of blue-blue-green and ultraviolet are the most effective (Weiss, 1943). Bertholf (1931, a,b,c, and 1932, reviewed by Weiss, 1943) established a spectral sensitivity curve for Apis sp. and Drosophila. He determined the intensity of a certain wavelength which was equally effective as a fixed intensity of white (Weiss, 1943). Two maxima were shown for Drosophila, ultraviolet light being the most effective.

Davies, (1951) studied the attraction of black flies to various coloured cloths. He used black as a control and compared the landing ratio $(\frac{\text{coloured cloth}}{\text{black cloth}})$ individually for each colour. He found that the attractiveness decreased from dark blue, dark brown, dark green, dark red to medium gray and white. The highest reflectance ratio corresponded to the lowest landing ratio. Colours reflecting the highest intensity between 400-660 m , i.e. in the blues were found most attractive.

## Materials and Methods

In 1959, coloured spheres of equal dimensions were hung up in one line on a string and painted with tanglefoot (Figure 8 A). Black flies landing on the balloons became entangled in the sticky substance and could thus be counted.

In 1960, coloured balloons were suspended from underneath the traps described in Chapter 2 B, replacing the cylinders (Figure 8 B).

Figure 8. A. Coloured balloons, smeared with tree tanglefoot used to compare the attractiveness of coloured objects to black flies.

B. Trap with coloured balloon to investigate the response of black flies to coloured objects.

A

B

The trap had a black canopy and a no-return chamber containing cyanide, therefore, the only difference between the traps were the coloured balloons. In 1959 it was established that an object, in that case a black cylinder or tub, did increase the efficiency of the trap. Apparently the insect was attracted to the object underneath the trap. It was frequently observed that the insects landed on this silhouette. Then the fly was attracted by the light shining through the no-return chamber above and it crawled up into this chamber. It was postulated that the more insects were attracted to alight on the coloured balloons, the more efficient would be the trap. Thus the size of the catch of a trap would provide an estimate of the response of the black flies to the various coloured balloons. Each time the traps were emptied, the balloons were interchanged in position, so that the data could be analysed according to a Latin square design. The following table shows the characteristics of the colours used in this experiment:

| Black | Blue | Green | Yellow | Orange | Red | White | |
|---|---|---|---|---|---|---|---|
| 560 | 488.5 | 543 | 577.5 | 593.8 | 612.5 | 574 | Dominant Wavelength in M |
| 19.38 | 11.7 | 66.99 | 492.5 | 313.9 | 224.6 | 835.9 | Total reflectance of all Wavelength relative to Magnesium oxide white |

Each of these seven colours was also applied to two wooden sticks (2 x 2 x 30 cm.) One set of sticks was suspended from one end into the current of the Whiteshell River. Thus they were hanging almost horizontally on the water (Figure 9 A). The other set of sticks was placed upright into the current submerged for about one-third of their lengths and supported by a submerged

A

B

board (Figure 9 B). At intervals of 3 to 13 days the deposited eggs were scraped off, air dried and weighed. At each count the positions of the coloured sticks were interchanged to conform to the requirements of a Latin Square design.

To obtain data on the spectral sensitivity of black flies a cage was used which was originally designed by Krijgsman (1930) to study responses of flies to odours (Figure 10). Two microscope lamps with white frosted 150 watt bulbs were placed one at each end of the cage. The light from each microscope lamp was directed through a trap made from plastic and glass. Monochromatic filters were fitted to the lamps. The intensity of the light was regulated by means of two rheostats. The light intensities were measured with a Weston Lightmeter (Model 756) for each rheostat setting used. Each experiment was repeated three times. The temperature at the entrance from the cage to the trap funnel remained within 1°C. the same for all filters used. Fifty to one hundred or more male and female flies were used in the experiments. Preliminary experiments showed that male and female flies reacted similarly. The flies had been hatched from pupae collected in the Whiteshell River. Identification of a sample showed that they were *Simulium vittatum*.

## Results and Discussion

Figure 11 shows the captures of black flies in four counts on the coloured balloons on August 13-14, 1959. It is quite obvious that black, blue and red were preferred in that order, while yellow and green were almost ignored.

Figure 10. Apparatus to Test Attractiveness of Light of Various Wavelengths to Black Flies

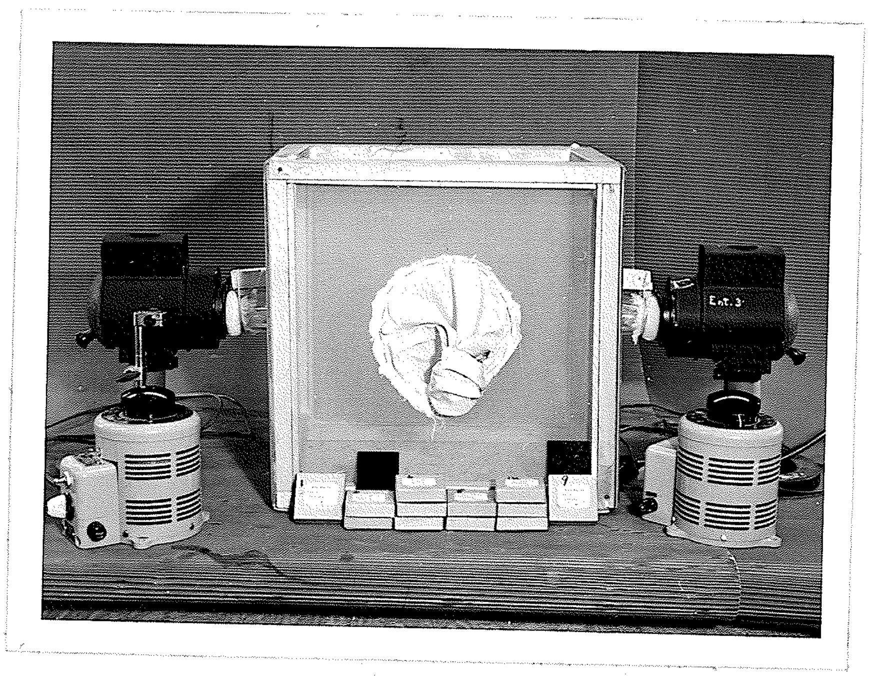
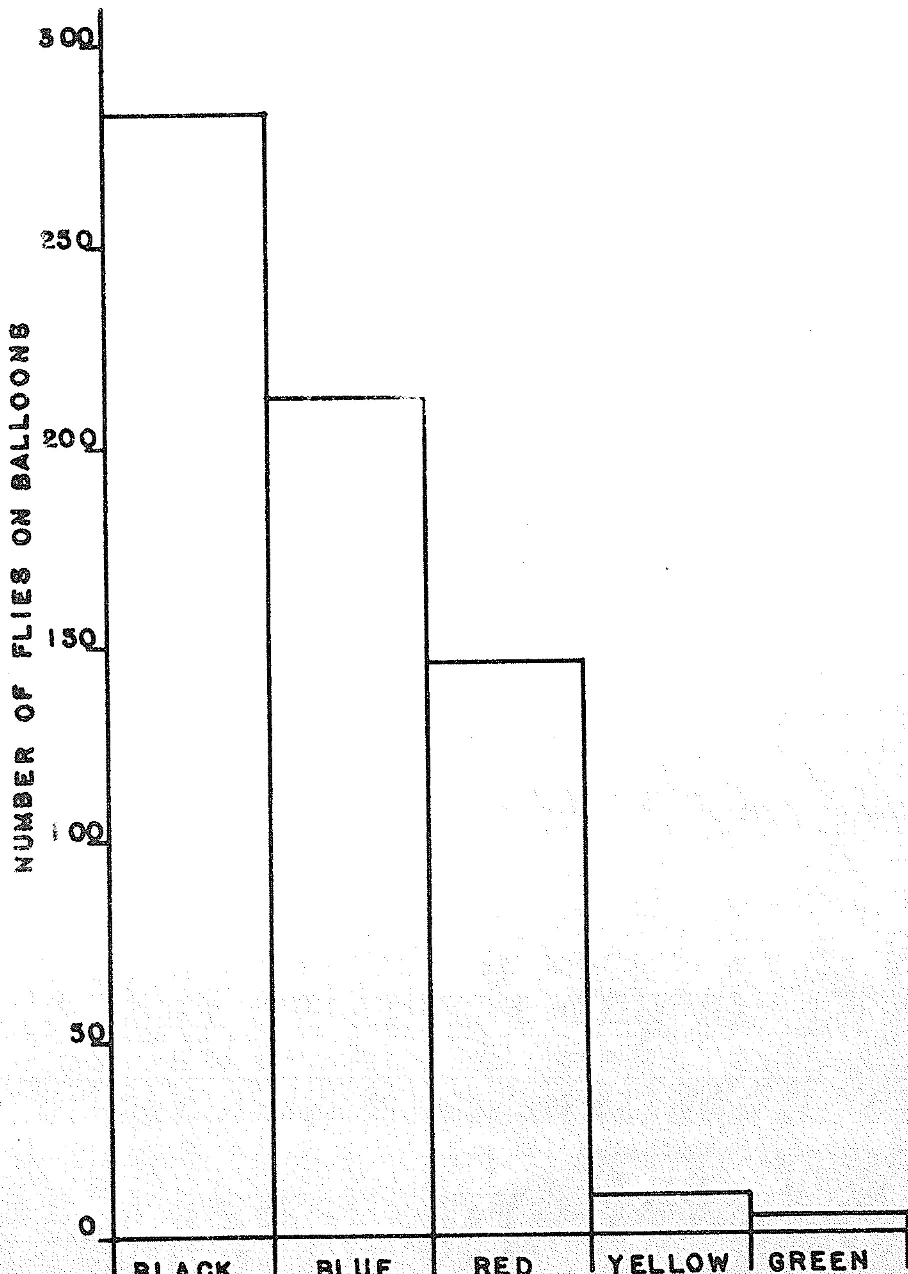

ExT. 3

Figure 11. Black Flies Captured on Coloured Balloons



NUMBER OF FLIES ON BALLOONS
300
250
200
150
100
50
0
BLACK
BLUE
RED
YELLOW
GREEN

The results of the experiment where the coloured balloons were tied underneath the traps are given in Table VI. The variability of the data does not permit drawing conclusions as to the differences in the attractiveness among the colours.

However the oviposition on coloured pieces of wood was quite good. Figure 12 illustrates the weight in milligrams of the dried egg masses oviposited on the individual pieces of wood. After six counts, white was substituted for black for the seventh count on both the vertical and suspended pieces (Table VII).

In general the black flies laid eggs on the sticks coloured yellow and green (Figure 12). It was often observed that black flies laid eggs very late in the evening, even at light intensities below the sensitivity of the light meter when it was difficult to observe the flies. It is possible that they selected the colours appearing the brightest to them because they could see them in the dim light and against the background of the dark river bed. The species involved were presumed to be *S. vittatum*, *S. decorum* and *S. venustum* because these were the species caught in the traps during the course of the experiment.

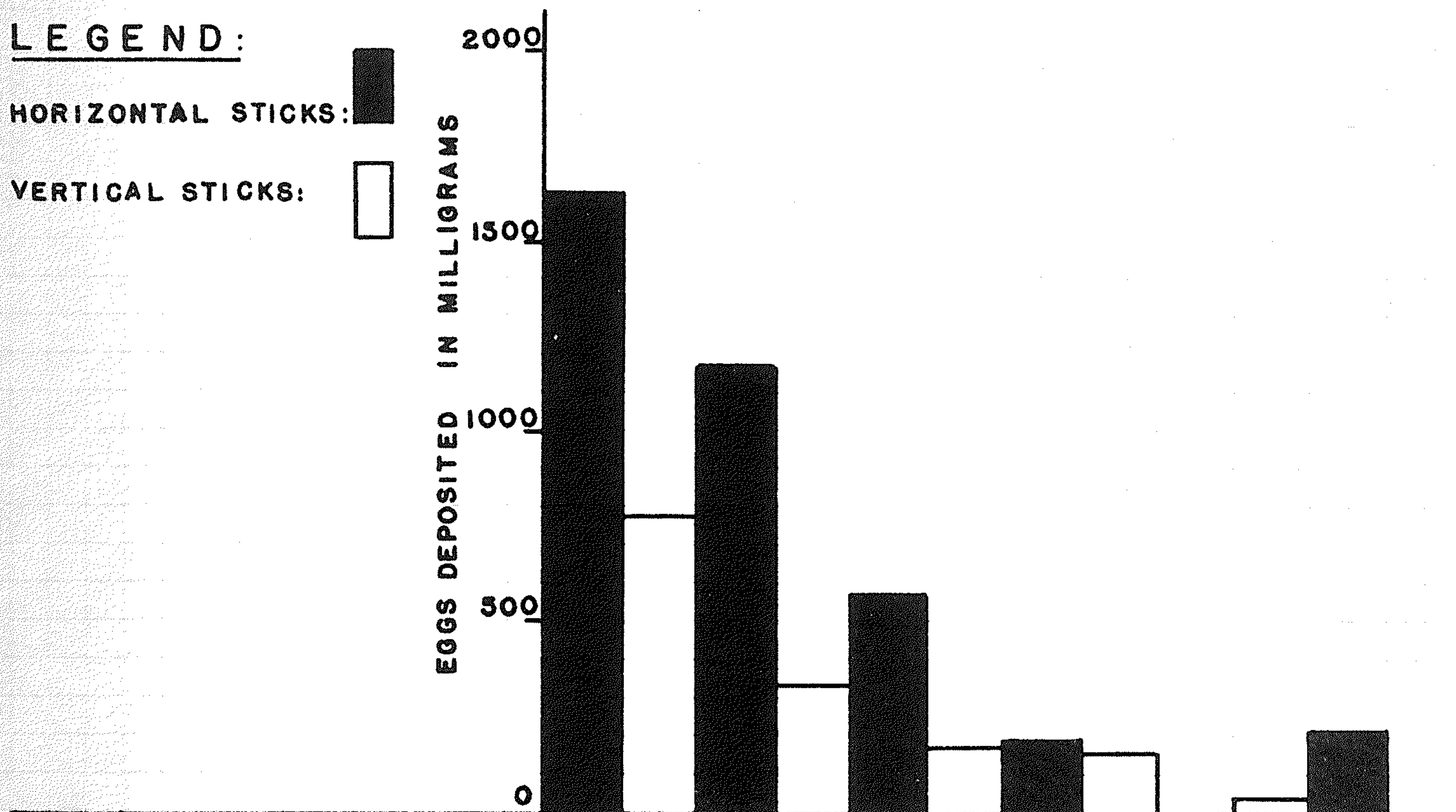
The results on the spectrosensitivity data demonstrated that black flies were most sensitive to the wavelengths 380-580 m$\mu$ (Table VIII). No great difference was found within these wavelengths. The blue region from 400-480 m$\mu$ attracted two black flies at a lower intensity (below sensitivity of the light meter) than the other colours. In the orange range 560-630 m$\mu$ and again in the region from 590-660 m$\mu$ higher intensities were required. For orange we needed 7 ft.-c. to draw the

TABLE VI

NUMBER OF BLACK FLIES IN TRAPS WITH VARIOUS COLOURED BALLOONS

| Black | Blue | Red | Orange | Green | Yellow | White |
|---|---|---|---|---|---|---|
| 7 | 4 | 3 | 7 | 8 | 0 | 0 |
| 4 | 3 | 1 | 0 | 0 | 0 | 0 |
| 4 | 8 | 3 | 4 | 3 | 1 | 2 |
| 1 | 2 | 3 | 3 | 3 | 3 | 1 |
| 0 | 2 | 2 | 0 | 2 | 0 | 2 |
| 51 | 2 | 1 | 1 | 5 | 0 | 6 |
| 1 | - | 1 | 11 | 1 | 0 | 3 |
| 68 | 21 | 14 | 26 | 22 | 4 | 14 |

Figure 12. Oviposition on Coloured Wooden Sticks




| | | | | | | |
|---|---|---|---|---|---|---|
| TOTAL REFLECTANCE OF ALL WAVE LENGTHS REL. TO MGO WHITE | 492.49 | 66.99 | 313.86 | 612.5 | 19.38 | 11.70 |
| DOMINANT WAVE LENGTH REFL. | 577.5 | 543.8 | 593.8 | 224.56 | 560.0 | 488.5 |
| APPEARANCE OF COLOUR TO MAN | YELLOW | GREEN | ORANGE | RED | BLACK | BLUE |

TABLE VII

WEIGHT OF AIR-DRIED EGGS IN MG. OVIPOSITED ON COLOURED STICKS, WHEN WHITE SUBSTITUTED BLACK

| | Blue | Red | Orange | Green | Yellow | White |
|---|---|---|---|---|---|---|
| Suspended | 47.85 | 1.2 | 0.0 | 156.55 | 83.4* | 203.1 |
| Vertical | 0.0 | 0.0 | 0.0 | 0.0 | 118.1 | 10.0 |
| Total | 47.8 | 1.2 | 0.0 | 156.55 | 201.5 | 213.1 |

* Algae were interwoven with eggs. Many of the eggs could not be separated and weighed.

TABLE VIII

INTENSITIES AT WHICH BLACK FLIES WERE ATTRACTED TO A CERTAIN WAVE LENGTH

| Filter No. and Colour | Wave Length | Foot Candles | No. of Flies in Trap |
|---|---|---|---|
| 1. Blue | 380-430 mμ | 0 | 0 |
| | | 0 | 0 |
| | | 1 | 2 |
| | | 2 | 2 |
| | | 3.5 | 7 |
| | | 6 | 5 |
| | | 10 | 9 |
| | | 15 | 15 |
| 2. Blue | 400-450 mμ | 0 | 0 |
| | | 0 | 1 |
| | | 0 | 4 |
| | | 0.5 | 2 |
| | | 2 | 6 |
| | | 4 | 6 |
| 3. Blue | 410-480 mμ | 0 | 0 |
| | | 0 | 1 |
| | | 1 | 1 |
| | | 3 | 6 |
| | | 6 | 6 |
| | | 10.5 | 3 |
| | | 16 | 18 |
| 4. Blue | 445-505 mμ | 0 | 0 |
| | | 1 | 5 |
| | | 3 | 10 |
| | | 6 | 9 |
| | | 9 | 5 |
| | | 17 | 9 |
| 5. Green | 470-530 mμ | 0 | 0 |
| | | 2 | 2 |
| | | 4 | 5 |
| | | 10 | 6 |
| | | 18 | 6 |
| | | 30 | 15 |
| | | 46 | 9 |
| 6. Green | 485-550 mμ | 0 | 0 |
| | | 0.5 | 1 |
| | | 3 | 6 |
| | | 6 | 5 |
| | | 10 | 4 |
| | | 18 | 13 |

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Continued - Table VIII

| Filter No. and Colour | Wave Length | Foot Candles | No. of Flies in Trap |
|---|---|---|---|
| 7. Green | 520-580 mμ | 0 | 0 |
| | | 1 | 3 |
| | | 3 | 1 |
| | | 6 | 5 |
| | | 10 | 5 |
| | | 16 | 6 |
| | | 26 | 13 |
| 8. Orange | 565-630 mμ | 3 | 0 |
| | | 7 | 1 |
| | | 13 | 0 |
| | | 22 | 1 |
| | | 31 | 3 |
| | | 45 | 2 |
| | | 61 | 4 |
| | | 79 | 4 |
| 9. Red | 590-660 mμ | 50 | 0 |
| | | 73 | 0 |
| | | 95 | 3 |
| | | 135 | 3 |
| | | 170 | 1 |
| | | 210 | 2 |
| | | 250 | 2 |
| 10. Red | 620-680 mμ | 100 | 0 |
| | | 130 | 1 |
| | | 170 | 2 |
| | | 220 | 0 |
| | | 270 | 1 |
| | | 320 | 1 |
| 11. Red | 640-700 mμ | 110 | 0 |
| | | 135 | 1 |
| | | 170 | 0 |
| | | 200 | 0 |
| 12. Red | 660-740 mμ | 45 | 0 |
| | | 50 | 0 |
| | | 60 | 0 |
| | | 75 | 0 |

first fly into the funnel and 95 ft.-c. for the red (590-660 m$\mu$). For the wavelengths over 640 - 700 m$\mu$ and up, intensities could not be increased enough to attract more than one insect.

It can be concluded that in the wavelength range from 380-740 m$\mu$, black flies were most attracted to light in the blue and blue-green region, i.e. 380-580 m$\mu$.

In a second series of experiments the flies were exposed to two sources of monochromatic light, one at each trap simultaneously. In each experiment the light source at one trap was kept constant in the wavelength range 380-430 m$\mu$ at 5 foot candles. The light source at the other trap was varied through various wave length bands, from 400 to 660 m$\mu$ and at different intensities. Table IX shows the results. The standard blue (380-430 m$\mu$, 5 ft.-c.) was more attractive than the longer blue wave length in the range 400-505 m$\mu$ .

An attempt was made to utilize the effectiveness of blue light to attract black flies into the no-return chamber of the trap in the field. The lids of the chambers were painted with four colours, but the lids were left somewhat transparent. Blue, red, yellow and white were compared to the control, which was left clear. In this way the flies that entered the space below the canopy were exposed to filtered light from above. It was expected that the more attractive wave lengths, as determined in the cage experiments in the laboratory, should have led more flies upward into the no-return chamber. A Latin Square design was employed. The results indicated no difference in the numbers of black flies captured.

TABLE IX

THE RELATIVE ATTRACTIVENESS OF A POINT SOURCE OF MONOCHROMATIC LIGHT TO BLACK FLIES

| No. of flies in cage | Constant colour | No. of flies attracted | Various colours | Foot candles | No. of flies attracted |
|---|---|---|---|---|---|
| 100 | Blue | 1 | Red | 240 (as | 0 |
| 100 | 380-430 mμ | 2 | 590-660 mμ | high as | 0 |
| 100 | | 2 | | possible | 0 |
| 100 | Blue | 2 | Orange | 100 | 2 |
| 100 | same | 1 | 565-630 mμ | 90 | 1 |
| 100 | | 0 | | 80 | 0 |
| 100 | | 1 | | 80 | 2 |
| 100 | | 1 | | 75 | 0 |
| 100 | | 6 | | 75 | 0 |
| 100 | | 2 | | 75 | 0 |
| 100 | | 0 | | 75 | 1 |
| 100 | | 1 | | 75 | 0 |
| 100 | | 1 | | 75 | 2 |
| 100 | | 3 | | 75 | 0 |
| 100 | | 2 | | 70 | 0 |
| 100 | | 1 | | 70 | 0 |
| 100 | | 1 | | 70 | 0 |
| 200 | | 11 | | 70 | 0 |
| 200 | | 10 | | 70 | 0 |
| 100 | Blue | 1 | Green | 45 | 1 |
| 100 | same | 0 | 520-580 mμ | 40 | 2 |
| 100 | | 2 | | 30 | 2 |
| 100 | | 1 | | 20 | 10 |
| 100 | | 1 | | 10 | 1 |
| 100 | | 2 | | 10 | 0 |
| 100 | | 3 | | 10 | 2 |
| 100 | | 0 | | 5 | 0 |
| 100 | | 1 | | 5 | 0 |
| 100 | | 4 | | 5 | 0 |
| 100 | | 2 | | 5 | 0 |
| 100 | | 3 | | 5 | 0 |
| 200 | | 8 | | 5 | 0 |
| 200 | | 5 | | 5 | 1 |
| 100 | Blue | 1 | Green | 5 | 1 |
| 100 | same | 3 | 485-500 mμ | 5 | 1 |
| 100 | | 0 | | 5 | 0 |
| 100 | | 6 | | 5 | 0 |
| 100 | | 4 | | 5 | 0 |
| 200 | | 5 | | 5 | 0 |
| 200 | | 13 | | 5 | 0 |

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Continued - TABLE IX

| No. of flies in cage | Constant colour | No. of flies attracted | Various colours | Foot candles | No. of flies attracted |
|---|---|---|---|---|---|
| 100 | Blue | 3 | Green | 5 | 3 |
| 100 | 380-430 mμ | 2 | 470-530 mμ | 5 | 1 |
| 100 | | 1 | | 5 | 0 |
| 100 | | 6 | | 5 | 0 |
| 100 | | 4 | | 5 | 3 |
| 200 | | 13 | | 5 | 2 |
| 200 | | 5 | | 5 | 3 |
| 100 | Blue | 2 | Blue | 5 | 7 |
| 100 | same | 2 | 445-505 mμ | 5 | 3 |
| 100 | | 2 | | 5 | 8 |
| 100 | | 4 | | 5 | 1 |
| 100 | | 0 | | 5 | 3 |
| 200 | | 1 | | 5 | 8 |
| 200 | | 3 | | 5 | 5 |
| 100 | Blue | 1 | Blue | 5 | 2 |
| 100 | same | 0 | 410-480 mμ | 5 | 4 |
| 100 | | 0 | | 5 | 2 |
| 100 | | 2 | | 5 | 2 |
| 100 | | 2 | | 5 | 3 |
| 200 | | 2 | | 5 | 9 |
| 200 | | 2 | | 5 | 5 |
| 100 | Blue | 2 | Blue | 5 | 4 |
| 100 | same | 2 | 400-450 mμ | 5 | 2 |
| 100 | | 1 | | 5 | 3 |
| 100 | | 0 | | 5 | 1 |
| 100 | | 2 | | 5 | 2 |
| 200 | | 2 | | 5 | 7 |
| 200 | | 5 | | 5 | 3 |

N = 100, and more than 200 as indicated.

CHAPTER VI

# DIURNAL ACTIVITY STUDY

## Review of Literature

The daily activity of black flies has been studied by Davies (1952). The study was made on *S. venustum* because this species made up about 90% of the population in Davies's experimental area. Davies differentiated four types of activities: flying, attraction, landing and biting. He found that the early morning temperature and light intensity determined the beginning of flying activity for the day. Few flies were on the wing below 275 and above 1600 foot candles, with a peak at 500 to 700 ft.-c. Activity was low below 60°F., high at 60°F. to 80°F. Wind speeds above 15 m.p.h. curtailed flying considerably, but at wind speeds below one mile per hour flying was at a peak. Changes of atmospheric pressure also influenced activity. A high rate of change of atmospheric pressure, especially when falling, coincided with high flight activity while a low rate of change coincided with little flying. According to Davies, humidities of 70 to 90% and similarly low to zero rates of evaporation, unless accompanied by low early morning temperatures, also favoured flying. The landing activity was inversely correlated with conditions that favoured flying activity. While more black flies were on the wing at temperatures of 70 to 80°F. and at rapidly changing, especially falling pressures, landing rates were low.

Another investigator of the same surname, Davies (1957) could not relate black fly activity to particular temperatures (except extremes) and humidities, but the time of day, degree of cloudiness and wind speeds were the important factors. Wolfe and Peterson (1960) chose four locations and observed 24 or 48 hour activity periods at each. They recorded the landing rate on an 18 inch square piece of blue serge cloth, the biting rate on the observer's forearm and the flying rate by the number collected in a certain number of sweeps around each observer. They took measurements every hour of atmospheric pressure, rainfall, maximum and minimum temperature, relative humidity, wind direction and velocity and degree of cloudiness. The species involved was again S. venustum. These workers found that activity started one hour before sunrise and ended one hour after sunset in the forested region. Flight activity began one hour earlier and ended one hour later in an exposed area. The biting ratio was higher in the forested area. Activity showed a bimodal, diurnal rhythm with the evening peak larger than the one in the morning. These peaks occurred at light intensities below 25 ft.-c. Flight decreased with winds over two miles per hour. A peak occurred during the day when a thunderstorm passed over the area and favoured higher activity by decreased light intensity and falling pressure. Wolfe and Peterson concluded that light intensity controlled flying more than any other meteorological factor when the relative humidity was over 50%, temperature over 45°F. and the wind speed less than two miles per hour.

## Materials and Methods

In 1959, during seven days and at two similar locations in the Whiteshell Forest Reserve, two insect traps were emptied every two hours.

The general weather picture for each two hour interval was recorded and measurements of the light intensity were taken just after the traps were emptied. Observations were made at various intervals from July 23 to September 4. The temperature alone was recorded on July 23. On the other days a hygrothermograph recorded both temperature and humidity. The catches of both traps were combined for each two hour interval. The traps were emptied in each case the previous night, so that the first morning collection represented the flight from dawn of that day. There was some possibility of continued flight on July 30th after 9 p.m. but an early morning collection of the traps after August 5th and 25th showed that only three flies had entered the traps from 9 p.m. in the evening to 7 a.m. on the next morning. On August 13th it was raining very heavily at 7 p.m. and continued till 3 a.m. on the next morning. Since there is no flight activity in heavy rain, no additional flies could have entered the trap on that evening. When the trap was emptied on July 23rd at 10.15 p.m. the light meter reading was zero and flight activity had ceased. In each case the total catch was converted to percentages of the day's maximum. This prevented seasonal variations in abundance from obscuring the meteorological effects.

## Results and Discussion

In Figure 13 A-G the percentages of black flies caught are plotted against the time of day. A morning and evening peak is apparent on some days but in general the morning peak is larger than the evening peak (Figure 13 and 14). On three days the time of maximal flight was 11 a.m., 1 and 3 p.m. respectively. This indicates that peaks occur whenever a

Figure 13. The diurnal rhythm of black fly activity plotted against the time of day, relative humidity and temperature.

A. July 23

B. July 30

C. August 5

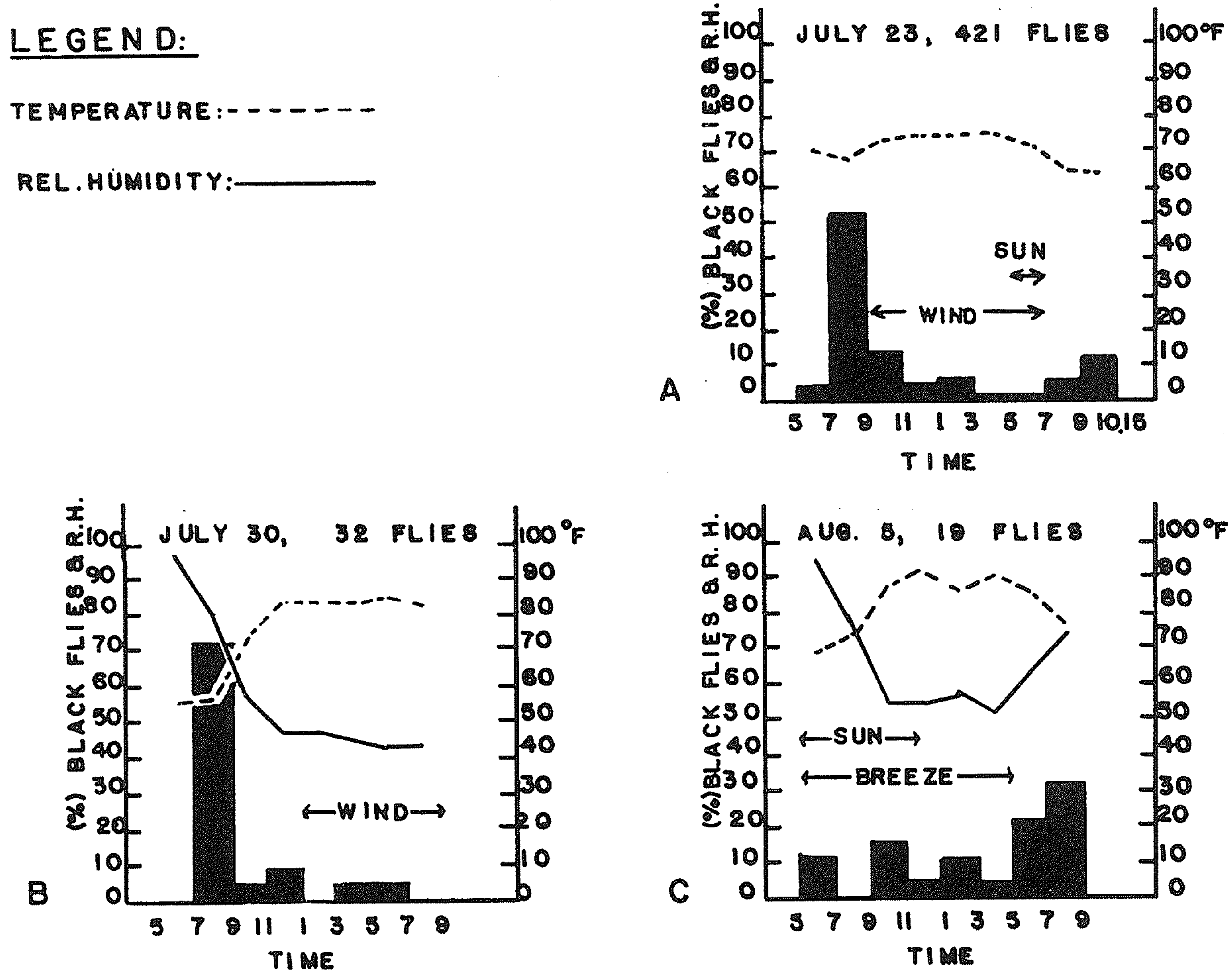

LEGEND:
TEMPERATURE:
REL. HUMIDITY:
A
JULY 23, 421 FLIES
(%) BLACK FLIES & R.H.
100 90 80 70 60 50 40 30 20 10 0
100°F 90 80 70 60 50 40 30 20 10 0
SUN
WIND
5 7 9 11 1 3 5 7 9 10.15
TIME
B
JULY 30, 32 FLIES
(%) BLACK FLIES & R.H.
100 90 80 70 60 50 40 30 20 10 0
100°F 90 80 70 60 50 40 30 20 10 0
WIND
5 7 9 11 1 3 5 7 9
TIME
C
AUG. 5, 19 FLIES
(%) BLACK FLIES & R.H.
100 90 80 70 60 50 40 30 20 10 0
100°F 90 80 70 60 50 40 30 20 10 0
SUN
BREEZE
5 7 9 11 1 3 5 7 9
TIME

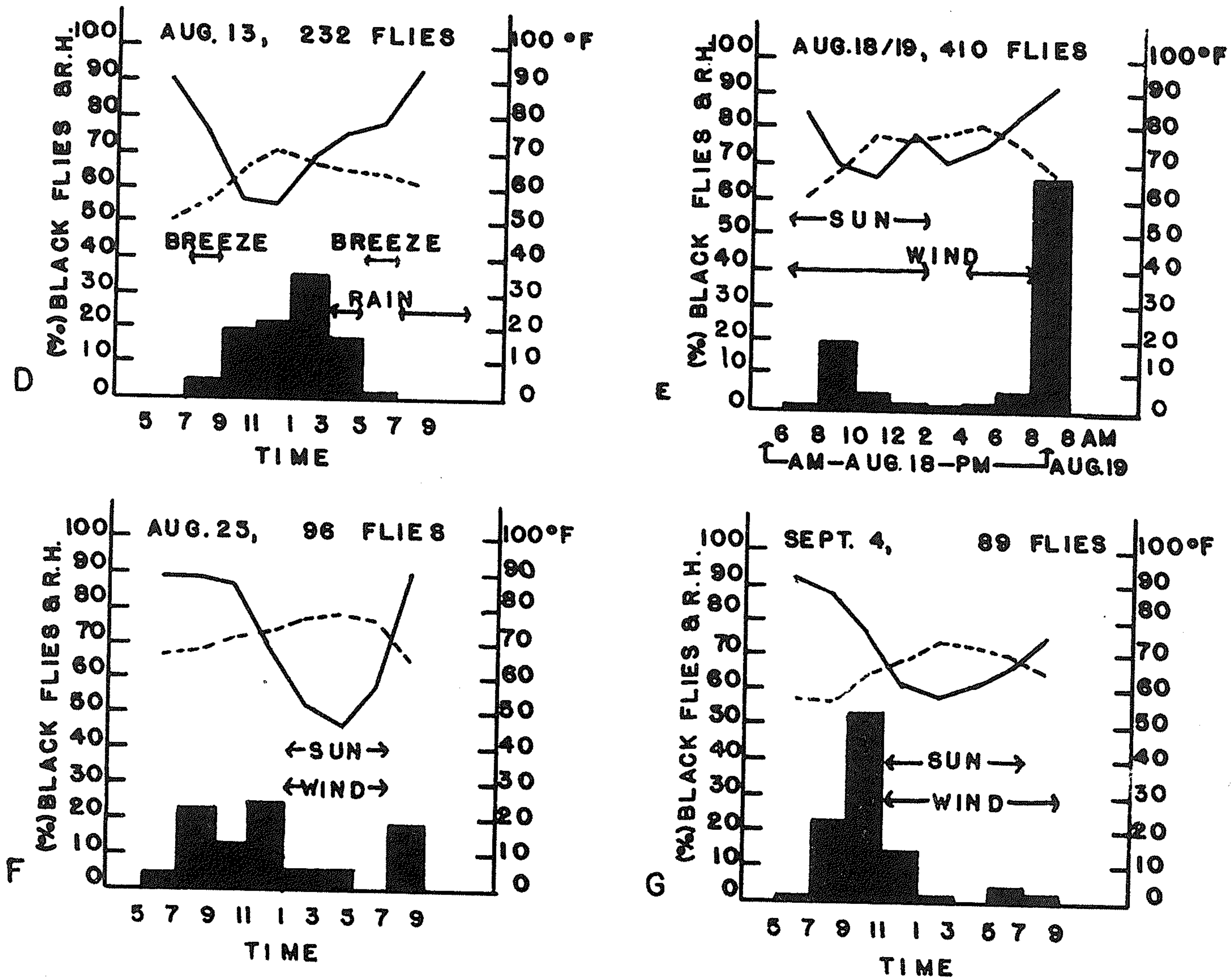
Figure 13. The diurnal rhythm of black fly activity plotted against the time of day, relative humidity and temperature. (continued)

D. August 13

E. August 18-19

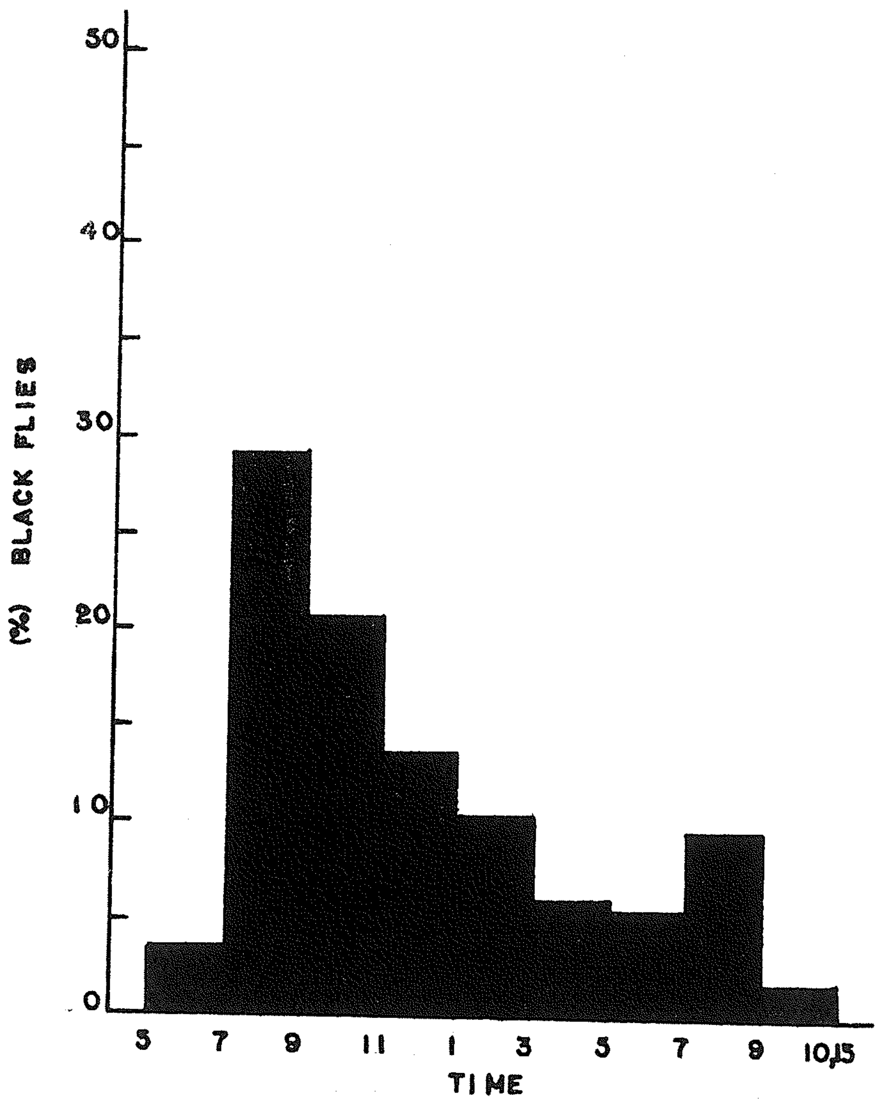
F. August 25

G. September 4



D
AUG. 13, 232 FLIES
(%) BLACK FLIES & R.H.
100 °F
BREEZE
BREEZE
RAIN
5 7 9 11 1 3 5 7 9
TIME
E
AUG. 18/19, 410 FLIES
(%) BLACK FLIES & R.H.
100 °F
SUN
WIND
6 8 10 12 2 4 6 8 8 AM
AM—AUG. 18—PM AUG. 19
F
AUG. 25, 96 FLIES
(%) BLACK FLIES & R.H.
100 °F
SUN
WIND
5 7 9 11 1 3 5 7 9
TIME
G
SEPT. 4, 89 FLIES
(%) BLACK FLIES & R.H.
100 °F
SUN
WIND
5 7 9 11 1 3 5 7 9
TIME

Figure 14. Average percent of flies caught over six days plotted against the time of day.



(%) BLACK FLIES
50
40
30
20
10
0
3
7
9
11
1
3
5
7
9
10.15
TIME

combination of meteorological factors is most favourable. Apparently flight is not governed by a fixed endogenous chronometer.

In Figure 13 A-G, the numbers of black flies are plotted against the time of day, the temperature and relative humidity. In Figure 13 B on July 30th, a large peak occurred in the period from 7 to 9 a.m. with a relative humidity of 80% but there was no flight before 7 a.m. although it was calm and clear with a light intensity of 450 ft.-c. On other occasions flight occurred at this temperature and light intensity. Therefore, the high relative humidity (97%) must have been the limiting factor. There was a small peak from 11 a.m. to 1 p.m. when some heavy rain clouds passed by.

On August 5th (Figure 13 C) the peak occurred in the evening when it was overcast and light intensities ranged between 30 and 9200 ft.-c. with very little wind in the morning and evening. Temperatures and relative humidities were similar but between 7 and 11 a.m. flight was reduced by light intensities ranging from 5500 to 10000 ft.-c. Only a light wind was observed in the morning and it was calm in the evening. Therefore, the high light intensities seemed to be the limiting factor in the morning and perhaps the wind to some extent.

On August 13th (Figure 13 D) the peak occurred from 1 to 3 p.m. with quite high catches in the four hours before and two hours after. Relative humidities and temperatures never reached levels to curtail flying seriously on this date. It was calm during the peak period and overcast with light intensities ranging up to only 700 ft.-c. The lower peak in the period 3 - 5 p.m. may be related to the light rain that occurred during this period. At 5 p.m. light intensities increased to 1700 ft.-c. and it became breezy, explaining at least in part the low catch during the early evening. From 7 to 9 p.m. again the high relative humidity plus some rain prevented a high flight activity.

On August 18th (Figure 13 E) it was windy and sunny until 2 p.m. and the light intensity remained over 2300 ft.-c. until 4 p.m. Between 4 and 6 p.m. light intensities dropped to 720 ft.-c., but it became windy again. Then between 6 and 8 p.m. flight conditions progressively improved: light intensities were about 300 ft.-c. but the wind did not calm down until after 8 p.m. allowing only a slight rise between 6-8 p.m. The very large peak capture when the traps were emptied on the morning of August 19 (Figure 13 E) probably includes flies active after 8 p.m., August 18 and before 8 a.m. August 19. During this period temperature and wind and for part of the time the humidity were all at levels that favour flight by the criteria of Davies (1952).

The high and low catches on August 25th and September 4th can be explained similarly (Figure 13 F, G).

On the average, the highest catch of the day was obtained under the following meteorological conditions: 70°F., 75% relative humidity, light intensities ranging from 654-4926 ft.-c., little or no rain and little or no wind.

These results agree quite closely with those of Davies (1952). Wolfe and Peterson (1960) on the other hand observed peaks of flight activity in the morning and a higher one in the evening at light intensities of less than 25 ft.-c., and wind speeds of less than 15 m.p.h.

Our results showed that black flies were flying most at any time during the day when conditions were favourable. On the average most flies were active between 7 and 9 a.m. (Figure 14).

Wolfe and Peterson (1960) measured the light intensity as it was reflected from a grey board instead of a white one used by Davies. The present author held the light target parallel to the sky and recorded the maximum reading. These differences in methods of measurement possibly explain the variations in the light intensities optimal for flight observed by the four authors.

In regard to the influence of light on black fly activity it may be recalled from an earlier section that egg deposition was observed at remarkably low light intensities.

CHAPTER VII

# SEASONAL ABUNDANCE AND TAXONOMIC DATA

## Materials and Methods

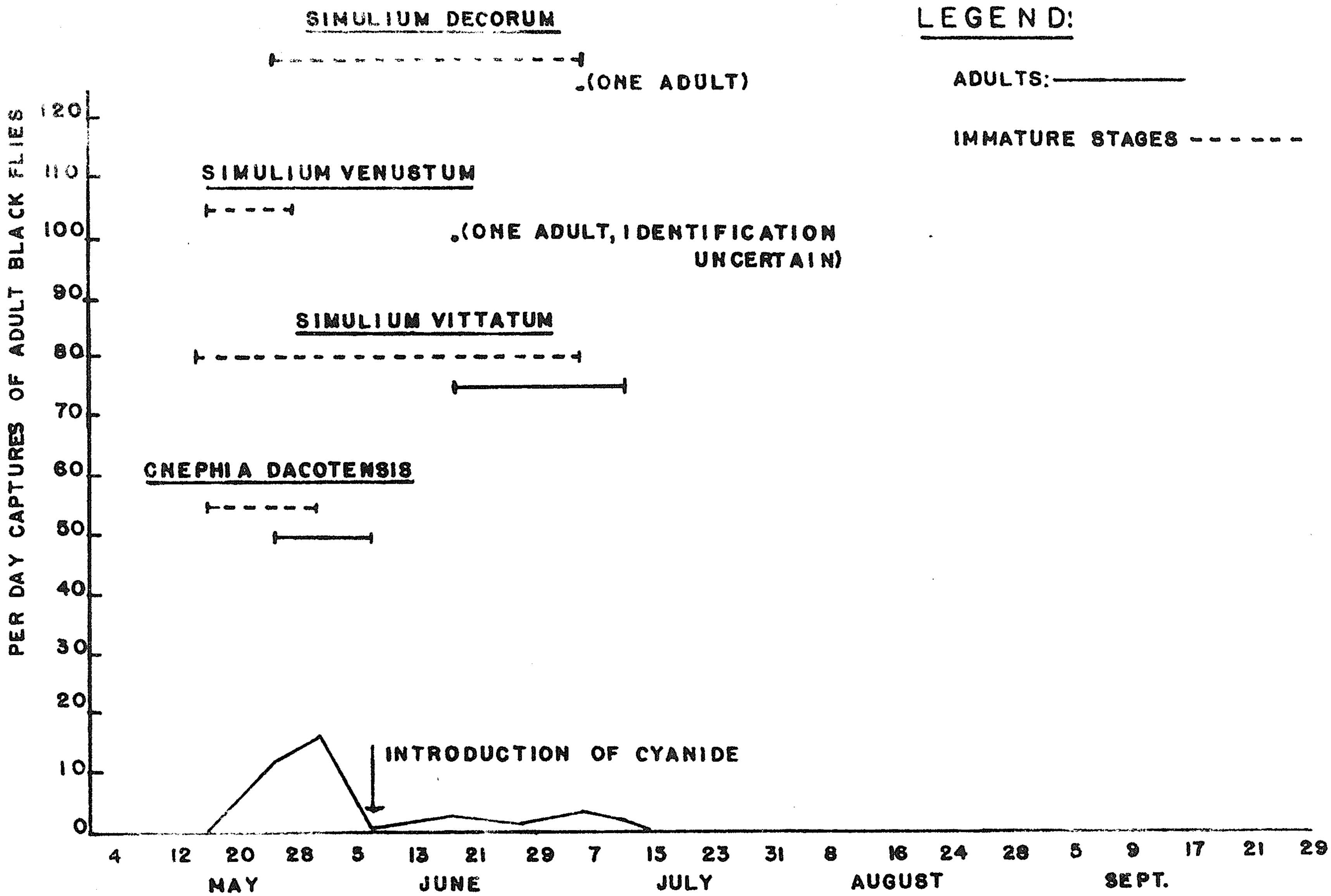
In each of three locations one "seasonal activity" trap was set up to monitor seasonal abundance. It was left unchanged with the exception that cyanide was added starting early in the season (see Chapter 2 B). One trap was located near La Salle, Manitoba on the banks of the La Salle River. At this locality the river runs over a concrete dam on the leeward side of which are many rocks and stones. The La Salle River flows at quite a low speed and carries much silt. But much of it settles out above the dam and then the water runs swiftly over the barrier. Until the early part of July a very high larval and pupal population was found at this locality. The dam appeared black with larvae. Later on water flow was much reduced and the temperature of the water had already reached 26.6°C. The larval population declined rapidly from then on.

The other two seasonal traps were located in the Whiteshell Forest Reserve along the Central Whiteshell Lake Road near White Lake. About one and one-half miles south-east of the trap site of White Lake, the Whiteshell river flowed through rapids where the larval population was high throughout the year. One trap was placed in the open on a flat treeless plot, the other in dense bush where it was shaded all day, about 35 feet from the edge of the forest.

Results and Discussion

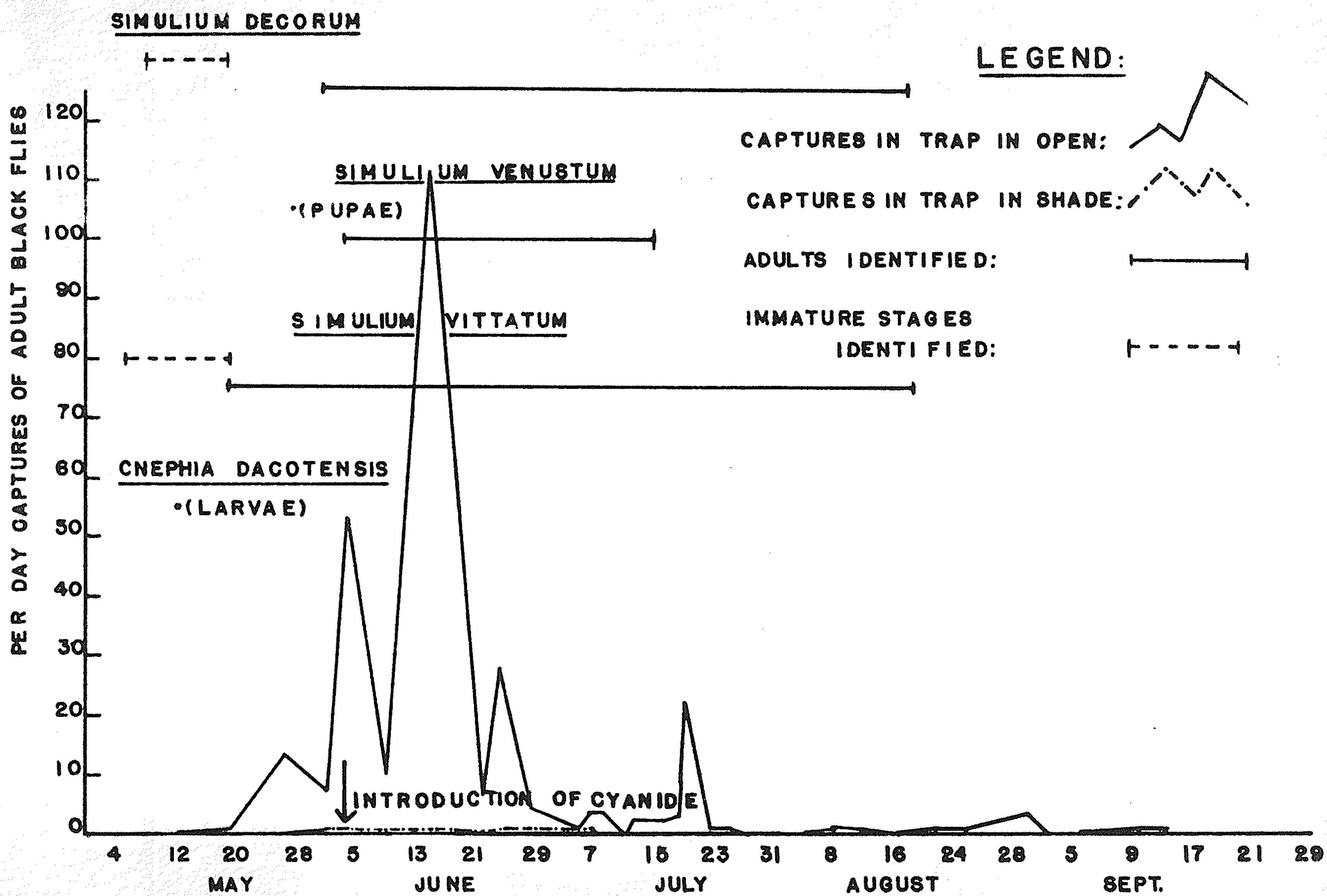
The trap catches (Figure 15) at La Salle coincide closely with the larval population at the dam. Up to May 31, no cyanide was used in the no-return chamber. The catches up to this date would likely have been three times as large if cyanide had been used (see Chapter 2 B). The peak of activity occurred on May 31. Figure 15 shows the species taken at La Salle in the trap and identifications from immature stages collected in the river. It is quite significant that only from the species *Cnephia dacotensis* were both males and females captured in the trap. This species, in contrast to all others collected at La Salle and in the Whiteshell Forest, does not feed on blood. Therefore, the behaviour of the males of blood sucking species must be different from those of non-blood sucking species. Also found were *Simulium venustum*, *S. vittatum* and *S. decorum*. The results from the seasonal activity data in the Whiteshell Forest Reserve are illustrated in Figure 16. Again no cyanide was used until June 3rd. Catches would likely have been three times as large until that date if cyanide had been used. The peak of activity occurred on June 15. Trap catches were very much reduced compared with 1959, when during July and August, 20-50 or more black flies per day were frequently collected. Even as late as on September 4, 1959, 48 flies were captured at the same locality in one trap. The design of this trap was very similar to the one used in 1960 except no cyanide was used, which would have increased the catches even more. Davies (1951) writes that black fly adults live for about three weeks. The summer 1960 was quite hot and dry (Records of the Meteorological

Figure 15. Seasonal abundance of black flies near La Salle, Manitoba, 1960. Adult and immature species taken near La Salle, Manitoba.



SIMULIUM DECORUM
(ONE ADULT)
LEGEND:
ADULTS:
IMMATURE STAGES
SIMULIUM VENUSTUM
(ONE ADULT, IDENTIFICATION UNCERTAIN)
SIMULIUM VITTATUM
CNEPHIA DACOTENSIS
INTRODUCTION OF CYANIDE
PER DAY CAPTURES OF ADULT BLACK FLIES
120
110
100
90
80
70
60
50
40
30
20
10
0
4
12
20
28
5
13
21
29
7
15
23
31
8
16
24
28
5
9
17
21
29
MAY
JUNE
JULY
AUGUST
SEPT.

Figure 16. Seasonal abundance of black flies in the Whiteshell Forest Reserve, Manitoba 1960. Adult and immature species taken in Whiteshell Forest Reserve.



SIMULIUM DECORUM
LEGEND:
CAPTURES IN TRAP IN OPEN:
CAPTURES IN TRAP IN SHADE:
ADULTS IDENTIFIED:
IMMATURE STAGES IDENTIFIED:
SIMULIUM VENUSTUM
•(PUPAE)
SIMULIUM VITTATUM
CNEPHIA DACOTENSIS
•(LARVAE)
PER DAY CAPTURES OF ADULT BLACK FLIES
120
110
100
90
80
70
60
50
40
30
20
10
0
INTRODUCTION OF CYANIDE
4
12
20
28
5
13
21
29
7
15
23
31
8
16
24
28
5
9
17
21
29
MAY
JUNE
JULY
AUGUST
SEPT.

Station at Winnipeg). Probably this shortened the life span and reduced the population of 1960 compared to 1959. The larval population was quite high again at one rapids in the Whiteshell River. However about one and one-half miles further north-west, at another rapids in the same river, not a single larva was found in the summer of 1960 compared to a high population in 1959. However in September 1960 larvae and pupae were again abundant. The writer is not able to offer an explanation for these differences. Figure 16 also illustrates that the trap placed in the shade of trees captured only very few flies, all of the species Simulium venustum. Specimens from adult and immature stages were identified as S. venustum, S. vittatum, S. decorum and Cnephia dacotensis in 1960. Cnephia dacotensis was only found in the larval stage. Adult females of S. vittatum and S. decorum were collected near Lake Francis, Manitoba, on June 13, 1960, and S. vittatum again at the same locality on June 20 and 27. Adult females of Prosimulium fuscum were collected at Bird Lake, Manitoba, on May 21, 1960.

One female adult of S. arcticum was captured near White Lake in the Whiteshell Forest Reserve on September 3, 1959, in addition to specimens of S. venustum, S. vittatum and S. decorum. Several female adults of S. hunteri were collected near La Salle, Manitoba, on June 22, 1959, in addition to S. vittatum and male and female adults of Cnephia sp.

CHAPTER VII

# ATTEMPTS TO REAR BLACK FLIES IN THE LABORATORY

## Review of Literature

As early as 1925 Puri succeeded in rearing adults of *S. aureum* Fries. and *S. erythrocephalum* (Deg.) from eggs or first instar larvae. Other species were reared by Smart (Smart, 1934 in Fredeen, 1959) and Vargas (Vargas, 1945 in Fredeen 1959). Usually the flowing water was produced by bubbling compressed air from the bottom of the container, thus creating a current and oxygenating the water. Food was provided in the form of algae, ground purina or powdered yeast and skim milk. Since 1950 Fredeen (1959) has undertaken extensive and quite successful rearings with several species including *S. venustum* Say, *S. vittatum* Zett., *S. arcticum* Mall., *Cenphia dacotensis* (D. & S.), etc. He experimented with three different techniques to circulate water: (1) compressed air; (2) a platform shaker and; (3) a rotating platform. The latter one was somewhat modified and used by the present author. Fredeen used similar food as mentioned above. Exact temperature control was not possible, so that the water temperature varied with the room temperature. The optimum temperatures seemed to be 19 to 21°C. Compressed air produced speeds up to 1.4 f.p.s., the platform shaker only 0.3 f.p.s. and the rotating platform up to 4.5 f.p.s. He used water from the river, aquarium, tap and distilled water. With *S. vittatum*, for example, he had a maximum survival of 42 adults from 100 larvae, hatched from an undetermined number of eggs. Up to 16% adults of *S. venustum* were obtained.

Partial surface disinfection of the eggs was effective with 5% KOH, improving hatchability and survival.

## Materials and Methods

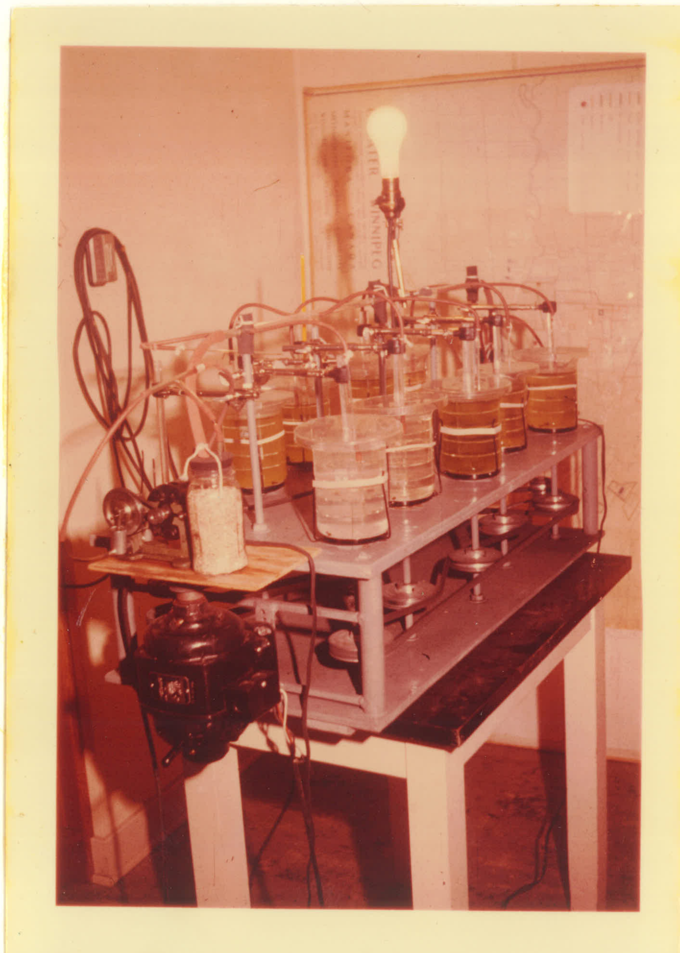
One test was carried out to determine the optimum length of treatment with KOH with respect to survival of the eggs by treating the eggs for various length of time.

A rotating platform machine, very similar to the one described by Fredeen (1959) was used for rearing larvae. At first two 1000 ml. beakers were rotated. Suspended into the water were four circular platforms made of clear plastic and fastened axially to a central shaft. As the beakers rotated the water rotated as well and flowed by the stationary, horizontal platforms. Then we built a similar machine with ten beakers lined up in two rows (Figure 17). Each row could be rotated at a different speed by means of variable sized pulleys. In addition, a variable speed motor allowed a very wide range of speed. To provide oxygen, holes were drilled through the platforms and a glass tube inserted to the bottom of the beaker. An aquarium pump bubbled air through the medium. Thus it was thought that the advantages of the rotating platform machine with large and variable speeds and that of the compressed air method, namely high oxygen tension were combined.

## Results and Discussion

An undetermined number of eggs were treated with 5% KOH. Treatment periods varied from 15-180 minutes. The eggs were then washed in distilled water. On the next day very few larvae had hatched from the

Figure 17. Apparatus used to rear black flies in the laboratory.



eggs that were treated for 15 minutes only and these were dead. A great number hatched four days later and these remained alive. From all other eggs, treated longer, very many larvae had hatched on the next day, but were dead. Only a few live ones were found four days later. Untreated eggs yielded much fewer larvae than the ones treated for 15 minutes or more. On August 28th, 750 eggs, collected a few days previously, were placed into two 1000 ml. beakers each. Dried baker's yeast was fed at rates of 0.01 to 0.3 gm. per beaker. On some days when the water was still quite cloudy from suspended yeast, the food was not replenished. The eggs had been sterilized with 5% KOH for 45 minutes and then washed. On August 31, the first larvae appeared and thereafter one beaker was supplied with air, the other not. Many larvae had hatched in both beakers but on September 11, 47 larvae could be counted in the oxygenated water, only seven in the other. On September 14th, the larvae had pupated in the water supplied with air. Nine pupae were counted in the aerated water on September 17th, but only three in the non-aerated water. Later on, more larvae pupated in both beakers. The first adults emerged on September 22. The oxygenated water yielded 15 adults, the other only six. The average temperature was about 17°C. ranging from 14°C. to 26°C.

In subsequent experiments fewer and fewer larvae hatched and only in one case, in the first week of November, eggs were reared through to pupae. Usually the larvae that had hatched died in the first or second instar. It seems that the eggs, which were collected in the fall, contained fully grown larvae ready to hatch, as indicated by the quick hatching of larvae on the first day after treatment with KOH. The deaths of these larvae soon after hatching is not explained. The eggs had been gathered from stones and vegetation in the Whiteshell River. Since S. vittatum is a prevailing species in this area in the autumn, it must be assumed that the eggs consisted largely of S. vittatum. This species overwinters in the larval stage and the eggs do not survive for long if stored at 1°C. At least one adult that was reared from eggs was induced to feed on blood from the arm of the author, when placed under a small clear plastic vial.

On January 17, several beakers were filled with sediment from two rivers in the Whiteshell Forest. About 400 eggs were isolated by washing the sand and gravel and detritus in progressively smaller sieves. However attempts to rear the larvae that had hatched failed. The larvae died in the first or second instar.

## SUMMARY

The orientation responses to visual stimuli and the diurnal activity of adult black flies were studied in the Whiteshell Forest Reserve in 1959 and 1960. The seasonal activity of Simuliids was investigated in the Whiteshell Forest Reserve and near La Salle in southeastern Manitoba in 1960.

A trap originally designed for the capture of Tabanidae (Thorsteinson, 1958) and improved by Bracken (1960) was further improved and used for the capture of black flies. The most efficient trap used in 1959 featured a black canopy instead of a clear one and a black cylinder suspended underneath the canopy. The trap used in 1960 contained sodium cyanide in "egg" form in the no-return chamber. This increased both the number of black fly captures as well as the quality of the specimens for identification purposes.

The perception of form by black flies was studied with two and three dimensional objects. These were painted black and smeared with tanglefoot. The numbers of black flies captured on the various forms gave evidence of the ability of black flies to differentiate shape. Six designs of two dimensional objects were made, divided into two categories: (1) "Solid" contours (circle, square and triangle) and; (2) broken contours (X, Y, and the outline of a quadrate consisting of four bars). It was found that the black flies were more attracted to objects with relatively unbroken contours than to those with broken outlines. This implies that black flies can visually discriminate

between these two classes of shapes. The Simuliids could not distinguish among objects of approximately equal "degree of brokenness" of contour. For example, circles, squares and triangles were equally attractive. Similarly the forms X, Y and the outline of a square all caught approximately the same number of flies. Three dimensional objects such as a horizontal and a vertical cylinder, a rectangular body and a cube did not attract significantly different numbers of black flies. These bodies are thought to have contours of similar "degrees of brokenness". When a moving body and a non-moving body were suspended underneath the canopy of the modified "helio-thermal" trap and compared, it was found that movement underneath the trap decreased the number of flies captured. It was thought that movement and a body with a large "degree of brokenness" both provide an increased optomotor stimulus. It seems that increased optomotor stimulus is inversely correlated to attraction. Spheres were painted blue, black, red, yellow and green and smeared with tanglefoot. The black flies were attracted to the black blue and red spheres very significantly more than to the yellow and green spheres. It was observed that black flies laid significantly more eggs on yellow and green coloured sticks, while avoiding almost entirely the black and blue ones. The diurnal activity study showed that black flies did not fly when the sky was clear, except in the morning or evening. The greatest number were on the wing when it was calm or nearly so, cloudy with temperatures at about 70°F., and 75% relative humidities. On the average, the greatest flight activity occurred between 7 and 9 in the morning.

The seasonal activity of black flies in 1960 reached a peak on

June 15 in the Whiteshell Forest Reserve and as early as on May 31 near La Salle. The abundance of black fly adults in the Whiteshell Forest Reserve in the latter part of the summer 1960 was very much reduced from 1959 when black fly adults occurred in large numbers until the early part of September. Cnephia dacotensis, a non-blood sucking species was found most abundant near La Salle. Simulium decorum, S. vittatum and S. venustum were also found near La Salle. In the Whiteshell Forest Reserve the same species were collected, but only a few larvae of Cnephia dacotensis. In addition several specimens of Simulium hunteri were captured in the Whiteshell Forest in 1959.

Attempts were made to rear black flies from eggs to adults in the laboratory. We were able to rear several adults only once in October, 1959. Subsequent trials failed. The larvae died in the first and second instar and the hatching percentage became very low later in the winter. It is assumed that the eggs were from the species S. vittatum. Eggs from this species cannot be kept viable over the winter when kept at 1°C. because in nature the larvae hatch in the autumn.

LITERATURE CITED

Bracken, G. K., 1960. Studies on the Host Orientation and Feeding Behaviour of Some Hematophagous Flies with Special Reference to Tabanidae and Stomoxys calcitrans (Linn.). M.Sc. Thesis, University of Manitoba, Winnipeg, Manitoba.

Bertholf, L. M. 1931 a, reviewed by Weiss, H. B., 1943. Colour Perception in Insects. J. Econ. Entom., 36: p. 6.

_______, 1931 b, reviewed by Weiss, H. B., 1943. Colour Perception in Insects. Journ. Econ. Entom., 36: p. 6.

_______, 1932, reviewed by Weiss, H. B., 1943. Colour Perception in Insects. Journ. Econ. Entom., 36: p. 6.

Cameron, A. E. 1918, in Davies, D. M. and B. V. Peterson, 1956. Observations on the Mating, Feeding, Ovarian Development and Oviposition of Adult Black flies (Simuliidae, Diptera). Can. J. Zool., 34: p. 622.

Davies, D. M., 1951. Some Observations of the Number of Black Flies Landing on Coloured Cloths. Can. J. Zool. 29: 65-70.

_______, 1952. The Population and Activity of Adult Female Black Flies in the Vicinity of a Stream in Algonquin Park, Ontario. Can. J. Zool., 30: 287-321.

Davies, D. M. and B. V. Peterson, 1956. Observations on the Mating, Feeding, Ovarian Development and Oviposition of Adult Black Flies (Simuliidae, Diptera). Can. J. Zool. 34: 615-655.

Davies, L. A., 1957. A Study of the Black Fly S. ornatum. Mg. (Dipt.) with Particular Reference to its Activity on Grazing Cattle. Bul. Ent. Res. 48: 407-424.

Edwards, 1921, in Davies, D. M. and B. V. Peterson, 1956. Observations on the Mating, Feeding, Ovarian Development and Oviposition of Adults Black Flies, (Simuliidae, Diptera). Can. J. Zool., 34: p. 624.

Fredeen, F. J. H., 1959. Rearing Black Flies in the Laboratory (Diptera, Simuliidae). Can. Ent. 91: 73-83.

_______, 1956. Black Flies, (Simuliidae, Diptera) of the Agricultural Areas of Manitoba, Saskatchewan and Alberta. Proceedings Tenth International Congress of Entom. 3: 819-834.

Von Frisch, K., 1950. Bees, their Vision, Chemical Senses and Language. Cornell University Press, Ithaca, N. Y. 1950.

Von Frisch, K., 1914 in Dethier, V. G., 1943. Insect Physiology ed. by K. D. Roeder.

Hayes, R. K., Immer, D. D. and Smith, D. C., 1955. Methods of Plant Breeding, Second Edition, McGraw Hill Book Company, Inc., New York, London, Toronto.

Hocking, B., 1960. Northern Biting Flies. Annual Rev. Entom., 5: 135-152.

Krijgsman, B. J., 1930. Reizphysiologische Untersuchungen an Blutsaugenden Arthropoden im Zusammenhang mit ihrer Nahrungswahl. 1. Teil Stomoxys calcitrans. Aus dem Zool. Staatsinstitut zu Buitenzorg, Java.

Morris, K. R. S. and Morris, M. G., 1949. The use of Traps Against Tse-tse in West Africa. Bul. Ent. Res., 39: 491-528.

Nicholson, H. P. and Mickel, C. E., 1950. The Black Flies of Minnesota (Simuliidae) University of Minnesota, Agric. Exp. Station, Technical Bulletin 192.

Puri, I. M., 1925 in Fredeen, F. J. H., 1959. Rearing Black Flies in the Laboratory (Simuliidae, Diptera), Can. Ent. 91 p. 73.

Rubtzow, J. A., 1939. Factors of Outbreaks of the Black Flies. (In Russian, 1939). Rev. Appl. Entom., 34: 42-44, 1947.

Sippel, W. C. and A. W. Brown, 1953. Studies of the Responses of the Female Aedes Mosquito. Bul. Entom. Res., 43: 567-574.

Smart, J., 1934 in F. J. H. Fredeen, 1959. Rearing Black Flies in the Laboratory (Simuliidae, Diptera), Can. Ent., 91: p. 73.

________, 1945. The Classification of the Simuliidae (Diptera). Trans. Roy. Entomol. Soc. London, 95: 463-532.

Smirnow, E. S. and Chuvakkina, Z. F., 1958. Visual Discrimination of Number, Size and Shape in Musca domestica. No. 29509. Biol. Abstracts, September 1958.

Snedecor, G. W., 1956. Statistical Methods, Fifth Edition. The Iowa State College Press, Ames, Iowa.

Thorsteinson, A. J., 1958. The Orientation of Horse Flies and Deer Flies (Tabanidae, Diptera), Ent. exp. and appl. I: 191-196.

Twinn, C. R., 1936. The Black Flies of Eastern Canada. Can. J. Res., D. 14: 97-150.

Vargas, L., 1945, in Fredeen, F. J. H., 1959. Rearing Black Flies in the Laboratory, Simuliidae, Diptera. Can. Ent. 91, p. 73.

Williams, C. B., C. A. French and M. M. Hosni, 1955. A Second Experiment on Testing the Relative Efficiency of Insect Traps. Bul. Ent. Res. 46: 193-204.

Williams, C. B. and L. Davies, 1957. Ultraviolet Traps for Female Black Flies, Nature, 179: 924-925.

Wolfe, L. S. and D. G. Peterson, 1960. Diurnal Behaviour and Biting Habits of Black Flies (Diptera, Simuliidae) in the Forests of Quebec. Can. J. Zool. 38: 489-497.