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A STUDY OF THE BIONOMICS AND CONTROL OF CERTAIN TABANIDAE (DIPTERA)

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A study of the bionomics and control of certain Tabanidae (Diptera)

by

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Thesis submitted in partial fulfillment of
the requirements for the degree of

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Introduction

The struggle between man and insects has been going on since the early days of history. Insects not only eat a considerable portion of our crops, destroy large amounts of household equipment, disturb livestock, but also transmit serious disease pathogens among man and animals. Man, on his part, has conquered a good many of these pests. Diseases like plague and malaria which used to sweep city after city have practically become things of the past, at least in some parts of the world. However, there still remain many disease-carrying and irritating pests against which little progress has been made so far. Tabanids are one of these.

The family Tabanidae is of great importance from a medical as well as an agricultural point of view. They are a cause of nuisance to man both directly and indirectly, directly by attacking man himself and indirectly by feeding on his animals. But despite their great importance, our knowledge of the bionomics and control of these flies is fragmentary and very little has been accomplished toward their eradication.

The present work was undertaken with two objects in view. First, to investigate the effects of various environmental factors influencing the activities of these flies at various stages of their lives, and second, to find the potentialities of some of the modern synthetic insecticides in controlling them. Consequently the studies are divided into two parts, bionomics and control.

During the present studies 'bionomics' has been used more or less synonymously to 'ecology' to denote the relationships of Tabanids to their environment.

Of the 27 genera (Philip, 1947) comprising the Tabanidae of the Nearctic region, only two, _Tabanus_ and _Chrysops_, were selected for study, this selection being based on their greater economic importance of all the genera in the family.

The species included during the present studies were _Tabanus lineola_ Fabr., _Tabanus quinquevitattus_ Wiedemann, _Tabanus reinwardtii_ Wiedemann, _Tabanus melanocerus_ Wiedemann, _Tabanus atratus_ Fabr., _Tabanus superjumentaris_ Whitney, and _Chrysops callida_ Osten Sacken.

In studies on bionomics, Part I, the literature has been reviewed along with the original observations in each section, while in Part II on control the literature is reviewed in a separate section.

Economic Importance

As pests of agricultural importance, tabanids produce losses of tremendous value. Their bites not only cause loss of blood, but are so irritating that animals give up grazing during the hours of fly activity. Thus a considerable loss is caused by these flies interfering with the feeding of the animals. Webb and Wells (1924) state that during the day when the flies are active, the livestock stop feeding and bunch together to save themselves from attack. It has also been reported that fattening of the cattle is greatly retarded by these flies. When the fly population is great, the attack may be so serious that the animals run away in harness, which sometimes results in serious accidents, as casualties, destruction of fences, machinery and the like. The writer has noticed that on days when the flies were abundant, the animals were continuously moving their heads and tails in attempting to avoid the flies. Sometimes they were seen bunched together under the shade of trees, and when driven out into the field, were reluctant to go, presumably because of the flies.

Another loss suffered from tabanid attack is that of reduced milk supply from disturbed animals, as a result of fewer hours of feeding. Howard (1916) makes a surprising remark on fly conditions in Minneosta, in saying that the presence of these flies reduced milk supply 100 per cent in three weeks.

When abundant, not only the domestic stock suffer but, in the words of Lugger (1896), "The moose and deer, attacked by such tormenters, lose all fear of man and plunge into rivers and lakes to escape their attack; they soon become very poor, as they have no rest to feed excepting at night."

Tashiro and Schwardt (1949) have made an estimate of the loss of blood caused by these flies. They weighed fully engorged and unfed females of *T. quinquevitattus* Wiedemann and *T. sulcifrons* Macquart and concluded that a single *T. quinquevitattus* could take an average of 0.074 cc. of blood, while a single *T. sulcifrons* could take 0.35 cc. of blood. Webb and Wells (1924) point out that eight flies of *T. phaenops* Osten Sacken, when fully fed, took one cc. of blood. They also state that the amount of blood taken depends primarily on the size of the fly, the bigger the fly the larger the amount of blood taken. It should be noted, however, that the above figures are by no means complete. Almost always when the fly leaves the host, blood continues to flow from the feeding wounds, which results in an increased loss of blood. The feeding wounds made by the tabanid flies open a way for the attack of other organisms. During the present studies it was a common sight to see the hornflies on such wounds. Such wounds also may make the animals susceptible to the attack of microorganisms.

Man also is subject to their attack. Kono and Takahashi (1940) report the stopping of a railway construction because of these flies biting the workers.

The bite of a horsefly is often painful. The author has been bitten on several occasions by specimens of T. quinquevitattus and T. lineola. Except for one time no swelling was noticed, though the bite caused a slight irritation each time. Once when bitten on the palm of the hand, swelling and slight irritation resulted, which disappeared in from two to three days.

Along with other blood-sucking diptera, tabanids have been seen to attack the skins of animals. Dinulescu (1939) states that although no evident injury resulted from their attack, such skins have been stated to crack during the process of tanning.

From a medical point of view, also, the family is important. Certain members of the family are vectors of important human and animal diseases. They act both as mechanical vectors and as intermediate hosts for various disease pathogens. Matheson (1950) has discussed the relation of tabanids to human and animal welfare, and the following account is based mainly on his work.

The filarial worm *Loa loa* Cobbold has been recovered from man for more than a hundred years. The microfilarae are found in the peripheral blood vessels generally between 9 A.M. and 2 P.M. It has been shown experimentally by the Connals (1921,1922) that *C. dimidiata* v.d.Wulp and *C. silacea* Aust. while feeding take up the microfilarae which in turn bore through the gut and come to lodge in the thoracic and abdominal muscles, where further development takes place. Mature larvae appear in the proboscis within 10 to 12 days, and the fly becomes infective, a condition which may last for five days. There is, however, every possibility that besides these two flies other species of Tabanidae on account of their blood-sucking habits serve as vectors of the disease.

Undoubtedly any of the blood-sucking tabanids are capable of mechanically transmitting the various species of trypanosomes, if they feed on the infected animals for a brief period and then immediately fly off to a susceptible host. This often happens in nature, where due to some reason or other a fly is unable to complete its blood meal on one animal and so goes to another. *Trypanosoma evansi* which is the causative agent of the highly fatal "Surra" disease has been shown to be transmitted in this manner by several species of tabanids (Matheson, 1950). Besides, they have been shown to transmit several other species of trypanosomes, as <u>Trypanosoma souanese</u> causing the "Elde bab" of camels.

It has been shown by Francis and Mayne (1922) that <u>C. discallis</u> Willist. is responsible for transmission of the bacterial disease "Tularemia" among guinea pigs and rabbits. According to them, transmission is entirely mechanical and the fly can remain infective up to 14 days after taking an infective meal. They have also shown that this fly obtains bacterium from jack rabbits and can transmit it to man, and is therefore responsible for numerous cases of "Tularemia" among humans.

That Anthrax can be transmitted mechanically by tabanids has been proved by Mitzmain (1914), who allowed the flies to feed on highly infected guinea pigs for some time and then transferred them to healthy animals. Mitzmain's claim has been further supported by Morris (1918) who showed transmission of the disease through the agency of <u>Tabanus</u> sp.

On the other hand, tabanids most probably play an important part in the pollination of saw palmettos belonging to the genus <u>Seronoa</u>. Mosier (1919) points out that saw palmettos on which the males of T. lineola and T. atratus were commonly feeding bore heavy crops of fruits in comparison to others. He suggests that this possibly was the result of pollination by these flies. However, this is a phase which demands further investigation, although it is quite likely that the males of different species, because of their feeding habits, are serving for the pollination of some of the beneficial plants.

Part I - BIONOMICS

Oviposition

General.

The oviposition of Tabanidae is a very interesting sight to watch. Since the great majority of their larvae are semi-aquatic, it is natural to assume that the eggs are laid in close proximity to water. This fact has been true in all cases observed by the author. However, it is sometimes difficult to find the egg masses of even the most common species in a particular region. T. nigrovitattus Macq., for example, is a very abundant species in some parts of the United States, but as yet nothing is known regarding its oviposition sites. Cameron (1926) is of the opinion that the shy and elusive nature of many species, together with very wide oviposition conditions, are mainly responsible for the negative results obtained in locating the eggs. Weston et al (1948) suggest that probably the extensive areas on the surface of marshes provide suitable places for T. nigrovitattus to deposit its eggs. The wide and varied larval habitat of species like T. nigrovitattus suggests that the eggs are laid on or near the ground over extensive areas which are suitable for their growth and development.

The oviposition sites of Tabanidae have been classified by Stone (1930) into the following four categories:

"1. Foliage or other objects over shallow, quiet water; the edges of shallow pools, etc.

2. Foliage or other objects over relatively deep water, as on water plants a considerable distance from shore, and on ledges over deep water.

3. Stones projecting above the bed of a flowing stream.

4. Vegetation over either moist or quite dry soil."

The method of oviposition is nearly similar with all the Tabanidae. Hine (1906) describing the process for C. moerens Walker says: "The female alights on the leaf with her head downward and begins the process by pushing the tip of her abdomen forward toward the under part of the thorax and placing the protruding end of an egg against the leaf. The end sticks fast in consequence of the glue-like substance which accompanies it, and she then moves the tip of her abdomen back to its normal position, thus freeing the egg. By similar movements one or two eggs are placed to one side of the first, and two or three on the other side of it. The unfinished end soon becomes V-shaped; she moves slowly forward and lifts the tip of her abdomen to one arm of the V and places eggs along down to the apex on this side. It was noted in specimens of this species observed that sometimes a female would place as many as three rows of eggs on one side, one after the other, before changing to the opposite side." Rau (1935) describes the egg laying of _T. atratus_ Fabr. in these words: "In the bright afternoon sunshine of a hot July day, the mothers took positions on the twigs, head downward, pumped the eggs out of the body and simultaneously packed them together, making a neat egg packet of the mass, ... The eggs were packed very close and adhered to one another."

Effects of environmental conditions on the oviposition of C. callida O. S.

Observations on the egg laying habits were made by the author, both in the field and in the laboratory. In the field, _C. callida_ O. S. was frequently observed ovipositing. The author has collected egg masses from _Iris versicolor_, _Sagittaria latifolia_, _S. latifolia_ forma _gracilis_, and _Agrostis alba_. This species apparently does not have any preference for leaf surfaces. Eggs have been collected on both the upper and lower surfaces and even on the leaf stalk. It seems, however, that smooth surfaces are preferred as a majority of egg masses were laid on such surfaces.

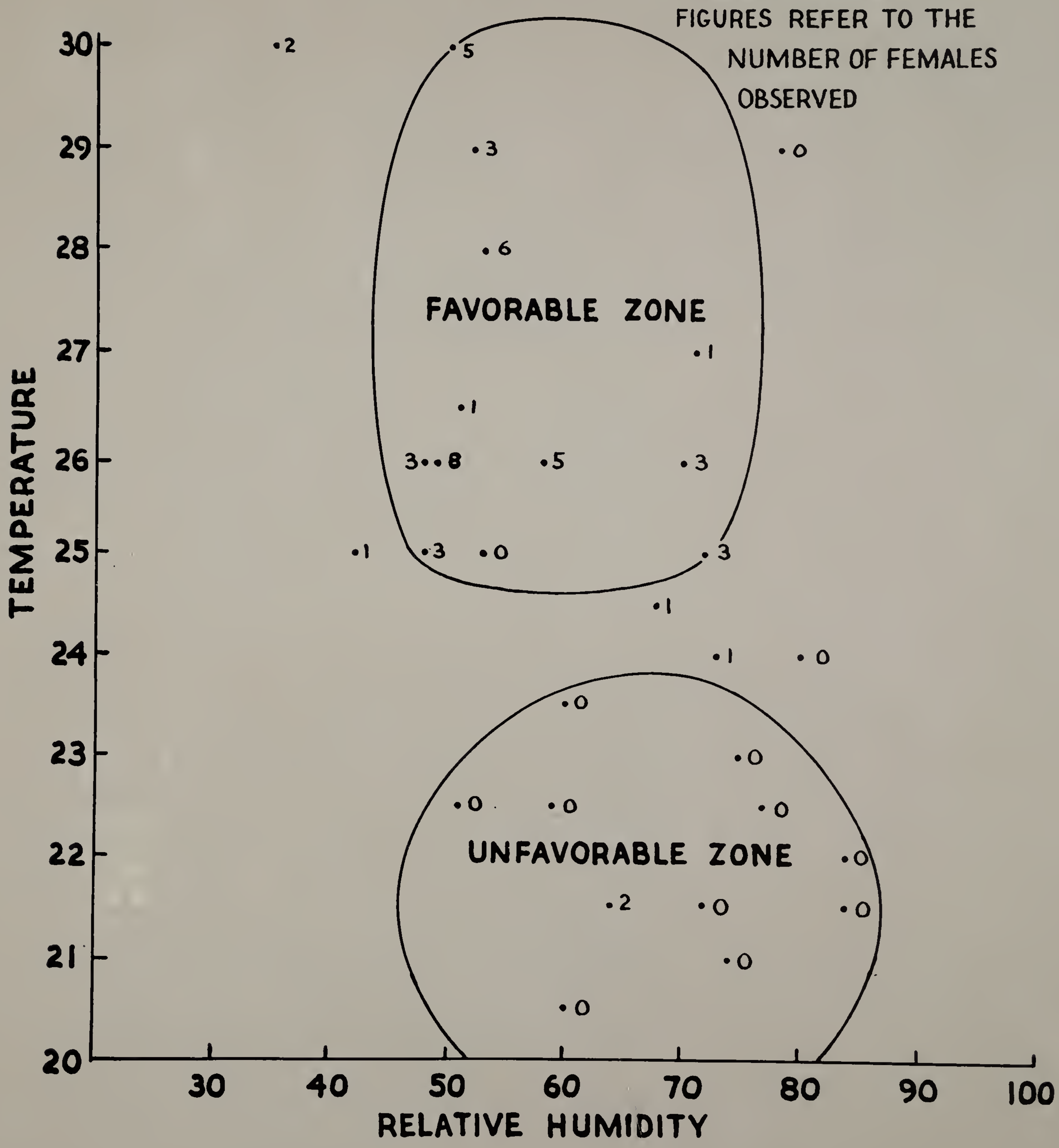
To investigate the time of day preferred by these flies for laying eggs, the oviposition sites were visited continuously in the morning between 7 and 9, and 11 and 12; in the afternoon between 5 and 6, and around 8, during the egg laying season of the species. It was only between 9 A.M. and 6 P.M. that the females were frequently observed in the act of oviposition.

The question arises as to what physical factors are responsible for this sequence and regularity in egg laying habit. Light has some significance in the oviposition of this species, as a great majority of egg masses collected were deposited on the plants growing on open sunny sides of the pond, as compared to those in shaded areas. This is further substantiated by the fact that within a range of 24° - 29° C. many more ovipositing females were observed on sunny days than on cloudy.

Temperature and relative humidity are important factors influencing oviposition (Figure 1). It appears that the favorable zone lies between 24.8° - 30.2° C. and 44 - 76 per cent relative humidity. The significance of temperature is shown by the fact that between identical range of relative humidity, oviposition was noticed above 24° C. but not below it.

Air movement or mechanical jarring of vegetation did not readily affect oviposition activities.

FIGURE I - EFFECT OF TEMPERATURE AND RELATIVE HUMIDITY ON THE OVIPOSITION OF C. CALLIDA O.S.



Another species observed while laying eggs in the field was _T. atratus_. The oviposition of this species has been recorded by several workers both in the field and under laboratory conditions. Hine (1906) observed oviposition at 11 A.M., and Rau (1935) on a warm sunny afternoon in summer. Schwardt (1932) obtained eggs on rice plants with caged females. The author observed oviposition in the field on two occasions, at 1 and 3 P.M. On both occasions the females were in relative shade, in contrast to the females of _C. callida_ which were simultaneously ovipositing in bright sunshine.

Oviposition under laboratory conditions.

Most workers have had little success in inducing tabanids to oviposit under caged conditions. Patton and Cragg (1913) constructed a six-inches deep iron tray containing water plants and covered with mosquito netting over a wire framework, and found such cages suitable for oviposition purposes. Later, cages built on the same plan have been used successfully by Webb and Wells (1924), after trying in vain a screen wire cage 5 feet high and 10 feet square constructed partly over water of a sluggish stream and containing a seven-month old calf besides water plants and other vegetation.

Cameron (1926) obtained egg masses from newly emerged females of C. fulvaster O. S. and T. reinwardtii Wiedemann in glass jars and vials. He also constructed cages for oviposition after the manner of Patton and Cragg (1913), and tried C. moerens Walker, C. mitis O. S., C. fulvester O. S., T. septentrionalis Loew, and T. reinwardtii Wiedemann for oviposition. All these species were reared in the laboratory and fed on sugar solution. Only C. mitis and C. moerens oviposited, the former laying one egg mass and the latter two. Cameron also tried in vain females captured by sweeping among grasses and around sloughs and taken while feeding on animals. Chrysops feeding on humans were also tried, but with negative results.

During the present work, engorged flies were collected in the field immediately after they had finished their blood meals on the animals, by placing wide-mouth vials over the flies. At first the flies were transferred to larger bottles containing grass leaves, but moisture condensed on the walls and killed the flies. Later the flies were transferred to cardboard cages covered with meshed cloth and lacking vegetation. In this way they were transported successfully to the laboratory.

The types of cages shown in Figures 2 and 3 were used for oviposition. The cages in Figure 2 were constructed of tarlatan cloth and corrugated cardboard. "The fabric was sewn by machine into nearly rectangular bags, each of which was then stapled to a cardboard end. The ends contributed rigidity to fabric cages and permitted installation of a simple, workable door which was held closed by friction alone." (Spear, 1950). A jar or dish containing plants of *Iris versicolor* was placed in each cage. Cloth soaked in honey solution was offered as food. Two to seven females were introduced in each cage, and the cages exposed at three different temperatures and humidities. Four species tested were *T. quinquevitattus* Wiedemann, *T. lineola* Fabr., *T. lasiophthalmus* Macq., and *T. superjumentaris* Whitney. A few females each of *T. quinquevitattus*, *T. lineola*, and *T. superjumentaris* oviposited (Table I).

Table 1

Oviposition of Tabanidae under laboratory conditions

	Temperature and relative humidity					
	24 - 26° C. 54 - 73 p.c.		24 - 31° C. 43 - 73 p.c.		27 - 30° C. 55 - 79 p.c.	
Species	No. of females	No. of egg masses	No. of females	No. of egg masses	No. of females	No. of egg masses
T. quinquevitattus	62	0	50	4	40	1
T. lineola	43	4	35	4	15	0
T. lasiophthalmus	30	0	45	0	25	0
T. superjumentaris	4	0	6	3	2	0

Significant results were not obtained, because of the low number of egg masses laid by each species. There may be several reasons for such a low oviposition. It is possible that most of the females collected had not mated before, or that the females require a blood meal before laying eggs. Also it is likely that the caged conditions produced an unfavorable environment for oviposition.

Cages used for oviposition

Figure 2. Tarlatan cloth and corrugated cardboard cages

Figure 3. Wire mesh wooden cage

Eggs

General features.

The eggs of Tabanidae are laid in masses, mostly in the vicinity of water. There is, however, a great variation in the selection of the oviposition sites. Some species almost always deposit their eggs on particular plant species, while others do not show any affinity for specific plants. T. stygius Say always oviposits on the upper surface of the Sagittaria leaves and, as Hine (1903) points out, "So closely is this habit followed that a hundred masses are found thus located to one placed otherwise." On the other hand, C. callida O. S. observed by the author deposits its eggs on several species of grass plants and wild iris equally well.

Patton and Cragg (1913) point out that the selection of oviposition sites has a very definite correlation with the future fate of the larvae. T. albimedius Walk., T. speciosus Ricardo, and the like, whose larvae are bigger and can swim well, lay their eggs over deep water, while the larvae of smaller species like T. ditaeniatus Macq., being devoid of air sacs and thus being weak swimmers, are liable to die if dropped in deep water. Such species have invariably been found to deposit their eggs on grass blades over shallow streams and small ponds, but never over deep water.

Cameron (1926) has, however, obtained egg masses from newly emerged females of *C. fulvaster* O. S. and *T. reinwardtii* Wiedemann in glass jars under laboratory conditions.

The number of eggs per mass is variable and differs with individuals and species. According to Stone (1930) the number of eggs in individual masses of Tabanidae varies between 100 and 800. The writer made counts of ten egg masses of *C. callida* which varied between 107 and 306, with an average of 240.5 eggs per mass. Two egg masses of *T. superjumentaris* Whitney laid in the laboratory contained 96 and 128 eggs, and those of *T. lineola* Fabr. 110 and 216. It was noticed in the case of *T. lineola* that the size of the egg masses laid in the laboratory was definitely smaller than those laid in the field. This may have been due to dietary deficiency. It has been suggested by many workers that a blood meal is necessary for oviposition. In all cases the eggs laid in the laboratory were deposited several days after a blood meal, during which time the females were offered honey solution. It may be that the lack of a blood meal resulted in the reduced size of the egg masses.

The coloration of eggs presents an interesting problem. All the egg masses of C. callida observed when freshly laid were white in color. The color changed to lustrous black in four to five hours, under laboratory conditions, and in one to two hours in the field when exposed to sunlight. However, egg masses of T. lineola and T. superjumentaris deposited in the laboratory retained the original whitish brown and shiny white color until hatched. These observations, in the case of C. callida, are strongly suggestive that the change of color is stimulated by higher field temperature and some fraction of light absent in laboratory, being much more rapid in bright sunlight than under laboratory conditions.

The eggs are cylindrical in shape, tapering toward the ends. The length varies between 1 and 2.7 mm. and the diameter between 0.2 and 0.4 mm. (Stone, 1930). Generally the species of Tabanus lay their eggs in several layers while those of Chrysops deposit only single layers. However, a few species, as C. celar O. S., lay several tiers of eggs.

Considerable time is required to deposit an egg mass. In two laboratory observations T. superjumentaris took 56 and 58 minutes to deposit egg masses. Females of C. callida observed in the field utilized 56 and 68 minutes for oviposition. Three times the females of this species were seen to fly away after 20 to 36 minutes of laying the eggs, probably because of some disturbance. The incomplete egg masses deposited by such females were smaller in size in proportion to the time utilized. The flies do not return to complete such egg masses. Presumably oviposition is completed elsewhere.

Not all the eggs or egg masses hatch, for various reasons. They may be parasitized by other insects, unfertilized, or attacked by microorganisms.

The incubation period is variable, largely as a response to temperature. Stone (1930) noted that the egg stage was prolonged in cool and cloudy weather, and Segal (1936) concurs in this opinion.

Effect of temperature on the hatching of the eggs of C. callida O. S.

Egg masses of *Chrysops callida*, collected shortly after being laid in the field, were incubated at three temperatures. Each leaf containing the egg mass was fastened to a cork with a pin and hung in a bottle containing water, as shown in Figure 4. The larvae after hatching fell into the water. This technique was very useful for collecting young larvae, as they survived in the water for more than 24 hours.

Figure 4. Egg bearing leaves pinned to corks in bottles

Table 2

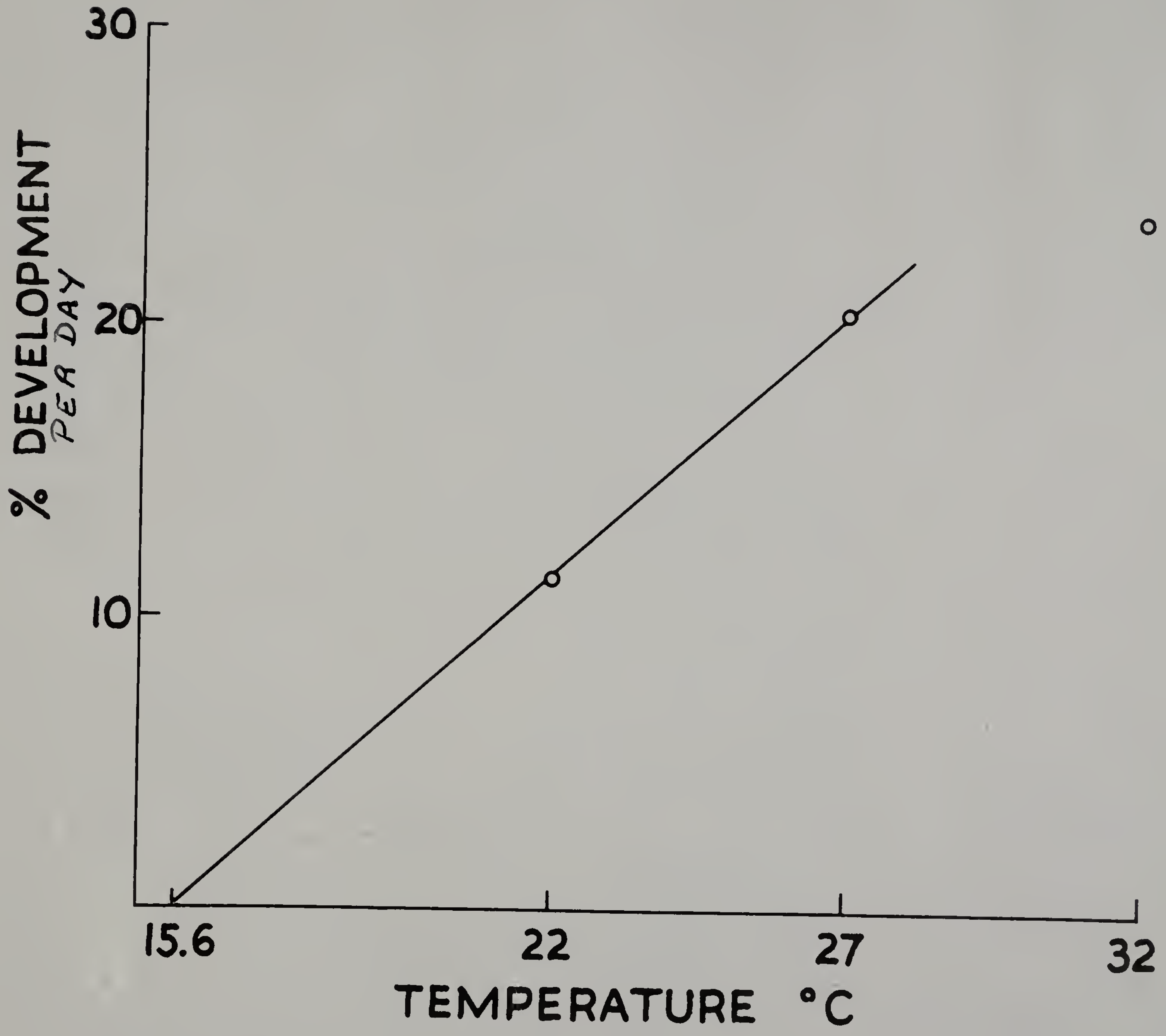
Duration of the egg stage of *Chrysops callida* at various temperatures

Temperature Degrees C.	Days to hatch 3	4	5	6	7	8	9	10	11	Average duration
22	0	0	0	0	3	1	2	2	2	8.9
27	1	2	6	0	0	1	0	0	0	4.9
32	2	5	2	1	0	0	0	0	0	4.2

It is evident that the incubation period decreased with an increase in temperature from 22° to 32° C. This suggests the probability that under field conditions eggs exposed to direct sunlight, because of increased temperature, would hatch sooner than those in the shade.

The threshold temperature for the development of eggs, as established by Figure 5, lies at 15.6° C. (Chapman, 1931). During the course of the present work it was also noticed that somewhat greater numbers of egg masses hatched at 27° C. than at 22° C.

FIGURE 5 - EFFECT OF TEMPERATURE ON THE DEVELOPMENT OF C. CALLIDA EGG MASSES



Larvae

General Characters.

Tabanid larvae possess eleven body segments, in addition to head and siphon. The small retractile head is provided with strong mouth hooks, which are adapted for piercing and extracting the contents of their prey. The antennae are well developed. The cylindrical body, tapering at both ends, has a shiny transparent striated integument through which the principal body viscera are usually visible. The siphon bearing the opening of the respiratory system at the end of the anal segment is capable of retraction and extension. A very characteristic feature of the larvae is the longitudinal striation of the body. The general coloration is variable. It may be white, white tinged with green or pink, greenish grey, brownish yellow, or chlorophyll green.

The larvae are metapneustic. There are two main tracheal trunks, conspicuously visible through the transparent integument. The diameter of these tracheal trunks along the body length differs in the two genera, Tabanus and Chrysops, and is important in separating them, as suggested by Marchand (1917). In agreement with Marchand it was observed that the diameter of the tracheal trunks in Chrysops larvae was uniform throughout the body, while

Tabanus larvae had somewhat inflated trunks posteriorly. These tracheal trunks end in a dorsally located spiracle on the siphon (Segal, 1936).

The most unique character of these larvae is Graber's organ, lying in the penultimate segment and visible through the two tracheal trunks in the living organism. This complex organ was discovered in 1878 by Graber. Segal (1936) has ably discussed this organ and the following account is based on his work. The principal part of Graber's organ is a chitinous sac enclosing within it small secondary capsules. The sac is invested externally by an epithelium similar in nature to the epithelium of the integument. This similarity according to Cameron (1926) suggests the possible origin of Graber's organ as an invagination of the integument. The capsules contain fluid in which are suspended black globular bodies held in position by a membrane. The number of these bodies within the organ varies with different species and new ones appear after each molt. The organ is provided with a muscular mechanism which controls its movements and has nerve attachments. The smaller capsules within the functional sac are remains of sacs of earlier instars.

The function of the organ is still in dispute. Graber (1878) assigned an auditory function to it because of its similarity to an otocyst. Lecaillon (1905-1906) is of the opinion that the organ has a glandular rather than sensory function. Paoli (1907) regards it as a sound-producing organ, which as Cameron (1926) points out is hard to believe, for according to him the clicking noise of the larvae in all probability is produced by the striking together of the mandibles and the maxillae. It has also been suggested by some workers that the noise is produced by the telescoping of the abdominal segments during locomotion. Cameron (1926) states that when the larva is at rest, the organ is practically stationary, except for occasional very slightly perceptible oscillations, but as it moves, the oscillations assume a frequency. To him the action of the organ and its otolith-like pigmented bodies suspended in the fluid of the capsule strongly suggest a static function to bring about the maintenance of equilibrium and orientation of the organism.

The larvae are either saprophagous or carnivorous or both. The mouthparts are well adapted for piercing and tearing the prey, which includes earthworms, snails, fly maggots, other available insect larvae, and the like. The process of feeding is similar with all species. Stone (1930) has described the feeding of T. reinwardtii Wiedemann and T. atratus Fabr. in these words: "Contact is made by means of a sharp downward thrust of the mandibles. (If one touches the head of a large Tabanus larva with a pair of forceps, a distinct click can be heard as the mandibles strike the metal. This downward thrust may be felt as a sharp, stinging prick if it strikes the hand, not sufficient to break the skin, but smarting for several hours after it occurs.) Having secured a hold, by means of a twisting, chewing motion an opening is made in the side of the worm and the whole head thrust in. Then turning first one way and then the other, the fluid contents are sucked out and they can be seen flowing through the pharynx and making the mid-gut red."

In the above quotation "smarting" without breaking or piercing the skin appears to be surprising. The writer could not verify the above statement, for every time a larva was handled it tried to crawl and escape instead of prickling the skin.

The efficiency of tabanid larvae in penetrating the soil and their great powers of crawling through small and narrow spaces is very noticeable. Several times the larvae when placed in the hand readily forced their way between the finger bases. They exhibit strong negative phototropism.

According to Stone (1930), "They cannot survive in frozen soil, at least if it is moist, as the writer discovered when trying to imitate natural conditions."

This suggests that in the natural environment, during winter, before the soil becomes frozen, the larvae migrate deeper into the soil.

Ecologically the larvae inhabit hydrophytic, mesophytic, or lotic areas. Though some species having well developed tracheal trunks can float on water, a great majority of them burrow in soil or mud soon after hatching. The feeding period lasts from the time of hatching until the approach of winter. During the winter the larvae cease feeding and hibernate. With the oncoming of spring, the larvae again renew feeding and after a time pupation may result. The pupation time is variable, differing with different species and even within the same species.

Collection.

Various methods have been used by different workers for the collection of tabanid larvae. Collection is often difficult, either because of their wide or varied distribution or because the larvae are not abundant, but this becomes comparatively easy with experience. Marchand in 1917 advocated his "sieve method" in which a lump of mud from a suitable locality is taken into a sieve and gently shaken in water. The soil is thus washed away and the larvae exposed. As the larvae are frequently found clinging to the grass roots, it is sometimes desirable to seize the bundles of the sod by the roots and shake them into the sieve with water thus exposing the larvae.

Subsequent workers discarded Marchand's device. Cameron (1926) and Philip (1928) used a hand fork and horticultural weeder, respectively. The method consisted in turning over the soil and thereby exposing the larvae. Philip (1928) recommends a special method for Chrysops larvae, consisting in wading along a steep margin and loosing the soil above the water edge by the weeder. The larvae are picked up as they appear. The remaining larvae are collected by pouring water on the loosened dirt.

Cameron's and Philip's methods are basically similar and have a great advantage over Marchand's sieve in that by the use of a hand fork or other tool it is possible to examine a much greater area in less time. However, these methods do not hold much promise, at least in cases where larvae are desired for rearing purposes, since they may be injured. Marchand's method, though much slower, is still the safest to collect the larvae for rearing and other experimental purposes.

A group of workers have recommended the transportation of mud from infested areas and recovering the larvae in the laboratory by drying the mud. Stammer's method (1924) consists in separating the soil from detritus by washing and placing the detritus in a strainer over a shallow pan of water. In this way the larvae fall into the water due to the drying of the detritus from the top. The remaining smaller larvae are obtained from the soil by sieving.

Logothetis and Schwardt (1948) dried sod over a screen wire, and Tashiro and Schwardt (1949) working with the same principle constructed an especial apparatus for larval collection. They, however, employed heat to activate the drying of the sod. The larvae were collected in pans of water as they migrated downwards as a result of surface drying.

The present work was started with the sieve method and at first a spade was used for digging. Digging with a spade was soon discarded in favor of a hand trowel. This made the work easier and gave as good or better results. The procedure consisted in cutting the vegetation from the selected areas, each area being one square foot; digging a few inches (4 - 6) deep, and placing the soil in a sieve. The sieve was then gently shaken in the water to wash off the mud. During this shaking the big larvae were easily detected and picked up with a forceps. They were placed in suitable tin containers and brought back to the laboratory.

Often the larvae were tangled in the roots of the plants. The method is quite satisfactory for collection if a small number of larvae are desired and the collector is quite sure of their distribution, but has its greatest drawback in being time consuming.

Population survey.

Bailey (1948) successfully used a pyrethrum-kerosene emulsion called "New Jersey mosquito larvicide" as a means of mass collection and population survey of tabanid larvae. This formulation was developed in 1930 ~~by~~ Ginsburg (1939) at the New Jersey Agricultural Experiment Station. Bailey diluted the concentrate seven to eight times with water and after cleaning away surface vegetation applied two gallons of the mixture to five square yards.

The writer used the "New Jersey mosquito larvicide" for the population survey. It contained 65 per cent of active ingredients composed of petroleum distillate, sodium lauryl sulfate, thiodiphenyl amine, and pyrethrins. The vegetation was cleared with a hand sickle and the emulsion, diluted from one to eight to one to twelve, was applied to square foot areas at the rate of one gallon to four or five square feet.

Within two to five minutes a number of organisms, including the tabanid larvae, came to the surface. Ten areas were observed at a time and the larvae collected with a forceps as they appeared. The retreating of the larvae from the mud was produced by the pyrethrum. Such larvae were paralyzed shortly after their appearance on the surface.

Table 3

The larval population of Tabanidae along the edge of the College pond (1949)

Number of square feet examined	Number of larvae collected Per sq. ft.	Total
13	0	0
9	1	9
9	2	18
4	3	12
3	4	12
1	6	6
1	10	10
Total 40		67
	Average per square foot	1.675

Table 4

The larval population of Tabanidae along the edge of brook (1949)

Number of square feet examined	Number of larvae collected Per sq. ft.	Total
10	0	0
6	1	6
7	2	14
1	3	3
2	4	8
1	7	7
1	8	8
1	9	9
1	10	10
Total 30		65
	Average per square foot	2.16

Table 5

The larval population of Tabanidae along the edge of brook (1950)

Number of square feet examined	Number of larvae collected Per sq. ft.	Total
60	0	0
22	1	22
6	2	12
9	3	27
2	4	8
1	6	6
Total 100		75
	Average per square foot	0.75

The major species involved at both the pond and brook included T. quinquevitattus Wiedemann, T. lineola Fabr., T. reinwardtii Wiedemann, and T. atratus Fabr. In addition, Chrysops larvae formed a considerably greater proportion along the college pond than along the brook.

Tables 4 and 5 show a marked difference between the larval populations along the same brook during two consecutive summers. The collections were made along the same brook both summers. Possibly the insecticidal applications during the first season destroyed the young larvae hatched following the treatments, as at least the kerosene might remain for some time.

The ease and effectiveness of the above method for making population surveys suggested its use for collection of larvae for rearing purposes. The larvae as they appeared were immediately transferred to untreated mud, brought back to the laboratory and placed in separate cans with food. Larvae collected by the "sieve method" were handled similarly as checks (Table 6).

Table 6

Effect of "New Jersey mosquito larvicide" on larvae

Number of larvae	Number dead after 25 hours	Number survived ten days	Percentage survival
40 (treated)	23	17	42.5
10 (untreated)	0	10	100.0

Since 42.5 per cent of the treated larvae appeared normal after ten days, this seems to be a satisfactory method of collecting larger larvae for rearing studies. During the test the smaller larvae were more susceptible to the insecticide. Adults of *T. quinquevitattus* and *T. lineola* have been reared from the larvae thus collected.

The larvicide was used successfully with dilutions of 1:14. At a dilution of 1:19 only one larva was collected in twenty square feet, but as stronger concentrations were not used to determine if larvae were missed due to greater dilutions of the insecticide, any precise statement regarding the inefficiency of the dilution cannot be made.

Movements in soil.

Except for occasional references stating their wide and varied occurrence a few inches deep in the soil, very little is known regarding the movements of tabanid larvae. Segal (1936) states that *Chrysops* larvae occur about two inches deep in the soil near the edge of any permanent pond in New York. A preliminary survey was made to determine the prevalence and distribution of larvae on the campus. Square foot samples of mud to a depth of 1 to 1.5 inches were placed separately in collection funnels shown in Figure 6. The larvae, if any, dropped into the bottles, containing water, below the funnel openings. Two 60 watt bulbs were fixed inside each funnel for drying the mud. The samples of mud completely dried within three to four days, and no larvae were collected after four days of drying.

After collecting the mud from the selected areas, the spots were sprayed with pyrethrum-piperonyl butoxide emulsion 1:14, to find if any larvae were present below the mud collected (Table 7).

Table 7

Occurrence of tabanid larvae with reference to depth during the summer (1950)

No. of areas	No. of larvae in upper 1 - 1.5 inches	No. of larvae below 1.5 inches
100	52	15*
Average larvae found per area	0.52	0.15

* Nine of the 15 larvae collected belonged to *T. atratus* Fabr.

The above findings have decided limitations. The depth at which the larvae occur would vary with different species, abundance of food in the habitat, and weather conditions. All species would probably move downward during winter when the upper layers become frozen, as the larvae "cannot survive in frozen soil, at least if it is moist" (Stone, 1930). The behavior of different species was significant. While most species were present within 1 - 1 1/2 inches depth, *T. atratus* always occurred below that depth. As for food, no generalization can be made. It seems that if the species is saprophytic, the food within the above limits would be abundant, but if predaceous it might have to move downwards, due to lack of sufficient food within the above limits.

The distribution of tabanid larvae at varying distances from the edge of the water bodies varies with different species. Logothetis and Schwardt (1948) found numerous larvae of _T. viscaris_ (_costalis_) in pastures and meadows, while Gerry (1948) reports the presence of 94 per cent of the larvae of _T. nigrovitattus_, a very abundant species, within 200 feet of the upland. The writer sampled soil for larvae at varying distances in the field by the use of pyrethrum-piperonyl butoxide emulsion and New Jersey mosquito larvicide after the manner described on page 30 (Table 8).

Table 8

Population of tabanid larvae at varying distances from water, along brook (1950)

Distance from water edge in feet	No. of areas tried	No. of larvae found	Average No. of larvae per square foot
0 - 1	100	75	0.75
1 - 2	20	4*	0.20
2 - 3	10	5**	0.50
3 - 8	50	0	0.0
8 - 50	100	0	0.0

* Found in 3 areas

** Found in 2 areas

No larvae were found beyond three feet of the water edge. One most probable reason for this absence beyond three feet was the low moisture content of soils in distant areas. This was further substantiated by the fact that even the larvae found within three feet of the water edge were present in areas presenting moisture content very close to that in areas within one foot of the water.

To determine the influence of moisture on larval movements to a depth of 2 to 3 inches, soil was placed in a 11 X 30 inch terrarium in the laboratory. Varied moisture conditions were maintained by supplying sufficient water to wet the soil at one end (Table 9). Leaves bearing the egg masses of C. callida and T. atratus were fixed so that the newly hatched larvae dropped on the mud. About twenty well developed larvae were also placed in the container. Housefly maggots were supplied as food.

Examination after four months (Table 9) revealed only 18 (15 large, 3 smaller laboratory hatched) larvae in the container. Thus three out of at least 3000 to 4000 newly hatched larvae of C. callida and T. atratus survived this period. There may be various reasons for the loss of the great majority of small larvae during the experiment. At the start, nearly the whole terrarium was saturated, or very nearly so, and this permitted larval movements all through the container. Later, as the moisture conditions became differentiated, the larvae moved toward the more favorable and moist portion, until the low moisture content of the drier part inhibited any further migration. It is very likely that the smaller larvae in the dry portion could not withstand lack of moisture, and died. Also the smaller larvae served as food for the bigger ones. This predatory habit was demonstrated while recovering the larvae, as a large *Tabanus* larva was observed to attack and feed on a smaller *Chrysops* larva. What proportion of the young larvae succumbed to predatism or to other causes is unknown.

Table 9

Final population of tabanid larvae in the terrarium after 4 months

Area	Temperature Range	Temperature Average	Percentage saturation of the soil	No. of larvae collected
1	20.5 - 23° C.	21.8° C.	91.3	13
2	20.5 - 23° C.	21.7° C.	81.5	2
3	20.5 - 23° C.	22.0° C.	63.8	3

The results showed the effect of varying moisture content of the soil on the abundance of the larvae. This further confirms the writer's findings that tabanid larvae generally prefer nearly saturated soil.

The presence of three well developed larvae in the drier portion of the terrarium is self explanatory, as well developed tabanid larvae can survive for months under unfavorable environmental conditions.

Effect of ecological factors on population.

The effect of ecological factors on tabanid larvae presents an interesting and puzzling problem, as little has been accomplished by previous workers.

Undoubtedly biotic and physical factors influence the prevalence of larvae in the soil. Cannibalism as well as predatism is common among many species and reduces the initial population considerably. The larvae are generally predaceous, feeding on earthworms, available insect larvae, and the like. Several workers have also reported the saprophytic habits of these larvae especially those belonging to the genus Chrysops (Segal, 1936). Several workers have pointed out that the young larvae have difficulty in locating food under laboratory conditions and suggest placing the larvae directly on the food. This suggests that organic matter may serve as food in their normal habitat. This view has been further substantiated during the rearing of larvae, by the high mortality which occurred shortly after hatching, which it was first believed was due to unsuitable physical conditions. Later bigger larvae also died, in

Figure 6. Funnels used for obtaining larvae from the soil

Funnel assembled

Funnel in parts

spite of exposing them to different temperatures and humidities, imitating the natural conditions closely. It seems likely that while many species are saprophytic in the earlier instars, they acquire predaceous habits as they mature. The writer, while digging the bigger larvae at different places in the field, observed that larval population along the edges of the water was much greater than away from them. It cannot be definitely stated, however, that this distribution was entirely in accordance with the food distribution, earthworms and the like, for it may have been more a result of temperature and moisture conditions of the soil, or an equal effect of both the biotic and physical factors.

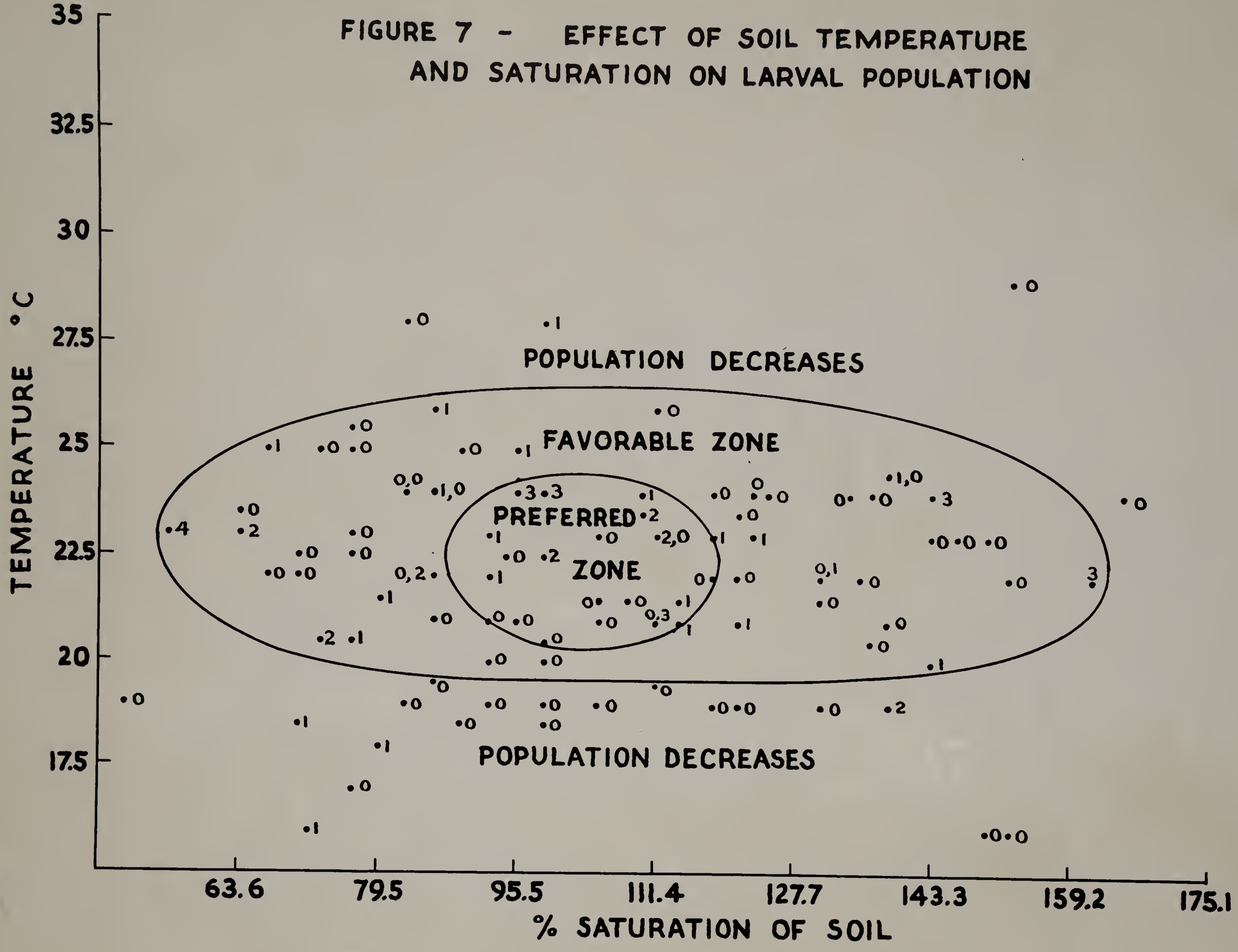
Parasites and predators on the larvae may also greatly influence their abundance. MacCreary (1940) and other workers have found tabanid larvae infested with certain nematodes. Philip (1931) has recorded Phorostoma sp. parasitizing the larvae of T. trimaculatus Palisot de Beauvois.

Moisture has a greater influence on local distribution than temperature. The difference between the temperature of the soil near and away from the water was not so marked as the moisture contents of the two locations. However, certain areas away from the water, and being equally moist to those near the water edge, were devoid of larvae. This is due to the fact that in most cases the females do not lay their eggs in areas away from water, and the larvae do not leave their favorable environment near the water edge.

A preliminary effort was made to find the correlation between larval infestation, soil temperature, and saturation. In the light of the "funnel tests" discussed on page 36, it was ascertained that most of the larvae occur between 1 and 1 1/2 inches in the soil and hence during the present experiments, the temperature and moisture at such depths were considered. The soil temperature was determined by inserting a thermometer in a small hole in the soil made previously by a peg. The percentage of saturation of the soil was determined by drying the samples in an oven with a temperature of about 100° C. The various samples completely dried within 48 to 72 hours. The saturation point of the soil was determined by placing the collected mud on a slanting glass plate and letting all excess water drip off. After the water ceased to flow off, the soil was regarded as saturated.

Areas presenting different temperature and moisture contents and containing larvae were selected for test purposes. The grass over the selected areas was cut with a sickle and the soil temperature determined in the manner described above. After taking the soil samples for moisture determination, population counts were made with use of insecticide formulations (Figure 7).

FIGURE 7 - EFFECT OF SOIL TEMPERATURE AND SATURATION ON LARVAL POPULATION



It appears that both temperature and moisture of the soil have important bearings on distribution of the larval population during the summer. The preferred zone lies between 20.5° and 24.5° C., and 87 per cent saturation to a supersaturation of 118 per cent. The moisture, however, seems to have a greater effect, for in the same temperature limits the population was greater in the above saturation belt than either above or below it. However, the population was not entirely limited to the above zone. A favorable zone extended from about 20° - 26.5° C. and 52 per cent saturation to a supersaturation of 164 per cent.

Rearing.

Rearing of tabanids under laboratory conditions is difficult. Degeer (1760), the Swedish naturalist, published for the first time an account of rearing a tabanid, *T. bovinus*, in jars of damp earth. As Degeer lost many of his larvae through cannibalism, subsequent workers fully realized the necessity of rearing the larvae separately (Hine, 1906; Mitzmain, 1913). Hine used jelly glasses covered with perforated lids for rearing the larvae separately. The larvae were placed in moist sand covered with leaves of water plants. Minute aquatic invertebrates, mainly crustaceans, were provided as food. Mitzmain (1913) kept the larvae in separate jars; one third of each jar was filled with clean moist sand and filter paper strips soaked in muck from the bottom of a creek were placed in the jars. Minute crustaceans, mosquito larvae, and angle worms were given as food. Cameron (1926) substituted small widemouth bottles of 3 1/2 ounce capacity and provided muscid and coleopterous larvae, earthworms, molluscs, and ox meat as food.

Patton and Cragg (1913), realizing the limitations of the above method for mass rearing, advocated collective rearing of tabanid larvae in young stages in trays containing moist sand or mud with some growing vegetation in it. They point out that about one-fifth of a total of 50 larvae in each tray will reach maturity in such trays, after which each larva should be placed separately in suitable jars. Neave (1915) has also favored collective rearing of tabanids.

Marchand (1917) states that the preceding methods have the disadvantage of keeping the larvae in sand or mud and consequently out of sight. The larvae have to be washed out of the mud for observations and this not only takes considerable time and disturbs the larvae, but is also liable to injure them. He kept the larvae of a number of species in test tubes, containing a rolled sheath of filter paper and water to a depth of about an inch to keep the filter paper moist. The larvae were prevented from escaping by a cheesecloth cover fixed with a rubber band. Marchand recommended this method for general use, especially when close observations were desired.

Isaac (1924) regards Marchand's device unnatural and unsatisfactory for young larvae. He employed tilted cages containing moist sand to provide moisture gradient in the form of small beakers for younger, and glass jars for older, larvae. Stammer (1924) reared larvae in covered glass dishes containing sand and moss. Philip (1928) combining the various techniques of the preceding workers, used with success small homeopathic vials containing short strips of tough paper toweling and covered with cheesecloth by means of a rubber band.

Schwardt (1931) used the earlier method for rearing larvae separately in half-pint jelly glasses fitted with perforated lids of tin and containing an inch of sand. Later in 1948, Logothetis and Schwardt in New York successfully reared tabanids in large shallow pans having mud freed from all arthropod life and slightly elevated at one end to provide a moisture gradient.

To sum up, none of the above procedures is entirely satisfactory for the rearing of tabanid larvae. The writer started rearing tabanid larvae separately in tin cans with mud. Housefly maggots were supplied as food. As most of the newly hatched larvae seemed to be unable to find their food, they were placed on the food by means of a brush. Because of rusting of the cans, small plastic cages were used instead (Figure 8). These cages were very handy and convenient to use. A single larva was placed in each cage containing some mud and food. The cans were cleaned frequently by adding a little water and shaking gently. During this process the larvae along with molted skins, food particles, and other wastes, came to the surface and the waste materials were easily removed.

Figure 8. Cages used for rearing tabanid larvae

The plastic cages were very convenient to use, but results were no better than those of former workers. Four species - *T. lineola* Fabr., *T. melanocerus* Wied., *T. reinwardtii* Wied., and *T. quinquevitattus* Wied. - have been reared from field larvae to adults. Two specimens of *T. lineola* were reared under laboratory conditions from the eggs laid by caged females. The total period of development was 340 and 344 days, respectively. A larva collected on September 1, pupated on January 3, a period of 125 days.

T. lineola is a widely distributed species in eastern North America, occurring as far west as Arizona. It is a major pest of livestock in this region. The above observations, though fragmentary, show that *T. lineola* has at most a single generation per year in this region, in comparison to at least two generations in Washington County, Arkansas, as recorded by Schwardt (1931).

T. melanocerus is a widely distributed species and has been recorded by Stone (1938) from Connecticut to Florida. He also points out that "It is extremely doubtful that this is the same as *Tabanus exaectuans* Linn. from Surinam or that *melanocerus* occurs in Central America, as has been suggested by Osten Sacken (1876-78) and Krober (1934)." However, the species does not have much economic importance in this region (Amherst, Massachusetts). Six larvae were collected from the Fort River (Amherst). They were found in the river bed and were collected by straining the mud through a sieve kept against the river flow. Each of the larvae was placed separately in covered petri dishes containing damp mud, tilted to provide a gradient of moisture. Three of these larvae pupated after 66, 67, and 79 days in the laboratory.

T. reinwardtii is distributed from Alberta to Nova Scotia and extends south to Colorado, Arkansas, and Georgia. As has been stated by Stone (1938) the number of the larvae found greatly exceeded the adults seen. The actual reason for this is unknown, but the writer believes that it is due more to high mortality of the larvae than to the secretive habits of the adults. The species has little economic importance in this region. Many larvae of this species were collected from the field, but a great majority died after 6 to 9 months in the laboratory. Two larvae pupated after 263 and 296 days in the laboratory.

T. quinquevitattus constitutes one of the major species in this region and is a troublesome pest of the livestock. Only one well developed larva collected in the field successfully completed development in the laboratory. This larva was collected on April 19, and pupated after one month under laboratory conditions.

C. callida is a common species in this region. A great number of egg masses collected from the field and larvae hatched from them were kept in small plastic cages similar to ones used for *Tabanus* species. An overwhelming majority of young larvae died within a week of hatching, and only 12 were reared to the 3rd instar. One of these survived through the 3rd instar and died after molting for the third time. The duration of the first two instars was as follows:

Number of larvae	Duration of Instars			
	First*	Second	Third	Fourth
11	Less than 1 hour	47-72 days	Died in 3-23 days	
1	Less than 1 hour	53 days	80 days	Died in 14 days

* All the larvae observed immediately after hatching had either molted or were molting

In spite of imitating natural conditions ~~by~~ and placing the larvae on food with a brush, no success could be achieved. It seems likely that the larvae of this species are saprophagous and that lack of sufficient organic matter in the habitat resulted in the high mortality. The possibility of injuring the larvae was practically negligible in the light of precautions taken.

Pupae

The prepupae of Tabanidae are characterized by amphineustic respiration and partially retracted head within the prothorax. The duration of the period is about 24 hours.

The pupa is obtect, somewhat rounded at the anterior end while tapering posteriorly. Stone (1930) has described tabanid pupae in these words:

"Head and thorax - These are closely fused. Anteriorly to each side are the short, rapidly tapering antennae overlying the eyes. Between these is usually a heavy ridge of chitin, the frontal carina, divided medianly by a notch and sometimes with each side again divided into two parts. Above these lies a pair of setiferous tubercles bearing one or two pairs of setae. Ventrally, on the fronto-ventral plate, are two pairs of setae and below these, a pair of short palpal sheaths. Back of the eyes, on the mesothorax, lie the prominent thoracic spiracles, flattened laterally and extending out from the body dorsally, each with an arcuate rima above and behind it. The wing pads reach the second abdominal segment.

"Abdomen - The first abdominal segment lacks an encircling row of spines and definite divisions setting off the lateral areas. Segments two to seven each bear a more or less complete ring of spines near the posterior third. Each segment is divided into a dorsal, two lateral and a ventral area separated by grooves. Each lateral area bears a short, truncate abdominal spiracle. The anal segment may, or may not, bear dorso-lateral and lateral combs of spines. Ventrally, in front of the anus is a row of spines running clear across in the male, but widely broken medianly in the female. The anal region is quite protuberant in the male and much less so in the female. The posterior part of the segment is composed of six heavy, sharp projections forming the pupal aster. This usually consists of two projections dorsally, a larger pair pointing dorso-laterally and another pair pointing ventrally and posteriorly."

In all cases observed the entire pupal stage was passed at the surface of the mud. This was surprising in the case of _T_. _melanocerus_. The larvae of this species were collected from a river bed and reared in petri dishes. The pupa always passed its life at the surface of the mud. Whether in nature such larvae pupate in their natural habitat or migrate to the shores before pupation is unknown.

In contrast to larvae, pupae have a short life lasting from a few days to two or three weeks. Even within the same species, pupal life may vary depending on environmental conditions. Cameron (1926) records that some individuals of *C. moerens* Walker completed pupation in six days, while others took sixteen days.

Adults

General characters.

The family Tabanidae, comprising about 2500 species, includes the horseflies, gadflies, and deerflies. It is divided into two subfamilies, Tabaninae characterized by the absence of ocelli and the spurs on the hind tibiae, and Pangoninae possessing these characters. The genus *Tabanus* belongs to the subfamily Tabaninae, while *Chrysops* is included in the Pangoninae.

The distinguishing characters of the family are the porrect three-segmented antennae, the third segment often ending in a blunt pointed process, consisting of from 4 to 8 more or less distinctly separated segments. The antennae in most genera are shorter than the head, though in the genus *Chrysops* they exceed the head in length.

The wing venation of the family is peculiar and presents little variation within the group. There are two submarginal and five posterior cells with the costal vein completely extending around the wing. Other peculiarities of the family are pulvilliform empodia, spurred middle tibiae, and large conspicuous squammae.

The two genera included in this study and belonging to the different subfamilies have the following characteristics:

1. Tabanus. The eyes are large and brilliantly colored. The ocelli are absent. The antennae consist of three joints, with the third joint further divided into smaller segments. The hind tibiae lack spurs at the tips.

2. Chrysops. As compared with Tabanus, Chrysops possess three ocelli on the vertex, and the hind tibiae are spurred at their tips. The pedicel is more than half as long as the scape. The dorsal margin of the wings is variously colored in different species.

Sexual dimorphism.

It is in the head structures that the principal sexual differences of Tabanidae are found. The eyes of the males are holoptic, while those of the females are separated by a broad band containing some calli at its lower border. The eye of the male is very often divided into two types of ommatidia, upper large ones and lower small ones. The color pattern is, however, confined to the lower ones. The antenna is more slender in the males than in the females, and the maxillary palpus of the male is much more reduced than that of the female. The male abdomen is narrower apically and the hairs of the head and thorax are generally darker than in the females. The terminalia, however, do not show any significant distinguishing peculiarities between the two sexes, as has been pointed out by Stone (1930), who concludes that the males resemble the females very closely except for secondary sexual characters.

Feeding habits.

The feeding habits of the two sexes are entirely different. Though the females are mostly blood sucking, and the males always subsist on flower nectar and the like, Hine (1903) and Stone (1930) have mentioned the female *Buplex rasa* Loew showing preference for nectar. In his discussion of *T. sulcifrons*, Hine (1906) states "I am thoroughly convinced that the females take much other food than blood and do not believe it would be overstating the facts to say that specimens of this sex may pass the period of adult life without taking blood at all."

The feeding process is similar among the females and has been described by Patton and Craig (1913) in the following words: "The fly settles down on the skin of the host, and by means of the tactile hairs on the end of the proboscis selects a suitable place. A firm hold is then taken of the skin by means of the claws on the feet, the labella are retracted to expose the piercing stylets, and are also diverged from one another so that their oral surfaces are applied to the skin. The mandibles and maxillae are then put in action, the former acting like a saw and the latter like a file, and by rapidly repeated movements cut a hole in the skin. Meanwhile the epipharynx and hypopharynx are drawn slightly upwards, by means of a pair of muscles which pass from the cornua of the buccal cavity to the epicranial wall in the region of the vertex. When the level of the blood is reached they are protracted. The pumping action in the buccal cavity then commences, the sphincter separating it from the pharynx being contracted. Immediately the cavity is full the sphincter relaxes, and the pharynx dilates as the blood is sucked into it from the first chamber. When the air pressure is in turn exercised on the pharynx the blood flows into the oesophagus."

The time taken by a fly to complete its blood meal and the site selected to feed differs with various species. The writer has observed specimens of *T. lineola* Fabr. and *T. quinquevitattus* Wied. completing their blood meals in from 3 to 6 minutes. The selection of feeding sites on the animals was noticeably different in various species studied. *T. quinquevitattus* preferred the underside - belly and udder - of the host, while *T. lasiophthalmus* Macq. fed mostly on the sides. *T. superjumentaris* attacked the back and sides. On several occasions this species was seen crawling on the animals' legs, but never in the act of sucking blood. T. lineola though seen mostly on the legs and sides, was not uncommon on the underside of the animals. At least two species of Chrysops observed fed mainly on the head and neck regions of the animals. Probably they prefer the ears more than any other part.

Sometimes a fly starts sucking the blood immediately after alighting on the host, while at other times it flies around, sits here and there several times, before beginning to feed. No difference could be observed among various species regarding this habit, which probably depends on the nature of the site where the fly first rests. The visitation of water surfaces by Tabanids has been recorded by many workers, but the purpose is unknown. Segal (1936) suggests that such visits may be for drinking purposes.

Attraction to moving objects and color.

It has long been known that tabanids are attracted to moving objects. They have been recorded moving with trains, cars, and other vehicles. McAtee and Walton (1918) have observed T. actaeon O. S. darting through the openings in a cabin. The writer has observed many specimens of T. nigrovitattus Macq. in areas of great abundance, entering cars with open windows, and has collected occasional specimens of T. quinquevitattus and T. lineola from the windshields of moving cars, in Amherst, Mass. Philip (1931) suggests that heat is mainly responsible for such attraction, as they are drawn to the warmest places in the car. He has also observed that heated tires attract many more flies than the cooled ones.

That certain colors appeal to the tabanids has also been mentioned. Philip (1931) states that horseflies prefer darker cows and even darker spots on the animals are more attractive. The writer, however, did not find any difference between the fly population on black, brown, or white animals. This in all probability was the result of working with different species. As with other blood-sucking insects, the preference toward individual animals was well marked. In the same herd, some cows appeared to be more susceptible than others to tabanid attacks.

Seasonal and relative abundance of major species.

Several workers have recorded the seasonal distribution of adult tabanids in their respective regions of work. During 1950 the population of major species of horseflies in Amherst was recorded by catching the flies on animals in the field over a period of 15 minutes each day. The flies were caught by means of a wide-mouth bottle after the manner described on page 14, from any and all animals possible.

The most important and abundant species in this region is T. lineola Fabr., along with its variety T. lineola scutellaris Walker. T. quinquevitattus also constitutes one of the major species. During 1949, this species was equally abundant and sometimes even greater than T. lineola, but surprisingly its numbers were considerably less than that of T. lineola in 1950. The summer of 1950 was much cooler than that of 1949. On hot days with a temperature of 35^{o} C. or so during 1949, as many as 21 specimens of T. quinquevitattus have been collected within 15 minutes. In 1950 no such temperature was encountered and this may have been a factor in the low collection of this species. T. lasiophthalmus comes third in its seasonal abundance and economic importance. It is the first of the three species to appear, builds up its population quickly, and then rapidly drops down.

The maximum numbers of flies caught in successive weeks from June to September have been plotted in Figure 9. It was a common observation in the field to find no flies one day, and a great number on the following day, depending upon the weather conditions. Hence the highest number of the flies captured during the week was used. This tends to eliminate the daily variations of weather. A very striking succession of the three species is obvious from

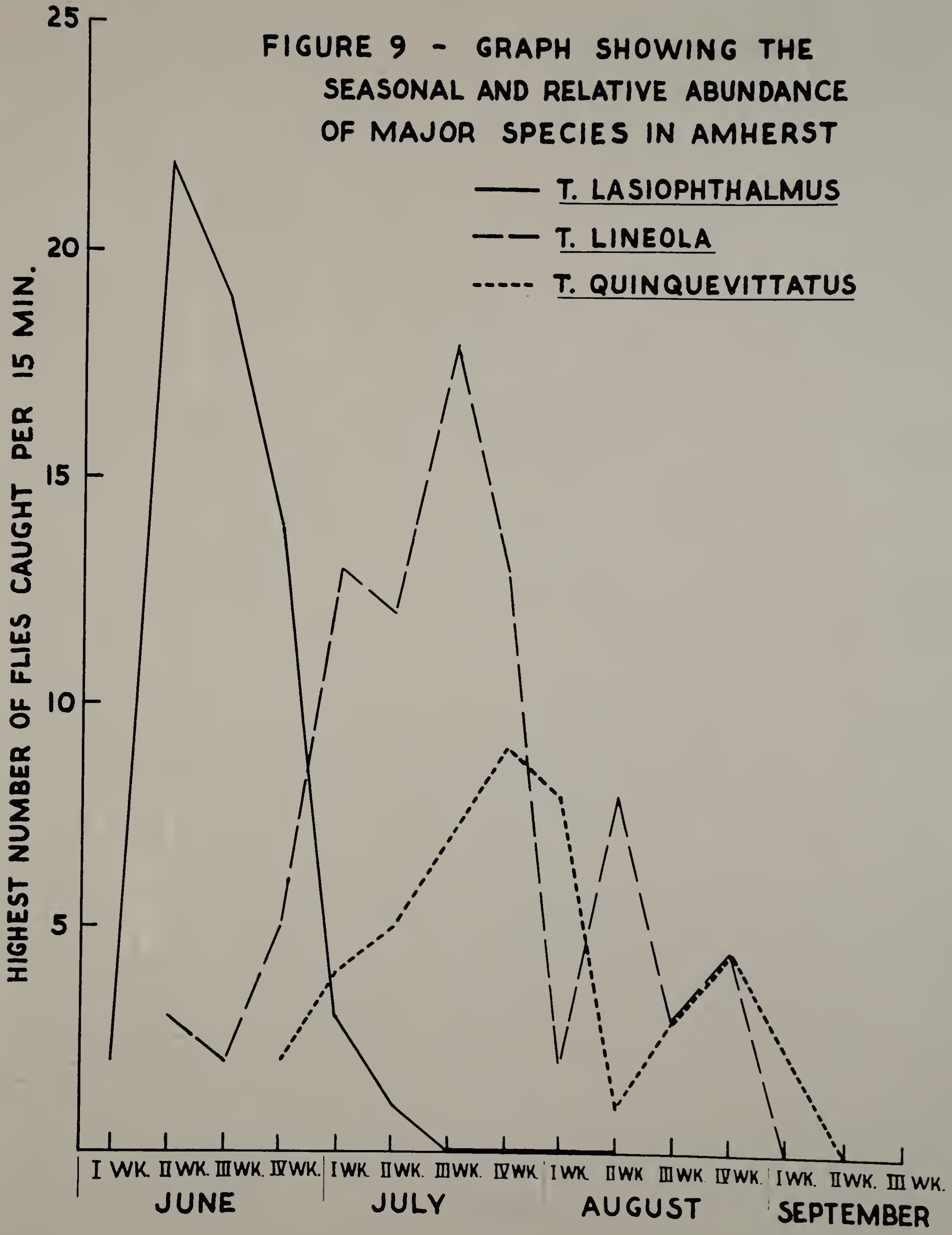


FIGURE 9 - GRAPH SHOWING THE SEASONAL AND RELATIVE ABUNDANCE OF MAJOR SPECIES IN AMHERST

the graph. *T. lasiophthalmus*, the first species to appear, was the first one to disappear. It was followed by *T. lineola*, and finally by *T. quinquevitattus*. *T. lineola*, the second in appearance, was the second to go; while *T. quinquevitattus*, which came last of all, was the last to go.

The results obtained may be compared with those of Tashiro and Schwardt (1949), who made a similar study in central New York. They record that *T. lasiophthalmus* appeared during the first week of June, reached a peak the following week, and practically disappeared by the first week of July. The present observations to a great extent agree with those of the above workers. *T. lineola* was not a major species in central New York though present during a large part of the fly season. In Amherst, *T. lineola* was a major species during a greater part of the fly season (Figure 9). *T. quinquevitattus* is a major species here as well as in central New York. Tashiro and Schwardt (1949) observed that *T. quinquevitattus* replaced *T. lasiophthalmus* in importance in the early part of July. It had the longest season and was the most abundant and important of all the species in that region.

Effect of weather conditions on fly activities in the field.

Several factors influence horsefly activity in the field. They are lovers of sunshine and warm weather.

Cool, cloudy and windy conditions limit their activities considerably, which practically cease during rainfall.

The writer has attempted to investigate the effects of each factor separately, and only data showing the effects of a particular factor when all other influences are favorable for fly activity have been recorded below.

Wind dominates fly activity in the field, irrespective of any other factor. Light to gentle wind with an approximate velocity of 4 to 12 miles per hour does not disturb the flies, but with the coming of fresh wind, 19 to 24 miles per hour, the activity rapidly decreases (Tables 10 and 11). It was commonly observed that under normal conditions for fly activities, a gust of fresh or strong wind took the flies from the animals, but they appeared again as the wind velocity decreased. Similar effects of wind have been recorded by Tashiro and Schwardt (1949).

Table 10

Effect of wind movement on tabanid activity (1949)

	Light to gentle wind	Fresh wind	Strong wind
Number of flies collected in 15 min.	0:1:9:3:19:9:23: 9:8:8:12:25:23	3:12	0:1:0
Average	9.75	7.5	0.33

Table 11

Effect of wind movement on tabanid activity (1950)

	T. lasiophthalmus	*T. lineola*	*T. quinquevitattus*
Light to gentle wind	22:7:6:19:14	12:12:18:11: 11:13:12	5:5:3:4:9:6:5
Average	13.6	12.7	5.28
Gentle to fresh wind	1:5:3	4:5:2	3
Average	3.00	3.66	3.00
Strong wind	2	--	--
Average	2.00	--	--

Effects of cloudy and sunny weather.

Light and rain play a significant role. The activity is much less during cloudy weather than under sunny conditions (Table 12). From field observations it can be safely concluded that fly activity is definitely negligible during rain. No flies were seen in the field between 23° and 24° C. during rain.

Table 12

Effect of light conditions on tabanid activity

T. lineola			*T. quinquevitattus*		
	No. of flies			No. of flies	
Temperature	Cloudy Days	Sunny Days	Temperature	Cloudy Days	Sunny Days
25° C.	8	12	24.5-25° C.	2	5
26-26.5° C.	14	12	25.5-26° C.	0	5
27° C.	7	13	25.5-26° C.	3	-
Average	9.66	12.33		1.66	5.00

Effects of temperature and relative humidity.

The preferred temperature for activity of *T. lineola* lies between 25° - 29° C. (Table 13). Activity was negligible at 20° C. No marked response to relative humidity could be obtained. However, the flies were active at the relative humidity existing when the temperature was favorable.

In all probability wind effects, though dominant, are temporary and the fly activity is greatly influenced by some combination of temperature and light conditions.

Table 13

Effect of temperature and relative humidity on tabanid activity

T. lasiophthalmus			T. lineola			T. quinquevitattus		
Temperature	Relative humidity	Number of flies collected	Temperature	Relative humidity	Number of flies collected	Temperature	Relative humidity	Number of flies collected
20	70	19	20	79	0	20	79	0
22	58	22	22	53	8	22	53	6
28.5	70	7	22.5	55	5	22.5	55	9
29.5	40	6	25	47	12	25	47	5
30.5	66	14	26	57	12	26	61	5
			26	61	4	28	62	5
			27	36	13	28	68	3
			27.5	45.5	12	29	58	4
			28	62	18			
			28	68	11			
			29	58	11			

Part II - CONTROL

Review of Literature

Porchinski (1889) concluded that as tabanids frequently visit the surface of water during the warm part of the day, a uniform layer of kerosene on the surface of water bodies would result in their destruction. Olsuf 'Ev (1935) and Lund (1943) report destroying tabanids by crude oil, kerosene, or No. 2 fuel oil on the surface of ditches and pools. Olenev (1929) recommended construction of small pits filled with water and covered with kerosene for control of tabanids.

The use of fly nets, burlap blankets, and the like, on horses and cattle has limited possibilities of protection, primarily with work or confined animals. As different species of tabanids show marked preference for various feeding sites on the animal's body, it is possible to cover the upper parts of the animals' bodies without interfering with their activities, in cases where the annoying species do not prefer the lower parts. However, the construction of suitable shelters where the animals may take refuge when the flies are active is of value.

Segal (1933) is of the opinion that Bourgault's fly trap can well be utilized for these flies. Such a trap consists of: "1. A darkened, partitioned building with entrance and exit doors. 2. A brush of leaves and branches. 3. A lighted chamber into which the flies are attracted after they are brushed off the animal, and where they are afterwards destroyed." As tabanids seldom enter buildings, advantage should be taken of their feeding habits. While feeding the flies are not easily disturbed and if the animals could be trained to enter the trap at such times, they would be relieved of the flies.

All such shelters and similar devices have undoubted significance toward horsefly control. The writer has observed animals getting considerable protection from the flies by simply gathering under the shade of some tree. Therefore, it is believed that any kind of shelter constructed in the field would protect the animals considerably. However, the animals thus sheltered would certainly lose grazing time, which seems to be the greatest drawback with the method.

Wells (1931) has found few specimens of T. lineola and T. sulcifrons at the dairy barn windows equipped with electric screens. No doubt such electrified screens do kill a few tabanids, but they cannot be regarded as having any utility in the control of these flies. The writer on several occasions observed specimens of T. quinquevitattus and T. lineola being killed by such screens. It seems that this is more of a chance killing rather than a practical method of control, for tabanids are flies of open land and are not attracted in great numbers to animals inside the barns.

Webb and Wells (1924) have suggested that "drainage will accomplish the ultimate control of the tabanid pest." They were led to this conclusion because of the absence of larvae in well drained fields. Draining of swamps has also been suggested as a control measure by Olsuf 'Ev (1935).

Discussing the control of T. atratus which oviposits on sticks and vegetation standing in or near water, Schwardt (1932) suggests the entire removal of vegetation within ten feet of water. In 1936 he again confirms his previous view in recommending the destruction of oviposition sites to be of some significance in horsefly control. As has been pointed out by him, such removal can only be helpful in certain cases where the oviposition sites can be located clearly.

Baits have also been tried against tabanids. Webb and Wells (1924) failed to catch T. phaenops O. S. in traps baited with bananas. They also hung over a fence a fresh beef hide treated with sweetened water containing arsenic and tartaric acid, but this was not successful. Frost (1936) attracted relatively large numbers of tabanids with attractants of which soap, sodium oleate, camphoric and oleic acids showed most promise. One gram of the attractant was added to refiner's syrup and water in the ratio of 1:20. Frost (1936) thus captured seven species of Tabanus and a few incidental Chrysops.

A number of chemical repellents have been tested for the control of horseflies. Most of them consist of kerosene, tar oil, and fish oil emulsions for external use, and various salts for internal use. Tedder (1925), Philip (1931), and others have reported on the successful use of repellents containing kerosene, tar, soap, and fish oil. It should be pointed out, however, that many oils having some repellent action often cause irritation, hence losing their value. Ochmann (1911) has recommended potassium tellurate for internal use. A "fly salt" containing 9.77 per cent free sulphur has also been recommended for internal administration to the cattle, but later experiments by Aicher et al (1927) do not support this view, and Philip (1931) goes so far as to say that buying such stuff is a waste of money.

The oncoming of modern synthetic insecticides opened a new field for horsefly control. Gjullin and Mote (1945) tried to control C. discalis Williston by DDT sprays. They sprayed cattle with 2 and 4 per cent DDT emulsions. The results, however, were not encouraging as no reduction of flies attacking the sprayed animals could be observed.

Howell (1949) in Oklahoma tried piperonyl and pyrethrum formulations against the horseflies. He made tests on cattle and let the sprayed and unsprayed animals move together in the same herd. The diluted emulsion concentrates at the rate of one part of the concentrate to 14 parts of water were applied at the rate of one liter of spray per animal per application. Five applications with each formulation were tried. The four formulations used are shown in the table below (after the author).

Formulation	Piperonyl butoxide	Piperonyl cyclonene	Pyrethrins A & B	Rotenone
143	6.67 gr.	---	0.67 gr.	---
232	5.33 gr.	---	0.13 gr.	---
235	---	5.33 gr.	0.13 gr.	---
334	5.33 gr.	---	0.13 gr.	0.67 gr.

The results showed that the emulsion 143 provided better control than others and gave a fair protection from two to three days. The addition of rotenone to the spray did not prolong or increase the insecticidal effects. It was also observed that cyclonene plus pyrethrum was less effective than piperonyl butoxide and pyrethrum. Bruce (1950) used pyrethrum plus piperonyl butoxide successfully against horseflies on beef cattle and recommends 1:9 (one part of piperonyl emulsion to nine parts of water) dilution to be effective for protecting the animals against these flies.

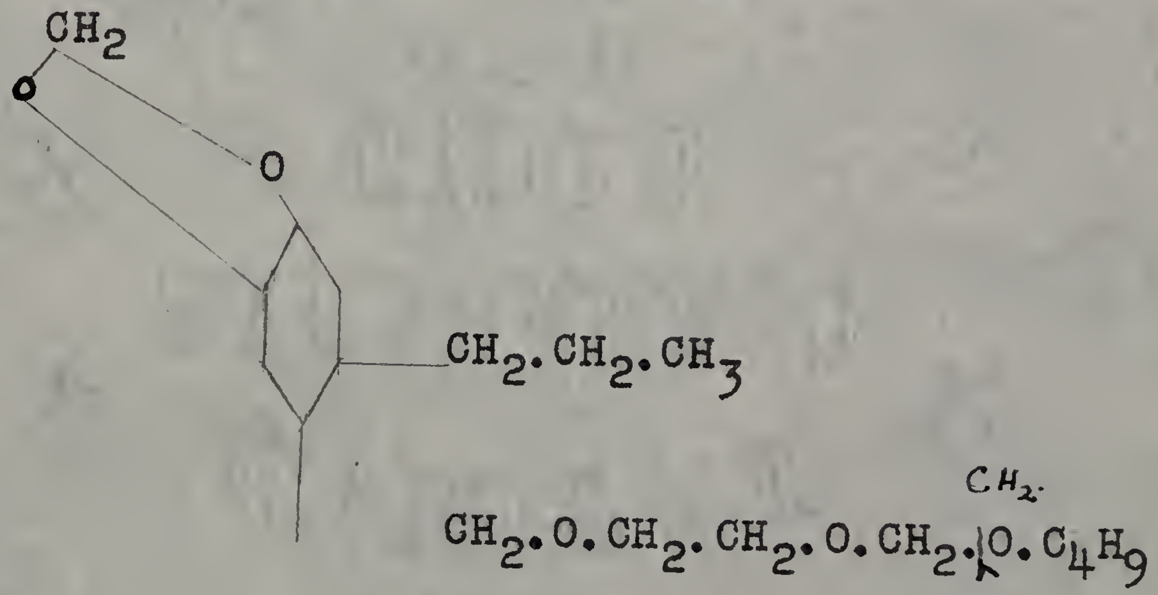
Howell and others (1949) made an attempt to control the resting places of tabanids by aerial applications using methoxychlor, toxophene, chlordane, and DDT. Ten per cent concentrations of these insecticides dissolved in a mixture of Number 1 fuel oil and cyclohexanone, with 0.5 per cent of an oil dye added to facilitate checking, were applied at the rate of two pounds per acre. No appreciable control was obtained with these insecticides. The species involved in their tests were T. abactor, T. sulcifrons, T. atratus, T. vittiger, T. mularis, and T. venustus, and a few species of Chrysops and Silvius. Gerry (1949), however, obtained satisfactory results with residual DDT-oil sprays by airplane against T. nigrovitattus. With two applications of DDT-oil sprays containing one per cent by weight of aluminum stearate, control was obtained for the entire season. Aluminum stearate was found very useful in prolonging the residual effect and increasing the coverage.

Gjullin and Mote (1945) though not getting any effective results on sprayed animals in the field, found C. discalis died within eight hours after an exposure of two minutes to 2 per cent DDT emulsion in glass jars. Ninety-eight per cent mortality of first and second instar larvae of C. discalis has also been reported by using DDT emulsion. Monro et al (1944) with aerosols consisting of five per cent pyrethrum extract having 20 per cent pyrethrins, two per cent sesame oil, and 93 per cent dichlorodifluoro methane, killed all tabanids and other flies exposed to 0.1 ounce per 1,000 cu. ft. at 70° F. to 80° F. for one hour.

Laboratory results, however, against tabanids cannot be considered significant. Tabanids are lovers of sunshine and open lands and to keep them surviving in the laboratory is in itself a problem, because of altogether different environment and unnatural diet. It seems that all such tests can at best give only a preliminary vague idea as to the relative effectiveness of insecticides for field experiments.

Protection of animals from Tabanids

Spraying the animals with insecticides, if effective, would be a suitable method of control. Pyrethrum has long been known for its effective insecticidal properties. Piperonyl butoxide is a new complex light-colored liquid with a mild pleasing odor. It is soluble in most organic solvents - alcohol, benzol, petroleum oil - and in liquified gases of the feron group, and has the following structural formula:



(After Wach, 1947)

Piperonyl formulations are relatively nontoxic to animals. McAlister <u>et al</u> (1947) have shown that it is less toxic to the laboratory animals than petroleum oils used in making spray solutions.

Chemicals used.

The chemicals used in these studies were combinations of piperonyl butoxide and pyrethrum; piperonyl cyclonene and pyrethrum; experimental fly repellent No. 1; and DDT. Piperonyl butoxide plus pyrethrum (T-143), a relatively stable emulsion, and piperonyl cyclonene plus pyrethrum (T-237), a quick breaking emulsion, were supplied by the United States Industrial Chemicals; while the Union Carbide and Carbon Corporation furnished "Crag fly repellent No. 1" for experimental purposes.

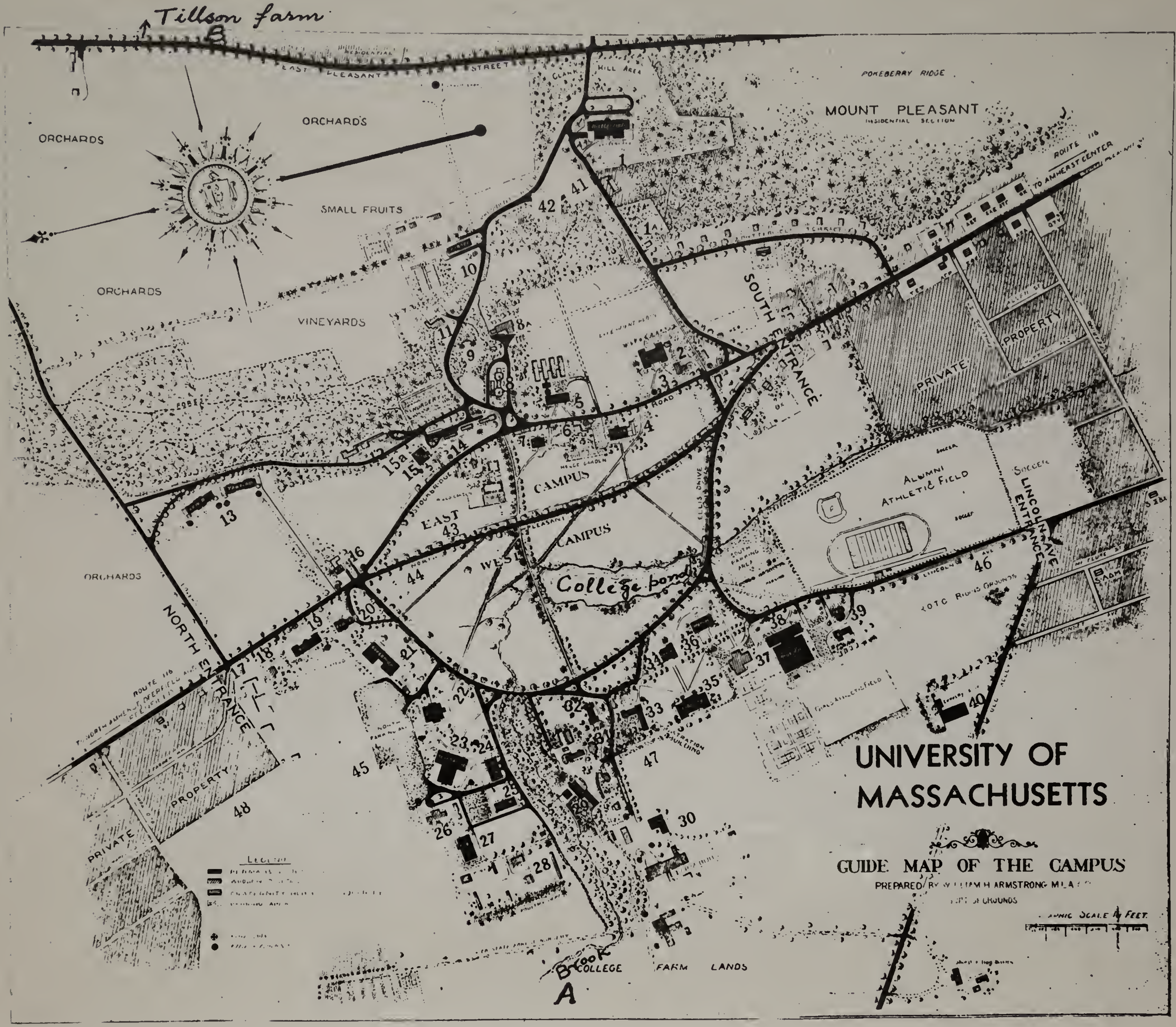
The pyrethrum piperonyl formulation consisted of 100 per cent active ingredients including petroleum oil, polyoxylethylene sorbitol mixed with ether ester, piperonyl butoxide consisting of 80 per cent of butyl carbityl 6-propyl piperonyl ether, 20 per cent related compounds; and pyrethrins. Cyclonene pyrethrins emulsion concentrates 10-1 consisted of piperonyl cyclonene, pyrethrins, solvent C, phenols S, Altox 1045 A and Iso propyl alcohol dissolved in ultrasene. The two formulations are comparable to each other in that each contains 10 grams of piperonyl butoxide or piperonyl cyclonene and one gram of pyrethrins per 100 milliliters. The experimental fly repellent No. 1 consisted of 100 per cent butoxy poly propylene Glycol as active agent. One per cent DDT sprays in water were prepared from a 25 per cent wettable powder.

Pyrethrum-piperonyl butoxide emulsion and cyclonene-pyrethrum emulsion were used in three dilutions with water, 1:9, 1:14, and 1:19. The fly repellent containing four ounces of an emulsifying agent per gallon was diluted with water at the ratio of 1:9. The dispersion thus formed was wiped by a cloth piece at the rate of two to three ounces per animal. Considering the impracticability of wiping, during the later part of the work the mixture was diluted with 36 to 45 volumes of water and the rate of application per animal was consequently raised to four or five times that of the original figures. This further dilution was made in order to facilitate spraying with a 3-gallon air sprayer.

Counts were made on the sprayed and unsprayed animals for a period of 15 minutes per animal daily following treatment, until the population on the sprayed animals was 50 per cent or more of the population on the unsprayed ones.

Experimental plots.

The tests were carried on at the University farms shown in Map 1, as A and B. These pastures provide ideal places for horsefly feeding on the animals. They are surrounded by favorable sites for development of larvae and resting places for adults. The test animals included beef



UNIVERSITY OF
MASSACHUSETTS

GUIDE MAP OF THE CAMPUS
PREPARED BY WILLIAM H ARMSTRONG M.L.A.
DEPT. OF GROUNDS

GRAPHIC SCALE IN FEET

cattle, dairy cattle, and horses. Only gentle animals were used for tests, because of convenience in spraying and counting the flies on them.

Tests with pyrethrum-piperonyl butoxide emulsion.

During the summers of 1949 and 1950, three concentrations of pyrethrum-piperonyl butoxide emulsion, 1:9, 1:14, and 1:19 were tried on beef and dairy cattle for protection against tabanids. Spraying was done with a 3-gallon air compressed sprayer. Sometimes it was necessary to tie a cow before it could be sprayed, as they seemed to be afraid of the sprayer and its noise. The amount of insecticide per animal differed slightly according to the size of the animal. In general it varied between two to three pints per head. Spraying was stopped before runn-off occurred and care was taken to apply uniform amounts of spray on the animals.

The tests on horses were carried on with the same three concentrations as were used on the dairy and beef cattle. As few horses were available for experimental work, one horse could be sprayed with one concentration during each test, as against two or three cattle sprayed with a single concentration during a test. In 1949 the horses were wiped off with a cloth soaked with the spray solution. This method was adopted because of the extreme nervousness of the horses to the sprayer. In 1950 wiping was given up due to its impractical nature, and spraying with a 3-gallon air compressed sprayer was adopted. After two or three applications, the horses seemed to get accustomed to the sprayer and did not give as much trouble as in the beginning. One of the horses always, and another occasionally, rolled on the ground immediately after spraying, possibly because of irritation caused by the insecticide. The results are presented in Tables 14 - 25.

Table 14

Population of tabanids on beef cattle sprayed with 1:9 pyrethrum-piperonyl butoxide emulsion

Test number	Number of flies caught per head in 10 min. on days following treatments 1 Sprayed	Check	2 Sprayed	Check	3 Sprayed	Check	4 Sprayed	Check	5 Sprayed	Check
1	1	7	4	9	0	2	0	0	11	13
2	1	11	3	14	1	3	14	15	16	18
3	3	16	2	11	0	0	1	0	12	10
4	1	24	1	1	4	9	0	0	0	0*
5	1	6	1	8	4	8	4	4		
6	0	0	1	1	0	0	0	0	0	0
					Continued rain for 3 days					
7	0	4	4	7	8	7				
8	1	1	0	0	4	17	10	14		
9	0	8	1	6	0	1	0	0	5	5
10	0	14	2	6	4	5				

* The weather was unsatisfactory for fly activities from 4th to 7th days after application, and on 8th day fly population was equal (12:12) on both the sprayed and unsprayed animals

Table 15

Population of tabanids on beef cattle sprayed with
1:14 pyrethrum-piperonyl butoxide emulsion

Test number	Number of flies caught per head in 10 min. on days following treatments									
	1		2		3		4		5	
	Sprayed	Check	Sprayed	Check	Sprayed	Check	Sprayed	Check	Sprayed	Check
1	1	16	8	11	0	0	2	1	8	10
2	6	3	0	0	0	0	2	3	5	3
3	1	3	2	1	1	6	6	7		
4	4	8	4	6	0	1	0	0	4	5
5	1	1	0	0	12	17	14	14		
6	0	0	1	1	0	0	0	0	0	0
					Continued rain for 3 days					
7	1	4	4	7	2	7	20	17		
8	0	6	5	8	5	8	0	0		
9	4	24	1	1	5	9	0	0	0	0*
10	10	14	4	6	10	5				

* The weather was unsatisfactory for fly activities from 4th to 7th day of application and on the 8th day the fly population was 10 on the sprayed and 12 on the check

Table 16

Population of tabanids on beef cattle sprayed with 1:19 pyrethrum-piperonyl butoxide emulsion

	Number of flies caught per head in 10 minutes on days following treatment					
Test number	1		2		3	
	Sprayed	Check	Sprayed	Check	Sprayed	Check
1	12	16	1	11	0	0*
2	0	3	0	11	4	6
3	12	8	16	17		
4	1	1	0	0	20	17
5	1	4	2	7	14	7
6	0	0	2	1	0 Continued rain for 3 days	0
7	3	6	6	8	9	8
8	10	14	2	6	12	5
9	0	1	2	5	4	5
10	3	4	0	1	2	3**

* The weather was unfavorable for fly activities on the 3rd and 4th days of the test. Population on 5th day of the test was 13 on sprayed and 10 on unsprayed animals

** Test performed when the population of flies was on the decrease for the season

Table 17

Percentage protection from tabanid flies on beef cattle sprayed with pyrethrum-piperonyl butoxide emulsion

Days after treatment	Concentration 1:9	 1:14	 1:19
	Percentage protection obtained		
1	91.2	64.5	26.3
2	69.8	29.2	53.7
3	51.9	33.9	0.0
4	12.1	0.0	---
5	3.9	5.5	---

Table 18

Population of tabanids on dairy cattle sprayed with 1:9 pyrethrum-piperonyl butoxide emulsion

Test number	Number of flies caught per head in 10 min. on days following treatments 1		2		3		4		5	
	Sprayed	Check	Sprayed	Check	Sprayed	Check	Sprayed	Check	Sprayed	Check
1	0	11	2	13	3	10	0	0	5	14*
2	No observations taken		0	0	0	3	1	4	2	3
3	0	9	2	8	1	15	8	9		
4	0	8	2	4	1	2	0	0	6	7
5	0	10	2	8	2	7	13	8		
6	1	7	0	0	2	4	4	5		

* The fly population on the 6th day was 17 and 16 on sprayed and unsprayed animals, respectively

Table 19

Population of tabanids on dairy cattle sprayed with 1:14 pyrethrum-piperonyl butoxide emulsion

Test number	Number of flies caught per head in 10 minutes on days following treatment 1 Sprayed	1 Check	2 Sprayed	2 Check	3 Sprayed	3 Check	4 Sprayed	4 Check
1	1	7	0	9	3	2	0	0*
2	2	11	5	14	0	1	14	15
3	0	11	2	13	7	10	0	0**
4	1	1	3	15	16	18	0 Continued rain	0
5	2	9	12	8	11	15	8	9
6	4	8	4	4	1	1		
7	3	10	5	8	4	7	7	8

* Population on 5th day: 11 on sprayed and 13 on unsprayed animals

** Population on 5th day: 17 on sprayed and 14 on unsprayed animals

Table 20

Population of tabanids on dairy cattle sprayed with 1:19 pyrethrum-piperonyl butoxide emulsion

	Number of flies caught per head in 10 minutes on days following treatment					
Test	1		2		3	
number	Sprayed	Check	Sprayed	Check	Sprayed	Check
1	4	11	12	13	9	10
2	10	9	10	8	13	15
3	2	8	4	1	1	1
4	3	10	8	5	5	7

Table 21

Percentage protection from tabanid flies on dairy cattle sprayed with pyrethrum-piperonyl butoxide emulsion

	Concentration		
	1:9	1:14	1:19
Days after treatment	Percentage protection obtained		
1	97.7	77.7	50.0
2	76.3	56.4	0.0
3	77.9	22.0	15.1
4	0.0	9.4	---

Table 22

Population of tabanids on horses sprayed with 1:9 pyrethrum-piperonyl butoxide emulsion

Test number	Number of flies caught per animal in 10 minutes on days following treatment							
	1		2		3		4	
	Sprayed	Check	Sprayed	Check	Sprayed	Check	Sprayed	Check
1	0	4	0	0	13	14		
2	2	9	0	1	0	0	18	19
3	0	6	3	5	1	9	3	3
4	0	3	0	3	0	2	0	0
							Continued rain	
5	0	0	0	0	0	0	2	3*
6	3	5	3	4	6	6		
7	2	1	1	1	4	7	2	6**
8	2	4	0	2	1	1	2	3
9	0	5	1	3	0	4	3	3

* The test was carried on in the beginning of the fly season

** The weather on the following 2 days was unfavorable for fly activities

Table 23

Population of tabanids on horses sprayed with 1:14 pyrethrum-piperonyl butoxide emulsion

Test number	Number of flies caught per animal in 10 minutes on days following treatment 1 Sprayed	 1 Check	 2 Sprayed	 2 Check	 3 Sprayed	 3 Check	 4 Sprayed	 4 Check
1	4	6	1	5	8	9	3	3
2	0	0	0	0	0	0	4	3*
3	0	2	3	3	3	2		
4	2	5	3	4	5	6		
5	0	2	1	1	3	7	2	6**
6	1	5	6	2	2	7	4	2
7	2	4	2	2	0	1	2	3

* Test conducted during the beginning of fly emergence

** The fly population on 5th and 6th days of the test was 0, 0 on the sprayed and 0, 1 on the unsprayed animals

Table 24

Population of tabanids on horses sprayed with 1:19 pyrethrum-piperonyl butoxide emulsion

Test number	Number of flies caught per animal in 10 minutes on days following treatment 1 Sprayed	Check	2 Sprayed	Check	3 Sprayed	Check
1	10	6	3	5	8	9
2	0	0	0	0	4	6
3	0	2	3	3	2	2
4	1	5	2	4	10	6
5	2	2	1	1	3	7*
6	6	4	3	2	1	1**
7	4	5	0	2	3	4

* Population on 4th day was 5 on sprayed and 6 on unsprayed animals

** Population on 4th day was 3 on sprayed and 3 on unsprayed animals

Table 25

Percentage protection from tabanid flies on horses sprayed with pyrethrum-piperonyl butoxide emulsion

Days after treatment	Concentration 1:9	1:14	1:19
	Percentage protection obtained		
1	75.6	64.7	5.8
2	56.0	8.3	29.1
3	42.5	33.3	12.0
4	0.0	11.7	

While discussing the relative effectiveness of the various concentrations used, it seems desirable to consider briefly the general characters of the three groups of animals and their duration of exposure to field conditions, as such factors greatly influenced the results. The beef cattle had the longest hair and were in the field continuously. Such long hairs protected the insecticide against sunlight and helped it to remain on the animals longer than on the dairy cattle or horses, with relatively short hairs. This is substantiated by the fact that on the fourth day of the tests with 1:9 dilution, a protection of 12.1 per cent was obtained on the beef cattle, 0.0 per cent on the dairy cattle, and 0.0 per cent on the horses (Tables 17, 21, 25). The figures on beef cattle and horses are of special interest in showing the effectiveness of hairs on the body in preserving the insecticides, as both groups were in the field most of the time.

The beef cattle were subjected to weather effects in the field continuously, while the dairy cattle were in the barn for a considerable time. Protection on three successive days with 1:9 dilution was 91.2, 69.8, and 51.9 per cent on beef cattle as against 97.7, 76.3, and 77.9 per cent on the dairy cattle.

The three dilutions showed a decrease in effectiveness with a corresponding increase in dilution, as 1:9 gave the highest percentage protection in all three groups of animals. The insecticide had little effectiveness when diluted 19 times, except for one day with dairy cattle, which may have been a result of these animals being kept in the barn for a considerable time.

Tests with pyrethrum-piperonyl cyclonene emulsion.

For comparative purposes tests with pyrethrum-piperonyl cyclonene emulsion were made with similar dilutions and in identical manner of application to that used in the case of pyrethrum-piperonyl butoxide formulations. However, the pyrethrum-piperonyl cyclonene emulsion is a quick breaking material and the spray had to be continuously agitated during applications.

The results obtained are shown in Tables 26 - 30, from which the relative inefficiency of cyclonene formulations in comparison with the butoxide formulations is apparent. In general, pyrethrum-piperonyl butoxide formulations not only showed superiority in giving higher percentage protection on the animals, but lasted longer. As the same types of animals were used under similar conditions in both cases, the inferiority of cyclonene can only be attributed to its quick oxidation as a result of its unstable nature.

The three dilutions showed a variation in the percentage of protection corresponding to that obtained with butoxide formulations. In other words, the percentage protection varied inversely with the dilution employed.

Table 26

Population of tabanids on beef cattle sprayed with various dilutions of pyrethrum-piperonyl cyclonene emulsion

		Number of flies caught per head in 10 minutes days after treatment							
		1		2		3		4	
Test number	Concentrations used	Sprayed	Check	Sprayed	Check	Sprayed	Check	Sprayed	Check
1	1:9	6	16	4	11	0	0	0	1
2	1:9	8	10	0	2	0	2	7	9
3	1:9	1	1	3	5	2	5	9	8
4	1:9	10	10	4	8	3	7	10	8
5	1:9	1	5	0	2	0	0	3	2
6	1:14	13	16	12	11	0	0	2	1
7	1:14	12	10	0	2	1	2		
8	1:14	1	1	0	5	4	5	7	8
9	1:14	0	5	1	2	0	0	2	2
10	1:19	13	11	15	13				
11	1:19	1	10	0	2	1	1	11	9
12	1:19	1	1	4	5	3	3	6	8
13	1:19	1	5	2	2	0	0	2	0
14	1:19	4	6	9	4	7	10		

Table 27

Percentage protection on beef cattle from tabanid attacks with pyrethrum-piperonyl cyclonene emulsion

Days after treatment	Dilution 1:9 Average population Sprayed	Dilution 1:9 Average population Check	Dilution 1:9 Percentage protection	Dilution 1:14 Average population Sprayed	Dilution 1:14 Average population Check	Dilution 1:14 Percentage protection	Dilution 1:19 Average population Sprayed	Dilution 1:19 Average population Check	Dilution 1:19 Percentage protection
1	5.2	8.4	38.1	6.5	8.0	18.7	4.0	6.6	39.3
2	2.2	5.6	60.7	3.25	5.0	35	6.0	5.2	0.0
3	1.0	2.8	64.2	4.25	1.75	28.5	2.75	3.5	21.4
4	5.8	5.6	0.0	3.6	3.6	0.0	6.3	5.6	0.0

Table 28

Population of tabanids on dairy cattle sprayed with various dilutions of pyrethrum-piperonyl cyclonene emulsion

Test number	Concentrations used	Number of flies caught per animal in 10 minutes days after treatment					
		1		2		3	
		Sprayed	Check	Sprayed	Check	Sprayed	Check
1	1:9	3	11	0	13	10	10
2	1:9	0	9	10	8	10	15
3	1:9	2	8	4	4	1	1
4	1:9	10	10	4	8	4	7*
5	1:14	5	8	9	11	13	14
6	1:14	0	1	3	15	14	18
7	1:14	10	11	10	13	12	11
8	1:14	3	9	2	8	12	15
9	1:14	7	10	4	8	6	7
10	1:19	13	11	16	13		
11	1:19	7	9	10	8	17	15
12	1:19	9	10	0	8	11	7

* Population on 6th day was 10 on sprayed and 8 on unsprayed animals

Table 29

Percentage protection on dairy cattle from tabanid attacks with pyrethrum-piperonyl cyclonene emulsion

Days after treatment	Dilution 1:9 Average population Sprayed	Check	Percentage protection	Dilution 1:14 Average population Sprayed	Check	Percentage protection	Dilution 1:19 Average population Sprayed	Check	Percentage protection
1	3.75	9.5	60.5	5.0	7.8	35.8	9.6	10.0	4
2	4.5	8.25	45.4	5.6	11.0	49.1	8.6	9.6	10.4
3	6.25	8.25	24.2	11.4	13.0	12.3	14.0	11.0	0.0

Table 30

Effect of pyrethrum-piperonyl cyclonene applications on horses against tabanid attack

Days after treatment	Dilution 1:9 Population on Sprayed	Dilution 1:9 Population on Check	Dilution 1:9 Percentage protection	Dilution 1:14 Population on Sprayed	Dilution 1:14 Population on Check	Dilution 1:14 Percentage protection	Dilution 1:19 Population on Sprayed	Dilution 1:19 Population on Check	Dilution 1:19 Percentage protection
1	0	6	100	4	6	33.3	3	6	50
2	4	5	20	6	5	0.0	10	5	0.0
3	3	9*	66.6	8	9	11.1	8	9	11.1

* Population on 4th day of the test was 4 on the sprayed and 3 on the check animals

Tests with experimental fly repellent No. 1.

Table 31 shows the results obtained by using fly repellent No. 1 against tabanids. The tests marked with an asterisk were performed during 1949, and the animals were wiped by a cloth soaked in the repellent. During the remaining tests, spraying was done with a 3-gallon air compressed sprayer.

Experimental fly repellent No. 1 provided a satisfactory control - above 50 per cent - for one day only. It had some residual effects on the second day, beyond which it did not show any effectiveness against tabanids. These results are in agreement with the manufacturers claims, who regard the material effective against horseflies for one to two days only.

Table 31

Population of tabanids on animals sprayed with experimental fly repellent No. 1

Test number	Animals used	Number of flies caught in 10 minutes per animal days after treatment 1 Sprayed	1 Check	2 Sprayed	2 Check	3 Sprayed	3 Check	4 Sprayed	4 Check
1*	Beef cattle	0	4	3	7	0	0	0	1
2*	Beef cattle	3	7	7	8	14	11		
3*	Beef cattle	0	3	0	0	0	0	0	1[1]
4	Beef cattle	0	0	1	0	Continued rain			
5	Beef cattle	0	4	2	7	14	9		
6	Beef cattle	2	8	4	6	0	1	0	0[2]
7	Beef cattle	1	0	0	0	9	17	16	14
8	Beef cattle	1	9	8	8	14	15		
9	Beef cattle	2	10	1	2	1	0	5	9[3]
10	Beef cattle	2	5	0	2	0	0	4	2
11*	Horses	0	6	1	2	6	7	13	14
12*	Horses	3	13	0	0	7	5		
13*	Horses	0	1	4	3	0	0	0	1
14*	Dairy cattle	0	7	3	8	6	11	12	14
15*	Dairy cattle	No observations		0	0	0	3	5	4
16	Dairy cattle	6	10	9	8	5	7		
17	Dairy cattle	0	0	3	7	2	8	8	9

[1] Population on 5th day was 4 on the sprayed and 4 on unsprayed animals

[2] Population on 5th day was 7 on the sprayed and 5 on unsprayed animals

[3] Population on 5th day was 2 on the sprayed and 3 on unsprayed animals

Table 32

Percentage of protection obtained on animals, against tabanids, with experimental fly repellent No. 1

Animals	Days after treatment 1	2	3	4
Beef cattle	78	35	1.8	7.4
Dairy cattle	64.7	34.7	55.1	7.4
Horses	85	38.4	0.0	13.3

The major species involved during the present studies were *Tabanus lineola* Fabr., *T. quinquevitattus* Macq., and *T. lasiophthalmus* Macq. Other species included were *T. superjumentaris* Whitney, *T. nigripes* Wiedemann, and *Chrysops callida* O. S. Occasional specimens of *T. atratus* Fabr. were also observed.

Discussion of results.

Of the various insecticides used during the present studies, pyrethrum-piperonyl butoxide formulations offered the best opportunities for the protection of animals against tabanids. The three dilutions of this material used showed a marked difference both in the period and degree of effectiveness. While dilution 1:9 provided more than fifty per cent protection for three days on the cattle and two days on horses, 1:14 dilution was good from one to two days, and 1:19 did not give any such (50 per cent or more) protection for even a single day, except in the case of dairy cattle.

The comparable dilutions of cyclonene-pyrethrum emulsion concentrate were found to be much less effective than the corresponding pyrethrum-piperonyl butoxide formulations, as they have a shorter residual effect than that of the pyrethrum-piperonyl butoxide emulsion.

Pyrethrum-piperonyl butoxide formulations, if it were not for their short residual effects, would have been the ideal insecticides against tabanids. They certainly kept the flies off the animals. The use of pyrethrum-piperonyl butoxide dilutions against tabanids would, however, depend on the economic importance of livestock in any region in relation to the cost of insecticidal applications. Another factor in this connection is the dilution of the insecticide with water. As shown by the above tests, at best a dilution of 1:14 (1 part of the emulsion to 14 parts of water) can be utilized with any degree of effectiveness against tabanids, and it is only ~~1:19~~ 1:9 dilution which can be safely recommended against these flies for a period of three to four days under suitable weather conditions.

The greatest advantage of pyrethrum-piperonyl butoxide formulations lies in their nontoxicity to animals. At present this is the safest insecticide known and can therefore be used as efficiently on dairy cattle as on beef animals.

As with most insecticides, weather plays a very important role on their efficiency. A heavy downpour of rain takes off most of the spray, necessitating another treatment. But here we have a fortunate state of affairs in the case of tabanid control. The unfavorable weather for the insecticide is also unfavorable for these flies. Ecological control creeps in, and one need not worry about the insecticidal effects, for the animals are protected anyway. The effect of weather conditions is very clear from Tables 14, 15, and 16. The same dilutions of pyrethrum-piperonyl butoxide emulsion gave a higher percentage protection on dairy cattle than on beef cattle and horses when observed in the field. In all probability this was the result of the dairy cattle being kept in barns during the afternoons when most of the showers occurred. The fly repellent No. 1 gives an appreciable protection, but for a very short duration, thereby limiting its uses to a great extent.

Prevention of oviposition

Probably the best method of controlling an insect pest is to prevent its reproduction. Various observers have suggested that the destruction of oviposition sites of tabanids offers good prospects of control. As is commonly known, almost all tabanids lay their eggs on vegetation, sticks, stones, and the like, in or very near to water.

The present series of tests was carried on to determine if DDT is capable of inhibiting _Chrysops callida_ O. S. from laying eggs. _C. callida_ lays its eggs in large numbers on vegetation along the edges of College pond. The eggs are laid on any sort of vegetation growing in about six inches of water. The females spend about an hour depositing an egg mass.

A preliminary test carried in 1949 (Table 33) shows that one per cent aqueous solution of DDT retarded oviposition. As this test was conducted late during the egg-laying season of the species, the low number of the egg masses is apparent. Furthermore, rain and unfavorable weather delayed oviposition to the third and fourth days following application of the DDT. During unfavorable weather - rain, strong wind, low temperature, and probably poor light - oviposition was negligible. After the sixth day of the test, no females could be seen ovipositing and observations had to be discontinued. This non-oviposition was the result of the outgoing season of laying eggs of the species concerned.

Table 33

Effect of 1 per cent DDT sprays on the oviposition of <u>Chrysops callida</u> O. S. during 1949

	Sprayed areas		Unsprayed areas	
Days after treatment	Total egg masses collected	Average egg masses collected	Total egg masses collected	Average egg masses collected
1	0.0	0.0	7.0	0.63
2	3.0	0.27	7.0	0.63
3	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0
5	2.0	0.18	7.0	0.63
6	1.0	0.09	4.0	0.36

During 1950, two sides of the pond were divided into sprayed and unsprayed areas, each area being 5 yards long and 1 foot wide. The selection of these sides along the pond was based primarily on the fact that they were mostly unshaded by shrubs and trees and thus constituted ideal oviposition sites for the species, which prefer sunny sites. The sprayed and unsprayed areas alternated with each other.

A one per cent DDT solution in water was prepared from a 50 per cent wettable powder. Spraying was done with a 3-gallon compressed air sprayer. Some settling of the suspension occurred, despite agitation. The areas were sprayed at the rate of 3 gallons of the spray per ten areas, or 50 yards.

Immediately after spraying a few females were seen ovipositing on the unsprayed sides of the leaves in the treated plots, and during subsequent spraying considerable numbers of egg masses were collected on untreated leaves.

Counts and removal of egg masses were made daily about 8:00 A.M. following treatments (Table 34). Daily observations were continued until the number of eggs deposited on the sprayed sites were about 50 per cent or more of the number deposited on the unsprayed ones.

Table 34

Effect of 1 per cent DDT sprays on the oviposition of Chrysops callida O. S. during 1950

	Sprayed areas		Unsprayed areas	
Days after treatment	Total egg masses collected	Average egg masses collected	Total egg masses collected	Average egg masses collected
1	35	3.5	93	9.3*
2	33	3.3	41	4.1
3	15	1.6	64	6.4
4	18	1.8	32	3.2
5	28	2.8	20	2.0

* Before spraying, the number of egg masses varied from 1 to 16 per area of 5 yards long

As shown in Figure 10, the reduction in oviposition on sprayed plots was appreciable for four days, but was reduced to zero on the fifth day.

The tests, therefore, suggest the possibility of preventing the tabanids from laying eggs, a method which might prove one of the best against these flies. Since the females take about an hour to lay a complete egg mass the chances of killing them through insecticidal applications are great. Though no noticeable inhibiting effect of one per cent DDT on the hatching of the eggs was detected, there is a possibility of destroying the egg masses by the use of some more effective insecticide.

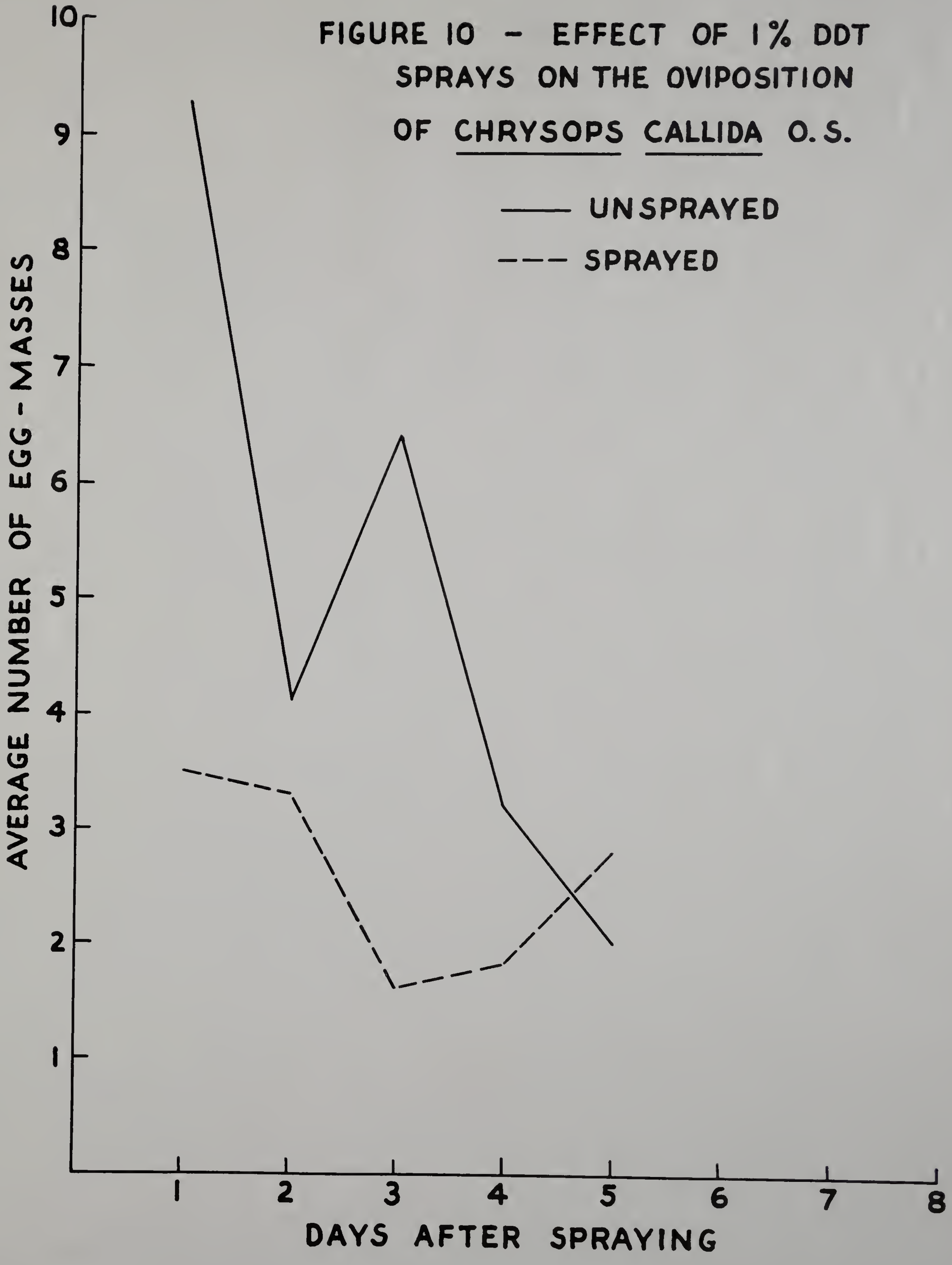


FIGURE 10 - EFFECT OF 1% DDT SPRAYS ON THE OVIPOSITION OF *CHRYSOPS CALLIDA* O.S.

There is a chance of destroying the natural enemies of tabanids through such applications. However, as the possible value of these enemies is not known, it is not possible to make a definite statement. A survey of literature reveals that practically nothing has been accomplished through natural enemies with respect to tabanid control.

Control of larvae

As Tabanids pass the greater part of their lives as larvae in the soil mostly along the edges of ponds, lakes, streams, and the like, an attempt was made to control them in the larval stage. The importance of controlling the larvae has been realized by various workers. Hine (1903), commenting on Porchinski's work for destroying the adults with kerosene on the surface of the water, observes: "It may be added from my own observations that the same application is of consequence in killing the larvae at the time they hatch and drop into the water. As the eggs of so many of our species are deposited over water and the larvae drop down into the water when they hatch, I am of the opinion that more striking results can be obtained from the use of kerosene on the surface of stagnant water in destroying larvae than in destroying adults." The writer has observed the hatching of C. callida both in the laboratory and in the field. In all cases observed the newly hatched larvae assembled on the surface of the egg mass and then dropped down in batches. As this species in most cases lays its eggs in such a position that the larvae would fall directly into the water after hatching, it offers possibilities of easy destruction by some chemical previously sprayed on the water surface.

Doten (1921) after surveying the life cycle of *T. phaenops* in order to discover the stage of its growth in which it might be controlled, concludes: "The one fact which seems to indicate a chance for control is the fact that in all the early part of its life, when the western green head horsefly is still a mud-inhabiting maggot, it is incapable of making its way to its food unless the mud is soft and liquid enough to permit the maggot to move about readily in search of other insects and earthworms. The drying of soil does not kill this maggot at once; it can endure long periods of drought and can go without food for a long time. Still, if the soil were made permanently moist and well drained, instead of wet and swampy, then the conditions would no longer be suitable and the maggots would be able to obtain very little food. Probably the eggs would not be laid by the parent fly over such soil nor would the young maggots develop."

Logothetis and Schwardt (1948) have also expressed a very similar opinion regarding horsefly control. As a result of their studies on *T. vicarius* they are inclined to believe that the treatments applied to pastures and the meadows for killing emerging flies might prove to be a suitable method of control if it could be done on a practical basis.

After a careful review of the available literature on Tabanidae the writer has reached the conclusion that the larval stage offers one of the best opportunities for the control of these flies.

An attempt was made to determine the distribution of the larvae in this region. At least three species involved in this investigation were *Tabanus lineola* Fabr., *T. quinquevitattus* Wiedemann, and *T. reinwardtii* Wiedemann. In all cases the larvae were confined within three feet of the water edge.

T. nigrovitattus Macq. is a very widely distributed and predominant species in the coastal region of Massachusetts, but even the larvae of this species show great localization. Gerry (1949) speaking of them says: "Larval collections showed that 94 per cent of the fly larvae are located on that portion of the salt marsh which lies within 200 feet of the upland." Now even in this example, if we can control 94 per cent of the larvae which are more or less localized, the control cannot be regarded as unsatisfactory. It is true that occasionally larvae of any species can be found in a somewhat unusual habitat, but this cannot be given too great an importance in planning extensive control programs.

The selection of a suitable insecticide for such control measures is another consideration. The larvae live underground for a year or even more and any insecticide destroying them during such a period would be satisfactory.

While working with "New Jersey mosquito larvicide" for collecting tabanid larvae, the writer became interested in exploring its potentialities for control work. Selected areas were sprayed with the larvicide and the larvae when driven out were placed separately on treated mud in small tin cans and brought into the laboratory. As a check, larvae collected without the use of any insecticide were used. Two concentrations (1:8 and 1:19) of the above larvicide, and one concentration (1:19) of pyrethrum-piperonyl butoxide emulsion were used. Both chemicals at the strengths tested were capable of killing the larvae (Table 35). The amount of time in which different larvae died was variable, because of two points. First, the larvae used during the present tests were of different ages; and second, they belonged to different species.

It appears that a dilution of 1:19 of pyrethrum-piperonyl butoxide emulsion is the most desirable from an economic standpoint. From one gallon of chemical, twenty gallons of spray can be prepared and this can be used to cover efficiently at least 160 square feet of area, as was the case in the above tests. Thorough removal of vegetation will permit a much more economical use of the insecticide.

In conclusion it may be pointed out that at present when we do not have any economical insecticide for controlling the adults, this larval control offers good opportunities.

The larvae undoubtedly burrow deep into the soil before the upper layers become frozen during winter and probably migrate upward during spring or summer, when pupation generally occurs. In agreement with Logothetis and Schwardt (1948), the writer believes that the best time for insecticidal applications would be just before pupation. Another suitable time may be immediately after oviposition when the newly hatched larvae can be attacked. In fact, only a few species are of acute economical importance in any particular region and after a study of such predominant species, the emergence and oviposition periods can be ascertained to form a basis for control projects.

Table 35

Effects of insecticidal applications on the mortality of tabanid larvae

Formulation used					
New Jersey mosquito larvicide 1:8		New Jersey mosquito larvicide 1:19		Pyrethrum-piperonyl butoxide emulsion 1:19	
Hours after treatment	No. of larvae dead	Hours after treatment	No. of larvae dead	Hours after treatment	No. of larvae dead
2	5	8	5		
4	6	10	2	21	5
6	11	21	3	22	8
8	6	22	5	23	2
9	1	24	1	46	2
10	7	28	4		
12	4	33	1		
16	4	34	3		
21	5	46	9		
23	1	52	2		
		69	1		
		76	1		
		120	1		
Average mortality time	9.34 hours		33.8 hours		24.6 hours

Natural enemies

The search for natural enemies of Tabanidae may well be appreciated in the absence of economically effective insecticides against the group. Although the writer has confined himself to the chemical means of control, a brief discussion of the natural enemies of Tabanidae seems proper.

A. PARASITES OF THE EGGS. Phanurus emersoni Girault, a minute hymenopteron insect, is one of the most important parasites on the eggs of Tabanidae. In localities where this parasite is present, a great majority of tabanid egg masses have been reported parasitized. Of the total number of egg masses collected in Texas (Segal, 1936), 93 per cent were parasitized by this insect. Parman (1928) remarking on the efficiency of Phanurus emersoni points out: "Egg-parasite rearing and dissemination, augmented by tabanid egg collecting (under conditions to be determined by the percentage of tabanid eggs parasitized, the number of tabanid eggs present, and the accessibility of the eggs for collecting), is a feasible method of tabanid control under certain climatic and physical conditions." Trichogramma minutum Riley attacks the eggs of Chrysops. During the present work many egg masses of C. callida O. S. parasitized by Trichogramma semblidis Aurivillius were collected. Webb and Wells (1924) found practically every egg mass of T. punctifer O. S. infested by a hymenopterous parasite, Prophanurus emersoni Girault,* in the Antelope Valley in Nevada and California. Anaphoidea sp. has also been recorded from egg masses of Chrysops aestuans by Philip (1931). Other parasites recorded from tabanid eggs include Phanurus tabanivorous Ashmead, Trichogramma evanescens West., and Telenomus sp.

B. PARASITES OF THE LARVAE. Unlike the eggs, the larvae are less liable to parasitic attack, because of their concealed habits. Comparatively few parasites have been reared from them. MacCreary (1940) reared two nematodes belonging to the genus Hexameris from Chrysops larvae. Marchand (1920) and Philip (1931) have also found tabanids infested with nematodes. According to Philip (1931) infestation occurs mostly at pupation time.

Philip (1931) has recorded Phorostoma n. sp. Aldrich parasitizing the larvae of T. trimaculatus, and this, according to him, is the first record of any insect parasitizing tabanid larvae.

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* All the available sources indicate that the genus Prophanurus has been incorporated into the genus Phanurus.

C. PARASITES OF THE PUPAE. Cameron (1926) seems to have been the first worker to record pupal parasites of tabanids. *Diglochis occidentalis* Ashmead was obtained from three species: *C. moerens* Walker, *C. mitis* O. S., and *C. excitans* Walker; while *Trichopria tabanivora* Fouts was reared from the pupae of *C. mitis* O. S. and *T. reinwardtii* Wied. Bailey (1947) has obtained *Trichopria tabanivora* Fouts from a pupa of *T. nigrovitattus* Macq. in Massachusetts.

D. PARASITES OF THE ADULTS. A chalcid parasite of tabanids in Tasmania has been reported by Nicholls in 1920. The larvae of this parasite were attached to the proboscis of the host.

Philip (1931) obtained a nematode, probably *Gordius*, from the abdomen of *T. astutus* Fabr.

Mites have also been recorded from several species of *Chrysops* and *Tabanus*. MacCreary (1940) has observed the larvae of Erthyraeidae on a female of *T. lineola* Fabr. He has also observed unidentified mites on *C. vitatta* Wied. Feng (1933) described adults of *Tabanus* species infested with mites in China. The parasitic role of mites seems doubtful, though Philip (1931) includes them under parasites in his discussion.

Predators on Tabanidae.

The larvae of Tabanidae in most cases fall into water immediately after hatching and probably a considerable number of them are eaten by fish and other aquatic animals. Dimick (1934) surveying the food of Oregon trout, points out that the larvae of tabanids are sometimes eaten by these fish. Cannibalism among tabanids in the larval form is another factor reducing their number considerably.

Birds have also been noted to capture both the adults and immature stages of horseflies. The crested flycatcher has been noticed to be the most significant in capturing adult flies, and the shore birds to be the most efficient predators on the larvae.

Spiders also destroy a considerable number of tabanids. MacCreary (1940) has found spider webs under the eaves of buildings containing a number of *T. nigrovitattus* Macq. and a few *Chrysops*.

MacCreary (1940) has observed *Stictia carolina* Fabr., a large wasp, capturing the adults of *T. nigrovitattus* and *T. lineola*. It is an extremely rapid flier and captures the horseflies on the wing as well as when on the host.

Philip (1931) records *Bembix spinolae* Lep. capturing female tabanids, and Parker (1917) has obtained both *Tabanus* and *Chrysops* from the nest of that species. *Bembix mobii* Handl., another predaceous wasp, has been seen by Neave

(1915) in the act of capturing the females of *T. taeniola* feeding on cattle. The introduction of these wasps has been suggested as a means of control for Tabanids, which have been reported to be scarce in areas where these wasps are present. Segal (1936) noticed *Vespa maculata* L. paralyzing the horsefly, biting off the wings, head and abdomen, and carrying the remaining thorax to the nest. He also mentions that the wasp *Monedula carolina* Drury is one of the most important predators of horseflies. These wasps supply horseflies to their larvae for food.

The robber fly *Erax aestuans* L. has been watched by MacCreary (1940) while feeding on *T. nigrovitattus*. It was observed piercing the thorax of the horsefly in order to reach the body contents.

Conclusions

1. Chrysops callida O. S. preferred a temperature of about 25° - 30° C. and sunny days for oviposition under field conditions.

2. The average duration for incubation period was 8.9 days at 22° C., 4.9 at 27° C., and 4.2 at 32° C. in the case of Chrysops callida, with a threshold at 15.6° C., under laboratory conditions.

3. New Jersey mosquito larvicide and pyrethrum-piperonyl butoxide emulsion was successfully used for driving the larvae from the soil for population counts and laboratory use. Larvae collected by this means were reared successfully in the laboratory.

4. The larvae of T. lineola, T. reinwardtii, and T. quinquevitattus were found within 1 to 1 1/2 inches of the soil surface during the summer months. However, the larvae of T. atratus always occurred below this depth.

5. Tabanid larvae in the field were limited to within 3 feet of the edge of the brook.

6. The population of larvae in the soil is mostly dependent on moisture. They live in nearly saturated to supersaturated conditions. The species involved were T. lineola, T. quinquevitattus, and T. reinwardtii.

7. Laboratory observations on the pupae of *T. lineola*, *T. reinwardtii*, *T. quinquevitattus*, and *T. melanocerus* revealed that this stage is passed at the surface of the mud.

8. The various species of flies prefer particular sites for feeding. *T. quinquevitattus* prefer the underside - belly and udder - of the host, while *T. lasiophthalmus* fed mostly on the sides. *T. superjumentaris* attacked back and sides of the animals.

9. The seasonal occurrence of the three major species, *T. lasiophthalmus*, *T. lineola*, and *T. quinquevitattus* showed marked succession ~~in abundance~~ in the order listed.

10. Wind dominated fly activities in the field, but its effects were temporary. No flies were seen during strong or fresh winds. The flies were much more active in bright sunlight than under cool cloudy conditions.

11. The most satisfactory spray for protecting the livestock from tabanid attacks was a 1:9 dilution of pyrethrum-piperonyl butoxide. The effectiveness varied greatly with the weather conditions. Rain took off most of the spray, necessitating repeated application. Under normal conditions, it gave satisfactory protection for from 3 to 4 days. The effectiveness of the insecticide decreased with the increase in dilution.

12. Dilutions of pyrethrum-piperonyl cyclonene corresponding to those of pyrethrum-piperonyl butoxide were less effective. However, a dilution of 1:9 pyrethrum-piperonyl cyclonene gave a somewhat comparable protection to that of 1:14 pyrethrum-piperonyl butoxide emulsion. Dilutions 1:14 and 1:19 of pyrethrum-piperonyl cyclonene emulsion did not show any promise of utility.

13. Crag fly repellent No. 1 repelled the flies but the short period of effectiveness rendered it inferior to the above formulations.

14. By spraying the egg-laying sites of *C. callida* with one per cent DDT suspension in water, an appreciable reduction in the rate of oviposition was obtained for four days.

15. Possibilities for a successful larval control of Tabanidae have been pointed out. The writer believes that larvae can be successfully controlled, at least in some regions, by soil treatments.

Summary

Bionomics.

The family Tabanidae is distinguished by porrect three-jointed antennae, pulviform empodia, spurred middle tibiae, large conspicuous aquammae, and a characteristic wing venation. The horseflies and deerflies are very irritating pests of livestock and man. Many species have been associated with the transmission of human and animal diseases. The species studied were T. lineola Fabr., T. quinquevitattus Wied., T. reinwardtii Wied., T. melanocerus Wied., T. atratus Fabr., T. superjumentaris Whitney, and C. callida O. S.

The eggs are laid in masses, mostly in the vicinity of water. The selection of oviposition sites differs with different species, some laying eggs on particular plants while others show no special preference. All the egg masses of three species, T. lineola, T. atratus, and C. callida, collected were laid in the immediate vicinity of water. The number of eggs per mass varied between 107 and 306, 96 and 128, and 110 and 216, with C. callida, T. superjumentaris, and T. lineola, respectively. Temperature has a marked effect on the hatching of the egg masses of C. callida. The average duration for the incubation period was 8.9 days at 22° C., 4.9 at 27° C., and 4.2 at 32° C. with a threshold at 15.6° C. Temperature ~~is~~ seems to be the most important factor influencing oviposition. Light comes next. The preferred conditions for oviposition of *C. callida* lie between 25° and 30° C. temperature and 45 to 72 per cent relative humidity. Sunny days are more favorable for oviposition. Few egg masses could be obtained under laboratory conditions from the four species of *Tabanus* tested.

The larvae possess eleven body segments in addition to the head and siphon. Their most distinguishing characteristic is "Graber's organ," of a disputed function.

Applications of New Jersey mosquito larvicide and pyrethrum-piperonyl butoxide emulsion have been used successfully for driving the larvae from the soil for population counts and in collecting larvae for rearing. The average larval population in 1949 was 1.675 per square foot along the college pond, and 2.16 along the brook. Similar counts along the brook in 1950 gave an average population of 0.75 per square foot.

Most of the tabanid larvae were within 1 to 1 1/2 inches of the soil surface during the summer months. One species, however, always occurred below this depth. The distribution of these larvae depends on the season, food conditions, and the species involved. No larvae were collected beyond three feet of the edge of the water.

A preliminary investigation regarding the occurrence of tabanid larvae with respect to ecological factors showed a preferred zone between 20.5° and 24.5° C. and 87 per cent saturation to a supersaturation of 118 per cent. Other factors liable to effect population include food abundance, parasites, predators, and the cannibalistic habits of many species.

No great success was obtained in rearing attempts. Four species, T. lineola, T. quinquevitattus, T. melanocerus, and T. reinwardtii were reared under laboratory conditions, from larvae to adult stage. Two specimens of T. lineola were also reared from eggs to adults. Newly hatched larvae of C. callida from egg masses collected in the field were not reared beyond the third instar, except in one case when the larva lived up to the fourth instar.

The pupae of Tabanidae are obtect, somewhat rounded at the anterior end but tapering posteriorly. In contrast to larvae, the pupal period is short, lasting from a few days to two or three weeks. In the laboratory the pupal stage was passed at the surface of the mud. In agreement with other workers, the writer had great mortality among the larvae as they neared pupation.

The seasonal occurrence of the three major species was determined. T. lasiophthalmus was the first species to appear, followed by T. lineola, and T. quinquevitattus appeared last of all.

Wind dominates fly activity in the field, though its effects are temporary. A gust of fresh or strong wind takes off all the flies from the animals, which appear again as the wind subsides. Fly activity is negligible during rain, and no flies were seen in the field at 23° - 24° C. while raining. Significant effects on the activities of flies were not noticed from the relative humidities encountered in the field. Fly activity was much retarded in cool cloudy weather.

Control.

Very little success has been attained in the past in control of Tabanidae. The writer believes that the larval stage offers one of the best opportunities for the control of these pests. Working in Massachusetts, Gerry (1949) found 94 per cent of the larvae of T. nigrovitattus localized within an area of 200 feet along salt marshes. In the same State, and studying different species, the writer has not collected any tabanid larvae beyond three feet of the water edge, and has found 1:19 pyrethrum-piperonyl butoxide emulsion an effective insecticide against the larvae. These findings, therefore, show that larval control of Tabanidae is possible at least in some regions. Further, the writer's findings that one or at most two treatments would efficiently control the Tabanids for one or two years, depending on the life cycles of the species involved, and that most of the larvae occur within 1 to 1 1/2 inches of the soil surface during the summer months, contribute toward the economical use of the insecticide.

The protection of animals against these irritating pests offers a serious problem. During the present studies various dilutions of pyrethrum-piperonyl butoxide, pyrethrum-piperonyl cyclonene, and Crag fly repellent No. 1 have been tested for protection of dairy and beef cattle and horses. The effectiveness of various insecticides is greatly influenced by weather conditions; rain takes off most of the spray, necessitating reapplication. Pyrethrum-piperonyl butoxide formulations were superior to other materials tested. Success with similar formulations has been reported previously by Howell (1949) and Bruce (1950). The present tests show that a dilution of one part of the emulsion to 9 parts of water would give a satisfactory control for three to four days, depending on weather conditions. The fly repellent No. 1, though capable of repelling the flies, was effective for one or two days only. These results were in agreement with the manufacturer's recommendations.

As the females utilize about an hour in laying a complete egg mass, there are possibilities of repelling or killing them through insecticidal applications on the oviposition sites. Oviposition sites of _C_. _callida_ sprayed with one per cent aqueous solution of DDT restricted oviposition for four days.

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