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AN ECOLOGICAL STUDY OF BLACK FLIES IN UPPER MICHIGAN

BY

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A thesis submitted in partial fullfilment of the requirements for the degree of Master of Forestry in the University of Michigan

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TABLE OF CONTENTS

INTRODUCTION

Black-flies (Simuliidae) are common blood sucking insects occurring in the wooded and partially wooded areas of Michigan. They live in various localities throughout the world from the tropic regions to the arctic circle, and from the lowlands to the tops of high mountain peaks. Sometimes certain species occur in such great numbers that they are a major pest of man and his domestic animals. Farmers, hunters, and fishermen know them as one of the most vicious of our biting insects. In spite of this, not until comparatively recently have entomologists of this country made many careful studies of their biology.

Although these insects are frequently mentioned in literature, most of these references consist only of fragmentary life history notes, prompted in many cases by an abundance of black-flies in restricted localities. The most important publications are those of Malloch (1914) and Dyar and Shannon (1927) which excel from the taxonomic and biological viewpoints. Metcalf (1932) discusses the ecology and habits of black-flies in this country. Wu (1931) carried on experimental studies of black-fly ecology in Michigan, but in some respects her work seems inadequate.

This study was started in the summer of 1939 in the vicinity of Camp Filibert Roth of the University of Michigan, located near Beechwood, Michigan. The work thus far has many of the characteristics of earlier works, in that, it has been largely concerned with chance observations made here and there in the field, without following any set plan of study. Field observations are supplemented by a study of the black-fly collections made in the summer of 1939, and by a review of the literature. This, then, is only a preliminary study designed to lay a foundation for a further investigation of the habits of black-flies in Upper Michigan. It will be concerned with black-flies in relation to forest resources in general, and game diseases in particular.

In the work thus far conducted, and in making plans for future work, many helpful suggestions and timely and worthwhile criticisms have been given to me by Dr. S. A. Graham and Dr. E. C. O'Roke of the School of Forestry and Conservation. I wish to extend my sincere thanks to them for this aid.

PLATE I.

Spill log in Cooks Run, a particularly favorable spot, for the development of black-fly larvae. (Cooks Run, near the bridge on Old U. S. 2 Highway)

SPECIES STUDIED

The original intention of this work was to make a study of all of the species of Simuliidae present in the Upper Peninsula of Michigan in the vicinity of Camp Filibert Roth. During the summer of 1939, S. vittatum Zett. and S. venustum Say were the only species collected. Others, however, are doubtless present. Adults of S. venustum appear to be scarace in this area, during the summer months, as less than one per cent of the pupae examined were of this species, and as the adults comprised only twenty per cent of the total summer's collection. It is very likely that the apparent scaracity of S. venustum is due to an annual variation of abundance. At other times of the year, the relative numbers of the two species may be very different. This scaracity of S. venustum does not exactly agree with the findings of other workers in different regions of Michigan. According to Wu (1931) both S. venustum and S. vittatum occur abundantly around Douglas Lake, and according to O'Roke (1934) S. venustum is the chief noxious species in that same locality. The investigations of Twinn (1933) and Hearle (1932) show S. venustum to be the most common species in a large portion of Canada, to the north of the area where this study was carried on. Twinn also states in the same article that S. vittatum is common

in several provinces of Canada.

At some later date, it is hoped that systematic collections of the various species of black-flies can be made in Upper Michigan. The relative abundance and distribution of the different species deserves particular attention as the biting habits are known to vary considerably.

Identification of these flies is not an easy task, as many of the characters used in distinguishing species are difficult to find and to recognize. This is particularly true in the adult stages. As a check in this work, specimens were sent to the United States Bureau of Entomology and Plant Quarantine for determination, and were verified as belonging to S. venustum and S. vittatum.

Because S. vittatum was the most abundant species, and hence the one most widely studied, this paper is confined almost exclusively to that species.

Eggs

The eggs (Plate VII) of S. vittatum are elongate, oval in shape (Malloch 1914 pg. 3). The measurements (Wu 1931) are : length, 0.25 mm., breadth, 0.15 mm., and height, 0. 15 mm. The eggs are held to one another and are fixed to the surface upon which they are deposited by a gelatinous like matrix. When first deposited they are a creamy white in color, but turn progressively darker as development advances, until at the time of hatching they are a dark brown or black color. Wu (1931) states that the eggs are deposited in long strings which wind about and over themselves forming in many cases masses several layers thick. No one has proøven that this string like character is confined strictly to S. vittatum, therefore dependance solely upon this might lead to error.

Larvae

S. vittatum larvae (Plate II) are pale, grayish white to black in color, soft bodied, cylindrical in shape, with the middle attenuated and the posterior and anterior ends enlarged. Body length varies from .3 mm. in the newly hatched larvae to 9.0 mm. in

PLATE II.

Larva of S. vittatum. Note the fans on the anterior end of the body, and the blood gills projecting from the dorsal portion of the caudal segment. (6 x natural size)

mature larvae ready for pupation. On either side of the head, there is a fan bearing organ which is used in straining the food from the water. The number of rays in the fans is usually constant within a species, and has been used to some extent as a character to differentiate species. Each fan of S. vittatum has 40 rays. The structure of the larval mouthparts varies in different species. S. vittatum (Malloch 1914) is distinguished from all other species except S. pictipes by having the labium with the central tooth trifid. S. vittatum is further separated from S. pictipes on the basis of blood gills. The blood gills are the larval breathing organs (Fig. 1) which project from a slit in the dorsal surface of the posterior body segment. This is another character which is somewhat distinctive in each species. In S. vittatum the blood gills are three in number, each being simple and unbranched.

Movement by the larvae is effected by a posterior disk which has a row of hooks around the margin; by an anterior proleg also equipped with hooks, and attached to the ventral side of the first abdominal segment; and by a silk thread which is produced by the salivary glands and exuded from the mouth. By means of the posterior disk and proleg, the larvae can move about with a looping gait characteristic of the measuring worms or Geometridae. By the aid of the silk thread,

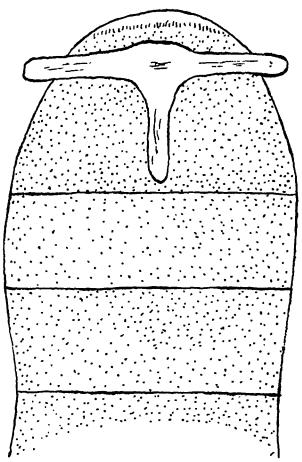


Fig. 1 - Dorsal view of the posterior three segments of an S. vittatum larva, showing the blood gills projecting from the caudal segment.

the larvae can retain contact with their resting places even when the current or other factors cause them to move considerable distance down stream. This past summer, larvae which were agitated, had the power to produce a silk thread as long as 5 inches. Upon removing the source of agitation, they had the ability to climb back up the silken thread to their original resting places.

Almost all of the references reviewed mentioned the fact that the food of blackfly larvae consists of algae. This agrees with my own findings. In many cases, the stomach and intestinal contents consisted primarily of desmids and diatoms, whereas in other instances desmids and diatoms were supplemented by other one celled algae, as well as by fragments of filamentous algae. In most every specimen examined, there was in the digestive tract, a certain amount of material which was not recognizable as to origin. Osborn (1880) makes the statement that certain of the southern "buffalo gnats" are carnivorous in the south. I have found no indication that this is true in S. vittatum.

Pupae

The pupae (Plate III) are formed inside the brown slipper shaped cocoons spun by the larvae. The chief characters by which pupae are separated are the

PLATE III - a.

Pupa of S. vittatum in the slipper shaped cocoon spun by the larva. (6 x natrual size)

PLATE III - b.

Pupae of S. vittatum scattered over the flat surface of a grass blade. Some of the pupae have emerged, leaving the empty pupal cases. (6 x natural size).

respiratory filaments which are constant in number in each species. The number is 16 in S. vittatum as contrasted with S. venustum, the other very common northern species of black-fly, which has only 6 respiratory filaments. The average length of the pupae of S. vittatum is 4.5 mm.

Adults

Adult black-flies are commonly called turkey gnats, buffalo gnats, or sand flies. The adults are usually black in color, but this does not serve to distinguish them, as many other flies of the same size are also black. Black-flies have a hump backed appearance, hence the name "buffalo gnats". This hump is due to an enlarged scutum and a reduced prescutum, and is more pronounced in the males than in the females in the species studied. Adults vary in size from less than 1 mm. to 4 mm. or slightly more in length. S. vittatum is a little more than 2 mm. in length. These flies can be separated from other members of the order Diptera by their short, compact, 11-jointed antennae, by the absence of ocelli, by their short strong legs, which have the femora broad and flat, and which usually have the tibae armed with terminal spurs. The wing venation differs from that which we find in other Diptera (Fig. 2). The adult

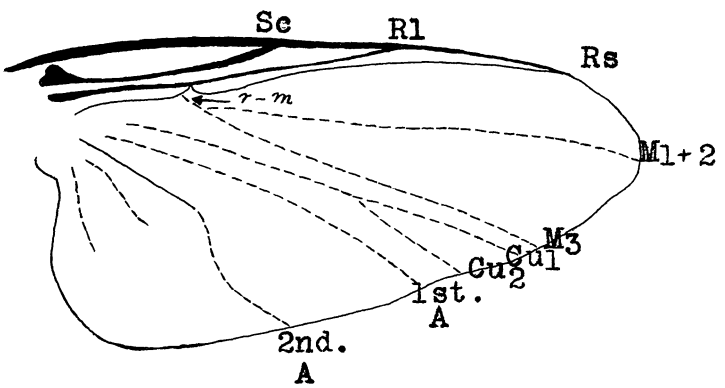


Fig. 2 - Wing of a Simulium. (After Comestock). An examination of the wings of S. vittatum shows that they have exactly the same venation as shown in this Fig.

PLATE IV - a. Adult male of S. vittatum (6 x natural size)

PLATE IV - b. Adult female of S. vittatum (6 x natural size)

male and female flies are readily distinguished by the eyes; in the males they are contiguous, covering the front, whereas in the females they are widely separated and smaller. In the male the eye facets on the lower one quarter of the corneal surface are quite small in contrast to the larger upper facets.

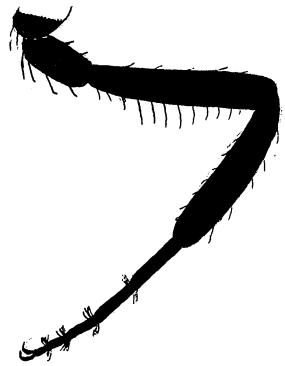
The adults of S. vittatum are distinguished from other species primarily by the color markings on the legs and thorax (Fig. 3). Malloch (1914) gives a detailed description of the males and females of this species, hence in this paper only the striking characters differing from those found in other species and used in differentiation purposes will be noted. The following characters are taken from Malloch's (1914) keys to adult male and female Simuliidae.

Males

The males are mostly black, only the legs and antennae having yellow markings. The legs have the basal joint of the hind tarsus bicolored. The mid-tarsus has at the most only the bases of the first and second joints pale. The stripes on the scutum are generally well defined, the black always broader than the white stripes. The total length is 2 mm. or slightly more.

Females

The body is black or gray with the scutum and



Anterior leg

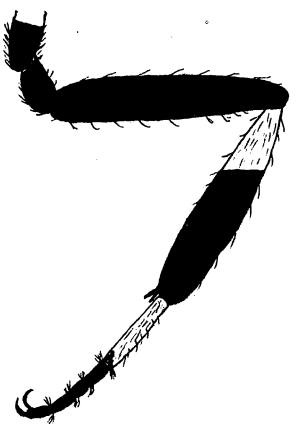
Middle leg

Posterior leg

Fig. 3a - Legs of the male of S. vittatum showing the zones of coloration.

Anterior leg

Middle leg



Posterior leg

Fig. 3b - Legs of a female S. vittatum showing the zones of coloration.

PLATE V. - Eye fly, Drosophila sp., a common associate of adults of S. vittatum and S. venustum (6 x natural size)

abdomen never yellow. The scutum has 5 very distinct brown stripes on a light gray ground. Tarsal claws simple with the base of each claw slightly tuberculate. The tibiae lack the silvery white coloring above as we find in S. venustum and which has been responsible for that particular species being called the "white-stocking flies".

Contrary to what might be assumed from reading through the keys, the markings on the scutum are very difficult to see in preserved materials. When specimens are placed in liquid preservatives these markings are often obliterated. They are most readily observed in material shortly after collection is made, hence it is highly advisable to determine specimens when fresh.

LIFE HISTORY AND HABITS

Knowledge of the life history of S. vittatum, as reported in the literature, is incomplete and many things dealing with their development and habits are unknown. The chief objective of this present paper is to point out these gaps which will be filled in the course of further work.

The eggs of S. vittatum, as far as written records show, are deposited only on objects in swiftly flowing streams. This, however, does not always hold as Dr. E.

C. O'Roke has observed larvae, probably of S. venustum or S. vittatum, living in the coves along Douglas Lake. This undoubtedly goes on in many lakes where the wave action agitates the water along the shore lines. When oviposition occurs in streams, the eggs are deposited on any objects which are either on the water's surface, which are kept moist by the occassional dipping of the object in the water, or which are continually moistened by the spray from rapids or falls. In the streams in the area studied, the most frequent places for oviposition were the blades of two species of manna-grass, Glyceria grandis and Glyceria striata. Never-the-less, it was not uncommon to find masses of eggs on floating algae, sticks, rocks, pieces of paper, or on the floating leaves of deciduous trees.

It is not known when S. vittatum begins ovipositing, but it has been reasonably assumed that oviposition starts in the early spring months, from late March to the middle of April, or as soon as the ice is gone from the streams and the air temperature has become warm enough for adult insect life. In the Upper Peninsula of Michigan, black-flies are reported to be unusually numerous during the latter part of April and during May. At that time, they are at their biting peak. It has not been possible thus far to make stream examinations prior to June, but on June 25, eggs were found abundantly in the streams.

Another observation which offers considerable proof that black-flies lay their eggs quite early in the spring is the fact that in June eggs are found high and dry on the leaves and stems of aquatic vegetation, unquestionably having been deposited there when the streams, swollen by spring break up, were at their high water stage. The snow melts and the ice usually leaves the streams during the latter part of March and the first two weeks of April.

From weekly examinations along Cooks Run it is obvious that black-flies continue ovipositing throughout the summer months. Almost invariably, every day spent in the field during the summer furnished some eggs which had been deposited but a short time, as evidenced by the coloration. Various authors have expressed opinions as to the number of broods of S. vittatum each year, but they are only speculative. From evidence thus far collected, it seems that there are two major times of oviposition; one in the early spring just after the pupation and emergence of the overwintering larvae, and the other in the fall, probably during October and early November. This latter period of massive oviposition is almost certain if my observations are indicative of general trends throughout Upper Michigan. On the 28th. of September 1939, larvae were found to be pupating in enormeous numbers

in Tamarack Creek. Collections were taken into camp, and on the way to camp and after arrival at camp, great numbers of the adults emerged from the pupal cases. It seems reasonable to assume, if not to state with absolute certanty that this is indicative of a general and wide spread emergence of adults during October. It also seems logical to conclude that this mass emergance will result in extensive oviposition. Hunter (1913) states that in Kansas there is a mass spring and fall emergance of S. vittatum. He does not say whether the fall brood oviposits at the time of emergance, or whether they pass the winter in the adult stage. It is quite possible that S. vittatum may overwinter in the adult as well as in the larval stage.

The developmental period of black-fly eggs is known to vary considerably. Wu (1931) gives 4 to 5 days as the usual length for development. Hunter (1913) states that in Kansas the probable length for development is about one week. He further states that this time is known to vary with temperature andrate of current or stream flow.

In some black-flies the eggs have been suspected as being the overwintering stage, but in S. vittatum, field observations indicate that the winter is usually passed in the larval stage. It was not possible to make winter examinations of the streams worked in the

summer of 1939, but observations were made in Illinois streams in the month of December of 1939, when only larvae were found. Intensive search in all likely places revealed no egg masses. This offers further substantiation of the assumption that S. vittatum does not, as a rule, overwinter in the egg stage.

When the eggs hatch, the larvae of S. vittatum coming from them are extremely small, and are very easily overlooked by the causual observer. Larvae are present at at all times of the year, and at all times, except the winter months, can be located in all stages of development. In this study, no investigation has been made as to the exact length of the larval period. Various workers have speculated on the length of larval development in this and in other species. One factor that is not known, and which serves to obscure the length of time for development, is the number of generations per year. Basing an opinion upon field observations in a restricted locality, there appear to be two major broods or generations, one emerging in the spring and one in the fall. In between these two, there are new generations being produced every day, depending somewhat upon such factors as air or water temperatures. Hunter (1913) estimated that in Kansas the usual time elapsing between the emergance of the larvae from the eggs

PLATE VI.

The case bearer, Brachycentrus nigrisoma, a common associate of the aquatic stages of black-flies. (6 x natural size)

until the time of pupation was from 3 to 4 weeks to several months.

Young black-fly larvae are found, as a rule, only in swiftly flowing water. However, they have been observed along the banks of streams where there was little swift water. This was easy to analyze, as the eggs which were laid on the overhanging bank vegetation, were at the time of oviposition in water made swift by the spring freshets. Further examinations failed to show any larvae in these quiet waters. The conclusion drawn was that death either occurred due to insufficient current to bring food, or that the larvae moved out into the swifter portions of the stream, where they were found abundantly during the entire summer.

In Cooks Run (Plate VIII) the population of black-fly larvae, as calculated by leaf counts, was approximately 30 per square inch of leaf surface, as contrasted with a population of 50 per square inch of leaf surface at Tamarack Creek. Observations made indicate that there is little difference in the rate of stream flow. The water was always warmer in Tamarack Creek, and indicated by deposits of sediment on the leaf surfaces, the food content of the water was unquestionably greater. By making a thorough study of these two extreme cases, as well as similar cases in the same locality, some of the obscure factors affecting larval distribution may

be considerably clarified.

Larval distribution within permament streams is not wholly explained by previous workers. If current is the controlling factor, why is it that black-flies are not found in all swift streams in a given locality? In Iron County, Michigan, certain streams contained very few larvae, whereas othershad many larvae in some spots and none in others where conditions of current were apparently favorable. The bank cover along streams where larvae are abundant seems to be important. In the portions of Cooks Run and Tamarack Creek where larvae were numerous, bank cover had been disturbed leaving openings. In both of these cases road construction and logging had disturbed the original cover, and left the streams virtually free from bank shade. This shade factor was observed in other places and seemed to hold very well. Larvae in great abundance were found only in open places where bank shade was little or lacking.

Distribution of larvae within a stream course can be effected without the necessity of oviposition going on along the entire stream. In this distribution there are two chief aids; namely high water and fishermen. High water moves debris, containing eggs, larvae or pupae down streams, and fishermen by kicking loose Ranunculus trichophyllum, and other shallow rooted water plants, enable

many larvae to move down stream. At one particular place these plants were observed to collect on the snags of a spill log, and there collecting, the larvae became established. This was evidenced by an especially heavy population of larvae and pupae on the log. No eggs were found nearer than ¼ of a mile up stream, offering further proof of this method of dissemination.

After the larvae have matured, spun their larval cocoons and pupated, again there is a stage in their life cycle which is variable in length. Wu (1931) calculated that 4½ days was the usual length of the pupal stage when the water temperature varied between 18 and 21.6 degrees Centigrade. Her experiments were, however, carried on under semi-artificial conditions. Hunter (1913) made the general statement that the length of the pupal period of S. vittatum ranges from 2 to 3 weeks. Here, again, is a place where more actual field imformation is needed. Pupae may be found during the entire summer months. It has been the usual thing not to find them in the winter months.

Adults may be found emerging from the pupal cases during the spring, summer and fall months. The adults of S. vittatum emerge from the pupal case under water and shoot to the surface. This was observed a number of times during the summer and it was only wished that a camera could be built which would catch this interesting phenomena, so that it might be preserved

for others to see. It is almost unbelievable that so small a fly can work itself from its pupal case and have enough power immediately at its disposal to rise against the current, almost straight up through the water into the air above.

Adult black-flies are diurnal at least as far as their biting habits are concerned. I find no records where adults have been collected away from water courses at night. It apparently is not common, but once during the summer of 1939 two adult females were caught after they had entered our laboratory, probably having been attracted by the gas lantern.

The biting habits of S. vittatum in Michigan have as yet not been investigated. In my own experience, the only black-flies in the Upper Peninsula of Michigan to bite have been the females of S. venustum. However, Hunter (1913) states that they do bite man. It has been assumed by various investigators that the females of all black-flies feed on blood. It appears that this is pure assumption. Wu (1931) states that adults of S. vittatum have oviposited in glass vials without having had at any time a meal of blood. On the contrary, she concluded that S. venustum requires blood before producing mature ova.

Female black-flies, as is the case with mosquitoes, is the only sex recognized as biting man and animals.

Either no explanation is given for this, or the statement is merely made that the male mouth parts are weak or undeveloped. Upon measuring the mouth parts of S. vittatum, the piercing mechanism of the females are found to be .58 mm. in length in contrast to those of the males which are .33 mm. long. This difference in length supplemented by the lack of sharp chitinized spines on the labrum-epipharynx, as are found in the females, is more apt to account for the difference in biting habit, rather than a weak or rudimentary character of the mouth parts of the males.

Assuming that we are right in concluding that male black-flies do not feed on blood, the question immediately arrises as to just what, if anything, they eat. The males of certain mosquitoes are supposed to feed upon the sap of plants, and it has been suggested that the same may also be true with black-flies. To my knowledge, however, no studies have been made, which shed any light on this particular question.

The distribution of adult black-flies from place to place and from season to season presents some very interesting problems. Just what environmental factors may cause adult black-flies to be particularly abundant in certain localities and at the same time be seemingly scarace or absent in other near by regions? In some cases the nearness of a particular location to

a suitable place for the aquatic stages to develop is without question of considerable importance. The distance that blackflies are able to fly, or the distance which they are carried by air currents is still problematical. Most of the references in the literature pertaining to flying distances are not based on reliable expermental evidence. During the summer of 1940 the intention is to check flight capacity in such a manner that we will be able to say with relative certanty just how far black-flies may be expected to move from known breeding grounds.

During the past summer adult black-flies were not at all numerous, and were not particularly noxious. A number of times, it was possible to make inquiry of fishermen about black-flies. Some of them had heard of them in the East and in Canada, whereas others were entirely unfamiliar with them. None reported having been bothered by them in Upper Michigan.

Black-flies were observed in a rather small number of situations. They were seen almost every day about Forestry Camp. To the north of Camp there is an opening in the timber stand which is utilized by the boys as a ball diamond. In this opening, female flies were often observed flying about in the early morning from eight to ten o'clock. As a rule, only females were observed and collected at this time of the day.

At night, however, from six o'clock to dusk, male flies were observed flying over some experimental hemlock logs. The grass and weeds were kept cut about these logs, leaving a lighter patch in the general cover of the land in the opening. At the same time flies could not be found flying over other portions of the opening.

In addition to these observations at the ball diamond, male black-flies were observed practically every evening flying or hovering near the door of the mess hall, in the camp, itself. Only once during the entire summer were females collected from these swarms. This offers strong support that these swarms are not mating flights, but are prompted by other factors. There was at this time of the evening, considerable warm air issuing from the mess hall as a result of the cooking of the evening meal. Whether this warm air or certain odors diffusing from the kitchen could have served as an attraction could not be determined. However, the fact that swarms could not be seen in front of any of the bunk houses or other camp buildings at the same time of the evening, offers strong support to the belief that some factors specific to the area in front of the mess hall were particularly favorable for these swarms.

During the summer, female black-flies were not observed along stream courses except when ovipositing, and males

except in the few cases when they were seen emerging from their pupal cases. Females were usually found in cut over stands of timber, and were particularly numerous on dark cloudy days when the humidity was high. There are unquestionably numerous factors in the environment which act on black-flies and affect their distribution. There is much need for further study to clear up the points which have been raised, as well as others which are not now apparent.

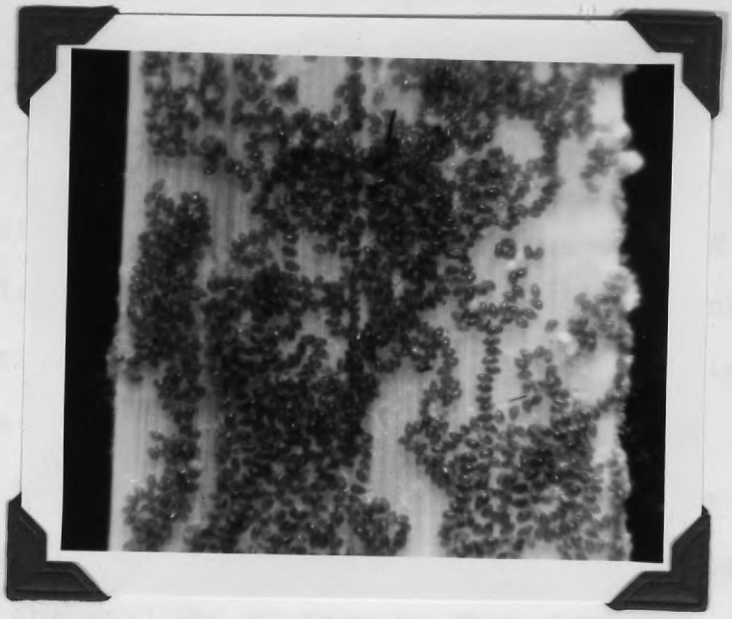
Adult black-flies are present in the Upper Peninsula all during the year, excepting in the very cold winter months. But as previously mentioned, there are two peaks of abundance, one coming in the early spring and one in the late fall. It is interesting to speculate on the factors back of the mass spring emergance. On checking streams in December of 1939, all black-fly larvae were approximately the same size. In September, the larvae in Tamarack Creek and Cooks Run ranged from young, just hatched, to those well reaching maturity. This makes it appear as if much the same factors may lead to to the spring abundance in black-flies as are found operating in the case of bark beetles; namely that the smaller larvae continue to grow during the winter months, while those closer maturity remain in a more or less static state of development, when winter sets in. The young larvae thus catch up with those farther advanced. If this

is true with black-flies the "catching up" occurs in the spring when we have hordes of black-flies appearing in the Upper Peninsula.

OVIPOSITION

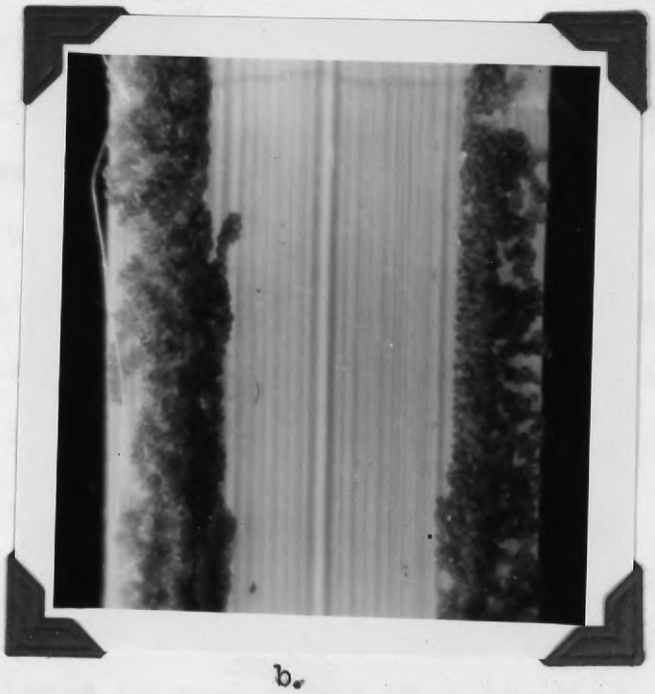
On August 6, 1939, Simulium vittatum were observed ovipositing on the leaves of Glyceria grandis in Cooks Run. This observation prooved to be such an unusual sight, that I feel it is well worth recording here.

About 4 o'clock in the afternoon the sky became overcast and within a few minutes it was almost as dark as dusk. All at once, adult females became numerous along the stream and began to rest on the grass blades floating on the water. The flies were so numerous that at one time 27 females were counted ovipositing on a blade of grass 7 inches long and ½ inch wide. The eggs were laid in long strings held together by a gelatinous like substance. The strings were continous until the flies were disturbed, or in some cases until they had completed oviposition. On this particular afternoon, most of the flies were placing their eggs on the underneath margin of the leaf surfaces (Plate VII b). While ovipositing, the flies held their bodies at right angles to the leaf edges with the legs on one side of the body grasping the upper leaf



a.

PLATE VII - Eggs of S. vittatum deposited on the upper surface of a floating blade of grass (6 x natural size)



b.

PLATE VII - Eggs of S. vittatum deposited on the lower surface of a floating blade of grass (6 x natural size)

surface and with those on the other side pressed against the lower leaf surface. For some time prior to this observation, it was a puzzle just how great masses of eggs could be deposited on the margin of grass blades under water without the fly being emersed while ovipositing. But under water ovipositing is not true at least with this species.

As the fly moves along the margin of the leaf, the legs against the lower surface are used to manipulate the strings of eggs as they pass out of the body. The legs kick them back under the leaf where they become attached to the leaf surface by the gelatinous like matrix enveloping them. Both margins of the lower side of the leaves were oviposited on. It was not uncommon to find flies ovipositing on the upper leaf surface, but in such cases the operation was not necessarily confined to the margins (Plate VII a). When on the upper horizontal portion of the blades, the flies used their legs only for walking, except that they were observed to use the metathoracic legs to kick the egg string loose when disturbed.

The upper side of the leaves of this grass are V shaped in cross section. Occasionally these blades become twisted in such a way that the V shaped side lies down against the water. In a few cases, flies

were underneath these leaves walking along in the groove or trough ovipositing their eggs. In these instances, the leaves had their margins touching the water, but the keeled centers were free from water. As these spaces were filled with air, they were quite ideal for oviposition.

Certain species of black-flies are reported as diving beneath the water to oviposit on stones lying below the water's surface. Comstock(1925) states that this habit has been observed in S. pictipes. As a check on this with S. vittatum a great number were immersed while ovipositing. They quickly released their hold, ceased ovipositing, and came to the surface. This together with the fact that they were at no time found naturally ovipositing beneath the water, strongly indicates that it is not a common practice with S. vittatum, if at all.

Oviposition normally occurs from 6 to 8 P. M. On this afternoon, however, I am strongly of the belief that the darkened sky, accompanied by the cooling of the air, so nearly duplicated the conditions which are usually present later in the evening, that the flies reacted to these factors of light and temperature, much as chickens would react to a sun eclipse by going to roost.

SEX RATIO

Wu (1931) furnishes the only imformation on the sex ratio of black-flies. She determined that the sex ratio of S. vittatum Zett., closely approximates a 1:1 ratio. Due to the fact that male and female flies are seldom found flying together, hence making it difficult to get a good sample for sex ratio studies, in this work, and examination of the pupae has been resorted to with the belief that it will give more significant figures. The following are sex ratio figures based upon examination of pupae from Tamarack Creek:

Collections made August 27, 1939: S. vittatum males 700; S. vittatum females 425, 2:1 ratio. Collections made September 28, 1939: S. vittatum males 482; S. vittatum females 479, 1:1 ratio.

My figures indicate that the ratio between male and female black-flies undoubtedly varies from one time of the year to another.

PLATE VIII.

The map on the following page covers an area of six townships located in Iron County, Michigan in the vicinity of Camp Filibert Roth. The red dots and numerals mark points where stream examinations were made in the summer of 1939, and where black-fly larvae were found. Note the few number of streams in these six townships. (from F. S. Map of The Ottawa Nat. Forest)

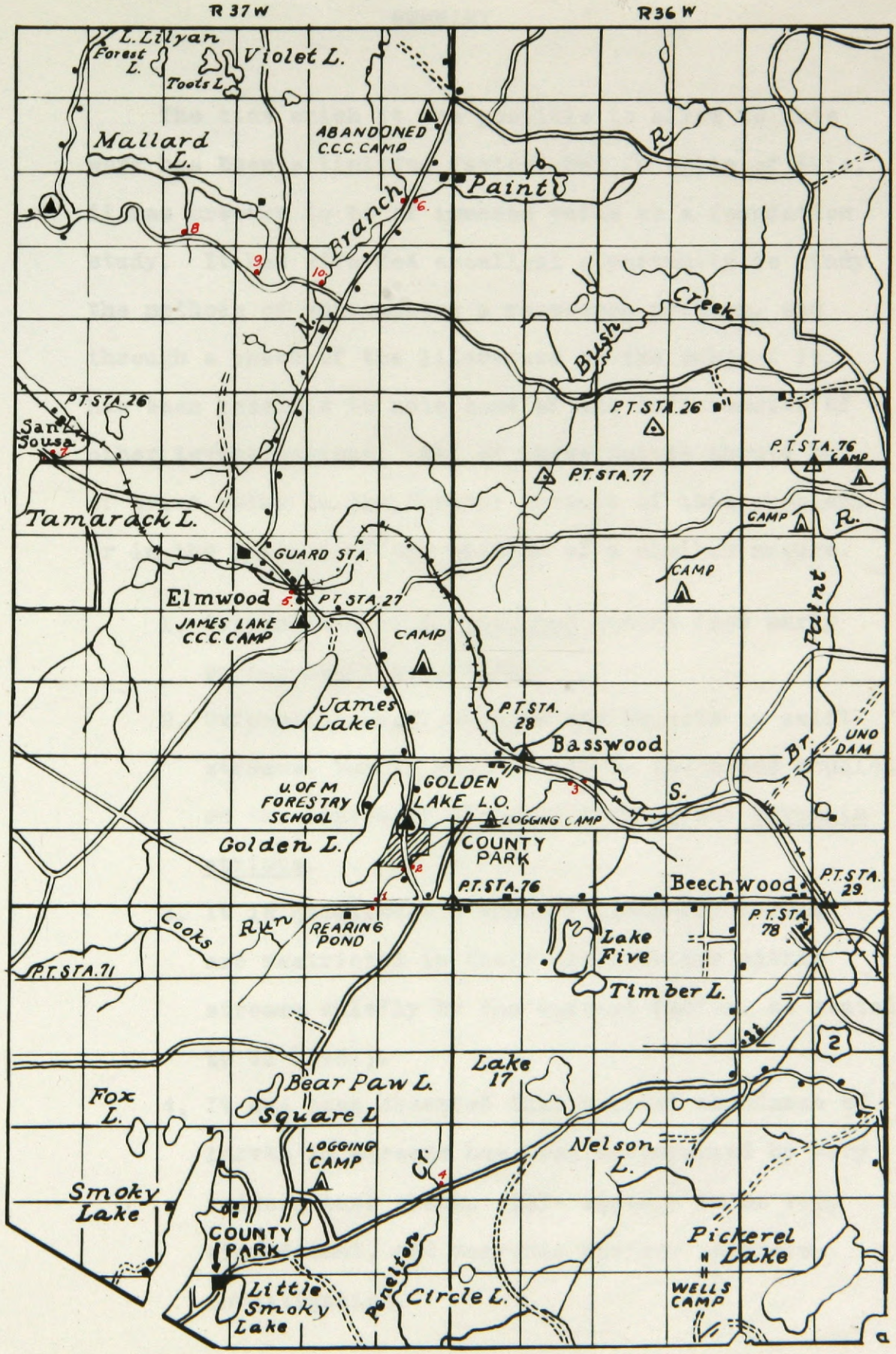

R 37 W
R 36 W
T 44 N
T 43 N
T 42 N
L. Lillyan
Forest L.
Toots L.
Violet L.
Mallard L.
ABANDONED C.C.C. CAMP
Paint R.
N. Branch
Bush Creek
P.T. STA. 26
San L.
Sousa
Tamarack L.
GUARD STA.
Elmwood
P.T. STA. 27
JAMES LAKE C.C.C. CAMP
CAMP
James Lake
P.T. STA. 77
P.T. STA. 76
CAMP
Paint R.
P.T. STA. 28
Basswood
U. OF M FORESTRY SCHOOL
GOLDEN LAKE L.O.
LOGGING CAMP
COUNTY PARK
Golden L.
Beechwood
P.T. STA. 29
P.T. STA. 78
Cooks Cr.
REARING POND
P.T. STA. 71
Lake Five
Timber L.
Lake 17
Bear Paw L.
Square L.
Fox L.
LOGGING CAMP
Nelson L.
Smoky Lake
COUNTY PARK
Little Smoky Lake
Penelton Cr.
Circle L.
Pickerel Lake
WELLS CAMP
UNO DAM
S. Br.

PLATE VIII.

SUMMARY

The time which it was possible to allot to this work has been a limiting factor, but in spite of this, it has proven to be of immense value as a foundation study. It has afforded excellent opportunity to study the methods of approaching a reasearch problem, and through a check of the literature on the subject it has been possible to note some of the deficiencies of other investigations. All of these points should be of great value in the further pursuit of this problem, or in the pursuit of any problem of a similar nature.

1. Oviposition of S. vittatum occurs from early spring until late fall.
2. Oviposition may occur on any objects in swift streams, but is most common in the areas studied on the leaves of Glyceria grandis and Glyceria striata.
3. It is questionable whether black-fly larvae are restricted in their distribution within streams chiefly by the current factor, as stated by Wu (1931).
4. It has been observed that a great abundance of larvae in streams has been accompanied by very reduced bank shade. This appears to be very significant, and warrants further intensive investigation.

5. From observations and collections made in the vicinity of Camp Filibert Roth during the summer of 1939, S. vittatum was more abundant than S. venustum.
6. S. venustum females were the only Simuliidae observed to bite man.
7. S. venustum females were found flying about most abundantly on dark cloudy days when the relative humidity was high.
8. Black-flies are not a serious menace to man in this area, except through the months of April and May.
9. Summer trout fishermen are not bothered at all by black-flies in this vicinity.
10. The small number of black-flies during the summer months greatly enhances this particular portion of Upper Michigan from the vacation and recreation viewpoints.

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APPENDIX

FURTHER WORK

The investigations which are the basis of this paper are preliminary in nature, and have barely touched upon many of the problems regarding black-fly ecology. Some of the important aspects of existing problems, together with imformation needed for their solution are presented in the following pages.

The chief purpose of further work will be to gather more complete imformation on black-fly activities in order that we will be in a better position to understand their part in the transmission of game diseases. This work is designed particularly to tie in with grouse disease investigations being conducted by Dr. E. C. O'Roke.

Time Required

This study should be carried on from the time of the first black-fly emergance in the spring until their disappearance in the fall. This would be a period of about seven months.

Questions to be Answered

1. What effect does light intensity have upon black-fly feeding activities?
2. What effect does relative humidity have upon these activities?

3. What are the effects of air temperatures upon their feeding activities?

4. What effects do cover types have upon the distribution and behavior of black-flies?

5. How far may adult black-flies reasonably be expected to fly from breeding grounds?

6. What effects do light intensity, water temperature, and rate of current have upon black-fly distribution in streams in this area?

Materials Needed

Animals - Since by this study it is hoped to tie black-fly activities as closely as possible with grouse, these birds will be used as experimental animals. For the first few weeks, they will be used along with chickens in order to establish whether or not chickens are equally susceptable to attack by the same or other species of black-flies. If chickens prove to be equally susceptable, they will be used in the remainder of the work. If the same condition is found true with snow-shoe and domestic rabbits the latter will be used. The use of domestic animals will faciliate the ease of care and handling. Grouse and snow-shoe rabbits will be trapped and chickens and domestic rabbits purchased from farmers and poultry dealers. One pair of grouse, one pair of snow-shoe rabbits, one pair of domestic rabbits, and one dozen chickens should suffice for this study, provided that they remain healthy.

Cages and feed are essential but their cost is a relatively small item. In this study, domestic animals used will be purchased after they are at least three to four weeks old. This will reduce chances of loss from disease. Cages will be made of hardware cloth. The bottom of the cages will be raised above the ground by a heavy wire frame fastened to the base. The wire bottom of each cage will enable the animals to be kept under sanitary conditions, and should further eliminate chances for disease.

Feeding young animals is sometimes quite a difficult problem. Feed for both the birds and mammals will consist of corn and some green supplement such as clover. In addition, the birds will be fed an egg mesh and will be furnished with a suitable grit. The grouse and chickens will be supplied with some animal food such as ant pupae or grasshoppers.

One hundred twenty five dollars should cover the entire cost of animals, cages, and feed.

Equipment and Instruments Needed:

1. 1 Maximum-minimum thermometer.
2. 3 -10 to 110 C thermometers.
3. 1 Wind guage.
4. 1 Exposure meter.
5. 1 Box compass.
6. 1000 record sheets for adult study.

7. 1000 record sheets for stream survey work.
8. 4 gross of small glass vials.
9. 6 dozen ½ pint jars.
10. 5 gallons of preservative.
11. 12 hardware cloth field cages.

Collection of Data

On alternate days during this seven months period work will be concerned with the adult study. Experimental animals will be taken to the field and placed in a particular cover type, e. g. as in a dense hardwood stand, or heavily cut over stand. This work will be started at daylight and continued in the evening until no flies are present. Upon arriving at each point of study the caged animals will be placed on the ground. The maximum-minimum thermometer will be placed so that it is at the same level as the animals, and so that it has as nearly as is possible the same exposure to sunlight. The exposure meter will be placed by the thermometer. The wind guage will be set up by the cages. These operations should take not to exceed five minutes.

After this preliminary set up is made, observations will be made on black-flies present. When they are observed to bite the experimental animals, the time of day will be recorded. Air temperature can be read instantaneously from the maximum-minimum thermometer. Light intensity can be calculated in one half

minute. Relative humidity can be determined with the hand aspirated psychrometer in from 1 to 2 minutes or less. Wind velocity will be calculated in feet per second, but will be determined for the entire period of observation at each plot, as we are more concerned with its affect upon abundance of blackflies than its affect upon biting tendancies. Underhill(1939) states that black-flies have been noted to take as long as three minutes to engorge blood. Three minutes is ample time for recording these measurements as well as for checking other miscellaneous imformation.

Abundance of adults will be estimated by counting the number to alight on an animal in a given length of time, such as so many per minute.

Cover types will be visited in a definite sequence during the summer in order that each will be examined the same number of times and during every hour of the day.

Observation Sheet For Field Use

Adult Study

Location _____. Cover type _____.

Date _____. Species of Black-fly to bite

_____. Number to bite _____.

Animal bitten _____. Time _____. Air temp.__

_____. Relative Humidity _____. Light intensity

_____. Wind velocity _____.

Length of feeding period _____. Activities following feeding _____. Miscellaneous Notes __

_____.

Every other day will be spent in traversing stream courses and studying the aquatic stages of black-flies. Population studies will be made under as wide a variety of conditions as possible, in both swift and sluggish water, and in warm and cold streams. These studies will be made by gathering at random ½ pint of leaves without regard to whether or not larvae are present. The number of samples needed can not be determined until the work is actually in progress. Counts will be made in the laboratory when the datum is analyzed. Water temperature, rate of current flow, and bank shade will be recorded at each point where population studies are made, and in addition at points where black-flies are absent. The rate of stream flow will be determined by the Pitot Tube or by the Price Directing Acting Stream Guage.

The main objective in this aquatic study is to locate positions in streams where black-flies are present. These points will be marked on maps for later reference. Collection of specimens and measurements at each of these stations should not take more than 10 minutes.

Stream Survey Data Sheet

Location _____. Stream _____. Station No. _____. Date _____. Time _____.

Water Temp. _____. Light Intensity _____. Current Rate _____. Black Fly Species present _____. Population Density _____. Blackflies Ovipositing _____. Fresh Eggs _____. Aquatic Plants present_____. Plants oviposited on_____. Miscellaneous Notes _____.

Analyzing Data

The data from the record cards taken in the field will be analyzed statistically and then presented graphically.

1. Air temperatures - On the adult record sheets we will have recorded the various temperatures at which black-flies were observed to bite in each cover type during the summer. By a study of this datum we can determine the range of favorable biting temperatures in each type, and the most favorable biting temperature in each type.

2. Relative Humidity - From the adult record sheets we will be able to determine the most favorable relative humidity for biting and the range in which biting occurs.

3. Sunlight intensity - We will be in a position to calculate the sunlight intensity most favorable for biting and the range of suitable intensity for biting.

4. Wind - By correlating wind velocities with the abundance of adults during the summer it may be possible to determine the effect of wind on flight distances.

5. From a study of stream data it should be possible to determine the range of water temperatures, current rate and light intensity which are favorable for aquatic black-flies.

This suggested future investigation affords a wonderful opportunity for original work. In the event that it is not possible for this study to be continued, it is hoped that this preliminary investigation and report will be of some value to others.