ECOLOGY OF MOSQUITO LARVAE IN THE WINNIPEG AREA AND EVALUATION OF INSECTICIDES FOR FUTURE USE IN MOSQUITO CONTROL.

A

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ABSTRACT

A survey of mosquito developmental sites around Winnipeg during 1967 and 1968, showed that mosquitoes use less than thirty percent of the available water for development and the amount of water present on the land for mosquito development is in part, determined by the length of time between rainfalls. The distribution of rainfall over the city largely determined mosquito abundance in any particular region. The time between rainfalls determined whether a new generation could be produced. Aedes vexans populations increased in size throughout the summer, provided precipitation patterns were favourable. Pools were used repeatedly by the same species,but most pools were shared by several species of mosquitoes.

Adult surveys by means of a light trap, indicated that mosquito species may vary in their response to light traps. Response to a light trap also depends upon the physiological state of the mosquito and atmospheric conditions. In regard to all species trapped, the adult population levels inside the city were smaller than those outside the city in both controlled and non-controlled areas. The ratio of inside/ outside populations in the non-controlled area was higher than in the controlled area.

On a monthly basis, or on a whole season basis, light trap population figures can be meaningful. However, on a

nightly, or even a weekly basis, it was found that light traps mainly monitor adult activity. Weekly or bi-weekly peaks or lows do not necessarily indicate a change in the adult population, only activity.

Natural repopulation of areas treated with insecticides did not indicate when insecticides were biologically inactive. Experimental plots were designed which enabled the determination of biological breakdown of an insecticide to the exact day.

Residue analysis for DDT in the soil of treated areas (approximately 10 years at 1 lb./acre/year) within Winnipeg showed an average of 3.32 lbs. per acre. This amount will undoubtedly increase if the use of DDT is continued in the Winnipeg area. Tests with fuel oil and flit revealed that fuel oil would produce almost identical results to those of flit against larvae. Pupae were not tested.

Polystyrene carriers in formulations of insecticides were more effective in the laboratory than in the field.

Tests on thermal fogs revealed that only adults that were contacted at the time of application were killed and no appreciable residual deposit of insecticide occurred.

From laboratory experiments Pimephales promelas, an indigenous minnow, appeared to be an effective predator and should be considered for distribution for mosquito control in semi-permanent and permanent pools around Winnipeg.

CHAPTER I

INTRODUCTION

Southern Manitoba has some of the most extensive and productive mosquito breeding grounds to be found anywhere. Much of the terrain around Winnipeg is ideal for mosquito development as the land is relatively level and contains numerous sloughs and ponds. The numerous roadside ditches are also excellent habitats for mosquitoes. The climate according to the Koppen classification is humid, thus there is generally ample moisture for floodwater mosquitoes.

The economic importance of mosquitoes is well known. Real estate values suffer and industrial efficiency can be lowered from mosquito annoyance. Mosquitoes are important from the standpoint of public health since they are known vectors of pathogens, some of which are fatal to humans. Malaria and yellow fever are two of the better known diseases. Canadians are fortunate, since the only mosquito borne disease in Canada is Encephalitis.

In regard to disease transmission, mosquitoes are not a serious problem in Manitoba, however they are responsible for an untold loss of time and money every year. Not only do they spoil summer recreation, but they are also a serious problem to Agriculture. Beef cattle lose weight and dairy cows give less milk. Farm workers have been driven from fields. Mosquitoes have also caused logging camps and construction projects to be shut down at a substantial cost to operators.

It is for reasons such as these that research on mosquitoes is justified and the money well spent.

The Problem

This study was conducted during 1967 and 1968 in and around Metro Winnipeg. The main investigation was concerned with the following:

A. Surveys of mosquito populations

   I A survey to determine the ecology and type of breeding sites around the Winnipeg Area.

   II An evaluation of adult mosquito populations.

B. Control

   I Evaluation of chemicals other than DDT for future use in mosquito control.

   II An investigation on the use of indigenous minnows as a possible means of biological control.

Importance of the Problem

Before a mosquito larval control program can operate effectively the precise location of breeding sites by intensive surveys is a prerequisite. A knowledge of the pest species, its habits and ecology greatly improve the effectiveness of control measures.

Adult surveys indicate to a small extent, the effectiveness of larval control because light trap catches often only reflect activity and not abundance. They give some indication of adult migration and flight patterns. If properly interpreted they can indicate trends in adult movement and behaviour, however, the latter statement requires a great deal of skill and knowledge and sometimes the final results will yield no positive information.

The use of insecticides during the last twenty years has increased to the point where they must be considered as a significant factor in the environment. For example, the increasing concern over the residual effects of DDT on other members of the ecosystem has caused the use of this chemical to be banned in some provinces and states. The toxic and residual effect of other insecticides demands that a more thorough investigation be carried out before they are used in the ecosystem to control insect pests.

In order to obtain the most effective and safe use of an insecticide, the interrelationships of such factors as fluctuating temperature, humidity, rainfall, sunlight, time of application, formulation, nature of the compound and surfaces to which the compound is applied should all be evaluated before the chemical is placed in the field. In addition to the above criteria, the nature, life history and ecology of the target organism should be thoroughly known to avoid misuse and abuse of chemical control.

CHAPTER II

SURVEY OF LARVAL DEVELOPMENTAL SITES DURING 1967 and 1968

Introduction

Collections of larvae in the Winnipeg area were made throughout the summer of 1967 and 1968 for the purpose of:

(1) Relating species of mosquitoes with particular habitats.

(2) Determining the succession of species in the pools.

(3) Determining the most abundant species throughout the summer.

(4) Relating common and uncommon species of larvae to common and uncommon species of adults in the survey area.

On the basis of adult and larval collections of mosquitoes in Manitoba, eight species were reported for the Winnipeg area by Knab (1907). Later work demonstrated that there were at least 22 species in southern Manitoba, Robertson (1921 - 1922) and we can assume some, or all of these occurred in Winnipeg as well. Robertson made his determination on adult mosquitoes.

McLintock (1944) made the first major survey of mosquito species of the Winnipeg area and listed 22 species, representing 5 genera. McLintock also carried out a preliminary study on mosquito developmental sites in and around Winnipeg.

PART A Larval Survey 1967

Scope and Methods

The perimeter highway (Manitoba 100) was chosen as the inner boundary for the study (Fig. I). The outer boundary of the study extended from two to four miles beyond the perimeter highway into the surrounding country-side. The outer boundary was determined largely by the time available, however it was also determined by availability and condition of connecting roads during each visit. Where connecting roads were absent, incomplete, or generally impassible, the survey extended further from the perimeter highway. This was to ensure that enough pools could be included to provide an adequate sample. Once the boundaries were established the survey area was divided into five sectors labelled A to E (Fig. I). These sectors were each of a size permitting one complete circuit of one sector per day. They were so designed that the entire area (five sectors) could be examined each week. Not all bodies of water were examined, since time did not permit this, however, those that were examined throughout the summer were representative of the remainder. An aerial survey was made after the first heavy rainfall in order that the investigator could become familiar with the area and could locate pools hidden from view during the ground survey.

The study was carried out by one summer student. His equipment included a car, half pint waxed paper food cartons, a dipper, pH paper, a yardstick, pocket thermometer and a camera. When a pool was examined the following variables were recorded: type of pool, length, number of larvae per dip, water temperature, p.H., pool and sector number, depth, width.

When larvae were found they were transferred to the paper cartons and brought into the laboratory for identification. If these larvae were other than fourth instar they were reared to fourth and identified. Pupae were reared to adults and identified.

Population estimates were obtained by stirring up the water and larvae in a pool; the size of the pool determined the number of samples taken. More than three samples were taken from large pools (750 sq.ft.); this could vary from four to twenty samples. The water volume of each pool was calculated and by multiplying the mean number of larvae per dip by the total volume of water, an estimate of the larval population was obtained. A picture of each pool was taken to assist in interpreting the ecology of mosquitoes in the survey area.

Results and Discussion

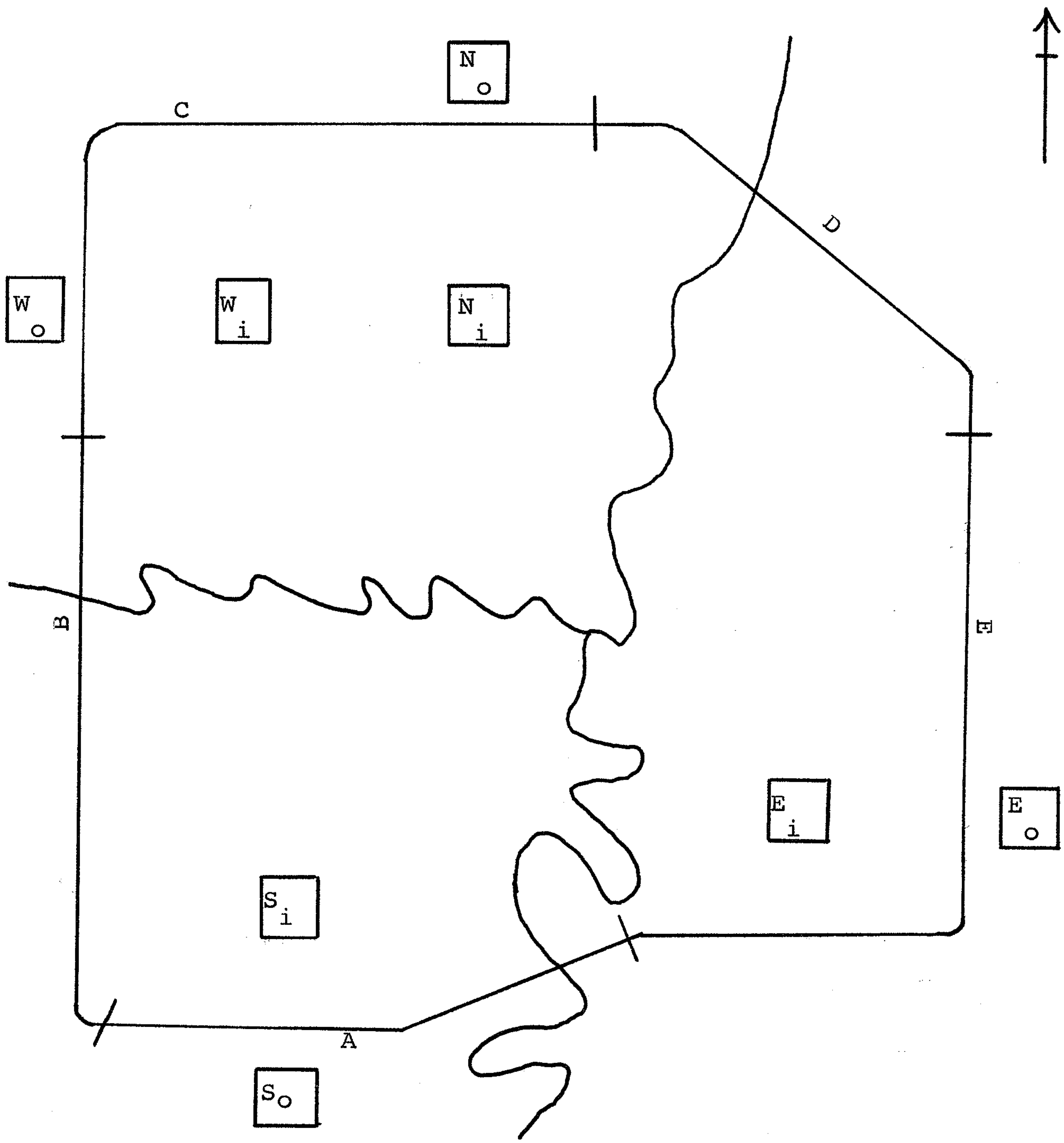
Throughout the entire survey area one hundred and nineteen pools with water were recorded in May, 1967. At the end of the summer this number had been reduced to twenty-four pools. Table 1 shows the phenology of these pools from May to August, 1967.

Figure I

Larval Survey Areas 1967 and 1968

Winnipeg

Figure I



The entire year of 1967 was noted for its lack of precipitation and was one of the driest in a decade. The amount of precipitation from November, 1966 to April, 1967 was 6.59 inches. Thus the amount of snow melt water available to form developmental sites for mosquitoes was much reduced. Very little precipitation fell during May and June in Winnipeg. Four meteorological stations in Winnipeg, (St. Boniface, Transcona, Winnipeg International Airport and The University of Manitoba) recorded from .81 inches to 1.10 inches of precipitation during May and .81 inches of this fell on May 1. From May 2 to June 19, a period of forty-eight days, the survey area received only .75 inches of rain. Consequently the number of pools with water decreased to fifty-five during June. On June 19 and 20, the survey area received an average of .97 inches but this was absorbed by the ground without raising the pool levels appreciably. No hatching of eggs was observed and the number of pools with water did not increase. More rain showers occurred between the dates of June 21 to July 6, but less than an inch of rain fell. On July 7, 2.5 inches of rain fell over most of the survey area and the number of pools with water increased in sectors C and D, Table 1. Another 1.13 inches of rain fell on July 22 and 23, but this did not increase the total number of pools. In fact there was a decrease over the number recorded earlier in July. The total number of pools with water remained fairly constant during the first half of August. The 1.81 inches of rain in the first week of August kept the water table fairly stable. During the latter part of August, the number of pools decreased to twenty-four.

Formation of Pools

The water present on the land surface in the spring is a combination of spring thaw and spring rains. Under average or above average climatic conditions the month of May will have the largest number of water bodies present in relation to any other month during the summer season. The majority of water bodies, due to evaporation, disappear within one to four weeks. Some pools persist from season to season.

All pools depend upon rainfall for their continued existence. Therefore during the late spring and throughout the summer months the amount of water present on the land surface is in part determined by the length of time between rainfalls. This factor influences the physical state of the soil which in turn influences the formation of a pool; if there is a long period of time between rainfalls the land becomes very dry; more water is required to reach the saturation point and until this point is reached a pool of any appreciable size cannot be formed.

The amount and type of rainfall assist in the formation of pools; if a gentle rain of one inch or more falls over a period of one or two days, provided the land is very dry, there will be little or no runoff to form a pool (e.g. June

19 & 20). On the other hand, a rainfall of one inch or more in one hour is sufficient to form a pool. Small pools formed in this way may or may not last more than a few days depending upon the physical properties of the soil. In a third case, if the land is moist the type of rainfall does not matter. The soil is either saturated or almost so and water will then accumulate. The resulting pool will last as long as it takes to evaporate.

Therefore the formation and existence of pools during the summer season depends upon (a) the length of time between rainfalls, (b) the amount and type of rain received and (c) the amount of moisture retained by the particular soils.

With these factors in mind the amount of water present on the land in any year will vary according to the length of time between rainfalls and so will the potential of any mosquito population in the area.

Classification of Developmental Sites, 1967 and 1968

As pointed out earlier, pool formation and consequently developmental sites depend upon (1) the amount of precipitation and (2) the length of time between rains. The following classification of developmental sites is therefore based upon the permanency of the pool, or the lack of it.

TYPE	SPRING	SUMMER
A	Less than 2 weeks	Less than 1 week
B	3 - 4 weeks	1 - 2 weeks

TYPE	SPRING	SUMMER
C	5 - 8 weeks (semi-permanent spring pool)	2 - 4 weeks
D	More than 8 weeks (permanent spring pool)	More than 5 weeks (summer pool) (semi-permanent 1967) (permanent 1968)

As defined here, the type A pool did not hold water long enough to permit mosquitoes to complete their life cycle during either the spring or summer periods. The type B pool held water for a period of 3 - 4 weeks in spring and 1 - 2 weeks in the summer, which was long enough for complete development. The type C pool remained beyond the time required to develop a brood of larvae and sometimes held water until the next rainfall. The type D pool did not dry up during the spring period and during 1967 (a dry year) such a pool dried up during the summer whereas during 1968 (a wet year) it did not. During 1967, there were no permanent summer ponds (water bodies too large to be called a pool) breeding mosquitoes within the survey area, although such undoubtedly existed elsewhere.

During 1967, there was more water surface per acre of land (more pools) during May than at any time during the summer (Table 1). This meant that the specific land areas that gave rise to spring type D pools, later formed summer type D and type C pools; spring type C later gave rise to summer type C and B; spring type B gave rise to summer type B and A; and spring type A pools did not hold water again

Figure II

Summer Larval Developmental Site

Classified as Type A

Figure III

Summer Larval Developmental Site

Classified as Type B

Figure II

Figure III

Figure IV

Summer Larval Developmental Site

Classified as Type C

Figure V

Summer Larval Developmental Site

Classified as Type D

Figure IV

Figure V

during that season. During 1968 the situation was quite different. There was more water surface per acre of land (more pools) during the August 20 - 28 survey than during the May 27 - June 7 survey (Table 8). However, there is some important information lacking in the 1968 spring survey and that is a report of the number of pools during late April. The spring of 1968 was very early and the May 27 - June 7 survey was too late to record most of the spring developmental pools. Many of the spring species were already adults by the end of May.

During 1968, for the majority of the pools at least, the spring type A,B,C and D became the summer types A,B,C, and D respectively. As can be seen from Table 8, the number of pools did decrease during June but increased again during July and August.

Utilization of Pools by Mosquitoes

As shown in Table 1 during 1967, 119 pools with water were recorded in May, while only 45 contained mosquito larvae. Thus only 38 percent of the recorded pools were being utilized by mosquitoes. By the end of June the original number of pools had decreased to 55 percent and not one of these contained mosquito larvae. This can be explained by the fact that the spring univoltine species had completed their development and the summer multivoltine group did not hatch until after the July rains.

Table 1

Phenology of Pools and Larval Breeding During 1967

Sector of survey area												
A		B		C		D		E		Total No. of Pools	Total No. of Pools with Larvae and Pool Type	DATE
P(1)	L(2)	P	L	P	L	P	L	P	L			
33	8	29	14	22	12	15	3	20	8	119	45(36B,8C,1D)	May 23-30
24	8	--	--	--	--	--	--	--	--	24	8(8B)	May 31
19	0	26	10	16	10	13	0	16	3	90	23(17B,5C,1D)	June 1-7
12	0	21	0	14	0	8	0	--	--	55	0	June 8-25
10	1	14	6	17	11	12	6	6	1	59	25(9B,4C,12D)	July 10-17
8	0	11	3	12	7	11	5	5	0	47	21(5B,1C,15D)	July 18-28
6	--	8	--	11	6	11	6	6	2	42	14(8B,6D)	Aug. 6-18
2	0	6	1	6	4	7	3	3	--	24	8)1B,3C,4D)	Aug. 21-28

(1) P - Number of Pools
(2) L - Number of Pools with Larvae

The 2.50 inches of rain recorded on July 7, 1967, increased the total number of pools in the survey area to fifty-nine (Table 1). The number of pools containing larvae was recorded to be twenty-five. Thus 42 percent of the recorded number of pools were used for mosquito development. Although the results show a second seasonal mosquito population, this is the first population of the summer mosquito complex and is definitely a new one. The survey June 25 recorded no mosquito larvae and confirmed that the inch of rain received on June 19 and 20 was inadequate to initiate a new egg hatch.

During the first part of August the number of pools containing larvae had been reduced from 52 to 14. These were mainly summer Type C and D pools. Thus 33 percent of the recorded pools were used for mosquito development. By the end of August, only 8 pools out of 24 contained larvae. The percentage utilization remained at 33 percent. With one exception, all breeding during August was in Type C and D pools, by species of <u>Culex</u> and <u>Culiseta</u>. These types of pools are typical for the above two genera.

<u>Population Estimates of Larvae</u>

The estimated larval populations within the survey area is shown in Table 2. The method of estimating the population is given on page 8.

Table 2

Estimated Larval Populations in the Survey Area, 1967

DATE	SECTOR					SEMI-MONTHLY TOTAL of all SECTORS
	A	B	C	D	E	
May 23-31	1,113,070	1,038,230	1,009,600	11,240	230,480	3,339,620
June 1-7	0	521,540	183,940	0	1,170	706,650
June 8-25	0	0	0	0	0	0
July 10-17	790,200	20,580	2,449,390	4,398,760	Trace	7,658,940
July 18-28	0	87,400	1,811,550	288,000	0	2,186,950
Aug. 6-18	0	0	238,800	43,200	100	282,000
Aug. 21-28	0	88,500	2,085	22,900	0	113,485

From the 45 pools containing mosquito larvae during May,1967, an estimated 3,339,621 mosquitoes were in a position to develop to maturity. During May the larval population consisted almost entirely of univoltine Aedes (Table 4). This population completed emergence about mid June and no more larvae were found until the rainfall of July 7. This rainfall initiated the hatching of first generation multivoltine species. The total July population in the survey area developed in 25 pools and was estimated at 7,658,940. Following this, the mosquito population began to decrease. Although Aedes larvae were found, the August larval population consisted mainly of Culex and Culiseta species (Table 6). The early August population of Aedes vexans was a second generation and hatched in response to rain showers which fell during late July and early August. Very few completed development because they had hatched in type A pools. Some Culex and Culiseta larvae also hatched in type A pools, but only those occurring in type C and D pools completed development.

Species Complex

Nineteen species of mosquito larvae, representing four genera, were found and recorded throughout the entire 1967 mosquito breeding season. These are shown in Table 3. This complex is divided into two major groups: the univoltine and the multivoltine mosquitoes. These two groups can be

Table 3

List of Mosquito Species, 1967 Larval Survey

Winnipeg

UNIVOLTINE	MULTIVOLTINE	PARTLY UNIVOLTINE PARTLY MULTIVOLTINE
Aedes barri	Aedes nigromaculis	Aedes canadensis
Aedes excrucians	Aedes vexans	Aedes campestris
Aedes fitchii		Aedes spencerii
Aedes flavescens		
Aedes intrudens		
Aedes communis		
Aedes riparius		
Aedes sticticus		
Aedes trichuris		
Anopheles punctipennis	Culiseta inornata	Culex tarsalis Culex restuans
Anopheles earlei		

further classified according to the life histories of the mosquito species Costello (1967).

The univoltine species can have only one generation a year since their eggs require several months of cold conditioning before they will hatch Costello (1967). Over 90 percent of the 3,339,621 mosquito larvae recorded in May were of the univoltine type (Table 4). The remaining 10 percent were of the multivoltine type. The latter hatch when water temperatures go above 10° c. Costello (1967).

Species and Their Distribution

Tables 4, 5, and 6 show the seasonal development of mosquito larvae throughout the spring and summer months. Table 4 shows the percent abundance of spring species. The population in the survey area consisted of approximately three million larvae (Table 2). The dominant species was *A. fitchii* ranging from 33.33 - 98 percent in different sectors. *A. flavescens* was second in abundance, ranging from 1.5 - 44.53 percent. Both species were found in all sectors of the survey. Sectors B, C, and E contained the greatest number of species although most of these were of minor importance in relation to the total population.

Table 5 shows the percent abundance of the early summer or the first of the multivoltine species populations. Development of larvae began with the July 7 rainfall. *A. vexans* of minor importance in Table 4 replaced *A. fitchii* as the

Table 4

% Abundance and Distribution of the 1967

Spring Larval Population

Date	Precipitation in Inches	Species	Sectors A	B	C	D	E
May 1 - June 10	1.11"	Aedes fitchii	97.5*	80.05	42.62	33.3	50.19
	(plus 7.44")	Aedes flavescens	0.5	18.03	21.99	33.3	44.53
	(of rain)	Aedes campestris	0.5	0.4	13.73	33.3	0.15
	(equivalent)	Aedes dorsalis	-	-	8.46	-	-
	(snowfall)	Aedes riparius	-	0.6	10.05	-	0.94
	(Oct.1-Apr.30)	Aedes excrucians	-	0.5	-	-	0.98
	(= 8.55")	Aedes spencerii	-	0.5	-	-	-
		Aedes barri	-	0.008	0.001	-	-
		Aedes canadensis	-	-	2.0	-	0.001
		Aedes vexans	-	-	-	-	0.21
		Aedes communis	-	-	-	-	0.50
		Aedes sticticus	-	-	-	-	0.45
June 22 - 24		0	0	0	0	0	0

* percentage of total per sector.

Table 5

% Abundance and Distribution of the 1967

Early Summer Larval Population

Date	Precipitation in Inches	Species	Sectors A	B	C	D	E
July 7 - July 20	2.50"	Aedes vexans	100*	15.41	86	89.49	-
		Aedes nigromaculis	-	1.15	-	-	-
		Aedes spencerii	-	-	6.55	0.6	-
		Aedes dorsalis	-	-	0.05	5.77	-
		Aedes campestris	-	-	0.40	0.33	-
		Culex tarsalis	-	83.71	7.0	-	-
		Anopheles spp.	-	-	0.1	-	-
July 22, 23		0	0	0	0	0	0

* percentage of total
per sector.

Table 6

% Abundance and Distribution of the 1967

Mid or Late-Summer Larval Population

Date	Precipitation in Inches	Species	Sectors A	B	C	D	E
Aug. 9 - Aug. 30	1.81"	Culex tarsalis	-	100*	81	72.19	-
		Culex restuans	-	-	19	3.29	-
		Culiseta inornata	-	-	-	14.68	-
		Aedes vexans	-	-	-	9.84	-

* percentage of total per sector.

dominant mosquito ranging from 15.41 - 100 percent throughout the different sectors. It is important to note in Table 2 that the three million larvae of the spring species, developed in 45 pools and consisted of 12 species. In Table 5, seven million larvae developed in 25 pools and consisted of only six species. This illustrates the significance of a few species, mainly multivoltine Aedes, developing in a relatively small number of pools. These multivoltine species have as many generations a year as climatic conditions will allow, since the eggs do not require cold conditioning before hatching. Also note that Culex tarsalis was important in Sector B. This is probably a second generation. It overwinters as an adult and it is unlikely that many of the overwintering adults live until mid-July. The first generation is small in numbers and isolated. Adult collections in light traps confirm a small overwintering population. Each year significant numbers of larvae or adults are not taken until late summer. Hence from a small beginning, it builds up to a fairly high level by late July or August.

Table 2 shows continuous larval development from July to the end of August. A close examination of Tables 5 and 6 reveal that the continuous breeding is due to three genera, Culex, Culiseta and Anopheles. These three genera of mosquitoes breed in type C and D pools by laying eggs directly on the water. The size of these populations is small compared to that of the aedine mosquitoes. This may be because they are breeding continuously whereas the size of the aedine mosquito populations depends upon (1) the number of eggs laid between rainfalls and (2) the size of the previous adult population. Thus one of the factors regulating the size of the *Culex*, *Culiseta* and *Anopheles* populations is the amount of water available for oviposition. Mortality of overwintering adults appears to be high and by the time a sizable population has developed the breeding season is over. Overwintering mortality of *Aedes* eggs is low, Costello (1967) and the data from Table 2 confirms this. Therefore at any one time the aedine population will be greater than the *Culex*, *Culiseta*, *Anopheles* population except during conditions of drought.

Conclusions

The results of Tables 4, 5, and 6 clearly show that the largest number of species developed during the beginning of the mosquito breeding season in 1967. The majority of these were univoltine and hence did not occur as larvae again during the summer.

With the first large summer rainfall multivoltine *Aedes* mosquitoes began to hatch. *Aedes vexans* dominated all other species and as far as can be determined there were at least two generations of *A. vexans*. The multivoltine *Aedes* mosquitoes continue to produce generation after generation if they have sufficient time to lay eggs between rainfalls and sufficient water in the pools to allow completion of their life cycle.

At the end of the summer season <u>Culex, tarsalis</u> was the dominant species. The majority of mosquito breeding occurred in two sectors, C and D. It was in those areas where the largest <u>A. vexans</u> and <u>Culex</u> larval populations were found. This was mainly due to poor drainage, which in turn leads to ideal sites for mosquito development.

PART B Larval Survey 1968

Scope and Methods

This survey was slightly modified from that of 1967. The survey area consisted of eight one-square-mile plots. The plots were located in four different directions from Winnipeg and were near the perimeter highway. In order to make a comparative study, four plots were located inside the perimeter highway and four outside (Figure I) labelled Ni, Wi, Si, Ei and No, Wo, So, Eo respectively.

The method of examination was the same as that in the 1967 survey. The data from each pool was recorded and a map made of each plot (Figures VII to XIV).

Population Estimates

Five surveys of the eight plots were made in 1968. Unfortunately, the first survey was incomplete. Due to an unusually early spring the majority of the univoltine species had emerged into adults before the survey could be organized. A large rainfall on May 14, 1968 brought about the hatching of an Aedes vexans population. As can be seen from Table 7, mosquito numbers increased from May - August. This again confirms the relationship of mosquito numbers being nearly directly correlated with increases or decreases in precipitation, presented in Part A. Table 7 also shows that there is considerable variation in mosquito numbers from one survey area to the other. As in the 1967 survey this is related to the variation in precipitation from area to area.

Table 7

Estimated Larval Population Per Square Mile, 1968

Date	Plots of Survey Areas								
	Wo[1]	Wi[2]	No	Ni	Eo	Ei	So	Si	Sub-totals for all Plots
May 24-June 7	1,818,075	155,280	1,049,240	808,000	339,575	1,667	5,010,002	0	9,181,839
June 10-13	0	0	16,250	500	0	0	0	0	16,750
July 8-10	411,250	0	685,750	145,415	89,665	1,790,000	625	0	3,122,705
July 18-19	0	0	0	0	0	0	0	0	0
Aug. 6-8	450,000	0	51,500	125,000	Trace	33,750	11,410,500	0	12,070,750
Aug. 20-28	5,381,000	0	587,550	128,100	5,499,400	23,350	160,306,500	-*	171,925,900

1 - West Outside
2 - West Inside

* - No Survey

Table 8

Utilization of Pools by Mosquitoes Within the 1968 Survey Area

	Plots of Survey Area*																Total No. of Pools	No. of Pools with L	% Utilization
	Wo		Wi		No		Ni		Eo		Ei		So		Si				
	P	L	P	L	P	L	P	L	P	L	P	L	P	L	P	L			
May 27–June 7	17	10	19	4	28	12	26	4	27	4	20	1	31	4	10	0	178	39	22%
June 10–14	6	0	13	0	20	3	22	1	23	0	20	0	18	0	5	0	127	4	--
July 8–10	7	3	16	0	21	9	20	5	26	15	22	5	24	2	12	0	148	39	26%
July 18–19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aug. 6–8	5	1	9	0	23	2	25	2	24	2	18	2	31	9	13	0	148	17	11%
Aug. 20–28	22	6	26	0	30	8	36	4	23	17	24	3	44	16	--	-	205	54	26%

P – Total Number Pools

L – Total Number Pools with Larvae

* – see Figure I

Utilization of Pools By Mosquitoes

Part A of the survey indicated that less than 50 percent of the available water was being used as developmental sites for mosquitoes. A more thorough survey was done in 1968 and all pools occurring within the eight square miles were examined. In 1967, only pools which appeared suitable for mosquito production were examined and included in the report. During 1968, the survey revealed that 21 percent of the available pools were used by mosquitoes (Table 8). The decrease in percentage of pool utilization during 1968 was due in part to the survey method and also to the increased precipitation over 1967. There were many pools formed in 1968 that were not pools in 1967. Also, with respect to species that have several generations, fewer pools were suitable for oviposition during the very wet summer of 1968.

Influence of Precipitation on Mosquito Numbers

The number of mosquitoes of the multivoltine group is related to levels of precipitation. Figure VI clearly shows four distinct population peaks. A. vexans was the dominant species in four of the five populations studied (Tables 9 and 13). An analysis of the precipitation levels and the length of time between rains, indicates that there were four generations of A. vexans during 1968. This is unusual, as in a normal year ~~we have~~ there are from two to three generations. However, the warm spring temperatures and the continued precipitation throughout the summer was responsible. From May to September Winnipeg received a record level of 18.45 inches of rain. The long term average for this period is 10.63 inches.

The rainfall of May 14 and 15, totalling 1.4 inches, plus increased temperatures were responsible for the first hatch of multivoltine mosquitoes. The larval population within the eight square miles during May 1968, was 9,181,839. The June 13 survey showed that there were still 16,250 larvae in one sector of the survey area. No further mosquito development was found until July 8, 1968. This early July population was due to rains on June 30 and July 1, 1968, totalling 3.20 inches. On July 13 and 15 another 2.91 inches of rain fell, but no additional breeding was found. This could be explained by the fact that all the eggs in the pools hatched on July 1 and 2; this generation did not have time to find hosts and oviposit. If some eggs had been laid they may not have hatched as they require five to six days to embryonate before they will hatch. The next significant rainfall was 1.28 inches, occurring on July 29 and 30. Mosquito populations were recorded on August 6 and 8 in the survey area. There was no larval development after this until the rains of August 15 and 18, when another and larger mosquito population was found (Table 7).

Conclusions

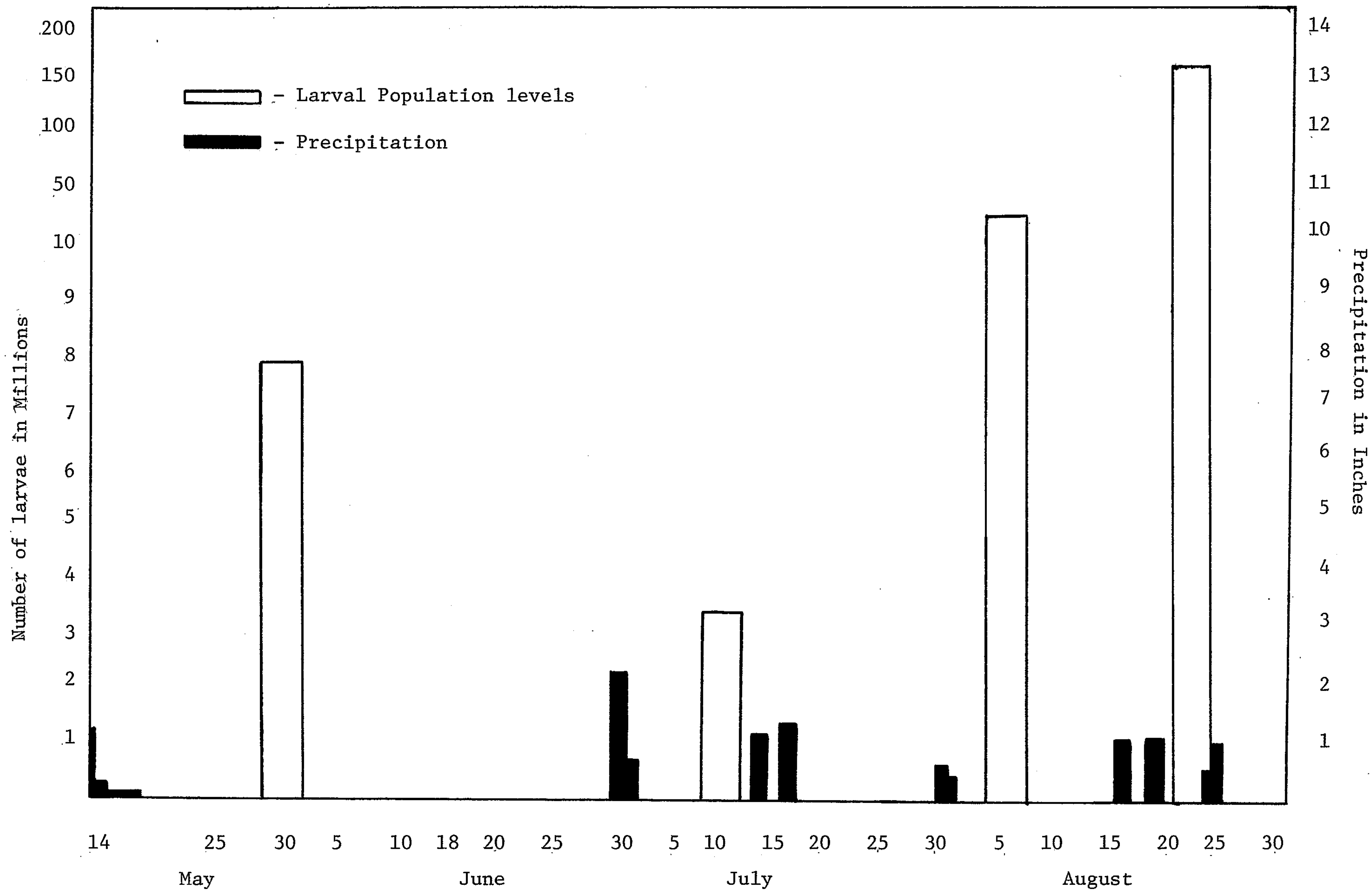
Rainfall of one inch or more during 1968 was adequate

FIGURE VI

Mosquito Larval Population and

Precipitation Levels During 1968

Figure VI


- Larval Population levels
- Precipitation
Number of larvae in Millions
200
150
100
50
10
9
8
7
6
5
4
3
2
1
Precipitation in Inches
14
13
12
11
10
9
8
7
6
5
4
3
2
1
14 25 30 5 10 18 20 25 30 5 10 15 20 25 30 5 10 15 20 25 30
May
June
July
August

to hatch mosquito eggs, if viable eggs were present and ready to hatch. The rains of July 13 and 15 did not give rise to a population since these rains fell before another generation of eggs were ready to hatch. Although precipitation and mosquito populations are closely related, it is the length of time between rainfalls that determines whether or not another population will occur. With regard to multivoltine species, a minimum of three weeks was required during 1968 for a generation.

Species and Their Distribution During 1968

The 1968 larval survey showed *Aedes vexans* to be the dominant species from May to September (Tables 9 - 13). Hatching of *A. vexans* in May of 1968 was due to the unseasonably early spring. Laboratory experiments have demonstrated that *A. vexans* begins to hatch at temperatures above 10° C. Costello (1967). The May 24 to June 7 survey was not a typical sample of spring univoltine species, since most of the univoltine species had emerged as adults before the 1968 survey areas were chosen. The May 24 - June 7 larval population therefore represented the first summer population, corresponding to the July 3 - 7 population for 1967, (Table 4). Table 9 reveals that *A. fitchii* and *A. flavescens* were the only univoltine species left by May 25, 1968. These can be considered as stragglers. Table 10 shows no additional larvae hatched during June 10 — 13. There was not adequate time between rains to give rise to a new

Table 9

Percentage Abundance of Larval Species During

May 24 to June 7, 1968

Date	Species	Survey Sectors Wo	Wi	No	Ni	Eo	Ei	So	Si
May 24 - June 7	Aedes vexans	90.06	96.71	90.26	86.63	100	100	83.36	--
	Aedes flavescens	7.28	---	---	2.97	---	---	---	--
	Aedes fitchii	2.41	---	1.42	---	---	---	16.64	--
	Aedes nigromaculis	---	3.21	1.34	---	---	---	---	--
	Aedes dorsalis	---	0.08	4.13	9.71	---	---	---	--
	Aedes spencerii	---	---	2.85	---	---	---	---	--
	Culiseta inornata	0.25	---	---	---	---	---	---	--

Table 10

Percentage Abundance of Larval Species

During June 10 to June 13, 1968

Date	Species	Survey Sectors							
		Wo	Wi	No	Ni	Eo	Ei	So	Si
June 10 - 13	Aedes vexans	---	---	3.07	50	---	---	---	---
	Aedes fitchii	---	---	92.31	50	---	---	---	---
	Aedes dorsalis	---	---	3.84	---	---	---	---	---
	Culiseta inornata	---	---	0.78	---	---	---	---	---

Table 11

Percentage Abundance of Larval Species

During July 8 to July 10, 1968

Date	Species	Survey Sectors							
		Wo	Wi	No	Ni	Eo	Ei	So	Si
July 8 - 10	Aedes vexans	91.48	---	85.56	---	66.38	99.1	100	---
	Aedes nigromaculis	9.42	---	.74	---	17.96	.9	---	---
	Aedes dorsalis	0.28	---	11.19	14.04	11.34	---	---	---
	Aedes spencerii	---	---	---	---	3.00	---	---	---
	Aedes campestris	---	---	2.51	85.96	1.32	---	---	---

Table 12

Percentage Abundance of Larval Species

During Aug. 6 to Aug 8, 1968

Date	Species	Survey Sectors							
		Wo	Wi	No	Ni	Eo	Ei	So	Si
Aug. 6 - 8	Aedes vexans	100	---	---	17.60	---	90.90	58.00	---
	Aedes dorsalis	---	---	---	12.80	---	---	34.10	---
	Culex tarsalis	---	---	19.61	---	---	---	0.80	---
	Culiseta inornata	---	---	80.39	69.60	---	9.10	7.10	---

Table 13

Percentage Abundance of Larval Species

During August 20 to August 28, 1968

Date	Species	Survey Sectors							
		Wo	Wi	No	Ni	Eo	Ei	So	Si
Aug. 20 - 28	Aedes vexans	100	---	20.24	18.98	20.00	---	91.70	
	Aedes nigromaculis	---	---	9.50	---	78.73	0.31	---	
	Aedes dorsalis	---	---	61.39	62.03	1.00	---	0.09	
	Aedes campestris	---	---	---	---	0.27	---	---	
	C. inornata	---	---	5.30	18.99	---	91.00	8.05	
	C. tarsalis	---	---	3.03	---	---	8.69	0.16	

generation. The second generation of A. vexans occurred after the June 30 to July 1 rains (Table 11). Table 12, shows A. vexans to be the dominant species; this represents a third generation. The development of a fourth generation at the end of August is evident (Table 13). This population was more than ten times larger than the previous one (Table 7). The size of this population was verified by biting counts in Winnipeg where residents experienced one of the highest September mosquito populations since 1962.

Repetitive Use of Pools by Mosquitoes

Pools where breeding occurred contained mosquito larvae more than once throughout the season, depending upon climatic conditions (Figures VII to XIV). The maps show that single use of pools was common. This can be explained by examining (Appendix II) which shows the species that utilized these pools. Aedes vexans used the same pool once, twice, and occasionally three times (Figures XII and XIII) East inside and South outside. The other plots have at least one pool which was used three times.

Examination of a large scale map reveals that in the majority of cases, those pools which are used more than once are in an area where a blood meal can be obtained close to the pool. On a small map such as Figure XII, all four pools are ditches in front of human dwellings and all four were used three times. Thus it is reasonable to hypothesize that pools will be used more than once if a blood meal is close by and alternatively, those pools used only once indicates that the gravid female must search for considerable distances before obtaining a blood meal.

Once a female has taken blood and is engorged, she probably flies to the nearest oviposition site available. The evidence for this is that gravid females are rarely, if ever, taken in light traps. Also, females with blood in their gut or with partially developed ovarion follicles are rarely taken in traps or sweep nets. Granted, very few females get blood and since normal placement of traps means they sample less than 1 percent of the population, the chances of trapping blood fed females is small. However, even intensive sampling as was done by Graham (1968), shows how rare it is for gravid or partially gravid females to be taken in traps.

From Appendix II we also see that more than one species of mosquito inhabits a pool at the same time and different genera will also use a pool at different times.

Conclusions

The distribution of rainfall influences mosquito numbers in any particular region. The time between rainfalls determines whether a new generation can be produced. A. vexans populations increase in size throughout the summer, provided the precipitation patterns are favourable. In 1968 the fourth generation was the largest. It was more than ten times larger than the third generation. Pools are used repeatedly and many pools contain several species of mosquitoes.

General Conclusions Concerning Larval Surveys for 1968

1. Less than 5 percent of the pools remained as type D over the entire season. Most being dry at least once in the five visits made.

2. The most productive pools were those with grassy bottoms. These were *Aedes vexans* developmental sites.

3. Two out of the eight areas Wi and Si showed no evidence of larval breeding. Wi had a few larvae during the first survey but Si provided no larvae over the entire season. This may have been due to mosquito control operations.

4. A large number of pools were close to animal life, for example in *A. vexans* sites:

   (a) No and Ni pools bordering dairy pastures and farm-yards.

   (b) Wo-vicinity of a swine enterprise, open barns and small exercise area.

   (c) Ei-ditches in front of twelve houses on street (only area of high larval populations in this sector).

   (d) So-100,000,000 larva found in farm-yard with livestock.

   (e) Eo-located near a beef cattle enterprise.

Figure VII

Map of West Outside Survey Plot, 1968

Mosquito Larval Development May to August

Figure VII

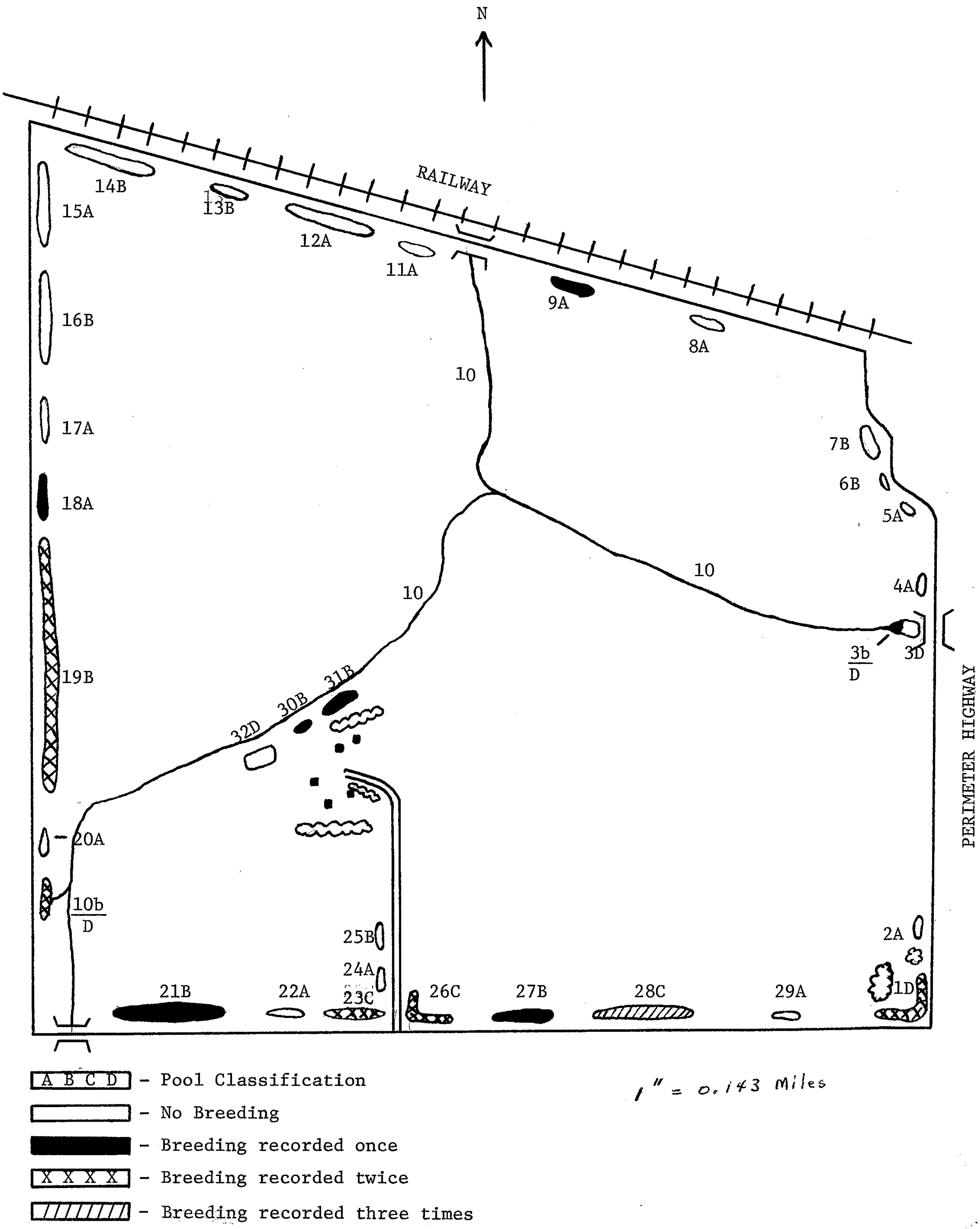
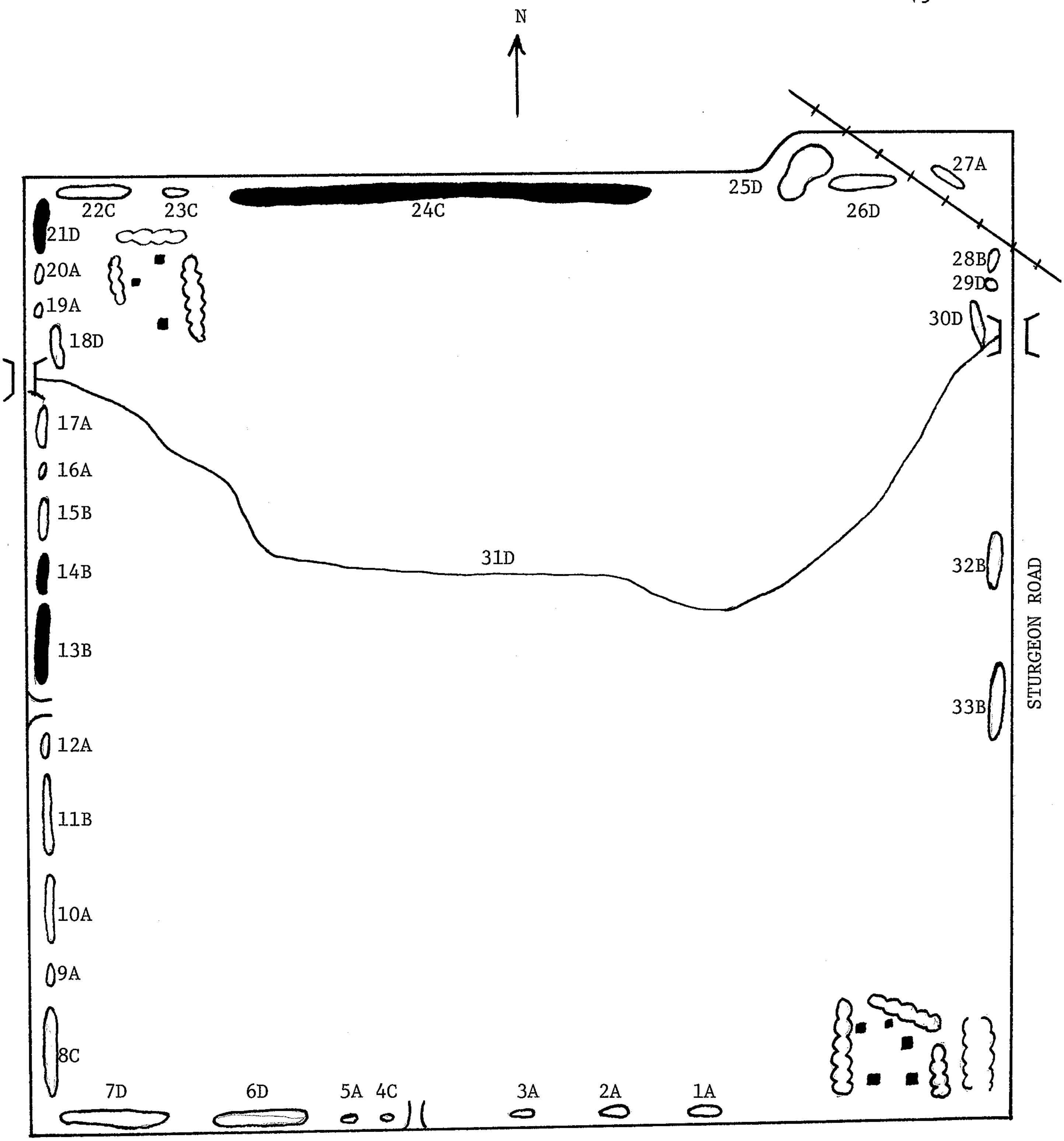

N
RAILWAY
14B
13B
15A
12A
11A
9A
8A
16B
10
17A
7B
6B
18A
5A
10
4A
10
3b
D
3D
19B
31B
30B
32D
PERIMETER HIGHWAY
20A
10b
D
25B
2A
24A
21B
22A
23C
26C
27B
28C
29A
1D
A B C D - Pool Classification
- No Breeding
- Breeding recorded once
X X X X - Breeding recorded twice
- Breeding recorded three times
1" = 0.143 Miles

Figure VIII

Map of West Inside Survey Plot, 1968

Mosquito Larval Development May to August

Figure VIII



A B C D – Pool Classification

– No Breeding

– Breeding recorded once

X X X X – Breeding recorded twice

/////// – Breeding recorded three times

1" = 0.143 Miles

Figure IX

Map of North Outside Survey Plot, 1968

Mosquito Larval Development May to August

Figure IX

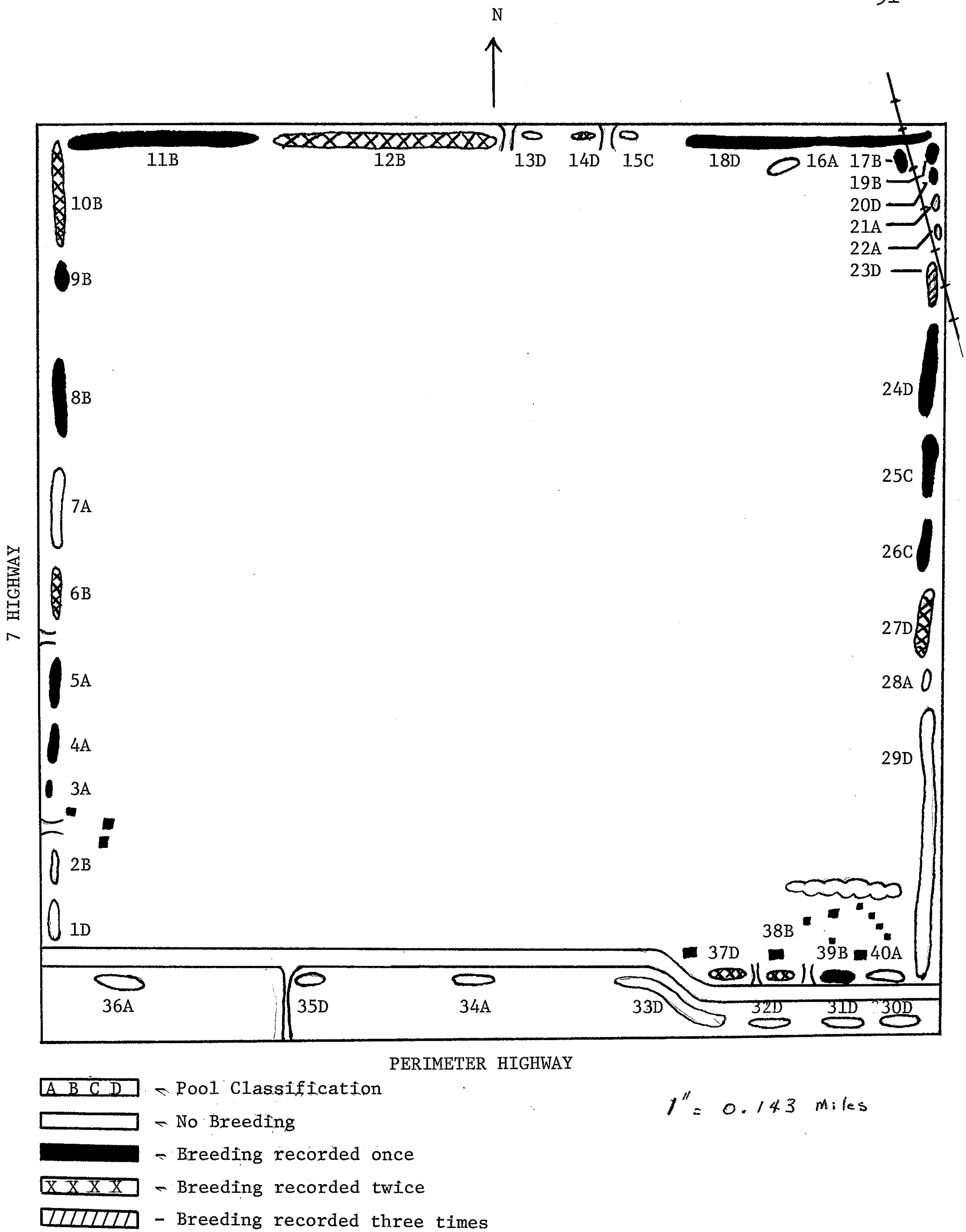
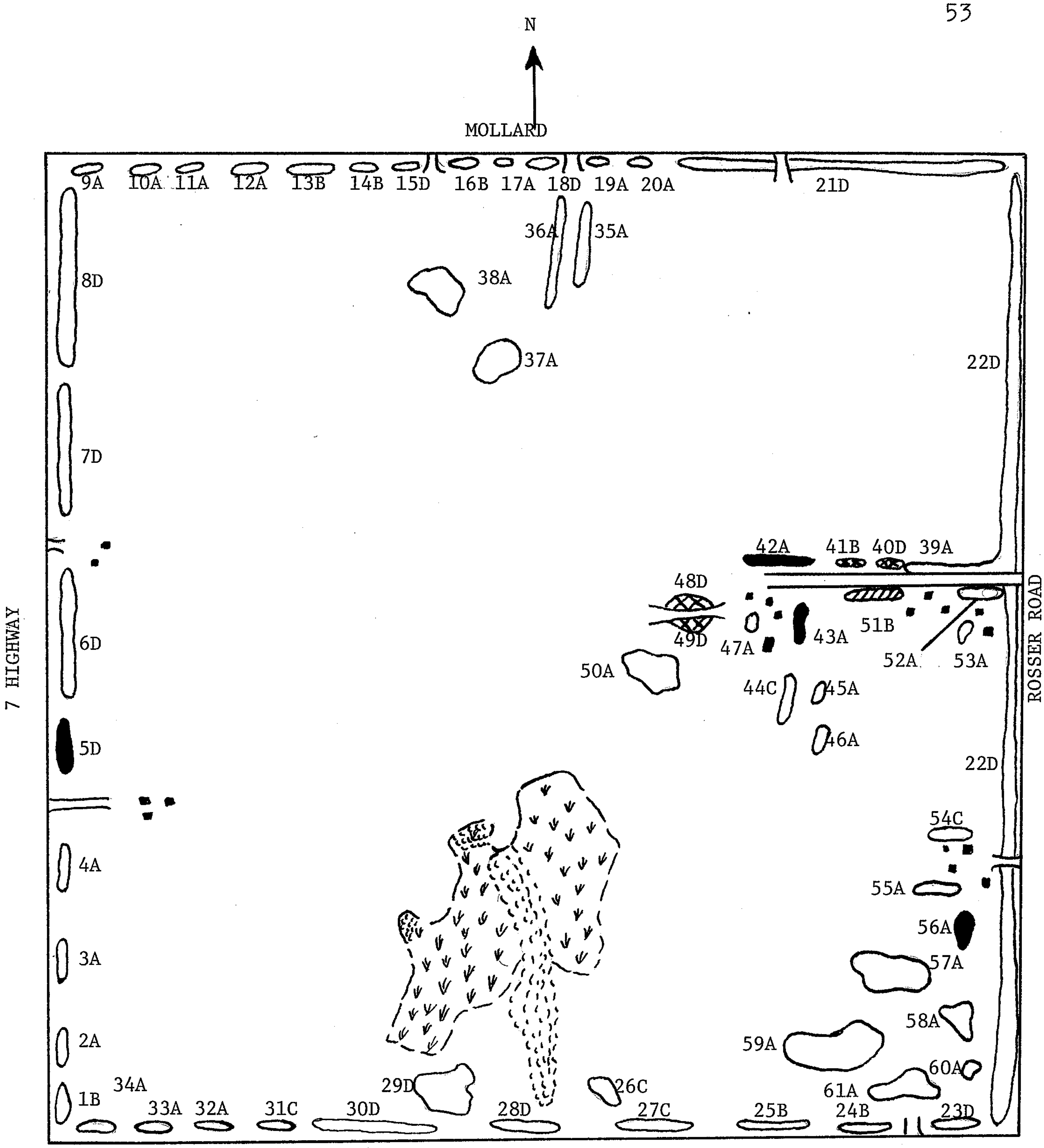

N
11B
12B
13D
14D
15C
18D
16A
17B
19B
20D
21A
22A
23D
10B
9B
8B
24D
25C
7A
26C
6B
27D
7 HIGHWAY
5A
28A
4A
29D
3A
2B
1D
38B
37D
39B
40A
36A
35D
34A
33D
32D
31D
30D
PERIMETER HIGHWAY
A B C D
- Pool Classification
- No Breeding
- Breeding recorded once
X X X X
- Breeding recorded twice
- Breeding recorded three times
1" = 0.143 Miles

Figure X

May of North Inside Survey Plot, 1968

Mosquito Larval Development May to August

Figure X



A B C D - Pool Classification

- No Breeding

- Breeding recorded once

X X X X - Breeding recorded twice

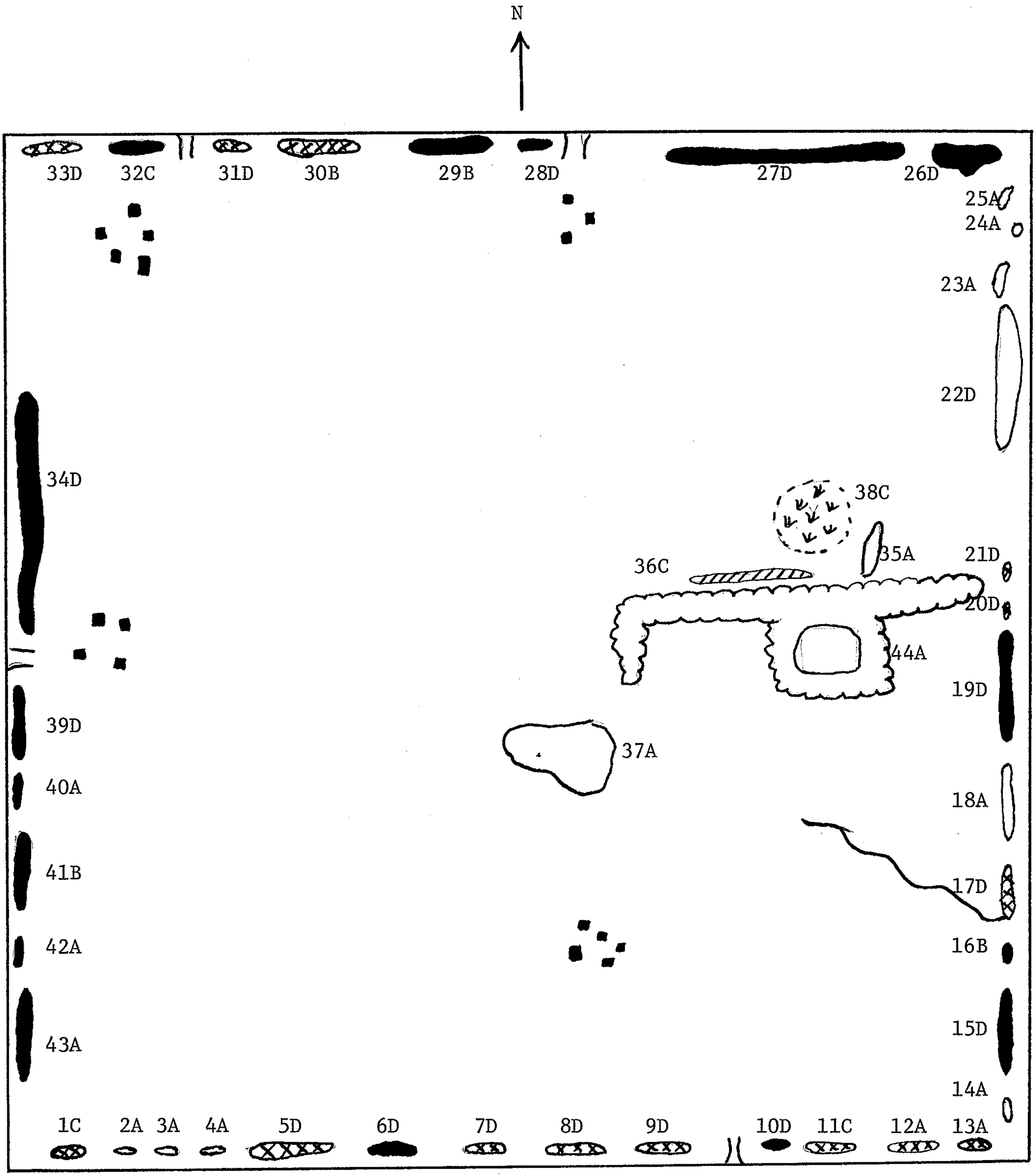
- Breeding recorded three times

1" = 0.143 Miles

Figure XI

Map of East Outside Survey Plot, 1968
Mosquito Larval Development May to August

Figure XI



A B C D - Pool Classification

- No Breeding

- Breeding recorded once

X X X X - Breeding recorded twice

- Breeding recorded three times

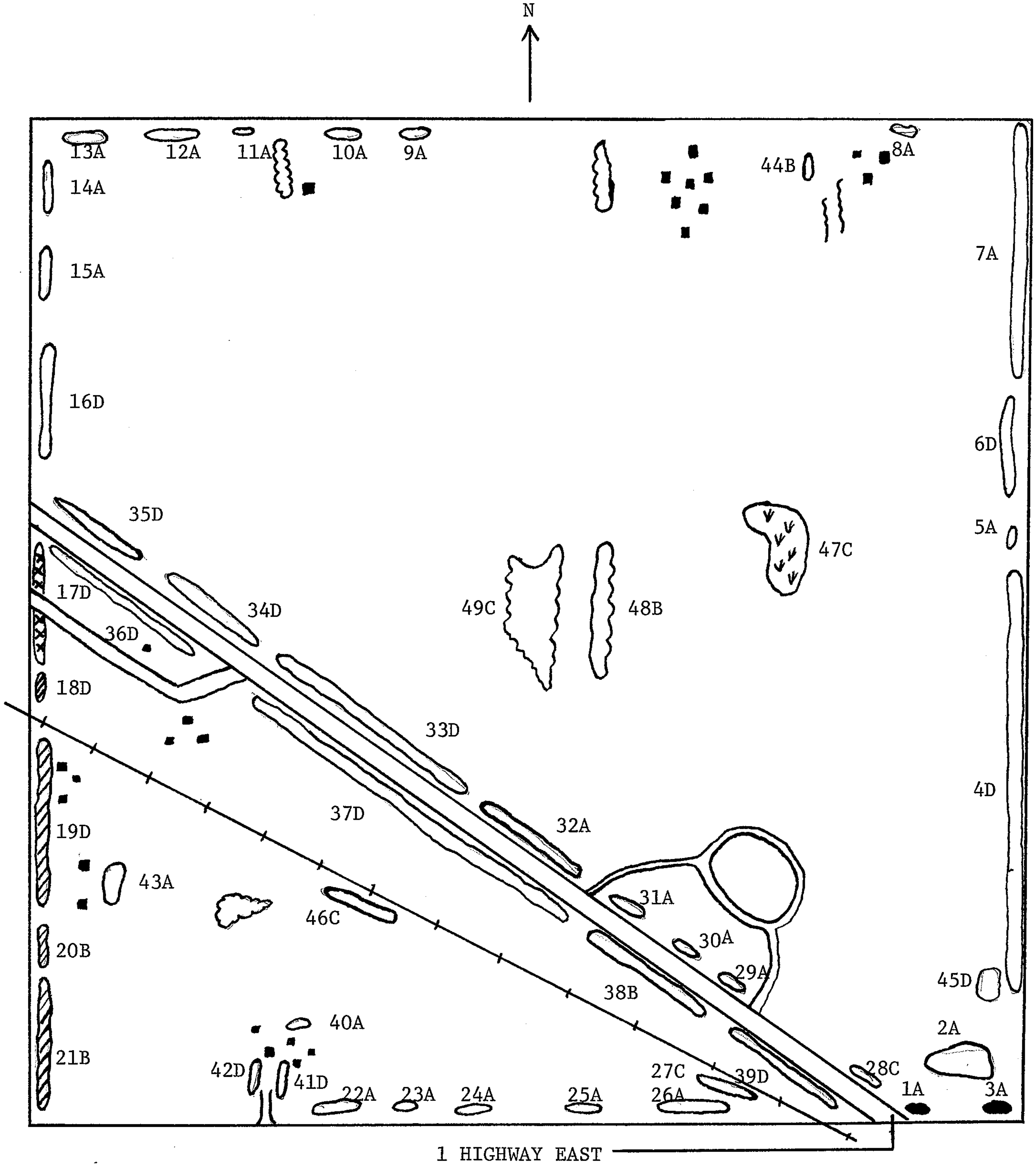
1" = 0.143 Miles

Figure XII

Map of East Inside Survey Plot, 1968

Mosquito Larval Development May to August

Figure XII



A B C D - Pool Classification

- No Breeding

- Breeding recorded once

X X X X - Breeding recorded twice

- Breeding recorded three times

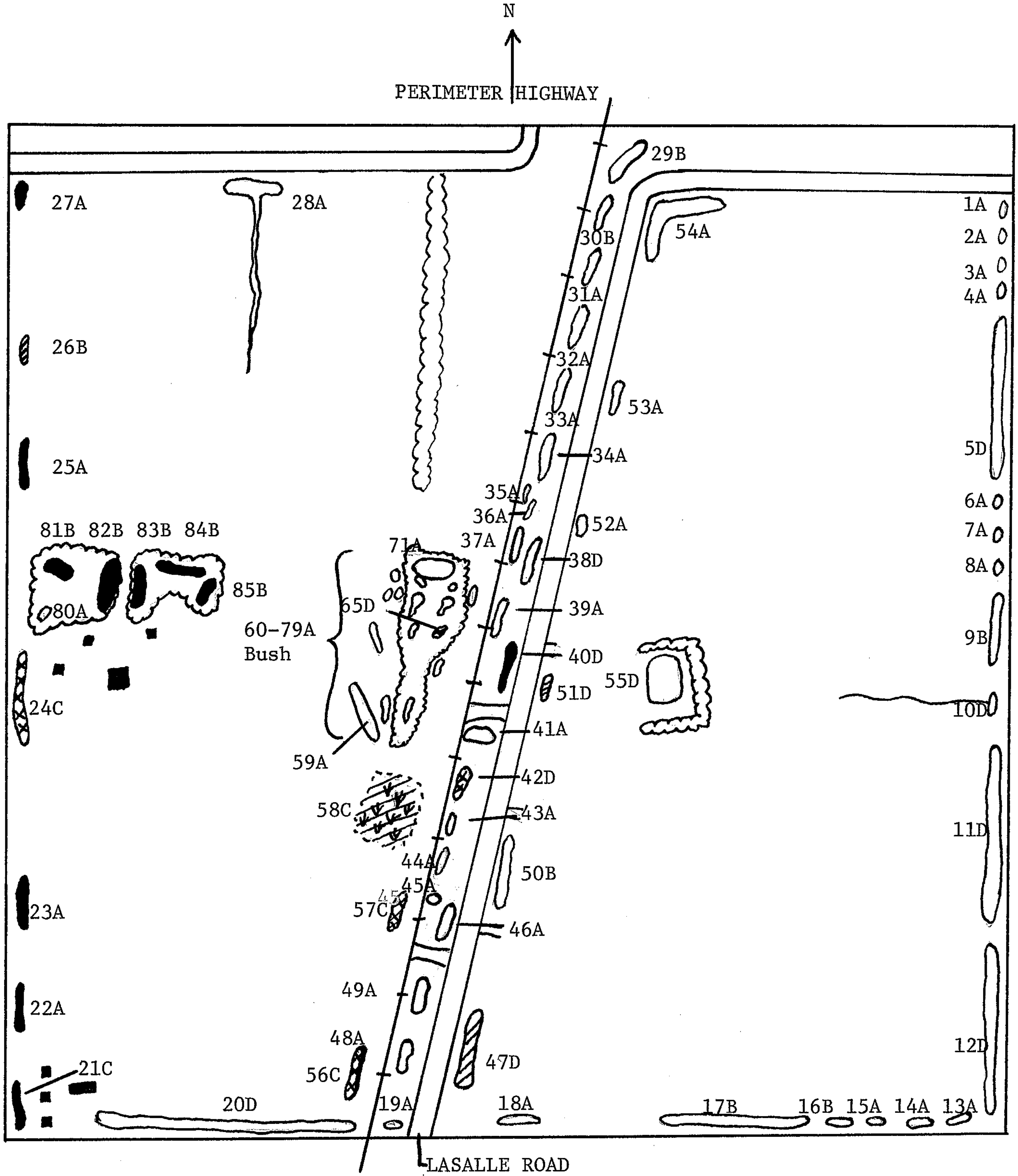
1" = 0.143 miles

Figure XIII

Map of South Outside Survey Plot, 1968

Mosquito Larval Development May to August

Figure XIII



A B C D - Pool Classification

- No Breeding

- Breeding recorded once

X X X X - Breeding recorded twice

- Breeding recorded three times

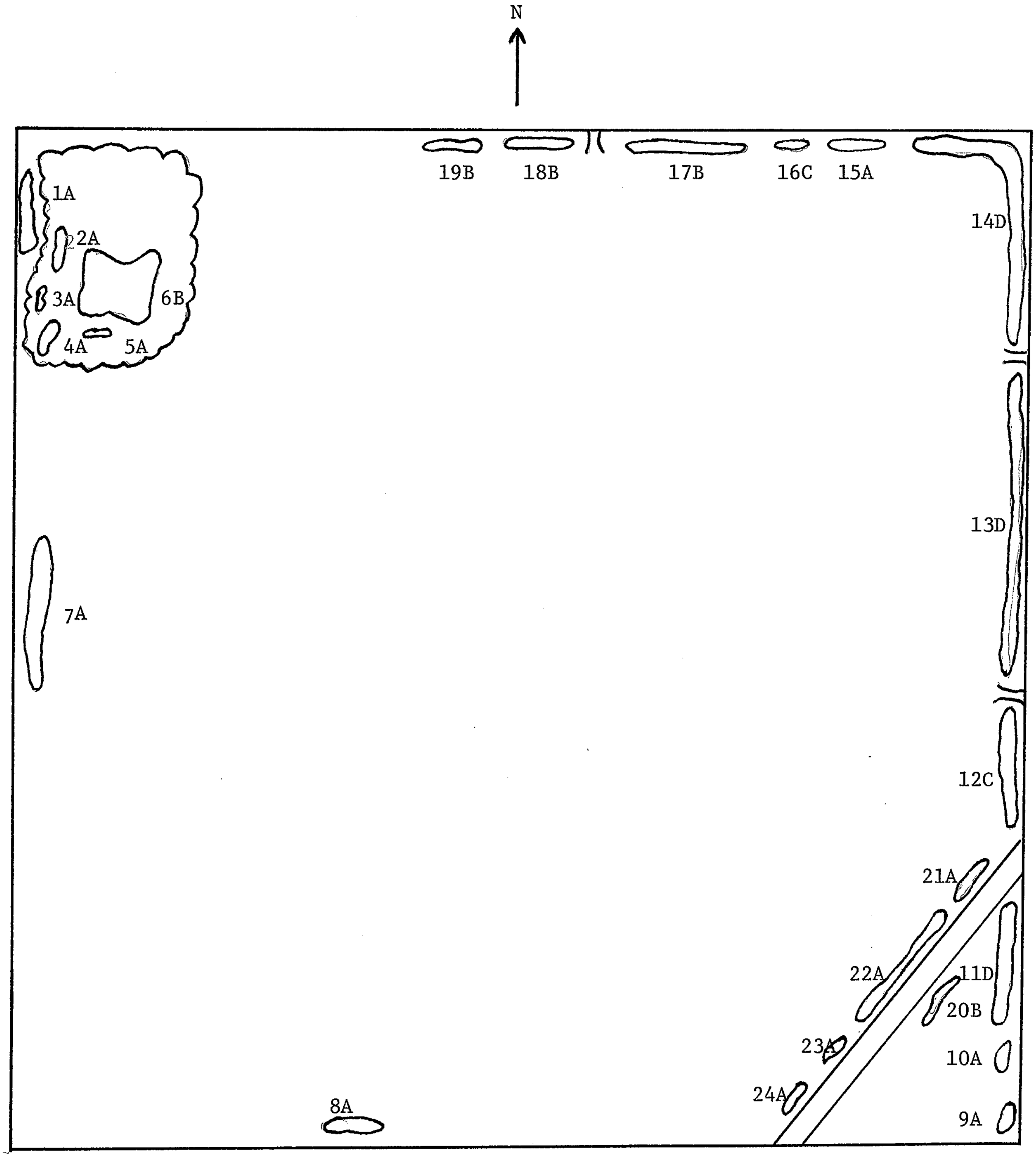
1" = 0.143 miles

Figure XIV

Map of South Inside Survey Plot, 1968

Mosquito Larval Development May to August

Figure XIV



A B C D - Pool Classification

- No Breeding

- Breeding recorded once

X X X X - Breeding recorded twice

/////// - Breeding recorded three times

1" = 0.143 Miles

CHAPTER III

SURVEY OF ADULT MOSQUITOES IN THE WINNIPEG AREA DURING 1967 and 1968

Introduction

The movement of adult mosquitoes is affected by air and ground temperatures, relative humidity, intensity of light, air currents, physiological state and intrinsic behaviour. Adult mosquitoes have diurnal periods of activity and quiesence. The activity period, which is largely spent in flight, appears to be initiated by a low level of light intensity Robinson (1952), Barr et al (1960), Bidlingmayer (1964), (1967), Pratt (1948), Provost (1959). This period of activity can be shortened, delayed or even postponed by additional environmental factors such as low temperature, low relative humidity and high wind speeds Provost (1952, 1957), Kennedy (1939), Bailey et al (1965), Taylor (1963), Bidlingmayer (1964), Hocking (1953). Variations in light intensity during the night, produced by cloud cover, or a bright moon are further responsible for modifying flight activity.

The above factors must be taken into consideration when sampling adult mosquito populations with light traps. Brust (1960) and Barr et al (1960) found that light trap collections of adult mosquitoes increased directly with increased light intensity. Bidlingmayer (1964) Horsfall (1943), Provost

(1959), and Pratt (1948) found that mosquitoes respond in greater numbers to light traps on moonless or cloudy nights than on moonlit nights. The resulting increase in numbers is misleading in data interpretation. Thus a knowledge of factors influencing light trap collections is required before conclusions based on data from light traps can be made.

Method and Materials

New Jersey light traps were operated in and around Winnipeg during the spring and summer months of 1967 and 1968. Each trap was fitted with a 25 watt bulb. The light and fan were controlled by an electric timer. The traps were operated from 19:00 hours to 07:00 hours. The catches were collected twice weekly in May and the first week in June. From June 7, 1967, and July 9, 1968, until the end of the summer each trap was emptied daily into half - pint food cartons and the collection labelled. This work was done by Metro employees and private citizens. The cartons were then collected twice weekly by a summer assistant. The adult mosquitoes were sorted as to sex, counted and at least twenty adult females per catch were identified. In 1967, seven traps and in 1968, six traps were operated inside Metro Winnipeg. During both years, one trap was located at each of the following locations: Legislative Greenhouse, Kildonan Park, Assiniboine Park, Brookside Cemetery, University of Manitoba Campus and the Windsor Golf Course. During 1967, one additional trap was located at Lot 62, St. Vital. As a comparison, six traps were operated outside the treated area in both years. The outside traps were set at a distance of two miles from the perimeter highway with the exception of the Glen Lea Research Station, which was 13 miles from the perimeter highway. The remaining traps were set up at Prairie Grove, Willow Grove and the farms of Mr. White, Mr. Storey and Mr. Baran.

In 1968, four traps were operated for two months in Selkirk, Manitoba to give additional information in the interpretation of light trap catches. The mosquito species in Selkirk are similar to those of Winnipeg; Selkirk had not practiced mosquito control during 1967, nor during May to August, 1968. The objective was to determine the base line of outside-inside trap catches where no control was used. From this base line, it might be possible to determine what the mosquito population would be in Winnipeg, if no control program existed.

Two traps were operated inside the city and two outside Selkirk during July and August, 1968. The inside traps were located at the homes of Mrs. Gallbart and Dr. Bankier. The outside traps were two miles beyond the city limits at the farms of Mr. Onyskis and Mr. Lebriecht. In Winnipeg, six traps were operated outside the control district and six inside. Only one outside trap was reported to the Metro Mosquito Abatement Office, twice weekly; counts and identification of the collections of the other five traps were made when time permitted. Identification and counts of all trap catches were completed by September, 1968.

Species of Adults and Percent Abundance, 1967 and 1968

In May, 1967, the most abundant adult was *Culiseta inornata* (85 - 90% of the population) followed by *Culiseta morsitans* and *Aedes spencerii* (Table 14). The most abundant larval species during May was *A. fitchii*, followed by *A. flavescens* and *A. campestris* (Table 4). *Culiseta* species overwinter as adults and consequently are the first adults taken in light traps. During late June and July, adults of *Culiseta* species become less common and only represent a small fraction of the population (Tables 15 and 16). The traps were not operated in May, 1968, but during June *A. vexans* adults comprised 50 percent of the population (Table 15). The reason for this was the warm 1968 spring temperatures and the heavy rains of May. In July of 1967 and 1968, *A. vexans* adults comprised 75 - 87 percent of the population (Table 16). In August of both summers, *A. vexans* comprised 46 - 58 percent of the population (Table 17). The decreased percentage of *vexans* was due to the increase of *Culiseta* and *Culex* adults. In September 1967, *Culiseta inornata* was the dominant species. The light traps were not operated in September 1968, but from larval populations (Table 13) it is quite predictable that the enormous adult populations experienced in Winnipeg were largely A. vexans; A. nigromaculis and A. dorsalis, with a fair number of Culiseta inornata. Since Culex and Culiseta females prepare for overwintering during Spetember, they would not take blood and their pest importance is diminished. The severe biting was in fact observed to be mainly A. vexans and A. dorsalis.

During 1967, there were two generations of A. vexans (Tables 4 - 6), while in 1968, there were four (Tables 9 - 13). The two additional populations of 1968 were due to the optimum spacing of above average precipitation.

Adult Populations Levels Inside and Outside Winnipeg, 1967 and 1968

It is clear from Tables 19 and 20 that the largest adult mosquito population trapped occurred in July of 1967 and 1968. The largest population probably occurred in September 1968, judging from Table 7 but the traps were not operated during this month. The population inside Metro Winnipeg in 1968 was almost three times larger than that of 1967. The 1968 outside populations, as indicated by light traps, were almost five times larger than those of 1967. The increased numbers can be explained by comparing the larval surveys of 1968 to those of 1967.

Relative Value of Inside-Outside Population Comparisons

Figure XV illustrates the inside-outside population

Table 14

Species of Adults and Percent Abundance in Winnipeg

During May, 1967

May

	1967		1968*	
Species	Inside	Outside	Inside	Outside
Culiseta inornata	84.38%	89.0%		
Culiseta morsitans	5.21	---		
Aedes spencerii	5.21	3.2		
Anopheles spp.	3.19	---		
Culiseta minnesotae	3.19	4.8		
Culex restuans	---	3.2		

* Traps not operated until June

Table 15

Species of Adults and Percent Abundance in Winnipeg

During June, 1967 and 1968

June

Species	1967 Inside	1967 Outside	1968 Inside	1968 Outside
Aedes flavescens	45.00%	45.15%	3.51%	4.50%
Culiseta inornata	15.60	14.70	25.96	14.60
A. fitchii	11.10	16.38	5.60	4.94
A. riparius	8.85	8.98	6.60	11.18
A. vexans	6.27	4.86	49.10	56.25
A. excrucians	2.26	1.65	1.10	0.59
C. restuans	2.09	1.15	---	0.94
Anopheles spp.	1.93	4.14	0.73	9.52
A. sticticus	1.29	---	5.20	3.80
A. spencerii	1.28	0.31	---	0.94
A. dorsalis	0.97	0.21	1.25	0.52
A. stimulans	0.85	0.41	---	---
C. morsitans	0.64	0.93	---	0.09
A. campestris	0.48	0.31	---	0.94
A. nigromaculis	---	0.62	---	---
C. tarsalis	---	---	---	0.13

Table 16

Species of Adults and Percent Abundance in Winnipeg
During July, 1967 and 1968

July

	1967		1968	
Species	Inside	Outside	Inside	Outside
A. vexans	87.50%	80.10%	77.85%	74.90%
C. inornata	3.08	3.00	13.45	17.10
A. flavescens	3.03	4.80	1.92	---
C. tarsalis	2.30	3.18	2.95	5.12
M. perturbans	1.43	1.52	0.22	0.56
A. fitchi	0.99	2.86	---	0.73
A. riparius	0.64	2.88	1.19	0.41
A. sticticus	0.11	0.16	0.35	---
A. nigromaculis	---	0.52	0.53	---
C. morsitans	---	0.30	0.61	---
C. restuans	---	0.27	0.30	0.59
A. dorsalis	---	---	0.15	---
A. excrucians	---	---	0.12	---

Table 17

Species of Adults and Percent Abundance In Winnipeg
During August, 1967 and 1968

August

	1967		1968	
Species	Inside	Outside	Inside	Outside
A. vexans	46.50%	54.38%	57.80%	58.50%
C. inornata	32.80	30.12	22.00	26.80
C. tarsalis	8.31	5.94	12.78	6.05
C. restuans	3.38	3.17	2.38	0.82
C. morsitans	1.41	2.30	2.38	3.19
Anopheles spp.	1.41	2.62	---	0.14
M. perturbans	0.83	---	---	---
A. riparius	0.78	0.14	---	---
A. flavescens	0.58	0.17	---	---
A. campestris	0.51	---	0.48	---
A. spencerii	---	---	---	3.67
A. dorsalis	---	---	0.91	0.37
A. nigromaculis	---	---	0.76	0.59

Table 18

Species of Adults and Percent Abundance in Winnipeg
During September, 1967 and 1968

September

Species	1967 Inside	1967 Outside	1968* Inside	1968* Outside
C. inornata	73.60%	64.10%		
A. vexans	8.80	19.90		
C. morsitans	5.61	7.90		
C. tarsalis	4.80	2.72		
C. restuans	4.40	1.89		
Anopheles spp.	2.00	2.72		
A. spencerii	0.80	---		
S. sticticus	---	0.52		
A. nigromaculis	---	0.34		

* Traps not operated.

curves for Winnipeg. Figure XVI illustrates the inside-outside population curves for Selkirk, where no control work was done during 1967 or 1968. The outside populations in both Winnipeg and Selkirk were greater than the inside populations. The major difference is that the outside populations in the Winnipeg area are twice the size of those in the Selkirk area. The inside population of both cities were nearly the same. If one can compare Selkirk to Winnipeg, in its capacity for mosquito production, we could have expected the inside population in Winnipeg to have been twice as large. I attribute this 50 percent reduction of adults in Winnipeg to the control of larvae and adults under the mosquito control program.

Comparison of Adult and Larval Populations from Winnipeg and Surrounding Area, 1967

The ratio of adult mosquitoes to larvae indicates that 0.168 percent of the adult population is being captured by the present number of light traps being used (Table 21). This compares well with the mark release experiments done by Provost (1952, 1957), Clark (1943), Bidlingmayer and Schoff (1954), Bailey, Eliason and Hoffman (1965), where recaptures of tagged mosquitoes were less than 1 percent. From this information, interpretation of adult mosquito activity and movement of populations by means of light traps would be misleading, since the indicated percentage capture is too small

Table 19

TOTAL NUMBER OF MOSQUITOES, MALE AND FEMALE, COLLECTED BY NEW JERSEY LIGHT TRAPS INSIDE METRO WINNIPEG 1967 and 1968

	May		June		July		August		September	
Location	1967	1968	1967	1968	1967	1968	1967	1968	1967	1968
Windsor Park	15	6	176	530	998	3,841	404	349	40	---
Legislative Green	25	3	262	420	2,149	1,185	579	560	98	---
Kildonan Park	17	8	116	159	477	580	237	613	53	---
Campus	16	7	114	787	1,332	4,208	498	1,633	21	---
Brookside Cemetary	10	0	57	125	214	864	63	758	3	---
Assiniboine Park	6	3	77	194	611	1,767	256	2,710	39	---
TOTAL	89	27	802	2,215	5,781	12,445	2,037	6,623	254	---

SUM TOTAL 1967, 1968 8,620 & 21,283
(June, July, August)

Table 20

TOTAL NUMBER OF MOSQUITOES, MALE AND FEMALE, COLLECTED BY NEW JERSEY LIGHT TRAPS OUTSIDE METRO WINNIPEG 1967 and 1968

	May		June		July		August		September	
Location	1967	1968	1967	1968	1967	1968	1967	1968	1967	1968
Willow Gr.	58	6	593	1,355	3,155	12,611	807	4,158	154	
Storey	31	-	258	1,903	1,050	11,124	788	7,167	318	
Prairie Gr.	16	-	624	735	3,616	7,452	910	20,688	145	
White	26	-	492	3,627	4,228	9,985	1,566	4,920	266	
Baran	11	-	283	781	1,159	4,014	681	2,672	187	
TOTAL	142	6	2,250	8,401	13,208	45,186	4,752	39,605	1,070	

SUM TOTAL 1967 & 1968 (June, July, August) 20,210 93,192

Figure XV

Mean Nightly Adult Catch Per Trap

in Metro Winnipeg, 1968

Figure XV

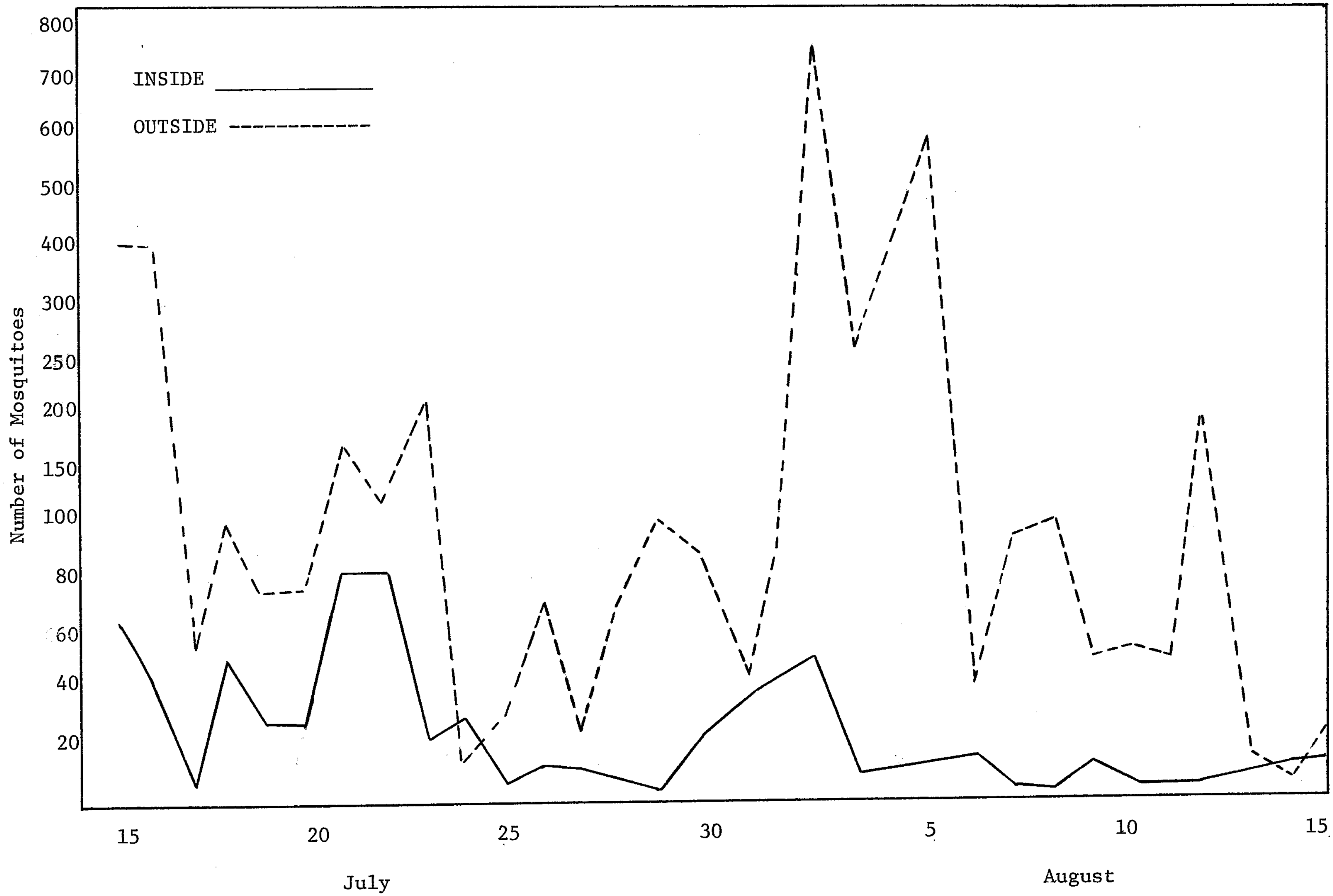
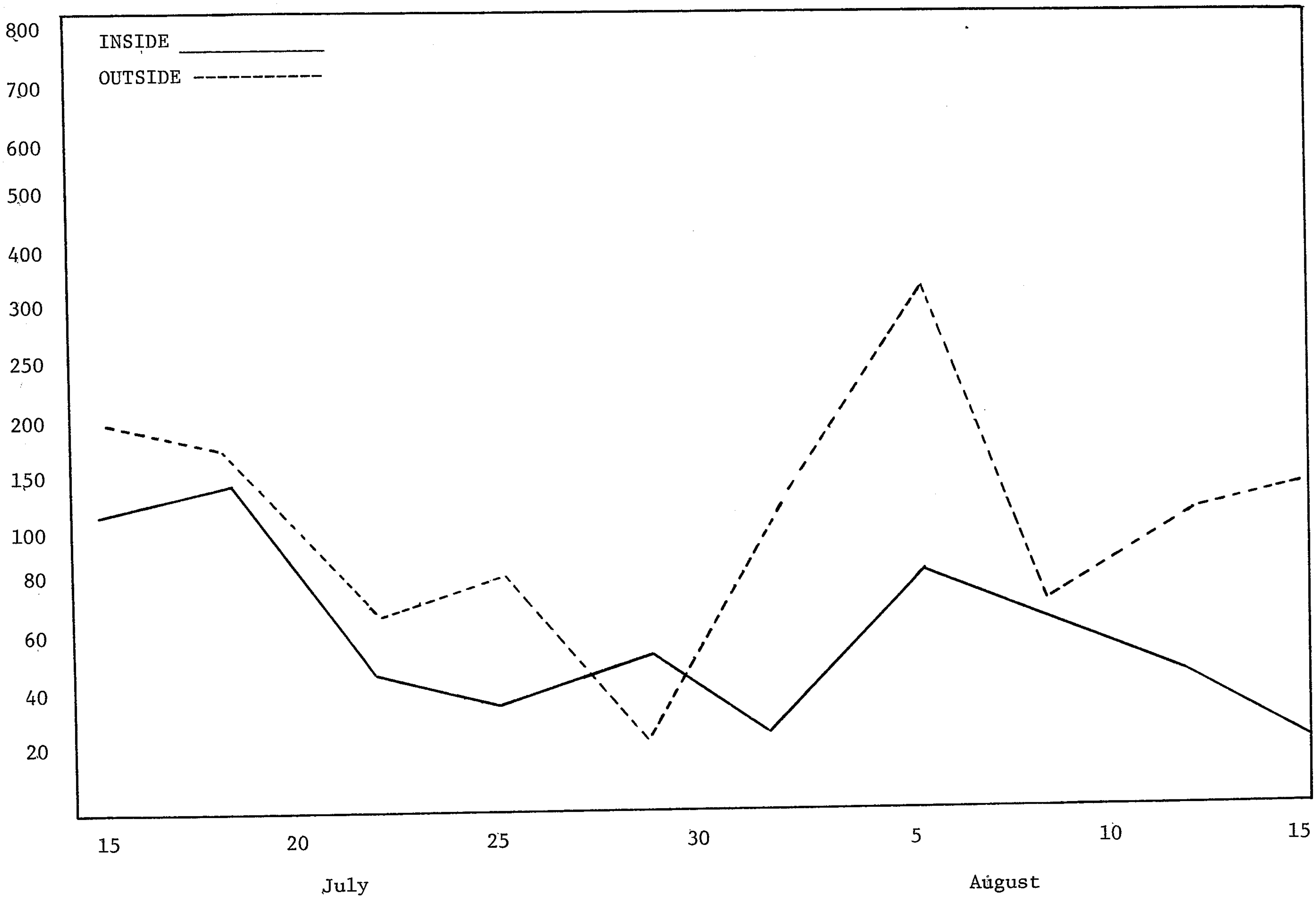

INSIDE
OUTSIDE
Number of Mosquitoes
800
700
600
500
400
300
250
200
150
100
80
60
40
20
15
20
25
30
5
10
15
July
August

Figure XVI

Mean Nightly Adult Catch
Per Trap in Selkirk, 1968

Figure XVI



INSIDE
OUTSIDE
800
700
600
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250
200
150
100
80
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40
20
15
20
25
30
5
10
15
July
August

a sample statistically upon which to base sound interpretation.

Conclusions

Adult light trap surveys mainly show that a small percentage of adult mosquitoes are attracted to light traps. The population levels inside a city are smaller than those outside a city in both controlled and non-controlled areas. There is good evidence that the inside population in a non-control area is higher than in a control area. The difference between the two might be a useful method of estimating the percent of control resulting from a mosquito abatement operation.

Comparing an adult population taken by means of light traps ten or more miles apart, with a larval population estimate, reveals that less than one percent of the adult population is being sampled.

From an analysis of the larval and adult populations within the Winnipeg area, the following conclusions can be drawn:

Light trap population figures can be meaningful if they are added up on a monthly basis for monthly population comparisons, or if they are added up for an entire season to compare to a previous season. This tends to cancel out the highs and lows that result from bursts of adult activity. Most of the nightly and even weekly peaks or lows are directly related to increased or decreased adult activity in response to daily, bi-weekly, or often weekly changes in mean temperature, wind and relative humidity (Costello, 1967; BRUST, 1960).

Table 21

Comparison of Adult Populations and Larval Population

Estimates 1967

Month	Sector A	B	C	D	E	Total	
May	1,113,071	1,035,230	1,009,600	11,240	230,480	3,339,621	L
	---	---	---	---	---		
	58	31	11	26	16	142	A
June	0	521,547	183,940	0	1,171	706,658	L
	0	0	0	0	0		
	593	258	283	492	624	2,250	A
July	790,200	20,583	2,449,397	4,398,760	Trace	7,658,940	L
		87,400	1,817,550	288,000	0		
	3,155	1,050	1,159	4,228	3,616	13,208	A
August	0	0	238,800	43,200	100	282,000	L
	0	88,500	2,085	22,900	0		
	807	788	681	1,566	910	4,752	A

Total Larvae - 11,989,219
Total Adults - 20,352
Ratio A/L - 0.168%

L - Larvae
A - Adults
--- - Larvae not recorded.

CHAPTER IV

INSECTICIDE STUDIES

Introduction

The addition of insecticides to the ecosystem for the past twenty years has increased to the point where it must be considered as significant. An important factor that must be constantly evaluated is the residual action of these toxic compounds. Numerous investigators Brooks, Smith, Schoof (1967), Chacko et al (1966), Edward (1964), Fahmy (1961), (1960), Harris, Lichtenstien (1961), Mann, Patchett, Batchelder (1960), Miles (1960), Nash (1967) have made important contributions to the literature on the residual action of insecticides. These contributions, however, differ with regard to the period of control claimed by each worker. The reason for discrepencies in control periods claimed stems from the lack of uniformity in testing techniques.

Investigations on effective control periods for several mosquito larvicides were conducted at Winnipeg during 1967 and 1968.

Field and Laboratory Studies Experiment I

Methods

Five formulations of DDT and one each of abate, dursban and baytex were tested to determine their residual action. All except two of the products tested were standard commercial preparations: 10% DDT formulated with bentonite granules, 30% DDT on vermiculite granules, 10% DDT on talc, 10% DDT on peat moss, 15% DDT in fuel oil, 1% abate granules, 5% dursban granules and 5% baytex granules. Each formulation was divided into five parts. Each part weighed 200 mg. and was in a 2" square sixty mesh nylon bag. One formulation sample consisted of five parts, thus one part could be removed each month. Each sample was placed (fall 1966) at the bottom of a different temporary pool near Winnipeg, Figs. XVII and XVIII.

In June, 1967 one bag from each insecticide sample was removed from the field and brought into the laboratory. Here a bioassay on the toxicity of each insecticide was carried out. On July 13, 1967, another bag from each sample was removed from the field, brought into the laboratory and bioassayed. The same procedure was followed on July 20, August 11 and September 10, 1967. On the completion of each bioassay with the exception of the first, the unused portion of insecticide was replaced into the bag and returned to the field.

The bioassay was modified from the W.H.O. test for resistance. Each insecticide was added to 250 ml. of water and placed in six inch petri dishes. The recommended field rates were used for each insecticide. A small quantity of dog food was added to each petri dish to supply food for the larvae. There was one control dish for each series of insecticides and four replicates of each treatment.

Ten fourth instar Aedes aegypti larvae were introduced into each petri dish; mortality counts were made at the end of a twenty-four hour period. Moribound larvae were considered as being dead.

Results

From Table 22, it can be seen that all of the nylon mesh bags contained biologically active insecticides throughout the entire summer. In all laboratory tests these preparations produced 100% mortality of mosquito larvae.

Mortality in the laboratory was 100%, however in the field, larvae were found in the pools containing the samples. These larvae were observed to feed on algae and fungi, the latter growing on and around the edges of the bags. The larvae developed to maturity in the pools and some were tested for resistance, using the standard W.H.O. methods, but no resistance was found.

Conclusions

The nylon mesh bags with a thin film of clay particles, algal and fungal growth on the bags, prevented the release of the insecticide. This may be representative of what happens when DDT or other insecticides settle to the bottom of a pool and are no longer effective. They are present but not biologically active. This situation could result with DDT when applied in fuel oil. Fuel oil evaporates and the DDT settles to the Bottom.

TABLE 22

Experiment I

Percent Larval Mortality Caused by all Insecticide Samples Kept in the Field for One Year. These Included DDT, Abate, Dursban and Baytex, tested at field rates.

Replicate of all Insecticides	Date Tested	% of Mortality
1	June 29/67	100
2	July 13/67	100
3	July 20/67	100
4	Aug. 11/67	100
5	Sept.10/67	100

Figure XVII

Experiment I - Temporary pool location of 1% Abate granules (five replicates) at start of experiment, fall of 1966.

Figure XVII

Figure XVIII

Experiment I - Temporary pool location of 30% DDT Vermiculite samples immediately prior to removal of one bag for analysis, July 20, 1967.

Figure XVIII

Vermiculite may be the best carrier for most temporary pool situations. One of the problems with a carrier that floats is that, if the pool is large, the wind carries it to the edge of a pool. This limits its effective control period and if runoff occurs there is danger of the vermiculite being carried into the drainage systems and eventually into a river or lake.

Field and Laboratory Studies Experiment II

The release of an insecticide from its carrier determines the length of its effectiveness in the field. For this reason various formulations and carriers of DDT were tested in the laboratory (after being removed from the field) using similar quantities of active ingredient.

Method

An additional amount of insecticide was removed from the samples containing DDT on vermiculite, DDT on bentonite and DDT on peat moss, used in experiment I. The method of analysis was the same as that used in experiment I with the exception that the insects were checked for moribundity and mortality at half hour intervals.

Results

Vermiculite and peat moss released DDT very slowly and only produced 100% kill in the laboratory after 19 hours. Bentonite produced a 100% kill in five hours. (Table 23).

Discussion

In the laboratory test, the treatment dishes were not disturbed, but the DDT dispersed in the water. Later experiments revealed that when larvae were screened off from the DDT source in a container, they were killed just as quickly as when they were allowed to swim to the source. Vermiculite and peat moss do not disintegrate in water, and hence the release of DDT from these carriers is retarded. Undoubtedly, a certain percentage of the insecticide also remains attached to the carrier and is not released into the water. Bentonite, on the other hand, disintegrates into a powder within one to two hours. Therefore, most of the DDT is released into the water and dispersed by brownian movement, or wave action in field pools.

Field Studies, 1967 - Experiment III

Methods

Experiment III consisted of placing insecticides in ditches where larvae were likely to occur the following spring (Figures XIX and XX). Insecticides were applied in November 1966 in six different locations outside of the perimeter highway. The treatments consisted of three formulations of DDT and one each of baytex, dursban and abate. These are as follows: 30% DDT on vermiculite, 10% DDT on bentonite, 15% DDT in fuel oil, 5% baytex granules, 5% dursban granules and 1% abate granules. Each treatment area was one acre in

Table 23

Experiment II

Speed of Release of DDT From Three Different Carriers

Carrier	Lbs. Active Ingredient/ Acre.	Hrs. to Beginning of Moribundity	Hrs. Till 100% Become Moribund	Hrs. Till 100% Mortality
Vermiculite	1	1.25	5	19
Peat moss	1	1.00	5	19
Bentonite	1	0.50	1.5	5

size and the insecticides were applied with a portable combination duster and sprayer.

Results

During May 1967, Aedes flavescens (5/dip) were found in the plot treated with DDT vermiculite, 1 lb. active/acre. Where DDT and fuel oil (1 lb. active/acre) had been applied Aedes fitchi (8/dip) were found in May 1967. Because of road conditions, the remaining sites were not examined until June and if spring larvae had been there they would already have developed to maturity and the adults emerged. The presence of frogs and other insects indicated that the insecticide, if still present, by June 1967 was not biologically active. Later studies on baytex, dursban and abate, showed that these compounds are not effective for more than a month to six weeks at the rate used.

Conclusion

In these preliminary tests the presence of spring larvae in two treated ditches indicates that the preseason fall application of 1 lb. active DDT/acre is not effective under some conditions. It is not known, whether these conditions are specific to ditches. The DDT may be covered with a thin layer of silt which washes into the pool during the spring runoff and renders the DDT biologically inactive, or the DDT may be carried away with the spring runoff. In the case of DDT on bentonite, it is not known if larvae were present in May 1967,

Table 24

Experiment III

Tests to Determine Residual Life of Field Applications. Insecticides were applied in November 1966 and checks were made for larvae the following spring.

Insecticide and Carrier	% Active Ingredient in Formulation	Formulation/ Acre	Active Ingred/ Acre in lbs.	Check Date 1967	Organisms Present When Checked
DDT on Fuel 0.1	15	1 gal	1	May	Mosquito larvae
DDT Vermiculite	30	4 lbs	1	May	Mosquito larvae
DDT Bentonite	10	10 lbs	1	June	Frogs
Baytex granule	5	2 lbs	0.1	June	Daphnia
Dursban granules	5	5 lbs	0.025	June	Frogs and Dyticidae
Abate granules	1	5 lbs	0.03	June	Dyticidae and Odonata

Figure XIX

Experiment III - Ditch A where 30% DDT on Vermiculite Applied at 1 lb. Active Ingredient Per Acre, November 1966.

Figure XIX

Figure XX

Experiment III - Ditch B where 10% DDT on Vermiculite Applied at 1 lb. Active Ingredient Per Acre, November 1966.

Figure XX

so this test was inconclusive. Later tests on baytex, dursban, and abate showed that they do not have sufficient residual life to be applied in the fall as preseason insecticides.

From these preliminary results, it is important that all fall applications of DDT be checked the following spring by adding larvae to the treated pools. The cage shown in figures XXIII and XXIV would be suitable for such tests.

Field Studies, 1968

Experiments I to III were preliminary. The experimental design relied on natural repopulation of treated areas by mosquitoes. The results did not indicate with any degree of accuracy when the insecticide became biologically inactive. For this reason, a more detailed experiment was designed. In this experiment, the method of determining the biological residual life of the insecticide was tested by introducing test larvae at regular intervals following application of the toxicant. Thus, there was no time interval between loss of activity and natural repopulation.

Methods

Sixteen pools, were constructed at the Glenlea Research Station. Each was ten feet in diameter, ten inches deep at the centre and shaped in the form of a cone so that pools were only one inch deep at the circumference. A layer of polyethelene was placed on the bottom of each pool and it projected two inches beyond the edge of the pool. Thus the pool edges were higher than the surrounding field (Figs. XXI and XXV). A two inch layer of sod was placed on top of the polyethylene lining and the natural vegetation allowed to remain. Fourteen pools were used as test pools, two were used for controls. Preseason applications of insecticides were placed in the pools in November 1967. Tests were conducted the following spring, by introducing larvae confined in special cages. Mortality was checked after a twenty-four hour period. (Fig. XXV). The cage was constructed of a loop of wire secured at one end. The form and size of the cage resembled a football. The wire loop was fitted into a lady's large size, light colored nylon stocking. The stocking was tied after the larvae were introduced into the cage. The light color of the stocking permitted easy observation during checks for mortality.

To prevent mortality due to environmental causes (temperature) mosquito larvae were collected in the field throughout the year and then introduced into the experimental pools (i.e. spring species of mosquitoes were introduced into the pools in the spring, summer species in summer and fall species in the fall). To ensure that there was no mortality due to larvae being confined in cages, twenty 2nd instar *Aedes vexans* larvae per cage were introduced into four cages and allowed to complete their life cycle in one of the control pools. These larvae developed into adults with a maximum of 5% mortality.

To determine insecticide effectiveness, a modified W.H.O. method of testing was followed. Mortality counts were made twenty-four hours after introduction. Moribund larvae were counted as being dead.

The breakdown of an insecticide was indicated when some larvae lived more than twenty-four hours in the chemically treated pools. The experiment was terminated when 95 percent of the larvae lived more than twenty-four hours. Once an insecticide in a pool was ineffective biologically, that pool was used for testing another insecticide. To check for contamination, larvae were introduced into such test pools and held for forty-eight hours. If mortality was 5 percent or less then that pool was considered to be ready to test another insecticide.

Pre-Season Treatments - Bioassy 1968 Experiment IV

Results

Insecticides listed in Table 25, were applied to the field pools at Glenlea during November 1967. The rates of application shown here were abnormally high and the reason for this was that an error was made in calculating the amount of material needed for each pool. The error was discovered after the applications were made and it turned out that ten times the desired amount was applied on all pools (Table 25).

Discussion

The data presented in Table 25 indicate that only the

Figure XXI

Pools at Glenlea Research Station for Evaluating Insecticides Used Against Mosquito Larvae.

Figure XXI

Figure XXII

Close Up of Several Pools as They Appeared After a Rain, 1968.

Figure XXII

Figure XXIII

Larval Cage for Insecticide Evaluation. Cage was constructed of a wire loop formed in the shape of a football and covered with a large nylon stocking.

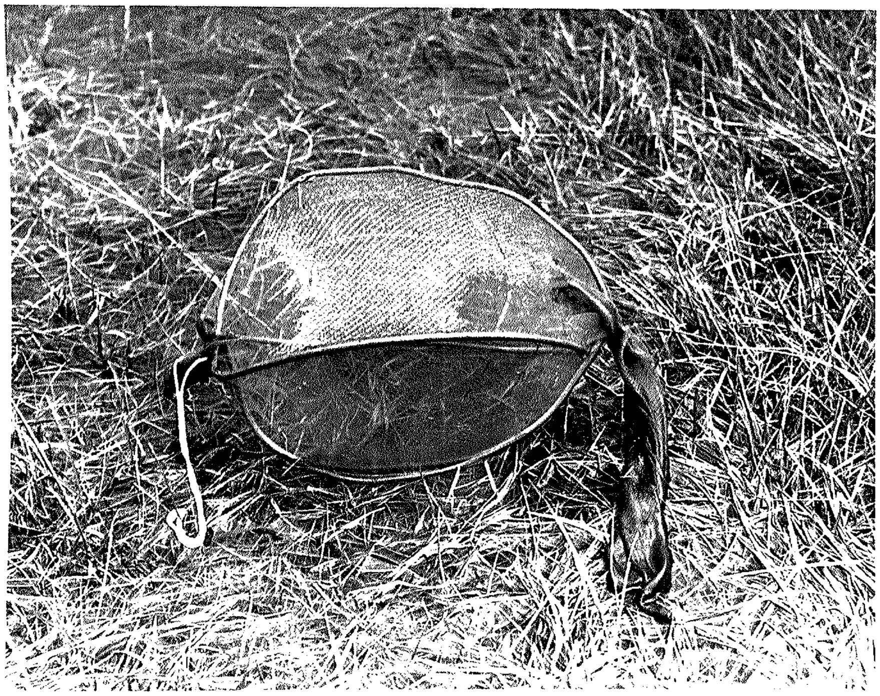

Figure XXIII

Figure XXIV

Larval Cage Partly Immersed in Test Pool

Figure XXIV

Figure XXV

Larval Cage During Test.

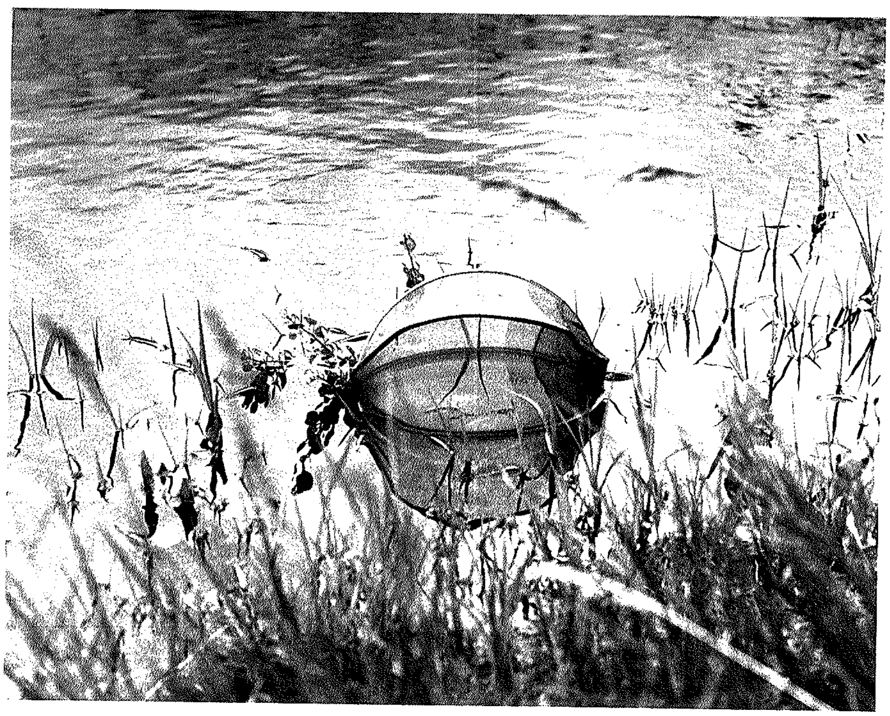

Figure XXV

preseason DDT formulations of 10 lbs. active/acre were residual and gave 100% control in May 1968. The other compounds tested failed to kill mosquito larvae during the spring of 1968. After ten months in the field pools, the DDT formulations were still effective. This was due to the long life of DDT and the heavy application placed in the field. None of the other insecticides should be considered for fall preseason applications.

Table 25

Experiment IV

Effectiveness of Preseason Applications of Insecticides In The Field. Applications were made in November 1967. Bioassays were made in May and August, 1968.

Compound	% Toxic Substances	Lbs. Active /Acre	1968 Date of Bioassay		% Control May	% Control Aug.
DDT Bentonite	10	10.0	May	Aug.	100	100
Baytex Granules	5	1.0	May	Aug.	0	-
M 3039, Dursban liquid	40	0.25	May	Aug.	0	-
Vermiculite DDT	30	12.0	May	Aug.	100	100
Control	0	0.0	May	Aug.	0	0
Fuel Oil DDT	15	10.0	May	Aug.	100	100
Malathion, technical	95	5.0	May	Aug.	0	0
U of M cmpd. Malathion	5	2.0	May	Aug.	0	-
Abate Granules	1	0.5	May	Aug.	0	-
M 3071 Dursban granules	5	0.25	May	Aug.	0	-
Control	0	0.0	May	Aug.	0	0
Baytex liquid	8 lb/gal	1.0	May	Aug.	0	-
Bayer 29493, technical	95	1.0	May	Aug.	0	-
M 3018, Dursban liquid	40	0.25	May	Aug.	0	-
Abate 4E, liquid	46	0.32	May	Aug.	0	-
Baygon, technical	97	0.7	May	Aug.	0	-

\- NOT TESTED.

Summer Application of Insecticides - Experiment V

Introduction

Preseason applications of insecticides (with the exception of DDT) were not effective at ten times the recommended rate. These ineffective preseason insecticides were again tested in June 1968 as a summer application, to determine their residual action.

Method

The same method of analysis was used to test the summer applications as was used in experiment IV and described in the section Field Studies, 1968.

Results

Baytex, malathion and baygon broke down in less than one week (Table 26). Bayer 29493 liquid and the U. of M. compound Malathion 5 percent granules lasted for more than one week but less than two weeks. Baytex 8 lb. liquid and abate 4E liquid were effective for less than three weeks but more than two weeks. Abate granules and the three dursban formulations lasted the longest, however, they were ineffective after four weeks (Table 26).

Conclusion

It appeared that abate and dursban were the best of the non-residual compounds to be used for mosquito control. Further investigations were needed at standard rates of application to determine this. (See experiment VII).

Table 26

Experiment V

Effectiveness of Summer Applications of Insecticides in the Field at Ten Times the Recommended Rate. Applications were made in June 1968.

Compound	% Toxic Substance	Lbs. Active /Acre	* Effective Control in Weeks
M3039, Dursban liquid	40	0.25	3 4
M3071, Dursban granules	5	0.25	3 4
M3018, Dursban liquid	40	0.25	3 4
Abate granules	1	5.0	3 5
Abate 4E, liquid	46	0.32	2 3
Baytex 8#, liquid	8 lb/gal	1.0	2 3
Baytex granules	5	1.0	1
Baygon, technical	97	0.7	1
Bayer 29493, technical	95	1.0	1 2
U. of M. compd. Malathion granules	5	2.0	1 2
Control A	0	0.0	0
Control B	0	0.0	0
Malathion, technical	95	5.0	1

* Effective period equal number of weeks mortality is greater than 90%.

Table 27

Experiment V1

Summer Application of Insecticides, 1968.
Number of days Baytex, Malathion and Baygon were effective in controlling mosquito larvae. Applications were made during July, 1968.

Compound	Lbs. Active Per Acre	Days Showing % Control 1	2	3	4	5
Baytex, 5% granules	1.0	100	100	100	100	0
Malathion, 95% technical	5.0	100	100	100	100	0
Baygon, 97% technical	0.7	100	100	100	100	0
Control	0.0	0	0	0	0	0

Table 28

Experiment VII

Effective period of non-residual insecticides applied at regular rates to field pools. Tests were made at the University Research Station, Glenlea, Manitoba during July and August, 1968.

Compound	lbs. active ingredient per acre	Days after application, on which tests were made and % control recorded.									
		1	2	3	4	5	6	7	12	14	19
Baytex granules, 5%	0.1	100	100	0	0	5	0	0	0	0	0
Baytex 8 lb. liquid	0.1	100	100	100	100	100	100	0	0	0	0
Bayer 29493, technical 95%	0.1	100	100	100	100	20	0	0	0	0	0
Baygon, technical 97%	0.07	100	50	80	20	0	0	0	0	0	0
Methoxychlor, technical 100%	0.5	100	100	100	100	100	100	0	0	0	0
Marlate, 2MR, 24% Meth.	0.5	100	100	100	100	100	100	100	0	0	0
Malathion, technical 95%	0.5	100	100	100	100	100	100	0	0	0	0
Abate sandgranules, 1%	0.05	100	100	100	100	100	100	100	0	0	0
Abate 4E, lqd.	0.032	100	100	100	100	100	100	100	0	0	0
Dursban, 40%, M3039 liquid	0.025	100	100	100	100	100	100	100	0	75	0
Dursban, granules 5% M3071	0.025	100	100	100	100	100	100	100	75	95	0
Dursban, 40% M3019 liquid	0.025	100	100	100	100	100	100	100	100	100	50

Summer Application of Insecticides - Experiment VI

The insecticides that broke down in less than one week were tested again using the same methods as in the previous experiment. This was done to determine how many days they would provide control. Larval mortality was recorded after twenty-four hours in the pools.

Results and Discussion

Baytex and malathion effectively killed larvae four days after the application, but then became ineffective (Table 27). Baygon gave effective larval control for three days, but produced no mortality on day four. For baygon and baytex granular, the length of control at ten times the recommended rate increased from one and two days respectively (Table 28), to three and four days respectively (Table 27). Malathion, at ten times the recommended rate, showed no change in effective control period.

Summer Application of Insecticides - Experiment VII

Experiment number VII was run to determine (a) the length of residual action of insecticides applied at recommended rates, (b) to see if there is any difference in length of residual action between insecticides applied at ten times the normal rate (Tables 26 and 27) and the recommended rate (Table 28).

Method

The method of analysis was the same as in the previous test. One other insecticide was added to this experiment - Methoxychlor (Marlate 2MR), 24% formulation, and technical Methoxychlor.

Results

The dursban compounds (Table 28) had the longest residual action lasting up to nineteen days. Baytex and baygon formulations had the least residual action: one to two days. Comparing Table 28 with the data of Tables 27 and 26, it appears that the length of residual action of many insecticides can be prolonged by increasing the amount of insecticide per acre. An exception to this was malathion. From Table 28 at 0.5 lbs. active per acre, the effective period was six days, at 5 lbs. active/acre, the effective period was four days. The difference may be because the 5 lb. rate was applied during July, when ambient temperatures were higher than August when the 0.5 lb. rate was tested. The effect of different rates of applications of all insecticides used in experiments V, VI and VII needs to be investigated in more detail and under standard conditions.

Discussion

At standard application rates dursban M3019, 40% liquid formulation had the longest control period (two weeks). Dursban 5% granules lasted seven days. Several insecticides could be considered if one was prepared to treat more than once per season, Abate 4E, abate 1% sand granules, and marlate 2MR (24% methoxychlor) and technical methoxychlor gave effective control for six days following treatment.

Conclusions

The most effective larvicide (longest control period) was dursban 40% liquid. However, the cost of this insecticide may be too great to consider using it at the present time. Registration for this product has been given in Canada (Feb. 1969) and increased demand should reduce the cost. Another suitable non-residual insecticide for mosquito control at present is methoxychlor. This is only two to three times the cost of DDT and with wider use in North America could become even more competitive in price.

Summer Application of Insecticides - Experiment VIII

Preseason treatments of DDT at ten times the recommended rate proved effective. Summer treatment of this insecticide at lower rates would provide further information on the biological effectiveness of this compound.

Method

Five rates of 30% DDT on vermiculite were placed in the field pools in August 1968. The larval bioassay was the same as in previous experiments.

Results

Rates less than one lb. of DDT per acre did not give 100% control. The 1 lb. rate was 100% effective for two days (days four and five, Table 29) and then became ineffective. At two and three lbs. per acre, DDT was effective for at least four days. The tests were terminated here unfortunately, so it is not known how long these rates remain effective. It is also significant that at 1 lb. active/acre, it took three days before the DDT caused mortality, whereas at two lbs., it took two days; at three lbs., only one day. This is probably due to the fact that vermiculite releases DDT more slowly than from bentonite or talc as is shown by results in Table 23 and an extensive study done by Sutherland and Mazurkewicz (1963). A certain concentration of DDT must be released before mortality occurs. In the case of 0.5 lb. per acre, the quantity used for the pool was only a few granules and these may have had DDT which was incompletely combined with the vermiculite and hence entered the water very quickly.

Discussion

The significant result of Experiment VIII is the implication that 1 lb. active DDT/acre does not control larvae for more than one week. If 2 or more lbs. per acre are applied, then the period of control is undoubtedly lengthened. It is known that 10 lbs./acre gave at least 10 months of control and probably longer (Table 25). The pools will be bioassayed again in 1969 to determine the effective period of control of the 2, 3, and 10 lb. applications.

The possible explanation for the short period of control at 1 lb./acre is that only about 0.01 lbs active DDT/acre is

Table 29

Experiment VIII

Effectiveness of Summer Applications of 30% DDT on Vermiculite at different rates per acre. Applications were made in August, 1968.

Compound	Lbs. Active ingredient/ acre	Days with Per cent Control									
		1	2	3	4	5	6	7	8	9	10
DDT	0.20	0	0	0	0	0	0	0	0	0	0
DDT	0.50	60	75	90	95	95	0	0	0	0	0
DDT	1.00	0	0	0	100	100	0	0	0	0	0
DDT	2.00	0	100	100	100	tests terminated here					
DDT	3.00	100	100	100	100	tests terminated here					

released by the vermiculite (Sutherland and Mazurkewicz, 1963). This may be sufficient to kill one brood of larvae. DDT is not soluble in water, settles to the bottom and becomes covered with particles of silt. The DDT is biologically inactive, though it has not degraded to any extent. We know from Experiment IX that it does not degrade quickly. Other workers, Edward (1964) and Edwards and Jeffs (1965) have shown that DDT remains in the soil for many years. A mean of 80 percent is left after one year and 50 percent after three years.

Past experience of the Metro Winnipeg mosquito control district indicates that their DDT applications almost last for an entire summer. There may be two reasons for this: (1) that DDT is applied in the same area year after year and an accumulation of DDT occurs (Table 31 shows there is an average of 3.32 lbs. on treated soils in Winnipeg) and this may control larvae for an entire season. (2) Bioassay studies have not been made on treated areas in Winnipeg, the DDT vermiculite application of 1 lb/acre (where no residues exist) is only effective for one week in terms of equivalent summer temperatures. We know that most of the wooded pools, where the preseason DDT vermiculite is applied, summer <u>Aedes</u> do not occur. Therefore, the application is only needed to kill the spring <u>Aedes</u>, and no evidence of insecticide impotency would be observed.

Conclusion

Areas in Winnipeg that receive preseason treatments of DDT should be bioassayed in the summer to determine the effective control period of the insecticide. More tests of the type begun at the Glenlea Research Station, need to be done to produce definite results for the future use of insecticides for the Winnipeg area.

Summer Application of Insecticides - Experiment IX

Chemical Analysis of DDT Residues on Soil in the Greater Winnipeg Area.

Introduction

The bioassay determined when an insecticide was no longer biologically active in water; it did not determine how much insecticide was present in the soil. An insecticide in the soil may still be active if soil in the pool is stirred up. DDT has a long residual life and repeated applications over a period of years may cause a buildup of insecticide in the soil. For these reasons, a soil residue test was carried out.

Method

In all samples, only the top ½ inch of soil and vegetation were taken for analysis and a total of 1½ lbs. (dry weight) was taken for each sample. The sample consisted of 75 - 100 circular plugs cut 1 inch in diameter using a sharpened 1 inch cork borer. The tube was set to go in only ½ inch

Table 30

Experiment IX - DDT Residues in Soil

Compound	ORF No.	% Moisture	Total Residue	Organochlorine residues in p.p.m. DDE	DDD	p,p'-DDT	o,p'-DDT
DDT & fuel oil - Soil #1	668	4.4	23.72	1.08	1.08	17.71	3.85
DDT & fuel oil - Soil #2	669	5.6	5.435	0.856	0.078	3.62	0.881
DDT & fuel oil - Soil #3	671	5.6	17.413	2.80	0.913	11.1	2.60
Vermiculite & DDT - Soil #4	672	7.4	39.05	2.77	1.07	29.9	5.31
Vermiculite & DDT - Soil #5	673 (c)	7.1	12.919	1.26	0.799	8.87	1.99
(reference) No DDT - Soil #6	674	8.2	0.044	0.005	0.001	0.028	0.010
12 lb. reference - Soil #7	675	17.4	96.27	6.83	2.44	66.6	20.4
DDT & fuel oil - Soil #8	676	8.4	125.39	4.40	4.89	88.4	27.7
Vermiculite & DDT - Soil #9	677	13.4	27.44	0.930	0.670	23.1	2.74
DDT & fuel oil - Vegetation #2a (d)	670	10.2	24.07	1.36	0.645	19.1	2.97

a. The soil samples contained varied amounts of vegetation, while the vegetation sample contained a small amount of soil. Following instructions received, the samples were analysed as received and the results are reported on the same basis.

b. The method is sensitive to 0.001 p.p.m.

c. Also contained 0.002 p.p.m. dieldrin.

TABLE 31

Experiment IX

Key to Sampling Sites June 6 and 10, 1968

#1 Ditch off Waverley, 2 miles south of the perimeter highway

Total DDT residues - 4.2 lbs. per acre (Fuel oil and DDT added once by the U. of M. in October 1966 at the rate of 1.0 lb. per acre. Test made in June, 1967 showed that larvae were not killed when reared in the ditch. Test made July, 1968 showed that all larvae died within 6 hours when placed in the ditch. (DDT source at present in the ditch is unknown).

#2 Grassy pool 200 yds. west of Waverley and just south of C.N. tracks (north of Wilkes Avenue).

DDT & fuel oil, preseason applications of 1 lb. per acre each year for more than 5 years. Heavy layer of dead grass covered the soil. Dead grass was removed first..Sample IIa - and soil was sampled below. Total residue in soil <u>0.67 lbs. per acre</u>. Total in vegetation above soil <u>3.0 lbs. per acre</u>. Combined vegetation and soil residues per acre <u>3.67 lb</u>.

#3 Grassy pool 200 yds. east of Waverley, just south of C.N. tracks (north of Parker Avenue).

DDT & fuel oil, preseason applications of 1 lb.

per acre/year for more than 5 years. Total residues, vegetation 2.17 lbs. per acre.

#4 Bush and open area sampled south of Wildes, west of Kenaston (north of Inland Cement Plant).

DDT vermiculite preseason treatment of 1 lb. acre/year for more than 5 years. Total DDT residues in soil and vegetation 4.87 lbs. per acre.

#5 Bush and open area sampled west of Kenaston, just about ½ mile south of Inland Cement Plant.

DDT vermiculite area like Sample #4. Total DDT residue in soil and vegetation, 1.6 lbs. per acre.

#6 Soil sample from Glenlea University farm.

No known application of DDT. Total DDT residues 0.005 lbs. per acre.

#7 Test Pool (78.5 sq. ft. in area) at Glenlea.

12 lbs. of DDT/acre were added in October, 1967. (DDT on vermiculite 30.6%; DDT % determined by National Testing Laboratory, Winnipeg in May, 1967). This was the assay standard. Conversion of ppm to lb./acre, (96.27 ppm = 12 lbs. 1 lb. DDT = 8.02 ppm).

#8 Test pool (78.5 sq. ft. in area) in Glenlea.

In 1967 15% DDT & fuel oil, mixed by Mosquito

Abatement District, was added to the test pool. The % DDT in the fuel oil was not confirmed. Consequently, this could not be used as an assay standard. The residue in lbs./acre on this pool was 15.6 (125.39 ppm ÷ 8.02 = 15.6 lbs. = 19.5%). Thus, the % DDT appears to have been 19.5% and not 15%.

#9 Bush area only, west of Shaftsbury and north of C.N. Tracks in Tuxedo DDT & vermiculite area, preseason treatment of 1 lb./acre for more than 5 years. Total DDT residues in soil and vegetation 3.42 lbs. per acre.

through the vegetation and into the soil below. The heavier samples (open areas) with less vegetation required fewer plugs than the bush area samples. The individual plugs for each sample were spaced 5 to 6 feet apart and approximately $\frac{1}{4}$ of an acre was used to gather the sample. This was done to insure that the sample was representative of the area.

Results

Tables 30 and 31.

Discussion

The Ontario Research Foundation residue testing laboratory is a nationally recognized laboratory and was recommended as a first class facility by A. W. A. Brown, of London, Ontario. The analyses are more complete than would generally be required, however it was necessary in this series of tests to know how much of the DDT residues present in Winnipeg soils are toxic to mosquitoes.

The P,P^{1}-DDT fraction and DDD fraction are the active ingredients, toxic to mosquitoes and other insects. The O,P^{1}-DDT is nearly inactive and the DDE is a breakdown product. DDT can be converted to DDE by a dehydrochlorinase enzyme of biological systems and bacteria may be responsible for the breakdown in soil. Breakdown also occurs under conditions of high pH. It was therefore necessary in these preliminary analyses to know how much of the DDT for example had been broken down to DDE. As shown in Table 1, only a small fraction had broken down and where residues existed, the active DDD and P,P[1]-DDT made up the largest fraction. Technical DDT, as produced by the manufacturer, normally contains 65-80% P,P-DDT, 15-21% of nearly inactive P,P[1]-DDT and up to 4% DDD (Metcalf, Flint & Metcalf, 1962). Hence all the three columns on the right side of Table 1 would be present when the technical DDT was applied. The DDE is a by-product and hence is part of the total residue. All four columns have been added for the purpose of reporting residues here.

The DDT and fuel oil samples taken from the Winnipeg area averaged <u>3.34 lbs. per acre</u> of total DDT residues (samples 1, 2, 3). The DDT and vermiculite treated areas from Tuxedo averaged <u>3.30 lbs. per acre</u> of total DDT residues (samples 4, 5, 9). The average in the six samples was <u>3.32 lbs. per acre</u>.

In one of the fuel oil and DDT tests, Samples 2 and 2a, 78% of the residue was in the heavy layer of dead grass above the soil and only 22% in the soil itself (Table 1).

There were only five samples in the present residue study that were designed to show whether there was an accumulation of DDT. These were samples 2, 3, 4, 5 and 9. Samples 6, 7 and 8 were reference samples and #2a was part of #2. Sample 1 was designed to see how much DDT was left after 1 lb. had been applied in 1966. However, there was an additional quantity of DDT which reached the ditch area concerned (source not known) between the dates June 1967 - June 1968. This was proven by larval tests done in the ditch at two different times (June 1967 and July 1968). The DDT could have come from run-off areas which were treated in late 1966, or early 1967. The DDT residue at the same site is now 4.2 lbs. per acre.

Insecticides persist in the soil for from a few days to many years. Whether the chemical disappears slowly or quickly from the soil, the soil animal populations usually remain changed for many months after the last residues have vanished Edwards,(1969). Edwards,(1964) found that DDT persisted longer than any other insecticide tested; 80% remaining after one year; on the average 50% remaining after three years. This ranged from 26-78%, depending upon soil type. Edwards and Jeffs (1965) found that larger doses of DDT required a longer time to break down than small doses (77% remained after 39 months at 60 lbs. and 73% remained after 39 months at 6 lbs.). Chemicals may still be found in soil long after any biological effects are observable.

Conclusions

DDT applied to the vegetation and soil in the Winnipeg area is gradually being accumulated by repeated ground and aerial applications made by the Mosquito Abatement District. If the use of DDT granules and ground spray is continued for the above areas, the amount of residue may become a problem as it is undoubtedly being passed through the ecosystem as has been shown by Diamond and Sherburne (1969), and Woodwell, Wurster and Isaacson (1967), and Edwards (1969).

It would be advisable to use some non-residual insecticide in place of DDT in areas where DDT has been used and is found to be ineffective (through bioassay tests). The residue level could then be monitored each year to determine the rate of breakdown until a residue level of 1 lb/acre or less is reached. The decision to use DDT in these areas might then be reviewed.

Laboratory Studies, 1968

Treatment Time for Different Instars - Experiment X

DDT on vermiculite was used to test the length of time required to kill different instars of mosquitoes.

Method

The method of analysis was the same as in field and laboratory tests. DDT (30%) on vermiculite at 1, 2 and 3 lbs./acre was used in all tests.

Results

One hundred percent mortality occurred in five hours against 1st instar larvae, seven hours against 2nd instar larvae, 19-24 against 3rd instar larvae and 22-24 hours against 4th instar larvae. Two and three lbs. application per acre gave the same results as 1 lb. per acre.

Conclusion

Younger larvae are killed in less time than older larvae, under the same treatment conditions. Fourth instar larvae live almost five times as long as first instar larvae treated with DDT. When field checks for mortality are made twenty-four hours should elapse before recording insecticide effectiveness.

Testing Flit as Larvacide - Experiment XI

Flit is a petroleum oil product of Humble Oil Company (ESSO), and is being manufactured for use against mosquito larvae. It is approximately $2.00 per gallon compared to 18¢ for fuel oil. It was compared to fuel oil, in laboratory experiments using larvae of *Aedes aegypti* for the bioassay.

Method

Described in paragraph 3, page 83.

Results

Results of the experiment are shown in Table 33. Flit at 3 gal/acre, produced the same larval mortality as Diesel fuel at 5 gal/acre. However, Diesel fuel compared favorably at the other concentrations (Table 33). At 10 gal/acre, both oils stopped controlling after 48 hours (less than 95% mortality). After three days of continuous testing, both diesel fuel and flit produced only 10% mortality at the highest concentration.

Table 32

Experiment X

Effectiveness of DDT on Vermiculite Against different Instars of *Aedes aegypti* mosquito larvae in the Laboratory.

Compound	lbs. Active / acre	Instar	Hrs for 100% Mortality
DDT on Vermiculite	1	I	5
DDT on Vermiculite	1	II	7
DDT on Vermiculite	1	III	19 - 24
DDT on Vermiculite	1	IV	22 - 24

TABLE 33

Experiment XI

Larval mortality of fourth instar *Aedes aegypti* using different concentrations of #2 fuel oil and flit. Tests were made at 75 degrees Fahrenheit.

Type of Oil	Quantity in gal/acre.	Larvae moribund (hrs. after treatment)	% Larval mortality after 24 hours
"FLIT"	10.0	12	100
	5.0	12	90 - 100
	3.0	12	70 - 80
	1.0	--	0
	0.5	--	0
"DIESEL FUEL"	10.0	18 - 20	90 - 100
	5.0	18 - 20	70 - 80
	3.0	18 - 20	10 - 20
	1.0	18 - 20	0 - 10
	0.5	-----	-

Tests for mortality on day four and day five were negative. At 5 gal/acre and less, both oils were effective for only 24 hours.

Conclusions

With regard to larval control, the results demonstrate that fuel oil will produce almost identical results to those of flit. The high rate of application for diesel fuel could be reduced by adding a "spreading agent". Symes et. al (1962), (page 19) recommended the use of sodium alkyl sulphate and alkylated aryl polyether alcohol. They claimed good control could be obtained using one to two gallons of diesel fuel per acre. Busvine (1951) also reports on the use of spreading agents and mentions oleic acid and commercial resin as good agents.

The above results on Flit MLO do not differ markedly from Micks et.al. (1968) with regard to control of instar IV larvae. However, Micks et.al. (1968) went further with their experiments to test control of pupae and adults. Flit was found by (Micks et.al.) to be effective against pupae and had delayed effects (By treating larvae, pupae died; by treating pupae, adults died). This aspect of the use of Flit should be investigated further. Other chemicals tested by Quraishi and Thorsteinson (1965) on Aedes aegypti also showed delayed effects resulting in pupal and adult mortality.

Effectiveness of Four-Insecticide Carriers - Experiment XII

Two new carriers for DDT, two for malathion, and one for abate were tested for larval control. The DDT carriers were compared to commercial products now in use. The malathion and abate granules were designed as slow-release pellets. The plastic coatings on the granules were designed to allow some insecticide to leak out. The plastic coated pellets contained malathion (5%), and abate (2%), and this work is reported in experiment XIII.

Method

Granules were formulated by the Plant Science Department, University of Manitoba, using DDT impregnated on peat moss and DDT impregnated on talc. Each type of the granule carried 10% DDT. These formulations were then sifted through a 100 mesh nylon cloth. The particles which did not pass through were placed in a four inch square bag of the nylon cloth. The fine particles were discarded. Previous work had shown larger particles carried more insecticide. The samples were placed in the field on October 27/66, in temporary pools where mosquito larvae were known to occur. Stock formulations of these insecticides were sealed in plastic bags and held in the laboratory for the purpose of comparison. After seven months the field samples were brought into the laboratory and tested against fourth instar *Aedes aegypti* larvae. The testing technique was the same as that for W.H.O. tests, except the samples were tested at field rates. The same procedure was followed for the commercial products.

Results

On June 27, 1967, the stock formulations of DDT were tested in the laboratory (against fourth instar *Aedes aegypti* larvae) at field rates. All formulations gave one hundred percent control. On July 13, 1967, the field samples were tested. The results are shown in Table 34. With 10% DDT on talc and 10% DDT on commercial bentonite, the larvae were all moribund in 1.5 hours after application. They were all dead within 24 hours. Two more tests were carried out with the same results as stated above. On the basis of this information, further tests with these compounds were discontinued.

With regard to the 10% DDT on peat moss and 30% DDT on commercial vermiculite, the DDT was released faster from the peat moss than from the vermiculite. However, within 24 hours both compounds gave 100 percent mortality. These tests were repeated three more times and the same results occurred. On the basis of this information, the tests were discontinued.

Discussion

There was no difference in effectiveness between DDT on bentonite and DDT on talc. With the exception of the faster release of DDT from peat moss, there was no difference in

Table 34

Experiment XII

The Effectiveness of the Test Formulations compared to Standard Commercial Products.
One lb. active ingredient per acre was applied in all tests.

Carrier	M & D	Alive	Field Rate lbs./acre	% Toxic Substance	% Kill
Bentonite c	10	0	10	10	100
Vermiculite c	10	0	4	30	100
Peat Moss	10	0	10	10	100
Talc	10	0	10	10	100
Control	0	10	0	0	0

M & D - Moribund and Dead
c - Commercial product

effectiveness between DDT on peat moss and DDT on vermiculite.

Plastic Carriers for Delayed Action of Non-residual Insecticides - Experiment XIII

Method

In 1967, a plastic carrier was prepared from methocel and ethocel. Malathion at the rate of 5 percent by weight, was incorporated into the granule in the following way. The core of the granule was a sand particle, coated with talcum powder, malathion and methocel. This was then closed up with a coating of ethocel and malathion to produce a granule which would release malathion over a long period of time (it was hoped that this might be 30 days).

In 1968, the outer ethocel coating was replaced with polyvinyl chloride and malathion. Both preparations, 1967 and 1968, were field tested in 1968. A 2 percent abate granule was also formulated in 1968, and field tested. This granule had the polyvinyl chloride coating similar to the second malathion preparation. Laboratory tests were also carried out on the malathion and abate granules.

Results

On July 25, 1967, the first test on the 5 percent malathion formulation (ethocel covering) was made in the laboratory. All rates 1, 2, 4, 8, 16, 32 mg., gave 100 percent control within twenty-four hours. The rate of 8 mg. is equal to 4 lbs/acre, or 0.2 lbs active ingredient/acre. This was the rate used for field trials (Table 35).

The second malathion carrier (polyvinyl chloride) was tested in the laboratory on 19/6/68 at a rate of 8mg. It gave 100 percent control during the first twenty-four hours, but no residual effect was produced.

The 2% (polyvinyl chloride) abate compound was tested in the laboratory at rates of 10 mg. and 5 mg. Both rates gave 100% control during the first 24 hours, but again no residual effect was recorded.

The three preparations were tested in the field pools at the Glenlea Research Station, Figure XXV. The results of these tests are shown in Table 35.

The only carrier that released its insecticide in amounts sufficient to kill mosquito larvae under field conditions was the methocel carrier. The polyvinyl chloride probably acted as a seal and did not allow the insecticide out of the granule. The ethocel coating is more porous and this is undoubtedly why these granules were effective.

Discussion

The plastic carriers tried here did not produce the slow release quality that was desired. The ethocel covered granules gave identical results to liquid malathion. The polyvinyl chloride coated granules of malathion and abate gave no control in the field. This was probably due to two

Table 35

Experiment XIII

The efficiency of insecticides on various plastic carriers in field trials, July 1968

Compound & Carrier	lbs. active toxicant / acre	Days with % control					
		1	2	3	4	5	6
Malathion 5% Ethocel 1967	0.2	100	100	100	95	75	0
Malathion 5% Polyvinyl Chloride 1968	0.2	0	0	0	0	0	0
Abate 2% Polyvinyl Chloride 1968	0.1	0	0	0	0	0	0

factors: (1) they should have been applied at heavier rates to permit sufficient insecticides to be released for control, say at 1 - 2 lbs. active/acre. (2) the polyvinyl chloride is too impervious and seals in the insecticide. More research with plastics and permeability of these is needed.

Residual Action of Insecticides on Adults - Experiment XIV

Introduction

Insecticide fogging is conducted by most mosquito abatement agencies in residential areas, parks and playgrounds. The majority of investigations have been aimed at improvements in techniques (Glasgow and Collins (1946), Horsfall (1950), Clarke (1949), Schechter et. al. (1962), Brown and Morrison (1955), Rathburn (1965)). Some people have compared thermal fogs with non-thermal fogs (Mount et. al. (1966), Miller et. al. (1967), Taylor and Schoof (1967), Clarke (1949)), and found very little difference. However, the one question left unanswered is how effective is fogging in reducing the number of adults in a control area?

Two experiments were conducted to determine whether there is any residual benefit from thermal fog applications of DDT and baytex.

Method

One formulation of 7% DDT in fuel oil and one of baytex (1 gal. No. 8 in 45 gal. No. 2 fuel oil) were applied as fogs in two different areas around Winnipeg. The applications were made with a truck mounted Tifa fogger by the Metro mosquito abatement district staff and equipment. Four screened cages, each containing twenty-five Aedes aegypti females were set at 5, 20, 40 and 60 yards from the path of the fogging machine. Mortality of mosquito adults was checked at one hour, 48 hours and 96 hours after fogging. When 100 percent mortality occurred, fresh adults were added to the cages.

Results and Discussion

Both the DDT and baytex applications of thermal fog produced 100 percent mortality in one hour in adults caged 5, 20, 40 and 60 yards beyond the path of the fogger.

The dead adults were removed from the cages after one hour and replaced with fresh adults. The second series of adults were still alive after 48 hours, Table 36. This means there was no insecticide residue (DDT or baytex) on the fibre glass screen of the cages or else the mosquito tarsal pulvilli would have absorbed it and the adults would have died soon after.

Vegetation fogged on 6/9/67 with DDT was tested for residue on 8/9/67. Fresh adults were put out in cages where one side of the cage was removed to allow the adults to rest on the grass. Mortality was checked on 10/9/67 and all adults were alive. The same test was done with the baytex treated area which was fogged on 8/9/67. Fresh adults were put out in cages on 10/9/67, where again one side of the cage was removed and the adults allowed to rest on the grass. In this case 20 - 30% mortality occurred by 11/9/67. However, since it was a cold night on 10/9/67, it is not known whether the mortality was caused by insecticide residue or cold weather.

Conclusions

As reported in Table 36, there appears to be no residual effect from either DDT or baytex applications using thermal fog. There is an initial kill, 100 percent mortality over the distance tested in the experiments. These results agree with those of Lofgren et.al. (1967), where he states "Both cold fogs and thermal fogs kill only those adult mosquitoes that are contacted at the time of application and no appreciable residual deposit of insecticide occurs." Thus relief from mosquitoes is temporary and lasts only until reinfestation occurs from breeding sites or from areas not treated. Horsfall (1950) states "That for fogging to be effective in any given area, that is to sufficiently reduce the adult mosquito population below the annoyance level, fogging would have to be carried out on a daily or twice daily basis". This is dependent on the activity of the adult population. If the adults are not actively moving about, an area may be free of mosquitoes, after it has been fogged, for perhaps 3 - 5 days.

Table 36

Experiment XIV - The Effectiveness of Thermal Fogs

Type of Test	Insecticide	No. Dead	No. Alive	Total No. Tested	Distance in Yards	Period of Rest Hours	Date Checked
Direct contact with fog cage	DDT*	25	0	25	5,20,40,60	1	6/9/67
Test for residual action of fog on cage	DDT	0	25	25	5,20,40,60	48	6/9/67
Test for residual action of fog on grass I	DDT	0	25	25	5,20,40,60	48	10/9/67
Test for residual action of fog on grass II	DDT	0	25	25	5,20,40,60	48	10/9/67
Direct contact with fog cage	Baytex*	25	0	25	5,20,40,60	1	8/9/67
Test for residual action of fog on cage	Baytex	0	25	25	5,20,40,60	48	10/9/67
Test for residual action of fog on grass I	Baytex	3	7	10	5,20,40,60	24	11/9/67
Test for residual action of fog on grass II	Baytex	2	8	10	5,20,40,60	24	11/9/67

*DDT rate - 7% in No. 2 fuel oil
*Baytex rate - 1 gal No. 8 in 45 gal. No. 2 fuel

CHAPTER V

PREDATION OF MOSQUITO LARVAE BY MINNOWS

Introduction

There are many species of minnows native to Manitoba (Hinks, 1943), but two of the better known ones are the spot tail minnow, Notrophis hudsonius Clinton and the fathead minnow Pimephales promelas Rafinesque. The latter is common in roadside ditches around Winnipeg and feeds on algae, insect larvae and small crustacea. A culture of the fathead minnow was maintained at the Department of Entomology and the minnows were tested for their ability to prey upon mosquito larvae. It had been observed earlier, during larval surveys in the field, that mosquito larvae were few or absent in pools where the fathead minnow occurred.

Method

A total of five experiments were conducted using four fifteen gallon aquaria filled with water to depths of 6, 12 and 27 cm. These aquaria were also fitted with thermostatically controlled heaters. The minnows were introduced singly or in pairs, when the tests were made. Aedes aegypti larvae were introduced into each tank daily, until there were larvae surviving at the end of a twenty-four hour period. The surviving larvae were recorded. Once this point was reached, it was repeated for four consecutive days. From this the mean consumption rate per fish per day was calculated.

Figure XXVI

<u>Pimephales promelas</u> Preying on Mosquito Larvae

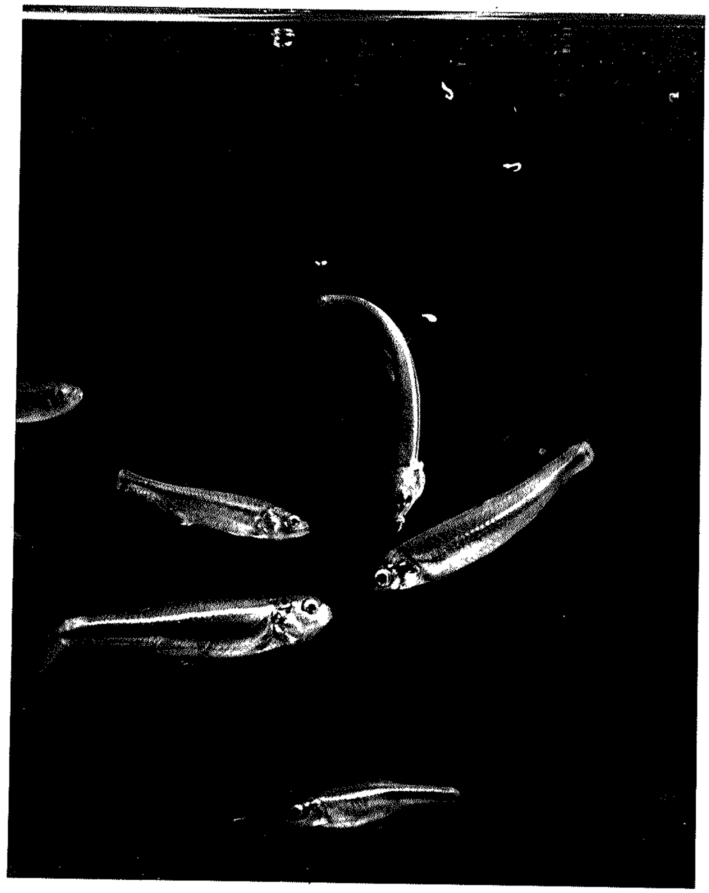

Figure XXVI

Figure XXVII *Pimephales promelas*

Habitat A in the Vicinity of Winnipeg

Figure XXVIII *Pimephales promelas*

Habitat B in the Vicinity of Winnipeg

Figure XXVII

Figure XXVIII

Table 37

Predation of Mosquito Larvae by Pimephales promelas in the Laboratory. The results show daily consumption of larvae per fish per day. The mean of 4 replicates is given.

Experiment Number	Water Temp C.	Instar	Water Depth cm.	Larval Consumption per Minnow per Day
I	19	4	12	99
II	19	4	12	106
	25	4	12	134
	30	4	12	138
III	30	pupae	12	132
	19	3	12	143
IV	25	4	6	105
	25	4	12	134
	25	4	27	160
V(1)	30	4	12	77

(1) 0.5 gms. of dry fish food was added to each aquarium in this experiment.

Results

Experiment I established a base line of larval consumption at 99 mosquito larvae consumed per fish per day. Experiment II shows that mosquito predation increases with increased temperature. Experiment III, in comparison to experiment II, indicates that these fish will consume more third instar larvae than fourth instar and more pupae than fourth instar larvae. Experiment IV shows that at a constant temperature predation increases with increasing water depth. In experiment V, the addition of fish food reduced predation on mosquito larvae by fifty-five percent. There was a surplus of dry fish food in each aquarium but the minnows still fed on mosquitoes, indicating a preference for live food.

Discussion

The laboratory experiments bear out the field observations that the fathead minnow is a mosquito predator. They also show that this minnow does not prey exclusively upon mosquito larvae. In the field, this minnow also lives upon algae and small crustacea. In the absence of mosquito larvae, the fish would not perish.

The fact that a pair of minnows consumed somewhat more mosquitoes than each did singly, indicates that there is some competition for prey.

The laboratory experiments showed that consumption increased with an increase in temperature. In the field, temperature would be a controlling factor for larval consumption since low water temperatures in the spring reduce the activity of all aquatic organisms. Reduced activity means less energy expended and subsequently a smaller food intake. Ecologically it would also assure an adequate food supply since spring populations of crustacea and algae are limited in comparision with summer populations.

In the field and laboratory it was observed that in shallow water the minnows remained under cover of any protruding objects. When they left the security of their cover, they became excited and swam about rapidly. They devoured only those larvae in their path. When the water was deep they appeared relaxed and swam in an easy and secure manner. The tendency to remain under cover was negative and they spent more time actively preying upon larvae.

Experiment IV (Table 37) shows increased larval consumption with increased water depths. This might be interpreted that in shallow pools decreased feeding is a survival behavior mechanism where feeding becomes minimal rather than maximal.

Although no tests were made on consumption of first and second instar larvae, there is no reason to believe that these fish would not prey upon small larvae. These larvae are as large as many algae and crustaceans.

Conclusion

The minnow *Pimephales promelas* should be field tested for mosquito control. From the laboratory experiments conducted, they appear to be effective predators and might be considered for distribution in semi-permanent and permanent pools around Winnipeg.

CHAPTER VI

SUMMARY

The 1967 and 1968 larval surveys revealed that the formation and existence of pools during the summer season depended upon (a) the length of time between rainfalls, (b) the amount and type of rain received and (c) the amount of moisture retained by the particular soils.

Developmental sites were classified as types A B C and D depending upon the length of time the water was present in the pools. Nineteen species of mosquito larvae were recorded in 1967 and the distribution of rainfall determined mosquito abundance in any particular region. Mosquitoes used less than thirty percent of the available water for development and breeding sites appeared to be in close proximity to the source of a blood meal. Pools were utilized more than once and in most cases were shared by several species.

The average number of mosquitoes produced from late May - September, 1968 was 3,200,000 in the four square mile plots located inside the control area, or 800,000/sq. mile. This means there were about 80,000,000 mosquitoes produced within the [illegible] boundary of the perimeter highway, or about 80 female adults for every resident of Winnipeg.

The four square mile plots located outside the perimeter highway produced approximately 200,000,000 larvae or 50,000,000/ sq. mile, during the same period. If we consider a 5 mile radius beyond the perimeter as the limit of mosquito flight to Winnipeg suburbs, we then have an area of 330 square miles. This could have produced approximately 16 billion mosquitoes. If an estimated 20% of the adult population migrated into Winnipeg, then there would have been 3,200 female adults per resident.

There is an urgent need to control mosquito larvae within the boundaries of the perimeter highway and to go beyond this to include the additional 5 mile radius outside of the city (total of 500 sq. miles). This need was already realized in 1927, the first year of operation of the anti-mosquito campaign in Winnipeg. Dr. H. M. Speechly recommended larval control over an area of 400 square miles. In 1929, the anti-mosquito campaign did in fact treat larvae over a 10 mile radius from the centre of Winnipeg (approx. 310 sq. miles). In 1940, the field manager John McLintock, again stressed the need to expand larval control when he stated "As previous reports have pointed out, a radius of a least 20 miles would have to be covered before complete eradication would be possible".

Adult surveys by means of a light trap, indicated that some mosquito species may be more attracted to light than others. Light traps do not give adequate information on mosquito movement since a comparison of larval estimates to adult catches revealed that less than one percent of the adult population was being sampled. Adult population levels <u>outside</u> a controlled area (Winnipeg) and a non-controlled area (Selkirk) were greater than those <u>inside</u>. The ratio of inside/outside populations in Selkirk (non-controlled area) was higher than Winnipeg (controlled area).

Natural repopulation of areas treated with insecticides did not indicate with any degree of accuracy when insecticides were biologically ineffective. New experimental design of plots enabled the exact determination in days. Dursban had the longest residual effect lasting up to three weeks. Baytex, malathion and baygon were ineffective in less than one week.

Soil and vegetation analysis of DDT treated areas in the Metro Winnipeg mosquito abatement district revealed that there is an average of 3.32 lbs. of DDT per acre on areas treated for approximately 10 successive years at 1 lbs./acre/year. This amount will undoubtedly increase if the use of DDT is continued. Comparing the effect of fuel oil and flit on mosquito larvae showed that both compounds produced almost identical results. Flit was slightly more effective at lower concentrations. Pupae were not tested.

Polystyrene carriers in formulations of insecticides were more effective in the laboratory than in the field.

Thermal fogs kill only those adults that are contacted at the time of application and cannot be considered to have a residual effect. Effectiveness of fogging depends upon the movement of adult mosquitoes which in turn is regulated by atmospheric conditions. Thus benefits obtained from fogs may last from one hour to several days. This would be dependent upon adult movement during evenings when temperatures and wind speeds are suitable for flight.

The fathead minnow *Pimephales promelas* appeared to be an effective predator of mosquitoes. Laboratory experiments showed that up to fifty percent of its diet is made up of living prey depending upon their availability. Field observations showed none or very few mosquito larvae to occur where these fish were present. These minnows should be considered for mosquito control in permanent and semi-permanent pools around Winnipeg.

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Appendix I

Larval Survey 1967

Date & Sector	Pool No.	Dimensions	Species	No./ dip	Approx. Pop.
23/5/67	1	100'x4'x8"	A. fitchii	1	3,900
A	5	3000x7x10"	A. fitchii	2	509,470
	6	300x4x6"	A. fitchii	1	8,784
			A. flavescens		
	10	300'x6'x10"	A. fitchii	2	437,250
	16	30x8x16"	A. flavescens	1/3	1,537
	21	200"x5x6"	A. flavescens	1	7,320
			A. fitchii		
	22	100x7x10"	Acampestris	1/2	4,270
	[illegible]	[illegible]	A. dorsalis		
	30	600x8x8"	A. fitchii		140,540
24/5/67	3	50x10x8"	A. fitchii	1/8	685
B			A. flavescens		
	4	200x15x8"	A. fitchii	Tr	Tr
	6	100x7x12"	A. fitchii	2	20,500
			A. flavescens	2	440,000
	8	300x10x12"	A. fitchii		
	10	1000x8x12"	A. fitchii	3	351,360
			A. flavescens		
	17	150x7x12"	A. fitchii	Tr	Tr
	18	200x8x12"	A	1	24,400
	19	1200x7x12"		1	123,000
	21	100x6x6"	A. spenceri	2.5	11,000
			A. fitchii		
	24	600x8x10"		1	58,560
	25	600x6x8"	A. fitchii	1/2	18,300
			A. excrucians		
	29	100x8x12"	A. fitchii	2	23,425
			A. riparius		
26/5/67	5	105x7x10"	A. fitchii	1	12,800
C	6	450x6x6"	A. fitchii		9,760
			A. flavescens		
			A. riparius		
	7	30'x40'x6"	A. fitchii		880
			A. flavescens		
			A. campestris		
	8	25'x3'x8"	A. barri	5	3,660
	10	100x7x15"	A. fitchii	20	256,200

Date & Sector	Pool No.	Dimensions	Species	No./ dip	Approx. pop.
	14a	100x8x15"	A. fitchii	2	29,300
			A. campestris		
	14b	20x25x6"	A. campestris	40	244,000
			A. dorsalis		
			A. canadensis		
	15	400x7x8"	A. fitchii	2	41,200
	18	600x7x8"	A. fitchii	1	41,500
			A. flavescens		
	19	3000x8x8"	A. fitchii	1/3	87,800
			A. riparius		
	20	2400x8x6"	A. fitchii	2	281,000
			A. flavescens		
			A. riparius		
	22	20x40x3"	A. campestris	1/2	1,500
29/5/67 D	1	100x2x6"	A. fitchii	6	8,800
			A. flavescens		
			A. campestris		
	5	250x5'x8"	-----		2,440
	8	10x20x6"	A. fitchii	Tr	Tr
30/5/67 E	4	200x24"	A. sticticus	2	4,880
	6	50x6x8"	A. fitchii	3	8,800
	7	150x20x18"	A. fitchii	3	197,600
			A. flavescens		
	10	50x50x12"	A. fitchii	1/10	3,660
	12	100x15x8"	A. flavescens	1/5	2,930
			A. campestris		
	16	35'x10'x3'	A. campestris	1/2	635
			A. fitchii		
			A. flavescens		
			A. excrucians		
			A. canadensis		
	17	50x30x12"	A. intrudens	1/2	11,000
			A. riparius		
			A. fitchii		
			A. excrucians		
			A. flavescens		
	18	40x10x10	A. fitchii	1/5	975
			A. vexans		
31/5/67 A	1	100x5x6"	A. fitchii	1	3,660
	5	600x7x10"	A. fitchii	3	153,000
	6	100x3x3	A. fitchii	2	2,200
			A. flavescens		
	13	100x2x6"	A. flavescens	1/2	730

Date & Sector	Pool No.	Dimensions	Species	No./ dip	Approx. pop.
	14	150x8x6"	A. fitchii	1/3	2,930
	22	144x24x8"	A. flavescens	2	3,515
	26	225x24	A. fitchii	1/10	5,500
			A. flavescens		
	30	600x4x8	A. fitchii	1.5	353,312
1/6/67 B	4	100x20x8"	A. fitchii	0.5	9,760
	6	80x8x6"	A. fitchii	4	18,740
	10	600x10x12"	A. fitchii	5	440,000
	19	500x6x10"	A. fitchii	0.5	18,300
	20	80x5x10"	A. fitchii	1	4,880
			A. flavescens		
			A. barri		
	24	400x10x24"	A. fitchii	1/10	11,712
			A. campestris		
	25	450x5x8"	A. fitchii	1/3	7,320
	26	60x10x10"	A. fitchii	1	7,320
			A. flavescens		
	29	120x4x6"	A. fitchii	1	3,515
2/6/67 C	1	50x4x8"	A. fitchii	1/3	660
	5	120x7x8"	A. fitchii	1/10	830
	10	100x3x3"	A -----	15	16,500
	14	15x20x8"	A. flavescens	1	146,400
			A. campestris		
	18	80x7x6"	-----	2	8,200
	19	450x7x8"	A. fitchii	Tr	Tr
	20	350x6x8"	A. flavescens	0.5	10,250
	21	15x10x18"	A. fitchii	1/3	1,100
			A. excursians		
	22	30x20x1"	-----	Tr.	Tr.
5/6/67 D	--	---	-----	---	---
6/6/67 E	4	10'x5'x6"	A. canadensis	3	1,171
	7	200x8x15"	A. fitchii	Tr.	Tr.
	18	30x5x3"	A. fitchii	Tr.	Tr.
7-25/6/67	--	----	-----	--	--
10/7/67 A	33	50x60x15"	Avexans	20	790,200
11/7/67 B	11	3x4x2"	Avexans	40	845
	14	8x60x3"	Avexans	8	10,100
	20	3x40x3"	Avexans	8	2,528
			A. nigromaculis		

Date & Sector	Pool No.	Dimensions	Species	No./ dip	Approx. pop.
20/7/67					
D	1	100x3x3"	C. tarsalis	10	7,902
			A. dorsalis		
			A. campestris		
	4	200x10x4"	C. tarsalis	15	105,600
	5	200x5x2"	C. tarsalis	50	89,500
	6	400x4x10"	C. tarsalis	60	85,000
	11	10x14x24	C. inornata	Tr.	Tr.
28/7/67					
E	--	------	------	--	--
6/8/67					
A	--	------	------	--	--
9/8/67					
B	--	------	------	--	--
11/8/67					
C	1	200x1.5x2"	A. vexans	80	43,500
	2	Drainage ditch	A. vexans	1.5	--
	10	100x6x6"	C. territans	1	3,200
	12	100x20x4"	C. tarsalis	15	105,000
	13	100x4x4"	A. vexans	2	2,800
	21	1500x8x4"	C. tarsalis	2	84,300
17/8/67					
D	1	150x3x4"	C. tarsalis	5	7,900
	5	200x2x3"	C. tarsalis	5	5,300
	6	40x1x1"	C. tarsalis	3	100
			C. inornata		
	8	10x20x6"	C. restuans	25	26,300
			A. vexans		
	11	8x8x15"	C. tarsalis	4	3,600
	13	8x2x4"	------	Tr.	Tr.
18/8/67					
E	2	6x4x4"	A. vexans	1	100
21/8/67					
A	--	------	------	--	--
21/8/67					
B	28	200x10x5"	C. tarsalis	10	88,500
23/8/67					
C	2	Drainage ditch	pupae	--	--
	12	50x10x2"	C. tarsalis	2	1,800
	21	10x3x.5"	C. tarsalis	20	250
	22	1x2x10"	C. territans	2	35
24/8/67					
C	8	10x4x1"	C. restuans	400	17,500
			C. inornata		
	11	6x5x10"	C. tarsalis	20	5,300
	13	5x.5x1"	-----	50	100

Date & Sector	Pool No.	Dimensions	Species	No./dip	Approx. pop.
	23	2x300x3"	A. vexans	25	3,950
	29	3x100x1"	A. spenceri	12	3,160
12/7/67 C	1	3x50x3"	A. vexans	12	6,060
	4	4x100x6"	A. vexans	30	63,215
	5	10x150x10"	A. vexans	12	157,400
	9	2x1000x2"	A. vexans	100	333,600
			A. spenceri		
			C. tarsalis		885,000
	10	8x300x6"	A. vexans	70	13,222
	12	125x20x6"	A. vexans	1	
	13	3x300x4"	A. vexans	60	189,600
	17	20x2500x6"	A. spenceri	1	263,400
	19	8x250x10"	A. vexans	30	527,000
	20	6x300x5"	A. campestris	1	77,900
			A. dorsalis		
	21	30x30x15	A. dorsalis	Tr.	Tr.
			A. campestris		
13/7/67 D	1	4x2500x6"	A. dorsalis	5	263,400
	2	3x200x5"	A. vexans	10	27,200
	3	irrigation ditch	A. vexans	Tr.	Tr.
			A. dorsalis		
	4	12x200x12"	A. vexans	6	152,000
			A. spencerii		
	5	8x2000x8"	A. vexans	35	3,953,000
	11	15x20x24"	A. vexans	1/2	3,160
17/7/67 E	9	100x4x1"	A. campestris	Tr.	Tr.
17/7/67 A	--	----	----	--	--
18/7/67 B	24	500x6x5"	Culex tarsalis	5	66,400
	25	100x4x2"	A. campestris	Tr.	Tr.
	28	300x10x4"	C. tarsalis	2	21,000
19/7/67 C	1	10x1x1"	A. vexans	200	1,750
	2	Drainage Ditch	---	4	---
	5	80x8x5"	A. vexans	20	57,000
	10	400x10x6"	A. vexans	80	1,686,000
	12	100x15x4"	A. vexans	1/2	2,600
	19	200x8x6"	C. tarsalis	25	210,700
	21	300x8x5"	C. tarsalis	4	42,500
			A. campestris		
			Anopheles spp.		

Appendix II

Larval Survey 1968

Date & Sector	Pool No.	Dimensions	Species	No.'s	Approx. pop.
22/5/68 W/O	1	250x7x6"	A. vexans	3/3	
			A. spencerii (adult)	1	
			A. fitchii	2	
			A. flavescens	1	
	9	minute	A. vexans	1	
			A. flavescens	3	
24/5/68 W/O	1	250x7x6"	A. fitchii	4	87,500
	3B	10x1x4"	A. fitchii	2	75
	3	150x15x4'	-----		
	6	40x4x2"	-----		
	7	60x40x3"	-----		
	13	30x2x1"	-----		
	14	60x2x2"	-----		
	19	1400x1'x4"	A. vexans	10/10	400,000
	10B	15x10x3'	A. flavescens	10/10	40,000
	21	350x4x4"	-----		
			A. fitchii	2	
	23	700x4x3"	A. vexans	5	17,500
	25	20x3x2"	-----		
	26	100x8x5½	A. vexans	10/10	1,000,000
	27	75x10x3"	A. vexans	5/5	
			A. vexans	5/6	10,000
	28	500x6x4"	A. flavescens	1/6	250,000
	30	3x1½x1"	A. vexans	6/6	10,000
			A. vexans	4	
	31	75x5x2"	C. inornata	2	3,000
29/5/68 W/I	4	1'x½x3/4"	------		
	6	450x4x6"	------		
	7	700x10x8"	------		
	8	750x6x8"	------		
	11	350x4x1½	------(skins)		
	13	400x3x2	A. nigromaculis	2	5,000
	14	100x2x2	A. vexans	5	280
			A. dorsalis	3	
	15	40x2x1"	------		

Date & Sector	Pool No.	Dimensions	Species	No.'s	Approx. pop.
29/5/68 W/I	18	200x12x6"	---		
	21	200x2x6"	A. vexans		150,000
	22	300x10x6"	---		
	23	125x6x6"	---		
			1 (Only) larva		
	24	1800x8x12"	A. flavescens		1
	25	300x100x24"	---		
	26	1000x15x12"	---		
	28	30x1x1"	---		
	29	10x4x12"	---		
	30	40x6x12"	---		
	31	6000x15x18"	---	fish	
30/5/68 N/O	1	200x5x3"	---		
	2	50x1x2"	---		
	6	60x2x2"	A. vexans	3	170
	8	100x4x3"	A. vexans	3	5,000
			A. vexans	1	
	9	60x4x3"	A. nigromaculis	1	3,000
	10	50x3x3"	---		
	11	900x4x8"	---		
	12	500x3x3"	A. vexans	3/3	320
	13	20x4x24"	---		
	14	100x4x4"	1 larvae only		1
	17	30x10x3	A. fitchii		
			A. dorsalis	2	
			A. vexans	2	
			A.nigromaculis	2	17,750
	18	2100x5x8"	---		
	19	30x8x4"	A. vexans		8,000
	20	500x10x6"	---		
	23	100x2'x4"	A. spencerii	2	
			A. vexans	7	
			A. fitchii	1	165,000
			A. dorsalis	1	
	24	750x16x6"	---		
			A. vexans	9	170,000
	25	100x5x4"	A. dorsalis	1	
	26	100x4x4"	A. vexans	11	
			A. dorsalis	1	130,000
	27	550x6x4"	A. vexans	10	550,000
	29	2000x5'x4"	---		
	30	10x10x2"	---		
	31	150x8x1"	---		
	32	700x10x2"	---		

Date & Sector	Pool No.	Dimensions	Species	No.'s	Approx. Pop.
30/5/68					
N/O	33	500x4x1"	---		
	35	6x1x14"	---		
	37	100x2½x4"	---		
	38	140x1x3"	---		
	39	200x1x2"	---		
31/5/68					
N/I	5	400x5x3"	---		
	6	1000x8x6"	---		
	7	800x4x3"	---		
	8	1200x8x8"	---		
	13	150x8x6"	---		
	14	100x4x2"	---		
	15	200x8x4"	---		
	16	300x8x4"	---		
	18	200x6x4"	---		
	21	2100x6x6"	---		
	22	5200x6x8"	---		
	23	500x8x6"	---		
	24	200x10x4"	---		
	25	100x8x4"	---		
	26	150x150x2"	---		
	27	100x10x8"	---		
	28	60x6x6"	---		
	29	150x150x8"	---		
	30	800x7x8"	---		
	31	250x4x4"	---		
	40	70x5x2"	A. flavescens	4	
			A. vexans	1	30,000
	44	50x10	---		
	48	120x8x6"	A. dorsalis	2	48,000
	49	100x6x6"	A. dorsalis	2	30,000
	51	100x2x4"	A. vexans	10	700,000
	54	10x2x1"	---		
3/6/68					
E/O	1	50x2x3"	A. vexans	4	6,250
	5	400x2x4"	A. vexans	8	333,325
	6	300x4x10"	---		
	7	100x2½x10"	---		
	8	375x4x8"	A. vexans	2	Trace
	9	400x2x6"	---		
	10	60x2x4"	---		
	11	250x2½x2	---		
	15	450x4x4"	---		
	16	25x2x3"	---		
	17	100x2x2"	---		
	19	300x3x4"	---		

Date & Sector	Pool No.	Dimensions	Species	No's	Approx. Pop.
	20	150x6x4"	---		
	21	100x3x3"	---		
	22	1200x3x8"	---		
	26	40x60x12'	---	fish	
	27	2100(collection of small pools)			
	28	40x15x10'	---	fish	
	29	800 x collection	---		
	30	800x4x3	---		
	31	40x4x3	---		
	32	150x5x3	---		
	33	2(20x4x3")	---		
	34	500x9x3	---		
	36	400x3x3"	C. inornata		
	39	2(15x3x3")	---	2	Trace
	41	75x4x1"			
5/6/68 E/I					
	4	2500x6'x8"	---		
	6	500x2'x1"	---		
	16	450x2'x3"	---		
	17	1000x1½x15"	---		
	18	150x5x8"	---		
	19	1000x3'x2"	---		
	20	100x1x2"	A. vexans	5	1,667
	27	100x3x4"	---		
	28	100x6x1	---		
	33	1500x30x2"	---		
	34	400x25x1"	---		
	35	A.10x5x6"	---		
		B.600x30x2"	---		
	36	1000x25x2"	---		
	37	A.1000x25x2"	---		
		B.400x30x2"	---		
	38	300x10x1"	---		
	39	500x2x1	---		
	41	100x8	---		
	42	100x15x12"	---		
	44	20x10x2	---		
	45	150x150	---		
5/6/68 S/O					
	5	3000x8x6"	---		
	9	100x3x2"	---		
	10	60x8x6"	---		
	11	800x6x4"	---		
	12	500x1x1"	---		
	16	400x6x1"	---		
	17	500x6x1"	---		
	20	A.1000x6x2"	---		
		B.500x6x2"	---		
	21	100x6"x1"			

Date & Sector	Pool No.	Dimensions	Species	No's	Approx. Pop.
	24	50x4x1"	---		
	29	100x6x1"	---		
	30	150x4x2"	---		
	38	250x10x1"	---		
7/6/68	40	150x25x2"	---		
	42	50x20x2"	---		
	49	50x1x1"	---		
	50	30x2x1"	---		
	51	8x4x6"	A. fitchii	1	Trace
7/6/68 S/O	55	75x55	---		
	56	100x1x1"	A. vexans	10	10,000
	57	4x4x2"	A. vexans	2	2
	58	500x100	A. vexans	10	5,000,000
	60	50x1x1"	A. fitchii	2	
	63	10x6"x1"	---		
	65	200x3x2"	---		
	66	10(2x2x1")	---		
	72	6x2x½"	---		
	73	5x4x4"	---		
	77	20x20	---		
	82	20x10	---		
	83	30x5	---		
3/6/68 S/I	6	100x100	---		
	11	800x3x6"	---		
	12	500x5x10"	---		
	13	2000x7"x12"	---		
	14	1000x3x3	---		
	16	10x5x15"	---		
	17	100x3x2"	---		
	18	60x5x3"	---		
	19	100x5x2"	---		
	20	50x3x1	---		
10/6/68 W/O	1	10x2x1"	---		
	3	100x10	---		
	10B	B.15x10x3	---		
	23	A.30x1x4"	---		
		B.30x1x3"	---		
		C.100x1x3"	---		
		D.20x2x2"	---		
	26	50x3x2"	---		
	28	400x2	---		
10/6/68 W/I	7	500x8x8"	---		

Date & Sector	Pool No.	Dimensions	Species	No's	Approx. Pop.
	8	A.200x4x2"	---		
		B.30x4x2"	---		
	13	50x1	---		
	18	100x6x3"	---		
	21	100x3	---		
	22	150x8x3"	---		
	23	50x1x2"	---		
	24	A.1200x8x8"	---		
		B.10x2x4"	---		
	25	250x50x12"	---		
	26	800x10x4"	---		
	29	10x4x8"	---		
	30	40x6x10"	---		
	31	6000x15x18"	---		
11/6/68 N/O	1	100x3x2"	---		
	10	20x1x1"	---		
	11	500x3x6"	---		
	13	10x4x18"	---		
	14	75x4x3"	---		
	15	30x5x12"	---		
	18	2000x5x8"	---		
	20	300x8x4"	---		
	23	A.50x6x4"	A. fitchii	3	15,000
		B.10x5x2"	---		
	24	500x10x4"	---		
	25	50x1x2"	C. inornata	2	Trace
	26	75x4x4"	---		
	27	400x5x3	---		
	29	2000x4'x4"	---		
	30	5x2x2"	---		
	31	50x8	---		
	32	500x8x2"	---		
	33	450x4	---		
	35	6x1x12"	---		
	37	20x1x3"	A. dorsalis	6	
			A. vexans	4	
			C. inornata	1	1,250
11/6/68 N/I	5	350x4x2"	---		
	6	800x6x4"	---		
	7	600x5x½"	---		
	8	1000x6x6"	---		
	15	150x6x2"	---		
	18	105x5x3"	---		
	21	A.150x6x4"	---		
		B.750x8x4"	---		
		C.750x6x3"	---		

Date & Sector	Pool No.	Dimensions	Species	No's	Approx. Pop.
	22	5000x5x6"	---		
	23	300x6x4"	---		
	26	50x50x1"	---		
	27	50x8x4"	---		
	28	50x5x4"	---		
	29	100x100x3	---		
	30	800x6x6"	---		
	31	200x4x2"	---		
	40	70x5x1"	---		
	41	50x10x1"	---		
	42	120x1x4"	A. fitchii	5	
			A. vexans	5	500
	44	20x10	---		
	48	100x5x3"	---		
	49	50x3x2"	---		
	54	10x2x1"	---		
12/6/68 E/O	1	60x1x2"	---		
	5	400x1x4"	---		
	6	250x2x6"	---		
	7	60x2x8"	---		
	8	A.20x2x4"	---		
		B.200x3x6"	---		
	9	300x2x4"	---		
	10	50x2x2"	---		
	11	200x2x2"	---		
	15	400x4x2"	---		
	17	25x2x2"	---		
	19	250x3x3"	---		
	20	100x4x2"	---		
	21	80x2x1"	---		
	22	1200x3x6"	---		
	26	50x30x10	---		
	27	1000x2x½"	---		
	28	40x12x6	---		
	31	40x3x2"	---		
	32	100x4x2"	---		
	33	A.10x2x1"	---		
		B.40x4x2"	---		
	34	450x9x3"	---		
	36	300x2x1"	---		
	39	A.10x3x2"	---		
12/6/68 E/I	4	2100x5x6"	---		
	6	450x2x1"	---		
	16	300x1x1"	---		

Date & Sector	Pool No.	Dimensions	Species	No's	Approx. Pop.
	17	A.500x1x12"	---		
		B.500x1x6"	---		
	18	50x5x4"	---		
	19	800x4x2"	---		
	21	50x1x1"	---		
	27	50x2x1"	---		
	28	50x3	---		
	31	100x10x2"	---		
	32	500x15x2	---		
	33	1500x30x1-8"	---		
	34	B.100x15x1"	---		
	35	A.8x3x4"	---		
		B.600x20x3"	---		
	36	500x15x2"	---		
	37	A.1000x25x3	---		
		B.100x10x1"	---		
		C.200x15x1"	---		
	39	250x10x1"	---		
	41	100x5x8"	---		
	42	100x12x12"	---		
	45	150x150	---		
13/6/68 S/O	5	2500x6x4"	---		
	10	50x6x4"	---		
	11	600x4x3"	---		
	12	100x2x1"	---		
	20	B.150x1x3"	---		
	34	150x10x1"	---		
	38	200x10x1"	---		
	40	50x25x1"	---		
	42	40x10x1"	---		
	46	50x10x1"	---		
	51	4x4x2"	---		
	55	75x55	---		
	58	400x100	---		
	65	100x3x1"	---		
	71	600x400	---		
	73	2x1x1"	---		
	77	20x20	---		
	78	40x40	---		
13/6/68 S/I	11	400x1½x2"	---		
	12	400x4x6	---		
	13	1800x6x8"	---		
	14	A.150x2x2"	---		
		B.600x5x4"	---		
	16	8x3x7"	---		

Date & Sector	Pool No.	Dimensions	Species	No's	Approx. Pop.
8/7/68 W/O	1	75x3x2"	---		
	3	100x10x3'	---		
	3B	10x1x4"	---		
	10B	15x10x3'	---		
	23	75x1x2"	A. vexans	10/10	31,250
	26	25x10x1"	A. vexans	9	
			A. nigromaculis	1	210,000
	28	150x3x1"	A. intrudens	1	
			A. dorsalis	1	
			A. nigromaculis	1	
			A. vexans	8	170,000
8/7/68 W/I	4	2x1x3"	---		
	6	150x3x4"	---		
	7	500x8x8"	---		
	8	250x5x2"	---		
	11	300x4x(wet)	---		
	13	100x4x(wet)	---		
	18	150x6x6"	---		
	21	100x4x2"	---		
	22	100x6x2"	---		
	23	50x2x2"	---		
	24	1400x6x6"	---		
	25	150x50x10"	---		
	26	800x10x3"	---		
	29	10x4x12"	---		
	30	40x6x12"	---		
	31	6000x15x18"	---	* Fish	
8/7/68 N/O	1	150x4x3"	---		
	10	30x2x2"	A. nigromaculis	10	5,000
	11	500x3x4"	A. vexans	6	
			A. dorsalis	2	
			A. nigromaculis	10	50,000
	12	100x2x1"	A. campestris		8,250
	13	10x4x20"	---		
	14	75x4x3"	A. campestris	3	
			A. vexans	7	30,000
	15	30x6x18	---		
	18	1800x4x6"	A. vexans	6	90,000
	20	350x8x5"	---		
	23	B.20x4x3"	A. vexans	10	
			A. dorsalis	1	5,000
	24	450x10x5"	A. vexans	10/10	375,000

Date & Sector	Pool No.	Dimensions	Species	No's	Approx. Pop.
	25	50x2x(wet)	---		
	26	50x3	---		
	27	150x5x3"	A. vexans	5	
			A. dorsalis	5	122,500
	29	1800x4'x4"	---		
	30	10x10x2"	---		
	31	50x10x1"	---		
	32	500x8x2"	---		
	33	400x6x1"	---		
	35	6x1x11"	---		
	37	2"x2"x½"	A. dorsalis	10/10	5,000
8/7/68 N/I	3	150x2x2"	---		
	4	75x2x2"	---		
	5	350x4x3"	---		
	6	800x6x5"	---		
	7	600x5x½	---		
	8	900x5x4"	---		
	10	20x5x¼	---		
	15	150x6x3"	---		
	18	100x6x4"	---		
	21	A.100x5x3	---		
		B.500x6x3	---		
		C.700x6x3	---		
	22	5000x5x6"	---		
	23	250x6x3"	---		
	28	50x3x3"	---		
	29	50x50	---		
	30	600x4x4"	---		
	40	50x5x1"	A. dorsalis	10/10	10,000
	41	20x10x1"	A. dorsalis	10/10	8,500
	42	120x8'x1" & 120x1'x4"	A. campestris	10/10	125,000
	48	80x6x3"	A. dorsalis	2	1,500
	49	50x3x2"	A. dorsalis	3	415
9/7/68 E/O	1	60x1x2"	---		
	5	400x1x4"	---		
	6	300x3x8"	A. vexans	9	
			A. nigromaculis	1	3,000
	7	75x2x8"	A. vexans	10/10	5,000
	8	250x3x6"	A. vexans	2	
			A. nigromaculis	1	25,000
	9	10(2x6"x1")	A. spencerii	2	
			A. vexans	8	1,500
	10	50x2x3"	---		
	11	200x2x3"	A. vexans	2	1,000

Date & Sector	Pool No.	Dimensions	Species	No's	Approx. Pop.
	12	60x1x1"	A. vexans	1	250
	13	40x3x1"	---		
	15	350x4x2"	A. vexans	3	11,650
	17	75x3x2"	A. nigromaculis	5	
			A. vexans	2	
			A. campestris	1	1,900
	19	250x3x3"	A. dorsalis	1	
			A. nigromaculis	2	
			A. spencerii	1	3,115
	20	100x4x2"	A. dorsalis	6	
			A. spencerii	1	11,000
	21	75x2x2"	A. nigromaculis	2	
			A. dorsalis	4	
			A. vexans	3	
			A. spencerii	1	200
	22	1200x3x6"	---		
	26	60x40x10'	---	Fish	
	27	2000x1½x1"	---		
	28	40x12x6"	---		
	30	100x4x2"	A. vexans	7	
			A. nigromaculis	3	16,500
	31	40x3x2"	A. vexans	8	
			A. nigromaculis	2	3,000
	33	40x4x2"	A. vexans	1	
			A. nigromaculis	1	4,050
	34	400x9x2"	---		
	36	150x2x1"	A. nigromaculis	10/10	2,500
	39	20x3x2"	---		
	41	50x4x1"	---		
9/7/68 E/I	4	2200x5x4"	---		
	6	500x5'x2"	---		
	16	300x1x1"	---		
	17	900x1½x4"	A. vexans	3	
			A. nigromaculis	2	10,000
	18	100x6x4"	A. vexans	10/10	1,000,000
	19	800x3'x2"	A. vexans	8/8	500,000
	20	20x3x2"	A. vexans	10/10	250,000
	21	75x1½x1"	A. vexans	10/10	30,000
	27	50x2x2"	---		
	31	75x10x1"	---		
	32	500x10x1"	---		
	33	1500x25x1-8"	---		
	34	B.100x15x1"	---		
	35	A.8x3x4"	---		
		B.500x20x2"	---		

Date & Sector	Pool No.	Dimensions	Species	No's	Approx. Pop.
	36	500x15x2"	---		
	37	1400x20x1"	---		
	39	100x5x1"	---		
	41	100x5x8"	---		
	42	75x12x12"	---		
	43	10x10x1"	---		
	44	15x10x2"	---		
	45	105x105 (dugout)			
10/7/68 S/O	5	3000x5x3"	---		
	9	100x3x2"	---		
	10	60x10x8"	---		
	11	600x4x4"	---		
	12	250x3x2"	---		
	16	50x6"x1"	---		
	17	450x6"x1"	---		
	20	A.60x2x3"	---		
		B.200x4x3"	---		
	26	2x2x1"	A. vexans	3/3	200
	30	100x4x1"	---		
	34	150x10'x1"	---		
	38	250x10x1"	---		
	39	60x1x6"	---		
	40	50x25x2"	---		
	42	50x20x3"	---		
	46	50x20x2"	---		
	48	80x10x½"	---		
	49	75x1x3"	A. vexans	6	425
	50	30x1x2"	---		
	51	5x4x6"	---		
	54	10x12x1"	---		
	55	75x55(dugout)	---		
	65	30x2x½"	---		
	82	10x6"x½"	---		
10/7/68 S/I	10	60x1x1"	---		
	11	600x2x4"	---		
	12	500x4x8"	---		
	13	2000x6'x8"	---		
	14	1000x4x4"	---		
	15	100x3'x1"	---		
	16	15x6x20"	---		
	17	100x3x2"	---		
	18	75x5x3"	---		
	19	100x4x2"	---		
	20	75x6x2"	---		

Date & Sector	Pool No.	Dimensions	Species	No's	Approx. Pop.
	22	100x2x1"	---		
8/8/68 W/O					
	1	20x3x2	---		
	3	75x10x4'	---		
	3B	20x3x3"	---	Fish	
	10B	15x10x3'	A. vexans	7	450,000
				Fish	
	14	2x1x½"	---		
8/8/68 W/I					
	6	150x6"x½"	---		
	7	300x6'x6"	---		
	18	100x6'x6"	---		
	21	100x4x¼"	---		
	25	100x4x8"	---		
	26	800x8x2"	---		
	29	6x2x10"	---		
	30	35x5x10"	---		
	31	6000x10x13"	(creek)	Fish	
8/8/68 N/O					
	1	100x3x3"	---		
	3	50x2x½"	A. dorsalis	2/2	Trace
	11	450x3x4"	---		
	12	100x2x1"	---		
	13	10x4x16"	---		
	14	75x4x3"	---		
	15	25x5x16"	---		
	18	1800x4x6"	---		
	19	20x5x3"	---		
	20	300x8x4"	---		
	23	A.50x1'x4"	---		
		B.30x10x3"	---		
	24	100x10x4"	---		
	27	75x5x3"	---		
	29	1800x4'x4"	---		
	30	10x10x4"	---		
	31	75x10x2"	---		
	32	450x7x2"	---		
	33	500x8x1"	---		
	34	75x5x1"	---		
	35	6x1x10"	---		
	37	30x2x4"	C. inornata	5	
			C. alaskensis	1	
			Culex tarsalis	1	50,000
	38	10x1x2"	C. inornata	7	
			Culex tarsalis	3	1,500

Date & Sector	Pool No.	Dimensions	Species	No's	Approx. Pop.
8/8/68 N/I	3	100x3x3"	---		
	4	75x4x3"	---		
	5	350x4x3"	C. inornata	7/7	87,500
	6	800x6x5"	---		
	7	600x3x1"	---		
	8	900x5x4"	---		
	10	20x5x½"	---		
	15	100x5x3"	---		
	18	100x6x4"	---		
	19	50x1x½"	---		
	21	1000x6x4"	---		
	22	3000x4x4"	---		
	23	200x6x3"	---		
	25	75x4x2"	---		
	26	25x20x½	---		
	27	75x6x1"	---		
	28	50x3x3"	---		
	29	75x50(marsh)	---		
	30	600x4x4"	---		
	40	24x3x½"	---		
	42	75x1'x3"	---		
	48	75x5x2"	---		
	49	50x3x2"	---		
	51	75x2x3"	A. vexans	6	
			A. dorsalis	4	37,500
	59	50x50x1"	---		
7/8/68 E/O	5	100x6"x2"	---		
	6	105x3x6"	---		
	7	70x2x6"	Culex tarsalis		Trace
	8	105x2x4"	---		
	9	200x2x4"	---		
	10	35x2x3"	---		
	13	10x2x1"	A. vexans		Trace
	15	350x4x2"	---		
	17	75x3x2"	---		
	19	250x3x3"	---		
	20	75x3x2"	---		
	21	50x2x1"	---		
	22	1200x3x4"	---		
	26	60x40x10'	---	Fish	
	27	2000x1'x	---	Fish	
	28	40x12x6'	---	Fish	
	30	100x3x2"	---	Fish	
	31	40x3x2"	---		

Date & Sector	Pool No.	Dimensions	Species	No's	Approx. Pop.
	32	75x4x1"	---		
	33	40x4x2"	---		
	34	1000x9x2	---		
	39	80x3x2"	---		
	41	20x3x½	---		
	43	75x10x1"	---		
7/8/68 E/I	4	2100x5x4"	---		
	6	500x2'x2"	---		
	14	20x6"x1"	---		
	16	200x6"x1"	---		
	17)	1200x4x8"	C. inornata	3	
	18)		A. vexans	1	3,750
	19) 20) 21)	1800x3x4"	A. vexans	5/5	30,000
	31	75x10x2"	---		
	32	500x10x1"	---		
	33	1500x25x6"	---		
	34B	100x10x1"	---		
	35A	8x3x6"	---		
	35B	500x20x2"	---		
	36	500x70x3"	---		
	37	1200x20	---		
	39	75x5x1"	---		
	41	100x5x8"	---		
	42	75x12x12"	---		
	45	150x150	---		
6/8/68 S/O	5,6,7,8	2800x5x3"	---		
	9	100x3x2"	---		
	10	50x8x4"	---		
	11	600x4x3"	---		
	12	200x3x2"	---		
	20B	15x1'x3"	---		
	21	25x6"x1"	---		
	24	50x9x4"	C. inornata	9	375,000
			A. vexans	1	
	25	150x4x4"	C. inornata	8	
			A. vexans	2	500,000
	26	10x2x2"	A. vexans	5/5	300
	29	50x3x1"	---		
	30	100x15x2"	---		
	31	50x3x1"	---		
	32	200x50x2"	---		

Date & Sector	Pool No.	Dimensions	Species	No's	Approx. Pop.
	33	20x5x1"	---		
	34	200x50x3"	---		
	38	250x15x2"	---		
	40	50x25x2"	C. inornate	10/10	261,000
	42	50x25x3"	C. inornata	4/4	290,000
	46	50x15x2"	---		
	47	20x5x1"	---		
	49	100x1x4"	Culex tarsalis	1	
			C. inornata	2	3,300
	50	40x2x2"	---		
	51	5x4x6"	---		
	51B	20x4x2"	A. vexans	6	
			Culex tarsalis	1	3,400
	54	60x2x1"	---		
	55	75x55	---		
	58	400x100	A. vexans	6	
			A.	4	
			Culiseta (sp)	1	10,000,000*
	65	50x3x1"	A. vexans	3/3	77,500
	82	20x6x1"	---		
	83	10x1x1"	---		
6/8/68 S/I	1	50x2'x1"	---		
	7	100x1'x2"	---		
	10	60x1x1"	---		
	11	600x2x4"	---		
	12	800x4x8"	---		
	13	2000x6'x8"	---		
	14	900x4'x4"	---		
	16	15x6x20"	---		
	17	100x3x2"	---		
	18	75x5x3"	---		
	19	100x4x3"	---		
	22	75x2x1"	---		
	20	75x6x2"	---		
20/8/68 W/O	1	175x7x5"	A. vexans	2	122,500
	2	6x4x2"	A. vexans	4	800
	3	400x15	---	Fish	
	5	10x1x1"	---		
	6	20x4x2"	---		
	7	60x40x3"	---		
	8	10x1x1"	---		
	9	20x1x1"	---		
	11	40x2x1"	---		
	12	150x1x½"	---		

Date & Sector	Pool No.	Dimensions	Species	No's	Approx. Pop.
	13	75x2x½"	---		
	14	40x3x1"	---		
	17) 18)	150x1'x6"	A. vexans	10	750,000
	19	1200x1x4"	A. vexans	10	4,000,000
	20B	40x10x1"	---		
	21	100x2x2"	A. vexans	4	8,250
	23	100x1x2"	---		
	24	5x2x½"	---		
	25	5x2x½"	---		
	26	25x10x1"	---		
	28	500x6x4"	A. vexans	8/8	500,000
	30	10x2x¼"	---		
22/8/68 W/I	1	20x2x2"	---		
	2	30x3x3"	---		
	3	10x3x2"	---		
	4	20x4x6"	---		
	5	10x1x1"	---		
	6	450x5x8	---		
	7	600x8'x10"	---		
	8,9	600x6x6"	---		
	10	100x4x2"	---		
	11	350x4x3"	---		
	12	10x3x1"	---		
	13	400x4x3"	---		
	14	75x2x2"	---		
	15	40x2x1"	---		
	17	20x1x1"	---		
	18,19,20	200x10x8"	---		
	21	200x4x3"	---		
	22	250x10x8"	---		
	23	125x6x6"	---		
	24	1800x8x1"	---		
	25	350x100x24"	---		
	26	1200x15x12"	---		
	28	30x1x1"	---	Fish	
	29	15x5x12"	---	Fish	
	30	40x6x12"	---	Fish	
	31	6000x10x18"	---	Fish	
20/8/68 N/O	1,2	150x4x4"	---		
	3	75x2x1"	---		
	4	35x4x2"	A. dorsalis	4/4	1,150

Date & Sector	Pool No.	Dimensions	Species	No's	Approx. Pop.
	5	50x4x2"	A. dorsalis	5	
			A. vexans	1	3,300
	6	75x3x3"	A. dorsalis	1	
			A. vexans	1	5,600
	8	75x3x3"	---		
	10	75x3x3	A. dorsalis	1	
			A. nigromaculis	1	5,600
	11	500x3x6"	---		
	12	100x2x2"	---		
	13	10x5x20"	---		
	14	75x4x3"	---		
	15	30x5x18"	---		
	18	2000x5x8"	---		
	19	30x6x3"	---		
	20	100x8x4"	---		
	23A	50x2x8"	(A. vexans	2	
			(A. dorsalis	4	
				2	375,000
	23B	30x10x3"	(		
	24	500x10x4"	---		
	25	25x2x1"	---		
	27	350x5x3"	---		
	29	1800x4x4"	---		
	30	50x10x6"	---		
	31	100x10x2"	---		
	32	700x20x2"	---		
	33	500x20x2"	---		
	34	800x6x1"	---		
	35	6x1x15"	---		
	37	25x2½x6"	---		
	38	40x1x4"	A. inornata	5	
			Culex tarsalis	4	
			A. vexans	1	
			A. dorsalis	5	3,250
	39	75x1x2"	A. dorsalis	7/7	6,250
23/8/68 N/I	3	100x3x3"	---		
	4	200x4x4"	---		
	5	400x5x4"	---		
	6	1000x8x6"	---		
	7	500x4x3"	---		
	8	1000x6x6"	---		
	10	20x5x1"	---		
	14	75x3x3"	---		
	15	150x7x5"	---		
	16	75x4x2"	---		

Date & Sector	Pool No.	Dimensions	Species	No's	Approx. Pop.
	18	150x6x4"	---		
	19	50x2x1"	---		
	21	2100x6x6"	---		
	22	5000x6x8"	---		
	23	250x6x3"	---		
	24	150x10x4"	---		
	25	100x6x4"	---		
	26	50x25x1"	---		
	27	75x6x1"	---		
	28	50x4x3"	---		
	29	100x100x2"	---		
	30	800x5x4"	---		
	31	200x4x4"	---		
	33	20x3x2"	---		
	39	20x1x2"	---		
	40	25x5x1/2"	---		
	41	20x10x2"	A. dorsalis		3,300
	42	100x1x3"	---		
	43	20x10x½"	A. dorsalis		4,000
	48	80x6x3"	---		
	49	50x4x3"	---		
	51	75x5x3"	A. vexans	4	
			A. dorsalis	4	
			C. inornata	4	117,500
	56	20x10x2"	A. dorsalis	4	3,300
	57	25x25x1	---		
	58	10x5x½	---		
	59	50x50x½	---		
28/8/68 E/O	1	20x1x1"	A. vexans	3	300
	5	400x2x6"	A. vexans	2/2	60,000
	6	150x3x8"	---		
	7	100x2x6"	---		
	8	250x3x6"	---		
	9	250x3x4"	A. vexans		1,250
	10	50x3x3"	A. vexans	11	
			A. nigromaculis	1	187,500
	11	200x2x4"	A. vexans	10/10	500,000
	12	75x3x3"	A. vexans	10/10	156,000
	13	75x3x2"	A. vexans	10/10	7,600
	15	400x4x3"	---		
	16,17	100x3x3"	A. campestris	1	
			A. vexans	2	
			A. nigromaculis	2	
			A. spencerii	1	500
	19	250x3x3"	---		

Date & Sector	Pool No.	Dimensions	Species	No's	Approx. Pop.
	20	75x3x2"	A. vexans	6	19,000
	21	75x2x1"	A. vexans	5	6,000
	22	1200x4x8"	---		
	26	60x40x10'	A. vexans Fish	7/7	100,000(est
	27	2100x4'x2"	A. vexans Fish	5	100,000
	28	40x15x6'	A. vexans Fish	2	30,000
	29,30,31,32,33	2500x4'x4"	A. vexans Fish	5	300,000(est
	34	1500x10x2"	A. nigromaculis	1	
			A. vexans	2	
			A. dorsalis	3	
			A. campestris	1	125,000
	36	300x200x2"	A. vexans	1	
	[illegible]	[illegible]	A. nigromaculis	4	5,000,000
	39,40,41,42,42	2500x6x2"	A. vexans	3	6,250
23/8/68 E/I	2	50x50x½	---		
	3	40x3x2"	A. nigromaculis	3/3	350
	4	2500x6'x6"	---		
	6	500x2'x2"	---		
	14	70x6"x1"	---		
	16	250x1x2"	---		
	17	1000x4x6"	---		
	18	10x3x6"	C. inornata	2	
			Culex tarsalis	6	3,000
	19,20,21	2000x3'x4"	C. inornata	5	20,000
	27	20x4x1"	---		
	28	50x6x¼	---		
	31	75x10x2"	---		
	32	500x15x2"	---		
	33	1500x30x6"	---		
	34	350x25x1"	---		
	35	A.10x5x8"	---		
		B.600x30x2"	---		
	36	800x20x3"	---		
	37	1400x20x1"	---		
	39	100x10x1"	---		
	41	100x8x8"	---		
	43	20x10x1"	---		
	45	150x150	---		
22/8/68 S/O	1-8	3500x5x4"	---		
	9	100x5x4"	---		
	10	60x15x8"	---		
	11	800x6x5"	---		
	12	500x4x4"	---		
	13,14,15,16	900x2x3"	---		

Date & Sector	Pool No.	Dimensions	Species	No's	Approx. Pop.
	17	500x1½x4"	---		
	18	75x1x3"	---		
	20	700x3x4"	---		
	21	100x2x3"	Culex tarsalis	10/10	37,500
	22	75x2x2"	Culex tarsalis	4	
			C. inornata	1	
			A. vexans	2	
			A. dorsalis	2	12,500
	23	75x10x4"	Culex tarsalis	3	
			C. inornata	3	125,000
	24	74x10x4"	A. vexans	2/2	312,500
	26	200x6x3"	A. vexans	3	
			Culex tarsalis	1	
			C. inornata	1	750,000
	27	50x5x2"	C. restuans	1	
			C. inornata	3	
			A. vexans	6	21,000
	28	700x10x6"	---		
	29	75x6x1"	---		
	30	100x15x2"	---		
	31	50x3x1"	---		
	32	200x50x2"	---		
	33	20x5x1"	---		
	34	200x50x5"	---		
	36	10x1x1"	---		
	38	200x15x2"	---		
	40	50x25x2"	---		
	42	50x25x3"	C. inornata	3/3	78,000
	44	20x15x2"	---		
	46	50x20x3"	---		
	47	20x10x2"	---		
	49	100x3x4"	C. impatiens		
			C. inornata	1,000,000	
	50	40x3x2"	---		
	51	A. 5x4x6"	---		
		B. 75x10x4"	A. vexans	10/10	1,250,000(est
	54	75x4x2"	---		
	55	75x55	---		
	56,57	200x3'x3"	A. vexans	5/5	1,500,000
	58	400x100x1"	A. vexans	8/8	50,000,000(est
	65	100x4x3"	A. vexans	10/10	500,000
	67	10x5x1'	---		
	72	10x5x1"	---		
	80,81	100x50x4"	A. vexans	10/10	41,650,000
	82	75x5x4"	A. vexans	9	
			C. tarsalis	1	320,000
	83	60x5x4"	A. vexans	4/4	250,000
	84,85	200x100x3"	A. vexans	10/10	62,500,000
S/I (No Survey)					