INVESTIGATIONS OF THE ORIENTATION BEHAVIOUR OF HORSE FLIES (TABANIDAE, DIPTERA) IN RELATION TO VISUAL PERCEPTION AND CHEMICAL CONTROL

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by
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ABSTRACT

by

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INVESTIGATIONS OF THE ORIENTATION BEHAVIOUR OF HORSE FLIES (TABANIDAE, DIPTERA) IN RELATION TO VISUAL PERCEPTION AND CHEMICAL CONTROL

The objective was to study the biology of horse flies, at Beaver Creek and Whitemouth Lake, with special emphasis on visual perception and orientation behaviour of flying horse flies through the experimental use of the modifications of the Manitoba Horse Fly Trap.

It was demonstrated that the behaviour of the horse fly was influenced by the wave lengths in the red region of the visible spectrum.

It was confirmed that highlights (reflection of the solar image) are significant in the attraction of horse flies to dark objects.

Continuous recordings of environmental factors on the density of flying horse fly populations were interpreted in terms of recordings of temperature, wind speed, sunshine, relative humidity and barometric pressure, and in terms of taxonomic analysis of the tabanid species captured.

Results of economic value were also obtained through the uses of the Manitoba Horse Fly Trap in conjunction with a new highly lethal insecticide without hazards to domestic livestock.

ACKNOWLEDGMENTS

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TABLE OF CONTENTS

CHAPTER PAGE

CHAPTER PAGE

LIST OF TABLES

LIST OF FIGURES

FIGURE PAGE

CHAPTER I

INTRODUCTION

In North America, some 335 species of tabanids have been identified. The tabanids, commonly known as "horse flies", and "deer flies", belong to the family Tabanidae, of the suborder Brachycera, order Diptera. Representatives of this family are found generally throughout the whole continent, but the highest populations are found in forested areas where permanent bogs, swamps, and lakes exist, since a wet habitat is preferred by the larvae of most species.

Cattle on farmland adjacent to swamp land where a high population of tabanids persist, receive a severe setback in milk production, and lose weight during the horse fly season. The female horse flies which apparently require a blood meal for ovary development, raise havoc with the cattle to such an extent, that often the cattle do not feed all day, but remain either in the barn or near a smudge. The female horse flies and deer flies do not restrict themselves to cattle, deer, and moose, but feed also on humans.

Many of our beautiful lakes, located in forested areas, attract thousands of people each summer and many of these people find the annoyance of this pest most unbearable.

Horse flies are attracted to mammals, particularly cattle and moose, as well as to various objects in the field. This orientation has been observed by earlier authors, but apparently has not been investigated systematically. Horse flies do not lend themselves to experimental study of orientation behaviour in the laboratory. Observation in nature is inconvenienced by the relatively rapid flight of the horse flies (Hocking (1953)), and the fact that the observer is himself a significant component in the perceptual field and directly influences orientation of these insects.

A device known as the Manitoba Horse Fly Trap for successfully trapping tabanids in the field, was developed by Thorsteinson (1958), and was later modified by Thorsteinson, Bracken, and Hanec (1964). The development of this trap was motivated initially by the need to control tabanids, in spite of a lack of safe and effective insecticides. This objective was realized only through a study of orientation behaviour in the field. In the course of development of this trap, the attractant principle was found to be overwhelmingly visual. This trap incorporates a silhouette which appears to function as a decoy, and it was proved useful for studying various aspects of the orientation of horse flies in their natural habitat in a way that minimizes the intrusive influence of the observer.

Since only the hematophagous sex (female) is attracted to the trap, the behaviour involved appears to be teleologically related to host seeking activity.

By providing a visual silhouette, and altering some physical properties of the trap, it was possible to study the influence of various insecticides on tabanids. In conjunction with insecticidal study for control of tabanids, the horse fly trap became very useful in the study of the correlation of flight activity with meteorological conditions. This trap is also used in the study of behaviour of Stomoxys.

The work in this thesis is divided into four sections. The first section deals with insecticidal work on horse flies and deer flies. The second section deals with the orientation and behaviour of tabanids to various shapes. The third section deals with the flight activity of tabanids in relation to climatic conditions. The fourth section is devoted to behavioural studies of stable flies, Stomoxys calcitrans L.

This thesis is based chiefly on field data obtained from investigation carried out during the summers of 1963 and 1964. In 1963, experiments were conducted at Beaver Creek, located on the west shore of Lake Winnipeg, 120 miles north of Winnipeg. This area, which is quite heavily forested, has permanent swamps, thus supporting a large population of tabanids. In 1964, the experiments were conducted at Whitemouth Lake, located between the Sandilands Forest Reserve and North West Angle Forest Reserve, some 100 miles south east of Winnipeg. This area consists of many sandy ridges which are bordered by permanent swamps, hence also supporting a large population of tabanids. The presence of cattle in this area permitted the study of the influence of practical horse fly traps placed near the animals.

The thesis is divided into chapters, each dealing with a single topic or topics, best considered together. Literature and the methods of investigation pertinent to the subject matter, are given at the beginning of each chapter. Discussion of results is also included in each chapter.

CHAPTER II

CONTROL OF TABANIDAE THROUGH THE USE OF INSECTICIDES

Literature Review

Dense population of tabanids occur in localities adjacent to permanent swamps, bogs, and forests. Cattle farmers living on these submarginal lands are exposed to excessive harassment to their cattle and themselves during the horse fly season. Water lovers at the many lakes find themselves constantly waving their arms wildly about, frantically trying to scare the tabanids away. Brown and Morris (1949) conducted laboratory and field tests of lindane, D.D.T., and dieldrin as adulticides for Canadian forest species of Tabanidae. Aerial application of .5 pounds of lindane per acre temporarily eliminated tabanids in open but not in dense forests. D.D.T. and dieldrin, produced unsatisfactory reduction. Howell, Eddy and Cuff (1949) studied the effect of aerial sprays on horse fly populations. They claim that through the use of methoxychlor, D.D.Y. toxaphene, and chlordane, no appreciable effect on horse fly population could be demonstrated.

Morris and Morris (1949) have demonstrated that small groups of traps, well sited in feeding grounds, bring about considerable reduction in the numbers of active, hungry tsetse flies in contact with their hosts although hardly affecting the main fly community.

The purpose of this investigation was to select a safe and effective insecticide which has a quick lethal knock-down, and would remain lethal throughout the horse fly season without being replenished.

Furthermore, this investigation necessitated the modification of the Manitoba Horse Fly Trap to be used with the insecticide. This was necessary to minimize personal attention and costs, particularly if many traps were set up for control purposes on cattle farms and around public beaches. The Manitoba Horse Fly Trap utilized a no-return chamber which had to be emptied twice daily at the height of the horse fly season. The purpose in this experiment was to modify the trap so that the trap could be emptied perhaps only once or twice throughout the entire horse fly season.

Modification of the Manitoba Horse Fly Trap to be used in conjunction with an insecticide.

Methods and materials. The Manitoba Horse Fly Trap was used in each experiment, but the no-return chamber was removed, and the apical end of the canopy was sealed with transparent plastic. The canopy used on traps in this and subsequent experiments was made of durable clear vinyl plastic.

In the first experiment carried out at Beaver Creek, each trap was fitted with a drop sheet of clear polyethylene. The drop sheet, used as a holding vessel, was fitted on the ground beneath the trap, and tied securely to the legs of the trap. (figure 1). The silhouette, a glossy black sphere, was treated with an insecticide on its upper surface.

In the second experiment, also carried out at Beaver Creek, the same trap design was used as in the former experiment, except that the insecticide was applied to the interior surface of the apical end of the canopy, and a glossy black horizontal cylinder was substituted for the sphere. The conical area treated extended from the apex down about seven inches.

In the third experiment, also at Beaver Creek, the drop sheet was removed, and the glossy black sphere was substitued with a glossy black hemisphere with the diametric plane open and facing up. This served as a silhouette and as a holding receptacle for the dead flies.

In the final experiment of this series carried out at Beaver Creek, the hemisphere was replaced by a glossy black sphere and funnel. The funnel measured twenty inches in diameter for the larger opening, three inches in diameter for the smaller opening, and fifteen inches in height. The funnel, painted glossy black, was attached to the upper surface of the sphere, which consisted of two hemispheres clamped together. Hence the funnel prevented the escape

FIGURE 1: A Manitoba Horse Fly Trap with a drop sheet on the ground to retain dead flies.

of too many horse flies, while the hollow sphere served as a silhouette and as a holding vessel.

In 1964, at Whitemouth Lake, the funneled sphere was replaced by glossy black icosahedron attached to a funnel. The icosahedron had a small door on the under side for the removal of dead horse flies (figure 2). An annular plastic baffle, five inches wide, was glued to the interior of the canopy, two-thirds of the way up the canopy, just above the open end of the funnel. The baffle further reduced the number of tabanids escaping from the trap.

Results and discussion. The trap fitted with the drop sheet was not very effective in retaining the dead horse flies. The drop sheet was exposed to the elements of the weather, consequently many of the horse flies were blown away by the wind or washed away by the rains. Furthermore, many horse flies that were knocked-down by the insecticide did not die immediately, and crawled away into the grass, making it difficult to ascertain the effectiveness of the chemical used. Treating the silhouette was ineffective since many of the horse flies did not alight on the silhouette, but flew upward to the apical end.

Treating the interior of the canopy at the apex proved very effective since the horse flies flew upward to the apex and remained there until they were overcome by the chemical, and dropped.

The use of the open hemisphere was not very effective since many horse flies escaped through the large opening between the silhouette and the canopy.

The funnel sphere silhouette, playing a double role, proved to be very effective in retaining the majority of the affected horse flies as well as attracting them. A funnel-icosahedron, was used in 1964 at Whitemouth Lake, because of its simplicity of construction from sheet metal. The icosahedron was as effective as the sphere in attracting the horse flies. The evidence for this comparison is presented elsewhere in this thesis.

The decoy silhouette, be it a sphere or an icosahedron, can hold up to one hundred thousand horse flies, whereas the no-return chamber held up to four thousand. The large capacity of the icosahedron, coupled with the ease of emptying it, made the trap very efficient as a practical trap.

The testing of various insecticides on tabanids.

Methods and materials. Eight chemicals were tested on tabanids in 1963. The chemicals and their concentrations are as follows:

(a) Bomyl (GC 3707): dimethyl-1,3-di(carbomethoxy)-1-propen-2-yl-phosphate. - 94% active ingredient - from Allied Chemical Corporation.

The concentration used was 94% active ingredient.

(b) Dieldrin : (not less than 85% of 1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,42,5,6,7,8,8a-octahydro-1,4-endo-exo-5,8-dimethanonaphthalene).

The concentration used was 20% E.M.C.

(c) DNOBP : 2-sec-butyl-4,6-dinitriphenol. - 53% active ingredient - from Dow Chemical Company

The concentration used was 53% active ingredient.

(d) 4-6-DNOC : 4,6-dinetro-o-cresol - from Eastman Organic Chemicals.

The chemical was dissolved in ethyl alcohol to saturation.

(e) Hercules 5727 : N-methyl m-isopropylphenyl carbonate - from Hercules Powder Company.

The chemical was dissolved in acetone to saturation.

(f) Bayer 29493 : O,O-dimethyl O- [4-(methylthio)-m-tolyl] phosphorothioate. - 46.1% active ingredient

The concentration used was 46.1% active ingredient.

(g) Cygon : O,O-dimethyl S(N-methyl carbamoylmethyl) Phosphoro dithioate - 43.5% E.M.C. - from American Cyanamid Company. The concentration used was 43.5% E.M.C.

(h) GC 4072 :

from Allied Chemical Corporation. The chemical was applied without dilution.

The insecticides were applied to the surfaces with one inch paint brushes. Only one application was made during each experiment. A plastic drop sheet was placed beneath the trap. The silhouettes consisted of glossy black spheres.

The efficiency of each insecticide is compared with an index trap. The index trap consists of a glossy black sphere and a no-return chamber. The captures were removed when the no-return chamber on the index trap was full of horse flies.

In 1964, the chemical, Bomyl, was used as the insecticide against horse flies. The concentration of Bomyl used was 94% active ingredient. In each experiment that Bomyl was used, it was applied once.

Results and discussion. The results are illustrated in Table I. Bomyl was found to be the most effective insecticide.

Bomyl produced a quick lethal knockdown. The effectiveness of the various chemicals wore off as the season progressed, but the rate of deterioration of Bomyl was found to be less than that of the other chemicals.

A very important factor must be considered with the use of Bomyl. This chemical has an oily consistency, so that on application, droplets of the chemical appear on the canopy. If the treated area is allowed to be exposed immediately to the horse flies, the flies, coming in contact with the chemical, become heavily laden with it. If any of the horse flies escape from the trap, they may be eaten up by birds which often are nearby, particularly on cow pastures. This chemical will then affect the birds as was the case in two instances. Forty cow birds, *Molothrus ater*, and one swallow, *Hirundo erythrogastra*, died around two Bomyl treated traps which were set up immediately after being treated. On examining their gizzards, horse flies were found in them. As a result, the other Bomyl treated traps that were set up later, were not put into operation for one week, during which time the chemical, Bomyl, dried up completely. After this important operation of drying out the chemically treated surface, no more dead birds were found around the traps. Bomyl-treated traps were placed only on farms free from domestic birds.

TABLE I

RATIO OF TABANIDS CAPTURED IN INDEX TRAP TO LETHAL KNOCKDOWN IN A TRAP TREATED WITH AN INSECTICIDE (I : K)*

Chemical	Total Captures	Mean I : K
Bomyl	6,084	2.5 : 1
Dieldrin	1,411	10.5 : 1
4,6-DNOC	1,392	10.7 : 1
DNO BP	1,117	13,3 : 1
Hercules 5727	1,007	14.8 : 1
GC 4072	529	13.6 : 1

* I = index

K = lethal knockdown

The captures from insecticide treated traps were buried after being counted.

It is conceivable that lowering the concentration of Bomyl may decrease its toxicity to birds, without losing any of its potency against tabanids. However, this will require more experimentation.

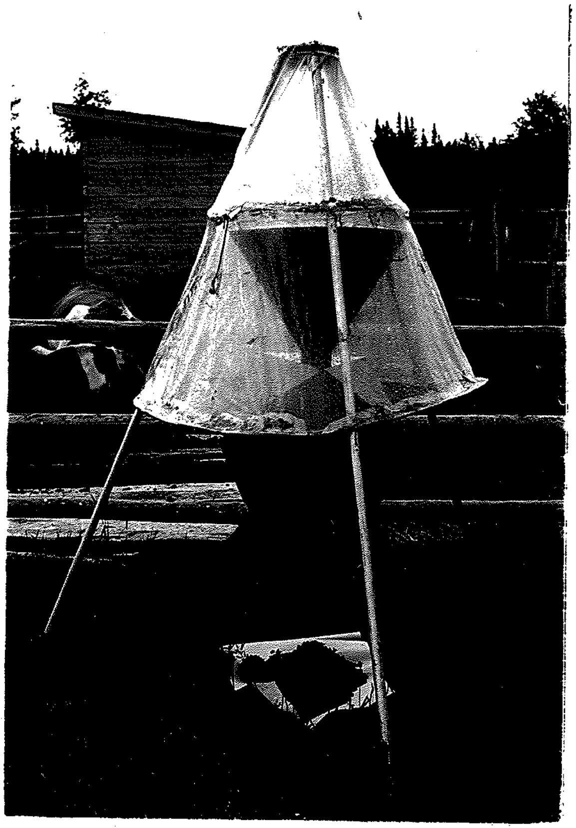
Practical use of chemically treated horse fly traps on farmyards.

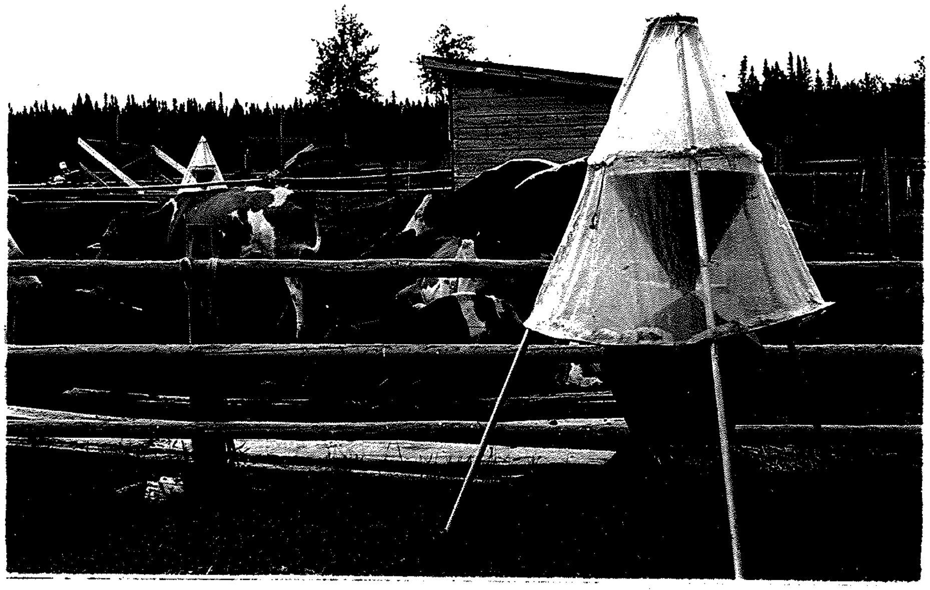
Methods and materials. Horse fly traps treated with Bomyl (94% active ingredient) and fitted with funneled icosahedra, were placed on the cattle farms. One trap was located at a horse riding ranch at Falcon Lake. On farms, the traps were located next to the corrals where the cattle congregated during the day. The traps were fenced in so that no damage would result to the animals or to the trap. The traps were located in an area which was sunny all day, and free from any obstruction, except for a fence between the trap and the animals (figure 3). The traps were set out during the third week of June, and remained there until autumn. The traps were usually emptied once a week during the height of the horse fly season, but once every two weeks later in the summer. The number of horse flies in each capture was determined by weighing them.

The first two traps were set out immediately after being

FIGURE 2: Manitoba Horse Fly Trap over a funnel icosahedron assembly. The door is opened to show how it is emptied.

FIGURE 3: Two practical Bomyl-treated Manitoba Horse Fly Traps located on a farmyard.





treated, but the subsequent traps were not put into operation for one week in order that the Bomyl treated surface was dry.

Results and discussion. The captures of tabanids at the four farms are illustrated in Tables IIA and IIB. At farm (1) during the period June 27 - June 29, the daily rate of capture per Bomyl-treated trap was 7,851 tabanids. The daily rate per Bomyl-treated trap for the period July 7 - July 13 at farm (1) was 5,781 tabanids.

On farm (2) the daily rate for the period June 26 - June 30, was 5,900 tabanids for one Bomyl-treated trap.

At all four farms, many stable flies were noticed around the cattle and horses, during July and August. These biting flies are also very bothersome to the animals. Many stable flies were noticed in the captures of each trap, but no counts were made of their number.

The fact that the trap is located near the cattle, does not remove the annoyance caused by the tabanids to the beasts. From observation, many tabanids were seen alighting on the animals and causing great harassment. However, the traps do destroy a large number of flies. There is no reliable basis as yet for estimating the decrement of the horse fly population. Whether the traps would depopulate critically the tabanids over a period of years, remains to be seen.

TABLE 11A: THE CAPTURES OF TABANIDAE ON FARM (1) AND FARM (2) AT WHITEMOUTH LAKE.

Farm (1)-located one half mile from Whitemouth Lake. 22 head of cattle were on the farm			Farm (2)-located four and one half miles from farm (1). 100 head of cattle were on farm (2)		
One trap was set up on June 15 and two more traps* were set up on June 25. The traps were separated from the cattle by a pole fence.			One trap was set up on June 26 and one trap was set up on July 1. The traps were enclosed with a slab fence.		
Date of removal of captures	No. of traps	Total captures	Date of removal of captures	No. of traps	Total captures
June 19	1	448	June 30	1	23,600
June 22	1	4,501	July 3	2	5,500
June 26	2	14,654	July 7	2	3,845
June 29	2	39,258	July 13	2	15,867
July 3	2	12,000	July 21	2	15,100
July 6	2	25,395	July 31	2	2,318
July 13	2	75,150	August 16	2	1,159
July 21	2	46,057			
July 31	2	25,073			
August 16	2	12,735			
Total		255,271	Total		67,389

* Of the two traps set up on June 25, one trap was treated with the chemical Bomyl; the other trap had a no-return chamber and a glossy black sphere. The count for the trap with the no-return chamber was 31,541 tabanids so that the total tabanids captured on farm (1) was 255,271+31,541= 286,812.

TABLE IIB: THE CAPTURES OF TABANIDAE AT FARM (3) AND AT FARM (4).

Farm (3)-located at Florze, 12 miles west from Whitemouth Lake. 80 head of cattle were on the farm.			Farm (4)-horse riding ranch at Falcon Lake. 25 horses were on the ranch.		
One trap was set up on June 24. The trap was enclosed with a pole fence.			One trap was set up on June 23. The trap was enclosed with a wire fence.		
Date of removal of captures	No. of traps	Total captures	Date of removal of captures	No. of traps	Total captures
June 29	1	4,786	June 30	1	1,433
July 6	1	7,541	July 9	1	1,900
July 13	1	8,346	July 23	1	5,030
July 22	1	8,314	Aug 16	1	168
Aug 16	1	4,213			
Total		32,200	Total		8,531

One can notice the different counts at the various farms. This can be accounted for by the different population densities at the various places, and possibly also by the type of fence placed around the trap. A slab fence obscures a great part of the silhouette, whereas the barb wire fence obscures very little of the silhouette. Furthermore, it is important to place the trap in areas where the cattle aggregate during the day. From observation, one can see numerous flies following the cattle. When the cattle were severely attacked, they gathered in the barnyard, where often a smudge was present.

The consensus of opinion expressed by the co-operating farmers, was that by setting a large number of Bomyl-treated traps around the areas where cattle aggregate and also on pasture lands, that the population of tabanids would be decreased considerably in the immediate vicinity and would give relief to the animals.

CHAPTER III

A STUDY TO DETERMINE THE DIRECTION FROM WHICH THE TABANIDS ORIENTATE TO A SILHOUETTE

Literature review

Thorsteinson, Bracken, and Hanec (1964) illustrated that a glossy black sphere, approximately 51 cm. in diameter, is a very attractive silhouette to tabanids. What attracts the horse fly and deer fly to the glossy black sphere is not definitely known. There is strong evidence that the tabanids orientate to a highlight, which is the reflection of an indistinct image of the sun, present on the illuminated side of the glossy black sphere, or that the tabanids orientate to the plane or degree of polarization of some of the reflected light (Bracken, Thorsteinson, and Hanec (1962). Bracken _et_ _al_ (1962) noticed that large numbers of tabanids were captured on the sunny side of a sticky stationary black silhouette. The indistinct image of the sun on the glossy black sphere is visible from all directions and from a great distance away, so that if the highlight or the polarized light is the orientating cue, then the tabanids could be homing in from any direction.

The purpose of this investigation was to establish from what particular direction, if any, did the tabanids approach the silhouette.

Methods and materials. Hemispheres, with the convex surface upwards, were used to transmit the highlight in the desired direction. The hemispheres were constructed from 1/8 inch glossy black perspex.

The outer surface of the hemisphere was sand blasted to render it matte black, except for a small area which remained glossy black. This area was determined by plotting the position of the solar reflection on the surface through the day as seen from eight directions along the line of sight parallel with the ground at 3 feet above the ground. The glossy black areas were determined in this manner so that each would scan one of the four right angled sectors of the field 45 degrees on each side of each cardinal direction.

The hemispheres were tethered, and the traps were set out in a diamond lattice arrangement. The hemispheres remained in the same position after each replicate. The captures were removed at the end of each day.

In 1963 the experiment was conducted in a small bush clearing near Beaver Creek. The traps were set out with the north scanner in the northern position of the diamond lattice arrangement, the east scanner in the eastern position, the south scanner in the southern position, and the west scanner in the western position. Five replicates were run.

In 1964, the same four traps were set in a large clearing at Whitemouth Lake. An index trap with a matte sphere was set up in the centre of the diamond setting (figure 4). The experiment was carried out in three different locations, but not simultaneously. In each location, five replicates were run. The first location had a large gravel ridge on the north side of the traps. The other two locations were large meadows with uniform growth of trees all around. For each replicate, the traps were allowed to operate one whole day before the captures were removed. This experiment ran through the whole fly season to include all the species prevailing in this area.

Results and discussion. The results obtained in 1963 at Beaver Creek are illustrated in Table IIIA. The Duncan's New Multiple Range Test at the 5% level indicates that the directional traps scanning east, north and south, captured significantly more tabanids than the directional trap scanning west. This difference may be due to positional effect, since the traps remained in the same position throughout the entire experiment. The position of each silhouette was not changed in order to avoid any interference that one trap might have imposed on the attractancy of the other traps.

The results obtained in 1964 at Whitemouth Lake are illustrated in Table IIIB. The Duncan's New Multiple Range

FIGURE 4: Directional hemispherical decoys tested in Manitoba Horse Fly Traps. The trap in the foreground is scanning west.

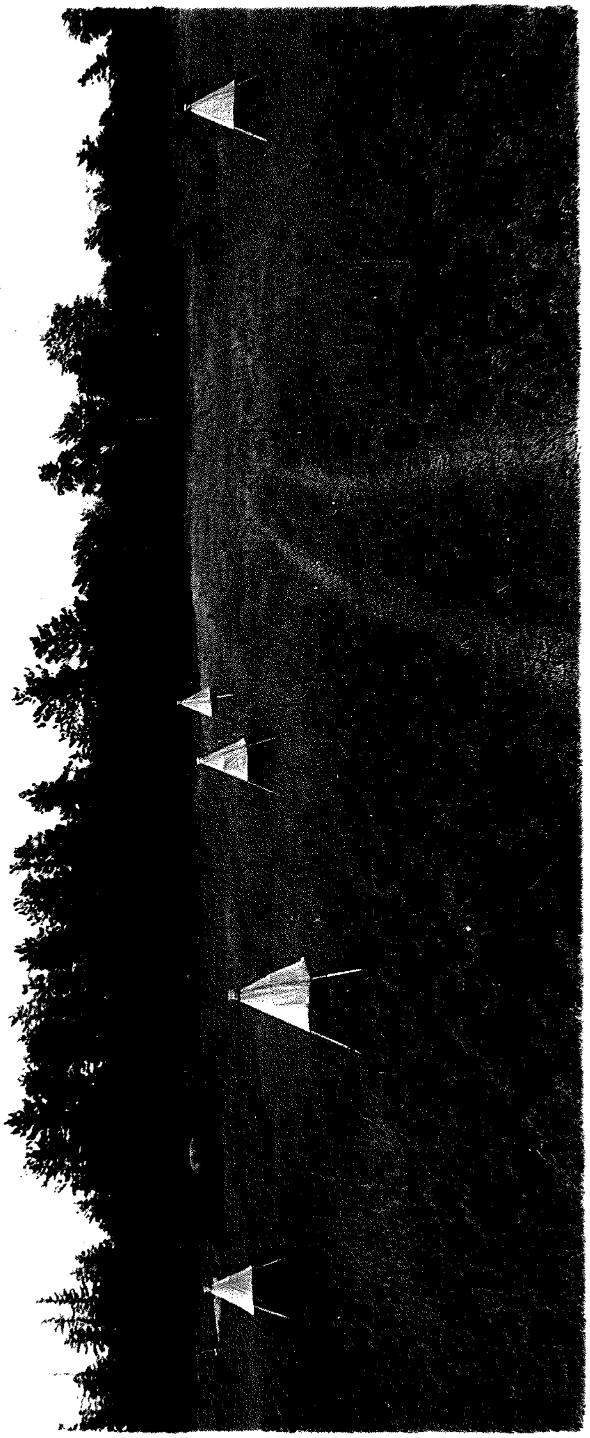


TABLE IIIA

CAPTURES OF TABANIDAE IN TRAPS WITH HEMISPHERES SCANNING NORTH, SOUTH, EAST, AND WEST AT BEAVER CREEK.

Direction Scanned	Total Captures	Transformed Means*
North	3,760	2.798
East	4,525	2.863
South	3,880	2.808
West	2,285	2.525

*Based on transformation of captures to logarithms. Duncan's New Multiple Range Test at the 5% level and the 1% level.

$$\begin{array}{cccc} \text{West} & \text{North} & \text{South} & \text{East} \\ 2.525 & 2.798 & 2.808 & 2.863 \\ \cline{2-4} \end{array}$$

Any two means underscored by the same line are not significantly different from each other. Any two means not underscored by the same line are significantly different from each other.

TABLE IIIB

CAPTURES OF TABANIDAE IN TRAPS WITH HEMISPHERE SCANNING NORTH, SOUTH, EAST AND WEST AT WHITEMOUTH LAKE.

Direction Scanned	Total Captures	Transformed Means*
North	13,693	2.885
East	14,120	2.929
South	13,304	2.935
West	14,170	2.946
Matte Index	6,887	2.561

* Based on transformation of captures to logarithms.

Duncan's New Multiple Range Test at the 5% level and the 1% level.

Index	North	East	South	West
2.561	2.885	2.929	2.935	2.946

Any two means not underscored by the same line are significantly different from each other. Any two means underscored by the same line are not significantly different from each other.

Test at the 5% level indicates no significant difference between any of the captures from the four cardinal directions. It appears that the big difference which occurred between east and west in 1963, can be attributed to positional effect.

The results, based on total daily captures, indicate that there is no particular general direction from which the horse flies orientate to the silhouette. Possibly if the captures could be analysed on the basis of shorter interval during the day, differences might show up, provided conditions favoured high flight activity throughout the day.

The results further confirm that a glossy black surface greatly enhances the attractiveness of a dark silhouette. The ratio of captures with the partially sand blasted silhouettes to the matte hemisphere is approximately 2:1. Bracken _et_ _al_ (1962) showed that a glossy black color is significantly superior to a matte black color by a ratio of 4:1. Hence, it appears that the results are consistent with the assumption that the highlight or polarized light, or both, reflected from the glossy black surface, are responsible for attracting the tabanids, even though none of the hemispheres scan the whole field. It is observed also that the 90 degree sector assumption applies only to a horizontal plane.

The fact that more horse flies were caught on the sunny side of a sticky, stationary, black silhouette, Bracken *et al* (1962), may be due to a thermal stimulus rather than a visual one. The sunny side of the black silhouette would invariably be warmer than the shady side, so that once the horse fly arrived on the silhouette due to a visual stimulus, the thermal stimulus at close range may be responsible for the horse flies aggregating more on the sunny side.

Investigations to determine the captures by a partly glossy hemisphere scanning the field in the forenoon, versus the captures by a partly glossy hemisphere scanning the field in the afternoon.

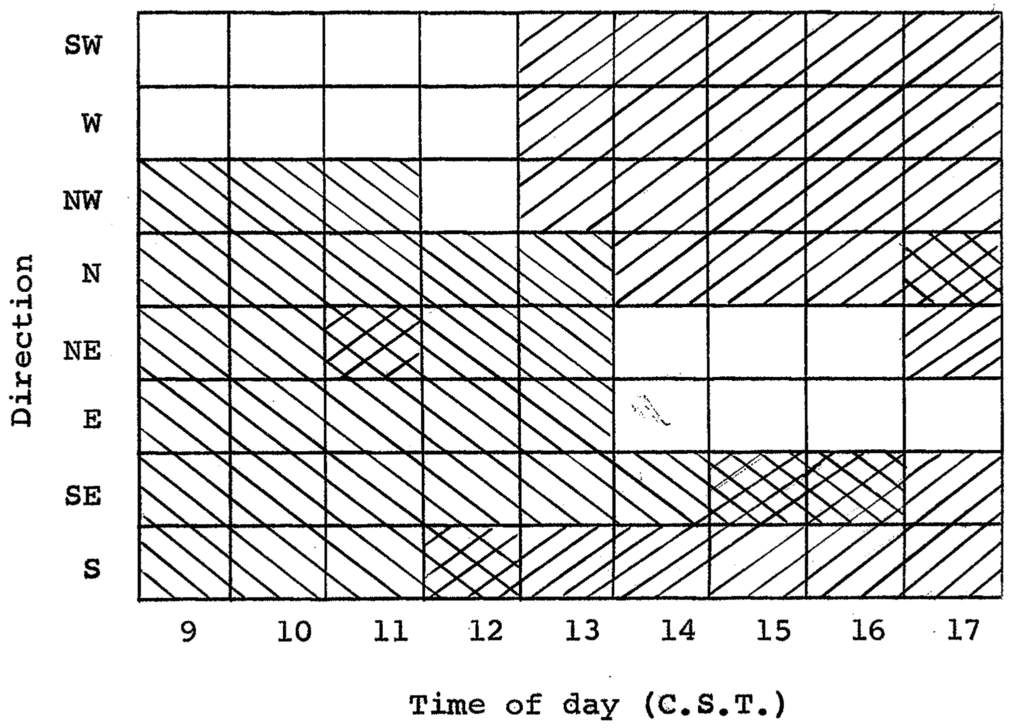
It was postulated tentatively that the peak of the flight activity during the day occurred in the afternoon. The purpose of this experiment was to determine whether a partly glossy black silhouette scanning the field in the late afternoon, was more effective than a partly glossy black silhouette scanning the field in the forenoon.

The hemispheres were matte black in color, except for the surface area which emitted a highlight at the direction - hours listed in Table IV for each silhouette. The surface areas which emitted the solar reflection was glossy black in color.

The hemispheres were tethered in each trap. The traps were cleared at the end of each day that the experiment was

TABLE IV

THE DIRECTION HOURS SCANNED BY THE MORNING HEMISPHERE AND EVENING HEMISPHERE



/// = evening hemisphere

\\\ = morning hemisphere

Total captures: morning hemisphere = 3,935

evening hemisphere = 4,875

Student's "t" test at the 5% level

t value for the test = .549

t.05 = 1.860 >.549 - not significant

There is no significant difference between the two treatments.

run. Five replicates were run.

Results and discussion. The results are illustrated in Table IV. The Student's "t" test showed no significant difference between the two treatments at the 5% level. The evening trap caught more tabanids, but it was not significantly higher than the morning capture.

The number of direction - hours for the morning hemisphere was 31 and for the evening hemisphere it was 30 during the time interval 900 hours to 1700 hours.

Although each hemisphere did not scan the field in all directions, each at its own particular time of day, each hemisphere had approximately the same number of direction - hours. The evening hemisphere, however, was scanning the field at a time when flight activity was higher, so that the captures in the evening hemisphere were expected to be much higher than those in the morning trap. The evidence for the peak of flight activity occurring in the afternoon is shown in Chapter VII of this thesis.

One plausible reason for the lack of a significant difference is that the evening hemisphere is not scanning in all directions. During the afternoon, the directions NE and SE were scanned for a short period of time, while the direction E was not scanned at all. By the same token, the morning hemisphere did not scan the directions W and SW in the morning, but at this time the flight activity is low, so that probably there was not as great a loss. At the same time that the directions E and NE were not being scanned, in the afternoon by the evening trap, the morning hemisphere scanned in the directions SE and N. These two factors would be working against the evening hemisphere.

CHAPTER IV

INVESTIGATION INTO THE EFFECT OF DIRECTION OF WIND ON THE CAPTURES OF TABANIDS

Literature review

Kennedy (1939) noted that female mosquitoes of *Aedes aegypti* orientated at random to a visual stimuli in the absence of wind, but when wind was provided, 85% of the active individuals flew against the wind.

Felt (1938) stated that insects seldom migrate, except when the air is in motion, and the locusts depend almost wholly upon the wind, simply using their wings to sustain themselves, and generally head into the wind.

Atkins (1958) noticed that a species of Coleoptera walked downwind, and flew with the wind when the wind was present.

Horsfall (1959-61) employing an insect trap without lights, showed that the mosquitoes orientated without regard to velocity or direction of wind during flight.

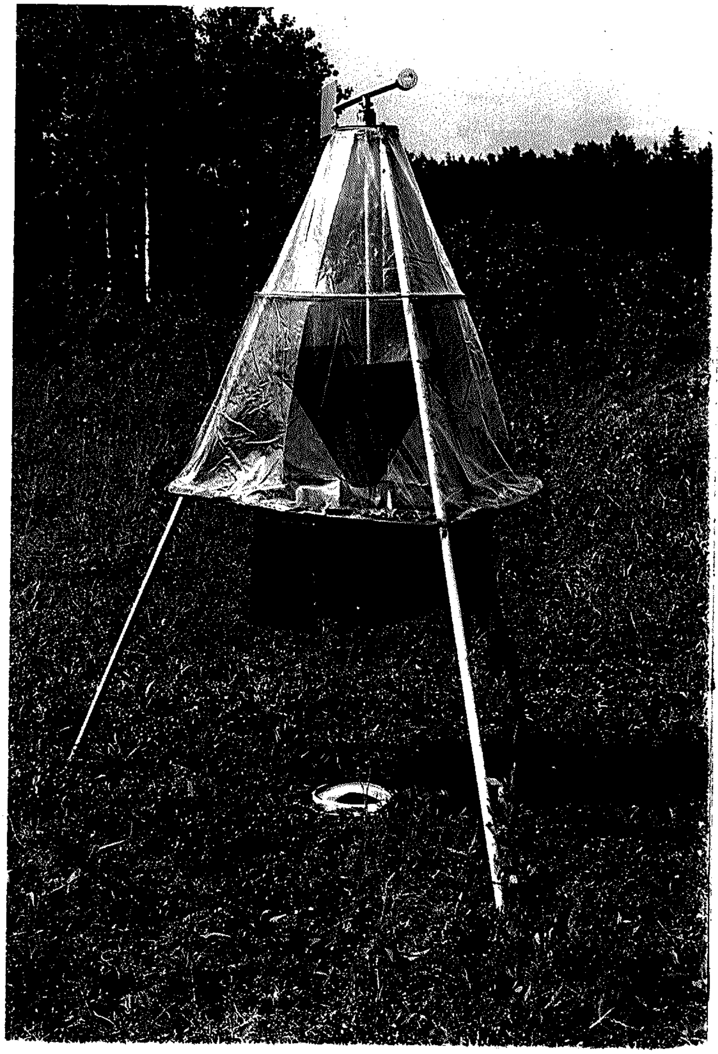
Williams (1930) considered flight data for butterflies and he found no relationship between the direction of the flight and that of the wind.

The purpose of this experiment was to determine whether wind had any influence on the approach of the tabanids to the silhouette.

Methods and materials. Four Manitoba Horse Fly Traps were set up in a large clearing at Whitemouth Lake. Two of these traps were index traps, one bearing a glossy sphere and one bearing a matte sphere. The other two traps were directional, one emitting a highlight upwind, and the other emitting a highlight downwind. The silhouettes in the directional traps were glossy black hemispheres, with the convex surface downwards. The highlight was produced by placing a shiny metal convex car hub-cap beneath the hemisphere in such a manner that the image of the sun would be reflected from the hub-cap on to the hemisphere, and outward. The hemisphere was enclosed with a matte black corrugated paper, except for ninety degrees of the circumference which was exposed, so that the highlight was visible in a quadrant of the field (figure 5). The hemispheres were attached to wind vanes by means of a shaft riding on a ball race. The hemispheres turned with ease, with a shift in the wind. These two directional traps were treated with Bomyl, and the dead tabanids were collected in the hemispheres. There were funnels placed above each hemisphere to minimize the loss of tabanids.

Twelve replicates were run, and after each replicate the position of the trap was changed to minimize the positional effect. The captures were removed when the

FIGURE 5: Manitoba Horse Fly Traps modified to scan according to wind direction; the trap on the left is scanning upwind and the trap on the right is scanning downwind.



no-return chamber of the index trap was full.

Results and discussion. The results are illustrated in Table V. The Duncan's New Multiple Range Test at the 5% level indicates that there is no significant difference between the upwind and downwind captures. The tabanids are stronge fliers, Hocking (1953), so that the wind direction probably has no effect on the approach of the tabanids to the silhouette.

The glossy black sphere index trap caught significantly more tabanids than did the matte black index trap or the wind directional traps. An index trap bearing a glossy black sphere was set up as standard procedure, and the result that it caught significantly more tabanids agrees with the expectation.

The matte black index trap captured significantly more tabanids than the wind directional traps. The matte black color is less effective than the glossy black color Bracken *et al* (1962). The solar highlight emitted from the wind directional hemispheres was small and weak in comparison to that emitted from the glossy black sphere. The area scanned by the wind directional traps was only a 90 degree sector of the entire field, which probably accounts for the low captures in the wind directional traps.

TABLE V

CAPTURES OF TABANIDAE IN TRAPS WITH HEMISPHERES SCANNING UPWIND AND DOWNWIND

Description	Total Captures	Transformed Means*
Upwind	6,843	2.487
Downwind	6,859	2.607
Matte	9,439	2.868
Glossy	18,116	3.144

*Based on transformation of captures to logarithms.

Duncan's New Multiple Range Test at the 5% level

Upwind	Downwind	Matte	Glossy
2.487	2.607	2.868	3.144

Any two means not underscored by the same line are significantly different from each other. Any two means underscored by the same line are not significantly different from each other.

CHAPTER V

THE ORIENTATION OF TABANIDS TO OBJECTS OF DIFFERENT SHAPES

Literature review

The problem of form discrimination has been studied critically for bees. Von Frisch (1950) showed that complex forms with irregular outlines were preferred, and that this attraction is interpretable in terms of optomotor stimulation. Tinbergen and Kruyt (1937) observed that objects with three dimensions served to orient a species of sphecid wasp, *Philanthus triangulum* Fabr. to its nest more effectively than flat ones. These authors also determined that larger objects were better than small ones for this orientation.

The tsetse fly trap employed by Morris and Morris (1949) was essentially a horizontal cylinder which according to the authors, best simulated a host animal. They concluded that curvature of the trap in the vertical plane was an important factor in its attractiveness to the tsetse fly. The trap constructed by Skuffin (1951), also presented such curvature, although the author makes no mention of the possible significance of this property in the attractiveness of the trap to the horse flies.

Snow (1957) and Pechuman (1961) mention that vehicles are excellent for trapping female tabanids. Pechuman (1961) states further that darker vehicles appear to be more effective for this purpose. Philip (1931), Hansens (1952), Tashiro and Schwardt (1931), and Bromely (1952) have noted that dark cattle were more readily attacked by tabanids than white cattle.

Thorsteinson (1958) described a trap for tabanids. Thorsteinson, Bracken, and Hanec (1964) described an improved design of the device described by Thorsteinson (1958). Thorsteinson _et al_ (1964), denoted the device as the Manitoba Horse Fly Trap. It incorporates a glossy black (or red) sphere about 24 inches in diameter, about three feet above the ground to attract the flies visually.

Bracken, Thorsteinson, and Hanec (1962) indicate strong evidence for the fact that the orientation cue to tabanids is the highlight, which is an indistinct image of the sun reflected from all sides of a glossy black sphere, or possibly the plane or degree of polarization of some of the reflected light. They postulate further, that to be exceptionally attractive, the sun's image or the cone of polarized light must be seen in a field (the rest of the silhouette) not physiologically brighter than the background.

The purpose of this investigation was to compare the effectiveness of various other shapes not yet tried, with that of the sphere.

In this chapter, six experiments are described. Each experiment will be considered separately.

The influence of various polyhedra on the captures of tabanids.

Methods and materials. The dimensions of the polyhedra are illustrated in Table VI. The polyhedra, constructed of plywood, resembled pyramids. A sphere 24 inches in diameter was used as control index. The silhouettes were all painted glossy black and suspended freely from the Manitoba Horse Fly Trap. The experiment was carried out in a large bush clearing at Beaver Creek.

The ten traps were set in a circle. The silhouettes were randomized and ten replicates were run. After each replicate, the silhouettes were changed so that each silhouette was set once in each of the ten positions. The traps were cleared when the first no-return was full of tabanids.

Results and discussion. The results are illustrated in Table VII. The total capture by the index trap is significantly greater than the captures by any of the polyhedra.

In comparing the three sided polyhedra versus the six sided polyhedra versus the twelve sided polyhedra, it was found by the Duncan's New Multiple Range Test at the 5% level, that the captures from the twelve sided polyhedra were not significantly larger than those from the six sided

TABLE VI

DESCRIPTION OF THE POLYHEDRA

Number of sides excluding base	Angle between base and side at the vertices	Perpendicular height from centre of base to apex of polyhedron	Distance from centre of base to vertices
3	30°	9.25"	15.95"
	45	15.95"	15.95"
	60	22.1 "	15.95"
6	30	9.25"	15.95"
	45	15.95"	15.95"
	60	22.1 "	15.95"
12	30	9.25"	15.95"
	45	15.95"	15.95"
	60	22.1 "	15.95"

TABLE VII

THE MEAN CAPTURES OF TABANIDAE IN TRAPS WITH VARIOUS POLYHEDRA

NUMBER OF SIDES	ANGLE OF INCLINATION		
	30°	45°	60°
3	51	140	82.3
6	96.7	270.7	147.7
12	117.6	346.2	284.3

THE MEAN CAPTURE OF THE INDEX TRAP WAS 1115.3

DUNCAN'S NEW MULTIPLE RANGE TEST AT THE 5% LEVEL BASED ON THE TRANSFORMATION OF CAPTURES TO LOGARITHMS.

(3,30)	(6,30)	(3,60)	(12,30)	(3,45)	(6,60)	(12,60)	(12,45)	(6,45)	INDEX
1.339	1.759	1.772	1.809	1.863	2.032	2.192	2.347	2.349	3.009
					———	———	———	———	
	———	———	———	———	———				

ANY TWO MEANS UNDERSCORED BY THE SAME LINE ARE NOT SIGNIFICANTLY DIFFERENT FROM EACH OTHER.

ANY TWO MEANS NOT UNDERSCORED BY THE SAME LINE ARE SIGNIFICANTLY DIFFERENT FROM EACH OTHER.

polyhedra, but both were significantly larger than the captures from the three sided polyhedra. During most of the day, the twelve sided polyhedron reflects highlights from nine sides; the six sided polyhedron reflects highlights from five sides; and the three sided polyhedron reflects highlights from two sides. Since the tabanids approach the trap equally from all directions, one can conjecture that the larger the area scanned by a silhouette, the better the captures should be, provided the comparison is made among the same shapes.

In comparing the three different inclinations of the sides of the polyhedra, it was found by the Duncan's New Multiple Range Test at the 5% level, that the 45 degree inclination was not significantly different from the 60 degree inclination, but both were significantly much more attractive than the 30 degree inclination. The highlights from the 30 degree inclination are reflected very steeply upward throughout the day, and the 30 degree polyhedra always appear as a matte black silhouette. The highlight from the 45 degree inclination are reflected nearly parallel to the ground for a longer period of the day than from the 60 degree inclination, so that one may conjecture that the 45 degree inclination would be more effective for attracting the tabanids.

The results in Table VII show that by far the least attractive form combines the fewest sides and the smallest angle of inclination (3, 30). The most attractive forms had both more than three faces and inclinations greater than 30 degrees. The remaining forms having only one but not both of these features were intermediate in attractiveness.

The surface areas of the polyhedra were not all the same, but the differences in surface areas among the polyhedra was in the range where the effectiveness of the trap does not change appreciably with size,Bracken (1962).

The sphere was superior to any of the other treatments confirming again the interpretation that attractancy varies with the number of sides.

The influence of matte and glossy spheres and hemispheres on the captures of tabanids.

Bracken *et al* (1962) have shown that glossy silhouettes of certain shapes (especially spheres) are much more attractive than similar silhouettes painted matte black. This provided plausible evidence that the solar highlights reflected from the silhouettes significantly increased the attractancy. These highlights are reflected in all directions from nearby to the horizon.

It was of interest to determine whether the upper or lower hemispheres were more important in this respect.

A preliminary experiment was conducted to compare the attractancy of glossy black hemispheres mounted convex upwards, as compared with one mounted downwards. This experiment was carried out in a small swampy bush clearing at Beaver Creek. The hemispheres (twenty-four inches in diameter) were painted glossy black and the diametric opening of each hemisphere was covered with matte black corrugated paper. The traps were placed about ten feet apart, and were interchanged after each replicate.

The results are illustrated in Table VIII. The Student's "t" test at the 5% level, showed no significant difference between the two silhouettes.

A much more elaborate experiment was conducted in a more suitable bush clearing following the preliminary experiment to determine whether the upper or lower hemispheres were more important in attracting tabanids.

<u>Methods</u> <u>and</u> <u>materials</u>. This experiment was run in a large bush clearing at Beaver Creek. Eight traps, set in a circle, were about twenty-five feet apart. The silhouettes, composed of hemispheres, are described as follows:

a) Two glossy black hemispheres clamped together with three small c - clamps to form a sphere.

b) Two hemispheres, one glossy black and one matte black, clamped together to form a sphere. The glossy black hemisphere formed the upper part of the sphere.

c) A glossy black hemisphere with the convex surface upwards.

TABLE VIII

CAPTURES OF TABANIDAE IN TRAPS WITH A GLOSSY HEMISPHERE CONVEX UP AND A GLOSSY HEMISPHERE CONVEX DOWN

Description	Captures *
Hemisphere convex up	13,749
Hemisphere convex down	18,046

*No significant difference between the two treatments.

d) A matte black hemisphere with the convex surface downwards.

e) Two hemispheres, one glossy black and one matte black clamped together with the matte black hemisphere forming the upper part of the sphere.

f) A glossy black hemisphere with the convex surface downwards.

g) Two matte black hemispheres clamped in the same manner, to form a sphere.

h) A matte black hemisphere with the convex surface upwards.

The hemispheres were contructed of glossy black perspex, and the matte surfaces were obtained by sand blasting the glossy surface.

The silhouettes were randomized with respect to position. Eight replicates were run, and after each replicate, the position of each silhouette was changed. The captures were removed as soon as one no-return chamber was full of tabanids.

Results and discussion. The results are illustrated in Table IX. Silhouettes (a), (b), and (c) are significantly more attractive than the other five silhouettes. The fact that silhouette (c) captured so many tabanids suggests that the lower half of a glossy black sphere contributes very little, if any, to the effectiveness of the silhouette. The results obtained from silhouettes (e) and (d) are in

TABLE IX

CAPTURES OF TABANIDAE IN TRAPS WITH GLOSSY AND MATTE BLACK SPHERES AND HEMISPHERES

Description	Total Captures	Transformed Means*
(a) Glossy glossy sphere	15,733	3.14
(b) Glossy matte sphere	14,508	3.10
(c) Glossy hemisphere convex up	14,004	3.08
(d) Matte hemisphere convex down	6,688	2.74
(e) Matte glossy sphere	5,385	2.63
(f) Glossy hemisphere convex down	5,142	2.64
(g) Matte matte sphere	2,630	2.36
(h) Matte hemisphere convex up	1,512	2.04

*Based on transformation of captures to logarithms.

Duncan's New Multiple Range Test at the 5% level

(h)	(g)	(f)	(e)	(d)	(c)	(b)	(a)
matte	matte	matte	------	------	glossy	glossy	glossy
-----	matte	glossy	glossy	matte	------	matte	glossy
2.04	2.36	2.63	2.64	2.74	3.08	3.10	3.14
					———	———	———
		———	———	———			
	———	———	———				
———	———						

Any two means not underscored by the same line are significantly different from each other.

Any two means underscored by the same line are not significantly different from each other.

agreement with this suggestion. Silhouettes (d), (e) and (f) are more attractive to tabanids than silhouette (h). Silhouette (d) is more attractive than silhouette (g). According to silhouettes (b) and (c), the lower matte hemisphere accounts for very few captures. According to results obtained with silhouettes (e) and (f) the upper matte hemisphere contributes very little to the captures of tabanids. Therefore, it was expected that silhouettes (d), (g) and (h) would be much less attractive, and the results confirm this fact, except for silhouette (d). The captures by this lower matte hemisphere presents an anomaly in that many more flies were caught than were expected on the basis of our hypothesis. One explanation for this anomaly is that the diametric plane of the hemisphere was not covered, so that the interior surface of the matte hemisphere reflected a diffuse image of the sun contrary to the intention of the experimental design. This reflection may be responsible for the larger capture of horse flies. This explanation brings the results into line with expectation.

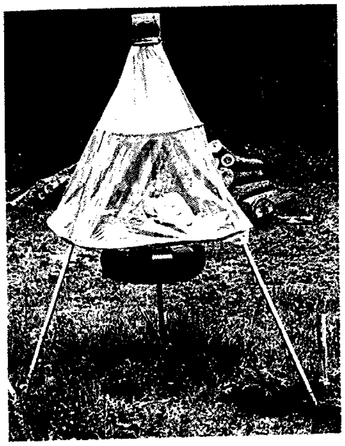
The high captures by silhouettes (a), (b), and (c), versus the very low captures by silhouettes (g) and (h) appear to substantiate the tentative explanation given by Bracken _et al_ (1962), that the sun's image or a beam of completely polarized light, provides an orientation cue for tabanids to various silhouettes.

The attractiveness of different shapes to tabanids.

Methods and materials. Five traps were set up at Whitemouth Lake. The following shapes were used as silhouettes: sphere, icosahedron, torus, hemisphere convex down with a shiny hub-cap beneath, and a hyperboloid (figure 6). The sphere was approximately 24 inches in diameter. The other silhouettes were approximately the same size in surface area. The torus was constructed of four, eight inch stove pipe elbows. The icosahedron was constructed of sheet metal. The hyperboloid was constructed of plywood and paper. The hyperboloid measured 36 inches high with the top and the base 20 inches in diameter and the middle 4.5 inches in diameter. Each silhouette, painted glossy black, was suspended freely from the trap. Five replicates were run, and after each replicate, the position of each silhouette was changed to minimize the positional effect. The traps were set in a circle in a large clearing, and the silhouettes were randomized. The traps were cleared whenever one no-return was full of tabanids.

Results and discussion. The results are illustrated in Table X. The hyperboloid tested was a very poor silhouette for attracting tabanids. The species composition was similar to that of the captures in the other trap, so that no preference by a particular species for the hyperboloid was noted.

FIGURE 6: Various silhouettes tested in Manitoba Horse Fly Traps; torus, icosahedron, sphere, hemisphere with ground mirror, and hyperboloid.



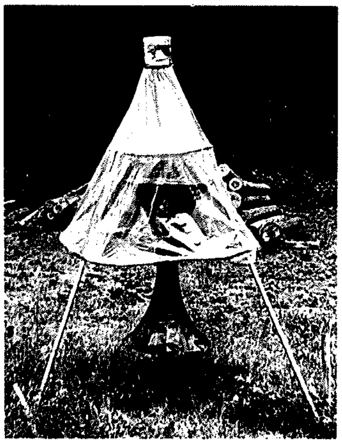


TABLE X

CAPTURES OF TABANIDAE IN TRAPS WITH DIFFERENT SHAPES

Description	Total Captures	Transformed Means*
icosahedron	4,048	2.882
sphere	3,063	2.735
torus	2,708	2.683
hemisphere convex down with hub-cap	2,381	2.646
hyperboloid	157	1.321

*Based on transformation of captures to logarithms.

Duncan's New Multiple Range Test at the 5% level and the 1% level

hyperboloid	hemisphere with hub-cap	torus	sphere	icosahedron
1.321	2.646	2.683	2.735	2.882

Any two means not underscored by the same line are significantly different from each other.

Any two means underscored by the same line are not significantly different from each other.

The icosahedron, sphere, torus and the hemisphere with a hub-cap beneath it were equally attractive, statistically, to tabanids.

The very low captures by the hyperboloid are possibly due to the fact that this object does not have the body that the sphere or the icosahedron have. The central part of the hyperboloid is very narrow, so that a highlight or a cone of polarized light may appear in the hyperboloid physiologically brighter than the background.

The other four silhouettes have large central bodies so that the sun's image or a cone of polarized light would be seen in the field not physiologically brighter than the background.

The glossy black hemisphere with the hub-cap beneath it, caught fewer horse flies than the sphere, torus or the icosahedron although when compared at the 5% level it was not significantly different. The reflection of the solar image from the hemisphere was not as intense nor as large as that perceived from the sphere. The hemisphere does not lend itself to reflecting any light beyond a certain level above the ground. This fact coupled with the weak highlight, may account for the lower capture in this trap.

The influence of a funnel in the capture of tabanids.

In the former experiment, the icosahedron was found to be a very good silhouette in attracting tabanids to the trap. Furthermore, the icosahedron can be easily constructed with sheet metal. For practical purposes on farm yards, a desirable silhouette is one that can be easily constructed with readily available materials, and yet have a high performance. However, in experimenting with the insecticides, a device had to be installed on the silhouette to retain the poisoned tabanids. A glossy black funnel was installed on the icosahedron for this purpose.

The purpose of this experiment is to determine if the presence of the funnel influences the effectiveness of the icosahedron.

Methods and materials. Three traps were set up at Whitemouth Lake, Trap one, treated with Bomyl, had a glossy black funnel above the icosahedron. Trap two had a glossy black funnel above the icosahedron and also a no-return chamber at the apex but was not treated with Bomyl. Trap three had a glossy black icosahedron and no-return but it did not have a funnel. The purpose of having a Bomyl treated trap was to see whether a large number of tabanids were escaping from the trap after having been in contact with the chemical.

Six replicates were run, and after each replicate the position of each silhouette was changed so that each silhouette was in each position twice. The position of the silhouettes was randomized. The captures were removed when ever one no-return was full.

Results and discussion. The results are illustrated in Table XI. The Duncan's New Multiple Range Test shows no significant difference between any of the treatments.

The Bomyl-treated traps captured the largest number of tabanids, suggesting that very few tabanids, if any, escaped from the trap. However, a small number of tabanids were noticed escaping from the trap and falling on the grass beneath the trap. Since these flies had come in contact with the chemical, they probably succumbed after leaving the trap.

Another experiment was conducted at Whitemouth Lake, to determine the influence of a shiny sheet metal icosahedron versus a glossy black icosahedron. Bracken (1962) showed that a highly polished surface of a cylinder, covered with aluminum foil was not attractive to Tabanidae.

Two icosahedron traps with funnels, were suspended in Bomyl-treated Manitoba Horse Fly Traps. One icosahedron and funnel were painted glossy black, whereas the other icosahedron and funnel were not painted. Both were constructed of sheet metal which had a high reflecting surface. Two replicates were run. The glossy black icosahedron captured 2,093 horse flies, whereas the shiny metal icosahedron captured 87 horse flies. The glossy black icosahedron and funnel caught significantly more tabanids

TABLE XI

CAPTURES OF TABANIDAE IN TRAPS FITTED WITH AN ICOSAHEDRON WITH ANDWITHOUT A FUNNEL

Description	Total Captures	Transformed Means*
icosahedron and funnel and Bomyl	3,382	2.712
icosahedron and funnel and no-return	3,155	2.667
icosahedron and no-return	2,179	2,474

*Based on transformation of captures to logarithms.

Duncan's New Multiple Range Test at the 5% level

icosahedron & no-return	icosahedron & funnel & no-return	icosahedron & funnel & Bomyl
2.474	2.667	2.712

Any two means underscored by the same line are not significantly different from each other.

than the unpainted icosahedron and funnel. The results provide more evidence that glossy black is a very attractive color to tabanids.

CHAPTER VI

THE ORIENTATION OF TABANIDAE TO OBJECTS EMITTING FILTERED HIGHLIGHTS

Literature review.

The relative sensitivity of insects to different regions of the spectrum has been the subject of numerous investigations. Cameron (1938) made an extensive review of the literature, paying particular attention to methods. He concluded that while the quantitative results of different methods were not comparable, there was generally good agreement as to the qualitative aspects of phototactic behaviour. He found that for the house fly, Musca domestica L., ultraviolet light at 365 mu was more stimulating than any other part of the spectrums examined. Stimulation fell off rapidly toward longer wave lengths, and no other maximum was observed.

Weiss (1943) studied the reactions of 14,000 insects which included 19 species of Coleoptera, two of Hymenoptera, and one each of Hemiptera and Diptera to different wave lengths at equal intensities. He found that, in the range of wave lengths between 365 mu and 740 mu, two peaks of maximum phototactic response occurred consistently; a maximum peak at 365 mu, and a smaller peak at 402 mu.

Ballard (1958) made a study of the phototactic response of Stomoxys calcitrans L. to wave lengths of light at two intensity levels. He used a "Y" tube method, and used filters to obtain light of different wave length. He found that at low intensity both sexes responded maximally in the region of 640 mu. At the higher intensity level, the males showed peaks at 390, 440, 515, and 640 mu, whereas the response of the female slowly decreased from 365 to 575 mu, and increased to a peak again at 640 mu. The peak at 640 mu had not been demonstrated previously in studies of other insects.

Hanec and Bracken (1962) investigated the phototactic responses of tabanids to light of different wave lengths at equal intensities, using a "Y" tube apparatus. He found that horse flies responded maximally at the shortest wave length tested, 405 mu and again at 515 mu. The response fell off rapidly toward the red region of the spectrum. Lack of response of tabanids to red light tends to support the hypothesis that horse flies are red blind, atleast when dark adapted so that red is physiologically darker. Bracken showed that spheres of low reflectance, viz. black was attractive to all species of tabanids.

The purpose of this investigation was to determine the influence of filtered highlights on light adapted tabanids. The work by Hanec and Bracken (1962) was carried out on dark adapted horse flies.

The influence of shiny bodies reflecting unfiltered solar highlight from a glossy black hemisphere.

Methods and materials. Two glossy hemispheres with convex surface down, were suspended in Manitoba Horse Fly Traps. The diametric plane was covered with a matte colored corrugated paper. The hemispheres were tethered. Under one hemisphere a concave chrome-surfaced door knob, two inches in diameter was placed in such a manner that it reflected the image of the sun on to the hemisphere. The highlight was visible from all directions. The intensity and the size of the solar image was much weaker and smaller than that perceived on a glossy sphere.

In a subsequent experiment, mirrors were used as the reflecting surface beneath the hemispheres. In this experiment, round shaving mirrors 4 3/4 inches in diameter were used. One mirror had a flat surface and one had a concave surface. In this experiment, three traps were set up, but after one replicate the concave mirror was removed because it focussed enough heat on the hemisphere to damage it, so that only the two traps were used to complete the experiment. The glossy black hemispheres were tethered, and their diametric plane covered with matte black paper. In both experiments, the positions were alternated.

Results and discussion. In the first experiment, two replicates were run. The trap with the hemisphere reflecting a highlight captured 1,248 horse flies, whereas the trap bearing a hemisphere with no highlight captured 997. The Student's "t" test at the 5% level should no significant difference between the two treatments. However, the hemisphere with a highlight caught 251 more, so that the highlight may have been a contributing factor. Since the highlight appeared weak and small, the door knob was replaced by mirrors. At the start of the experiment, three traps were set up. Beneath the second hemisphere was placed a concave mirror which focussed a very intense and bright highlight on the hemisphere. This highlight was approximately an inch in diameter. Beneath the third hemisphere was placed a flat mirror which reflected on the hemisphere a large highlight, not very intense, and within this weak highlight was the solar image, intense and bright. The highlight from the two hemispheres was directional for a period of three hours, so that the highlight was not visible from all directions. The highlight was more intense to the naked eye than that perceived from a glossy sphere convex upwards.

After one replicate, the trap bearing the concave mirror was dismantled, since the concave mirror focussed the light on the perspex hemisphere which caused a section of it to melt or burn. However, the counts for the first replicate showed 759 for the concave mirror, to 159 for the flat mirror, and 240 for the mirrorless unit. Since only one replicate was run, one cannot infer any conclusions. It does suggest that a very intense highlight may be very attractive to tabanids.

The two remaining traps were continued and determined the captures for a highlight versus no highlight. Four replicates were run, and the captures were 4,845 for the trap with a highlight, and 4,638 for the trap without a highlight. Student's "t" test at the 5% level showed no significant difference.

The influence of filtered highlights on the captures of Tabanidae.

Methods and materials. Five traps were set up at Whitemouth Lake. A glossy black hemisphere with a convex surface down was suspended from a Manitoba Horse Fly Trap in each case. All the hemispheres were tethered. The reflecting object beneath the hemisphere consisted of a spherical glass mirror, 12 inches in diameter. The filters were made of 10 mil acetate, and were cut in strips 7 inches by 4 feet. The filters were suspended over the glazed ball in an arc in such a manner that the light rays from the sun were normal to the filter. This was necessary so that the solar image would not be reflected from the surface of the filter on to the hemisphere, but that the solar image from the spherical mirror would be reflected on to the hemisphere.

In the first experiment, red, blue, and yellow filters were used. Five replicates were run, and after each replicate the position of each silhouette and filter was changed. The captures were removed after the no-return chambers were approximately three quarters full.

In the second experiment, the yellow filter was substituted by a green filter,and again five replicates were run, with the positional changes after each replicate.

The intensity of the filtered light was determined by a Weston Illumination meter. The intensity was standardized to one level by adding more filter sheets to a particular filter requiring a lower intensity. Hense, one sheet of red filter, two sheets of blue filter, four sheets of yellow filters, and one sheet of a green filter were used. By the use of a prism, it was determined that the red filter transmitted red only; the blue filter transmitted yellow, green, blue and violet; the green filter transmitted yellow, green and blue; and the yellow filter transmitted red, or ange and yellow.

Results and discussion. The results are illustrated in Table XIIA and Table XIIB. There is no significant difference between any of the treatments in either experiment according to Duncan's New Multiple Range test at the 5% level. The highlight from the hemisphere due to the spherical

TABLE XIIA

CAPTURES OF TABANIDAE IN TRAPS FITTED WITH RED, BLUE, AND YELLOW FILTERS

Description	Total Captures	Transformed Means*
Red	5,945	3,028
Blue	5,002	2.937
Yellow	4,872	2.946
No filter	5,636	3.037
No highlight	4,176	2.894

*Based on transformation of captures to logarithms. Duncan's New Multiple Range Test at the 5% level and the 1% level, shows no significant difference between any of the means.

TABLE XIIB

CAPTURES OF TABANIDAE IN TRAPS BEARING RED, GREEN, AND BLUE FILTERS

Description	Total Captures	Transformed Means*
Red	6,435	3.0936
Blue	6,080	3.0677
Green	4,994	2.9596
No filter	6,165	3.0840
No highlight	5,104	2.9777

*Based on transformation of captures to logarithms.

Duncan's New Multiple Range Test at the 5% level and the 1% level shows no significant difference between any of the treatments.

mirror is not very intense nor large in area, but it can be viewed from all directions.

There is no significant difference between the no filter trap and the no highlight trap, which agrees with the results obtained from the two previous experiments. This would imply that the highlight is too weak to make the silhouette more attractive than the hemisphere without the reflecting body beneath it.

Another experiment was set up to study the influence of the filtered highlight on the capture of tabanids. Four traps were set up near the area where the other filter experiments were run. The reflecting object beneath the hemisphere was a convex mirror, 13 inches in diameter. In one trap, a red filter was placed over the mirror; in the second trap a green filter was placed over the mirror, in the third trap, there was a mirror without any filter; in the fourth trap there was no mirror. The filters were made of perspex, 12 inches wide by four feet long. They were placed over the convex mirrors in the form of an arc, with the surface of the filter normal to the rays of the sun. The hemispheres used were glossy black, with the diametric plane closed with matte corrugated paper and facing upward. The hemispheres were tethered. (figure 7).

FIGURE 7: Manitoba Horse Fly Traps modified to control quality of light reflected from silhouette.

The red filter transmitted red light only, and the green filter transmitted green and blue light.

Twelve replicates were run with positional changes after each replicate. The position of the silhouettes and filters was randomized. The captures were removed whenever the no-return chamber on one trap was full.

Results and discussion. The results are illustrated in Table XIII. The trap without any reflector beneath the hemisphere (no highlight) caught significantly fewer flies than the other three traps with highlights. This provides further evidence that a highlight significantly increases the attractancy of a glossy black silhouette.

The red highlight and the green highlight attracted significantly more tabanids than the unfiltered highlight. This significant difference implies that the spectral quality of the highlight or the intensity of the highlight or both are important. A tentative hypothesis arises, that if the intensity of the highlight is too high it may decrease the attractancy of the silhouette. Another tentative hypothesis is that ultraviolet inhibits the effect of the highlight since the filters reduce considerably the amount of ultraviolet light reaching the hemispheres.

There was no significant difference between the attractancy of the green filter and the red filter. This significant

TABLE XIII

CAPTURES OF TABANIDAE IN TRAPS WITH RED AND GREEN FILTERS

Description	Total Captures	Transformed Means*
Red filter	12,148	2.968
Green filter	11,697	2.970
No filter	10,220	2.852
No highlight	7,749	2.713

*Based on transformation of captures to logarithms.

Duncan's New Multiple Range Test at the 5% level and the 1% level

No highlight   No filter   Green   Red

2.713   2.852 $\underline{2.970 \quad 2.968}$

Any two means underscored by the same line are not significantly different from each other.

Any two means not underscored by the same line are significantly different from each other.

FIGURE 7: Manitoba Horse Fly Traps modified to control quality of light reflected from silhouette.

performance of the green highlight is in contrast with the low attractancy of a green sphere in the field, Bracken _et al_ (1962). The significant captures by the trap with the red filter contrasts with the postulate that horse flies are red blind, Bracken _et al_ (1962).

CHAPTER VII

FLIGHT ACTIVITY

Literature review.

The flight activity of Tabanidae has received little attention, particularly in Manitoba. Twinn, Hocking, McDuffie and Cross (1948) reported that *Tabanus affinis* lost ground only slowly when in pursuit of a train travelling at about 30 m.p.h.; there were no observations on windspeed, and the flies may have been utilizing air currents drawn along with the train.

Hocking (1953) recorded the maximum speeds in continuous flight of *T. affinis* at 375 cm./sec., and the maximum speed in a short burst at 658 cm./sec.

Howell, Eddy and Cuff (1949) reported that temperature and rainfall appeared to be the most important factors affecting the horse fly population. They found the greatest number of flies on a warm day following two days of rainfall and a week of cool weather, and the smallest number on the coldest day.

Brown and Morrison (1955) recorded the highest activity index of horse flies under conditions of high overcast or slight cloud cover characteristic of warm fronts, rather than in full sunlight. They state that activity almost ceased when the air temperature fell to 60°F., even in full sunlight. They also reported that wind speeds exceeding 20 m.p.h., commenced to decrease the tabanid activity.

Miller (1951) found at Churchill, Manitoba, that the highest average activities were encountered in the temperature range of 68° to 73°F., but that activity increased continuously, as the light intensity increased.

Pechuman, Teskey, and Davies (1961) found that tabanids are most active on warm sunny days, with the number of attacking females greatly affected by slight drops in temperature, and increase in wind speed, or a reduction in the sunlight. They state further that certain species appear to be crepuscular in habits, and others attack more viciously during the approach of a storm front.

The seasonal distribution of Tabanidae in Manitoba, is divided into three periods, Hanec and Bracken (1964). The first period extends from the end of May to June 14. During this period there was a rapid build-up of the early summer species, which included mainly _Hybomitra metabola_ and fewer _H. nuda_ and _H. illota_.

The second period extends from June 15 to June 30. During this period there was a decrease or disappearance of early species, and emergence of mid-summer species, such as H. lasiophthalma, H. epistates, and H. frontalis.

The Chrysops species generally came out during this period. The third period occurred from July 1 to August. The same species as in the second period predominated. H. typhus became extremely prevalent during July, but diminished rapidly toward the end of the month. H. frontalis and T. similis and a few Chrysops species continued into August.

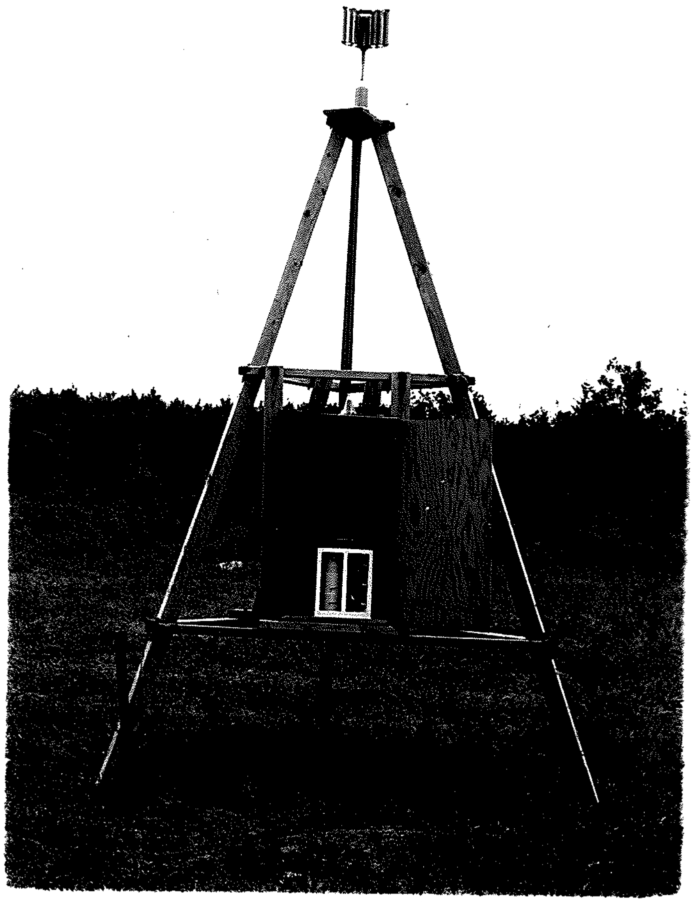
The purpose of this experiment was to study the influence of weather on daily activity of the tabanids as well as the seasonal activity of the tabanids.

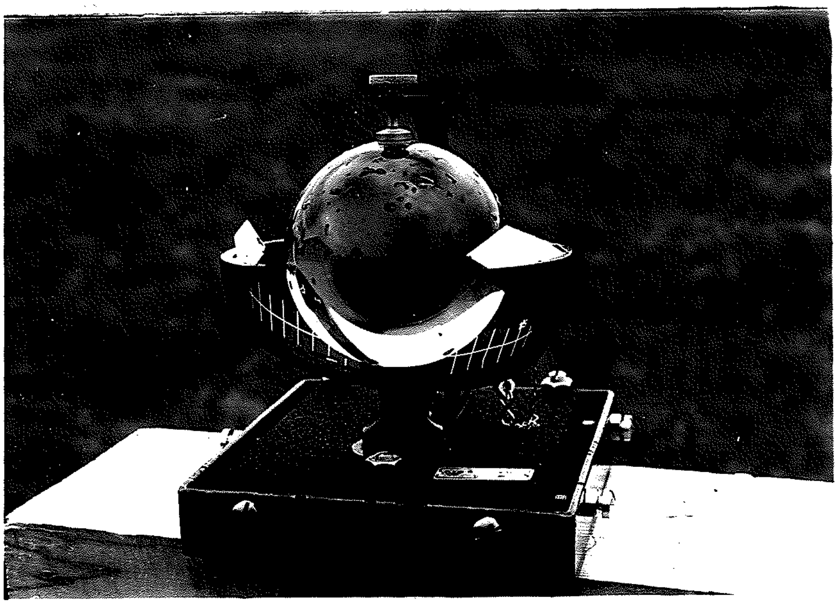
Methods and materials. This experiment was conducted on the north shore of Whitemouth Lake. The soil type was sandy; this area borders the eastern side of the Sandilands Forest Reserve. The flora of this area consisted mainly of Pinus banksiana, Quercus species, Corylus species, Vaccinium species, Populus tremuloides, Betula species, and other short shrubs and grasses. Permanent swamps were located to the north within one mile of the working area. The lake, which has a marshy shoreline, was within ¼ mile of the working area.

The following weather instruments (figure 8) were set up in the field to record the weather data:

(1) Campbell Stokes sunshine recorder No. 1601

FIGURE 8: Instruments used in the collection of weather data for the study of the flight activity of tabanids are the sunshine recorder, wind velocity and wind direction recorder, and baro-thermo-hygrograph.





(2) meteorograph (Baro-thermo-hygrograph) No. 253a

(3) wind measuring device with mechanical transmission, parts No. 1460, 1463, and 1480. These three instruments were manufactured by Wilh. Lambrecht, Göttingen, Germany.

The horse flies and deer flies were captured in a Manitoba Horse Fly Trap, utilizing a glossy black sphere and a no-return chamber. The trap, set near the recording instruments, was not in the best location for capturing the greatest number of tabanids but it was in a location where the captures were still high and where the trap would be exposed to a greater range of climatic factors.

The captures were removed at 1000 hours, 1200 hours, 1400 hours, 1600 hours, 1800 hours, and 2100 hours. These times were not strictly observed each day, since time had to be spent on the other experiments, so that it was difficult to adhere to these times without avoiding the risk of losing important information in the other experiments. Furthermore, during Saturdays, Sundays, and early Mondays, this experiment was not run since no one remained at the field station. An electronic counter was tried for the purpose of counting the tabanids throughout seven days a week, but by the time it was perfected the horse fly season was coming to an end.

Results and discussion: Twenty-four species of tabanids were caught in the flight activity trap. The early species which appeared during the first week of June and lingered on into the beginning of July were *Hybomitra metabola*, *H. nuda* and H. *lasiophthalmus* (figure 9a). H. *epistates* and *H. illota* also appeared early in June but these two species persisted through the whole horse fly season which terminated approximately at the beginning of August. *H. typhus* appeared in the last week of June, rose suddenly to a high peak during the middle of July, and then disappeared towards the end of July. *H. epistates* and *H. typhus* were the two most abundant species comprising approximately 85% of the total captures during July. *H. epistates* was most abundant in the captures during the first week of July while *H. typhus* was most abundant during the second week of July (figure 9b). *H. frontalis* and *Tabanus marginalis* appeared in small numbers during the third week of July and persisted into August.

The key factors involved in this discussion of the flight activity of tabanids are listed as follows:

I. Population repletion factors:
    1. Emergence from larval habitat.
    2. The flights to the adult habitat.

II. Activity:
    3. Sunshine

4. Moisture
5. Temperature
6. Wind

III. Population depletion factors:

7. Mortality
8. Capture by the trap

Undoubtedly, there may be other factors involved in the influence of flight activity, but only the key factors listed will be considered in the intrepretation of the results obtained in this experiment.

It is assumed that the captures of tabanids by the flight activity trap is the measure of the population of tabanids. The available population of tabanids was determined by their emergence in the local region (area from which the horse flies emerge and have some chance of flying in their lifetime close to the trap). The available population at a given time includes tabanids that approach the trap sufficiently close to be attracted.

Climatic factors influence the flight activity very significantly. Sunshine, which affects other climatic factors, directly influences the flight activity of tabanids. The maximum flight activity occurred during the afternoon (figures 10a and 10b) when there was maximum sunshine and high temperatures. Toward evening as the sun descended the flight activity decreased, even though the temperature remained high, and as the sun disappeared, the flight activity ceased. In the early morning as the sun appeared, the horse flies did not fly immediately. Flight activity commenced around 800 hours when the temperature was around 20°C.

Moisture, as rain, played an important role in the flight activity of tabanids. Rain may have an important effect on the emergence rate of tabanids. During rainy days, the adult horse flies did not fly. During the period June 17-20 (figure 11) it drizzled for four days and the flight activity was zero. Relative humidity did not appear to have a strong influence on the captures of tabanids during the day.

Temperature influenced the flight activity very appreciably. Some of the effects of temperature have been discussed under the topic of sunshine. Horse flies were not very active at a temperature below 20°C (figure 11).

Wind did not appear to have an appreciable effect on the flight activity of tabanids. The winds were not exceedingly high during the season, often averaging about seven to ten miles per hour.

The population was depleted throughout the season due to mortality by natural causes as well as captures by the trap. It is difficult to ascertain whether the trap captures were significant in lowering the population. However, for interpreting the fluctuations in captures in figure 11, it is assumed that the trap depletes the current population appreciably.

In figure 11, gaps appear in the lines during June 27-29, July 4-6, and July 11-13. There were no data available for these periods.

No attempt will be made to interpret the small oscillations in the captures which occurred at the beginning of the season. It is assumed that small oscillations probably occur in the emergence of a species before a mass emergence of that species arises.

On June 24, there was a sharp increase in the overall captures (figure 11). This increase can be attributed to a mass emergence of the species _H_. _epistates_ (figure 9b). On June 25 and June 26 the captures leveled off which may be attributed partly to depletion of the current population by the trap. On June 30, there was a very high capture which again can be attributed to mass emergence of the species _H_. _epistates_. On July 1, there was a sharp drop in the captures which can be attributed to the sharp decline in temperature and partly to the depletion of the current population by the trap. On July 2 and 3 there was an increase in the captures again even though the temperature remained relatively the same. This increase may be attributed to continued emergence of *H. epistates* which appeared to be levelling off at this point.

On July 9 and 10, there was a very sharp increase in the captures which corresponded with the appearance of a new species *H. typhus*. This sharp increase can be attributed to mass emergence of this new species. On July 14, and particularly on July 15, the captures decreased even though the temperature remained very high. The decrease in the captures can be attributed partly to the depletion of the current population by the trap and partly possibly to a great decrease in emergence. On July 16, the captures increased sharply which can be attributed to the rise in temperature which soared to 40°C on that day. In the evening of July 16, a severe electrical rainstorm occurred dumping 2½ inches of rain by morning. On July 17 there was a sharp decrease in the captures of tabanids which can be attributed to high mortality due to the storm. After this date there was a slow resurgence of the flight activity but the captures were low. On July 31, the experiment was discontinued as the horse fly activity appeared to come to an end.

Utilizing the assumptions and the key factors influencing the captures, explained in this discussion, a mathematical formula can be written down to explain briefly the relationship between captures and flight activity. This formula merely reveals the picture of flight activity in brief form and is not intended to be used in mathematical manipulations. There are not sufficient data at this time to formulate a precise formula for flight activity and capture relationship.

$C = f\ (P_t)$

where, C = captures

P_t = population in flight near the trap at a particular time

and $P_t = f(A)\int(E-M)dt$

where, E = rate of emergence up to a particular time

M = rate of mortality by all causes up to the particular time.

A = activity factors - temperature, etc.

The average temperatures (figure 9a, 9b and 11) were determined by the use of a planimeter No. 33/90031.

<u>Example</u>: July 2

The constant of the planimeter = .0105

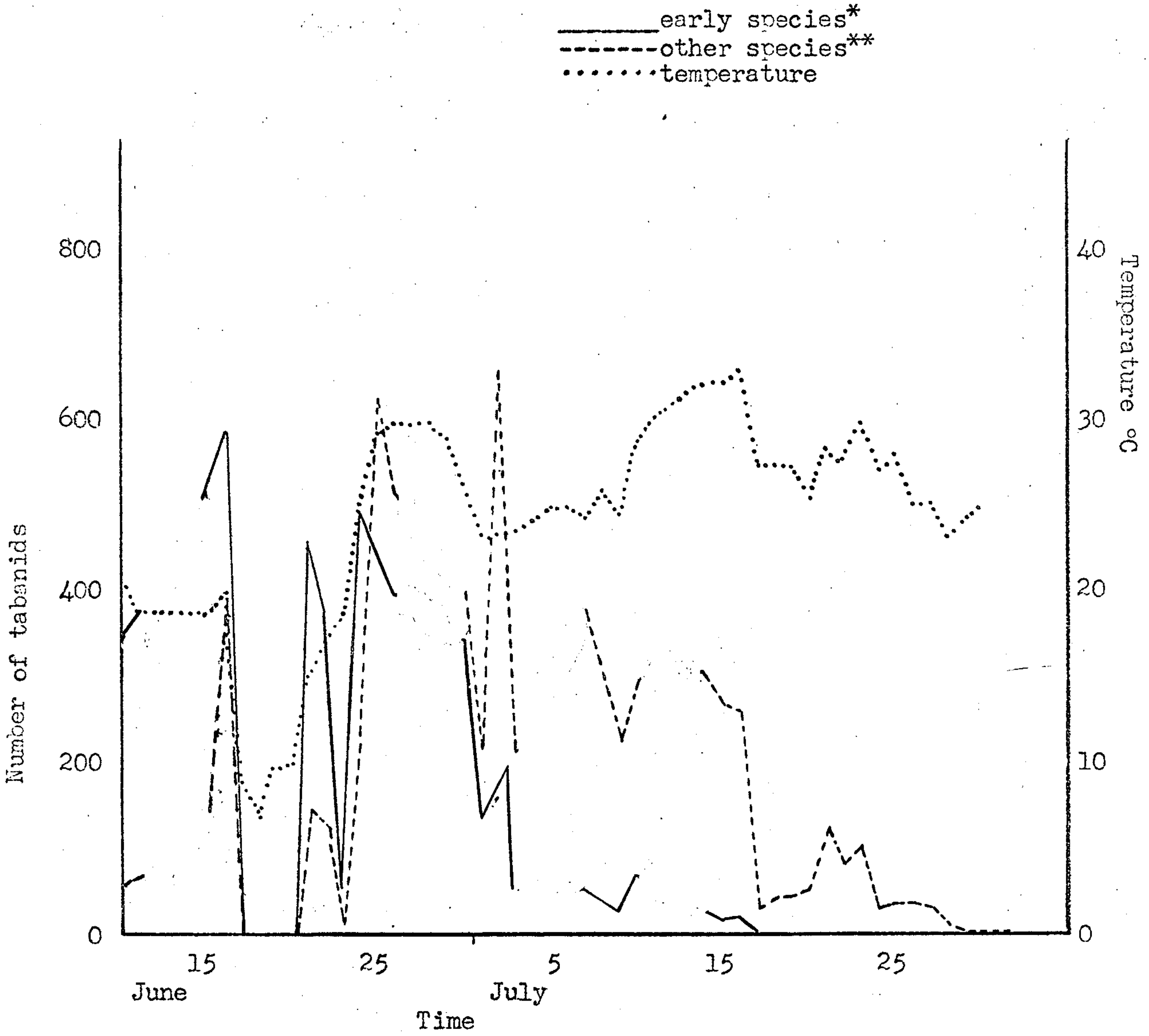
The area of the space bounded by the temperature trace using the 10° line as the base line was (287x.0105) square inches.

The average height = $\frac{287 \times .0105}{5.875}$ inches where the base was 5.875 inches in length.

The number of degrees per inch height was $\frac{480}{19}{}^{\circ}$

The average temperature = $\frac{287 \times .0105 \times 480}{5.875 \times 19} + 10^{\circ}$

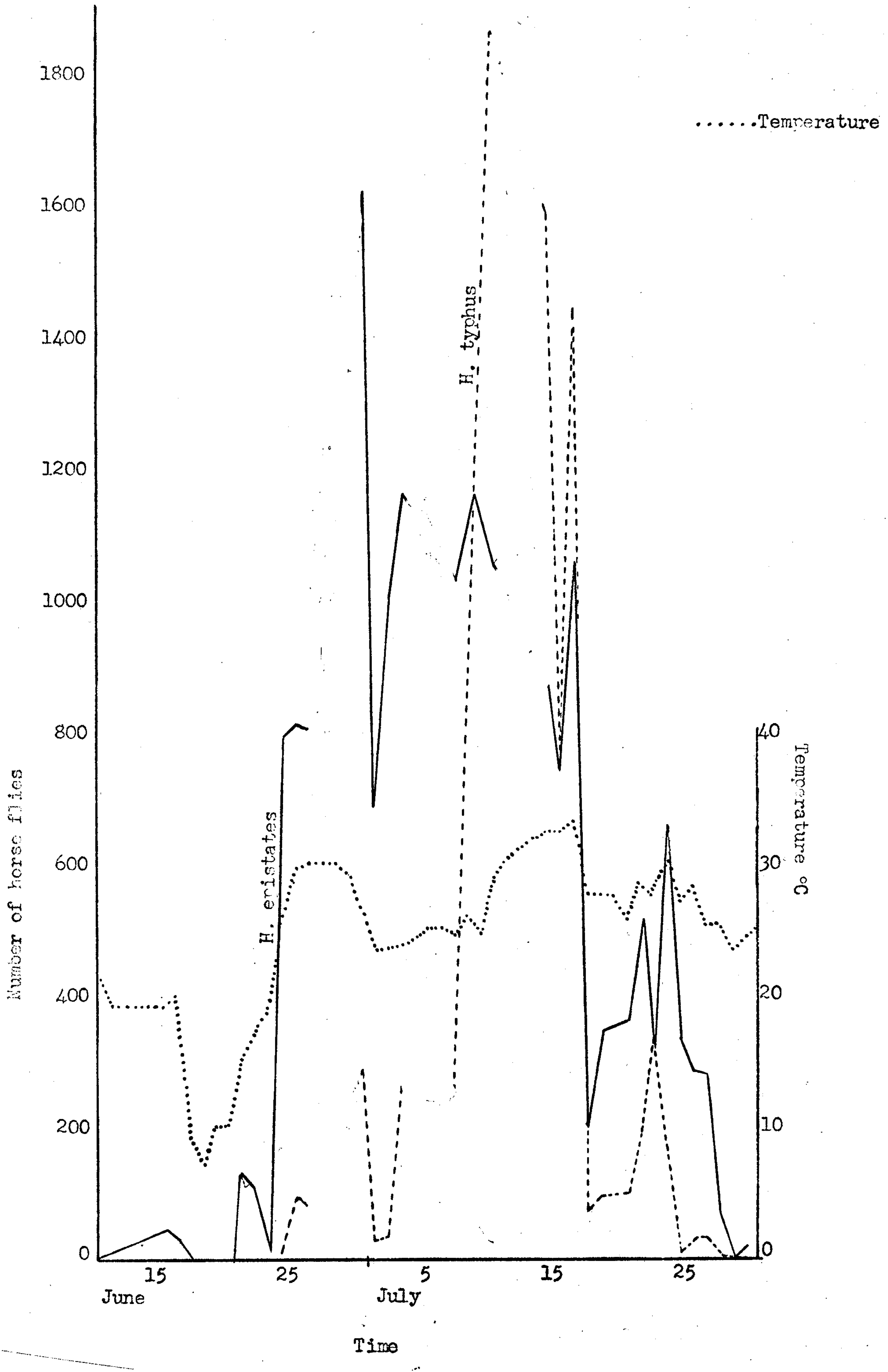
FIGURE 9a: The seasonal distribution of the early species and other species of tabanids except *Hybomitra epistates* and *H. typhus*.



* Early species include: *Hybomitra metabola*, *H. lasiophthalmus*, and *H. nuda*.

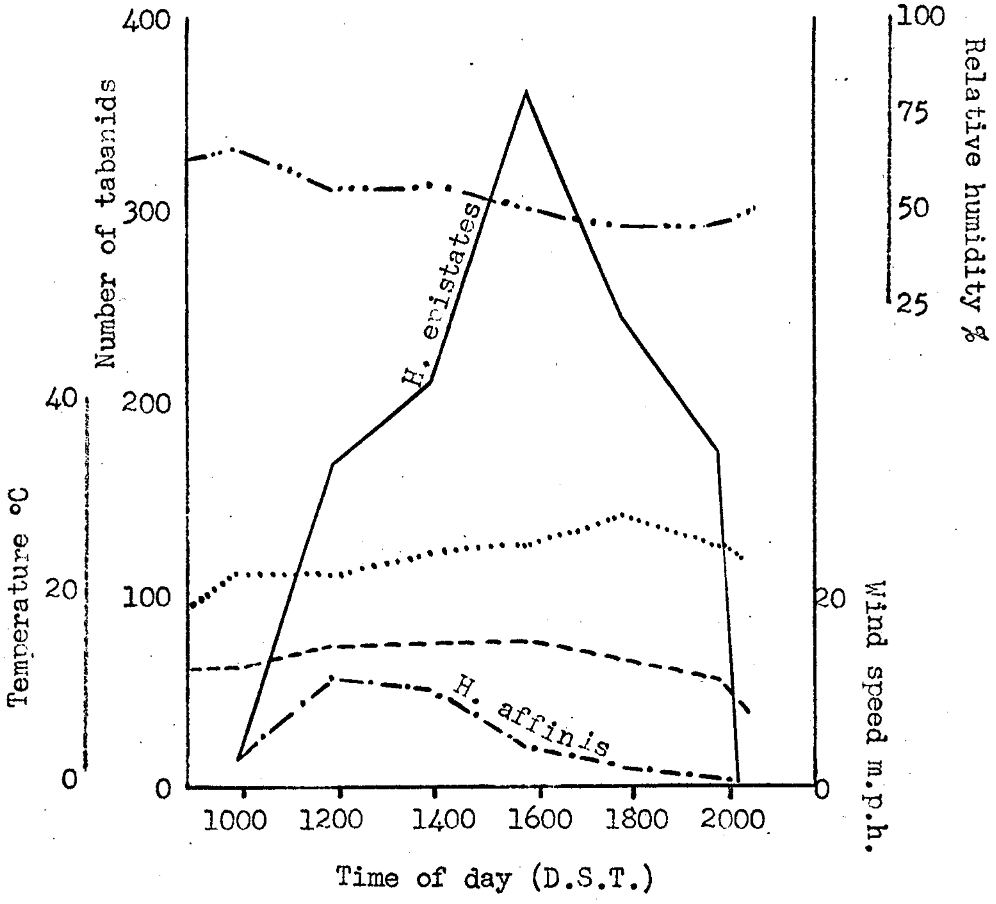
** Other species include: *H. illota*, *H. affinis*, *H. arpadi*, *H. trepida*, *H. zonalis*, *H. frontalis*, *H. microcephala*, *T. marginalis*, *T. similis*, *T. liorhinus*, *Chrysops mitis*, *C. excitans*, *C. indus*, *C. frigidus*, and *Haematopota americana*.

FIGURE 9b: The seasonal distribution of *H. epistates* and *H. typhus*.



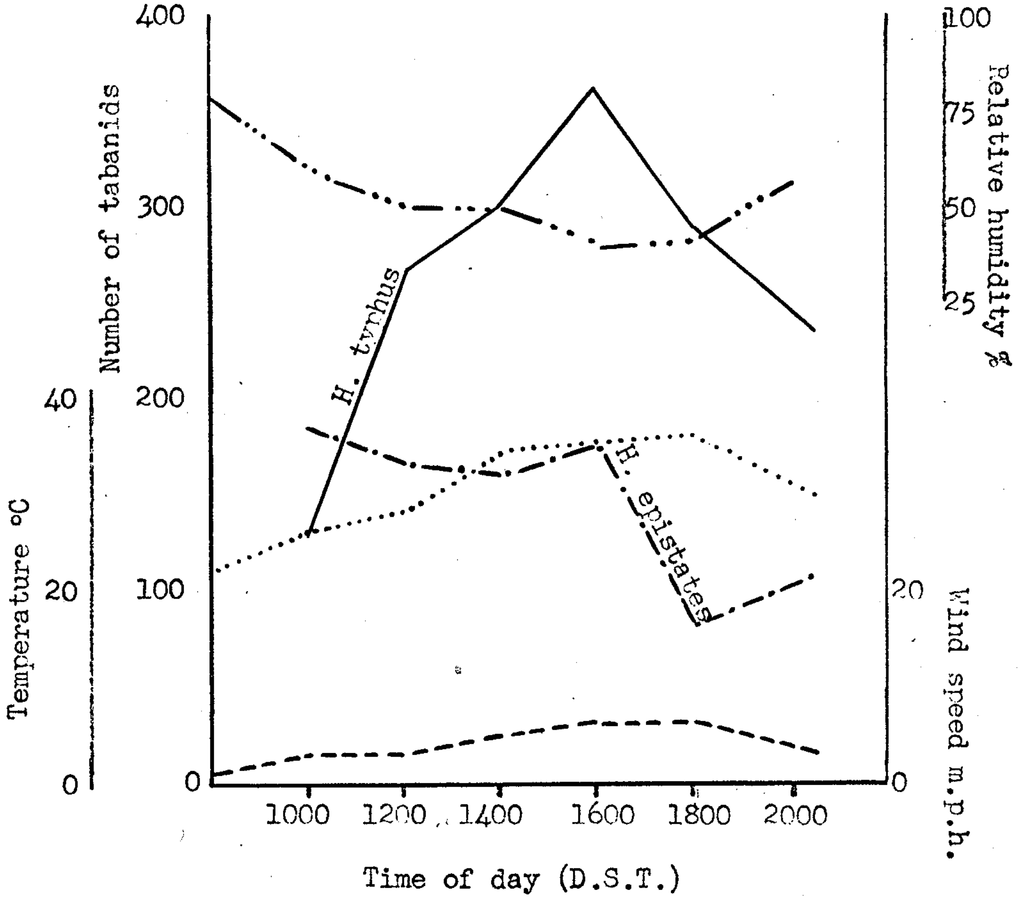
• • • • • Temperature
Number of horse flies
0
200
400
600
800
1000
1200
1400
1600
1800
Temperature °C
0
10
20
30
40
H. eristates
H. typhus
15
25
5
15
25
June
July
Time

FIGURE 10a: The daily distribution of *H. epistates* and *H. affinis*, and the record of temperature, wind and relative humidity, for July 2.



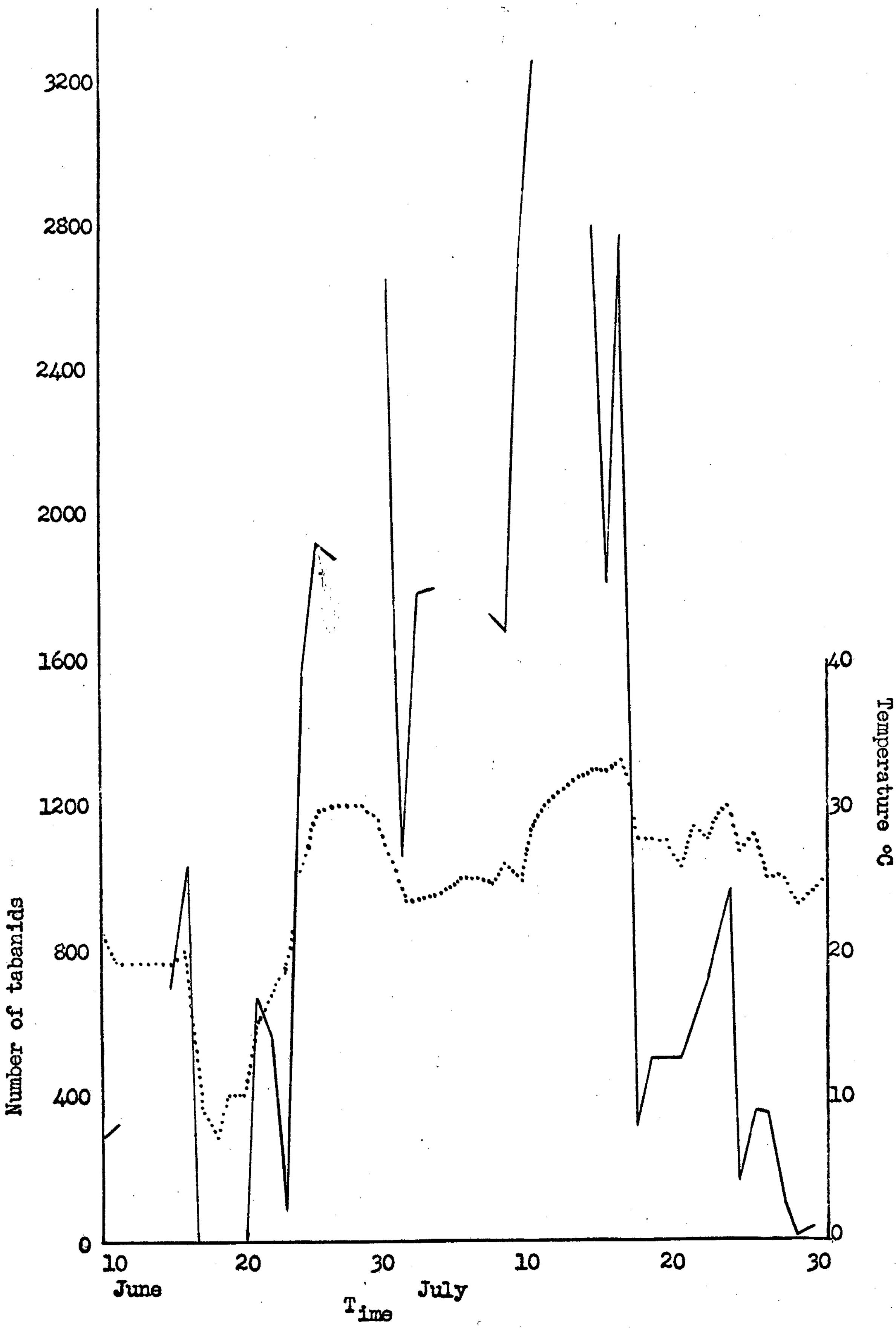
··········Average temperature of the time interval.
----------Average wind speed during the time interval.
—··—Average relative humidity of the time interval.

FIGURE 10b: The daily distribution of *H. epistates* and *H. typhus*, and the record of temperature, wind and relative humidity, for July 14.



········ Average temperature of the time interval.
-------- Average wind speed during the time interval.
——··—— Average relative humidity of the time interval.

FIGURE 11: The captures of tabanids during the horse fly season, and the record of the average daily temperature.



Solid line = number of horse flies
Dotted line = average temperature of the time interval 8:30 a.m. = 9:30 p.m.

CHAPTER VIII

THE ORIENTATION BEHAVIOUR OF STOMOXYS CALCITRANS L.

Literature review

Most people are familiar with biting flies particularly the horse fly, mosquito and the stable fly. The mosquito is usually crepuscular in its biting habits. The horse fly and the stable fly are diurnal feeders as many people well know. The unrest caused to domestic animals by the tabanids and the stable flies is often so severe that many farmers have to keep the cattle in the barn all day.

The stable fly, in some localities is referred to as the August black fly. This name is not officially recognized. Its derivation probably stems from the fact that during August the horse fly season is at an end and the stable flies are then more noticeable. The stable flies are active mainly during July and August (Hanec 1955) but they will linger on into September and October. During July, the horse flies and stable flies are both bothersome but in many cases the horse flies alone are blamed for the unrest caused to domestic animals. This is probably because the horse fly is so much larger than the stable fly and also so numerous at this time.

The stable fly differs from most hematophagous insects in that both sexes feed on blood. The stable flies prefer shady sites (Hanec 1955). He observed that the favorite resting places appeared to be shady sides of building and fences near the barns, on barn ceilings and the darker and cooler parts of the barn. This behaviour was observed even in cooler weather.

Metcalf and Flint (1939) state that stable flies develop in masses of straw, grain, piles of grass, weeds, and other materials that have become water soaked or contaminated with manure.

The purpose of this investigation was to determine the influence of glossy black and matte black spheres on the captures of stable flies.

Methods and materials. The experiment was conducted in August, 1963, at Glenlea, 12 miles south of the University of Manitoba. Four Manitoba Horse Fly Traps were set up by an old abandoned barn. The silhouettes suspended freely from the traps are described as follows:

(a) glossy-glossy sphere - upper and lower glossy black hemispheres clamped together with c-clamps.

(b) glossy-matte sphere - upper glossy black hemisphere and lower matte black hemisphere clamped together.

(c) matte-glossy sphere - upper matte black hemisphere and lower glossy black hemisphere clamped together.

(d) matte-matte sphere - upper and lower matte black hemispheres clamped together.

The position of the spheres was randomized and after each replicate the position of each silhouette was changed to minimize any positional effect. Four replicates were run.

Results and discussion. The results are illustrated in Table XIV. The results indicate that the stable flies are attracted equally well to glossy and matte spheres. Hanec (1955) reported that the stable flies preferred shady spots to sunny locations. He stated, further, that the stable flies most often bite the cattle around the legs. This implies that the stable flies may be flying near the ground. If such is the case, then the spheres, both glossy and matte black, will appear dark on the underside where it is shaded from the sun. Since both silhouettes appear dark both would be as attractive.

The practical Bomyl treated horse fly traps, located on the various farms, captured small numbers of stable flies.

In 1964 three traps were set up near Piney, Manitoba to determine the population of horse flies and other biting flies particularly stable flies. One trap was set up at Horseshoe Lake, about seven miles west of Piney; one trap was located at Edbom's barn near Piney; and one trap was set up at Badger, ten miles north of Piney. Each trap was fitted with a glossy black silhouette and a no-return chamber. The trap at Horseshoe Lake was fitted with a glossy black sphere. The silhouette used at Badger was a glossy black cylinder and the silhouette used at Edbom's barn was a glossy black hemisphere convex upward.

The captures were removed by a local resident at various times through out the season. The captures of stable flies were as follows:

	Badger	Edbom's barn	Horseshoe Lake
July 1 - 31	8	7	22
August 1-September 2	23	155	67

The counts of stable flies for the season do not appear very high but their presence in the traps shows that the Manitoba Horse Fly Trap is effective in attracting them.

TABLE XIV

THE CAPTURES OF STABLE FLIES, *STOMOXYS CALCITRANS* L. IN MANITOBA HORSE FLY TRAPS WITH GLOSSY BLACK AND MATTE BLACK SPHERES

Silhouette	Total Capture	Mean Capture
(a) glossy glossy sphere	182	45.5
(b) glossy matte sphere	131	32.75
(c) matte glossy sphere	117	29.25
(d) matte matte sphere	98	24.5

Duncan's New Multiple Range Test at the 5% level

(d) matte	(c) matte	(b) glossy	(a) glossy
matte	glossy	matte	glossy
24.50	29.25	32.75	45.50

Any two means underscored by the same line are not significantly different from each other.

CHAPTER IX

SUMMARY

Six insecticides were tested on tabanids. The most effective insecticide was Bomyl. It was applied to the interior surface of the canopy at the apical end of the Manitoba Horse Fly Trap. This chemical had a quick lethal knock-down and remained lethal throughout the entire horse fly season without being replenished.

A practical trap was sought to be used in conjunction with the chemical, Bomyl, for the control of tabanids on farms with cattle. A Bomyl-treated Manitoba Horse Fly Trap with a glossy black icosahedron and funnel assembly proved to be very effective. The icosahedron, constructed of sheet metal, served as a silhouette and as a retaining vessel for the dead tabanids. During the last week of June the daily capture per trap on one farm was 7,581 tabanids. On this farm, the total capture for two Bomyl treated traps during the horse fly season was 255,271 tabanids.

The direction from which the tabanids orientate to a silhouette was studied. Four hemispheres were used, each scanned only one of the four right angled sectors of the field 45 degrees on each side of each cardinal direction. The attraction of the silhouettes from all directions was equal.

When a partly glossy hemisphere scanning the field in the forenoon was compared with a partly glossy hemisphere scanning the field in the afternoon, horse flies were attracted to either in nearly equal numbers.

The influence of wind direction on the approach of tabanids to the silhouette was investigated. Two glossy black hemispheres were used, one scanning upwind only and one scanning downwind only. There was no difference in the upwind captures versus the downwind captures. Wind direction, therefore, did not appear to play a significant role in the approach of tabanids to a silhouette.

The orientation of tabanids to objects of different shapes was studies by evaluating captures in Manitoba Horse Fly Traps fitted with these objects. 3-sided, 6-sided, and 12-sided glossy black polyhedra with 30°, 45°, and 60° inclinations of the sides, were compared. The results indicated that the least attractive silhouette comprised of 3 sides and an inclination of 30°. The silhouettes, which had <u>both</u> more than 3 sides and the inclination greater than 30°, were the most attractive, and the silhouettes having only one of these characteristics but not both were intermediate in their attractancy.

The orientation of tabanids to glossy black and matte black spheres and hemispheres was studied. The glossy black hemisphere with the convex upward and the two spheres with the top hemispheres glossy black were significantly more attractive than the matte black spheres and hemispheres and the glossy black hemisphere convex downward. This result confirms that a highlight greatly increases the attractiveness of a dark object.

The orientation of tabanids to various shaped forms including a sphere, icosahedron, torus, hemisphere convex downward with reflecting mirror beneath and hyperboloid was studied. The hyperboloid was least attractive and the other four silhouettes were equally attractive.

The influence of a funnel to the attractiveness of the icosahedron used in the practical Bomyl-treated traps, was investigated. It was shown that the funnel, used in the practical trap located on farmyards, had no effect on the performance of the icosahedron.

The orientation of tabanids to object emitting filtered highlights was investigated. The red highlight and the green highlight were both significantly attractive to tabanids. The influence of the red highlight on the tabanids contrasts with the hypothesis that horse flies are red blind.

The daily and seasonal flight activity of tabanids was studied. Twenty-four species of tabanids were captured. The two major species _H_. _epistates_ and

H. typhus comprised approximately 85% of the total captures during July. H. epistates reached a high peak during the first week of July and H. typhus reached its high peak during the second week of July. During the day, the peak of flight activity was during the period from 2:00 o'clock to 4:00 o'clock p.m., at a time when the sunshine was near maximum and the temperature was approaching maximum.

The key factors which influenced the flight activity of tabanids were emergence, mortality due to all causes and climatic factors, particularly temperature and sunshine. The relationship between captures and the population may be described mathematically although this formula is not intended for mathematical manipulations.

$$C = f\,(P_t)$$

where, C = captures

P_t = population in flight near the trap at a particular time

and $P_t = f(A)\int (E-M)\,dt$

where, E = rate of emergence up to a particular time

M = rate of mortality by all causes up to the particular time

The orientation of stable flies, Stomoxys calcitrans L. to glossy black and matte black spheres was investigated briefly. Glossy black spheres and matte black spheres were equally attractive to stable flies.

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