OBSERVATIONS ON SOME MUSCID AND CALLIPHORID FLIES
ASSOCIATED WITH FARM ANIMALS WITH
SPECIAL REFERENCE TO THE HOUSE
FLY, *Musca domestica* L.
(DIPTERA)(MUSCIDAE)

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by
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ABSTRACT

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OBSERVATIONS ON SOME MUSCID AND CALLIPHORID FLIES ASSOCIATED WITH FARM ANIMALS WITH SPECIAL REFERENCE TO THE HOUSE FLY, *Musca domestica* L. (DIPTERA) (MUSCIDAE).

Observations were made at the animal barns at the University of Manitoba during the summers of 1953 and 1954 to determine the population fluctuations of the house fly, *Musca domestica* L., stable fly, *Stomoxys calcitrans* (L.), some undetermined calliphorids, and horn fly, *Siphona irritans* L. The house fly was the most abundant species studied and reached a population peak during August and September. Stable flies reached a peak from the middle of July to about the third week in August. Calliphorids are early-summer flies and reach their population peak in July. The habits, oviposition and habitats of these flies were also studied.

House fly dispersion was studied in a dairy community near Fort Whyte, Manitoba. House flies, fed radioactive phosphorus in sugar solution, were released in the experimental area, and fly populations from the various farms were sampled and tested for radioactivity. Results indicate that adult house flies orientate to wind-borne odors. They also migrate from one farmstead to another in sufficient numbers

to demonstrate that fly control requires community effort.

Overwintering of house flies in Manitoba and cold resistance of egg, larval, pupal and adult stages were also investigated. At 40°F. the egg is the least resistant, whereas the pupal stage is the most resistant. House flies overwinter in heated animal barns by slow, continuous breeding. Probably they also overwinter in favorable unheated barns.

ACKNOWLEDGEMENTS

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CHAPTER I

INTRODUCTION

> And there came a grievous swarm of flies into the house of Pharoah, and into his servants' houses, and into the land of Egypt, and the land was corrupted by this kind of flies.- Exodus 8:24 (Douay Version)

Perhaps with the exception of honey bees and locusts, no other insect has had so much significance in man's life as the common house fly. The house fly does not sting or bite man or his animals nor eat his crops and therefore, in earlier times, it was tolerated as an unavoidable nuisance, ignored or even regarded as an animal that made the dwelling more homelike. Few attempts were made to control flies and these invariably ended as failures.

With the advance of medical knowledge, the realization that house flies are important vectors of disease has spurred attempts to control them. Removal of breeding places of this pest were first advocated as a control. Due to the laxity and carelessness of a few individuals in a community, control by sanitation could not eliminate the house fly populations effectively.

With the advent of the new synthetic insecticides, it was believed house flies could be controlled expediently and inexpensively. This approach has also failed. The house fly quickly developed resistance to such potent poisons as DDT and its analogues and continues to be an elusive foe.

It appears now that to combat flies successfully, both sanitary and chemical poisoning methods are essential. Community control as well as individual attempts must be carried out. Community control raises several important problems.

The problem

This investigation had the following objectives: (a) to determine the population fluctuations of some of the muscids and calliphorids associated with farm animals; (b) to study the effect of wind direction and odors on dispersion of house flies and migration from one farm to another in a dairy community; and (c) to determine whether and how house flies overwinter in Manitoba.

Importance of the study

The medical and veterinary importance of the house fly is now widely recognized. Metcalf and Flint (1939) state, "the common house fly is the most dangerous animal living within the boundaries of many of our states". This may be true when one considers the house fly's association with filth and disease organisms, its high fecundity and its short reproductive cycle. Metcalf, Flint and Metcalf (1951) say further "it has been shown that house flies are naturally infected with the pathogens of more than 20 human diseases, and many authorities believe that the fly is an important vector of typhoid fever, epidemic or summer diarrhea, amoebic and bacillary dysentery, cholera, poliomyelytis, and various parasitic worms". These authors estimate that in 1936, in the United States, about 25 million dollars were spent on treatment of diseases spread by house flies. This does not include the vast amounts of money spent each year in controlling this pest.

The range of this insect extends from the sub-polar regions to the tropics. Wherever man has migrated, the house fly has followed. The house fly has an exploring habit and is a very curious animal but new territory is not very inviting to the fly unless it contains the elements associated with human habitation, especially animal husbandry.

The cosmopolitan distribution of the house fly and its significance to human welfare has stimulated considerable investigation and a voluminous literature has appeared. Strangely enough, very few deal critically with the problems with which this investigation is concerned. In the past fifty years, investigations have been conducted to determine the flight habits of the house fly but the results are at such variance that it is difficult to draw any sound conclusions from them. This suggests that the flight habits of the house fly are influenced by factors which may vary under different environmental conditions. The problems of population fluctuations and overwintering must be solved for each geographical area separately because of the different climatic and environmental conditions which are encountered from one locality to another. No work of this kind has been done previously in Manitoba.

House fly fluctuations, dispersion and overwintering are interrelated when one considers house fly control on either the community or individual level. If it can be ascertained when the population begins to increase, control can be timed before the population is at its peak. Knowledge of flight habits is very important in fly control because they determine to what extent efficiency is reduced by invasions from nearby untreated fly breeding places. In community fly control the necessary size of the campaign area depends on the flight habits of the fly. If flies do overwinter in our region and the overwintering places are known, these could be disinfested during the winter and the fly populations would not increase as rapidly the following summer. These considerations prompted the investigations described in this thesis.

Location of the study

Population fluctuations and overwintering were studied at the University of Manitoba. House fly dispersion studies were made in a dairy community near Fort Whyte, Manitoba.

Organization of the thesis

The thesis is divided into four chapters. The first chapter constitutes the introduction. In Chapter II the investigation of the population fluctuations is presented. Chapter III deals with dispersion of house flies together with a review of literature. Chapter IV describes the work done on overwintering of house flies. Due to the variety of topics involved in this thesis, summaries of the chapters will be made at the end of each chapter in place of a general summary for the whole thesis.

CHAPTER II

OBSERVATIONS ON SOME MUSCID AND CALLIPHORID FLIES ASSOCIATED WITH FARM ANIMALS

Introduction

In this study an attempt has been made to determine the population fluctuations and habits of some of the muscids and calliphorids associated with farm animals. The knowledge of natural population fluctuations of flies is academically interesting and practically important. If the periods of population increase and peaks are known and the factors which contribute to the rise and fall of the population are determined, it may be possible to remove these factors to keep the insect numbers down. If the environmental factors are beyond control then it would be profitable to know the best time to apply chemical control to kill the insect. Applying control at a low level of insect population is undoubtedly less expensive and more effective than applying it at the peak of an insect population. The lack of information on this subject indicates the need for study.

Materials and Methods

Observations were made during the summer of 1953 and 1954 to determine the population fluctuations and habits of some of the muscids and calliphorids associated with farm animals. This investigation was initiated in 1953 at the

University of Manitoba. Fly surveys were made in the swine barn, dairy barn and the beef barn where the animals were kept all summer. During May, June and July adult fly collections were made every day. During August and September fly collections were made three times a week. In 1954, fly collections were again made at the University animal barns until the end of July. After this period an extensive fly control program was instituted in the barns and the observations were discontinued. During the summer of 1954, fly populations were also observed in several dairy and swine barns near Fort Whyte, Manitoba. The observations were made about once a week throughout the summer.

In the barns, fly collections were made with a conventional insect net. Fly collections on manure piles were made by means of fly traps (West, 1951). These traps consisted of a wooden frame 10 inches long, 8 inches wide and 6 inches high. The top was covered by a screen and the bottom was open to permit the flies to enter. A V-shaped screen, opening towards the bottom and with the top edge perforated, was placed inside the wooden frame. A four inch hole was made in one side of the box to permit the removal of trapped flies. When the trap was in operation the hole was covered by a board. The trapped flies were killed with carbon tetrachloride.

Fly collections and observations were usually made between one and three o'clock in the afternoon. At this time the flies were most active. The most abundant flies were the house fly, Musca domestica L., the stable fly, Stomoxys calcitrans (L.), several undetermined species of calliphorids, and the horn fly, Siphona irritans L., in that order.

Results and discussion

House fly, Musca domestica L.

1. Population fluctuations

House fly collections and observations were initiated on May 5, 1953. During the remainder of May and the first three weeks of June the house fly population was very small (Figure 6). The flies were found in the swine barn resting on the hogs and on the ceiling and walls of the pens. During this period no house flies were collected on the manure piles outside the barns. On June 22, house flies were first collected on the swine manure pile outside the barn. During the first week of July, house flies began to infest the other barns. This suggests that the focal point of the house fly population was the swine barn. This might well be because the swine barn was infested with flies during the winter of 1953-54 and with the advent of warm weather, they first spread to the swine manure outside the barn and then to the other barns.

The first large increase in the house fly population occurred during the second week in July. This was probably due to the hot weather which began at that time and also because the swine manure outside the barn had not been removed for about two weeks. These two factors combined to make ideal conditions for the sudden increase of the house fly population. This increase continued and by the second week in August house flies became more numerous that any of the other species of flies. This was true in all the barns, and in the dairy and beef barns the house flies outnumbered all other flies combined by at least two to one. All through August and most of September the house fly population remained very high, then began to drop during the last week in September probably due to the prevailing low temperatures. The most striking decline occurred during the first week of October. During the remainder of October few house flies were seen outside the barns. On October 24, a survey was made and no house flies were seen outside the barns but when the dry straw cover was removed from the swine manure pile a large number of newly emerged flies were seen crawling over the manure. These flies probably emerged from the manure and stayed close to the warmth of the pile.

During the winter of 1953-54 house flies continued to infest the swine barn in small numbers. House flies were breeding in empty feeding troughs where small amounts of feed were left in the corners of the troughs. The flies clustered around the radiators and near infra-red lamps that were used to warm the new-born pigs. The temperature of the barn during the winter was about 65°F. A few house flies were also seen in the dairy barn during the winter. These flies were very sluggish and clustered around radiators and near the calves that were penned in the barn all winter. The temperature in this barn varied from about 55°F. to about 60°F. throughout the winter.

In the spring of 1954, house fly population surveys were continued in the animal barns at The University of Manitoba and in several dairy and swine barns near Fort Whyte, Manitoba.

At the University the fly populations were very small during May, June and most of July. This was probably due to the cold wet weather that prevailed during these months. House flies did not visit manure piles outside the barns until the first week in July. This was about two weeks later than in 1953. Large populations of house flies did not build up until the first week of August. During that week the increase was very rapid. During one three-day period the house fly population tripled in the swine barn and the number of flies visiting the manure piles increased enormously. Fly traps were used to determine the number of flies visiting the manure piles. The population of flies in the swine barn was determined by the number of flies that were caught on sticky fly-papers that were hung in the barn for a period of three hours each day. These methods were very effective in evaluating the relative size of the populations during the survey.

In the second week in August a thorough fly control program was started at the University barns. Manure was removed twice a week and methoxychlor was sprayed in the barns by means of an electric sprayer at least once a week. This practice gave very effective control and because natural fluctuations of the house fly population could not be observed, the survey was discontinued.

Observations on house fly populations were also made at several dairy barns and piggeries in a dairy community several miles away from the University. In spring the fly populations in all the dairy barns were very small. The piggeries were much more heavily infested with flies. One of these piggeries was very unsanitary both inside and outside. Large piles of manure were kept in the immediate vicinity of the barn and in one area of the barn a large amount of stale bread, spoiled vegetables and meat was kept. These were cooked and served as feed for the hogs. This room had a very large population of flies, about 500-1000 flies were counted per square foot on the ceiling and walls. No fly control was undertaken in this barn and large populations of flies were found here all summer until late fall.

House fly populations were low in the dairy barns all summer. Several of the farmers resorted to fly control by spraying or fogging the barns with methoxychlor just prior to milking, when all the cows were in the barn. This served to eliminate the flies that came into the barns with the cows. During the day when the cows were pastured the barns were usually free of flies except for the sections where the calves were penned. The cattle stalls were cleaned every day and at most of the farms there were very few fly breeding sites around the barns.

2. Breeding places

The main source of flies at the dairy farms appeared to be the calf pens. The manure in these pens was not removed for several weeks at a time. Fresh straw was merely put on the old manure when the latter became wet. The farmers claimed that this practice was carried on to supply the calves with plenty of warm bedding to prevent rheumatism. During a period of several weeks a thick carpet of manure and wet straw accumulated on the floor under the calves. This became an excellent fly breeding medium. As most of the calves were milk-fed, the manure was very odiferous and very attractive to flies.

On several occasions this manure was examined in some of the barns and was found to contain thousands of house fly maggots and pupae. Sometimes, dense clusters of newly emerged adults were seen on the walls near the floor. On examination it was found that they were emerging from pupae in the wet straw on the floor of the pen.

Another material which proved to be an excellent house fly attractant and egg laying site was brewer's grain, a waste material from breweries. This material was hauled from the brewing plants and kept in bins in the barns for several days while it was being fed to the cattle. Although the grain did not remain in the barns long enough for the flies to breed in it, nevertheless it served as a powerfull attractant after it had been stored one or two days and fermentation had begun.

Large populations of flies were also present in milk houses where milk was processed immediately after milking. The milk houses were usually situated near the barns or sometimes in a separate section in the barns. Although electric insecticide vaporizers utilizing lindane were employed in most of the milk houses, they were not very effective. During milking time, when it was desirable to have as few flies as possible in the milk houses, the doors were open and large numbers of flies entered. Many flies fell into containers of processed milk and had to be removed, involving a waste of time and milk. There is also the danger if the flies carried disease organisms, consumption of unpasteurized

FIGURE 1 and 2. Crowded stabling of calves in small pens resulted in accumulation of manure and subseque production of large numbers of maggots.

FIGURE 3. Open stabling of calves. Manure was replaced by dry straw every day and consequently very few maggots were produced under these conditior

FIGURE 4. Aerosol machine used to fog barns just prior to milking.

FIGURE 5. Manure piles behind a piggery. Large amounts of manure were stored behind this piggery and numerous numbers of maggots were breeding in the manure and wet earth near the manure piles. These unsanitary conditions caused this farmstead to be the most fly infested in the distri

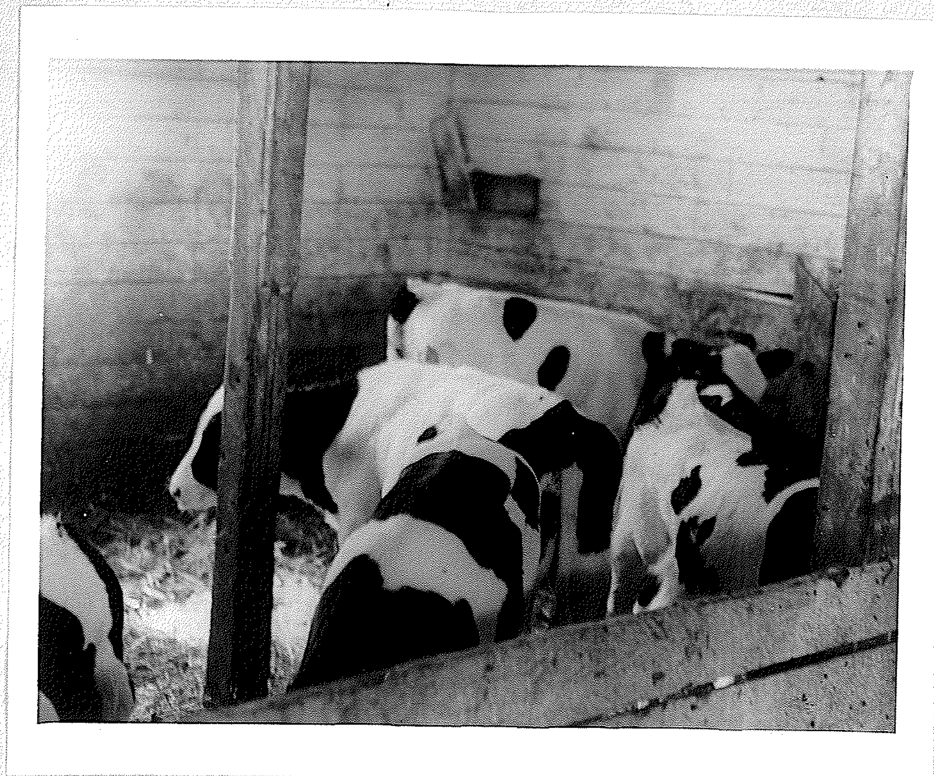


FIGURE 1

FIGURE 2

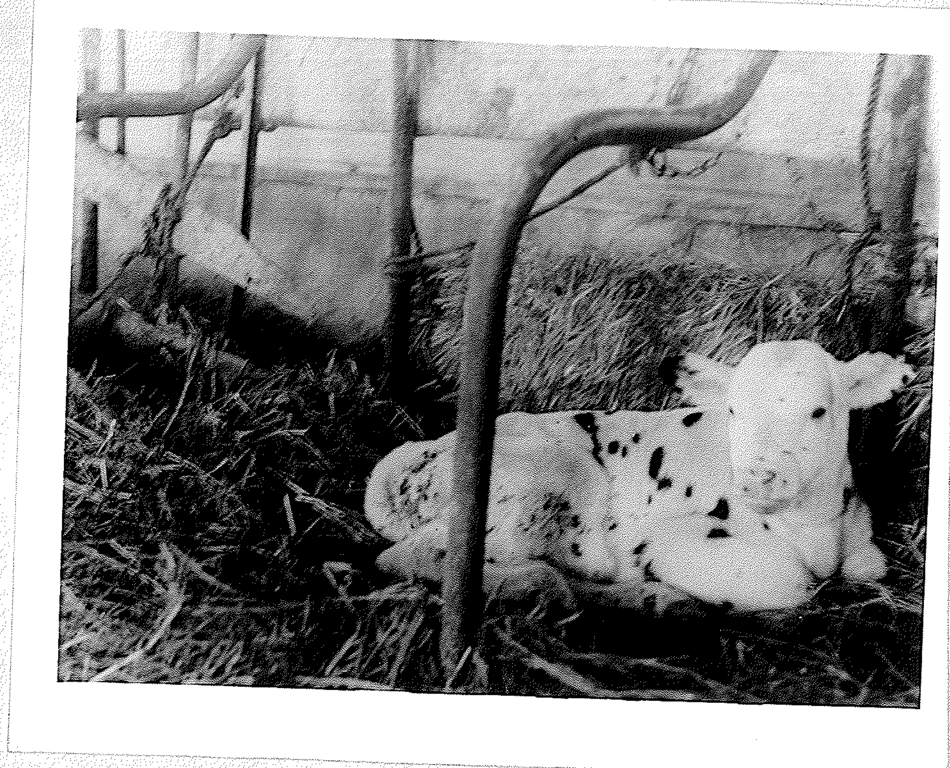


FIGURE 3

FIGURE 4

FIGURE 5

milk could be dangerous. This possibility does not seem very remote when one considers that flies visit filth and decaying matter where dangerous pathogens may be present. One dairy visited had a refrigerated milk house and very few flies entered it even when the door was left open.

3. Oviposition

House flies did not begin oviposition to any extent in the manure piles until the beginning of July in 1953. This was the beginning of a period of hot weather and the flies began to move to the manure piles in great numbers. The flies preferred small depressions on the sunny side of the manure pile for oviposition sites. These depressions were usually covered loosely with a thin layer of dry straw through which the flies crawled to reach the damp warm manure underneath. Here they deposited large numbers of eggs. The maggots were usually found in the same place where the eggs were laid. Just prior to pupation the maggots crawled to drier parts of the manure pile and pupated in pockets or small depressions in the straw layer, usually on the sunny side of the manure pile.

Swine manure attracted enormously larger numbers of house flies than did cow manure. The number of maggots that was found in cow manure was also much smaller than that found in swine manure.

To determine the relative attractiveness of the two kinds of manure, an experiment was conducted using caged flies. Fresh warm cow manure and swine manure were placed in small glass dishes measuring about two inches in diameter and one-half inch high. Altogether eight tests were made. Each test consisted of one dish of each manure placed side by side in a cage of flies. Each test was replicated twice in sequence in each cage. Four cages of flies were used and each cage contained about 200 flies. The duration of each test was about three hours. In that time the manure surface did not dry enough to prevent the flies from laying eggs in it. The manure was then removed from the cages and the eggs were counted under binoculars. The results are shown in Table I.

The laboratory results (Table I) and field observations leave little doubt that swine manure is a much better house fly attractant and oviposition medium than cow manure. Calf manure is probably much more attractive to house flies than cow manure perhaps because of the large amount of milk in the calves' diet.

West (1951) cites several Scandinavian workers as stating that house flies are more attracted to swine manure than to any other manure. It is also suggested that pig manure is a better breeding medium than cow manure. To determine this, preliminary experiments were conducted in the laboratory at the University of Manitoba during the winter of 1954.

TABLE I

NUMBER OF EGGS DEPOSITED BY CAGED FEMALE HOUSE FLIES IN PIG AND COW MANURE DURING A THREE HOUR PERIOD THE UNIVERSITY OF MANITOBA, 1955.

Cage No.	Test No.	Number of eggs deposited: Cow Manure	Number of eggs deposited: Swine Manure
I	1	5	1355
	2	1	984
	Total	6	2339
II	3	0	760
	4	0	535
	Total	0	1295
III	5	0	357
	6	0	425
	Total	0	782
IV	7	0	183
	8	1	289
	Total	1	472
Total		7	4888

Equal weights of dry cow manure and swine manure were moistened and warmed at 30°C. for three days. House fly eggs were then put into the manures. Duration of larval and pupal stages, size of the pupae and the number of flies that emerged from each manure were noted. It was found that the larvae in the cow manure required at least three days longer to reach pupation than those in the swine manure. The pupae in the swine manure were all uniform in size and about twice as large as those in the cow manure. Emergence of adults from the swine manure was about 80 per cent whereas from the cow manure it was about 33 per cent. Swine manure, therefore, seems to be not only more attractive but also a better food for larval development.

Stable fly, *Stomoxys calcitrans* (L.)

1. Population fluctuations

Stable flies were mostly concentrated around the dairy and beef barns. On June 9, 1953, adults were first observed feeding on cattle. In about ten days the population increased and the flies began to spread to the swine barn. However the stable fly population in the swine barn remained very low and rarely were more than about ten flies caught in that barn in any one day. The population increased at a slow rate until the middle of July. From then on, it remained static until approximately the third week in August. After that the population decreased rapidly and by the first week in September only a few flies were observed in the dairy and beef barns. At this time the stable flies were inactive and the majority of them were resting on the walls and ceiling of the barn and only a few ventured to feed on the cattle.

2. Habits

The habits of the stable flies were observed to differ in several ways from those of the house flies. Stable flies do not do as much useless flying as the house flies. They fly to the animals, locate a spot to feed and remain there for a period of time and then fly away to rest on a wall, ceiling or other location. Their favorite feeding site appears to be on the animals' legs just below the knees. Unlike the house fly, the stable fly is not easily disturbed when feeding. When resting, the engorged stable fly rests with its abdomen apparently touching the surface, with the result that the body of the fly is at an angle to the surface on which it is sitting. This is in contrast with the house fly which rests horizontally with the surface.

The stable flies are not as sensitive to temperature changes as the house flies. Unlike house flies, which are most active in hot sunny locations, stable flies prefer shady sites. The favorite resting places appeared to be shady sides of buildings and fences near the barns, on barn ceilings and the darker and cooler parts of the barns. This phenomenon was observed even in cooler weather. The majority of the stable flies were observed in the cool barn rather than outside where the temperature was higher. This insect is therefore well named the stable fly! When house flies were sluggish and inactive during cool days, stable flies continued to feed on cattle and fly actively in the barns. Perhaps stable flies have a lower threshhold temperature for flight than house flies.

3. Oviposition

The oviposition habits of stable flies differ considerably from those of house flies. House flies prefer to lay eggs in depressions in manure where many flies will congregate and lay large numbers of eggs. Stable flies do not congregate in any one favorite site. House flies prefer to oviposit in swine manure; very few stable flies were observed or trapped on swine manure. Stable flies were observed ovipositing in old, crusted cow manure inside the beef barn and in fresh chicken and horse manure outside the barn. Old, dry horse and chicken manures and fresh cow manure did not attract stable flies. Metcalf and Flint (1939) state that stable flies develop in masses of straw, grain, hay, piles of grass, weeds, and other materials that have become water-soaked or contaminated with manure, and in the excrement of animals only if it contains much hay or straw. These authors also claim that the female stable fly deposists five or six hundred eggs in four or five batches. In this study many female stable flies were observed from the time they landed on a manure pile until they flew off and no such large batches of eggs were laid by these flies. The flies usually laid about ten to fifteen eggs in one spot and then proceeded to another spot. The largest observed number of eggs laid by one fly was 48, over a period of about three minutes. The eggs were laid in horse manure. The reason for the discrepancy may be that the female stable flies lay different number of eggs in different media.

The cow manure in which stable flies oviposited was in the barn and crusted on the surface but moist underneath due to seepage from a nearby stall. The manure was in constant shade and the air temperature was never above 70°F. The eggs were deposited in crevices in the crust, on wet and dry pieces of straw, on the surface of the crust and in manure-soaked earth around the manure. The female usually deposited a group of about ten to fifteen eggs in a crevice. Only one or two eggs were laid haphazardly on the other sites. Apparently the stable fly does not lay a large number of eggs until it finds a suitable location for oviposition. It does this by moving its ovipositor over the surface of the manure and poking it into cracks and crevices.

When ovipositing in fresh horse manure, the female pushed its ovipositor into the ball of strawy excretion and deposited a number of eggs. The eggs were also laid in open spaces between the balls of manure if the location was moist and shady, although excessively wet spots were avoided. The eggs were rarely laid in compact masses but were scattered over a diameter of about one-half inch and from one-eighth to one-quarter inch below the surface. No oviposition was observed on dry warm upper surfaces of the manure balls.

Stable flies oviposited most prolifically during the latter part of June and during July. The most favored period for oviposition was from late morning to mid-afternoon. After the first week of August the number of eggs laid dropped considerably even though the temperature and manure remained as favorable as during the active oviposition period. On examination of female stable fly ovaries at intervals during the remainder of the summer it was observed that the eggs were rarely fully developed. The flies congregated in barns and visits to manure piles for oviposition were few and sporadic. A reproductive diapause may possibly occur during this time of the year.

4. Rearing

Although thousands of eggs were deposited in the different manures, development in the laboratory and in the barn yard in most of these media proved unsuccessful. In the laboratory eggs were placed in cow, horse, swine and chicken manure but flies could not be reared in any of these except chicken manure. Stable fly eggs were placed in fresh chicken manure and put in the insectary where the temperature ranged from about 60° to 80°F. Maggots hatched in about two days. Pupation began twelve days later and adults began to emerge about twelve days after pupation began. Stable flies were also trapped as they were emerging from puparia collected from chicken manure. This occurred on August 12, 1954 when four adult stable flies were trapped in comparison with several thousand house flies.

Calliphorids

1. Population fluctuations

These are commonly known as blow flies, bluebottle flies and greenbottle flies. Calliphorids were the most abundant of the flies studied during the spring and early summer. When the survey was begun on May 4, 1953, calliphorids were quite numerous. The most intense concentration of these flies was around the swine barn particularly around the swine manure pile and the sunny south wall of the swine barn. The population did not change noticeably during May but during the warmer weather in June it began to increase. The population reached its peak during the last week in July and then began to drop during August. By the end of August the population was quite small and remained so during the remainder of the summer.

2. Habits

The calliphorids concentrated their activity around the swine barn and especially on the swine manure pile. Very few were observed near other barns or inside barns. They were the first flies to commence laying eggs in the swine manure and until the end of June almost all adults that emerged from pupae collected in swine manure were calliphorids.

Calliphorids appeared to be very sensitive to temperature changes. A few degrees made a great difference in their activity. They were most active and abundant on hot, quiet humid days. On cooler days (60-70°F.) they confined themselves to sunny, windless shelters and very few ventured to oviposit in manure piles.

Horn fly, *Siphona irritans* (L.)

1. Population fluctuations

This insect made only a few sporadic appearances during the summer of 1953. At no time was the population large or continuous. Horn flies were first observed feeding on cattle on June 15. They were present for a period of about two weeks. Then there followed a period of wet cool weather after which only a few horn flies were seen until the third week in July when the population increased for several days and then dropped again. During the first week in September the population began to increase once more and became larger than at any previous time. The population again dropped during a period of cool weather and there were no further appearances of the pest during that year.

Summary and Conclusions

Population fluctuations of house flies, stable flies, horn flies and undetermined calliphorids were investigated during the summers of 1953 and 1954. The study was done at the animals barns at the University of Manitoba and at several dairies and piggeries near Fort Whyte, Manitoba.

Fly counts and frequent subjective observations on the various populations were made during the summer. The results are summarized schematically in Figure 6.

There is evidence to indicate that calliphorids are spring and early-summer flies. They reach their population peak at the end of July and then diminish rapidly. This is in contrast with the house fly population which is still increasing at that time. No evidence was found to suggest that the early decline of the calliphorid population was caused by adverse climatic or nutritional conditions. Perhaps a reproductive diapause commences at this time.

Stable flies appear to be mid-summer flies. In 1953, the population gradually increased until the middle of July, remained high for about one month and then declined.

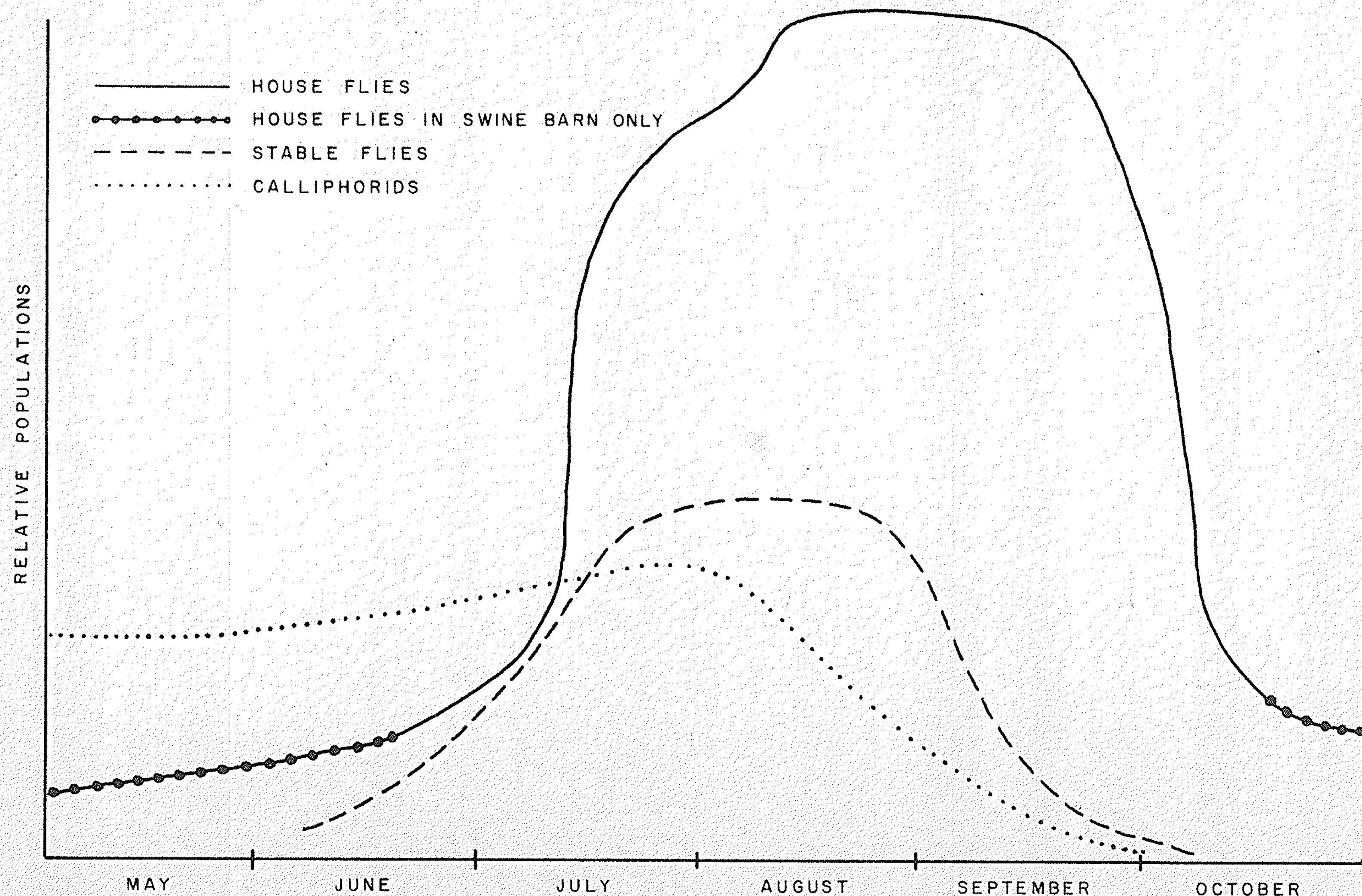
House flies are late-summer flies. They reached their highest population level at the beginning of August and remained high until the advent of cold weather in the fall. Since the quantity of breeding media was constant, the temperature is the major variable influence on the house fly population. This was apparent during the early summer

FIGURE 6

THE RELATIVE POPULATION DENSITIES OF ADULT HOUSE FLIES, STABLE FLIES, AND CALLIPHORIDS FROM MAY TO OCTOBER IN 1953 AT THE ANIMAL BARNS AT THE UNIVERSITY OF MANITOBA

FIGURE 6

THE RELATIVE POPULATION DENSITIES OF ADULT HOUSE FLIES, STABLE FLIES, AND CALLIPHORIDS FROM MAY TO OCTOBER IN 1953 AT THE ANIMAL BARNS AT THE UNIVERSITY OF MANITOBA



increase. According to the weather records for the summer of 1953, temperatures of 80°F. or over occurred for several days during the middle and latter part of June. It was during this period that large numbers of house flies and masses of eggs were observed on the swine manure pile. Undoubtedly this accounted for the rapid increase in the number of house flies during the early part of July.

The house fly population levelled off during August and September after the rapid increase in July. This is expected when a very rapidly increasing population is breeding in a relatively fixed quantity of media. The population density represented in the graph (Figure 6) is probably an expression of the capacity of the breeding medium to support normal growth of house fly larvae. It is strange that overcrowding did not occur with resultant growth of undersized adults.

The habits of the flies studied also differ. House flies and calliphorids prefer hot sunny exposures and swine manure as an egg-laying medium. Stable flies preferred the cool interior of the barns and shady locations outside. They also preferred fresh horse and chicken manures as egg-laying media. However these manures are not suitable breeding media because very few stable flies emerged from these materials.

Laboratory experiments and field observations indicate that swine manure is a more effective house fly attractant than cow manure. It also appears to be more favorable as a breeding medium.

CHAPTER III

A STUDY OF THE ENVIRONMENTAL FACTORS AFFECTING THE DISPERSION OF HOUSE FLIES (*Musca domestica* L.) IN A DAIRY COMMUNITY NEAR FORT WHYTE, MANITOBA

Introduction

Odor and air currents are important factors in the orientation and distribution of many of our economic pests. It is difficult to evaluate the role of these two factors separately. Because the house fly is one of the most important economic pests, many investigations have been made to study the relation of wind and odors to the distribution of this pest. However, the results have been so variable that no clear concept of this relation has emerged.

A knowledge of the flight habits of house flies in relation to wind and odors should aid fly control in several ways. In restricted districts or establishments it should help in determining the extent to which fly breeding areas in the neighborhood affect control operations. It should aid in the study of fly-borne diseases. A knowledge of the flight habits of flies would also help in determining the size of the area that would have to be treated in any control campaign aimed at reducing the fly population in a district.

House fly control as practised at present requires a combination of thorough sanitation supplemented with the use of insecticides. Farms vary considerably in the standard of sanitation maintained. The question arises whether a farmer who conscientiously applies house fly control measures on his premises will find his efforts frustrated by invasions of house flies breeding on less sanitary farmsteads in the neighborhood. To answer this question it is necessary to understand the factors that affect house fly dispersal. These include the effect of wind direction and intensity of wind-borne odors on the direction of house fly migration, the distance that house flies will migrate and the "urge" in house flies to migrate. Some of these questions were answered in investigations during the summer of 1954 by releasing and recovering radioactive adult house flies.

The location of the study was in a dairy community near Fort Whyte, Manitoba.

Review of the literature

A review of the literature of house fly dispersion reveals a variety of approaches to the problem, with little agreement in results. Parker (1916) reviewed house fly dispersion studies made from 1907 to 1914. The earliest work was done by Arnold in 1907 in England. He released 300 flies marked with white enamel and recovered five at distances of 30 to 190 yards from the release point. Copeman, Howlett and Meriam, also in England, in 1911 liberated marked flies at a refuse site about one-half mile from a village and recovered several at various places in the village. Hine in

1911, released 350 house flies marked with gold enamel and recovered some during a three-day period at distances of 600 to 1200 yards away from the release point. He concluded: "any reasonable distance may be travelled by a fly under compulsion to reach food or shelter". Hewett in 1912 conducted investigations at Ottawa in which 13,600 marked flies were released. He found that wind was the chief factor in determining the direction of distribution; the flies dispersed with the wind. Hindle in 1914 liberated over 25,000 marked flies and established 50 recovery stations. Among other conclusions he stated "house flies tend to travel against or across the wind; this direction may be directly determined by the action of the wind, or indirectly owing to the flies being attracted by any odors it may convey from a source of food". Zetek in 1914 released about 5,000 marked flies and recovered about 17 in a building one-half mile away from the release point.

It is apparent that these investigations and observations were incomplete. The recovery percentage was in most cases insufficient for the general conclusions that were reached. The suggestions as to factors influencing or determining dispersion are neither convincing nor conclusive except perhaps in Hindle's work where a large number of flies were released and many collecting points were established.

Parker (1916) in a city in Montana, investigated the distance of flight and factors which influence dispersion of house flies in an urban area. During a period of 39 days, 68 lots or about 400,000 marked flies were released. Parker claimed that on a long period basis such as a whole season, wind may be of no importance in fly dispersal. He found no evidence to indicate that wind acts as a stimulus even when a shorter period of time is considered. Considering that the longest distance at which the flies were recovered was only two miles and only 0.2 per cent of the flies were recovered, the recovery percentage might be too low to be reliable in drawing any conclusions. Parker considered the wind to have a secondary function in insect flight; the wind channels the odor being emitted from a given source and carries it a greater distance than the odor would otherwise diffuse. The wind, in this case, acts as a vehicle for odor rather than as a direct flight stimulus itself, i.e. the flies orientated to the odor rather than to the wind.

Bishopp and Laake (1921) released house flies marked with powdered red chalk in a farm area near Dallas, Texas. Marked flies were recovered as far as 13.14 miles away from the release point. From their results they concluded that among the stimuli inducing dispersion, the odor of food and oviposition sites appear to be the strongest. They also stated that the house fly has a definite migratory tendency because it will by-pass breeding and feeding sites in its flight. Their marked flies travelled in greatest numbers with the wind but some also flew against and at right angles to the wind. Bishopp and Laake concluded that "under natural conditions the influence of moderate winds on dissemination is not of great importance".

Lindquist (1951) marked about 36,000 flies with radioactive phosphorus and released them in an agricultural area near Corvallis, Oregon. He recovered tagged flies 12 miles away from the release point. Lindquist claimed that wind has no effect on the dissemination of house flies because tagged flies were recovered in all directions from the release point. However, more radioactive flies were recovered in traps situated in barn yards than in those situated in open fields.

Shoof _et al_ (1952) released about 87,000 radioactive house flies in Phoenix, Arizona. He found that the principal zone of dispersion was within one mile of the release point, although movement of flies occurred up to four miles from the release site. Shoof stated that if attractive stimuli of "equal" intensity surround a given point, then dispersion can follow a random design. Where the attractivity is unequal, dispersion is channelled along the paths of greater fly attractivity. Shoof believes that "area attractivity" is a major factor in governing house fly dispersion.

Yates _et al_ (1952) tagged about 54,000 house flies with radioactive phosphorus and released them in an agricultural area. Radioactive house flies were recovered as far as 20 miles away from the release point. These workers found that house flies moved in greater numbers downwind than upwind.

Quartermann et al (1954) investigated house fly dispersal in an urban environment in Savannah, Georgia. The flies were marked with several radioactive substances and dyes. In their first test, four release points were employed and in the second test eight release points were used. About 50,000 house flies and 20,000 flies of other species were released. In the first test most of the flies recovered were caught within one-half mile of their respective release points. In the second release the dispersion was more uniform and extended up to four miles from the release points. The investigators found that house flies dispersed in all directions but tended to concentrate in those areas which were most attractive to them. The poorer residential area, the business district, and miscellaneous places such as horse stables, dairies and small garbage dumps were most attractive to the house flies. These authors also stated that fly-producing sites outside the city contributed substantially to the city's fly population.

Quartermann et al (1954) also investigated fly dispersal in a rural area near Savannah, Georgia. Two releases were made,-- the first from one farm unit, the second from five different farms about two to four miles apart. In all, about

48,000 radioactive flies were released. In the first release 7.8 per cent of the radioactive flies were recovered and after the second release 0.9 per cent of the released flies were recovered. The authors stated that about 25 per cent of the tagged flies migrated from the release points. In both releases, house flies dispersed at random over an area eight to ten miles in diameter. Within the dispersal area, flies tended to congregate at premises where food and breeding material were abundant.

Description of the release area

The experimental area was a dairy community situated about two miles east of Fort Whyte, Manitoba. There were seven dairy barns and two swine barns located from one-quarter to about two miles away from the release points. All the farmsteads, except one, were reasonably clean and no manure was kept near them. The manure was either spread on the fields or stored in one-load piles some distance from the barns. At the time of the release the land area between the release points and the farmsteads was in grain and pasture but no cattle were pastured there during the collecting periods. This excluded the possibility of the released flies flying to the cattle and then going with the animals to the various barns.

Materials and methods

Rearing and tagging house flies

For the first release, adult house flies were reared in the laboratory at the Department of Entomology, The University of Manitoba. The rearing medium was a swine feed, obtained from the piggery, consisting of oats, barley, wheat, alfalfa, soybeans and added proteins, all mixed and ground. Water was added until the medium was moist. A small quantity of 'Moldex' was added to the medium to inhibit molds.

About 15,000 pupae were removed to a 30 x 24 x 36 inch screen cage in the insectary. The adult flies emerged over a period of about ten days and were fed on sugar, skim milk powder and water. Adult house flies for the second release were obtained from pupae collected in swine manure near the swine barn at The University of Manitoba.

Three days before the release, food was removed and the flies were starved for two days. An aqueous solution of radioactive phosphorus (P^{32}) was then fed to the flies. A 1.5 ml. sample of the P^{32} solution containing 480 microcuries per cc., was diluted with 200 ml. of distilled water and put in five small dishes in the cage. Corrugated paper was placed in the liquid and then sugar was sprinkled over the paper to attract the flies. The flies fed on this solution for one day. Several samples of 100 flies were checked for radioactivity and about 97 per cent were significantly radioactive according to the laboratory radioactivity monitor used.

Methods of recovering released house flies

Fly collections from the different farms (Figure 7) were made in the evenings of the first, second and fifth days after the first release. On the first day, three methods of collecting flies were used, namely fly traps baited with sour cream cheese, sticky fly-papers, and sweeping with an insect net. The fly traps were found to be ineffective because the bait in most of them was removed by dogs or cats. The sticky papers and sweeping were used for all the other collections. Three or four sticky papers were hung in each barn in places where the fly population was highest. Sweeping was done after the cows were brought into the barns for milking. Usually at this time the maximum number of flies was present in the barn. Sweeping proved to be very satisfactory because large numbers of flies were caught in a short time.

Adult house fly collections after the second release were made at various intervals during a seventeen day collecting period. The samples were taken from the same farms that were used as collecting stations after the first release. It was impossible to collect flies at regular intervals after this release due to the heavy rains that fell during the collecting period. The experimental area was bounded by earth roads which were usually muddy during this period and impassable by automobile.

The collected flies were killed with carbon tetrachloride and checked for radioactivity in the laboratory at the University.

Results and discussion

First release

The temperature and humidity data during the collecting period were obtained by use of a hygrothermograph at The University of Manitoba. The wind direction and velocity were obtained from the Dominion Meteorological Office at Winnipeg.

The mean daily temperature during the collecting period was 65.8°F. The mean maximum was 74.8°F., and the mean minimum was 56.8°F.

At the time of the release, 11:00 A.M. on August 5, 1954, the wind was blowing from the northeast at about 13 miles per hour. During the late afternoon the wind velocity dropped and by evening a gentle breeze was blowing from the north. The average wind velocity for that day was about 8 miles per hour. During the remainder of the collecting period the wind was unsettled and the direction shifted several times a day. The weather was sunny with intermittent cloudiness throughout the experimental period. Traces of precipitation occurred in the area on August 7 and 8. Relative humidity was over 60 per cent during most of the collecting period.

Of the 15,000 radioactive adult house flies released, 548 or 3.7 per cent were recovered during the three collecting

TABLE II

NUMBER OF TAGGED ADULT HOUSE FLIES RECOVERED ON FARMS AFTER RELEASE FROM AN OPEN FIELD FORT WHYTE, MANITOBA 1954 *

Collecting station	Distance from release point (yards)	No. of flies checked**	No. of radioactive flies caught	% of recovered tagged flies	% of radioactive flies recovered
1 Dairy barn	920	948	27	4.9	.18
2 Dairy barn	440	3392	112	20.4	.74
3 Dairy barn	815	2899	42	7.6	.28
4 Dairy barn	880	1390	266	48.5	1.77
5 Dairy barn	860	1407	91	16.6	.61
6 Dairy barn	2045	3441	1	.18	.006
7 Swine barn	1935	2927	3	.54	.020
8 Swine barn	3520	5455	2	.36	.013
9 Dairy barn	3190	1165	4	.72	.026
Totals		23,024	548		3.645

* 15,000 radioactive flies were released.

** Many thousands of flies were not counted because there were no radioactive specimens among them.

days (TableII). Five hours after the release, 280 or 51.1 per cent of the tagged flies eventually recovered were caught, some of them two miles from the release point. On the same day, 221 or 79 per cent of the tagged flies caught that day were collected on farms 4 and 5. (Figure 7). Only 59 radioactive flies or about 21 per cent were caught on the other farms. Farms 4 and 5 lay in the direction from which the wind was blowing. Farms 1, 6, 7, 8 and 9 lay in the opposite direction. The uneven distribution of radioactive flies suggests that the flies did not disperse at random but orientated to some directional stimuli. These stimuli appear to be wind, or wind-borne odors. Farms 4 and 5 were the most effective attractants because the wind blew directly from them and consequently most of the released flies flew to these two farms.

It appears that the primary factor influencing dispersion in this type of release was odor, channelled and intensified by wind in a definite direction. In such a situation flies disperse along a channel of maximum intensity of attractive odor rather than at random.

This conclusion is confirmed by the following considerations. If the dispersion were at random in an area with a radius of two miles, which was the distance of the farthest farm from the release point, it can be computed that only two flies should be found, on the average, per acre. In an area

[illegible]

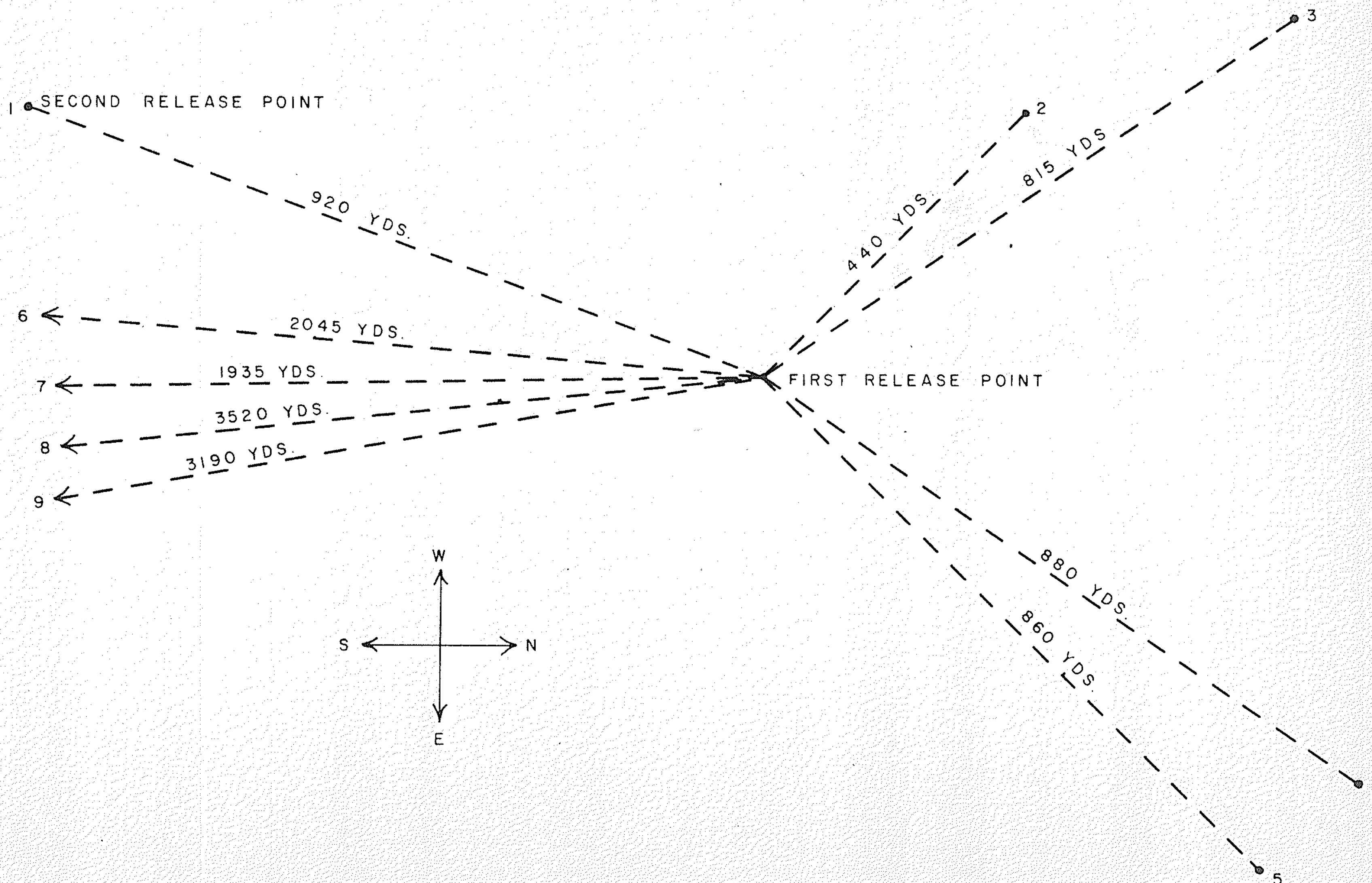
FIGURE 7

DIRECTION AND DISTANCES OF COLLECTING STATIONS FROM RELEASE POINTS FORT WHYTE, MANITOBA 1954

FIGURE 7

DIRECTIONS AND DISTANCES OF COLLECTING STATIONS FROM RELEASE POINTS

FORT WHYTE, MANITOBA. 1954



with a radius of one-half mile, only 30 flies should be caught on the average per acre if the distribution is random. Since the fly populations were quite low at this time, it is estimated that about one-tenth of the entire fly population in the barns was checked for radioactivity. Therefore, if each of the farm premises where the collecting was done is assumed to occupy an area of one acre, only three tagged flies would be caught on the average on the farms one-half mile away from the release point if the dispersion were random. The experimental results show that on farm 4, which was about one-half mile away from the release point, 58 times that number of tagged flies were caught. On farm 5, 15 times as many flies as expected were caught on the day of the release. More flies than expected with random dispersion were caught on farms 1, 2 and 3. Farms 2 and 3 were situated at an angle to the direction of the wind. Farm 1 was much closer to the release point than the other farms and consequently the probability of finding tagged flies there was greater.

Earlier workers, Bishopp and Laake (1921) and Lindquist et al (1952) concluded that adult house flies disseminate at random or have a tendency to fly with the wind. This suggests that there is little relation between the wind direction and fly dispersion. This discrepancy may have been the result of the different trapping methods used. The earlier workers used baited traps whereas in the present investigation the whole farm yard served as a bait and was undoubtedly a more effective attractant over a greater distance. The small quantity of bait used in traps might not affect orientation of flies at the release point. It is understandable that under these circumstances house flies might disperse at random. The small baited traps would then attract only those flies that chanced to arrive in their vicinity. On the other hand, the volume of odors emanating from farm yards should reach the release point in sufficient intensity to affect orientation of the flies. This difference in the experimental conditions seems adequate to explain the conflicting results.

West (1951) cites earlier work of Carment and Hindle who claimed that house flies when not "forcibly diverted from their course" tend to travel against or across the wind. They suggested that wind-borne odors are important but positive anemotaxis may also be involved. The results obtained in the present study of fly dispersal do not provide an estimate of the role of anemotaxis but they do definitely indicate that adult house flies orientate to wind-borne odors of sufficient intensity.

Second release

The second release was made on August 23, 1954, when about 10,000 radioactive house flies were released on a dairy farm yard (Farm 1, Figure 2). In the second release an attempt was made to determine whether house flies disperse from one farm unit to another within the experimental area. Before the release a survey was carried out and no radioactive flies were found from the first release.

The temperature was quite low during the period following the second release. The mean daily temperature was 60.5°F., mean maximum was 70.8°F., and mean minimum was 50.2°F. The weather was unfavorable for insect flight; heavy rains, drizzle, heavy cloud cover and prevailing cool north winds occurred during this period.

Of the 10,000 tagged adult house flies released, 7.17 per cent were recovered (Table III). About 125,000 house flies were checked for radioactivity during the seventeen day collecting period. About 79 per cent of the recovered radioactive flies were caught on the farm where they were released and the other 21 per cent were caught at eight other farms from one-half to two miles from the release point. No tagged flies were collected on one of the farms which was located two and one-half miles away from the release point. Most of the flies that left the release point were caught in the two piggeries and in the two dairy barns nearest the piggeries. These two piggeries and dairy barns were close together and situated in the same direction from the release point.

The low percentage of tagged flies caught at the farms other than the release point was probably due to the adverse weather during the collecting period. The low temperatures

TABLE III

NUMBER OF TAGGED ADULT HOUSE FLIES RECOVERED ON FARMS
AFTER RELEASE IN A FARM YARD
FORT WHYTE, MANITOBA 1954 *

Collecting station	Distance from release point (yards)	No. of flies checked	No. of radioactive flies caught	% of recovered tagged flies	% of radioactive flies recovered
1 Dairy barn	Release point	9810	567	79.07	5.67
2 Dairy barn	880	8340	6	.83	.06
3 Dairy barn	1580	13817	9	1.25	.09
4 Dairy barn	1760	8012	2	.27	.02
5 Dairy barn	1700	4532	0	-	-
6 Dairy barn	1130	8685	22	3.06	.22
7 Swine barn	1130	15988	81	11.30	.81
8 Swine barn	2640	32897	11m	1.53	.11
9 Dairy barn	1960	12036	19	2.65	.19
10 Dairy barn	4400	10906	0	-	-
Totals		125,023	717		7.17

* 10,000 radioactive house flies were released.

combined with rain and cloud cover undoubtedly hindered flight. Relation between the direction of the wind and fly dispersal was difficult to establish due to the shifting winds during the collecting period.

Summary and conclusions

Two releases of radioactive adult house flies were made in a dairy community during the summer of 1954 to determine (a) the effect of wind direction and wind-borne odors on dispersion of house flies; and (b) whether house flies disperse from one farm unit to another within the experimental area.

Adult house flies were tagged by feeding on radioactive phosphorus in aqueous solution sweetened with sucrose. The first release was made on August 5, when about 15,000 radioactive flies were released. The second release was made on August 23, when 10,000 tagged adult house flies were released. Samples of flies were collected from the various farms in the district and checked for radioactivity with a monitor.

The results from the two releases indicate that (a) adult house flies orientate to wind-borne odors from farm yards, and (b) adult house flies migrate from one farmstead to another in appreciable numbers even in weather suboptimal for flight. This indicates the necessity of community rather than individual attempts to control this pest.

CHAPTER IV

INVESTIGATIONS CONCERNING OVERWINTERING OF HOUSE FLIES IN MANITOBA

Introduction

In this investigation attempts were made to determine whether house flies overwinter under Manitoba winter conditions and if so by what means. The overwintering problem is particularly interesting and important in areas with a severe winter climate such as that found in Manitoba. Solving this problem would shed information as to the cold resistance and winter adaptations of this insect. It could also become an important factor in controlling this pest. If it were certain that house flies do overwinter in Manitoba and these places known, then by disinfesting the overwintering sites during the winter, house fly populations would undoubtedly require longer to reach to high levels during the summer than they normally do.

Several investigations into this problem have been made by earlier workers in other parts of the world. However, the results are mostly contradictory or not applicable to this area.

Review of the literature

Hibernation and overwintering

A review of literature on this problem yields many contradictory observations and very few experimental results. Most of the previous work by other workers has been done in warmer regions of the world and hardly apply to Manitoba.

West (1951) reviewed the observations of several earlier workers. Newstead in 1907 and 1909 claimed that the house fly passes the winter only in the adult stage. Copeman in 1913 suggested that the pupal stage may also hibernate. Williston in 1908 and Howard in 1911 stated that the normal survival was in the pupal stage. Howard also claimed that dormant adults are significant in bringing the house fly population through the winter. Skinner in 1913 and 1915 came to the conclusion that "house flies pass the winter in the pupal stage and no other".

Hewitt (1912) stated "most of them (flies) die; the remainder hibernate". He further stated "the remnant of the flies persisting during the winter months go into complete hibernation. They select some hidden crevice, as for example, behind wood-work or wall-paper for the winter rest and here they remain until the warm days of spring". Hewitt (1915) claimed that immature stages are not likely to overwinter. Dormant and periodically active adults overwinter in northern latitudes.

The above-mentioned authors presented no experimental evidence to substantiate their conclusions. They all claimed that the house fly hibernates in one or another of its life stages. It is interesting that they all agreed that house flies hibernate, however, none presented the slightest evidence that house flies diapause in any life stage.

The following authors contradict the hibernation theory and give experimental evidence that house flies are able to live through adverse cold weather by continuous slow breeding.

Bishopp et al (1915) believed that the species is dependent largely on those individuals which pass the winter in the immature stages, or those which continue to breed during the winter. In their experiments in Dallas, Texas, house fly larval and pupal stages survived for a period of six months. In November, 1913, larvae were put in manure and left outside. In May, 1914, live pupae were still present. It was not stated when the larvae pupated. The mean temperature during the experimental period was 56°F. The coldest day occurred in February when the temperature went down to 10°F.

Dove (1916) also working in Dallas, Texas, found that adult house flies could not survive three days of continuous freezing temperatures. Half-grown larvae were kept alive for 90 days. The experimental temperature was not stated. Young larvae were kept alive for 67 days but only if fresh manure was added periodically.

Matthyse (1945) working in Clinton County, New York, stated " the most important method of overwintering is by continuous breeding indoors". He reached this conclusion by observing that house flies bred all winter in dairy barns where the temperature never fell below freezing.

The evidence accumulated by these workers suggests that winter breeding rather than hibernation occurs. The immature stages of the house fly develop very slowly during adverse weather conditions and then grow normally when warm weather arrives. It is interesting that the normally most active growth stage, the larva, was able to survive longest under certain conditions in cold weather (Dove, 1916).

Cold resistance

Information in the literature as to cold resistance of different life stages of the house fly is very meagre. West (1951) reviewed work by earlier authors. Lorincz and Makara in 1935 found that at temperatures ranging from 46.4°F. to 50°F., eggs had to be incubated for seven days before hatching occurred. Kobayashi in 1921 working in Korea noted that the egg stage was the least resistant to cold. This author stated that at 50°F. all eggs and larvae perished. Bodenheimer in 1931 estimated the critical temperature for house fly larvae at 41°F. Contrary to this, Petrishcheva in 1932 found that mature larvae survived for 14 days at temperatures ranging from 28.4°F. to 30.2°F. Mature larvae did not pupate at temperatures lower than 50°F.

Winter observations in dairy and swine barns

Observations on overwintering house flies were made in the dairy and beef barns at The University of Manitoba during the winter of 1953-54. Animals were kept in these barns all winter and both barns were heated. The temperature in the swine barn ranged from 55°F. to about 65°F. during the winter months. The dairy barn was heated only in the section where the calves were penned. Here, the temperature was about the same as in the swine barn.

House flies bred continuously in the swine barn during the winter. Maggots and pupae were found in unused feeding troughs where the remains of swine feed still persisted, between the wall and feeding troughs where manure and feed had been scattered by the hogs, underneath the troughs, and in manure on the floor. Large numbers of maggots were also found in manure under infra-red lamps which were used to warm newborn pigs. Pupae were found mostly in dry manure and straw that accumulated under the feeding troughs. Maggots and pupae were found developing at temperatures ranging from about 48°F. to about 90°F.

The majority of the adult house flies in the swine barn concentrated in the pens in the middle of the barn where the temperature was usually the highest and where no drafts occurred when the barn doors were opened. Fly activity remained low even when the temperature was around 70°F. Instead of resting on the hogs the adult flies preferred to remain on the walls of the pens, around troughs and other objects such as electric wires, radiators and water pipes. When disturbed the flies merely flew up to the ceiling and remained there.

During the winter of 1954-55 observations on fly activity were made until the beginning of February. The fly population in the swine barn was much higher than during the winter of 1953-54. This was probably due to the larger number of infra-red lamps in the barn. Most of the adult house flies concentrated in the warmer pens where the young hogs were kept. The older hogs did not attract as many flies as did the young pigs even when they were kept in the warmer pens. The pens that held suckling pigs were particularly attractive to the adult house flies. The adult fly population dropped to a very low level when about half the pens were thoroughly cleaned and painted during January, 1954.

One interesting example of the fly's ability to take advantage of a favorable situation was noted during the winter of 1954. A sick sow had lain in approximately the same spot in a pen for about three days. When the wet straw was removed from under her, a very large number of maggots was found to be developing in this material. A large number of females must have oviposited in the wet warm manure near the sow and the maggots found this location ideal for development.

During the winter of 1953-54 a few adult house flies were observed in the warmer sections of the dairy barn. The barn was heated only in the section where the calves were penned and the temperature here was about the same as in the swine barn. During December, 1954 and January, 1955, no adult house flies were observed in the dairy barn.

During the last week of December, 1954, a large dairy barn and a piggery in the vicinity of Fort Whyte, Manitoba, were visited to determine if any adult house flies were over-wintering. The dairy barn was particularly well constructed and about 90 head of cattle were kept in it all winter. At the time of the visit, several adult house flies were observed flying near sunny windows and some were seen resting on the cows. The farmer claimed that during the milking period in the morning many flies came to the milk containers. The temperature in the mornings was about 65°F. to 70°F.. This was considerably higher than during the day when the barn doors were left open. On February 1, 1955, another visit was made to this farm. At this time no house flies were observed. The barn was quite cool and very damp. It is very doubtful whether adults would fly in this environment even if any had been present. No search was made for immature stages of the house fly.

The piggery was visited on the same days as the dairy barn. It had been one of the most heavily infested barns in the district during the previous summer. During the winter about 200 to 300 hogs were kept in it at all times. At the time of the first visit, a considerable number of adult house flies were seen flying in the sunny parts of the barn. On February 1, 1955, no living flies were observed in this barn. This barn was also very damp and cool.

During December, 1954, a small barn was experimentally infested with adult house flies. On December 13, about 20 hogs were put in this barn and about three days later several thousand flies were released in this barn. About two thousand flies were put in each of two cages and suspended in the barn. The caged flies were provided with sugar and water. The barn was a wooden structure about 15 feet wide by 40 feet long. During the experimental period all the entrances were closed except for one small door about two feet wide and three feet high through which the swine entered and left the barn. The air temperature in this barn was only about 20°F. higher than the outside temperature. The manure remained frozen except for the part where the hogs slept. Since the barn was not heated, the only sources of warmth were the animals and the manure.

The outside temperature was relatively mild during the first two weeks of the postrelease period. The average maximum was 23.4°F. and the mean minimum was 8.1°F. On five days the temperature rose to 30°F. or more.

On December 22, about one week after the release, many flies were observed resting on the walls and ceiling of the barn. They were inactive and could not be induced to fly. The caged flies were more active. Feeding was observed and some of the flies attempted flight. The barn temperature was about 50°F. and the outside temperature was 38°F. at the time.

During the first week of January, 1955, the weather became colder and the outside temperature dropped to -10°F. for three consecutive nights. The temperature in the barn went below freezing and all the manure, except that in the immediate vicinity where the pigs slept, was frozen. The air temperature in the barn was about 20°F. On January 8, no living flies were found in the cages in this barn. There were many flies clinging to the walls and ceiling of the barn but on closer examination they were found to be dead and desiccated.

During the latter part of January the barn was again visited but no living flies were observed. The manure was now about a foot in depth in some parts of the barn and was emmitting a considerable amount of heat. The manure temperature varied from below freezing to about 82°F. The air temperature above the manure was 32°F. and the outside temperature was 14°F.

At this stage of the investigation it would be unwise to state any conclusions from the results obtained so far. Although many thousands of adult house flies were released in the barn, only a relatively few were found or observed on the walls and ceiling. The fate of the remainder is unknown.

Whether they are hibernating will become apparent when warmer weather arrives and the surviving flies, if any, will begin to fly. Immature stages would be very difficult if not impossible to find in the large amount of manure that has now accumulated. If any eggs were laid by the flies there appears to be no reason why the immature stages may not be developing in the manure.

Cold resistance

This investigation was undertaken to determine the cold resistance of the egg, larval, pupal and adult stages of the house fly. The work was done in a constant temperature cold room maintained at 40°F.

Materials and methods

About 100 newly-laid eggs were placed on wet blotting paper and put in separate tightly closed dishes. These dishes were placed in the cold room and one such dish was removed to room temperature every 24 hours. The eggs were left in the dish for another 24 hours and then a count of the hatched maggots was made.

Larvae were placed into the cold room in the same medium in which they had been developing. A number of larvae was removed at about weekly intervals and put in fresh medium at room temperature. The number of maggots that survived and pupated, and the number of adults that emerged from these pupae was recorded. Newly-hatched larvae, half grown larvae and fully developed larvae were used in the test.

Pupae were also placed in the cold room in the same medium in which they had pupated. At weekly intervals a number of pupae was removed from the cold room and placed in emergence cages at room temperature. The number of adults that emerged was observed.

Several thousand adult house flies, about one week old, were placed in a cage and put in the cold room. The cage was constructed from an old butter box. The boards were removed from one side and a screen was placed over the opening. A hole was made in one of the boarded sides and a sleeve was fitted to this hole. The inside of the cage was coated with a thin layer of molasess on which the flies could feed. A container of sugar and powdered skim milk was also placed in the cage. Moisture was provided by several dishes of water which were placed on the floor of the cage. Strips of blotting paper were placed over these dishes and care was taken to keep the paper constantly wet.

Results and discussion

1. Egg stage

The results are summarized in Table IV. From the results obtained, it appears that at 40^{o}F. the maximum length of survival for house fly eggs is 96 to 120 hours or three to four days. The greatest mortality occurred after the second day. No hatching was observed in the cold room. One dish containing

TABLE IV

SURVIVAL OF HOUSE FLY EGGS AT 40°F.
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No. of eggs removed from cold room	No. of hours at 40°F.	No. hatched at 80°F.	% hatched
90	24	82	91
120	48	104	85
52	72	30	57
76	96	2	2.7
114	120	-	-
156	144	-	-

several hundred eggs was removed to room temperature and kept there for ten days, but no hatching occurred. In a control test at 80°F., 94 per cent of the eggs not subjected to cold were viable.

2. Larval stage

Larvae were able to survive considerably longer than eggs at 40°F. The results are summarized in Table V. Larval survival was determined by the number of larvae that formed normal pupae at room temperature. Table V summarizes the results obtained from a test which involved larvae of all ages. In other tests, newly-hatched larvae survived for nine days at this temperature. When they were transferred to a fresh

TABLE V

SURVIVAL OF HOUSE FLY LARVAE AT 40°F.
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No. of larvae removed from cold room	No. of days at 40°F.	No. of normal pupae formed	% normal pupae	No. of adults emerged from pupae
100	11	60	60	32
100	14	44	44	16
100	18	4	-	-
100	22	-	-	-
200	29	-	-	-

medium at room temperature, a large number of them completed their development, pupated and adults emerged. After nine days at 40°F., although some pupae appeared normal and healthy in the cold room, they did not develop further at room temperature. They turned brown then black and died in a few hours.

The half grown larvae survived for 15 days at 40°F. After this period most of them died in the cold room or very shortly after being brought into warmer temperature. No growth in size occurred in the cold room.

Full grown larvae survived for 23 days in the cold room. No normal pupation occurred in the cold room. After about 10 days in the cold, the maggots began to form abnormal pupae (Figure 8). These had the shape of a larva but the hard puparium of a pupa. As the time in the cold increased, more

FIGURE 8

ABNORMAL PUPAE FORMED BY MATURE HOUSE FLY LARVAE AT 40°F.

THE UNIVERSITY OF MANITOBA

1954-55

FIGURE 8

of these metathetelic pupae were formed. Hundreds of the abnormal pupae were removed to room temperature but no adults emerged from them. The maggots also became spotted after about two weeks in the cold room. These maggots were alive and moved in the cold but when they were removed to a warm room the whole body became brown, then black and the maggots died very shortly. The full grown larvae were considerably more active in the cold room then the younger larvae. When they were exposed to light, many of them burrowed back into the medium. After about two weeks in the cold room many were still capable of crawling when they were placed on paper in light in the cold room. The younger maggots were completely immobile and inactive in the cold room. A few managed to move the anterior part of their body but the majority merely contracted their bodies and remained so. One of the strangest enigmas encountered in this work is the observation that many normal, healthy and active cold larvae removed to a warm temperature turned brown and died in a few hours.

3. Pupal stage

Survival of pupae was based on the number of adults that emerged when removed to room temperature. The results are summarized in Table VI.

It is apparent that of the immature stages, pupae are the most cold resistant at 40°F. Complete mortality at this temperature requires about seven weeks as compared with about

TABLE VI

SURVIVAL OF HOUSE FLY PUPAE AT 40°F.
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No. of pupae removed from cold room	No. of days at 40°F.	No. of adults emerged at 75°F.	% emergence
92	8	65	70.6
30	15	8	26.6
25	20	3	12.0
100	30	3	3.0
100	39	3	3.0
100	45	1	1.0
200	51	-	-

three weeks for full grown larvae. The mortality rate of the pupae increased very rapidly after two weeks in the cold room. It is very doubtful that this mortality was due to desiccation because in the course of the test many pupae were examined and very few were dry. After about seven weeks in the cold room, most of the pupal cases contained rotted immature bodies.

In another experiment, mature pupae survived for only 21 days in the cold room. Young pupae survived for 29 days.

No emergence occurred in the cold room. Toward the end of the survival period adults had considerable difficulty in freeing themselves of the pupal cases. Often only the anterior part of the body emerged and the abdomen remained in the case. The insect was unable to free itself and died in a few hours. Many adults emerged successfully but died in a few hours although food and water were provided for them.

4. Adult stage

A few of the adult house flies were able to survive for about five weeks in the cold room. Six flies survived for this period and when they were removed to a warm room they lived for about another week and then began to die. Only one fly survived for ten days after removal from the cold room. Considering that the flies were one week old when they were put in the cold room, the total life span of the longest surviving adult was about seven weeks.

When the flies were first placed in the cold room they clustered in the corners of the cage and many were quite active for about one week. After about two weeks in the cold the clusters appeared to break up. At this time the mortality began to increase and the flies were very sluggish and inactive. Although many of the flies were resting on the sugar and wet paper, feeding was not observed.

During the experimental period several flies were removed at weekly intervals from the cold room and provided with an egg laying medium. In a warm room these flies soon became active and readily laid viable eggs.

Summary

Observations made during the winters of 1953-54 and 1954-55 provided evidence that house flies can breed continuously through the winter in heated dairy and swine barns. Observations made during December, 1954, showed that adult house flies were able to survive until the end of December in unheated dairy and swine barns near Fort Whyte, Manitoba.

Cold resistance of the various stages of the house fly was studied during the winter of 1954-55 in a cold room at the Department of Entomology, The University of Manitoba. The results indicate that at 40°F. the egg stage is the least resistant to cold. Eggs survived for only four days in the cold room. Larval survival varied from nine to 23 days, increasing with age. The pupal stage proved to be the most resistant to cold at 40°F. Pupae survived up to 45 days. No larval growth occurred in the cold room nor did any adults emerge from the pupal stage. Adults survived for approximately five weeks in the cold room.

Conclusions

The results from this investigation and from previous work by other investigators strongly indicate that the immature stages of the house fly are capable of adapting themselves to adverse cold conditions. If this is true then there is strong circumstantial evidence to suppose that house flies can overwinter by slow development in most well constructed barns where animals are kept all winter in Manitoba. To substantiate or refute this hypothesis, careful observations will have to be made in the barns in early spring for house fly activity. If living house flies can be found in barns before the weather outside is warm enough for flight, there will be no doubt that the flies overwinter in Manitoba.

When it is definitely established that house flies overwinter in Manitoba in favorable sites, the problem of dispersion will become very important. Undoubtedly not every farmstead or barn will be favorable for house fly overwintering. Certain favorable barns will serve as loci for fly breeding and from which fly populations disperse to other farms. If these centers of infestation are disinfested before fly activity commences in spring, the fly population in a community may be lowered. This aspect of house fly control has been overlooked by investigators and yet perhaps may be the most efficient and inexpensive method of control. Further research should be directed along this line to determine the plausibility and practicability of such a scheme.

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