ORIENTATION, DISPERSAL AND CONTROL OF MOSQUITOES IN THE GREATER WINNIPEG AREA

A

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TABLE OF CONTENTS

CHAPTER PAGE

CHAPTER continued PAGE

CHAPTER PAGE

LIST OF TABLES

LIST OF FIGURES

FIGURE continued PAGE

FIGURE continued PAGE

ABSTRACT

by

Norman Robert Brandt

ORIENTATION, DISPERSAL AND CONTROL OF MOSQUITOES IN THE GREATER WINNIPEG AREA

Mosquitoes orientated significantly in an upwind fashion. In spite of this however, many still flew downwind. Chironomids however, orientated significantly in a downwind direction. On the contrary, many still flew upwind. Moths orientated neither in an upwind or downwind direction. Local air currents including vortices, but also lees influenced the catches within the insect traps and were misleading when determining whether insects flew upwind or downwind.

Mosquitoes (*Aedes aegypti*) attempted to keep the background stationary or moving from the front of the eye backwards during flight. This phenomena was not exhibited by *Aedes vexans* or *Aedes implicatus*.

Mosquito flight (*Aedes aegypti* and *Aedes vexans*) was stimulated by increased wind velocity followed by complete stoppage of wind. This behaviour was not characteristic of *Aedes implicatus*. The flight periods of *Aedes aegypti* were longer than those of *Aedes vexans*.

Dispersal by wind or migration from an external breeding site, was found to influence mosquito distribution in the Greater Winnipeg area.

Certain species of mosquitoes were found to be characteristic of specific areas in and surrounding Metro Winnipeg.

The amount of precipitation had a direct effect on the intensity of the mosquito infestation.

Tests have shown that no resistance to D.D.T., Gamma BHC or dieldrin have developed in the mosquitoes of the Winnipeg area.

Saponin indicated that it could have practical application for mosquito larval control.

CHAPTER I

INTRODUCTION

It is interesting to trace the origin and history of this word 'mosquito' and why it of all others should have come to be used. Clearly the word 'mosquito' is of Spanish or Portuguese origin and it is probably correct to say that it must have come originally from Spanish or Portuguese America. The earliest work dealing with the mosquito in what may perhaps be called medieval literature is Aldrovando (1602), a massive work entitled 'De Animalibus Insectis'. During the period comprised in the latter half of the eighteenth and first half of the nineteenth century, roughly 1750-1850, the mosquito was mostly written about as a natural history object (Christophers, 1960). From that time onward many scientific publications and texts have been written on the biology and the behaviour of the mosquito.

The abundance of the mosquitoes within an area is determined by numerous interacting features of the environment. Water is essential, and collections of transient water are especially productive. Broad acreages of poorly drained land, tidal marshes, floodplains of rivers, ponded areas of prairies, plains, and muskeg are sources of great populations. Streams and pools polluted by animal and various other wastes may yield hords of mosquitoes. Moderate summer temperatures favor populations in all sources. Lastly, ample food for larvae and food for adults near larval sites go far toward making large populations of mosquitoes (Horsfall, 1955).

Mosquitoes are the reservoir for a number of agents pathogenic to man and other animals. Plasmodia, viruses, and roundworms are particularly adaptable to life in mosquitoes. In some cases, bacteria may also be associated with mosquitoes (Horsfall, 1955). Mosquitoes are known to transmit malaria, dengue, yellow fever, filariasis and the viral encephalitis of man, as well as numerous diseases of lower animals (Trembley, 1955).

Mosquitoes are long-legged insects, the females having beadlike antennae and the males having antennae of the plumose type. The four stages of the life cycle are: the egg, the larva, the pupa, and the adults. The larvae are aquatic and are called wrigglers; they have large heads with fairly long antennae, a large swollen thorax, and a cylindrical abdomen (Ross, 1956). The pupae are also aquatic, free living, and active. Both the female and male mosquitoes feed on nectar and water but unfortunately in most species the females seek a blood meal which under natural conditions is necessary for the production of fertile eggs.

Since the female takes a blood meal when the occassion or opportunity presents itself, it is necessary that mosquito control be practised in most parts of the world and expecially in Winnipeg because the climate in this area is well suited to the life habits of the mosquito. In Winnipeg mosquito control is carried out by The Mosquito Abatement Branch, The Metropolitan Corporation of Greater Winnipeg. The area treated by sprays, fogs, dusts, or granules has increased yearly and now blankets approximately 276 square miles. This area is worked by 29 men and 11 trucks equipped with various devices including foggers largely, to eradicate mosquitoes.

CHAPTER II

MOSQUITO BIOLOGY

The Egg, Oviposition, and Hatching

Mosquito eggs are elongate and bilaterally symmetrical and bounded by a thick shell which is pierced at the anterior pole by the micropyle through which the sperm passes during fertilization (Clements, 1963). Mosquito eggs are heavier than water; those laid on water are supported by the surface film and usually bear structures which make them lie in a particular position (Trensz, 1933). At oviposition and for some hours afterwards, the egg shell is a two layered structure but becomes three, when a serosal layer is secreted by the embryo. Mosquito eggs also vary in resistance to external elements as we go from species to species. Many will survive the entire winter (Aedes) and hatch in spring; others can be stored for lengthy periods in a desiccator or a jar. The eggs of Aedes aegypti when first laid are translucent and pure white, but within one or two hours they become grey or even black (Christophers, 1960).

Egg laying is performed in many ways. The eggs may be laid singly on the water surface, as in Anopheles, the female hovering over the water or resting on it. They may be laid in rafts on the water surface as in Culex, Culiseta, and certain Mansonia. Females of Aedes and Psorophora lay their eggs singly either in moist soil in a location liable to flooding or at the edge of small bodies of water such as those occurring in tree holes. Aedine eggs are often coated with a sticky secretion which attaches them to the substrate (Clements, 1963).

In Aedes aegypti the first indication of hatching is the appearance of a slowly - widening transverse crack in the dorsal surface of the egg shell towards the anterior end. Pulsations in the head of the embryo are swallowing movements of the pharynx and the distension of the intestine produces the turgor required to detach the cap from the remainder of the shell. As the cap breaks from the shell, the anterior part of the larva is rapidly extruded and a quick movement of the larva, which is now greatly elongated, finally liberates it from the shell (Christophers, 1960).

Developement

In 5-7 days the larvae mature and transform into pupae. The pupal stage lasts 2-3 days, during which time the body form of the adult develops. At emergence, the pupa surfaces and the outer pupal skin splits, allowing the fully developed mosquito to escape. Since the whole cycle occurs in 9-12 days, many generations are produced during the summer season.

Reproductive Behaviour - Mating

It was not until Roth (1948) investigated the mating behaviour of Aedes aegypti in detail that the significance of sound in mating was clearly demonstrated. A resting female might be surrounded by males, some even touching her, but no male would attempt to copulate with her until she took to flight. Employing tuning forks, the range of frequencies which attracted males of Aedes aegypti was found to be similar to the fundamental frequency of the flight tone of the female. Virgin males will respond to a slightly wider band of frequencies than those which have mated (Roth, 1948).

Males of Culiseta inornata give a mating response after accidentally touching with their legs males or females of their own or other species. Mechanical stimulation of the legs will also elicit a mating response. Swarming is not found in Culiseta inornata but both sexes make repeated short flights among the grass and mating occurs after a male touches a female or after a female flies within about 1 cm. of a male without necessarily touching him; in the latter case mating occurs in flight (Rees and Oniski, 1951; Downes, 1958).

Swarming

The assembly of male mosquitoes in swarms at twilight is a very familiar sight. The swarms frequently develop a few feet above the ground over swarm markers, light or dark objects which contrast with the background. When a female flies into or near a swarm, her flight tone acts as a social releaser so that males are attracted to the source of the sound and seize the female, one copulating with her. If a swarm marker is moved, the swarm moves with it; if the swarm marker becomes smaller, the swarm becomes more compact.

Nielsen and Nielsen (1953) concluded that individual males swarmed at the same place each evening and that each was present for only a fraction of the total duration of the swarm, the time at which any individual swarmed being determined by its sensitivity to light.

Although any marker may attract two or more species, the different species are normally found to form separate swarms owing to the differences in orientation to the marker, for example in height of swarm, or in time of swarming (Downes, 1958).

Downes holds the view that swarming has obvious advantages for mating because the insects are not as widely dispersed. Nielsen and Haeger (1960) point out that in many species which swarm regularly, mating is very rarely seen in swarms although it is often seen away from them, and also that swarming is limited to periods of twilight whereas, in many species which swarm, mating can take place throughout the day.

CHAPTER III

INSECT ORIENTATION TO WIND

Introduction

Kennedy (1939) has made a detailed investigation in the laboratory of the responses of females of *Aedes aegypti* during flight to certain visual stimuli and to wind. He noticed in the absence of wind the mosquitoes were orientated at random. In two experiments when wind was provided 82 and 85% of the active individuals flew against the wind but when the experiment was performed twice in complete darkness only 55 and 63% flew against the wind. It was concluded that free upwind orientation was not an orientation to the wind itself, since it was effectively eliminated in darkness, but it was related to the apparent movement of the background. This was repeated by Kalmus and Hocking (1960).

In January (1963) The United States Department of Agriculture stated in an article on insect light traps that most insects orientate in an upwind fashion.

Felt (1938) stated that insects seldom migrate except when the air is in motion and that locusts depend almost wholly upon the wind, simply using their wings to sustain themselves and generally head into the wind. He also notes that wind drift may carry young Gypsy Moth Caterpillars over the water for 6 and 13 miles respectively. In this case the insects would be travelling passively with the wind.

Shemanchuk, Fredeen, and Kristjanson studied flight range and dispersal habits of Aedes flavescens tagged with radiophosphorous. The majority of tagged adults collected near the release point, and all of those collected at a distance had apparently moved with the prevailing wind.

Atkins in 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 approached the trap without regard to velocity or direction of the wind during flight.

Williams (1930), examined butterflies and he found no relationship between the direction of the flight and that of the wind.

Investigations were carried out on the relationship existing between insect flight and wind direction if any such relationship exists.

SECTION I

Method and Apparatus

The investigations were done 12 miles south of the Fort Garry Campus, at the Glenlea Research Station. The apparatus employed is shown in Figure I. It is a sectional plywood device which was constructed at the university. It was mounted on a stationary stand 15 inches high. Between the stand and the revolving apparatus was an automobile bearing to provide for rotation of the large trap. Within this circular revolving trap were located four New Jersey Light Traps which were facing different directions and were separated from one another by plywood partitions. On the upper surface of the large revolving device was mounted a large wind vane so attached that one of the four New Jersey Traps was always facing into the wind. On the opposite side, another New Jersey Trap was located in the lee side of the rotating trap.

Experiment A

The number of insects was counted and the ratio of the catches of each trap determined. A correlation of catches to wind direction was then attempted.

Experiment B

To eliminate or attempt to eliminate some of the local air currents around the large revolving apparatus, mesh wire was attached to the circumference of the large revolving trap, one foot away from the outer edge. The wires were smeared with a very sticky substance carrying the brand name 'Tanglefoot'. The New Jersey Traps were not removed when the wire mesh was attached. The number of insects entangled were counted and respective ratios of all four sides determined. Figure 2 illustrates how this mesh wire was attached.

The number of insects was counted at the usual interval of 3-4 days unless weather conditions were too unsuitable. Figure 3 illustrates the manner in which the New Jersey Traps were numbered when located in the large revolving apparatus for Experiment A, and Figure 4 illustrates the labelling for Experiment B.

Figure 1. The Large Revolving Apparatus Containing Four New Jersey Mechanical Light Traps

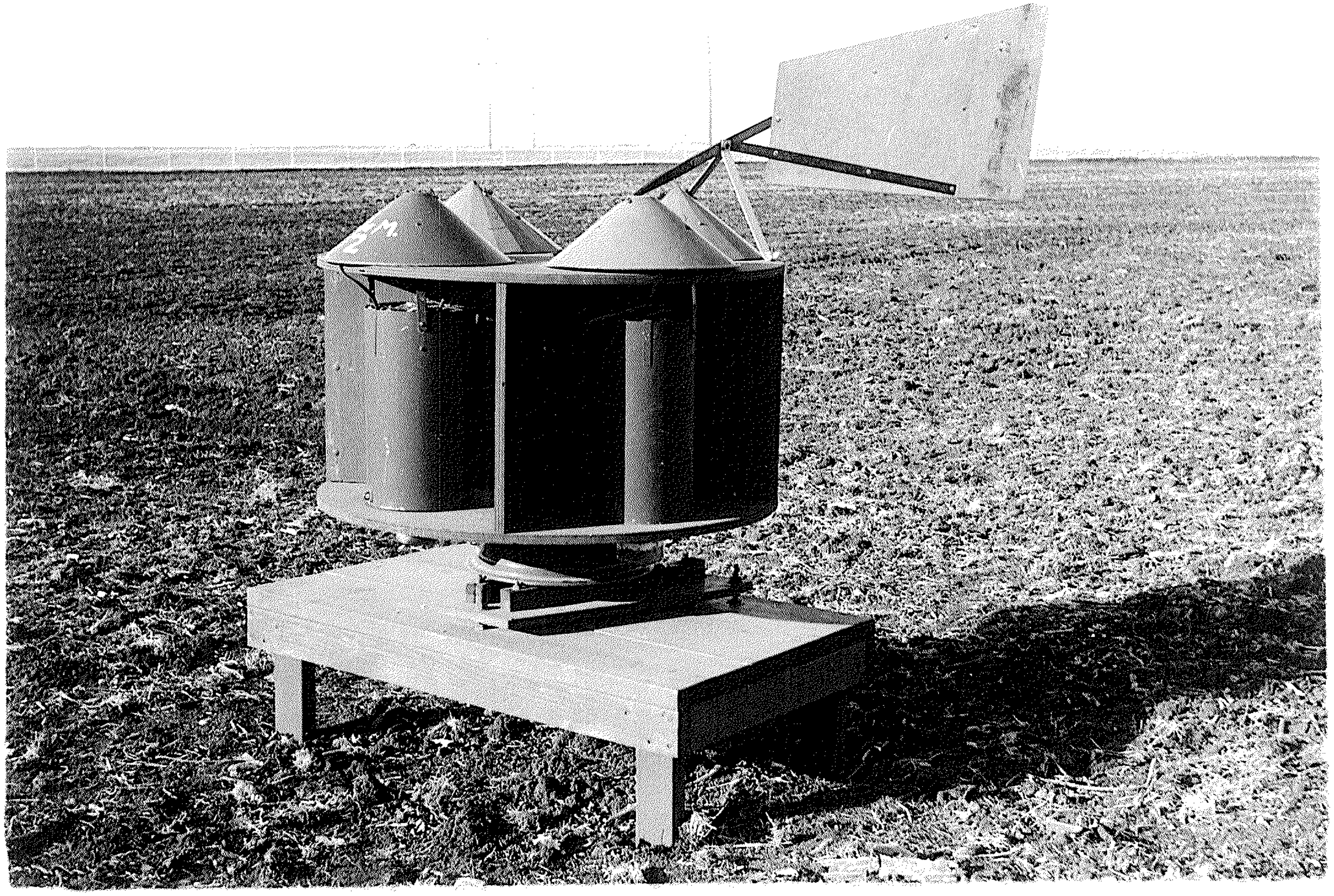


Figure 2. The Large Revolving Apparatus Containing Four New Jersey Mechanical Light Traps Circumvented By Wire Mesh

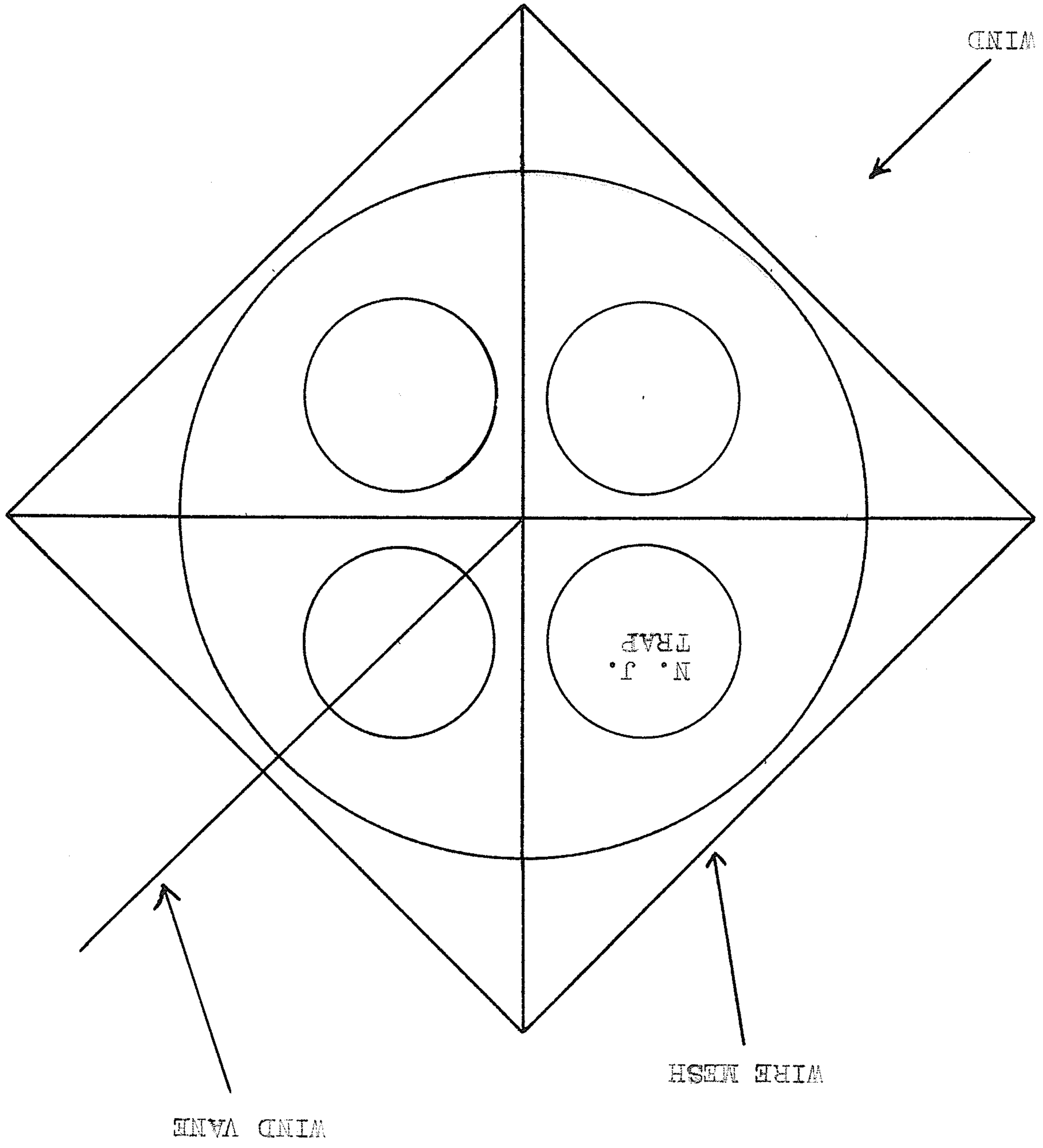

WIND
N. J.
TRAP
WIND VANE
WIRE MESH

Figure 3. The Labelling Of The New Jersey Light Traps Located In The Large Revolving Apparatus For Experiment A - Top View

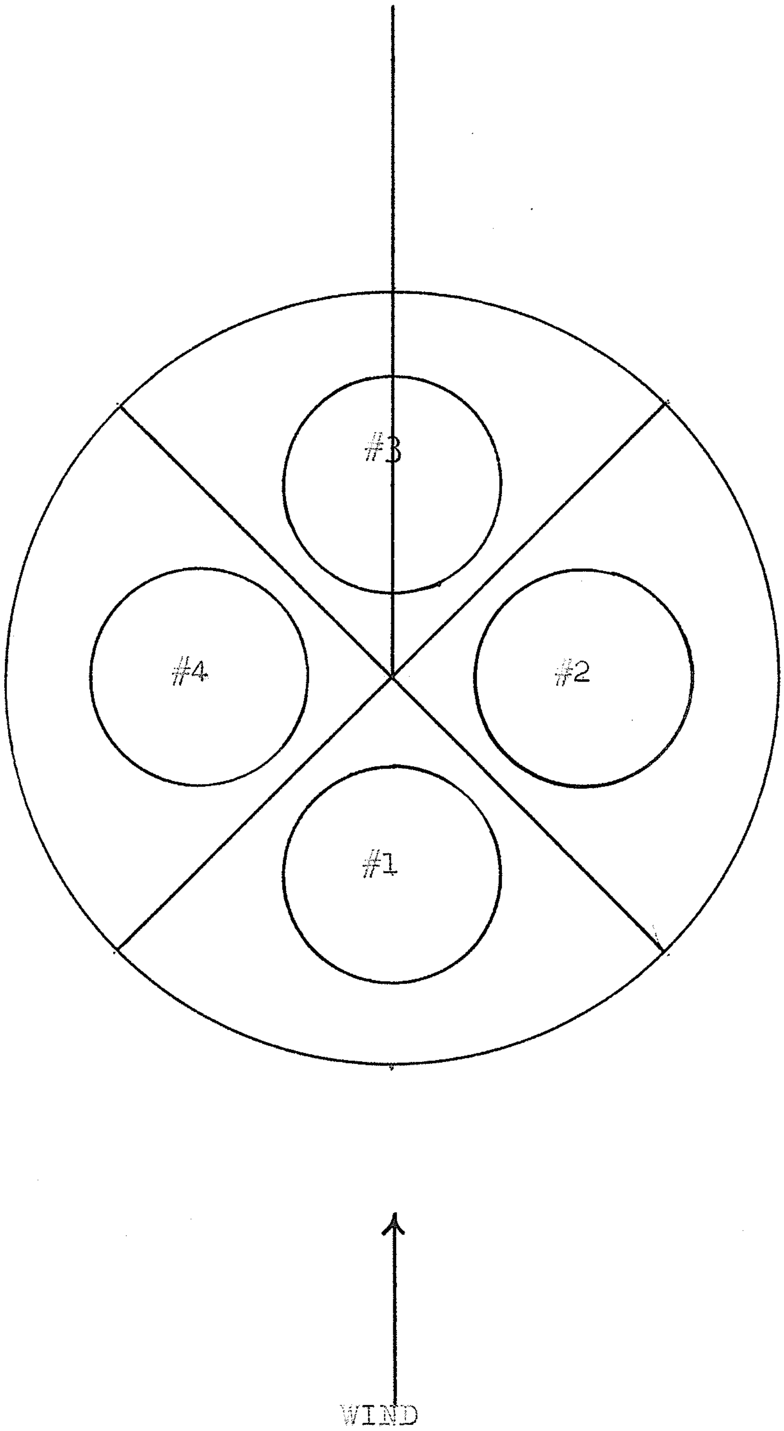
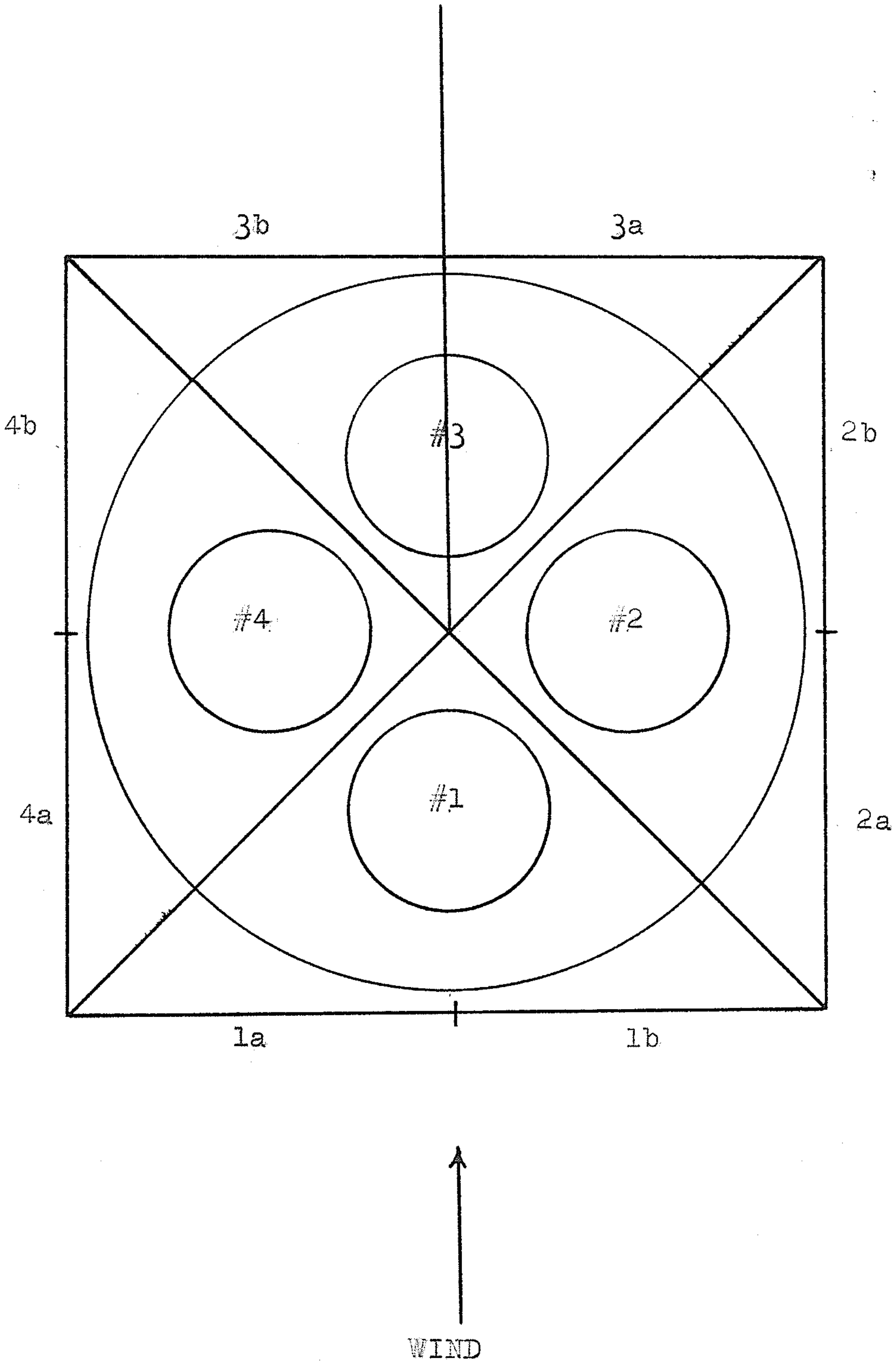

#3
#4
#2
#1
WIND

Figure 4. The Labelling Of The Wire Mesh Surrounding The New Jersey Mechanical Light Traps For Experiment B - Top View



3b
3a
4b
2b
#3
#4
#2
#1
4a
2a
1a
1b
WIND

TABLE IV

Results - Experiment A

Date	No. of Days	Trap Number	Moths	Midges	Mosquitoes	Total Count
10/8/63	3	1	43	172	210	425
" " "	"	2	49	144	248	441
" " "	"	4	119	476	514	1109
" " "	"	3	164	335	1007	1506
13/8/63	3	1	47	28	48	123
" " "	"	2	71	47	264	382
" " "	"	4	99	60	286	445
" " "	"	3	266	316	1439	2021
16/8/63	3	1	19	131	34	184
" " "	"	2	19	22	44	85
" " "	"	4	18	36	47	101
" " "	"	3	63	42	146	251
20/8/63	4	1	24	15	33	72
" " "	"	2	24	16	37	77
" " "	"	4	62	55	176	293
" " "	"	3	61	79	187	327
26/8/63	3	1	18	30	12	60
" " "	"	2	24	48	26	98
" " "	"	4	48	57	52	157
" " "	"	3	128	148	114	390
30/8/63	4	1	12	10	5	27
" " "	"	2	9	19	9	37
" " "	"	4	20	17	20	57
" " "	"	3	61	47	92	200

The final totals of all the traps combined were as follows:

1	163	386	342	891
2	196	296	628	1120
4	366	701	1095	2162
3	743	967	2985	4695

The Ratio of the Combined totals of all the traps for all insects was as follows:

1 : 1.25 : 2.42 : 5.26
#1 #2 #4 #3

The Ratio of the combined totals of all the traps for mosquitoes only was as follows:

1 : 1.83 : 3.20 : 8.72
#1 #2 #4 #3

A chi-square test revealed a significant difference between upwind and downwind traps for mosquitoes, midges and moths at both .01 and .05 levels.

TABLE V

Results - Experiment B

Date	No. of Days	Trap Number	Moths	Midges	Mosquitoes	Total Count	
4/6/63	4	1a	2	105	6	113	221
" " "	"	1b	1	105	2	108	
" " "	"	2a	4	100	10	114	251
" " "	"	2b	3	123	11	137	
" " "	"	4a	0	142	1	143	358
" " "	"	4b	4	205	6	215	
" " "	"	3a	3	166	13	182	390
" " "	"	3b	9	187	12	208	
6/9/63	2	1a	0	76	2	78	151
" " "	"	1b	2	71	0	73	
" " "	"	2a	0	115	1	116	260
" " "	"	2b	0	141	3	144	
" " "	"	4a	1	121	0	122	263
" " "	"	4b	0	140	1	141	
" " "	"	3a	0	212	4	216	469
" " "	"	3b	1	250	2	253	
10/9/63	4	1a	0	74	0	74	138
" " "	"	1b	0	64	0	64	
" " "	"	2a	0	71	0	71	204
" " "	"	2b	0	131	1	132	
" " "	"	4a	1	109	0	110	294
" " "	"	4b	0	173	11	184	
" " "	"	3a	0	203	5	208	444
" " "	"	3b	0	235	1	236	

The final totals of all the traps combined were as follows:

Position	Total
1a	510
1b	
2a	715
2b	
4a	915
4b	
3a	1303
3b	

The Ratio of the combined totals for all species of insects of all the wire meshes was as follows:

1	:	1.4	:	1.79	:	2.55
1a & 1b		2a & 2b		4a & 4b		3a & 3b

The ratio of the combined totals for mosquitoes only was not available because of the few mosquitoes due to the lateness of the season.

Results - Experiment A

The trap #3, located on the leeward side of the large rotating apparatus collected or caught the largest number of insects. To enter this trap, one might suppose that the insect had to fly in an upwind direction. This is the simplest and most obvious interpretation of this experiment. However, other interpretations will follow in the discussion. Fewer insects were caught in traps #2 and #4 and still less in trap #1.

Results - Experiment B

The results were very much the same as Experiment A. However, the ratios between the different traps was not as extreme.

Discussion

From the above results, can it be assumed that insects fly upwind? Does the insect possess enough energy to sustain flight against the wind? The insect could utilize less energy at a given ground speed by flying with the wind.

One of the most important factors which should be considered before making any hard and fast conclusions is the direction and velocity of the wind in various positions close to the large revolving trap. The various wind currents around this large revolving device could to some extent control the distribution of insects in each of these New Jersey Light Traps. This suggestion is brought forth because of the difference in ratios between

Experiment A and Experiment B; the ratios between the light traps in Experiment B being less extreme than those encountered in Experiment A. The difference in wind currents was not as pronounced away from the large revolving apparatus as they were adjacent to it.

Numerous wind readings were taken at various distances around the large revolving trap and some of these will follow in table form. These figures reveal the extent of variation of wind velocities at different locations around the large revolving trap. The various positions at which the readings were taken have been designated by capital letters, and numbers. The wind readings were taken with a cup wind recorder.

Table One

These wind readings were replicated 6 times and were taken 6 inches outward from the circumference or external edge of the large revolving apparatus. Figure 5 illustrates the positions at which the wind readings were taken.

Table Two

These wind readings were taken one foot away from the circumference of the large revolving trap and were replicated 5 times. Figure 6 indicates the positions at which the observations were made.

Table Three

In this table the wind readings were taken at various distances to determine the distance at which the flow of air is influenced by this large revolving trap. Four replicates were taken in this instance and the position of the readings is shown in Figure 7.

The large revolving apparatus was so designed that one New Jersey Trap was always located in the lee of the wind. Lighter-bodied insects such as mosquitoes and midges tend to aggregate within the lee of an object. These insects would therefore probably fly into New Jersey Trap #3, because this trap would be the closest and would be easiest to fly into. It would also form the largest image on the insect eye. From all the wind readings it is obvious that the wind velocity is far less within the lee of the trap than anywhere else. The lee of the large revolving device extends for a distance of about three yards, and any insect passing within three yards of the circumference of the large revolving trap, on the lee side of the trap, would be very much more likely to enter trap #3 for the reasons given.

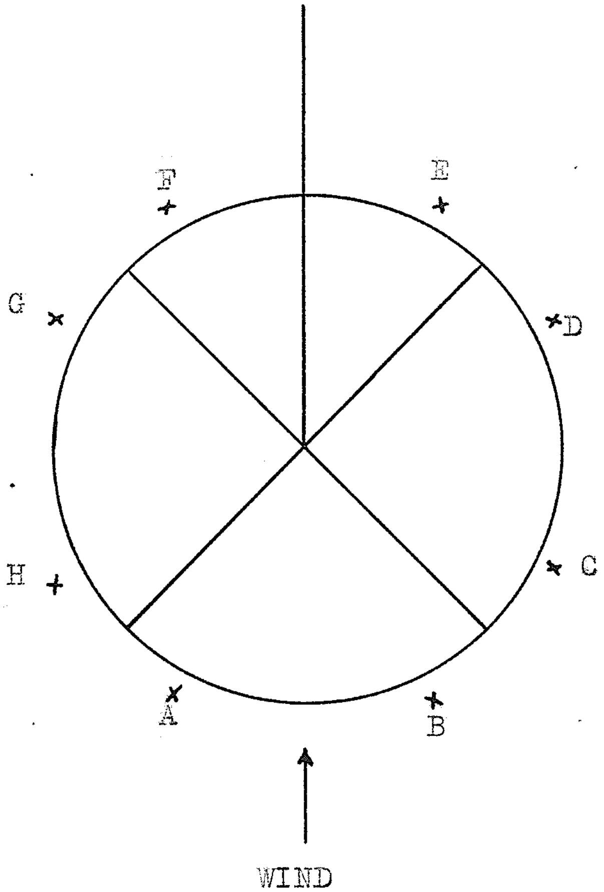
The insects would find it more difficult to enter trap #2 and #4 because of the high wind velocities passing adjacent to these traps which was revealed by the wind readings taken six inches from the large revolving trap and from Figure 9.

Figure 5. The Positions at which the Wind Readings Were Taken for Table I. The Readings Were Taken 6 Inches from the Circumference of the Large Revolving Apparatus

(A) Top View

(B) Side View

A



B

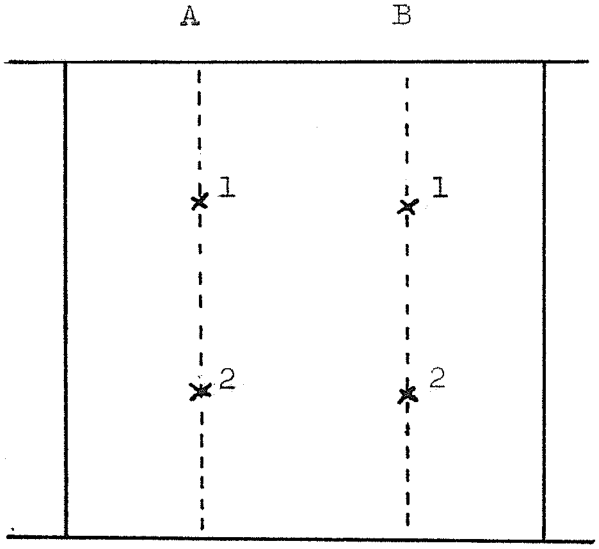
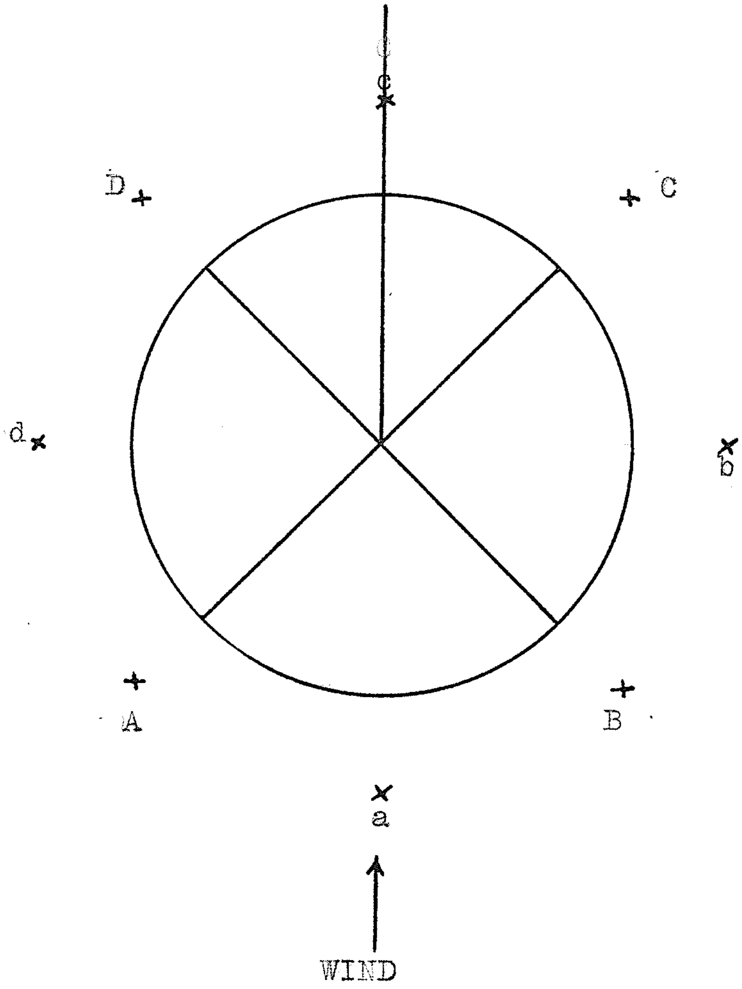


Figure 6. The Positions at which the Wind Readings Were Taken for Table II. These Wind Readings Were Taken One Foot from the Circumference of the Large Revolving Apparatus.

(A) Top View

(B) Side View

A



B

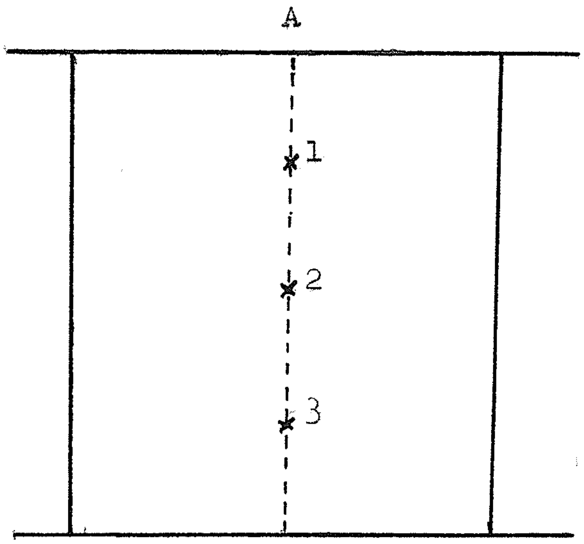
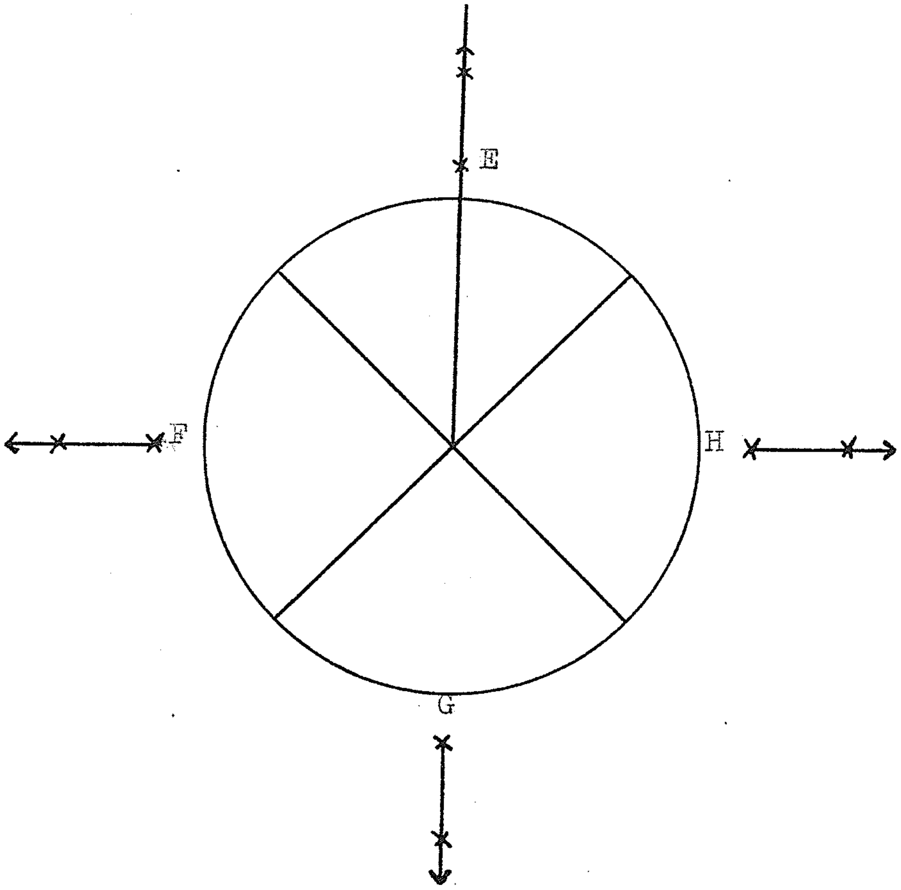


Figure 7. The Position of the Wind Readings Taken for Table III. These Wind Readings Were Taken at Varying Distances from the Trap up to 8 Yards.

(A) Top View

(B) Side View

A



B

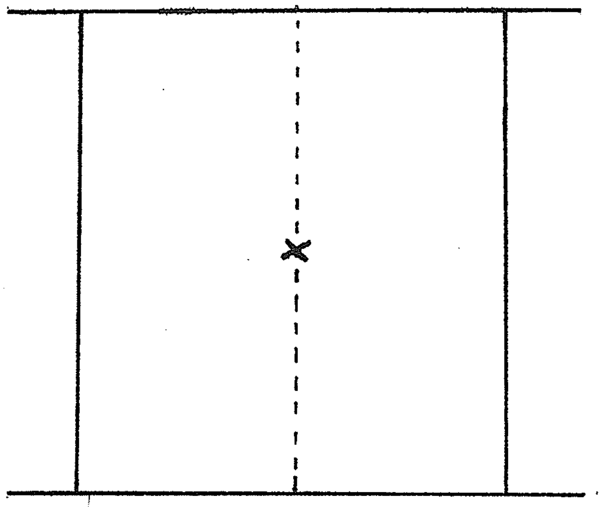


TABLE I

WIND READINGS TAKEN 6" FROM THE LARGE REVOLVING TRAP IN METERS PER SECOND

Position	Total	Means	
(A) 1	836	139.3	Windward
2	682	113.6	
(B) 1	843	140.5	
2	614	102.3	
(C) 1	1253	208.8	Side
2	1013	168.8	
(D) 1	650	108.3	
2	780	130.0	
(E) 1	260	43.3	Leeward
2	273	45.5	
(F) 1	469	78.1	
2	307	51.1	
(G) 1	953	158.8	Side
2	872	145.3	
(H) 1	975	162.5	
2	1104	184.0	

TABLE II

READINGS TAKEN ONE FOOT FROM LARGE REVOLVING TRAP IN METERS PER SECOND

Position		Total	Means
(A)	1	758	151.6
	2	720	144.0
	3	609	121.8
(a)	1	581	116.2
	2	459	91.8
	3	510	102.5
(B)	1	721	144.2
	2	552	110.4
	3	519	103.8
(b)	1	598	119.6
	2	486	97.2
	3	612	122.4
(C)	1	412	82.4
	2	296	59.2
	3	244	48.8
(c)	1	129	25.8
	2	72	14.4
	3	104	20.8
(D)	1	392	78.4
	2	423	84.6
	3	414	82.8
(d)	1	586	117.2
	2	537	107.4
	3	524	104.8

TABLE III

READINGS TAKEN AT VARIOUS DISTANCES FROM THE LARGE REVOLVING TRAP IN METERS PER SECOND

TOTALS

Position	1 ft.	1 yd.	2 yd.	3 yd.	4 yd.	5 yd.	6 yd.	7 yd.	8 yd.
E	306	416	745	786	901	891	978	1019	1050
F	1063	869	903	919	788	914	947	946	844
H	1054	958	1108	1131	1114	1052	1127	1172	1001
G	634	952	931	1027	967	1086	1132	1209	1134

MEANS

E	76.5	104.0	186.2	196.5	225.2	222.7	244.5	254.7	262.5
F	265.7	217.2	225.7	229.7	197.0	228.5	236.7	236.5	211.0
H	263.5	239.5	277.0	282.7	278.5	263.0	281.7	293.0	250.2
G	158.5	238.0	232.7	256.7	241.7	271.5	283.0	302.2	283.5

Standard Error of the Mean - 47.49

OUTREADINGS

READINGS TAKEN 1 FT. - 8 YD. AWAY FROM THE TRAP TO BE USED AS A CONTROL

Replicate 1	318
Replicate 2	321
Replicate 3	256
Replicate 4	295

The wind readings on the windward side of the large revolving trap were found to be less than on the sides of the large revolving trap parallel to the New Jersey Traps #2 and #4. This could be due to the shape of the large revolving trap or to back pressure created when the air blows directly against the frame of the large revolving trap.

The circulation of air around the New Jersey Traps was verified employing tiny pieces of 'kleenex'. These tiny pieces of kleenex were introduced into the air currents flowing around the trap. The air currents around the New Jersey Traps numbered two and four were not as consistent as those encircling trap number one, and these local air currents were almost non-existent around New Jersey Trap #3. These local air currents could perhaps partly explain why New Jersey Trap #3 collected so many more insects than traps numbered one, two and four. The insect would be confronted with less wind resistance when entering trap #3. Figure 8 illustrates the circulation of the air around trap #1 on a windy day.

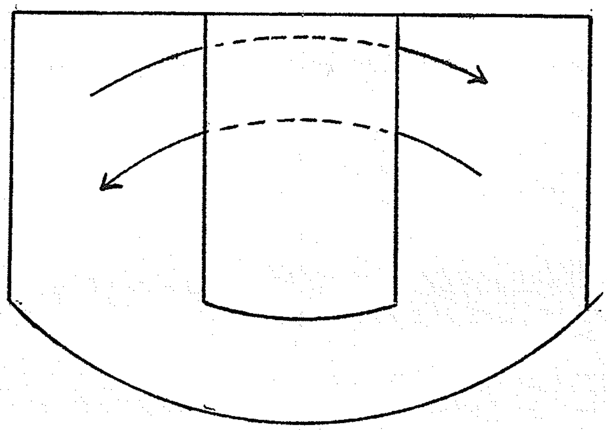
There is still another reason why the insects may not be flying upwind. When the wind is blowing, many different vortices are formed around this large circular revolving insect trap. These vortices differ in direction and velocity in comparison to the wind present. One of the most important vortices formed is found on the lee side of the large revolving trap. The direction of the air currents comprising this vortex is illustrated in Figure 9.

Figure 8. The Circulation of Air around New Jersey Trap #1 on a Windy Day

(A) Front View

(B) Top View

A



B

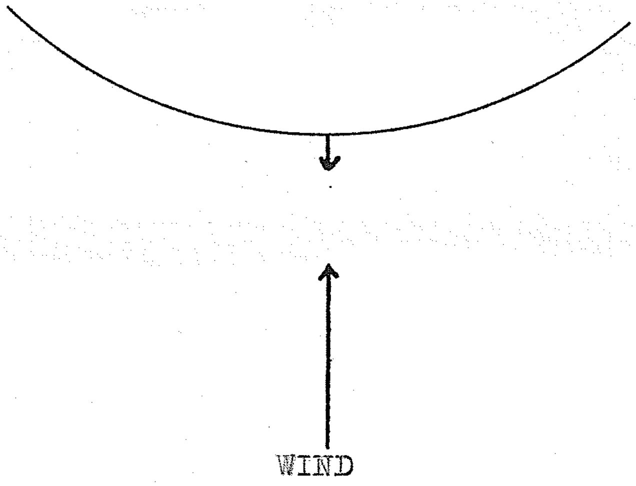
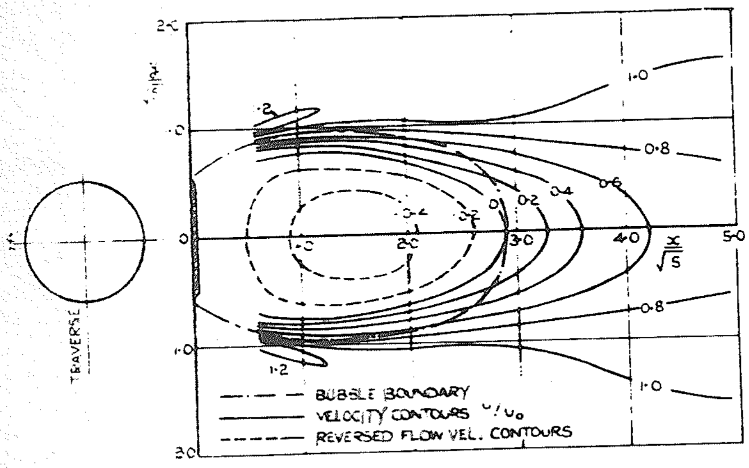
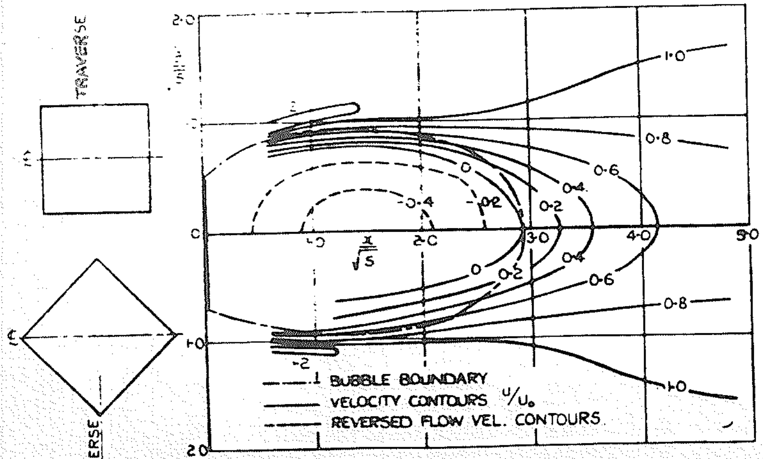


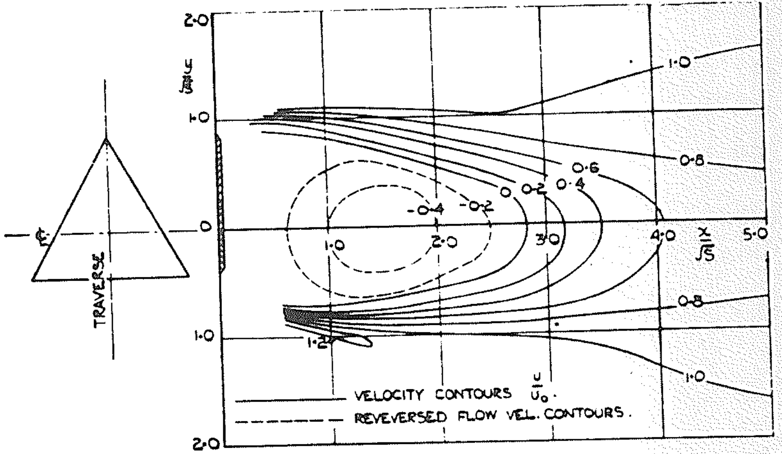
Figure 9. The Wind Direction in the Vortex Formed on the Lee Side of the Large Revolving Insect Trap



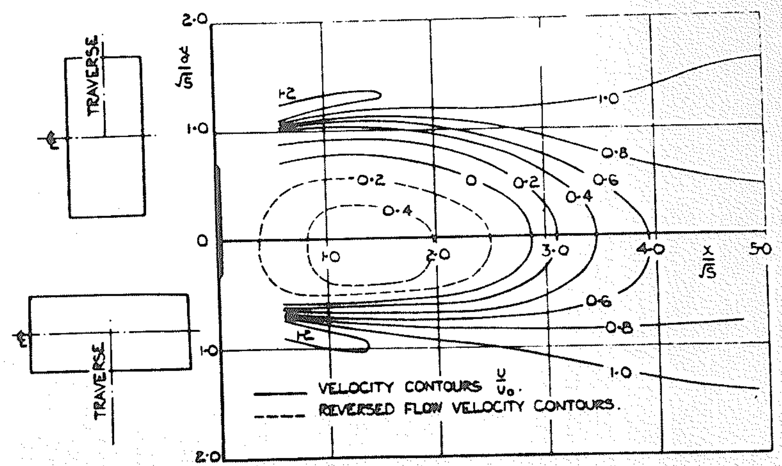
(a) CIRCULAR PLATE (S = 25·1 SQ. IN.)



(b) SQUARE PLATE (A=1·0 S=25·0 SQ. IN)



(C) TRIANGULAR PLATE (S=25·0 SQ. IN).



(d) RECTANGULAR PLATE (A=2·15, S=27·0 SQ. IN.)

FIGS. 6a to 6d. Flow behind flat plates.—Velocity contours.

If insects do fly upwind, why doesn't the insect fly into the wind on the lee side of the large revolving trap? If this were the case, the New Jersey Trap #3 would not collect most of the insects as was shown by the results. If most insects fly upwind, there is still a large number of insects which do not according to the figures obtained from the observations. Also, if the velocity of the air currents comprising the vortex on the lee side of the trap were high enough, the insect could remain in this vortex for some time. This would facilitate the insect's entrance into New Jersey Trap #3.

Conclusion

From the contents of the discussion, it is not quite clearly established whether the three groups of insects fly upwind or downwind. Is the distribution of insects in the traps actually due to upwind flight or is it due to the various wind currents encircling the large revolving trap? In an effort to clear up this ambiguity, different directional traps were designed and tested the following summer.

SECTION II

Method and Apparatus

The following investigations were attempted in the same area as those in Section I. Different directional traps were designed for these experiments and a distant view of one of the traps is shown in Figure 10. The entire directional trap was mounted within a tripod on a plywood frame. These directional traps were customary New Jersey Traps from which the canopy had been removed and was replaced by a different mechanism.

Close-up views of the upwind and downwind traps are illustrated in Figures 11 and 12. The cylindrical mechanism which replaced the canopy was attached to a wind vane and revolved on a ball bearing race. Each cylinder was lined with silver paper to enhance the brightness of the 150 watt bulb used. A narrow slit was cut into the cylinder allowing light rays to pass out only in one direction; either upwind or downwind. Whatever the case, the direction with respect to the wind was controlled by the wind vane attached to the revolving cylinder. Enough space was allowed below the revolving cylinder to enable insects to be sucked down into the trap. The light rays emanating from this space however, were only visible from a short distance and would only affect local insects or insects in the immediate vicinity of the trap. The two traps (upwind and downwind) were placed a distance of approximately 100 feet apart.

A small building was located in the vicinity of the directional traps which contained wind-recording equipment (Figures 13 and 14). Simultaneous wind records were obtained for both velocity and direction when the traps were operating. An attempt was made to correlate wind direction and velocity with the catches obtained.

The directional traps were operational from 8 p.m. to 7 a.m. and were emptied after one night of operation in every case. The mosquitoes, midges and moths were counted in every replicate.

TABLE VI

Results

The results were as follows:

	UPWIND			DOWNWIND		
	Mosq.	Midges	Moths	Mosq.	Midges	Moths
June 29-30	4002	359	31	3288	1174	49
Jun. 30-Jul 1	557	585	67	419	464	38
July 1-2	164	481	38	143	644	47
" 2-3	298	1501	85	445	2508	113
" 9-10	1156	1242	116	473	1025	110
Interchanged Trap Positions						
July 14-15	924	592	60	221	811	85
" 20-21	198	2519	117	126	2408	132
" 21-22	201	2522	100	107	3017	69
" 22-23	131	417	27	48	491	21
" 28-29	11	161	39	6	167	19
Totals	7642	10379	680	5276	12709	683
Grand Totals		18701			18668	

Using a Chi - Square Test, a significant difference was found for mosquitoes and midges between upwind and downwind directions at both .05 and .01 levels. There was no significant difference for moths between upwind and downwind directions. The total number of insects for both upwind and downwind directions were the same in that they showed no significant difference.

Figure 10. A Distant View of the Newly Designed Directional Trap.

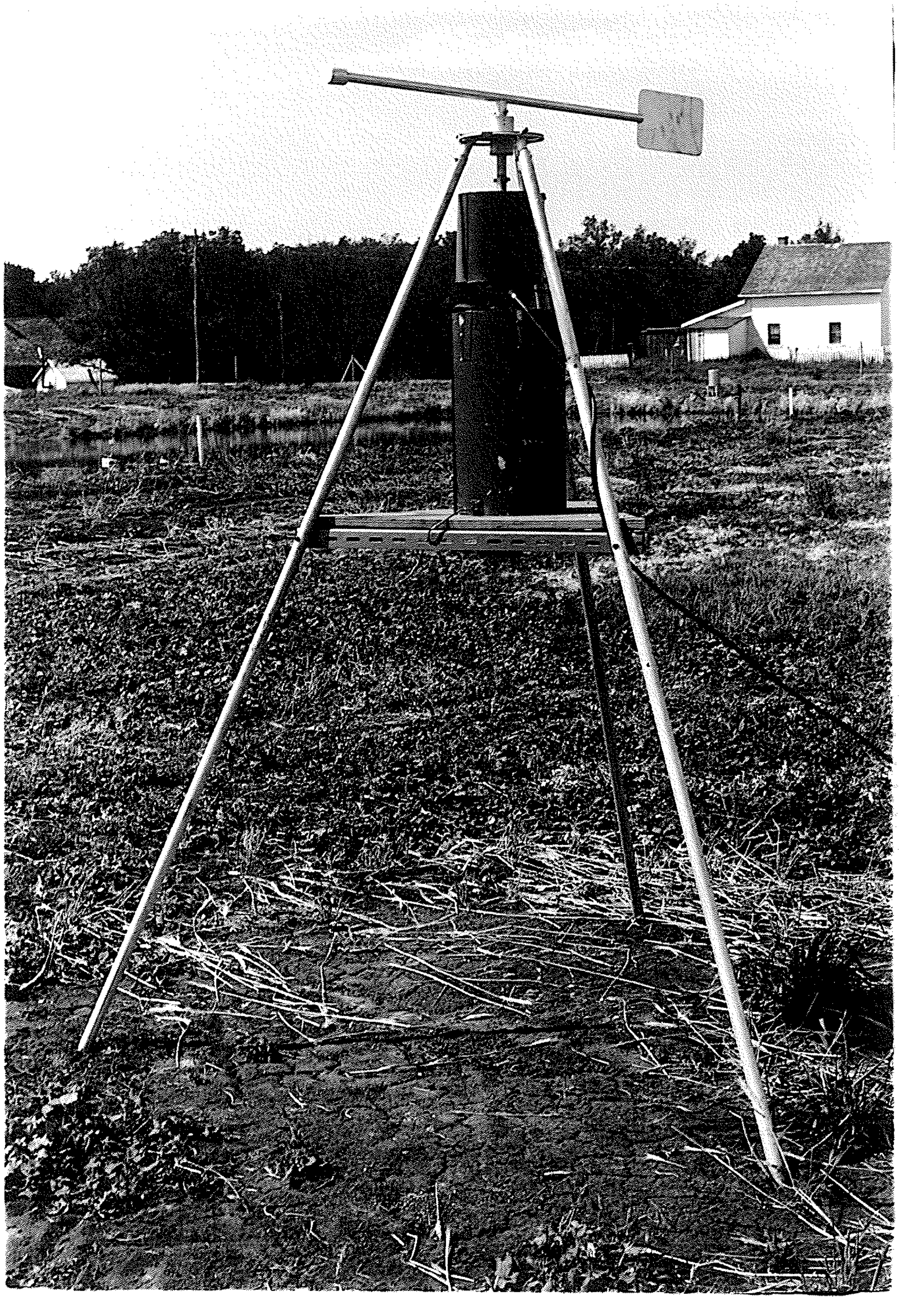


Figure 11. A Close-up View of the Upwind Trap

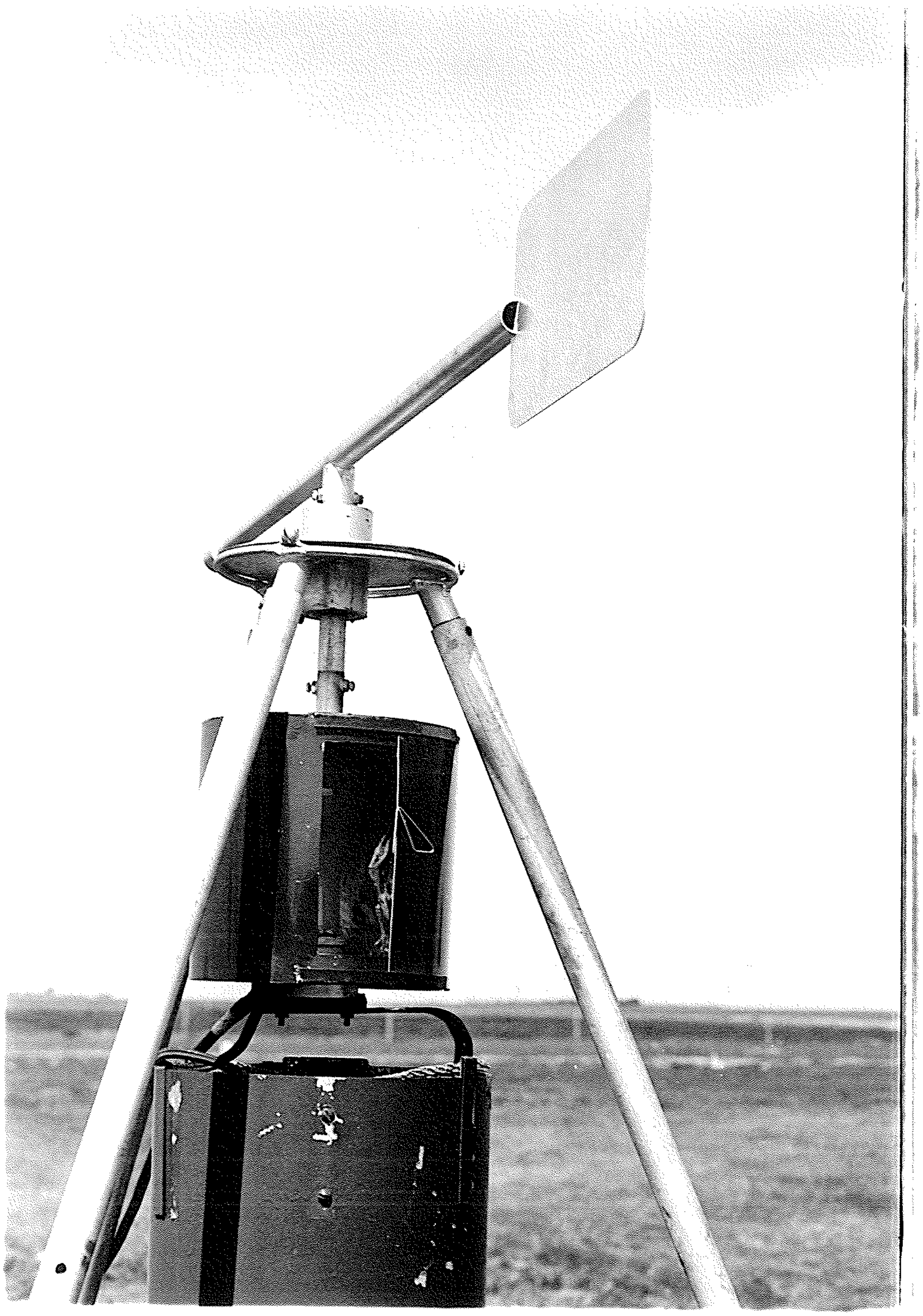


Figure 12. A Close-up View of the Downwind Trap

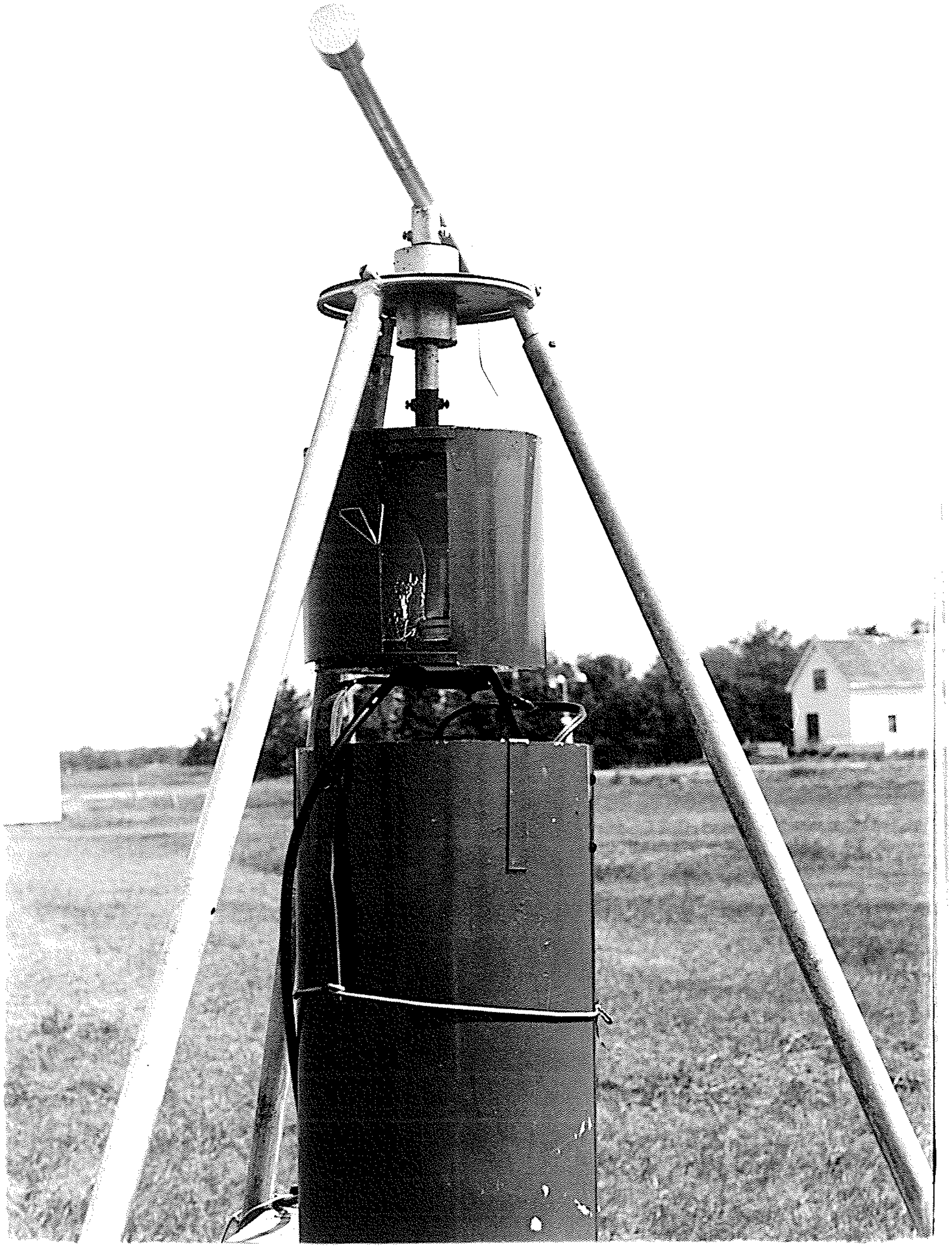


Figure 13. The Wind-Recorder and Chart

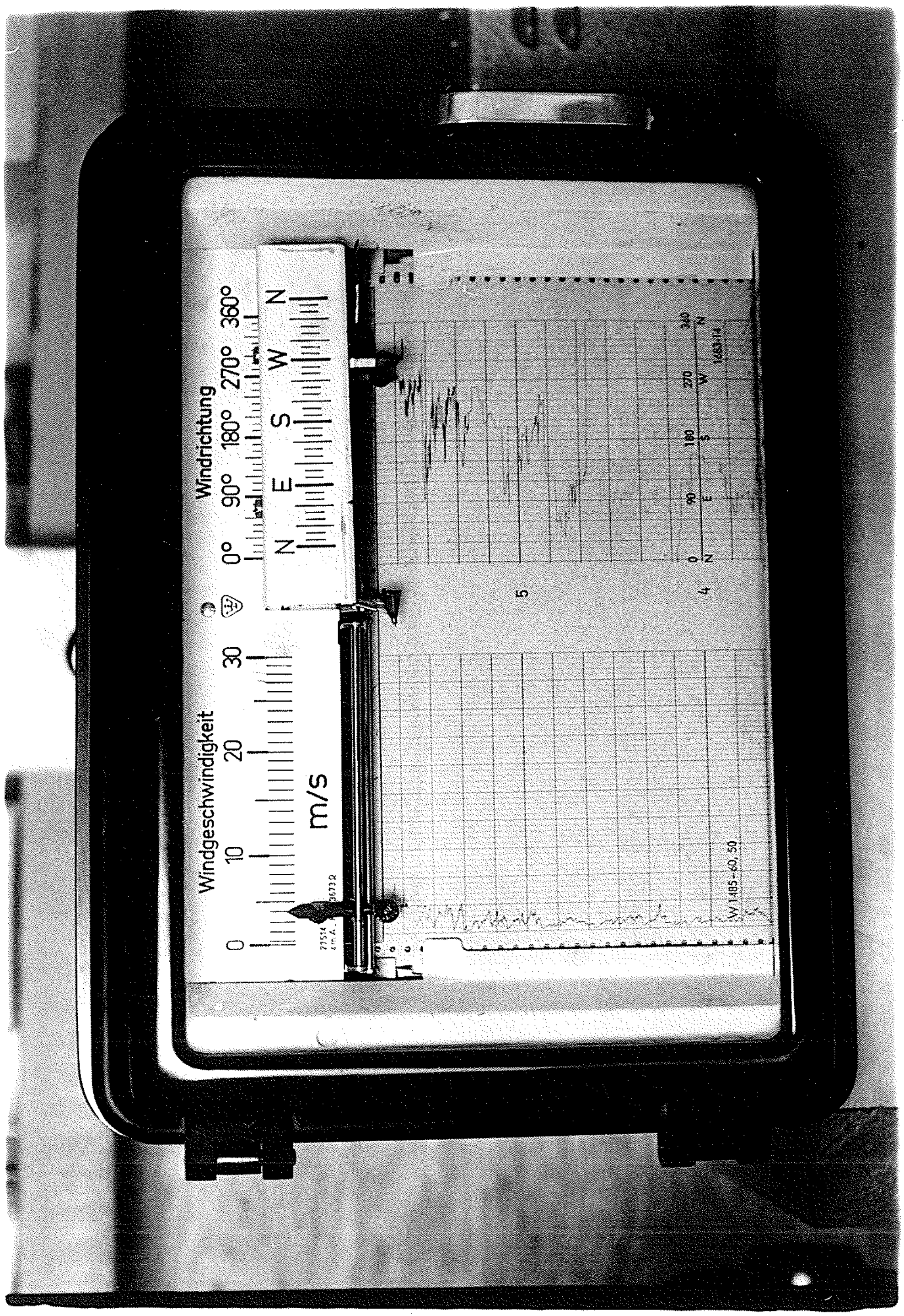
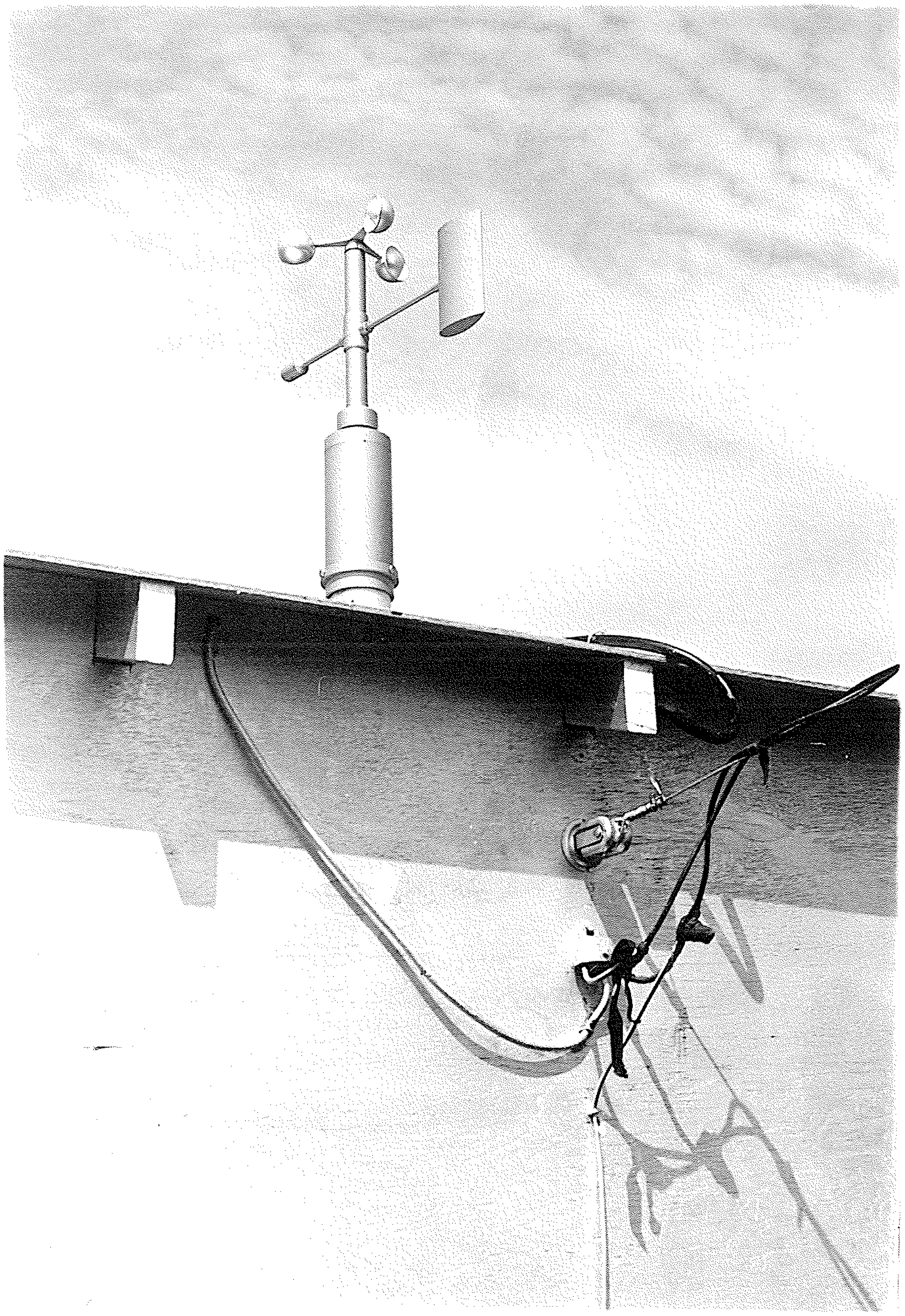

Windgeschwindigkeit
0
10
20
30
m/s
Windrichtung
0°
90°
180°
270°
360°
N
E
S
W
N

Figure 14. Velocity and Directional Components Associated with Wind Recorder Shown in Figure 13.



Discussion

By designing different directional traps, it was possible to drastically reduce the ratios between upwind and downwind catches. The ratio of downwind to upwind catches in the large revolving trap for mosquitoes only was 1 : 8.72. The same ratio for the newly designed directional traps was 1 : 1.44. The downwind to upwind ratio for all species of insects was 1 : 5.26 in the large revolving trap and 1 : 1.01 in the new directional traps. Another important feature is the reversal of chironomid orientation from significant upwind orientation in the large revolving trap to significant downwind orientation in the new directional traps. These preceding ratios and facts prove the great influence exerted by the wind currents surrounding or encircling an insect trap.

The fact that chironomids significantly flew in a downwind direction may suggest that they are weaker fliers than most mosquitoes and may be involuntarily dispersed by the wind.

Only in one case were more mosquitoes found in the downwind trap. In this particular night, (July 2-3) and this was the only night, the air was completely calm for approximately 3 hours. Perhaps by chance the downwind trap collected more mosquitoes than the upwind trap. Also, during this particular night the wind direction was north before the calm. Therefore this means that the light was shining in a southerly direction from the upwind trap. It is possible that 'Static Bias" of the site was involved and more mosquitoes were present south of the directional traps at this particular time.

In 3 replicates, more chironomids were caught in the upwind trap, although the differences between the upwind and downwind traps were not as great as the other 7 replicates. Wind velocity did not seem to differ greatly in these 3 replicates in comparison to the remaining 7.

Conclusions

1. Mosquitoes tend to orientate significantly in an upwind direction. In spite of this however, many still fly downwind.

2. Chironomids tend to orientate significantly in a downwind direction. On the contrary, many still fly upwind.

3. Moths orientate neither in an upwind or downwind fashion.

4. Local air currents including vortices, but also lees influence the catches within insect traps and can be misleading when determining whether insects fly upwind or downwind.

SECTION III

PLOTTING AN INSECT'S FLIGHT PATH

By taking insect flight speed, wind velocity and direction into consideration, it is possible to plot the insect's flight path attracted to a light source on graph paper. In the following figures, "A" represents the attracting light and "B" is the original position of the insect. The insect flight path is a solid line commencing at "B". The following is a list of figures illustrated in the ensuing pages.

Insect Orientation to Light Commencing at Various Positions or Angles Relative to the X-axis

Figure 20 - A 15 degree angle where insect flight speed equals two times the wind velocity.

Figure 21 - A 45 degree angle where insect flight speed equals two times the wind velocity.

Figure 15. Insect Orientation Directly Towards Attracting Light - Insect Flight Speed Equals Wind Velocity

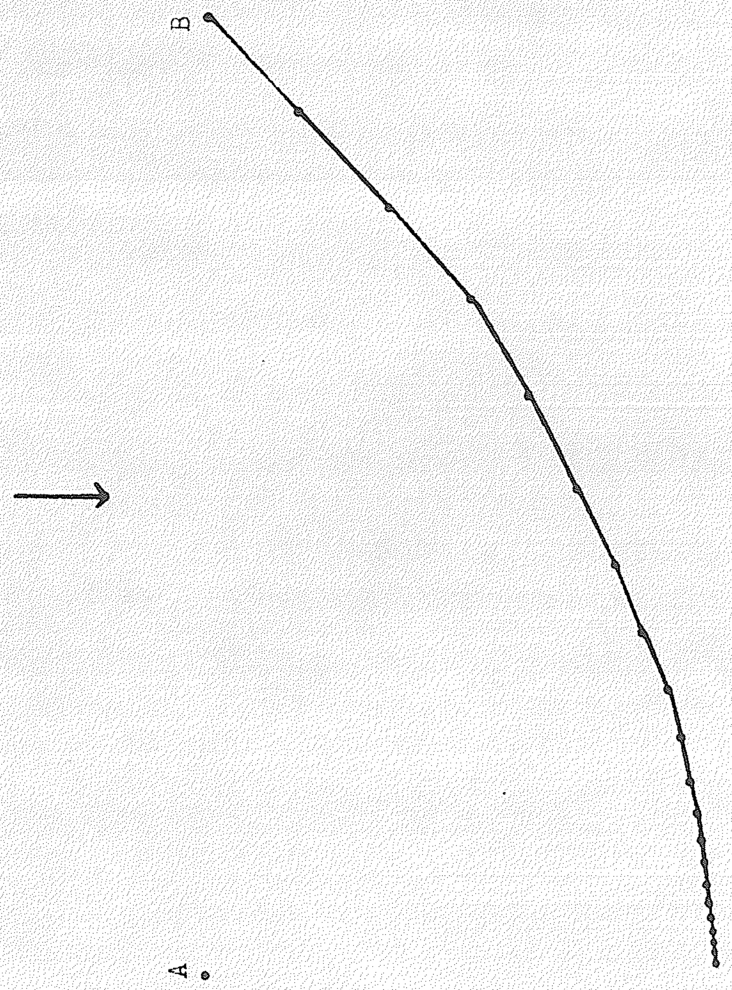

B
A

Figure 16. Insect Orientation Directly Towards Attracting Light - Insect Flight Speed Equals One-Half Wind Velocity

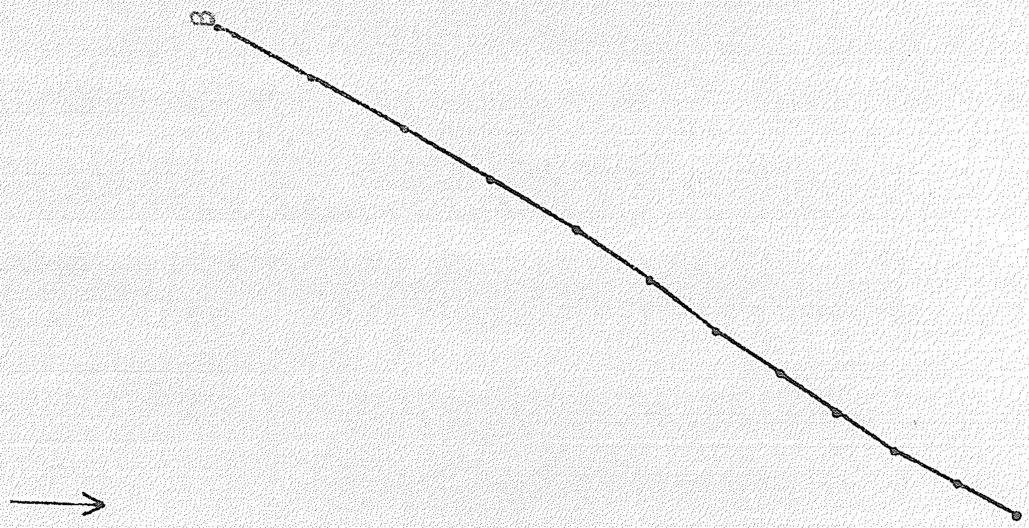

B

Figure 17. Insect Orientation Directly Towards Attracting Light - Insect Flight Speed Equals Two Times Wind Velocity

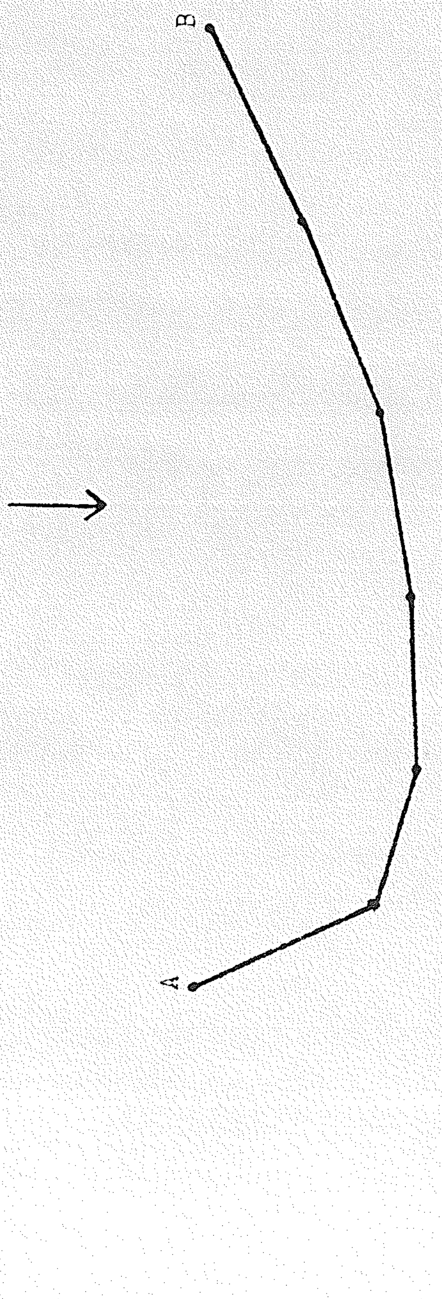

B
A

Figure 18. Insect Orientation at a 90 Degree Angle Relative to the Direction of the Insect Eye from the Light - Insect Flight Speed Equals Four Times the Wind Velocity

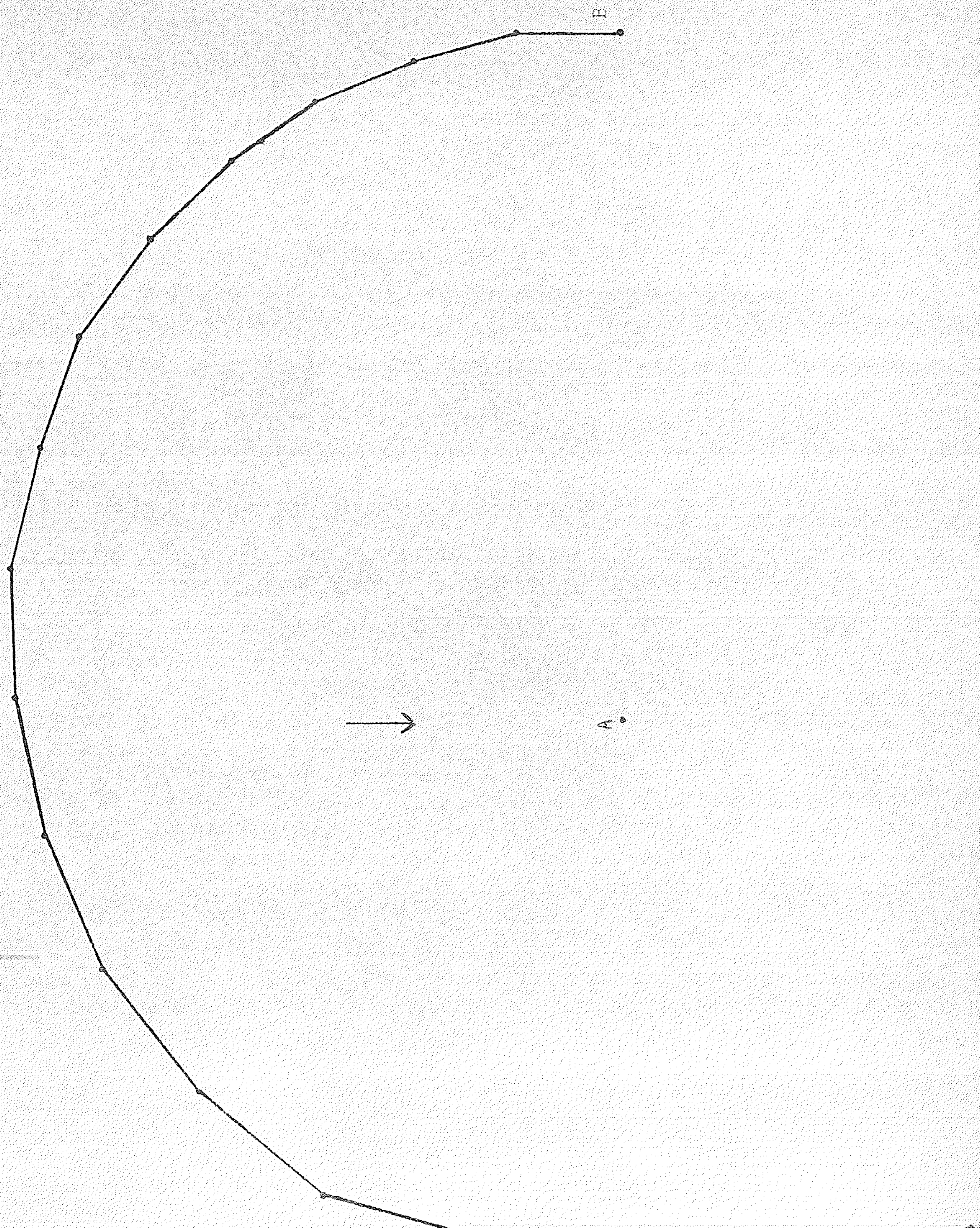

B
A

Figure 19. Insect Orientation at a 45 Degree Angle Relative to the Direction of the Insect Eye from the Light - Insect Flight Speed Equals Wind Velocity

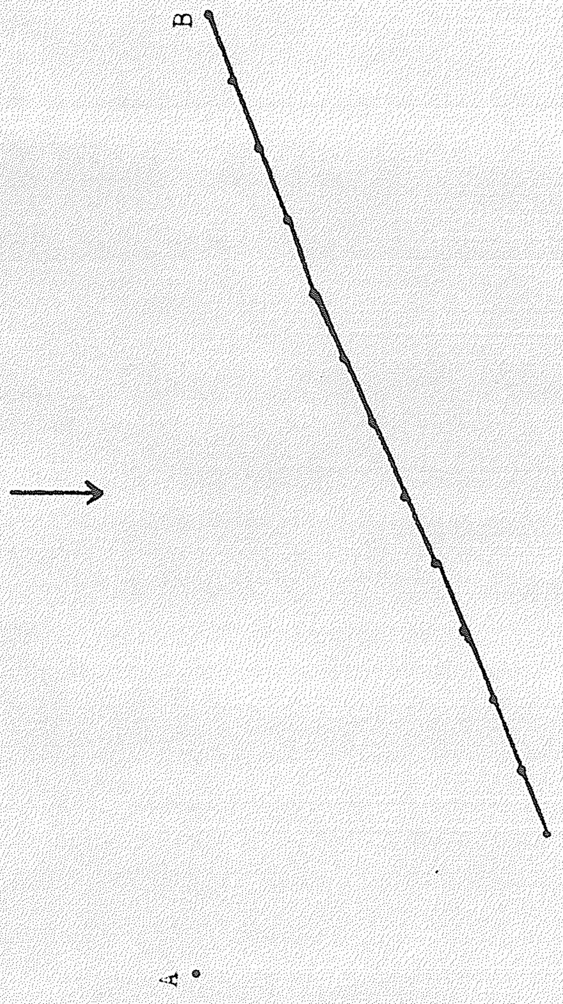

B
A

Figure 20. Insect Orientation to Light Commencing at Various Positions or Angles Relative to the X-axis - A 15 Degree Angle where Insect Flight Speed Equals Two Times the Wind Velocity

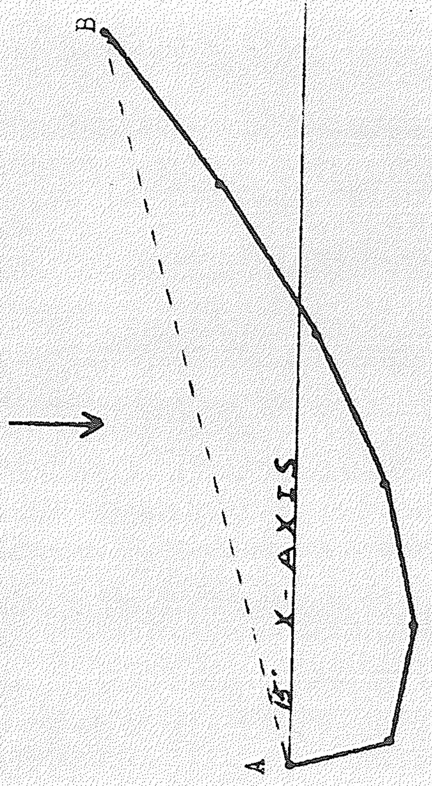
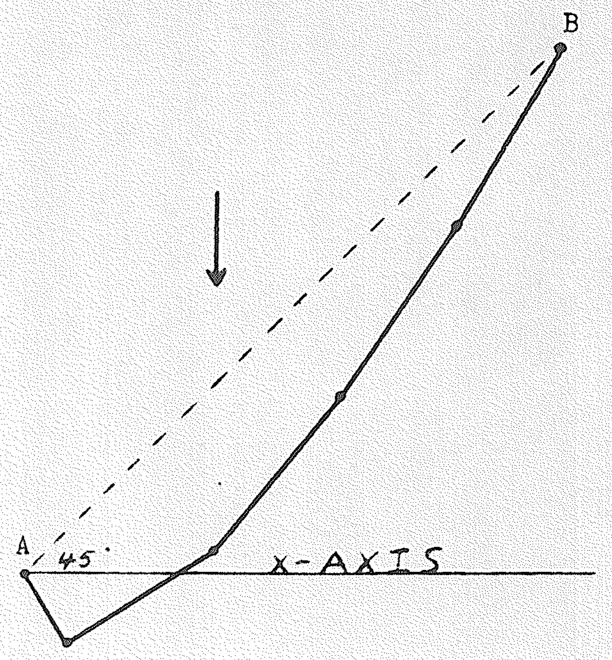

B
15°
X-AXIS
A

Figure 21. Insect Orientation to Light Commencing at Various Positions or Angles Relative to the X-axis - A 45 Degree Angle where Insect Flight Speed Equals Two Times the Wind Velocity


B
A
45°
X-AXIS

Theoretically an insect can orientate to an attracting light from various angles and directions. Figures 15 to 21 illustrate some of these alternatives.

In Figures 15 -17, insect orientation is directly towards the light. In Figure 15, insect flight speed is equal to the wind velocity. The insect however, does not reach the attractant designated as 'A' but attains a stationary point a considerable distance from the light source. The insect is not able to fly directly to the attractant because of pressure exerted by the wind which has been represented by an arrow. Since the insect flight speed is equal to the wind velocity, the insect is unable to advance in the direction of the attractant. In Figure 16 the insect flight speed is equal to one-half the wind velocity. The insect in this case is swept diagonally away from the attractant. The insect's flight speed is unable to cope with the increased wind velocity. In Figure 17, the insect flight speed is equal to twice the wind velocity. In this instance, the insect is able to overcome the wind and reaches the attracting light after its flight path has almost formed a semi-circle.

In Figure 18, insect orientation is at a 90 degree angle relative to the direction of the insect eye from the light and the insect's flight speed is equal to four times the wind velocity. In this case, the insect never reaches the attractant 'A' but forms a spiral with its flight path. In Figure 19, the insect flight speed is equal to the wind velocity but orientation is at a 45 degree angle relative to the direction of the insect eye from the light. The insect however, never reaches its destination.

In Figures 20-21 insect orientation to light commences at various positions or angles relative to the X-axis. In both cases, insect flight speed is two times the wind velocity, but in Figure 20 the angle of orientation is 15 degrees and in Figure 21 the angle is 45 degrees. In both cases the insect reaches the desired area.

CHAPTER IV

MOSQUITO FLIGHT RESPONSES TO VISUAL INPUTS AND WIND CURRENTS IN A WIND TUNNEL

Kennedy (1939) confirmed the importance of the background in mosquito orientation. When caged mosquitoes were stimulated to fly in still air over a moving, striped substrate, 80% flew in the direction of movement of the substrate but faster than the substrate although their orientation was random when the substrate was stationary. In these experiments, the few mosquitoes which flew downwind or against a moving substrate appeared to be unstable whereas those flying upwind or with the substrate were perfectly stable.

Kennedy noted that when substrate movement was too rapid, the mosquitoes alighted. This was at a velocity of about 3.3 m.p.h.

Kennedy discovered that a decrease in wind speed stimulated mosquitoes to take off so that the number taking off when wind speed had dropped to a certain level was far greater than the number which had been taking off while the wind speed was constant at that low level.

A similar set of experiments was attempted but a different apparatus was employed.

Method and Apparatus

The apparatus that was used is shown in Figure 22 and Figure 23.

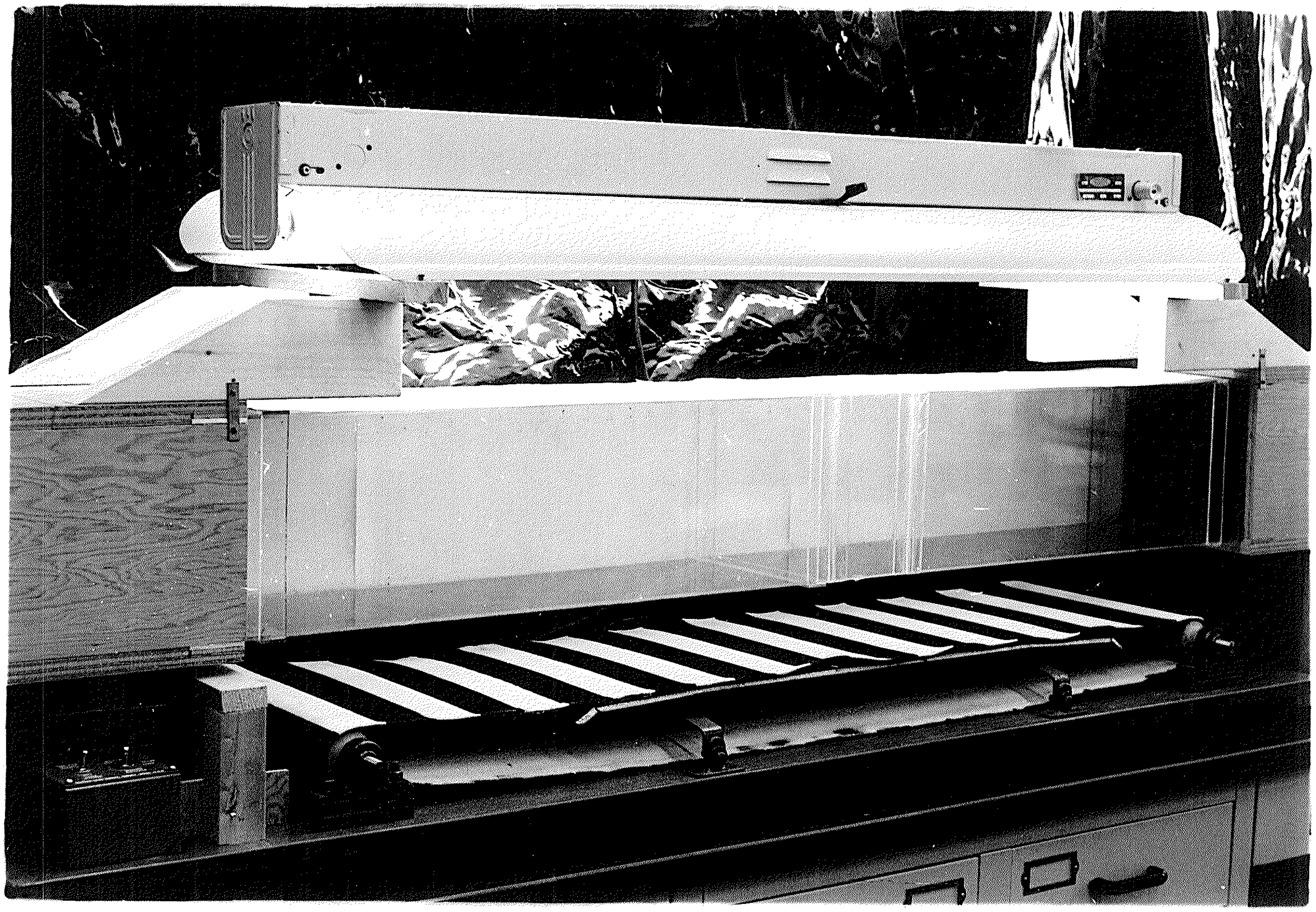
The entire length of the wind tunnel including plywood and 'Perspex' sections was 10' 8". The height and width of the tunnel were 8 inches in both dimensions and the clear perspex or obervation section was separated from the plywood sections by screens. An oil burner fan was installed on one side of the tunnel to provide wind or air currents when necessary. The length of the observation section was 4' 8" and the plywood sections were respectively 4 and 2 feet long. The longer plywood section was placed on the opposite side of the oil burner fan, which drew the air, to allow for the air currents to straighten out and be less turbulent. Small hinged doors were cut into the plywood sections so that the mosquitoes could be stimulated to fly by a breath of air if need by.

The moving background was provided by a canvas belt 4 feet long and one foot in diameter. The entire belt fitted directly under the observation chamber of the wind tunnel. Upon the canvas belt were alternately painted black and white stripes approximately 2 inches in diameter. The belt revolved or rotated upon 2 washing machine rollers and was driven by a 'Ratiotrol Direct Current Motor' developing 1/12 of a horsepower at 1750 r.p.m. The speed of the belt rotation was controlled by a motor speed control box. The speed of the rotating belt was approximately 1.7 to 2 m.p.h. at a setting of 55 on the control box. The speed of the oil burner fan when in use was controlled by a rheostat.

A fluorescent lamp was supported above the observation chamber to

Figure 22. The Entire Leng~~ht~~th of the Wind Tunnel

Figure 23. A Close up View of the Flight Chamber



provide for better visibility for the observer. To reduce image interruptions from other sources, the tunnel was covered with white paper allowing space for observation and for image input.

Experiment A

The test mosquitoes were *Aedes aegypti*, *Aedes implicatus* and *Aedes vexans*. The effect of image input on flying individual mosquitoes was determined. Flight was initiated by a sharp rap on the flight chamber or by a breath of air. The mosquitoes were allowed 2 minutes in the tunnel before the experiment was attempted for adaption purposes. Belt rotation was set at a speed of about 1.7 to 2 m.p.h. and was increased from 3.4 to 4 m.p.h. when necessary. The direction of belt rotation was alternated from left to right as the mosquitoes responded. Sufficient time was allowed for the mosquitoes to fly opposite to substrate direction or movement if they so desired. The insect was allowed to respond 4 times within each replicate and 5 replicates were completed.

Experiment B

The test mosquitoes were the same as in Experiment A (*Aedes aegypti*, *Aedes implicatus* and *Aedes vexans*). The effect of a high wind velocity for one minute followed by a complete stoppage of wind was determined. Twenty mosquitoes were used in each replicate and these were allowed 2 minutes to adapt to surrounding conditions in the flight chamber. The number of take offs in the minute preceding the wind treatment were counted. This was followed by one minute of high wind velocity of about 15 miles per hour. The number of take-offs were counted within each of the following minutes until the mosquitoes became relatively inactive. The number of mosquitoes flying after or at the end of each minute was also estimated. Five replicates were attempted; each replicate consisted of 5 parts. Three replicates were attempted with *Aedes aegypti*. Different mosquitoes were used for each replicate.

Mosquito orientation with respect to wind and the effect of a combination of wind and substrate movement was also determined.

Results - Experiment A - Responses to Visual Inputs

Aedes aegypti were held at room temperature and a relative humidity of 57% and were fed sugar solution.

TABLE VII

Female #1	Dial Setting	Time Belt Started	Mosquito Position	Belt Direction	Succeeding Eventful Times
14 days old	55	To secs.	left	left - right	
			right	left - right	T_2 secs.
			right	left - right ↓* right - left	T_{30}
			left	right - left	T_{40}
			left	right - left ↓ left - right	T_{80}
			right	left - right	T_{85}
			right	left - right ↓ right - left	T_{120}
			left	right - left	T_{123}

* Indicates reversal of belt direction from left - right to right - left at T_{30} seconds.

TABLE VIII

Female #2	Dial Setting	Time Belt Started	Mosquito Position	Belt Direction	Succeeding Eventful Times
19 days old	55	To secs.	right	right - left	
			left	right - left	T_2 secs.
			left	right - left ↓ * left - right	T_{45}
			right	left - right	T_{47}
			right	left - right ↓ right - left	T_{95}
			left	right - left	T_{105}
			left	right - left ↓ left - right	T_{135}
			right	left - right	T_{138}

* Indicates reversal of belt direction from right - left to left - right at T_{45} seconds.

TABLE IX

Female #3	Dial Setting	Time Belt Started	Mosquito Position	Belt Direction	Succeeding Eventful Times
19 days old	55	To secs.	right	right - left	
			left	right - left	T_2 secs.
			left	right - left ↓* left - right	T_{30}
			right	left - right	T_{35}
			right	left - right ↓ right - left	T_{53}
			left	right - left	T_{60}
			left	right - left ↓ left - right	T_{80}
			right	left - right	T_{84}

* Indicates reversal of belt direction from right - left to left - right at T_{30} seconds.

TABLE X

Female #4	Dial Setting	Time Belt Started	Mosquito Position	Belt Direction	Succeeding Eventful Times
19 days old	55	To secs.	right	right - left	
			left	right - left	T_7 secs.
			left	right - left ↓* left - right	T_{30}
			right	left - right	T_{36}
			right	left - right ↓ right - left	T_{60}
			left	right - left	T_{63}
			left	right - left ↓ left - right	T_{90}
			right	left - right	T_{93}

* Indicates reversal of belt direction from right - left to left - right at T_{30} seconds.

TABLE XI

Female #5	Dial Setting	Time Belt Started	Mosquito Position	Belt Direction	Succeeding Eventful Time
19 days old	55	To secs.	right	right - left	
			left	right - left	T_5 secs.
			left	right - left ↓ * left - right	T_{35}
			right	left - right	T_{37}
			right	left - right ↓ right - left	T_{60}
			left	right - left	T_{65}
			left	right - left ↓ left - right	T_{90}
			right	left - right	T_{92}

* Indicates reversal of belt direction from right - left to left - right at T_{35} seconds.

Short flights of about 18 inches were attempted against stripe movements, but then the mosquito returned immediately to flight in the same direction as substrate movement. Flight with substrate movement was direct and rapid the entire length of the tunnel. Attempts to fly against substrate movement were irregular and hesitant. Flight with substrate movement was at a much lower altitude in the flight tunnel than flight against substrate movement. Contrary to Kennedy's observation the mosquitoes never settled or alighted when stripe movement surpassed flight speed. In some cases, the insect skimmed along the base of the tunnel but never did settle.

Aedes implicatus

The test insects were held at room temperature and 57% relative humidity. They were 2 days old and fed on sugar solution.

The response to image input was very poor, in fact there was no response at all. Flight was very difficult to induce and when it occurred, it was short and sporadic.

Aedes vexans

In an effort to increase the life span of this species, the insects were kept in the constant temperature room. The females were 6 days old and had been fed honey solution. They were kept at a temperature of 70 degrees F. and 60% relative humidity.

In contrast with Aedes implicatus, flight was much easier to initiate. The test insects however, flew with and against substrate movement quite readily. In very few cases, did they exhibit the same behaviour as Aedes aegypti.

Results - Experiment B - Mosquito Response to Complete Stoppage of Wind Following High Wind Velocity

Aedes aegypti were held at 70 degrees F., 60% R.H. and were fed honey solution. The insects were 4-5 days old.

TABLE XII

Replicate 1a

No. of take-offs in one minute preceding wind - 6

No. of take-offs following wind treatment in succeeding minutes		No. of mosquitoes flying at the end of each minute
0 - 1 minutes	12 take-offs	8
1 - 2 "	2 "	5
2 - 3 "	2 "	3
3 - 4 "	2 "	5
4 - 5 "	2 "	4
5 - 6 "	3 "	2
6 - 7 "	2 "	3

Replicate 1b

No. of take-offs in one minute preceding wind - 0

0 - 1 minutes	8 take-offs	5
1 - 2 "	2 "	7
2 - 3 "	5 "	6
3 - 4 "	3 "	5
4 - 5 "	2 "	4
5 - 6 "	3 "	2
6 - 7 "	1 "	1

Replicate 1c

No. of take offs in one minute preceding wind - 4

No. of take-offs following wind treatment in succeeding minutes		No. of mosquitoes flying at the end of each minute
0 - 1 minutes	14 take-offs	6
1 - 2 "	2 "	5
2 - 3 "	3 "	4
3 - 4 "	3 "	3
4 - 5 "	3 "	2
5 - 6 "	1 "	0

Replicate 1d

No. of take-offs in one minute preceding wind - 1

0 - 1 minutes	12 take-offs	4
1 - 2 "	6 "	5
2 - 3 "	5 "	7
3 - 4 "	2 "	3
4 - 5 "	3 "	1
5 - 6 "	2 "	1
6 - 7 "	4 "	2
7 - 8 "	3 "	2

Replicate 1e

No. of take-offs in one minute preceding wind - 3

0 - 1 minutes	10 take-offs	7
1 - 2 "	4 "	7
2 - 3 "	4 "	4
3 - 4 "	2 "	1
4 - 5 "	3 "	1
5 - 6 "	4 "	2
6 - 7 "	2 "	2
7 - 8 "	3 "	3

TABLE XIII

Replicate 2a

No. of take-offs in one minute preceding wind - 4

No. of take-offs following wind treatment in succeeding minutes		No. of mosquitoes flying at the end of each minute
0 - 1 minutes	11 take-offs	5
1 - 2 "	4 "	2
2 - 3 "	2 "	1
3 - 4 "	1 "	1
4 - 5 "	2 "	1
5 - 6 "	1 "	1

Replicate 2b

No. of take-offs in one minute preceding wind - 2

0 - 1 minutes	10 take-offs	8
1 - 2 "	2 "	6
2 - 3 "	1 "	5
3 - 4 "	1 "	4
4 - 5 "	0 "	3
5 - 6 "	2 "	4
6 - 7 "	2 "	2

Replicate 2c

No. of take-offs in one minute preceding wind - 3

0 - 1 minutes	9 take-offs	7
1 - 2 "	2 "	7
2 - 3 "	1 "	4
3 - 4 "	1 "	2
4 - 5 "	2 "	1
5 - 6 "	3 "	2
6 - 7 "	1 "	2

Replicate 2d

No. of take-offs in one minute preceding wind - 2

No. of take-offs following wind treatment in succeeding minutes		No. of mosquitoes flying at the end of each minute
0 - 1 minutes	6 take-offs	5
1 - 2 "	3 "	5
2 - 3 "	1 "	4
3 - 4 "	2 "	5
4 - 5 "	2 "	4
5 - 6 "	1 "	2
6 - 7 "	2 "	2

Replicate 2e

No. of take-offs in one minute preceding wind - 1

0 - 1 minutes	9 take-offs	5
1 - 2 "	1 "	6
2 - 3 "	3 "	4
3 - 4 "	2 "	3
4 - 5 "	1 "	2
5 - 6 "	2 "	2
6 - 7 "	2 "	1

TABLE XIV

Replicate 3a

No. of take-offs in one minute preceding wind - 3

No. of take-offs following wind treatment in succeeding minutes		No. of mosquitoes flying at the end of each minute
0 - 1 minutes	12 take-offs	5
1 - 2 "	2 "	1
2 - 3 "	4 "	0
3 - 4 "	2 "	2
4 - 5 "	2 "	1
5 - 6 "	2 "	1

Replicate 3b

No. of take-offs in one minute preceding wind - 3

No. of take-offs following wind treatment in succeeding minutes		No. of mosquitoes flying at the end of each minute
0 - 1 minutes	7 take-offs	4
1 - 2 "	4 "	1
2 - 3 "	4 "	3
3 - 4 "	2 "	1
4 - 5 "	2 "	1
5 - 6 "	2 "	2
6 - 7 "	2 "	2

Replicate 3c

No. of take-offs in one minute preceding wind - 1

0 - 1 minutes	8 take-offs	5
1 - 2 "	3 "	2
2 - 3 "	4 "	3
3 - 4 "	3 "	2
4 - 5 "	2 "	3
5 - 6 "	2 "	2
6 - 7 "	1 "	1

Replicate 3d

No. of take-offs in one minute preceding wind - 2

0 - 1 minutes	8 take-offs	4
1 - 2 "	3 "	5
2 - 3 "	0 "	2
3 - 4 "	4 "	2
4 - 5 "	1 "	2
5 - 6 "	2 "	3
6 - 7 "	3 "	2

Replicate 3e

No. of take-offs in one minute preceding wind - 1

No. of take-offs following wind treatment in succeeding minutes		No. of mosquitoes flying at the end of each minute
0 - 1 minutes	11 take-offs	7
1 - 2 "	1 "	5
2 - 3 "	2 "	6
3 - 4 "	4 "	4
4 - 5 "	3 "	3
5 - 6 "	3 "	3
6 - 7 "	0 "	2

Aedes vexans were held at 70 degrees F., 60% R.H. and were fed honey solution. The insects were 4-5 days old.

TABLE XV

Replicate 1a

No. of take-offs in one minute preceding wind -2

No. of take-offs following wind treatment in succeeding minutes		No. of mosquitoes flying at the end of each minute
0 - 1 minutes	9 take-offs	1
1 - 2 "	2 "	1
2 - 3 "	0 "	0
3 - 4 "	1 "	0

Replicate lb

<u>No. of take-offs in one minute preceding wind</u> - 1

No. of take-offs following wind treatment in succeeding minutes		No. of mosquitoes flying at the end of each minute
0 - 1 minutes	7 take-offs	0
1 - 2 "	7 "	1
2 - 3 "	6 "	1
3 - 4 "	2 "	0
4 - 5 "	2 "	0
5 - 6 "	2 "	0
6 - 7 "	0 "	0

Replicate lc

<u>No. of take-offs in one minute preceding wind</u> - 1

0 - 1 minutes	16 take-offs	2
1 - 2 "	5 "	1
2 - 3 "	3 "	0
3 - 4 "	1 "	0
4 - 5 "	4 "	0
5 - 6 "	1 "	1
6 - 7 "	2 "	1

Replicate ld

<u>No. of take-offs in one minute preceding wind</u> - 2

0 - 1 minutes	14 take-offs	1
1 - 2 "	7 "	1
2 - 3 "	5 "	1
3 - 4 "	5 "	1
4 - 5 "	2 "	0
5 - 6 "	3 "	0
6 - 7 "	3 "	0
7 - 8 "	1 "	0

Replicate 1e

No. of take-offs in one minute preceding wind - 1

No. of take offs following wind treatment in succeeding minutes				No. of mosquitoes flying at the end of each minute
0 - 1	minutes	13	take-offs	1
1 - 2	"	6	"	0
2 - 3	"	5	"	0
3 - 4	"	4	"	0
4 - 5	"	2	"	0
5 - 6	"	5	"	0
6 - 7	"	1	"	0
7 - 8	"	3	"	0
8 - 9	"	1	"	2

TABLE XVI

Replicate 2a

No. of take-offs in one minute preceding wind - 4

No. of take-offs following wind treatment in succeeding minutes				No. of mosquitoes flying at the end of each minute
0 - 1	minutes	12	take-offs	2
1 - 2	"	8	"	0
2 - 3	"	7	"	1
3 - 4	"	6	"	1
4 - 5	"	4	"	1
5 - 6	"	5	"	1
6 - 7	"	4	"	2
7 - 8	"	5	"	0
8 - 9	"	3	"	0
9 - 10	"	2	"	1

Replicate 2b

No. of take-offs in one minute preceding wind - 5

No. of take-offs following wind treatment in succeeding minutes		No. of mosquitoes flying at the end of each minute
0 - 1 minutes	12 take-offs	1
1 - 2 "	8 "	1
2 - 3 "	6 "	2
3 - 4 "	5 "	0
4 - 5 "	4 "	0
5 - 6 "	2 "	0
6 - 7 "	1 "	0

Replicate 2c

No. of take-offs in one minute preceding wind - 0

0 - 1 minutes	6 take-offs	1
1 - 2 "	5 "	0
2 - 3 "	2 "	0
3 - 4 "	5 "	0
4 - 5 "	1 "	0
5 - 6 "	4 "	1
6 - 7 "	2 "	1
7 - 8 "	2 "	0

Replicate 2d

No. of take-offs in one minute preceding wind - 3

0 - 1 minutes	10 take-offs	2
1 - 2 "	4 "	1
2 - 3 "	6 "	1
3 - 4 "	5 "	0
4 - 5 "	5 "	2
5 - 6 "	4 "	1
6 - 7 "	3 "	0
7 - 8 "	3 "	0
8 - 9 "	3 "	1
9 - 10 "	2 "	1

Replicate 2e

No. of take-offs in one minute preceding wind - 5

No. of take-offs following wind treatment in succeeding minutes		No. of mosquitoes flying at the end of each minute
0 - 1 minutes	13 take-offs	2
1 - 2 "	6 "	0
2 - 3 "	4 "	1
3 - 4 "	4 "	0
4 - 5 "	4 "	1
5 - 6 "	4 "	0
6 - 7 "	6 "	0
7 - 8 "	2 "	0
8 - 9 "	3 "	0

TABLE XVII

Replicate 3a

No. of take-offs in one minute preceding wind - 1

No. of take-offs following wind treatment in succeeding minutes		No. of mosquitoes flying at the end of each minute
0 - 1 minutes	15 take-offs	1
1 - 2 "	2 "	0
2 - 3 "	1 "	0
3 - 4 "	3 "	1
4 - 5 "	1 "	0
5 - 6 "	3 "	2

Replicate 3b

No. of take-offs in one minute preceding wind - 3

0 - 1 minutes	11 take-offs	2
1 - 2 "	6 "	2
2 - 3 "	6 "	1
3 - 4 "	7 "	1
4 - 5 "	5 "	1
5 - 6 "	5 "	0
6 - 7 "	5 "	0
7 - 8 "	3 "	0
8 - 9 "	1 "	0

Replicate 3c

No. of take-offs in one minute preceding wind - 1

No. of take-offs following wind treatment in succeeding minutes		No. of mosquitoes flying at the end of each minute
0 - 1 minutes	16 take-offs	1
1 - 2 "	15 "	2
2 - 3 "	8	1
3 - 4 "	4	0
4 - 5 "	2	0
5 - 6 "	3	0
6 - 7 "	3	0
7 - 8 "	1	0

Replicate 3d

No. of take-offs in one minute preceding wind - 3

0 - 1 minutes	11 take-offs	1
1 - 2 "	5 "	1
2 - 3 "	4 "	1
3 - 4 "	3 "	1
4 - 5 "	1 "	1
5 - 6 "	1 "	0
6 - 7 "	1 "	0

Replicate 3e

No. of take-offs in one minute preceding wind - 2

0 - 1 minutes	8 take-offs	1
1 - 2 "	5 "	0
2 - 3 "	5 "	0
3 - 4 "	5 "	1
4 - 5 "	4 "	1
5 - 6 "	2 "	0
6 - 7 "	3 "	0
7 - 8 "	2 "	0

TABLE XVIII

Replicate 4a

No. of take-offs in one minute preceding wind - 3

No. of take-offs following wind treatment in succeeding minutes		No. of mosquitoes flying at the end of each minute
0 - 1 minutes	12 take-offs	1
1 - 2 "	6 "	2
2 - 3 "	6 "	1
3 - 4 "	1 "	0
4 - 5 "	2 "	0
5 - 6 "	0 "	0

Replicate 4b

No. of take-offs in one minute preceding wind - 2

0 - 1 minutes	11 take-offs	1
1 - 2 "	5 "	1
2 - 3 "	3 "	0
3 - 4 "	1 "	0
4 - 5 "	2 "	0
5 - 6 "	3 "	0
6 - 7 "	2 "	0

Replicate 4c

No. of take offs in one minute preceding wind - 1

0 - 1 minutes	12 take-offs	1
1 - 2 "	5 "	0
2 - 3 "	5 "	0
3 - 4 "	2 "	0
4 - 5 "	3 "	1
5 - 6 "	0 "	0

Replicate 4d

No. of take-offs in one minute preceding wind - 0

No. of take-offs following wind treatment in succeeding minutes		No. of mosquitoes flying at the end of each minute
0 - 1 minutes	11 take-offs	1
1 - 2 "	6 "	1
2 - 3 "	5 "	0
3 - 4 "	1 "	0
4 - 5 "	3 "	0
5 - 6 "	1 "	0

Replicate 4e

No. of take-offs in one minute preceding wind - 1

0 - 1 minutes	15 take-offs	1
1 - 2 "	7 "	1
2 - 3 "	3 "	0
3 - 4 "	4 "	1
4 - 5 "	1 "	0
5 - 6 "	3 "	0
6 - 7 "	1 "	0
7 - 8 "	1 "	0

TABLE XIX

Replicate 5a

No. of take-offs in one minute preceding wind - 9

No. of take-offs following wind treatment in succeeding minutes		No. of mosquitoes flying at the end of each minute
0 - 1 minutes	15 take-offs	1
1 - 2 "	9 "	1
2 - 3 "	12 "	2
3 - 4 "	7 "	1
4 - 5 "	7 "	0
5 - 6 "	5 "	0
6 - 7 "	4 "	0
7 - 8 "	5 "	0
8 - 9 "	6 "	1
9 - 10 "	2 "	1

Replicate 5b

No. of take-offs in one minute preceding wind - 5

0 - 1 minutes	10 take-offs	2
1 - 2 "	5 "	1
2 - 3 "	7 "	0
3 - 4 "	6 "	1
4 - 5 "	9 "	0
5 - 6 "	6 "	0
6 - 7 "	6 "	0
7 - 8 "	6 "	2
8 - 9 "	4 "	0
9 - 10 "	6 "	0

Replicate 5c

No. of take-offs in one minute preceding wind - 9

0 - 1 minutes	15 take-offs	2
1 - 2 "	11 "	1
2 - 3 "	8 "	0
3 - 4 "	10 "	1
4 - 5 "	6 "	0
5 - 6 "	6 "	0
6 - 7 "	8 "	0
7 - 8 "	8 "	0

Replicate 5c (continued)

8 - 9 minutes	7 take-offs	0
9 - 10 "	6 "	0

Replicate 5d

No. of take-offs in one minute preceding wind - 14

No. of take-offs following wind treatment in succeeding minutes		No. of mosquitoes flying at the end of each minute
0 - 1 minutes	19 take-offs	1
1 - 2 "	15 "	3
2 - 3 "	9 "	3
3 - 4 "	8 "	0
4 - 5 "	7 "	2
5 - 6 "	7 "	0
6 - 7 "	9 "	0
7 - 8 "	5 "	0
8 - 9 "	10 "	1
9 - 10 "	11 "	1

Replicate 5e

No. of take-offs in one minute preceding wind - 10

0 - 1 minutes	19 take-offs	1
1 - 2 "	9 "	2
2 - 3 "	10 "	2
3 - 4 "	9 "	2
4 - 5 "	9 "	0
5 - 6 "	7 "	0
6 - 7 "	12 "	0
7 - 8 "	9 "	1
8 - 9 "	5 "	0
9 - 10 "	10 "	2

Aedes implicatus however, did not react to increased wind speed followed by complete stoppage of wind.

In most cases, both Aedes aegypti and Aedes vexans usually headed into the wind when it was produced in the flight tunnel, and when substrate movement was stationary. Only occassionally did they fly with the wind.

When substrate movement was opposite to wind direction, the mosquitoes (Aedes aegypti and Aedes vexans) headed into the wind. The same was true when wind and substrate movement were in the same direction.

Discussion

Experiment A. The mosquitoes flew in the same direction as substrate movement in an effort to keep the image inputs constant on the eye. The mosquitoes did not settle when the speed of substrate movement surpassed their flight speed. If the mosquito would have settled, image input from the canvas belt would still have taken place due to continued background movement. Perhaps for this reason the mosquitoes did not alight.

Aedes implicatus did not react to any of these stimuli in Experiment A. It is only very rarely caught in our light traps.

Experiment B. Five parts were attempted within each replicate for an important reason. This was done to determine how much punishment by high winds that a mosquito would actually withstand. In all cases it was shown that the insect could be thrown against the screens five times in each replicate and was still able to give a good response. This was done because in nature the insect is presumably subjected to a great deal of physical stress during storms.

Another reason why these investigations were attempted is concerned with migration. This increased flight activity after a lull in the wind could explain how the mosquitoes are eventually carried into the upper atmosphere by updrafts. Before the insect can be carried high into the atmosphere it must leave the ground.

Another important theory can be deduced from the above data. More take offs can be noted for Aedes vexans but more mosquitoes are flying at the end of each minute in the case of Aedes aegypti. This indicates that the flight period of Aedes aegypti was and is considerably longer than for Aedes vexans .

Aedes implicatus did not react to the treatment.

Conclusions

1. Mosquitoes tend to keep the background stationary or moving from the front of the eye backwards during flight.

2. Mosquitoes flight is stimulated by increased wind velocity followed by complete stoppage of wind.

3. Once again it was noticed that mosquitoes orientate upwind.

4. Species differences in behaviour were noticed in both Experiments A and B.

CHAPTER V

ADULT POPULATION SURVEY

Light Trap Catches

During the summer of 1963, an adult population survey was conducted of the Greater Winnipeg Area and the surrounding districts. The purpose of this survey was to determine the abundance of mosquitoes, and once this was accomplished, exterminate them by some efficient method. These light trap catches give the observer an idea of the abundance of mosquitoes in spite of competition from other light sources. However, the numbers of mosquitoes caught in light traps near full moon are only a small fraction of the numbers taken around new moon (Horsfall, 1943; Pratt, 1948; Onishi, 1959). This method of trapping may not reflect mosquito annoyance accurately because the mosquitoes which were collected were not biting, but were merely being attracted to the light. On the other hand however, a 'biting collection' would be time-consuming and painful and was not attempted.

Method and Equipment

The light trap employed was the Standard New Jersey Light Trap. The light traps were mounted on a tripod and placed near a source of electricity. Electric timers were used to automatically control the flow of electricity to the trap, and therefore the hours of operation could be set as desired; the traps were operational from 8 p.m. to 7 a.m.

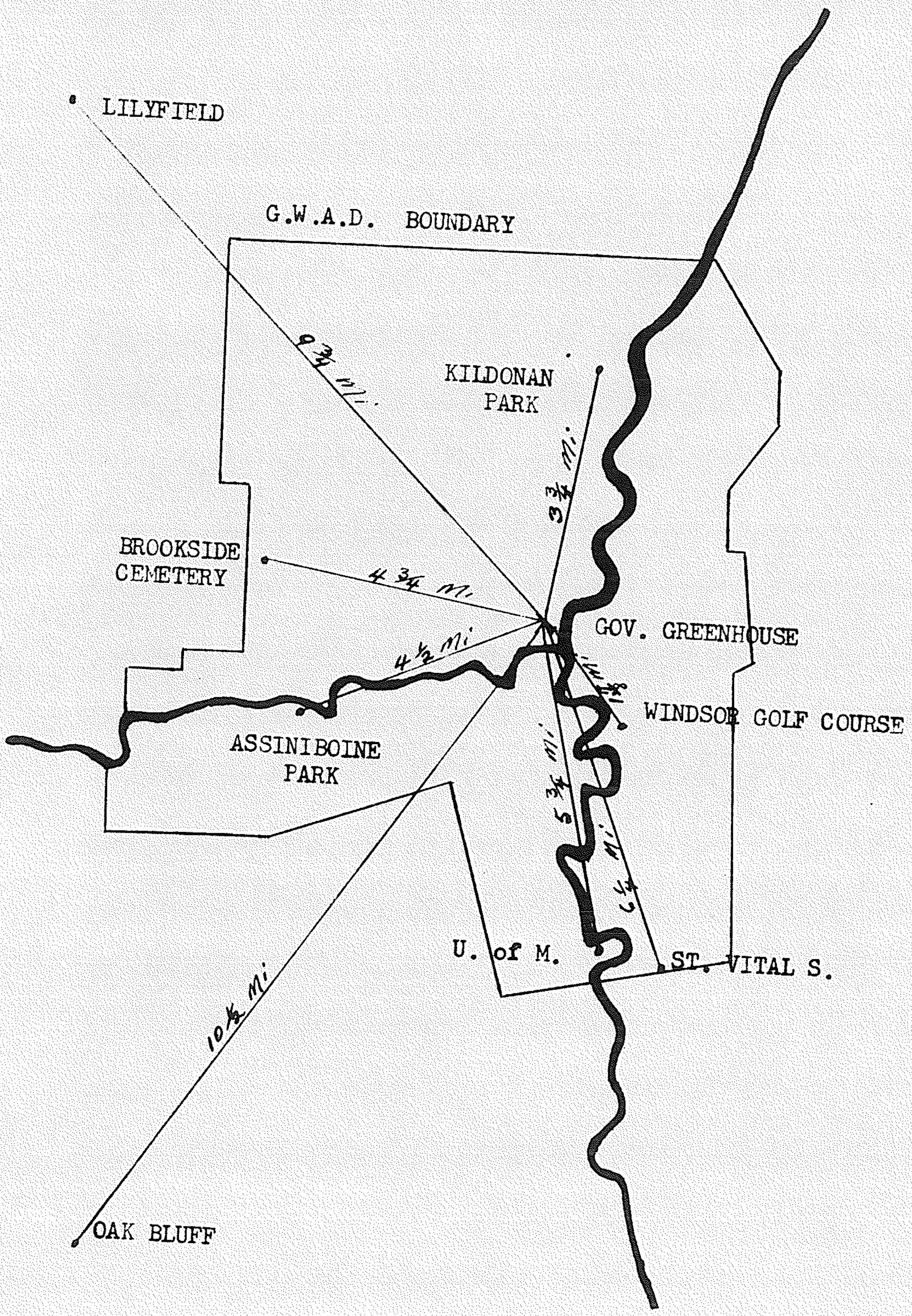
The traps were set up at various locations shown on the following map (Figure 24) within and surrounding the Greater Winnipeg Area. The purpose of setting the traps outside the Winnipeg area was to obtain a comparison of insecticide treated and untreated areas. Two New Jersey Traps were set up outside the sprayed area, and seven were set up within the area. The New Jersey Traps outside the sprayed area were located west of Winnipeg at Oak Bluff, and north of the city at Lillyfield. Those set up within the sprayed area were located at the University of Manitoba, Assiniboine Park, Brookside Cemetery, Kildonan Park, the Government Greenhouse at the Legislative Buildings, Windsor Golf Course, and in south St. Vital.

When all the extraneous material was separated from the light trap catches, the number of mosquitoes for each particular area was telephoned to The Mosquito Abatement Branch. The areas which showed the highest infestation within the sprayed area were treated first.

Results

The results of the mosquito survey are illustrated in Figure 25. This figure also illustrates the temperature (mean and normal) and the individual rainfalls. There is an obvious difference between the sprayed and unsprayed areas. Perhaps the biggest difference can be noticed from mid-June to the end of the first week in July. On June 27th the average

Figure 24. Locations of the New Jersey Light Traps 1963


LILYFIELD
G.W.A.D. BOUNDARY
9¾ Mi.
KILDONAN PARK
3¾ Mi.
BROOKSIDE CEMETERY
4¾ Mi.
GOV. GREENHOUSE
4½ Mi.
1¾ Mi.
WINDSOR GOLF COURSE
ASSINIBOINE PARK
5¾ Mi.
6½ Mi.
U. of M.
ST. VITAL S.
10½ Mi.
OAK BLUFF

number of mosquitoes in the sprayed areas were about 350 females per day. On the same day the average number of female mosquitoes within the unsprayed area averaged approximately 2900. This same point is evident in the two later peaks in August.

In spite of the above conclusive results one very interesting feature arose. Kildonan Park which is located within the sprayed area still maintained very high counts. The counts from this area almost rivalled those of the unsprayed areas. The catches from another area however, Assiniboine Park, which is within the sprayed area, remained low throughout the entire summer season. The fact that makes the high counts of Kildonan Park still more surprising is that this area was fogged more than any other because of theatrical productions at Rainbow Stage. It was fogged 51 times during the summer, with a daily fogging when the summer theatre was open. The counts from Assiniboine Park were considerably lower even though this area was fogged only 35 times. Figures 26, 27 and 28 indicate the above relationship between Oak Bluff (unsprayed area), Kildonan Park (sprayed area), and the other sprayed areas. The figures show that at the peak of light trap catches on June 27th the number of females mosquitoes at Oak Bluff were 3000, at Kildonan Park 1650, and at Assiniboine Park 390.

To conclude, it was quite evident that the traps located in the sprayed areas collected less mosquitoes than those located in the unsprayed areas.

Discussion

There are two lines of reasoning which one could follow in order to explain the continued high counts in Kildonan Park. Firstly, that more breeding areas are located near Kildonan Park and that all of these breeding areas are not being treated by the fogging crews. Secondly, that the mosquitoes are migrating or being dispersed by strong winds into the Kildonan Park area from some external breeding site.

The first suggestion cannot be ruled out entirely but it is less likely to be the case. Because of the large extent of fogging most of the breeding areas were hit, and a larval survey during the summer in and around the Kildonan Park area did not uncover any breeding areas which had not been fogged or dusted. The Red River located on the east side of the Park is probably not important for breeding because the native mosquitoes are not likely to breed in running water. The principal genus in the Winnipeg area is Aedes, and this group prefers still standing water with organic matter. In spring, Culiseta is most important and these prefer stagnant waters polluted with fecal and urine excreta. The river however, may have another influence upon the mosquito populations but this will be elaborated upon later.

The second suggestion is that the mosquitoes may be migrating or dispersed by strong winds into the Kildonan Park area which is more likely than the first. Wind currents may act to extend a specific insect's flight range, by assisting the flight of the insect; or they may literally carry the insect, winged or wingless, from one area to another (Wellington, 1945).

The mosquitoes, however, must attain a higher altitude if they are to be dispersed by strong winds. Felt (1928) states roads produce convection currents which may be distinctly felt 1000 feet above the surface and convectional currents produced by a heated land surface over warmer parts of the earth may easily attain 15,000 feet. These convectional currents if they can support birds (Felt, 1928) could lift lighter insects to high altitudes where they could be transported by strong horizontal winds. These horizontal winds may attain a velocity of up to 200 m.p.h.

The direction of the wind at the surface of the earth may not be the same as in the upper atmosphere. Williams (1930) provides figures to show how wind directions vary with height.

Altitude in Meters	Prevailing Winds
500	SSW - W
1000	SW - W
2000	SW - NW
4000	WSW - NW
6000	W - NW

The mosquitoes could also be stimulated to fly by changes in light intensity towards the evening or by the lessening or wind velocity at the same time of the day (Kennedy, 1939). The flight range of mosquitoes was estimated by Hocking (1953) on a flight mill. The flight range of our worst mosquito pest, *Aedes vexans*, was found to be from 26-48 kms. *Aedes dorsalis* 24 kms., and *Aedes flavescens* 11 kms. From these results it is possible that mosquitoes could fly voluntarily or involuntarily into Kildonan Park from an external breeding site.

Felt (1928) elaborates upon the physical effects of streams on air currents. These natural features usually lower the temperature and therefore, there are frequently descending currents caused by the cooler air seeking its level over water surfaces. This tends to bring drifting objects nearer to the surface of the earth and may explain the increased populations at Kildonan Park.

The Red River could have some effect upon mosquitoes flying high in the atmosphere. This river is much wider and would have a more pronounced effect than the smaller Assiniboine River adjacent to Assiniboine Park. Perhaps for this reason the counts were considerably lower at Assiniboine Park than at Kildonan Park. By the same token, counts were lower at Windsor Golf Course, and the Legislative Buildings. The smallest number of mosquitoes in light trap catches have consistently been captured at Brookside Cemetery where neither downdrafts nor wind-breaks are prevalent due to a river of any kind.

The above data are confirmed by Figures 26, 27 and 28 which summarize captures during 1963.

In the peak periods shown in the Tables xx (June 20 - July 4) and xxi (August 19-26) less than 50% of the female mosquitoes captured at Brookside Cemetery belong to the species *Aedes vexans*. In Table xxii (August 6-15) 60% of the mosquitoes belonged to this species which is 8.7% less than Kildonan Park. All other areas in Tables xx, xxi, and xxii showed a distribution of 75-90% *Aedes vexans*. *Aedes vexans* is the most energetic migrant of all our native mosquitoes; it is the smallest species, again a feature associated with long range displacement of air. Since Brookside Cemetery does not have any streams or wind barriers near to it, the New Jersey Trap located there, collected fewer *Aedes vexans* than those in any other areas.

Another interesting feature is the large variety of mosquito species found at Brookside Cemetery. In Table xx (June 20 - July 4), *Aedes dorsalis* comprised 31% of all the mosquitoes collected and *Aedes flavescens* 15% of the collections. For these particular species of mosquitoes all other areas were far below these percentages. This could suggest that the area in and around Brookside Cemetery is favourable for the life cycle of these two species. In Tables xxi (August 19 - 26) and xxii (August 6 - 15), these two species of mosquitoes were hardly present in the Brookside area. This may suggest that *Aedes dorsalis* and

Aedes flavescens reach population peaks during certain periods of the summer. This is contrary to Aedes vexans which was very prevalent throughout the entire summer as is illustrated by all three tables. A complete analysis of these data would require information about the species complex during the larval stages.

The adult survey proved to be a very interesting feature of this program and all the experiments will be investigated more thoroughly this summer.

Figure 25. Survey Graph 1963

A. Relationship for the Number of Female Mosquitoes caught between the Sprayed Areas and the Unsprayed Areas

B. Normal and Mean Temperatures

C. Individual Rainfalls

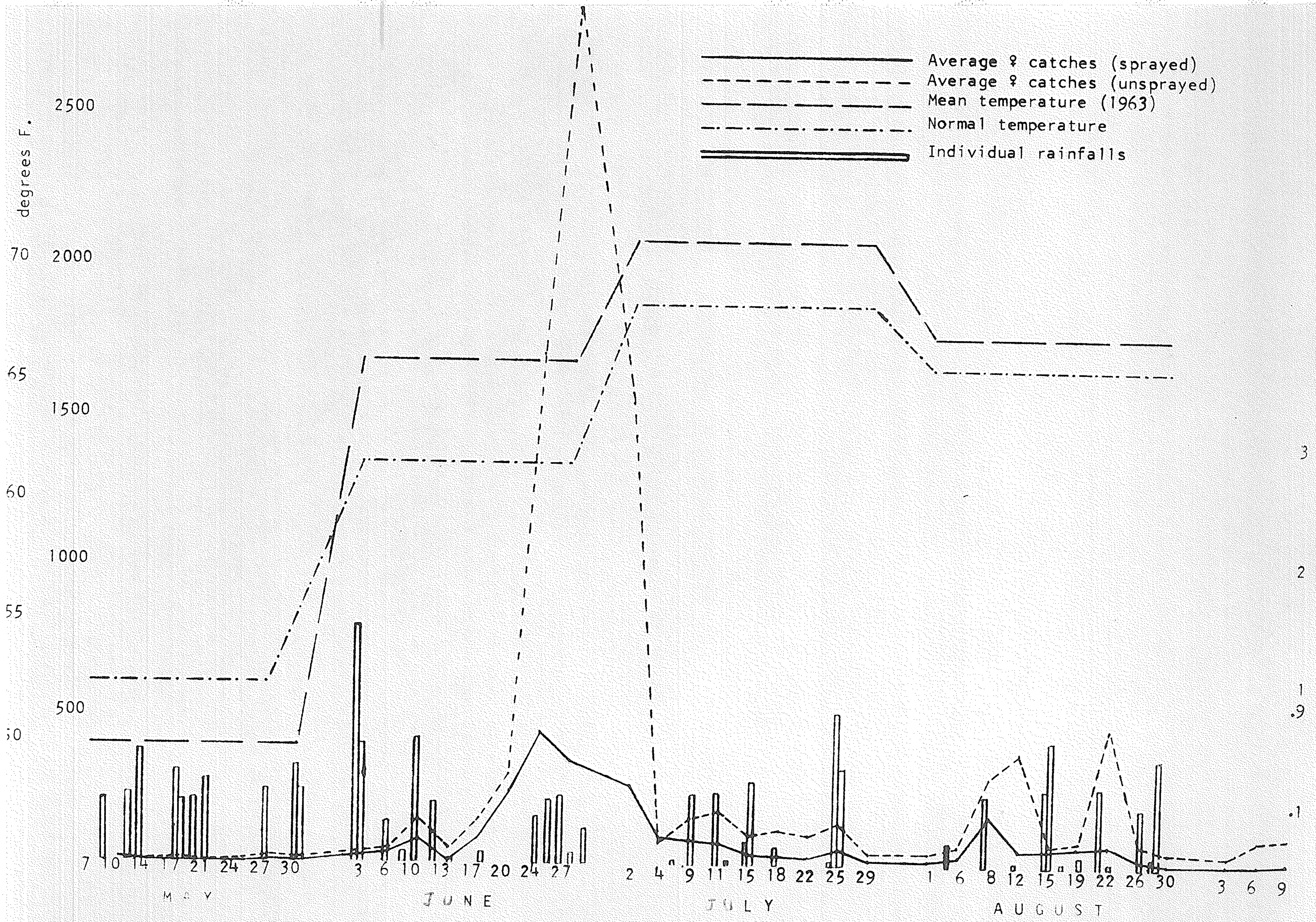

Average ♀ catches (sprayed)
Average ♀ catches (unsprayed)
Mean temperature (1963)
Normal temperature
Individual rainfalls
degrees F.
70
65
60
55
50
2500
2000
1500
1000
500
3
2
1
.9
.1
7 10 14 17 21 24 27 30
MAY
3 6 10 13 17 20 24 27
JUNE
2 4 9 11 15 18 22 25 29
JULY
1 6 8 12 15 19 22 26 30
AUGUST
3 6 9

Figure 26. The Number of Female Mosquitoes caught in an Unsprayed Area - Oak Bluff

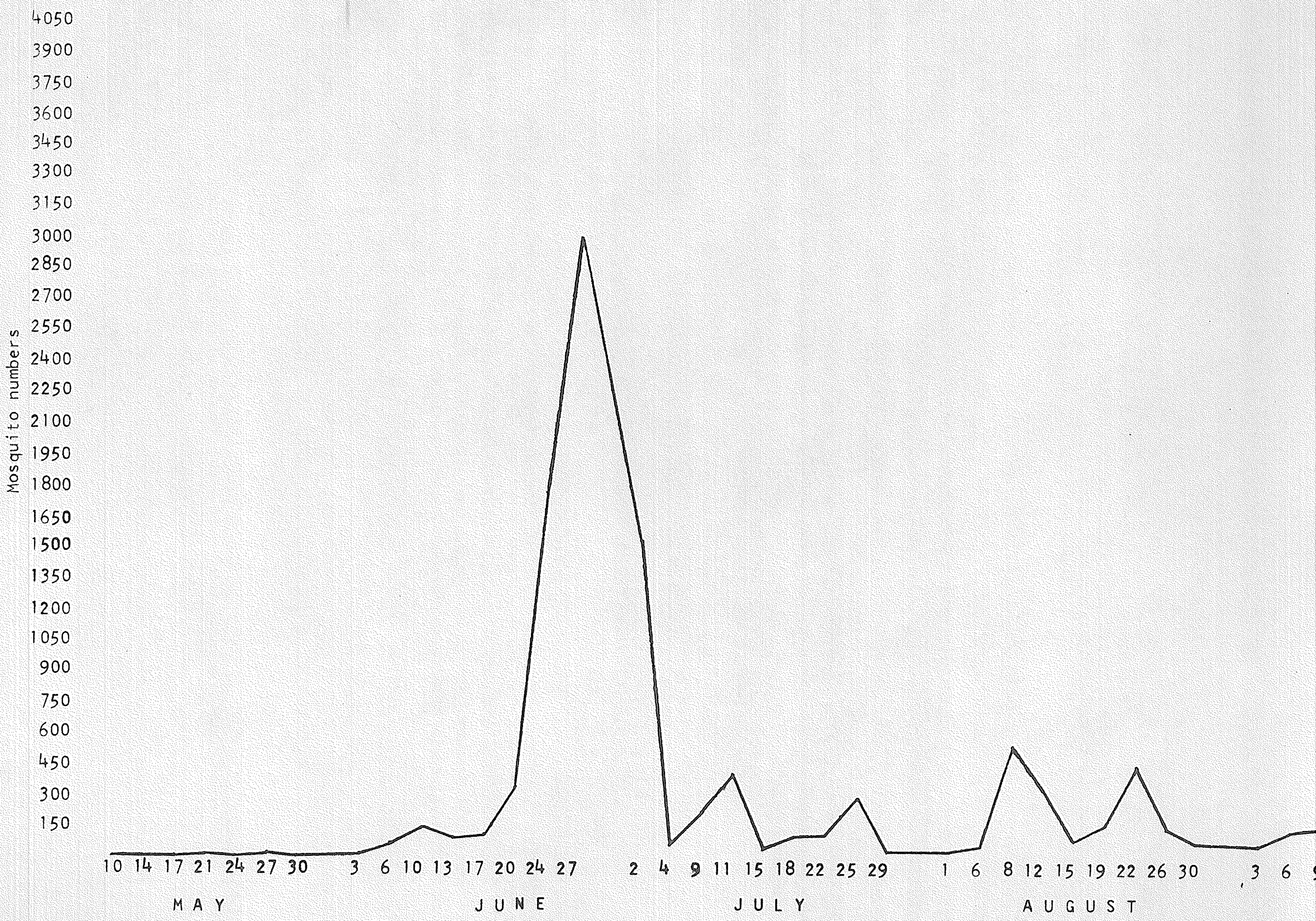

Mosquito numbers
4050
3900
3750
3600
3450
3300
3150
3000
2850
2700
2550
2400
2250
2100
1950
1800
1650
1500
1350
1200
1050
900
750
600
450
300
150
10 14 17 21 24 27 30
3 6 10 13 17 20 24 27
2 4 9 11 15 18 22 25 29
1 6 8 12 15 19 22 26 30
3 6
MAY
JUNE
JULY
AUGUST

Figure 27. The Number of Female Mosquitoes caught in a Sprayed Area - Kildonan Park

AVERAGE ♀ CATCHES PER TRAP – KILDONAN PARK

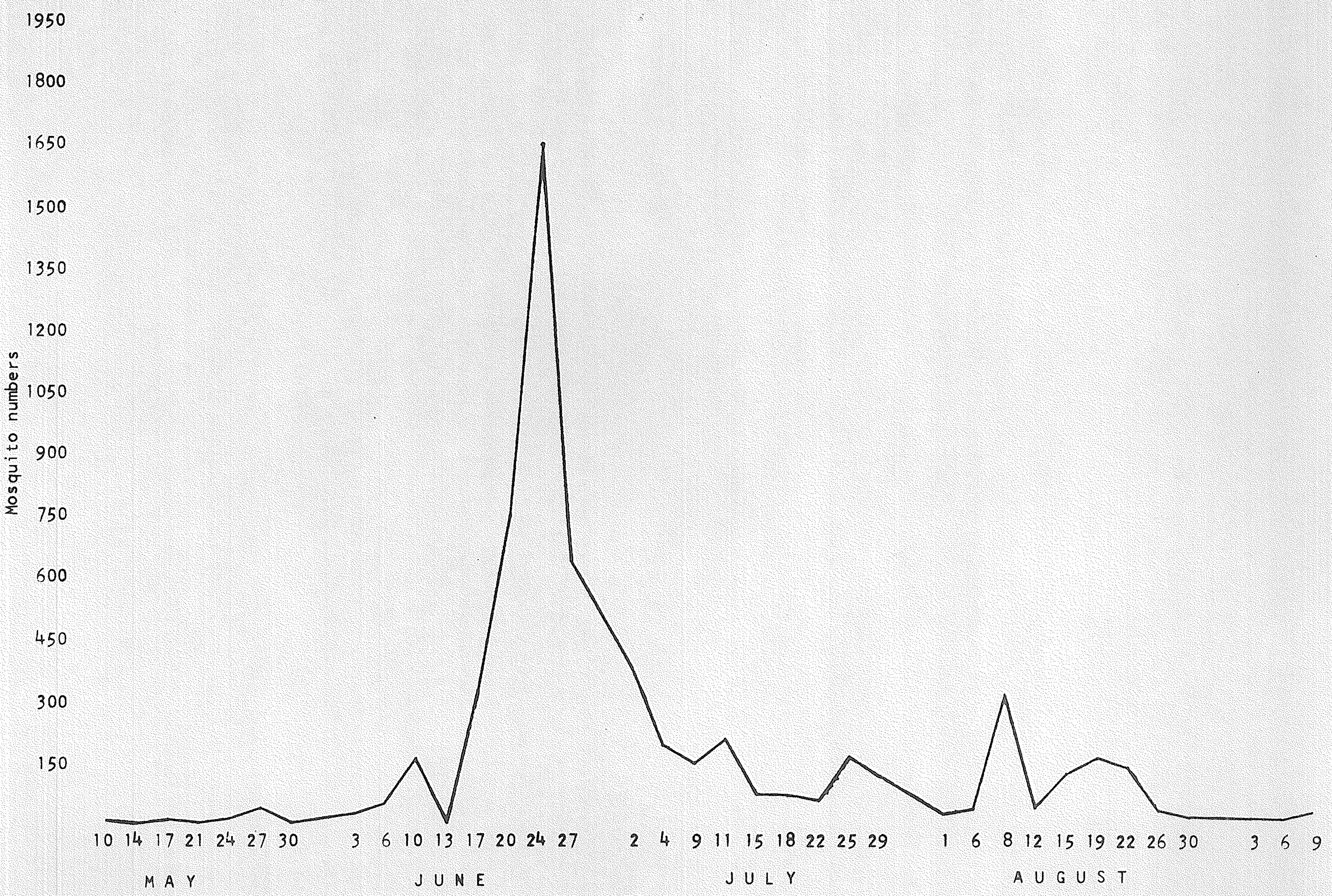
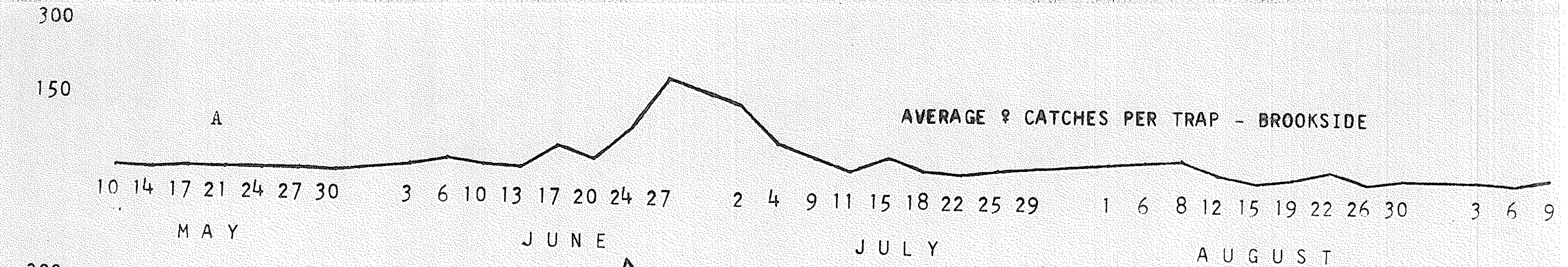
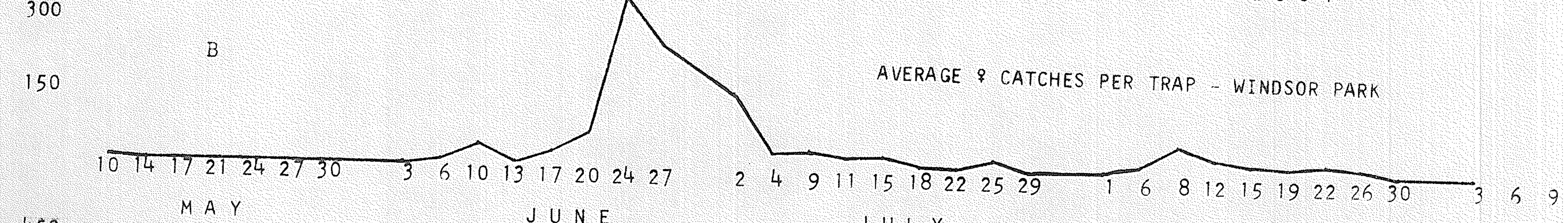


Figure 28. The Number of Female Mosquitoes caught in other Sprayed Areas

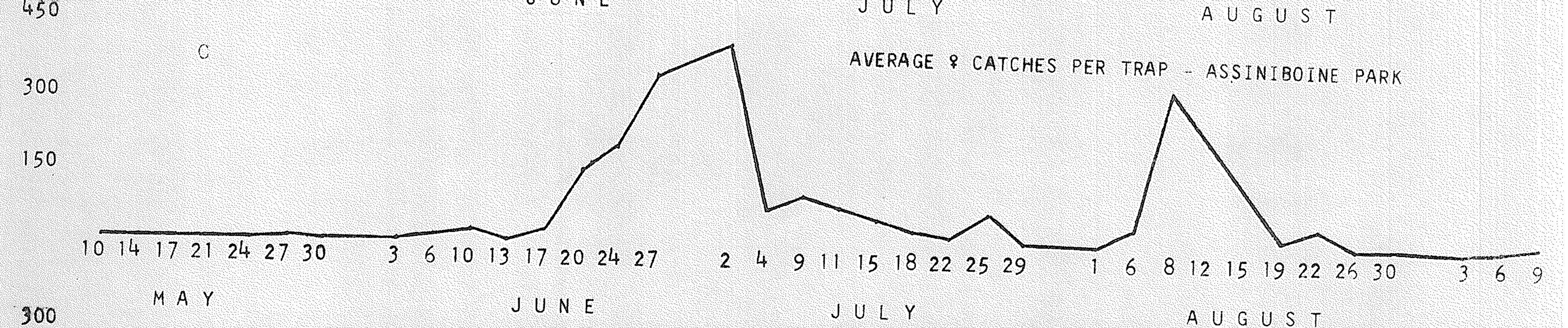
A. Brookside Cemetery
B. Windsor Park
C. Assiniboine Park
D. Legislative Buildings
E. St. Vital



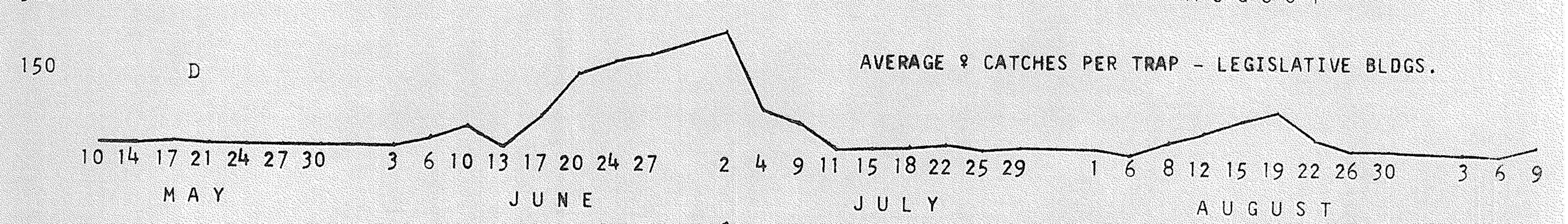
AVERAGE ♀ CATCHES PER TRAP - BROOKSIDE



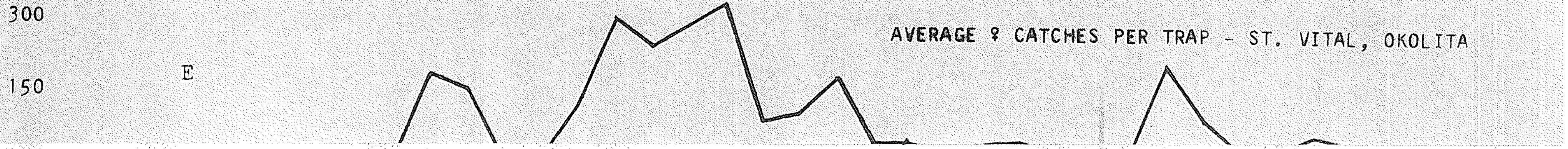
AVERAGE ♀ CATCHES PER TRAP - WINDSOR PARK



AVERAGE ♀ CATCHES PER TRAP - ASSINIBOINE PARK



AVERAGE ♀ CATCHES PER TRAP - LEGISLATIVE BLDGS.



AVERAGE ♀ CATCHES PER TRAP - ST. VITAL, OKOLITA

TABLE XX

Average Percentage of Mosquito Species (Females) During a Period of Peak Adult Activity (June 20-July 4, 1963) at Eight Collection Sites

Trap Sites	University of Manitoba	Oak Bluff	Assiniboine Park	Brookside	Kildonan Park	Legislative Buildings	Windsor Golf Course	St. Vital
Species								
Aedes vexans	93.0	88.0	75.0	46.0	91.0	89.0	91.0	84.0
" dorsalis	1.1	0.0	16.5	31.0	0.5	4.5	4.0	5.0
" flavescens	1.0	7.1	1.5	15.0	3.0	3.5	2.0	1.0
" spencerii	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
" campestris	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
" stimulans	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0
" excrucians	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0
" cantator	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0
Culex pipiens	0.0	2.6	0.5	1.5	1.0	0.0	0.0	0.0
" tarsalis	1.0	0.0	1.0	1.5	1.5	1.5	0.0	0.4
Culisita inornata	2.1	1.5	4.0	3.0	3.0	1.5	3.0	7.0
Anopheles earlei	0.0	0.0	0.0	1.0	0.0	0.0	0.0	2.6
Totals	5063	21738	4457	1832	12879	3232	3120	4146

Date based on five collections

TABLE XXI

Average Percentage of Mosquito Species (Females) During a Period of Peak Adult Activity (August 19-26, 1963) at Eight Collection Sites

Trap Sites	University of Manitoba	Oak Bluff	Assiniboine Park	Brookside	Kildonan Park	Legislative Buildings	Windsor Golf Course	St. Vital
Species								
Aedes vexans	95.0	86.6	90.0	41.6	90.0	93.3	88.3	85.0
" dorsalis	0.0	0.0	3.3	0.0	1.6	0.0	0.0	0.0
Culiseta inornata	1.2	3.3	5.0	18.3	1.6	0.0	1.6	3.3
" melanura	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Culex pipiens	1.2	1.6	1.6	28.3	3.3	3.3	1.6	3.3
" peccator	0.0	1.6	0.0	0.0	0.0	0.0	0.0	0.0
" tarsalis	0.0	0.0	0.0	3.3	3.3	0.0	0.0	1.6
" restuans	1.2	0.0	0.0	8.3	0.0	0.0	0.0	1.6
" coronator	0.0	0.0	0.0	0.0	0.0	1.6	0.0	0.0
Anopheles earlei	0.0	6.6	0.0	0.0	0.0	1.6	8.3	5.0
Totals	547 *	2652	242	205	1231	579	171	545

Data based on three collections
* Data based on two collections

TABLE XXII

Average Percentage of Mosquito Species (Females) During a Period of Peak Adult Activity (August 6-15, 1963) at Eight Collection Sites

Trap Sites	University of Manitoba	Oak Bluff	Assiniboine Park	Brookside	Kildonan Park	Legislative Buildings	Windsor Golf Course	St. Vital
Species								
Aedes vexans	93.7	88.8	95.0	60.0	68.7	95.0	95.0	80.0
" dorsalis	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
" flavescens	0.0	0.0	0.0	1.6	0.0	0.0	0.0	0.0
" cantator	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
" spencerii	0.0	0.0	2.5	0.0	0.0	0.0	0.0	0.0
Culiseta inornata	0.6	3.7	2.5	3.3	1.2	0.0	2.5	5.0
" melanura	0.0	0.0	0.0	1.6	0.0	0.0	0.0	3.7
Culex pipiens	1.2	1.2	0.0	31.6	2.5	5.0	1.2	1.2
" tarsalis	1.2	1.2	0.0	1.6	25.0	0.0	0.0	0.0
" stigmatosoma	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0
Anopheles earlei	0.6	5.0	0.0	0.0	1.2	0.0	1.8	10.0
Totals	1149	3105	845 **	223 ***	1374	17 *	354	1224

Data based on four collections
* Data based on one collection
** Data based on two collections
*** Data based on three collections

A COMPARISON OF ADULT SURVEYS - 1959, 1962 AND 1963

A comparison of various adult surveys has led to some interesting considerations. One of the more prominent ones is the number of peaks of populations for the individual surveys. In 1959, there were 3 more obvious peaks, 6 in 1962 and 3 again in 1963. The peaks in 1962 were also much higher than the other two surveys showed. These various features are illustrated in Figure 29.

A definite correlation can be seen between the amount of precipitation and the number and height of the peaks. The precipitation and temperatures are shown in Tables xxiii, xxiv and xxv. Precipitation however, seems to have the greatest influence upon mosquito populations. The greatest number of peaks found in 1962 were due to very heavy precipitation in July and August. This was also a contributing factor to the lateness of one of the peaks which extends into September. The precipitation for both July and August combined was approximately 8 inches above normal (Table xxiv). The precipitation in 1959 was only slightly above normal (Table xxiii) and below normal in 1963 (Table xxv).

In 1959, the first peak in mosquito population was considerably earlier than 1962 and 1963. This was probably due to the earlier spring rains in 1959. The first heavy rainfalls in 1959 have been recored as early as from the 3rd to 5th of May, almost 2 weeks sooner than 1962 and 1963.

Figure 29. The Average Female Catches outside Metro - 1959, 1962 and 1963

AVERAGE FEMALE CATCHES OUTSIDE METRO - 1959, 1962, and 1963

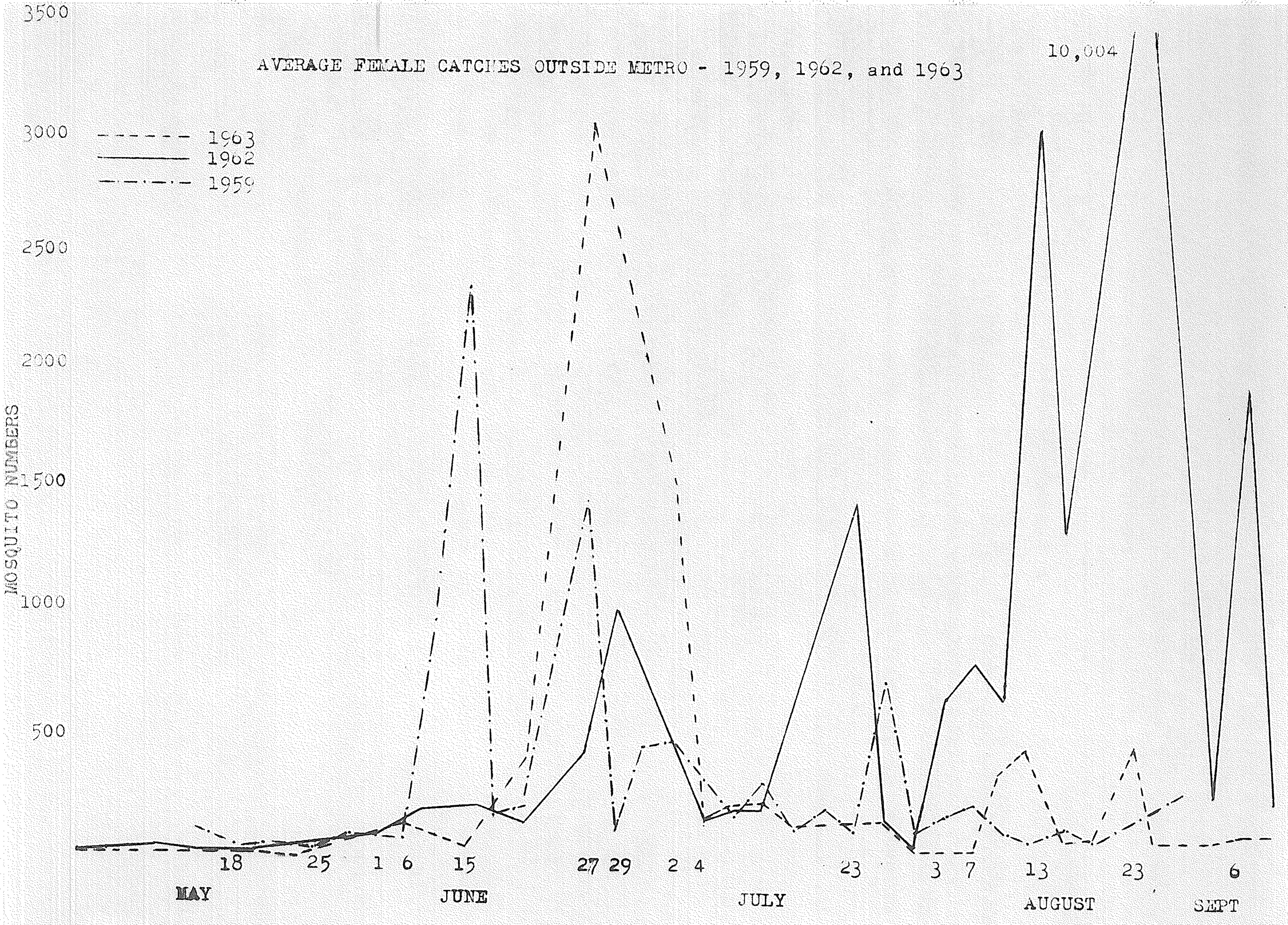


TABLE XXIII

Precipitation 1959

	May		June		July		August	
	2	.03''	2	.06''	1	.01''	2	.25''
	3	.37	6	.35	3	.19	5	.08
	4	.60	7	.51	4	.83	9	.45
	5	.66	8	.12	6	.04	10	.03
	10	.51	9	.23	7	.08	13	.22
	12	.08	10	.33	8	.50	15	.08
	17	.06	11	.06	10	.03	16	.07
	18	.02	17	.20	13	.05	19	.95
	22	.08	20	.10	14	.81	21	.15
	24	.44	26	.36	20	.07	22	1.50
	26	1.20	28	.01	21	.79	26	.16
	27	.50			22	.09		
	28	.08			25	.08		
Totals		4.63		2.33		3.57		3.94
Normal		2.18		3.18		2.94		2.53

Temperature 1959

	May	June	July	August
Mean	49.1	63.2	67.8	67.4
Normal	51.9	62.0	67.1	64.5

TABLE XXIV

Precipitation 1962

May		June		July		August
7	.21"	4	.26"	3	.53"	Not available
9	.12	7	.18	4	1.89	
13	.52	10	.07	6	.03	
14	.90	14	.62	7	.33	
15	.11	15	.37	8	.09	
17	.42	24	.61	9	.10	
19	.43			10	.20	
22	.35			20	1.77	
23	.59			22	.38	
29	1.01			23	.11	
30	.50			24	.59	
31	.05			28	.02	
				29	.04	
				30	.03	
Totals	5.21		2.11		6.11	6.83
Normal	1.97		3.19		2.71	More than 4" above normal

Temperature 1962

	May	June	July	August
Mean	51.5	65.1	65.6	65.3
Normal	52.4	61.7	68.3	Less than one degree below normal.

TABLE XXV

Precipitation 1963

May		June		July		August	
7	.11''	3	1.47''	7	.01''	5	.04''
12	.19	4	.61	10	.20	8	.20
13	.52	6	.07	11	.22	12	.01
17	.36	8	.02	13	.01	15	.26
18	.12	10	.64	15	.04	16	.65
19	.13	12	.11	16	.32	18	.01
20	.28	13	.01	18	.03	20	.02
26	.24	18	.02	24	.01	21	.28
30	.42	23	.08	25	.87	23	.01
31	.22	25	.14	26	.41	27	.10
		26	.18			28	.02
		27	.02			29	.49
		29	.06				
Totals	2.59		3.43		2.12		2.09
Normal	1.97		3.19		2.71		2.76

Temperature 1963

	May	June	July	August
Mean	49.8	66.2	71.3	67.2
Normal	52.4	61.7	68.3	66.0

CHAPTER VI

INSECT MIGRATION AND DISPERSAL

The purpose of this investigation was to determine if mosquitoes were migrating into Winnipeg from an external breeding site. Interest in migration was aroused when counts in an often sprayed area (Kildonan Park) remained high in spite of the excessive fogging.

Method and Apparatus

The design of the tall trap was obtained by personal communication from Taylor. The trap was erected in an area geographically similar to that of Kildonan Park at Glenlea on the banks of the Red River. The trap was set up near to the river in order to obtain maximun advantage of down drafts which could bring or transport insects closer to the surface of the earth. The distance from the trap to the river was approximately 75 metres.

A photograph of the tall trap is illustrated in Figure 30 and the general layout surrounding the trap is shown in Figure 31. The entire structure was 40 feet tall and was mounted on a cement base. A 30 foot pipe, 10 inches in diameter was mounted on a 10 foot stand construced from marine plywood and angle iron. The stand was 30 inches square in dimensions. Within the stand, mounted on the cement base was a 3/4 H.P. motor which propelled a furnace blower (Figure 32).

The air was sucked through the entire structure and expelled through an opening at the base of the stand. The corners of the plywood stand were fitted as tightly as possible to ensure maximun performance from the blower. The top of the pipe was left entirely open allowing all species of insects to be sucked in. A screen funnel 4 feet long, was attached to the base of the pipe and its purpose was to direct insects into a cyanide jar (Figure 33). The electric motor with the blower was allowed to run continuously both day and night. The catches were collected and counted.

Results See Following Table (XXVI)

TABLE XXVI

Date	No. of Days	No. of Mosq.	Females	Males	Aedes vexans	Culex tarsalis	Culiseta inornata	Aedes stimulans
June 22	1	1	0	1				1
" 23	1	1	1	0	1			
" 24	1	0	0	0				
" 25	1	0	0	0				
" 26	1	1	1	0			1	
" 29	3	138	26	112	26			
" 30	1	44	4	40	4			
July 2	2	813	32	781	32			
" 3	1	1867	21	1846	21			
" 6	3	815	35	780	35			
" 7	1	5	3	2	3			
" 8	1	939	30	909	29	1		
" 9	1	292	2	290	2			
" 10	1	34	2	32	2			
" 13	3	38	7	31	7			
" 14	1	44	10	34	5		5	
" 16	2	37	5	32	3		2	
" 17	1	149	3	146	3			
" 20	3	121	8	113	6	1	1	
" 21	1	2	1	1		1		
" 22	1	5	1	4		1		
" 24	2	1	0	1				
" 28	4	44	2	42	Too damaged to identify			
" 30	2	73	4	69	4			

Only the females have been identified in the above table. The males were usually always Aedes vexans. Occassionally male Culiseta inornata (5) were caught. Moths, aphids, ichneumonids, midges and other insects were also caught.

Discussion

Heavy rains occurred within and surrounding the metro area from June 16 - 20th. Many 1st - 2nd instar larvae were observed at Oak Bluff on June 22nd. By June 26th these larvae had moulted 3 times and given rise to the 4th instar. At this time however, there were no biting mosquitoes. Intense biting occurred in the metro area on Sunday evening, June 28th. Many pupae were collected Monday morning, June 29th at Oak Bluff with biting being extremely intense. The New Jersey Traps were collected on Tuesday, June 30th at Oak Bluff and a grand total of 3016 mosquitoes had been trapped with females out-numbering males almost 2 to 1 (females - 1920 and males - 1096). On July 3rd however, the ratio of females to males was 1 to 2 (females - 351 and males - 702). From the above data, it seems that the female mosquitoes emerged about the same time as the males did. Females on Sunday evening, June 28th were far too numerous to have emerged locally and probably migrated or were dispersed into the metro area.

Three days before the female population peak occurred in Kildonan Park, the female population peak occurred in the tall trap increasing from 4 female mosquitoes on June 30th to 21 on July 3rd per day (Figure 34). The males showed the same pattern in that the peak male population in the tall trap occurred 3 days before the peak male population in the New Jersey Trap at Kildonan Park. This could suggest that mosquitoes were migrating into the Winnipeg area from an external breeding site and therefore the tall trap set outside the metro area collected peak populations 3 days sooner than the New Jersey Trap at Kildonan Park. Further investigations are however still necessary to clarify this point. To make the situation more ideal, a tall trap should have been located at Kildonan Park.

It is also interesting to note that in spite of the lack of rain since mid-June, the New Jersey Traps in all areas and the tall trap at Glenlea still collected many male mosquitoes on July 28th.

TABLE XXVII

	Females	Males
University of Manitoba	57	47
Oak Bluff	231	316
City Park	25	18
Brookside	0	0
Lillyfield	146	415
Kildonan Park	142	117
Legislative Bldg.	95	157
Windsor Park	9	17
Okolita	170	97
Totals	875	1184

Since the average life span of a male mosquito is only 2-3 weeks, where are they coming from? The only probable answer is that the males were migrating into the Winnipeg area from outside metro where some heavy rains had occurred. This is borne out by the fact that in the outside area traps at Oak Bluff and especially Lillyfield the males far outnumbered the females.

Aedes vexans, *Culex tarsalis* and *Culiseta inornata* were most often found in the tall trap and were therefore probably migrating. Other common species as *Aedes dorsalis* and *Aedes flavescens* were however never found in the tall trap and were either too rare or did not migrate.

Conclusion

From the above date, it is quite reasonable to conclude that migration of mosquitoes is occurring into the Winnipeg area but further information especially utilizing a few more tall traps would be helpful. It appears that the tall trap captures the invading mosquitoes mainly after they arrive rather than during arrival.

Figure 30. The Tall Trap Used for Migration Studies

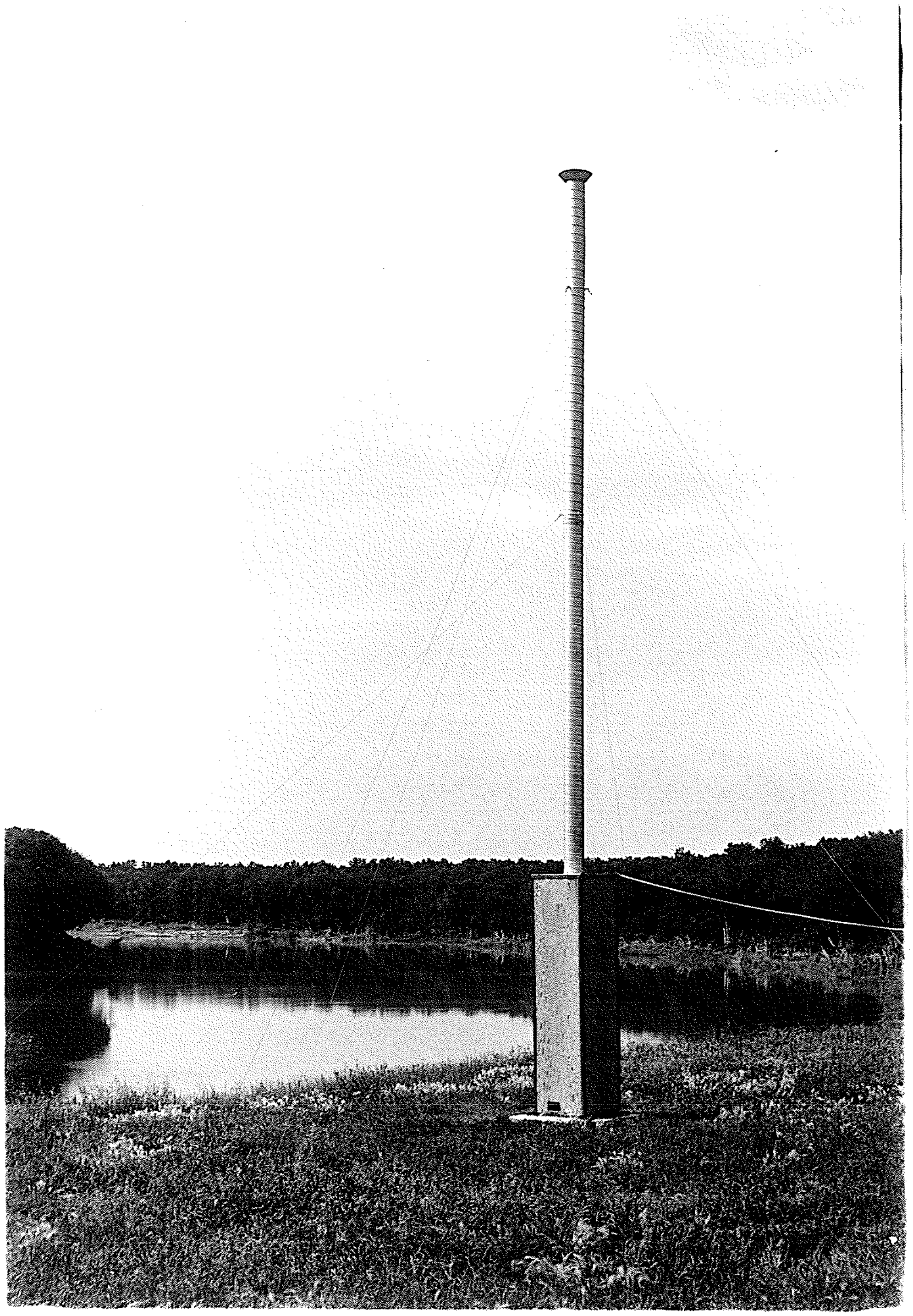


Figure 31. The General Layout of the Land surrounding the Tall Trap

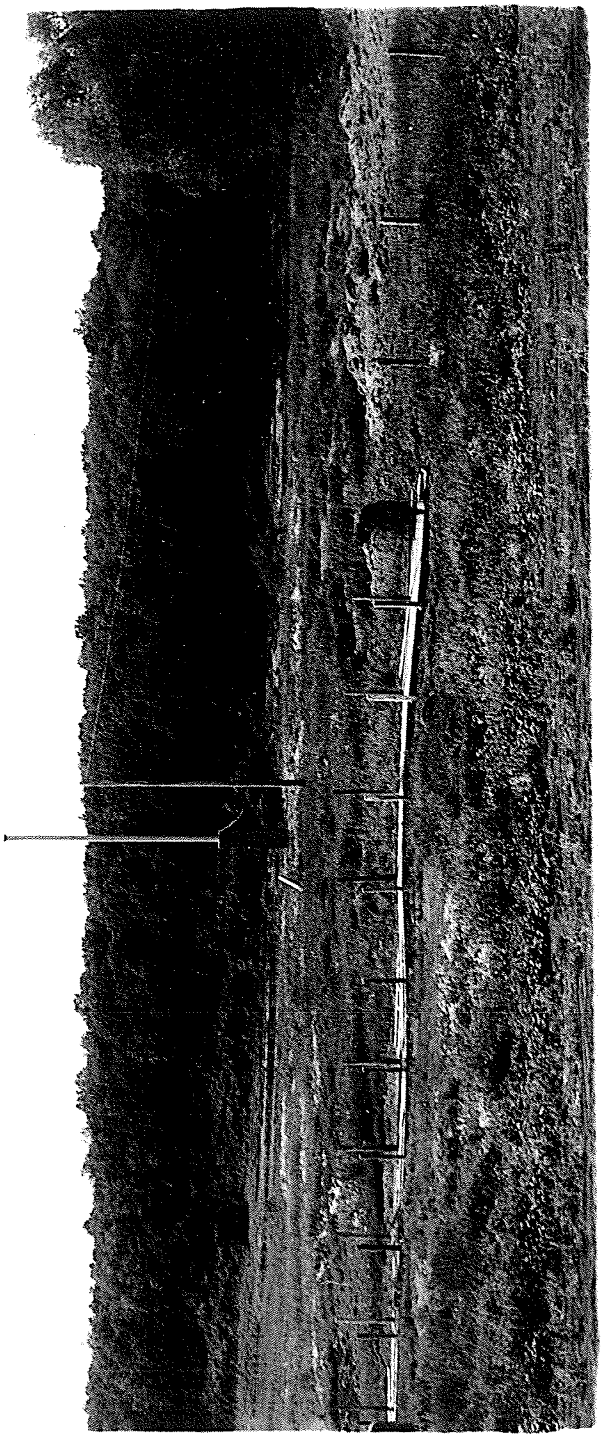


Figure 32. The 3/4 H. P. Motor and Furnace Blower Mounted within the Stand on the Cement Base

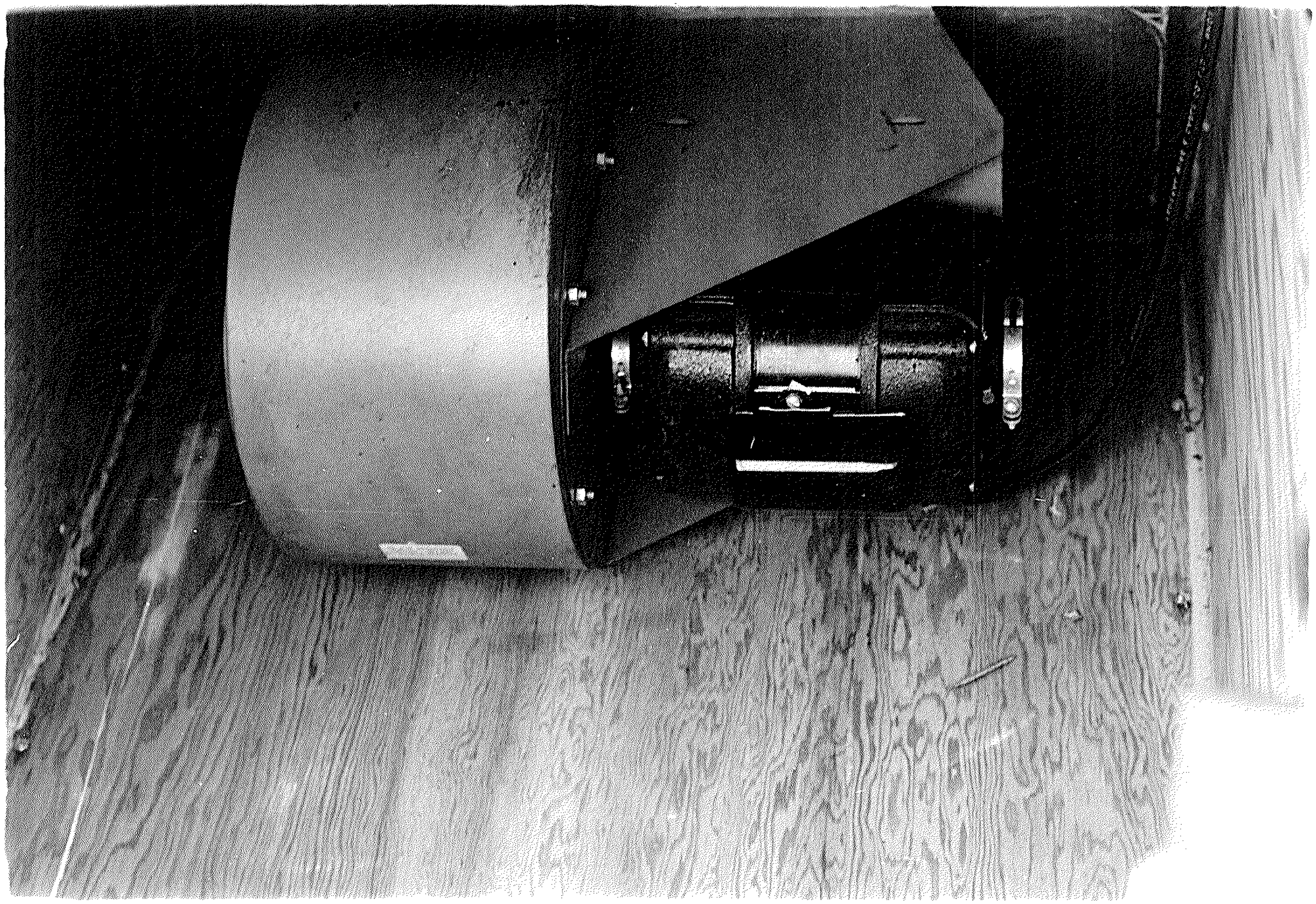


Figure 33. The Cyanide Jar Attached to the Base of the Funnel

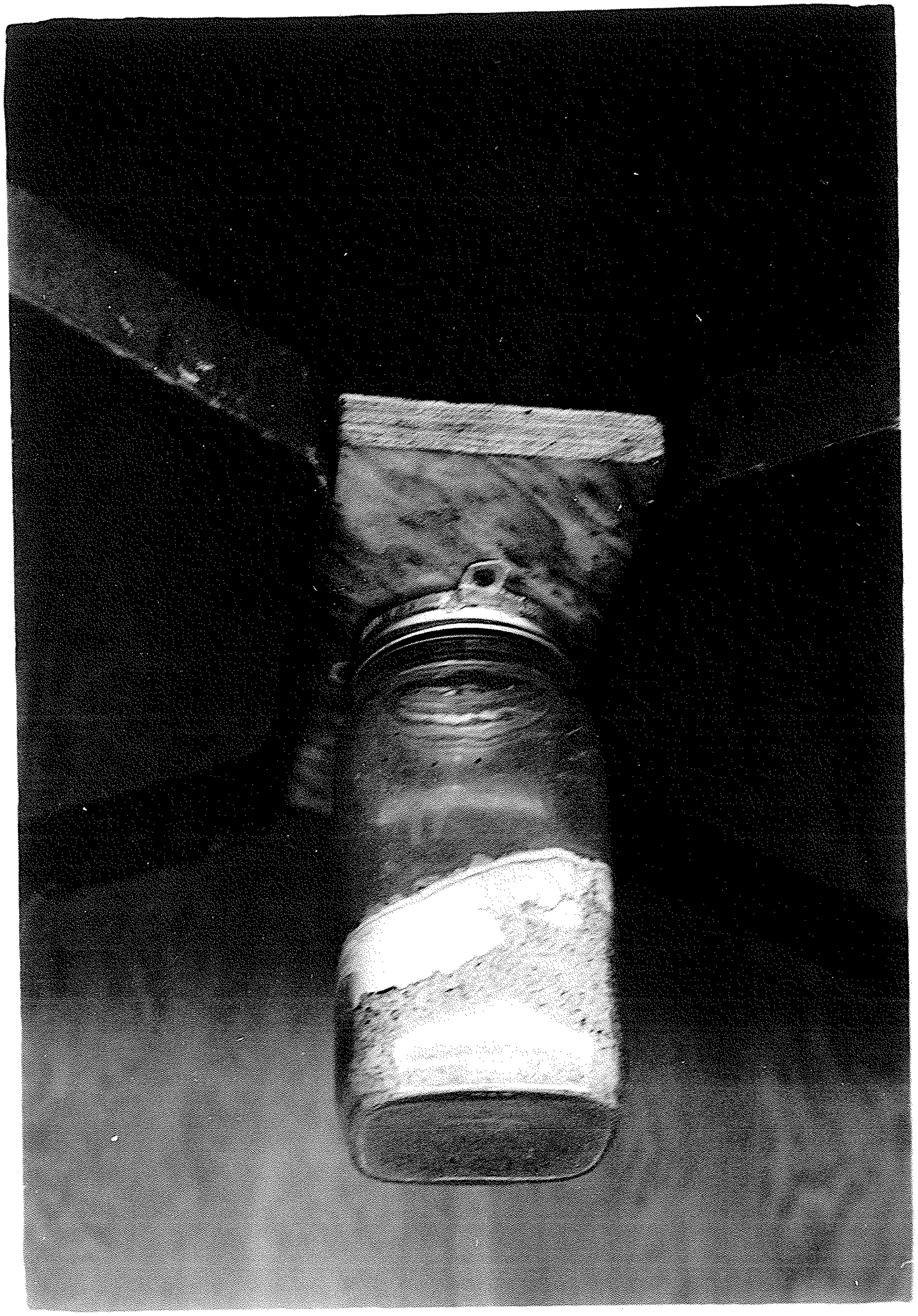
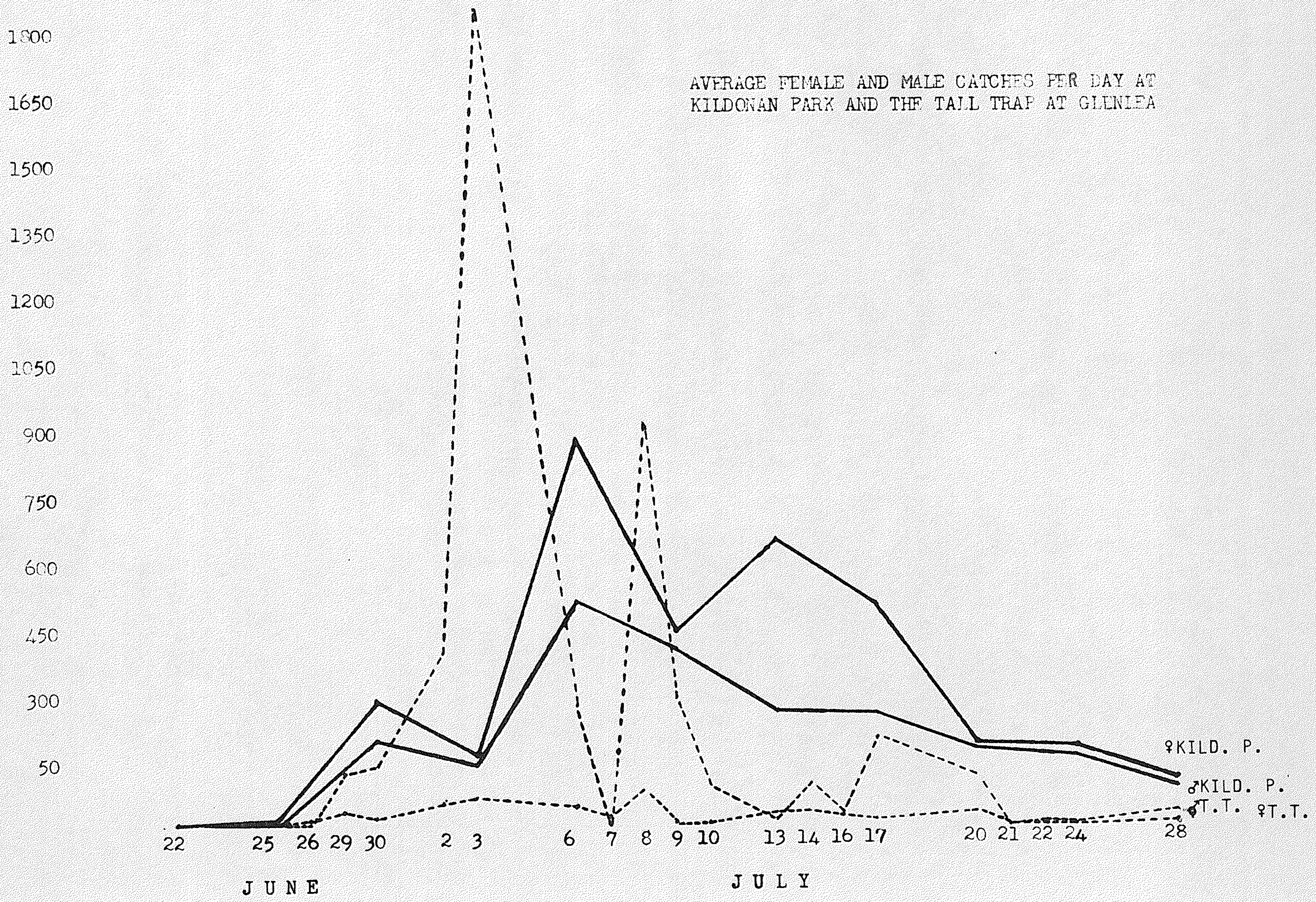


Figure 34. The Average Daily Female and Male Catches from the New Jersey Trap at Kildonan Park, and from the Tall Trap at Glenlea



AVERAGE FEMALE AND MALE CATCHES PER DAY AT KILDONAN PARK AND THE TALL TRAP AT GLENLEA

CHAPTER VII

SECTION I

INSECTICIDE RESISTANCE TESTS

In the last decade or slightly more there has been increased concern over the developement of resistance by numerous insects to insecticide applications. In a little more than ten years about forty species of insects of public health importance have developed resistance to the synthetic organic insecticides which formerly controlled them. This severe setback to the large-scale campaign against insect - and tick-borne diseases has led to much work on resistance particularly in house-flies and mosquitoes. The problem, however, is not recent, nor is it confined to insects of medical importance, for it first arose in pest control on fruit crops. In 1908 lime-sulphur failed to control the San Jose scale in parts of U.S.A. even when applied at a dose ten times greater than that which formerly gave excellent control (Way, 1959).

By 1943 the resistance of codling moth in Virginia, U.S.A. could not be overcome by trebling the number of spray applications, by doubling the volume of spray applied each time, by increasing the dose of arsenic or by various other variations of procedure.

In increasingly large areas throughout the world, house-flies and mosquitoes have developed resistance to chlorinated hydro-carbon insecticides such as D. D. T., BHC, and dieldrin. Sometimes they have become practically immune. Thus, certain strains of mosquitoes have a resistance of about 300 times normal to D. D. T. and 800 times normal to dieldrin. The same has been found true for the house-fly (Way, 1959).

Durham, 1957, states that organic phosphorous insecticides are assuming an increasingly important role in mosquito control because of the widespread developement of insect resistance to D. D. T. and, in a somewhat lesser degree, to other chlorinated hydro-carbons. This was also enlarged upon by Schoof (1960).

Many different species of mosquitoes are resistant to insecticides. Aedes aegypti in Trinidad, Anopheles sundaicus in Java and Anopheles gambiae in Northern Nigeria are either resistant to dieldrin or D. D. T. (Brown, 1959).

Larvae of Culex pipiens taken in 1947 from the Pontine Marshes near Rome proved to be more resistant to D. D. T. than a laboratory strain. In 1949, larval populations of salt-marsh mosquitoes (Aedes taeniorhynchus and sollicitans) at Cocoa Beach, Brevard County, Florida, proved to be resistant to D. D. T. treatments which had adequately controlled their predecessors in the preceding four years; in the laboratory they proved to show 18% mortality to concentrations that killed 90% of normal populations. In the same year, larval populations of Culex and

Aedes had proved resistant to D.D.T. in California (Brown, 1951).

Although resistant strains are being found in mosquitoes, they are still more prevalent in the common house-fly (Brown, 1951). Many other species of insects can be added to the list.

Due to this increase in resistance, the resistance or susceptibility of mosquito larvae to insecticides was tested in the Winnipeg area and the method and results of these tests will follow presently.

Method and Apparatus

The resistance test kit was supplied by The World Health Organization in Geneva. Lots of 20-25 larvae were distributed in each of twelve small beakers each containing 25 mls. of water. Concentrations of D.D.T., Gamma BHC, and dieldrin of .004, .02, .10, .50, and 2.50 p.p.m. were employed using two beakers with each concentration together with a control. These concentrations were obtained by adding one ml. of the insecticide to 250 mls. of water. The water that was used was mostly the water in which the larvae were found and if this was not sufficient, a small amount of tap water was added. The test larvae were left exposed to the insecticide for 24 hours before the results were taken.

Results

In all the tests that were made no resistance was found (Tables xxviii, xxix and xxx). Only the pupae survived.

Conclusion

There was no resistance found in mosquito larvae to various insecticide applications.

TABLE XXVIII

WORLD HEALTH ORGANIZATION
REPORT FORM

Test for Insecticide-Resistance in Mosquito Larvae

1. Locality: Winnipeg, Man. Investigator: N. Brandt - E. Kuch
2. Species of mosquito: Instar: 3rd
3. Insecticide tested: DDT Grade (purity):
4. Date of test: May 30/63
5. Temperature at which test was performed: 21°C
6. Results of test (Abbreviations: "L" - living, normal or slightly affected; "M" - moribund: "D" - dead):

Concentration of insecticide in test suspension	Replicate number	Final condition of larvae at 24 hrs				
		L	M	D	Total	Percent M + D
.004 p.p.m.	I	2	0	18	20	90%
	II	0	0	20	20	100%
.02 p.p.m.	I	0	0	20	20	100%
	II	0	0	20	20	
.10 p.p.m.	I	0	0	20	20	100%
	II	0	0	20	20	
.50 p.p.m.	I	0	0	20	20	100%
	II	0	0	20	20	
2.50 p.p.m.	I	0	0	20	20	100%
	II	0	0	20	20	
Control (without solvent)	I	18	0	2	20	10%
	II	15	0	5	20	25%
Supplementary Concentrations	I				~~20~~	
	II				~~20~~	
	I					
	II					

Remarks:

WORLD HEALTH ORGANIZATION

REPORT FORM

TABLE XXIX

Test for Insecticide-Resistance in Mosquito Larvae

1. Locality: University of Man. Investigator: M Brandt & E Kirch
2. Species of mosquito: Instar: 3. 3rd
3. Insecticide tested: Gamma BHC Grade (purity):
4. Date of test: July 31
5. Temperature at which test was performed: 27 °C
6. Results of test (Abbreviations: "L" - living, normal or slightly affected; "M" - moribund: "D" - dead):

Concentration of insecticide in test suspension	Replicate number	Final condition of larvae at 24 hrs				
		L	M	D	Total	Percent M + D
.004 p.p.m.	I	6	2	12	20	70%
	II	7	1	12	20	65%
.02 p.p.m.	I	0	0	20	20	100%
	II	0	0	20	20	
.10 p.p.m.	I	0	0	20	20	100%
	II	0	0	20	20	
.50 p.p.m.	I	0	1	19	20	100%
	II	0	0	20	20	
2.50 p.p.m	I	0	0	20	20	100%
	II	0	0	20	20	
Control (without solvent)	I	17	0	3	20	15%
	II	18	0	2	20	10%
Supplementary Concentrations	I					
	II					
	I					
	II					

Remarks: The immature mosquitoes found which were dead were pupae.

TABLE XXX

WORLD HEALTH ORGANIZATION

REPORT FORM

Test for Insecticide-Resistance in Mosquito Larvae

1. Locality: Winnipeg　　Investigator: N. Brandt & E. Kusk
2. Species of mosquito:　　Instar: 2 - 3
3. Insecticide tested: Dieldrin　　Grade (purity):
4. Date of test: June 12
5. Temperature at which test was performed: 24 °C
6. Results of test (Abbreviations: "L" - living, normal or slightly affected; "M" - moribund: "D" - dead):

Concentration of insecticide in test suspension	Replicate number	Final condition of larvae at 24 hrs				
		L	M	D	Total	Percent M + D
.004 p.p.m.	I		0	25	25	100
	II		0	25	25	100
.02 p.p.m.	I		0	25	25	100
	II		0	25	25	100
.10 p.p.m.	I		0	25	25	100
	II		0	25	25	100
.50 p.p.m.	I		0	25	25	100
	II		0	25	25	100
2.50 p.p.m.	I		0	25	25	100
	II		0	25	25	100
Control (without solvent)	I	23	0	2	25	8%
	II	20	0	5	25	20%
Supplementary Concentrations	I					
	II					
	I					
	II					

Remarks:

SECTION II

Saponin as a Larvacide

From prior experiments it was discovered that saponin at a concentration of .1% prevented the moulting of Melanoplus bivitattus when the insects had advanced to the second or third instar. The chemical saponin, was obtained from Mann Research Laboratories and is a mixture of quilliac acid and sapotoxin which are both glucosides. It is obtained from the bark of the quillaia saponaria tree and is imported from the Chile in South America.

The same type of investigations were attempted using Aedes aegypti mosquito larvae in the first instar. Two experiments were completed employing different concentrations for each and the results were as follows:

Experiment A

These investigations included the following concentrations of saponin: .1, .5, 1, 5, and 10%. A small amount of dog food was added to each concentration and a control with water and dog food was run with the experiment.

Experiment B

The concentrations of saponin employed for this experiment were:

.5, .05, and .005% together with a control as in Experiment A.

Results - Experiment A

After 48 hours, none of the mosquito larvae in any of the concentrations had moulted and all were dead. All larvae in the control treatment developed normally to the adult stage.

Experiment B

After 48 hours, all the larvae at .5% concentration were dead. Two out of 10 were still alive in the .05% concentration and all the larvae were alive in .005% concentration. After 72 hours all the larvae in .05% concentration were dead, but still living and moulting in .005%. After 6 days pupation had taken place in .005% concentration and in the control normal developement continued.

Conclusion

Saponin definitely inhibits moulting of *Aedes aegypti* mosquito larvae and may have practical significance in the future.

CHAPTER VIII

SUMMARY

The orientation experiments in the summer of 1963 were attempted with a large revolving trap containing four New Jersey Traps facing different directions. The shape of the trap however, resulted in the formation of many unwanted vortices and lees. Different directional traps were designed for the following summer and were much more effective. The ratio of downwind to upwind catches was drastically reduced when the new directional traps were employed. Mosquitoes orientated in an upwind direction, but many still flew downwind. On the contrary, chironomids flew in a downwind direction but many still flew upwind. Moths orientated neither in an upwind or downwind fashion. No significant differences for the total number of insects between upwind and downwind flight directions was found.

In the laboratory, the reactions of flying mosquitoes to a moving background were tested. *Aedes aegypti* attempted to keep the background stationary or moving from the front of the eye backwards during flight. Flight with substrate movement was direct and rapid, but attempts to fly against substrate movement were irregular and hesitant. Flight with substrate movement was at a much lower altitude in the flight tunnel. The mosquitoes never alighted when stripe movement surpassed flight speed. *Aedes vexans* and *Aedes implicatus* did not react in the same manner to background movement as did Aedes aegypti. In contrast with Aedes implicatus however, flight was much easier to initiate with Aedes vexans.

A high velocity of wind followed by complete stoppage stimulated certain mosquito species to take off. The flight periods of Aedes aegypti were found to be longer than those of Aedes vexans. This was illustrated by the fact that more mosquitoes were flying at the end of each minute for Aedes aegypti. Aedes implicatus did not react to the take off or flight stimulant.

A survey of the adult mosquito population was carried out in an effort to compare treated with untreated insecticide areas. In 1963 the light trap catches were much higher in the untreated areas in comparison with the treated one. The migration of mosquitoes into the Greater Winnipeg area from an external breeding site was reasonably extablished by utilizing a tall 40 foot trap designed by Taylor. The peak catches in the tall trap were almost simultaneous to those in the New Jersey Trap at Kildonan Park.

Tests revealed that insecticide resistance had not yet developed in the native mosquitoes. Three insecticides (D. D. T., Gamma BHC and dieldrin) were tested at various dilutions and all of them proved to be quite effective after a 24 hour period.

Saponin proved to be an effective larvacide at minute concentrations. Concentrations of 10, 5, 1, .5, .1, .05 and .005% were tested. After 72 hours, all the larvae from 10-.05% concentrations were dead. Those in the .005% concentration developed normally.

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