New York State Museum Bulletin

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CHARLES C. ADAMS, *Director*

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ILLUSTRATIONS

BLACK FLIES AND OTHER BITING FLIES OF THE ADIRONDACKS

By C. L. Metcalf D.Sc.

Field Entomologist, New York State Museum

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INTRODUCTION; THE PROBLEM[1]

No one who has ever visited the Adirondacks requires praise of this wonderland of woods, mountains, streams and lakes. The State of New York has wisely set aside a great preserve of 2,000,000 acres in the heart of the Adirondacks as a playground for her people and for all others who care to come. The region is blessed with a cool, invigorating climate and abundant opportunities for rest and healthful recreation of every kind. It offers to the lover of the out-of-doors, every phase of natural grandeur and beauty; and to the serious student of the natural sciences, inexhaustible opportunities for research. This territory is singularly free from serious disease problems, dangerous animals and poisonous plants. It is doubtful if a better investment for the health and happiness of the people could have been made.

There is, however, one serious problem that casts a shadow over the glory of the Adirondacks. Several kinds of biting flies have found there a habitat unusually well suited to their life requirements, and have so far appropriated the area that they are able successfully to challenge man's possession of it during a considerable part of the vacation season. They are so prevalent and troublesome during six to eight weeks in spring and early summer, that those who have had experience with these insects rarely visit the Adirondacks during this period; while those who do not know fly conditions, and those whose work or pleasure takes them there regardless of the flies, often suffer torment from these pests unless they use special precautions to avoid their attacks.

Leading Adirondack business men declare that the potential value of the park is reduced 40 to 50 per cent each season by the plague of flies. Thousands who could, and otherwise would enjoy the unparalleled beauty of the mountains in June and early July refuse to come at all during the fly season. Others swelter in the heat of their city apartments or go elsewhere until the middle of July or later, rather than brave the punishment inflicted by the black flies and punkies. Biting flies thus interfere seriously with the biggest industry of the Adirondacks, namely, recreation. On this account the purpose of the park is, to a considerable extent defeated; and the shortness of the season thus brought about makes business enterprises hazardous and often unprofitable, to the detriment of every legitimate interest in the park area.

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[1] This particular project was initiated and directed by Dr Robert D. Glasgow, State Entomologist of the State Museum, who also collaborated in preparing the present Bulletin. W. E. Sanderson collaborated in all the field work.

At the request of a large number of Adirondack business men and residents, the State Entomologist's Office of the New York State Museum undertook to organize and direct a comprehensive survey of the biting fly problems in this area. During the summer of 1929 the authors of this report spent the months of July and August in what was frankly a tentative and preliminary survey of the situation with the definite purpose of determining the seasons, the nature, and the extent of the various fly plagues, the nature and the amount of the losses occasioned thereby; and of collecting other information upon which to base future experimental studies of methods which may promise the largest degree of practical control for all of these biting flies, at least about human habitations. This survey covered practically every section of the vast Adirondack park area: the Fulton Chain of lakes, Big Moose lake, Raquette lake, Long lake, Tupper lake, Massawepie park, the Saranac lakes, Lake Placid, Loon lake, Tahawus, Indian lake, Keene valley, Mount Marcy and Lake Piseco. Collections were made at 399 different stations on 242 different streams. Over 2000 miles were traveled by automobile and between 300 and 400 miles of mountain trails and streams on foot, in an effort to gain a fundamental knowledge of the nature and the magnitude of the problem.

Before the most effective and practical control measures can be found, it will be necessary to know very thoroughly the life histories of these pests, and their habits during each of their developmental stages and throughout the year. It is only through such intimate knowledge of an insect pest that we may discover the "weak link" in its life chain, at which we may strike most effectively.

This knowledge can be gained only by many months of patient observation, and scores or even hundreds of experiments under varied conditions. Those interested in this project, therefore, must face the probability that the successful mastery of black flies and punkies may require several years of intensive study and experiment. The problem is, however, inherently no more difficult than the control of many agricultural pests and will doubtless yield in the same way to intensive study.

The findings of the first summer, although they represent only two months' work, are being presented at this time, together with such data from the literature on these pests as seem pertinent to Adirondack conditions. It is hoped that this bulletin may serve a useful purpose in answering some of the questions which arise concerning these insects and in helping those who encounter these pests to avoid unnecessary punishment by them. It should be clearly understood that this is merely a preliminary report, based upon the

first season's work. Many questions have been uncovered which can be answered only by further observation and research. Many details of the annual cycle, and of the ecological relations of these insects are still unknown; and the whole problem of effective control remains before us.

THE BITING FLIES

Importance of biting flies. During the season of great abundance the biting flies constitute almost a dominant group in the great ecological complex centering about man's interest in the Adirondacks. They affect, among other things, five distinct interests: profit, pleasure, return from public investment, health and efficiency of labor.

1 Those who are financially interested in hotels, resorts, clubs, supply houses, transportation companies, real estate and other phases of business in this area, find the ratio of overhead and maintenance to income unusually high, because of the very short season during which there is profitable business. The shortness of the season is caused primarily by black flies.

2 The summer visitor who goes too early to the Adirondacks for rest, recreation and sport is usually disappointed or is only partially successful because of the limitations upon his activities and enjoyment that are imposed by the flies.

3 The State of New York, which is the largest owner of property in this area, is losing a great part of what should be the full return from its Adirondack investment because one kind of fly converts an otherwise ideal playground into a place of torment for a month or two each spring, while other kinds continue to annoy throughout the season.

4 Several large tuberculosis sanitariums have been established in the Adirondack area, and the thousands of patients in these and in private cottages are seriously hampered in their essential outdoor routine in the health-giving mountain air and sunshine during June and early July, by the attacks of black flies. During the "fly season" the patients are often terribly punished, and sometimes driven indoors by the hordes of these bloodthirsty insects. At night the punkies may make adequate ventilation of sleeping rooms difficult.

5 The biting flies in the Adirondacks interfere seriously with the efficiency of workmen engaged in outdoor occupations, and are responsible for a heavy increase in labor turnover. These insects, therefore, cause a large increase in the cost of labor in the construction and maintenance of roads, of telephone, telegraph and power lines, of buildings, of golf courses, and in the cost of lumbering,

gardening and all other kinds of outdoor work. In one case that came to our attention, road repair work, which might have been completed early in spring was being done at the height of the tourist season with consequent inconvenience, because the pestilence of black flies made earlier work inadvisable.

Furthermore, deer and wild game generally, as well as pets and all other kinds of domestic animals, suffer severely from the attacks of black flies, which find these creatures even more defenseless than man.

Kinds of flies. There are primarily five kinds, or groups, of two-winged, blood-sucking insects in the Adirondack mountains.

Black flies unquestionably rank first in importance; the punkies are second. In the northeastern section of the mountains many rate the punkies as most important. Mosquitoes are probably third, although we found less complaint of them than of the others. The stable fly is apparently fourth, on the whole, and deer flies or horse flies, as a group, fifth. There is much difference of opinion in different sections, due in part to differences in interests of the persons interviewed and in part to the experiences that happen to be freshest in the minds of informants at the time of the interview. For the automobile tourist, the indoor worker and the dinner-and-dance house guest the punkie is the most serious. For the fisherman, hiker, camper and golfer the black fly is unquestionably the worst. The stable fly frequently makes life unpleasant about porches, boat-landings, bathing beaches and even in dining rooms and offices, and where common, renders serious golfing almost impossible. The deer fly pursues fishermen, hikers and horseback riders, and, according to accounts of our informants, has a special predilection for the wet bodies of bathers.

Where flies come from. All of the insects discussed in this bulletin pass through four distinct stages of development during their growth: the egg, the larva, the pupa and the adult. The life of each individual begins with the egg, deposited by the winged fly. This egg hatches, not into a small fly, as some suppose, but into a kind of maggot or wormlike stage (called the larva), which is the growing stage of the fly, just as a tadpole is the growing stage of a toad or frog. In this condition (figures 2, 8) the fly completes its growth. The larva does not reproduce itself, but next undergoes a period of alteration during which the adult, or fly, is formed from the tissues of the larva: this transformation period is called the pupa (figure 9). From the pupa finally comes the adult fly. Once having acquired wings the fly grows no more. The function of the

winged stage is to mate and lay eggs and this is the only stage that lays eggs or reproduces.

Eggs, larvae and pupae of any kind of fly are usually found in the same situation; the adult fly has a very different mode of life. The habitat where the eggs are laid and in which the young feed and grow is therefore called the breeding place. The breeding places of the different groups of biting flies are usually quite unlike.

Black flies breed only in swiftly flowing water such as the rapids of trout streams (figures 12–20).

Punkies, according to Pratt (1907) and others, breed in the standing water of hollow stumps, tree holes and in other similar accumulations of stagnant water.

Mosquitoes of various species breed also in water, but never in swiftly moving water. Most of the common species prefer still and somewhat stagnant water such as is found in watering troughs, rain barrels, discarded tin cans, eaves troughs and the like (figures 22–26).

The stable fly breeds in moist fermenting vegetable matter such as rain-soaked straw, or hay or grass clippings (figure 21).

The deer flies or horse flies develop in moist earth or mud, such as occurs about margins of swamps, drainage ditches or even in low, poorly drained meadows (figures 27, 28).

BLACK FLIES

Importance of black flies. These are the flies that drive visitors out of the mountains, and even send some of them to hospitals. When numerous, they are almost intolerable.

It is especially unfortunate that their period of activity coincides with the best fishing season, and the time when the vernal beauty of the mountains is at its height. They attack in greatest numbers in or near woods and brush, being especially abundant along the banks of trout streams, but we have found them in abundance and biting on the summits of Whiteface, McIntyre and Marcy mountains, in the broad sunlight and with an appreciable breeze.

Their relation to the health of the well and of convalescents alike is a serious matter, because they prevent the free use of the out-of-doors, and they inject a venom that frequently causes a general physiological reaction and occasionally results in pronounced illness. They do not come indoors. Since they bite during the day, they destroy most of the pleasure in golf, and make serious match playing impossible. For many who seek rest rather than

sport, however, whose chief activities are indoors, and whose chief interests are in dining, dancing, and indoor games, they may have much less importance than the punkies, stable flies and mosquitoes.

The bite of the black fly is usually not painful at the time it is inflicted. One may watch a fly inflate its body with one's own blood without feeling any pain whatever; or see flies biting the forehead or eyelid of a companion who is unconscious of their presence. Leon (1909) believes that the saliva of the black fly acts as an anesthetic and also renders the blood more fluid. The pain, however, soon begins; and, depending upon individual susceptibility, the burning, aching and itching of the wound may continue for hours or even for days. Blood often flows from the wound, and individuals are sometimes seen with streaks of blood running down the face, arms or legs. Local oedema and erythema generally result. Swellings may be formed on the neck and face, sometimes as large as marbles, completely closing one or both eyes. Ears, wrists and ankles may be swollen to twice normal size. The face may be so swollen and discolored as to be unrecognizable. In severe cases the general picture is similar to that of an erysipelas. Each puncture is followed by a hemorrhage and leaves a clot or hemorrhagic spot usually followed by the slow development of a weeping papule or nodule. Violent itching usually persists for days or weeks. Scratching breaks these papules and frequently results in pus infections and sometimes in streptococcus infections that may terminate seriously or even fatally.

The venom seems to have a specific effect on glands of the neck and those before and behind the ears (posterior auricular and occipital glands) especially of children. The symptoms of adenopathy may arouse suspicion of mastoiditis, and may persist for several days to a week. Such swelling of the glands may cause a distressing stiff neck. There are sometimes fever, chills, generalized pain and stiffness. Older persons complain of loss of appetite, and general illness and, in many cases, rightly or wrongly attribute a general debility, persisting for several years, to a severe experience with black flies.

The bites of black flies are probably never directly fatal. The serious after effects usually result from streptococcus infections due to scratching the inflamed skin with the finger nails. There are authentic records of gangrenous infection resulting in loss of sight, following a bite on the eyelid (Leon).

The exasperating tendency of the fly to crawl into the nose and

mouth has been said to result in asphyxiation, especially of animals, either by the mechanical obstruction of the air passages by great numbers of the flies, or by the swelling of the membranes due to their bites. Other injuries attributed to black fly bites in the published accounts, include anemia from the loss of blood when swarms of flies are attacking, a general poisoning from the toxic saliva of the flies, and a reflex nervous effect or shock. Georgévitch (1909) has described a trypanosome found in the stomach of a Hungarian black fly. He found it only in the first generation of flies in the spring and considers that this may explain the greater virulence of the bites in the early part of the season.

Stokes (1914) has shown that dried or alcoholic specimens of one species of black fly (*Simulium venustum*) contain, especially in the anterior part of the body, the toxic agent of the living fly; and, when injected experimentally, this material produces the characteristic lesions and symptoms of the bite. He found the toxic agent to be unaffected by alcohol, glycerine or a 5 per cent solution of bicarbonate of soda or by dry heating at 100° C. for two hours, although it was destroyed or rendered inactive by hydrochloric acid, in a concentration of 0.25 per cent, and by pancreatin.

The attack of black flies is totally different from that of mosquitoes. These flies hover about the body, being especially noticeable around the head. Their flight is swift and jerky but almost entirely noiseless. They can not be driven away by striking at them. They readily alight on skin or clothing and run greedily over the body like lice. Their bodies are firm enough so that they can squeeze under clothing and hair and feed on the tender protected skin, under conditions where mosquitoes would be crushed. Their attacks are especially annoying about the eyes, ears and nose, but they bite any exposed part of the body, crawl into the hair to feed, and they run under the clothing so that in severe cases the entire body may be poisoned by their bites. Possibly it is the shortness of their mouth parts that leads them to seek the thin skin beneath the clothing, about the eyes, nose and ears and along the forehead and the back of the neck. They appear also to be strongly attracted by broken skin, and often mass their bites in a small area which later becomes scaly or incrusted.

Aside from the bites of black flies their habit of crawling louse-like over the body, into the clothing and about the eyes, ears and nostrils is very annoying, and for the nervously inclined well-nigh intolerable.

How to recognize black flies. Black flies are small, chunky flies, about the dimensions of a piece one-eighth of an inch long from the small end of an ordinary flat toothpick. It would require five to ten of them to equal in mass or bulk the head of an ordinary safety match. The bodies of different species range from 1/12 to 1/6 inch long by about 1/30 to 1/20 inch wide. The spread of the wings is from ¼ to ⅓ inch.

Technically black flies (figure 1) may be recognized:

(1) By the appearance of the large wings which are half as broad as long, entirely free of scales or prominent hairs, and which have three or four veins near the front margin (the *costa, subcosta* and branches of the *radius*) heavy and hairy, the other seven or eight (the *medius, cubitus* and *anal* veins) very slender and indistinct.

(2) By the robust, firm-walled, hump-backed body. The head is rather small and set low against the thorax which is large and considerably arched dorsally, giving the buffalolike or humped-back appearance.

(3) By the thick, short, eleven-segmented antennae, which project forward from the head like horns, the segments of which are mostly thicker than long and indistinctly separated. As contrasted with mosquitoes the antennae are not longer than the width of the head.

(4) By the rather short and stout legs, as contrasted with mosquitoes or gnats.

(5) By the piercing mouth parts, which are shorter than the antennae and, for the group, two or three times as broad. The maxillary palpi are four-segmented and longer than the antennae.

Eggs of black flies. The laying of eggs has not been observed during this investigation; but masses of eggs believed to be *Simulium* have repeatedly been taken from stones, sticks and vegetation in the same places where the larvae and pupae were developing.

According to other observers, the eggs are laid mostly in late afternoon, on the moist surface of stones, leaves or sticks, at or near the surface of running water. They are laid in a single layer, the eggs touching each other. Since several females may oviposit in one spot there is considerable overlapping, and very large masses, several inches across, have been recorded.

When laid, the eggs are whitish or cream colored. They become darker as development of the larval embryo progresses, passing through shades of yellow and brown to nearly black. The surface of the egg is smooth and shiny. The eggs of certain species are subtriangular in outline, that is, with one side nearly straight, the other angular, and the head end more pointed than the other end. They are about 1/60 inch long.

According to Jobbins-Pomeroy (1916) the eggs can not withstand dessication, the embryo becoming distorted on the second day after removal from water. In his experiments not a single egg hatched following such a period of dessication. According to the

same author, a female of *Simulium venustum* laid about 350 eggs, and the maximum number probably never exceeds 500.

Cameron (1922), however, thinks the eggs of a Canadian black fly, *Simulium simile,* "may be capable of withstanding prolonged periods of dessication, as has been suggested by Edwards for the eggs of *S. latipes.*" He states that when breeding places are left exposed by the receding water for periods of two or three weeks at a time, they may be found to contain thousands of first stage larvae a few days after the water rises again and covers the stones.

O'Kane (1926) also believed, from studies made in New Hampshire, that *Prosimulium hirtipes* (Fries) may spend the summer in the egg stage along the beds of streams that dry up in summer, but rise with the coming of the fall rains and have an abundant supply of cold water from late fall to late the following spring.

Larvae of black flies. To find the young of black flies one should go to the swiftest part of a stream, where the water churns or boils over stones, sticks, logs or other obstructions, or where vegetation such as the leaves of trees or of grasses or sedges, breaks the surface of the current into ripples. Remove the stone or other object from the water and examine it in bright light (figures 12–20).

On the downstream side of the stones the dark gray to black-appearing "worms" or "maggots" (figures 10, 11) will be found squirming or writhing slowly over the moist surface. They almost invariably curl the body into a "U" or "J" when removed from the water and this posture is one of the most characteristic field recognition marks. Such a curved dark larva, under one-half inch long, slenderest at midlength, and writhing slowly from side to side, is likely to be that of a black fly. It must be remembered, however, that many kinds of insects live in such situations and only a careful comparison with the figures and descriptions should satisfy the layman that he is dealing with black flies.

If one looks into the water in favorable spots one may usually see them in good light and against objects that are not too dark. While undisturbed, they lie straight, attached by the posterior or thicker end of the body and with the rest of the body floating free. In very slow water they may stand somewhat upright, but in the swift current of Adirondack streams they are generally stretched taut and straight downstream, and wave in the current like a banner in the wind.

In Death brook near Raquette lake counts were made of the larvae clinging to the solid rock outcrop in the bed of the stream.

Several counts showed approximately 800 larvae to the square foot on this rock. They were often very nicely spaced at intervals of one-eighth to one-quarter inch apart, sideways, and far enough apart lengthwise to clear the swaying bodies of those in front of, or upstream from them.

One hundred twenty-five larvae and pupae were taken on a single dead leaf caught in the current of a brook near Old Forge on August 18th. On a single stone, six inches in diameter, in Bear brook near Raquette lake, 1500 cocoons were counted.

A very unusual concentration of larvae was discovered at the outlet of Lake Twitchell on August 21st. Black fly larvae usually cling individually, each attached to the rock or leaf. In this case, however, where the water spilled over the dam, larvae were found piled up on stones, eight to ten deep, in wriggling masses one-half inch thick by several inches across (figure 10). They were mostly clinging to each other rather than to the underlying stone. The number of larvae that could be scraped from one stone about ten inches in diameter was preserved and subsequent count showed that this one stone supported 2880 larvae.

The larva ordinarily needs to move but little, for the current of the stream brings it food and air. It is conceivable that its entire development may often take place on the very rock on which the eggs were laid. The larva is capable of locomotion, however, by alternate use of the anterior and posterior suckers, probably entangled in the silk matrix spun over the rock surface. This locomotion has often been described as a looping movement like that of a measuring worm. In our observation, however, it is mostly a sideways bending of the body in which the whole body is kept close to the stone, while the tail end is brought up near the head. The body is not bent upward like the measuring worm, obviously because of the resistance of the rapidly flowing water.

If the larva becomes dislodged by the swift current or from other cause, it spins out a tiny rope of silk from the mouth, which checks its rush downstream until it can again attach itself; or, after recovering its equilibrium, crawls back by this thread to its former position.

We have found the larvae on various kinds of supports. The bed rock of the stream, the downstream surface of stones of all sizes, twigs, sticks and leaves, especially such as lie directly across the stream and nearly parallel with the surface of the water, leaves of trees and grass and sedges, objects of iron, partially submerged in the stream, and pieces of paper caught in the current, all serve as anchorage.

It appears that the nature of the surface or material makes little difference, so long as it affords an anchorage in sufficiently swift current. The sticks of beaver dams were found to be grossly infested at Keene and along the outlet of Sagamore lake (figure 20). Flumes or spillways, or waterfalls over dams, are usually heavily infested, provided there are irregular surfaces near enough to the surface of the water to make ripples. As has been pointed out by Miss Reeves (1910), a sandy or fine gravel bottom does not form an acceptable place for black flies to anchor.

The larva of a black fly is a most interesting creature (figures 2, 8). The larvae vary in size, according to species and age, from almost invisibly small, up to a little over half an inch long. The species encountered in this investigation are about one-third inch long by one-twentieth inch in diameter when full grown. The body is subcylindrical, slenderest at the middle. The posterior third or fourth is distinctly enlarged, club-shaped. The anterior or head end is slenderer and terminates in the brownish head, bearing in front the mouth fans, which look to the naked eye a pair of hooks, one hook curving toward either side. The middle region of the body is slenderest and in this region the segments are about a half wider than long. The body is grayish to blackish in color and indistinctly segmented, there being about 12 segments besides the head (figures 2, 8).

The tail end of the body terminates in a "sucker" or circular area about half the diameter of the largest body segment. The rim of this sucker is palisadelike, and armed with many longitudinal rows of minute, chitinized, basally directed, slender thorns. It is primarily with this sucker, by entangling its tiny thorns into the matrix of silk spun by the larva, that the larvae are enabled to hang on to the surface in rapids and cascades of streams.

The larva has no legs except a single, unpaired proleg arising from the ventral side of the first segment behind the head. This projects forward beneath the head, is nearly as long as the head, and terminates in a sucker, bounded by a zone of minute hooklets somewhat like that on the posterior end. This anterior sucker is only about one-fourth or one-fifth the diameter of the posterior one.

The head is the most complicated part of the larva. The structures which look like curved hooks to the unaided eye, prove to be marvelously constructed mouth brushes or fans used in collecting food. Each consists of a short, thumblike segment, from the apex of which arise 30 to 60 minute, curved hairs, palmately arranged, and forming at each side of the head a cup- or scoop-shaped rake or

strainer. These fans strain microscopic plants and animals from the water and waft the food material into the mouth.

The published discussions of larval food indicate that various species of larvae feed on microscopic organisms of both animal and plant nature, including desmids and diatoms (of the genera *Nitzschia, Gomphonema, Navicula*), algae (of the genera *Ulothrix, Cladophora, Vaucheria, Conferva, Scenedesmus, Chlamydomonas, Euglena, Characium* and probably *Spirogyra*), bacteria, parts of phanerogamous plants, and minute animals such as certain crustacea (Copepods and Isopods).

Very close to the base of each mouth fan rises a slender, four-segmented, inconspicuous antenna. Midway along the side of the head, in a pale-colored area are two very small, intensely black, pigmented spots, the eye-spots, which are not functional in the larva. On the under-front (ventro-cephalic) side of the head, and overshadowed by the mouth fans, are the larval mouth parts. These consist, first, of a simple, hingelike upper lip or labrum at the front of the head, directly between the mouth fans; secondly, of a pair of hairy and spiny mandibles directly beneath (ventral to) the bases of the fans and of about the same size as the basal segment of the latter; thirdly, of a pair of maxillae lying beneath the mandibles and closer together than they are, and consisting of a firm, cylindrical, thumb-like palp and a hairy lobe (the lacinia). In the center of the mouth lies, fourthly, a complicated, hairy, bilobed hypopharynx, through which the silk threads spun by the larvae emerge from the mouth. Finally the mouth is closed beneath by the firm chitinized mentum of the labium or labial plate, which has characters of specific value (figure 3).

Near the posterior sucker on the dorsal or back side of the larva are the organs with which it breathes. These consist of three lobes or clusters of soft, white blood-gills that are extensions of the rectal wall and are often completely retracted into the rectum. Most specimens when removed from the water do not show them at all. Each of the three lobes may be simple or may be subdivided into a number of lobes according to the species (figure 4).

According to Jobbins-Pomeroy (1916), the larvae of *Simulium vittatum* and *S. bracteatum* have the three lobes practically undivided; *S. jenningsi* has 6–5–6 subdivisions of the three lobes, *S. venustum* 7–7–7, and *S. pictipes* 13–16–13, in typical forms, though there is some variation. Most of our specimens show 30, arranged 10–10–10, although in other respects they are nearest to the descriptions of *S. venustum* and dissection of the developing pupal tracheae

shows the six branches characteristic of that species. Some have three unbranched lobes and are probably *Simulium vittatum.* Another species has six short papillae on the basal half of each lobe.

Anchored thus in the swift water, feeding upon minute plant and animal life which the current brings to it and which it is able to catch with its fans, breathing by extracting oxygen from that in solution in the water with its rectal gills, occasionally being dislodged by the force of the current and having to struggle back up the "life-line" it spins as it lets go, and constantly subject to the attacks of a variety of enemies, the larval black fly lives a daring, sporty life of a month to six weeks, during which it grows from a tiny thread-thin worm, less than one-thirtieth inch long to the full size described above. During its growth the larva of *S. simile* completely sheds the larval skin six times, according to Cameron (1922), and in each of these stages (instars) its body is as perfectly formed structurally as that of man or any other animal and is similar to the full grown larva described above.

Pupae of black flies. When the larva is full grown it prepares for the transformation to the adult by spinning a cocoon. In the species encountered in this investigation, the cocoon is shaped like a wall pocket, wall vase, or half cone, or like a sandal. The side nearest to the support is flat and the other side evenly convex. The downstream end is wide open and has a heavily woven, strong rim. The open end is diagonally truncate, the side next to the support extending forward further than the upper side. The rest of the cocoon is often thinner, loosely woven, semitransparent and formed of threads irregularly matted together. It is complete on the ventral side only about half its length (figure 9, *a*).

The cocoon seems to serve more as a method of anchorage in the swift water than for protection.

The pupal stage, as found in the cocoon, is very different from both the larva that precedes it and the adult into which it soon transforms. It is shorter, thicker and usually more brownish than the larva. On the exterior may be recognized practically all of the appendages and structures of the future fly, but they are soft, thick, more or less rudimentary and inclosed by a pellicle or pupal bodywall. The shape conforms nicely to the cocoon, being a cone, somewhat flattened on the ventral side, and diagonally truncated in front. The body has greatly shortened and thickened, being now about half as long as the larva, but nearly the same length as the adult, largest at the anterior end, which fills the open end of the cocoon, and gradually tapering to the tip of the abdomen (figure 9).

The head is bent downward and backward so that the face and mouth parts are appressed to the stone or other surface that bears the cocoon, and the eyes, hooded over by the incased antennae, give a somewhat owl-like aspect to the face.

Between and behind the eyes lie the broad mouth parts, the labrum, the maxillae and their palps, and the labella being visible externally.

Males can be distinguished from females in the pupal stage, as in adults, by the fact that the eyes of the male meet on top of the head while in the female the eyes are separated by a band called the frons and vertex. Since this part of the head occupies the open end of the cocoon, it is possible to tell, without removing the pupae from their cocoons, which will transform to males and which to females.

The thorax is strongly humped, as it is in the adult, and bears at its anterior angles the most conspicuous appendages of this stage. These threadlike structures, often as long as the rest of the body, are the tracheal gills, or organs of respiration (figure 9). They attach to the prothorax, and extracting oxygen from the water, pass it inward to the tracheal system, and also disperse the waste gases from the body.

The number of branches ("filaments") and manner of branching of the tracheal gills is characteristic of the different species of black flies: there are, according to Malloch (1914), four filaments in *Simulium bracteatum* and *S. johannseni,* six in *S. meridionale* and *S. venustum,* eight in *S. piscicidium* and *S. metallicum,* nine in *S. pictipes,* ten in *S. jenningsi,* 16 in *S. vittatum,* 22 to 25 in *S. forbesi,* 48 in *Prosimulium pecuarum* and 60 or more in *P. hirtipes.*

The wing pads cover the sides of the pupa near mid-length, their tips nearly meeting on the ventral side at the middle of the body. They are about one-third as large as the wings of the adult and, like all the other appendages, securely incased to the walls of the body.

Between the wing pads and the developing mouth parts lie the fore and middle leg on each side, the tarsus of the front pair reaching to just beyond the tip of the wing. The hind pair of legs is folded up entirely beneath the wing pads, except for the terminal segments of the tarsi, which are narrowly visible beneath the anal margin of the wing, toward its apex.

The abdomen is larger than in the adult. It shows clearly nine segments. There are certain, very perfect hooks on the abdomen, that engage some of the threads of the cocoon and in this way the pupa is anchored in its cocoon. In *Simulium venustum* there are four such hooks, opening toward the front, on each side of the third

and fourth segments on the upper side; usually eight smaller but similar ones on the second segment, eight smaller ones on the seventh segment, and eight or more on the eighth, while on the under side there are two close together on each side of the fifth segment and two or three more widely separated on each side of the sixth and seventh segments.

Life cycle of black flies. It has, of course, been impossible to follow the life history of the black flies during this preliminary survey. So far we know nothing about the winter condition of these insects in the Adirondacks. It seems probable that they winter as small to full-grown or nearly full-grown larvae or as pupae, varying with the different species, and that the very numerous larvae found during July and August are the developing flies for next spring's brood. Some species, however, apparently winter in the egg stage.

Jobbins-Pomeroy (1916) says:

The number of generations varies according to the species and the latitude. In the Southern States the species seem to breed continuously from about the middle of March until the approach of severe cold weather, generally about the end of November. The life cycle of one generation during the summer takes approximately four weeks: seven days in the egg stage, 17 days as larvae, and four days as pupae. The time from the egg to the adult stage varies according to the rise and fall of the temperature. There are probably from five to six generations annually in South Carolina of the species here dealt with, except *S. pictipes,* which normally has three generations. In Illinois there are only three or four generations of *S. venustum* annually.

Emery (1914), in discussing the development of *S. vittatum* in Kansas, calculated eight to ten days for the egg stage, eleven weeks for the larval stage, and five or six days for the pupa, the larvae wintering over from eggs hatched in October, and pupating early in April.

Cameron (1922) says, of *S. simile* in Saskatchewan, that there are at least four generations, but that the generations are not well defined. He continues:

Larvae in all stages of development and pupae are found during June, July, August, September and, in mild autumns, a few may occur in the early part of October. As a general rule, however, they disappear completely when the temperature of the water falls below 50° F., and no trace of them is to be found until the following summer. It is practically certain that no larvae or pupae remain in the river during the winter, and, as the species reappears next summer as first stage larvae, it is probable that *S. simile* winters over in the egg-stage.

Forbes (1912) says:

Our species differ also in the number of generations, the two especially southern forms (*pecuarum* and *meridionale*) having, so far as known, but one generation in a year, which reaches the winged stage in early spring; while the two most abundant northern forms (*venustum* and *vittatum*) appear in the winged stage at intervals throughout the summer, and evidently have two or more generations —just how many is not yet known. *Simulium pictipes* also develops at least two generations . . . . In the two species whose life histories have been fairly well followed, namely *pictipes* and *venustum,* about two months elapse in summer between the laying of eggs and the appearance of the winged fly, the egg stage lasting about one week, the larval, four weeks, and the pupal, three. In colder weather the development proceeds more slowly. As these species hatch from the egg in New York in the first part of May, there is time, at this rate, for three successive generations, the last of which hibernates in the larval stage, pupating in April of the following year. We have sufficient data concerning the times of occurrence of the winged black flies in Illinois to bring all but three of our species under this category.

Kinds of black flies in the Adirondacks. In spite of the many years that have elapsed since the first work was done on Adirondack black flies, there seems to be much uncertainty in the literature as to the specific identity of the fly which is primarily responsible for the annoyance to man in this region.

Needham (1901, p. 407, 408) says:

The most abundant and important animal in the rapids is the black fly, *Simulium venustum* Say . . . . It must be another, earlier species of black fly which makes all the trouble in the Adirondacks with its bites; for this one is quite peaceably disposed. Guides have a saying that, when the black flies put on their white stockings in June, the trouble is about over. This species has the "white stockings."

Dyar and Shannon (1927, p. 45) say of *S. venustum,* "Extremely abundant throughout North America, probably extending into the Arctic Circle . . . . In some regions it is exceedingly annoying to man and animals."

Johannsen (1903, p. 380) says of *S. venustum*: "This species is very common in the Adirondacks, where it proves to be a great annoyance to travelers." The basis for this statement is not made clear for he fails to give any localities or dates, except to say, "I have found it in Ithaca, N. Y., and I have seen specimens from Moscow, Marsh, and Albion, Id., and Battle Creek, Mich."

Forbes (1912) says of *S. venustum*:

This species and *S. vittatum* are together called "the black fly" in northern latitudes . . . *Venustum* is the species found so disturbing by Agassiz in 1850, as described in his "Lake Superior": "Flies

exceedingly troublesome" says the narrator, under date of August 12, "rising in swarms from the blueberry bushes when we touched them" . . . That conditions in that region are still the same is shown by an article in the 12th Report of the Michigan Academy of Science (1910).

Miss Reeves (1910) says:

In June 1909, members of the engineering staff of the University of Michigan were driven from their camp on Douglas lake in Cheboygan county by the black flies and at the end of the month it was deemed best to postpone for one week the opening of the Engineering Camp and the Biological Station on Douglas lake on account of these pests. . . . Eggs, larvae and adults were collected and determined as *Simulium venustum,* an identification which was kindly confirmed by Professor O. A. Johannsen . . . No other species of black fly was found.

Comstock (1925, p. 824) says:

The Adirondacks black fly, *Prosimulium hirtipes* — This is a widely distributed species but it has attracted most attention in the mountains of the Northeastern States, where fishermen find it to be a scourge in May and June. The white-stockinged black fly, *Simulium venustum* — This species is widely distributed and is one of the more common species of the genus. It can be distinguished from the other species mentioned here by the fact that the tibiae are silvery white above. In the Adirondacks it appears later than *Prosimulium hirtipes* and is not so serious a pest.

Dyar and Shannon (1927, p. 9) say of *Prosimulium hirtipes* (Fries): "*P. hirtipes* attacks man rarely and does not appear to be a severe pest to livestock."

Malloch (1914, p. 20) says of *P. hirtipes* (Fries):

This fly is reported [he does not say by whom] to be a very persistent biter and does not confine its attentions to cattle, but attacks human beings as well.

Jobbins-Pomeroy (1916, p. 7) says:

A detailed study was made by the writer in the region of Spartanburg, S. C., of the feeding habits of *Simulium venustum,* which was found from early spring to late fall engorging within the ears of horses and mules. Though invariably present on these animals, they were seldom found on cattle or on man. The severity of the attacks of this species depends both upon the time of year and the time of day. It is generally believed that the worst attacks occur in early spring and in early fall, and the writer found adults more numerous during the first three weeks of September than they had been since the middle of June. They appear to be most active from 3 p. m. to almost dusk. They are rather easily disturbed while feeding, and unless much distended will struggle violently to disengage themselves from the long hairs in the interior of the mules'

ears. It has been noticed repeatedly that even the well-engorged specimens will retract their beaks and successfully fly away and not fall to the ground and crawl away to die, as has heretofore been claimed by certain writers. The fact that they are so easily disturbed and bite only under certain conditions probably accounts for the failure thus far of all efforts to get them to engorge while in captivity.

Weed (1904, p. 136) says:

The common species of black fly in New Hampshire, as determined through courtesy of Dr L. O. Howard of the United States Department of Agriculture, is *Simulium venustum* Say.

Strickland (1913, p. 406 and 408) says:

The commonest Simuliid around Boston, in Spring, is *Simulium* (*Prosimulium*) *hirtipes* . . . . by the middle of November *S. hirtipes* was once more hatching out from recently deposited egg masses. The latter species seems to aestivate throughout the Summer, for no signs of it were seen between the end of May and the beginning of October.

Of the specimens collected by us during July and August 1929, the vast majority fit the description of *Simulium venustum* Say in most particulars, and are very probably of that species. The following species were also collected during this investigation: *Simulium vittatum* Zetterstedt, *Simulium piscidium* Riley, *Eusimulium bracteatum* Coquillett, *Eusimulium johannseni* Hart and three additional species which we have not determined.

PUNKIES, NO-SEE-UMS, MIDGES OR GNATS

Importance of punkies. The prevalence of these pests coincides with the present season of greatest tourist activity in the Adirondacks. Many persons who never come into the mountains until the black flies are practically gone consider punkies the more serious pest. Punkies are not excluded by ordinary screening. They come into tents, cabins, houses, hotels, dining rooms, dance halls, bedrooms. In many sections they make it impossible to have lights for reading or any activity after dark. They make it uncomfortable to stroll about or work in the yard, sit on porches or boat-landings, or enjoy any quiet, restful occupation in the evening hours. They prevent sleep; people often fight them until 2 to 4 o'clock in the morning and are commonly awakened by them as early as 5 a. m. When they are abundant windows must be kept closed, and in hot weather this becomes intolerable. Night workers suffer.

A matron at one of the clubs expressed the common feeling in these words: "We cannot read or do anything in the evening. They sting all evening long. I have gone to bed when I felt like

crying about them. It would not be possible to have guests here before July 1st."

In contrast with the black fly, the bite of the punkie is instantly painful — somewhat like a spark of fire thrust against the skin.

With most persons the after effects are slight or negligible. Certain individuals, however, if their reports may be credited, suffer seriously from swelling and prolonged dermatitis.

The insects show a preference for the back of the ears and neck, but when abundant, bite any exposed part of the body. I counted 12 punkies on the back of one hand at the same moment, at Rondaxe lake about 6 o'clock on the evening of July 11th. This is simply an indication of their general abundance all over the face, hands and arms. Under such circumstances the frequently recurring, hot, stinging bites on all parts of the head and hands give the victim little opportunity to think of anything else. The bite of the punkie, if not interrupted, continues for a minute or more. The little fly elevates the hinder portion of the body at a 30 to 40 degree angle, and the successive thrusts of its beak into the skin can be felt, as feeding progresses. The tiny fly is not easily dislodged while feeding, and may easily be crushed before it releases its mouth parts and escapes.

How to recognize punkies. The punkie is the smallest fly that bites human beings. Punkies are familiarly spoken of as "them little devils." The Indian name "No-see-ums" is not much used in the Adirondacks, where they are more frequently called "midgets" or "midges" or "gnats." The punkie can literally and comfortably pass through the eye of a needle. The eye of a no. 5 sewing needle measures about one-eighth inch long by one-fiftieth inch across. The body of the average punkie is about one-twentieth inch long by one-sixtieth inch across.

The punkie is even more hump-backed than a black fly, but more slender, less chunky, somewhat more mosquitolike in build. The legs are longer relatively than those of black flies, and shorter relatively than those of mosquitoes (figure 33).

All of the punkies we collected during the summer of 1929 are of one species, *Culicoides biguttatus* Coquillett. While several other very closely related species are known to occur in the Adirondacks, so far as 1929 is concerned, this was the only species of importance.

This fly is in general a shiny, dirty brown color, with a grayish pruinose cast, except for the eyes which are jet black and the halteres which are whitish. The legs and antennae are yellowish and the abdomen blackish.

The occiput, thorax, and first segment of the abdomen are somewhat bristly. The scutellum is about three times as wide as long and the postscutellum prominent, bulbous. There are apparently nine abdominal segments, the first five subequal, the remaining ones gradually smaller.

The wings are faintly spotted and their veins very indistinct as shown in the figure. There is a very dark spot, like a stigma, at the apex of the first vein (radius 1) about the middle of the front margin of the wing. It covers about half of the small closed cell and extends slightly beyond the apex of R 1 and a little way into cell R 2 + 3. There are many minute, microscopic brown hairs on the wing membrane.

Both basal and distal of this dark spot are the only prominent white spots on the wing. Both of them reach across the wing at least to R 2 + 3. There are other darkened areas or faint and indefinite spots due to more or less clouding in each cell.

The antennae are about half as long as the body, slender, beadlike toward the base, filiform on the outer part; and with a few short hairs on each segment. There are 15 segments (authors say "14, rarely 13," having apparently overlooked the first one). The second segment (apparent first) is about twice the diameter of the others. Segments 3 to 9 are subequal, half as long and wide as the second. From the 10th to the 15th the length gradually increases, 11 to 14 being about equal, while 15 is twice as long as 4 or 5, and somewhat more slender. Each segment bears from six to 12 slender hairs, each about as long as the longest antennal segment, which form a more or less definite whorl on each segment.

The eyes practically meet on top of the head, even in the female. The facets of the eye are unusually large, and round instead of hexagonal, there being about 200 facets in each eye. The frons above and between the antennae is narrowly elevated and swollen. The face is much broader than the frons and strongly emarginates the eye just below the base of the antennae.

Mouth parts of a punkie. From the lower end of the face are suspended the mouth parts, which are the point of greatest interest in this little fly, since its punishment is a bite and not a sting as some have supposed.

The beak is shining, polished, stiff, about as long as the width of the head, approximately 1/125th inch in length, which is therefore the maximum depth of the bite.

Arising from the sides of the beak near the base are the five-segmented, antennalike, maxillary palps. They are about as long as the beak, the first segment very short, almost unrecognizable, the second longest, cylindrical, the third a little shorter, curiously expanded about midlength, the fourth and fifth short, together equalling the second. The palps bear scattered short hairs similar to those on the antennae.

The beak is a complicated organ consisting of the following parts — a labrum-epipharynx, two mandibles, two maxillary blades, a hypopharynx and a labium — all of approximately equal length.

The mandibles are shaped like knife blades, exceedingly thin, the tapered, pointed part of the blade at the end being provided on the median edge with about 16 serrations or exceedingly small, rounded teeth, of nearly equal size.

The maxillary blade is little more than half as wide as the mandible, widest near the base, its distal fifth tapered down to a sharp-pointed end which hooks sideways (lateral). On the lateral edge of this hooked part are about fifteen, minute, sharp teeth.

The labrum-epipharynx is about the same width as the labium, smooth, polished, straight-sided. The tip of the labrum is serrated at each side, with about half a dozen sharp, curved teeth and there is a pair of slightly heavier, curved ones at the very apex.

The hypopharynx is as thin as the mandible, spatula-shaped, roundingly attentuate at the tip where it is serrated for a sixth of its length, like the labrum, with about eight straight teeth at each side. There is a median longitudinal line, full length of the hypopharynx, which is probably a salivary duct through which any poison it may inject is passed into the wound.

The labium bears, about midlength of its ventral side, a pair of very prominent bristles, nearly half as long as the labium. The labium widens slightly at the end and is partly divided into a pair of poorly differentiated labella. The latter are similar to those of mosquitoes and not of horse flies, there being no trace of pseudotracheae.

Habits of punkies. These little midges alight on any exposed part of the body and run rapidly and greedily over the skin, like lice. When a feeding area to their liking has been selected, they elevate the hinder part of the body and, anchoring the claws of all six feet into the skin, they force their mouthparts quickly into the flesh. Apparently a poison is injected, as the mouth stylets penetrate, for the sensation is that of a sudden very hot prick, like a tiny live coal or hot needle might make.

Punkies when biting, are oblivious to everything else and have some difficulty in releasing their beaks, when disturbed. It requires considerable prodding to cause them to let go.

The attacks of punkies usually come on suddenly and, according to our experience, attacks may begin from 4 to 6 o'clock in the afternoon, increasing in severity to reach a culmination between 9 and 11 o'clock in the evening. Sometimes their attacks occur, at least sparingly, throughout the night, but the usual experience is that there is some respite from before midnight until dawn, when they again become very troublesome. This morning period of activity appears to reach a climax between 6 and 7 o'clock, and the punkies have ordinarily disappeared by 9 or 10 a. m., and in sunny places usually by 7.30 or 8 a. m. In general it may be said that the punkies are gone by the time the dew is off the grass in the morning and very few are ordinarily encountered again until sundown.

They are attuned to a moderate degree of illumination and appear to find optimum conditions for feeding at or near dawn and dusk and about artificial lights at night. Their small size, amounting almost to invisibility, their enormous numbers, the impossibility of driving them away or screening them out, or of finding a retreat where one may escape their hot painful pricks, combine to exhaust the patience, completely prohibit contemplation or concentration, and shatter the nerves of all but the most stoical.

Geographical and seasonal distribution. Punkies seem to be generally distributed throughout the Adirondacks. If reports of their importance may be credited, it would seem that they are more abundant and troublesome in the northern and eastern portions of the mountains than in the southwest. There is much variation in local distribution, some places being heavily infested, while others, not far distant, are comparatively free. They seem to concentrate about lakes and especially in swamps and bogs. Of the places where we have been most severely attacked by them, three were on the shores of lakes, one in a sphagnum and pitcher-plant bog, one along a river, within a mile of a large lake, and two part way down mountain trails near small brooks.

The punkie season usually begins about the time the worst of the black fly season is over or a little before. In a very general way, for the Adirondacks as a whole, it may be said to extend from late June or July 1st to the middle of August.

Life cycle of punkies. Not much has been published on the life history, breeding habits or control of punkies and nothing on the species encountered in the Adirondacks.

According to Pratt (1907), the related species, *Culicoides* (*Ceratopogon*) *guttipennis* Coquillett, breeds, in Virginia, in very dirty water in the holes in stumps of poplar trees, or other tree holes containing water, along with mosquitoes, rat-tailed maggots and other larvae. He believed that the larvae feed on débris at the bottom of these holes and on the cast skins and dead bodies of mosquitoes and other larvae. According to Pratt, the punkie larva is a very slender, white, threadlike worm, with a small brownish head, and less than one-sixth inch long. It swims restlessly about in the water, with an undulatory motion, frequently coming to the surface and then descending. He believed that these larvae may winter, frozen in the ice, and thaw out in spring to complete the life-cycle.

The pupa of the Virginia species was one-eighth inch long by about one-thirtieth inch wide in front, narrowing gradually to a bifurcated tail end. It had thoracic breathing trumpets like a mos-

quito pupa. Pupae were found floating just below the surface of the water (figure 33).

Larvae which we believe may be the young of the Adirondack punkie, *Culicoides biguttatus,* were found in the water of pitcher-plants, in tree holes and in holes in rocks. The itinerant nature of the work during the summer of 1929, however, prevented rearing flies from these larvae. We are consequently unable to speak definitely about the breeding habits of this species.

Some closely related species have been reared from human and animal excrement, others from the nests of ants, and others from water-soaked bark, rotting wood and leaves.

THE STABLE FLY

Importance of the stable fly. In offices and kitchens, on golf courses and bathing beaches, in dining rooms, on verandas, about stables and in public buildings of many kinds, this good-sized grayish fly slips quietly in and out in search of human or animal blood. Its presence is scarcely noticed until announced by an acutely painful bite about the ankles or lower limbs. This fly is an especial punishment to women with thin hose, or none at all, although it is capable of biting through two pairs of heavy golf hose. The fly is relatively noiseless and distinctly stealthy in habits and its bites almost always come as a surprise to the victim. The bite is second only to that of deer flies in painfulness, but there is almost never any history of serious after effects, and the pruritus and oedema are less pronounced than with black flies, punkies or mosquitoes. A little oozing of blood usually follows the withdrawal of the stable fly's beak.

Like many of the other biting flies, stable flies are especially active and voracious on muggy or lowery days. Increased barometric pressure is supposed to be the factor that drives them into the shelter of houses and other buildings. This is the same fly that annoys horses, mules and other animals by biting, especially about the legs. Its preferred feeding ground is demonstrated also when it attacks persons, for it usually bites about the ankles. Thin-clad or bare legs present an especially attractive invitation for this pest to feed, and these flies rarely bite the arms or any other part of the body except the legs.

The great abundance of this fly comes in August and September, especially, but it is present in June and in increasing numbers as the weather warms and the season progresses.

How to recognize the stable fly. This insect is almost universally confused with the house fly, although some indication of a dis-

tinction is expressed by the name "biting house fly." It is locally known as the "hog fly," "wild fly," "straw fly" and "biting house fly." The entomologists' name, *stable fly,* seems to be practically unknown in the Adirondacks.

It may be easily distinguished from the house fly (1) by the fact that it bites, for the true house fly is totally incapable of piercing the skin; (2) by its grayer, slightly broader, and squattier body; (3) by the fact that it generally rests head downward; and (4) upon careful examination, by the rigid, slender beak that always protrudes forward or downward from the lower side of the head.

The easiest way to make the acquaintance of this fly and to learn to distinguish it from the true house fly is to visit stables, pastures or feed lots where horses or mules are feeding or resting. Examine the legs of the animals and watch them stamp their feet, to dislodge the biting pests. Many of the flies will also be found resting on stanchions, stalls and mangers about the stable, where they habitually choose a vertical surface and rest on it, head downward. At frequent intervals they take short rapid flights for mating or for no apparent purpose, or glide to the legs of the animal to feed. They are very easily disturbed when feeding and are expert at dodging the slap of one's hand or the tail of an animal.

This is the only one of the five kinds of flies discussed in this bulletin in which both males and females are biters and bloodsuckers. In all of the others only the females have this odious habit.

The stable fly is of the same size as the common house fly from which it is rarely distinguished except by entomologists. The body measures from one-fourth to one-third inch long, the head and thorax being one-third as wide, and the abdomen noticeably broader and flatter. The general color is mottled grayish and black, with a slight brownish tinge. The thorax shows alternate gray and black stripes and the abdomen has a characteristic pattern of nine, dark brown spots on the grayish ground color. The first seven spots are arranged in the shape of a double diamond or figure 8. The head and thorax bear prominent scattered bristles, the abdomen and legs numerous finer ones. The head is large, hemispherical, and sits close to the thorax.

The wings are nearly as long as the entire body, more than one-third as wide as long, entirely transparent except for the half-dozen brown veins that traverse the membrane, and almost totally devoid of scales or hairs. The exact pattern of the cells made by the course of the veins is somewhat characteristic of the species. Behind the base of each wing are two white membranes (the tegulae) nearly half as big as the eyes, folded against each other.

The hind leg is about as long as the entire body, the others slightly shorter.

In the female the abdomen about equals the thorax in mass, and it is broadly oval; in the male it is much smaller and more pointed to the apex. The last three noticeable segments each bears, in front on the median line, a triangular dark brown spot and a pair of rounded, well-separated ones near the posterior border forming a figure 8 or double diamond as mentioned above. The last pair is larger but less distinct and all three pairs are inconspicuous in the male.

The antennae, which are only half as long as the head, are curiously pressed against the face in an oval depression so that they are easily overlooked. They are about one-fourth as wide as long and consist of only three segments, of which the ovate third bears a porrect, dark, tapering plume, or bristly hair, and a number of minute microscopic pits believed to be organs of smell.

The eyes do not meet on top of the head even in the male but the whitish frontal band separating them is, in the male, only half as wide as in the female, where it is nearly half as wide as the entire head.

Mouth parts of the stable fly. Suspended from the lower part of the head is the curious elbowed beak with which the insect bites, looking almost like a seventh leg, being of the same general color and size as the legs, but only half as long, polished and not bristly. This proboscis when fully extended is seen to consist of two segments, the basal one less than half as long as the terminal one and both tapering towards their tips, as seen in front view. The proboscis is nearly one-tenth inch long.

The basal segment bears two, very slender, yellowish palps nearly as long as this segment. The distal segment bears two very slender stylets (the *labrum-epipharynx* and the *hypopharynx*) attached near its base but lying in a groove along the front of this segment and rarely seen. These stylets form the food channel and also carry the poison into the wound from the salivary glands (figure 5).

At the apex of the beak are the two, slightly diverging, hairy labella which are believed to make the wound when the fly feeds.

Often the proboscis folds back at the elbow so that the first segment and its palps are not seen and the long distal segment then projects straight forward from the rear, underside of the head, forming the best single field recognition mark of this species.

The mouth parts are very different from those of mosquitoes, black flies or deer flies. They have fewer parts, only two stylets instead of

the usual six, and the beak or labium is pointed, rigid, and provided with minute, sharp teeth. These teeth, at the end of the labium, are believed by some authors to be the cutting organs, which, by the rapid protraction and retraction of the labella, make the wound. Having broken the skin to the level of the capillaries, the blood is drawn by a sucking pump in the head through a minute channel between the labrum-epipharynx and the hypopharynx.

Eggs, egg-laying and hatching of stable flies. After mating, the females of the stable fly find their way to some pile of compact, wet and fermenting ("heating") grass, straw or strawy manure and thereon lay their elongate, creamy white eggs (figure 21). In two or three days incubation has been completed and the egg hatches. The new stable fly appears, however, not with legs, eyes, wings or other appendages like the parent, but as a very minute colorless worm or maggot.

Larvae of the stable fly. By lacerating portions of the fermenting grass or straw, the maggot gets its food and grows rather rapidly, so that within ten days to a month it has, under favorable circumstances, reached a length of about three-fourths of an inch.

The tapering, pointed end is the head end, at the apex of which the mouth hooks and some sense papillae are located. Besides the two or three small segments immediately associated with the head there are ten large segments which increase rather regularly in diameter toward the large truncated or slightly convex tail end. Here, curiously enough, are located the organs with which the larva breathes: a pair of small, blackish, rounded triangular, eyelike spots located at the upper third of the somewhat shield-shaped posterior aspect and known technically as stigmata.

Each stigma is about one-tenth the width of the segment that bears them and the two are separated by more than twice (nearly three times) their own width. Under high magnification each stigma is seen to be nearly triangular, with the angles rounded, and bears near the center a round "button," between which and each angle, is a sinuous, nearly S-shaped, slit or spiracle through which the gases of respiration pass.

These stigmata furnish the best means of distinguishing stable fly larvae from house fly larvae, which are also found in manure, although rarely in grass or straw uncontaminated with fecal matter. In the house fly each stigma is about one-seventh the diameter of the segment that bears it and the two are separated by only about one-third the diameter of one stigma. The button of the house fly's stigma is nearer the median edge of the stigma and the slits are more sinuous than in the stable fly.

There is also near the head end of the larva a minute pair of prothoracic stigmata used in respiration.

On the ventral side of the larva, increasingly noticeable on segments 6 to 12, are certain spinose ridges that help the larva in crawling. These maggots are very active and intensely averse to light, so that, if exposed as where the material in which they are living is scattered, they quickly wriggle to cover and disappear among the litter.

Puparia and the pupal stage. When full fed and grown the larva makes a remarkable case in which its body is built over into the form of the fly. This case (called a *puparium*) is composed of its own skin greatly shortened, thickened and hardened to make a barrel-shaped or seedlike brown body with convex ends, completely closed and waterproof, but with a pair of breathing pores or stigmata near the anterior end. The posterior stigmata of the larva remain in its skin and furnish, just as during the larval stage, the best characteristics for recognition of this species. The ten large larval segments are also easily recognizable in the puparium while the small ones of the head end have been retracted. The puparium measures about one-fourth inch long by one-tenth inch in diameter and is a little more abruptly rounded at the rear end than in front.

Inside this case the pupa is formed, and separates from the dead larval skin while the outer skin or puparium becomes a rich, polished, chestnut brown.

The true pupa from inside the puparium is creamy white, of such a size and shape as to fit and fill the puparium, and with the developing eyes, antennae, legs and wings of the mature fly occupying much the same position as has been described for the pupa of the black fly.

The insect during the pupal stage of course takes no food and has no communication with the exterior except through the pair of small breathing organs or stigmata near the anterior end of the body.

When it has completed the external and internal reorganization of the larval body into that of the adult, it forces off (by inflation and expansion of the still soft wall of a part of the head) the anterior portion of the puparium as a lid or cap, at a split which girdles the puparium in the region of the third large larval segment (the metathoracic segment). It then crawls out of the old larval skin, sheds its pupal skin. After coloring up, hardening the skin, expanding the wings and drying out the body wall, the new fly, like the parent that laid the egg, has been produced and is ready in an hour or two to attack man or animal for blood, to mate and to lay its eggs.

Life cycle of the stable fly. Such is the life cycle of the stable fly: egg, larva and pupa (in the puparium), occuring only in wet and

fermenting masses of vegetable or animal matter which furnish food for the larvae, while the adult must have blood for food and is an active, aerial or flying insect that frequents human and animal habitations.

Bishopp (1913) states that in warm weather the meal of blood may be digested and the fly feed again the same day. Since there are frequently many interruptions before the fly succeeds in getting a full meal, it seems certain that a single fly may inflict a number of painful bites every day. Bishopp believed that at least three feedings on blood are necessary for the production of eggs. After laying 100 or more eggs the female again seeks some animal, to feed on blood, after which more eggs develop in her body. Three or more such depositions of eggs may be made by the same fly and at least 600 eggs may be laid by a single female. Bishopp has kept the adults alive under as near normal conditions as were possible in captivity for from two to four weeks. The flies avoid strong wind, a point of which advantage may be taken in securing relief from their attacks. They are at home both in sunlight and shade and do not hesitate to come indoors to persist in their nefarious work.

The flies follow horses and other animals, may be carried considerable distances in railway coaches, and perhaps occasionally in automobiles. They cross lakes in canoes and larger boats, and, of course, the hardy adults may disperse themselves considerable distances by flying.

The complete life cycle from egg to adult fly normally requires about three weeks to a month.

The normal winter condition in the northern states is, according to Bishopp, as larvae or pupae, in or near the organic material which furnishes the larval food.

MOSQUITOES

Where mosquitoes come from. It is well known that all mosquitoes develop in water and, for the most part, in still water. Some species breed along the margins of slow streams. No mosquito larvae have any means of maintaining their position in swift water, like black fly larvae, and they never breed in it.

The prevailing opinion among residents of the Adirondacks is that mosquitoes come from swamps, and no doubt some do. The importance of the small accumulations of still, and more or less stagnant water, however, must not be overlooked.

We found mosquitoes breeding in enormous numbers in a roadside watering trough (figure 22), in the catch basin beneath an outdoor

washbowl of a mountain cabin (figure 25), in holes in the rock along the beds of streams (figure 26), in discarded tin food cans and buckets, in roadside ditches, and in pitcher plants in the bogs (figure 24).

How to recognize mosquitoes. Mosquitoes are too well known to require detailed descriptions here. Most persons would resent the suggestion that they could not recognize mosquitoes. Yet it is common for people to mistake many kinds of midges, that often swarm over swamps in clouds, for mosquitoes, and even the large crane flies are frequently supposed to be mosquitoes of enormous size.

Mosquitoes can generally be distinguished from similar looking flies by the fact that the veins of the wings are fringed with flattened hairs or scales. They rarely exceed one-half inch in length and most Adirondack species are about one-third inch long. The body is slender, the head small, and the legs, antennae and mouth parts are very long in proportion to the body. Their delicate bodies do not enable them to crawl under clothing, but with their long mouth parts they are enabled to bite through the clothing wherever it touches the skin. The mouth parts are sufficiently described by figure 6 and its legend. The proboscis is commonly one-sixth to one-eighth inch long.

The bite of a mosquito is immediately painful. It may cause considerable local irritation, and, depending upon individual susceptibility, may be more or less serious. The bite frequently gives rise to a hivelike wheal, whitish on top and surrounded by a reddened area, that itches intensely and intermittently for days. The itching is said by Schaudinn to be due to a species of yeast plant that lives regularly in the body of the mosquito and is inserted hypodermically when the mosquito bites.

Life cycle of mosquitoes. Different species of mosquitoes have different life cycles, some wintering as eggs, larvae or pupae in the bottoms of ponds and puddles and others as adults in dwellings, hollow trees and other shelters. The eggs, larvae, pupae and adults of three common forms are shown in figure 7. The eggs are generally laid on the surface of still water and they hatch into the wingless and legless larvae. The larval and pupal stages are always passed in the water, being the familiar "wrigglers" and "tumblers" of rain barrels and stagnant pools.

Larvae of mosquitoes. The head of the larva is large and provided with complex mouth brushes or fans that strain food from the water and waft it into the mouth. The food consists of small plants or animals, dead insects, algae, etc. The larvae have no legs. Near

the rear end of the body, on the next to the last segment, is a short tube of varying length which the larva must thrust up through the surface film at frequent intervals in order to breathe. That is why the wrigglers always return soon to the surface when they have been scared down. There are also some tracheal gills at the very tail end, but the gills alone will not keep the larvae alive. They must come to the surface to breathe (figure 7).

Pupae of mosquitoes. The larvae may complete their growth in a few days to a few weeks under favorable conditions. They then measure about one-third inch long. When full grown they change quickly to the pupal stage. This pupa has no cocoon or puparium and it is remarkable in that it swims about with the larvae in the water. The breathing organs are on the thorax in this stage, and the eyes, antennae, legs and wings can be seen developing, as in the pupae of the other flies already described. After a few hours to a few weeks as a pupa, the skin splits down the middle of the back and the adult, coming out between the pupal breathing organs, balances on the shed pupal skin until its wings spread or harden and then flies away to mate and provide for offspring by laying more eggs.

DEER FLIES, HORSE FLIES, MOOSE FLIES, EAR FLIES

Importance of deer flies. The various species of the family Tabanidae, known in the Adirondacks as deer flies and moose flies, are the largest flies in this region that regularly bite man. The insects' purpose in biting, as in the other cases discussed in this paper, is to secure blood for food. They feed most commonly on horses, cattle and the larger wild game animals, but when a man invades their lairs, he frequently suffers the same punishment that is the common lot of the dumb animals.

Since deer flies are characteristically insects of the wild, and rarely come into or near houses, they are primarily serious for fishermen, hunters, mountain climbers, lumbermen, road builders and others whose work or pleasure takes them into the woods and swamps or upon the lakes.

They seem to be attracted by wet skin and are especially serious to bathers. Their preference for horses makes them a serious pest about stables where high-bred horses are kept. Their attacks upon horses may lead also to accidents to riders.

Although a dozen different species were taken about human beings during the summer, one species, *Chrysops lateralis* Wd. outnumbered all others ten to one in the Adirondacks during July and

August 1929. The species of deer flies in the order of their frequency in our collections (July and August 1929) are as follows:[1]

Chrysops lateralis Wd.
Tabanus trispilus Wd.
Tabanus astutus O. S.
Tabanus septentrionalis Loew
Chrysops vittatus Wd.
Tabanus trepidus Mc Dun.
Tabanus nivosus O. S.
Tabanus affinis Kirby
Pangonia tranquilla O. S.

How to recognize deer flies. The large size of deer flies and moose flies as compared with the other biting flies, and especially their habit of flying rapidly about the head in wild gyrations and with a loud buzzing noise, should enable anyone to recognize them as they attack. They appear to attack about the head and neck of man and other animals as characteristically as the stable fly takes to the legs.

The common deer flies (*Chrysops* species) may be recognized by the spotted wings and, on closer examination with a lens, by the presence of stout spurs at the end of the hind tibiae, the more elongate first and second segments of the antennae, and the absence of a "thumb" at the base of the third segment: while the moose flies or larger horse flies (*Tabanus* species) have the wings clear or hyaline, no spurs on the hind tibiae, the basal segments of the antennae short, and the third segment with a well-developed side process or "thumb" at the base. The eyes of these insects are often gorgeously colored.

The color markings of the various species vary greatly. The specific characteristics of *Chrysops lateralis* are: the large brown crossband of the wings does not reach entirely across the wing; the exact size and shape of the brown spot and clear areas beyond the crossband; the base of the wing is clear, except along the front margin; the abdomen is yellow, with a pair of converging black spots on the second segment and others on the third and fourth segments.

Habits of deer flies. Only the females suck blood, and consequently males are not found about man or animals. In males the eyes touch on top of the head, while they are separated in the females. The males are said to feed on flowers and the females also sometimes visit flowers. They are often found resting on brush about wooded areas and on the grasses and sedges of swamps and marshes. The adults of both sexes visit pools of water and the margins of lakes and dip into the surface of the water.

In many cases the buzz of the deer fly is worse than the bite. When they do bite, however, the wound is the most painful of all those discussed in this bulletin. The mouth parts appear to have a

[1] The author is indebted to the late Professor James S. Hine for confirmation of these determinations.

slashing or cutting effect instead of the end-thrust characteristic of the mosquito. They make consequently a larger hole and when the mouth parts are withdrawn a drop or two of blood oozes from the wound.

We know of no important after effects from the bites of deer flies upon man. They are, however, suspected of the transmission of certain diseases among men and domestic animals. The fact that they are readily disturbed while feeding and consequently may have to bite several different persons or animals to get a full meal of blood, makes the danger of infection from their mouth parts a serious consideration.

Mouth parts of deer flies. The organs with which the deer fly bites will not be described in detail here. In general they resemble the mouth parts of a mosquito or black fly, except that the labella are greatly developed, more like the house fly. These are adapted for taking up liquids and the deer fly probably drinks other liquids besides the blood it draws.

Life cycle of the deer fly. The life history of the Adirondack deer fly has not been studied. From our knowledge of related species, it may be safely assumed that the eggs are laid on the leaves of aquatic plants standing above, or floating on, the surface of the water. We found eggs of some Tabanid on the leaves of a sedge floating in Fall stream (figure 32). Masses of two or three hundred eggs may be deposited by a single female. From these eggs hatch very slender larvae that taper toward each end, are usually shining white in color, without definite legs or eyes, and with respiratory organs at the rear end and on the sides of the prothorax, much as in the stable fly.

The young maggots drop or crawl into the water after hatching upon the leaves and live until grown, in the water or the soft mud of lake margins, streams or ditch banks, swamps and marshes. They feed in the larval stage upon small living animals such as earthworms, or other insects in the soil, and even attack other larvae of their own kind. When full grown they pupate like the other flies discussed. No cocoon or puparium is formed in this case. When the adult emerges the pupal skin is often left about the margin of a pond or floating on the water. In the case of most deer flies there is probably one generation a year, the winter being passed as larvae and the adults appearing over a scattered period in the summer, when mating takes place and a new generation is started by laying eggs again.

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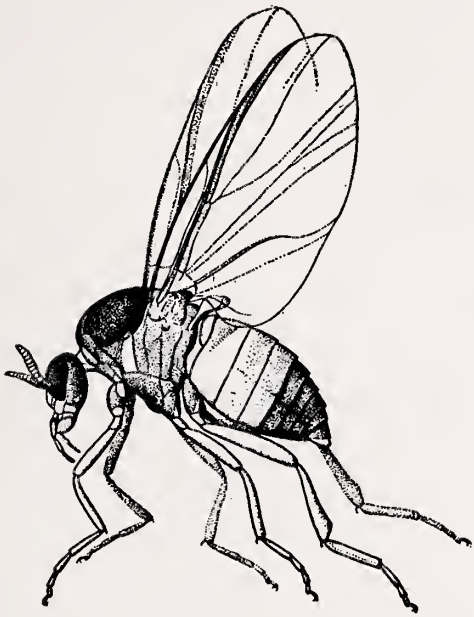

Figure 1 A black fly greatly enlarged in side view. Note the characteristic hornlike antennae, the pendent mouth parts on the under side of the head and the characteristic venation of the wings. (From Ky. Agr. Exp. Sta. Bul. 159)

Figure 2 Larva of a black fly, *Simulium venustum,* side view, showing at the extreme left the mouth fans which are used in securing food; beneath, the mouth parts; on the under side of the body, the unpaired anterior sucker or proleg; above its base, underneath the skin of the larva, the developing respiratory filaments for the pupa; and at the posterior end at the extreme right the larval gills, above, and the anal sucker, below. (From Ky. Agr. Exp. Sta. Bul. 159)

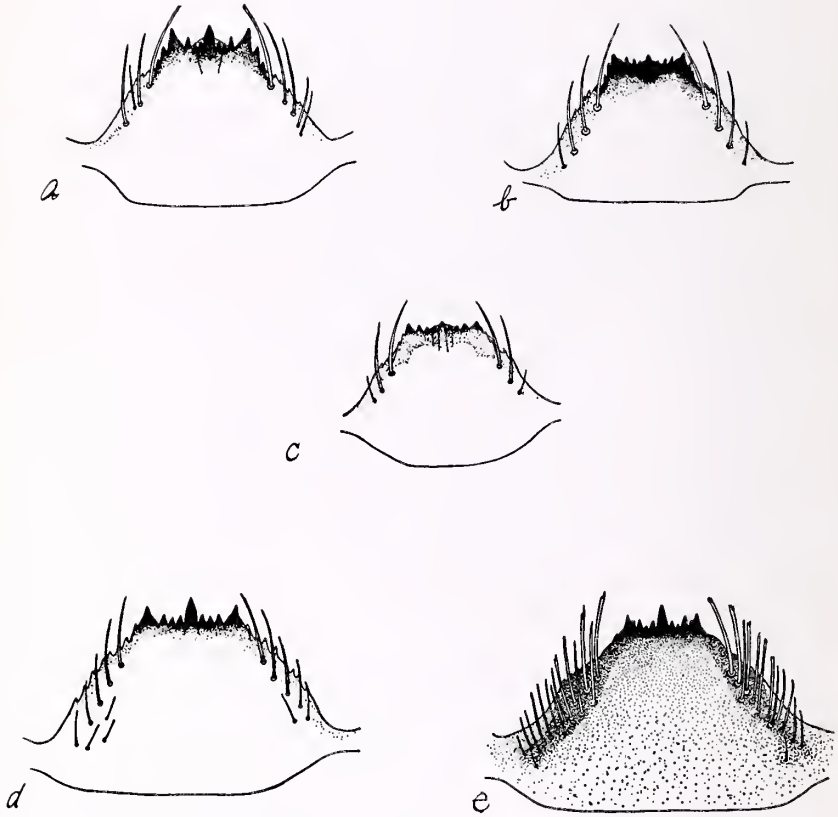

Figure 3 The lower lip or labial plate of the larvae of different kinds of black flies, showing characters used in distinguishing different species. *a Similium bracteatum; b S. venustum; c S. jenningsi; d S. vittatum; e S. pictipes.* (From Jobbins-Pomeroy, U.S.D.A. Bul. 329)

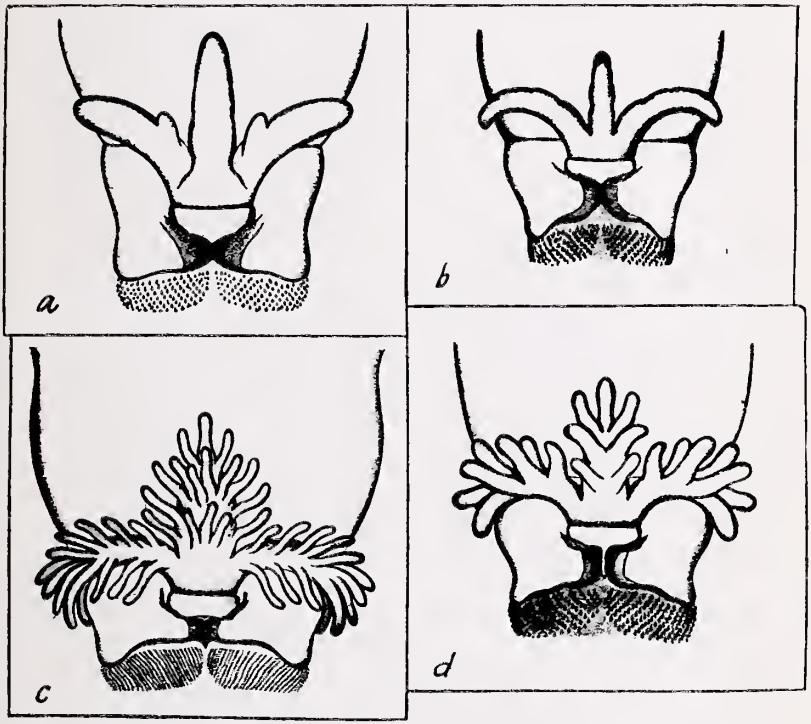

Figure 4 Posterior ends of the larvae of four different kinds of black flies, showing the exposed rectal gills or larval respiratory organs and also the palisadelike rows of hooks on the anal sucker. *a Similium vittatum; b S. bracteatum; c S. pictipes; d S. venustum.* (From Jobbins-Pomeroy, U.S.D.A. Bul. 329)

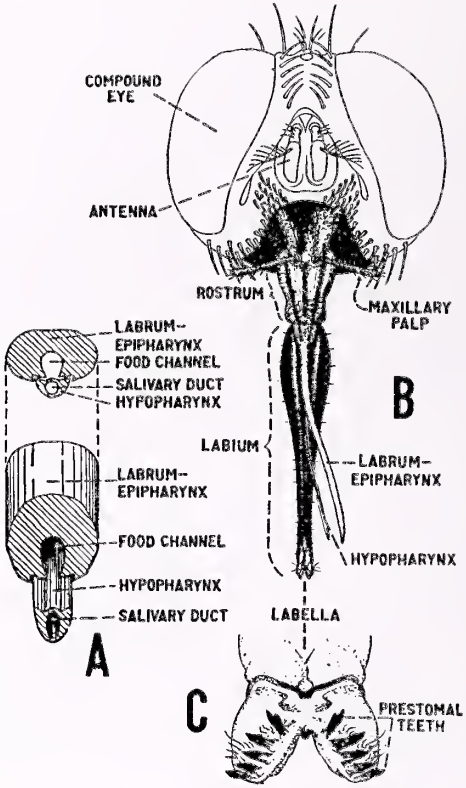

Figure 5 The biting organs of the stable fly; piercing-sucking mouth parts as found in the stable fly; special biting fly subtype. *A* Cross section and isometric projection of the stylets to show the food channel and salivary duct. *B* Front or dorsal view of the head and mouth parts with the stylets spread out from the labium. *C* The labella more magnified to show the prestomal teeth, which are cutting organs, according to Patton and Cragg. Much enlarged. (From Metcalf and Flint, Destructive and Useful Insects)

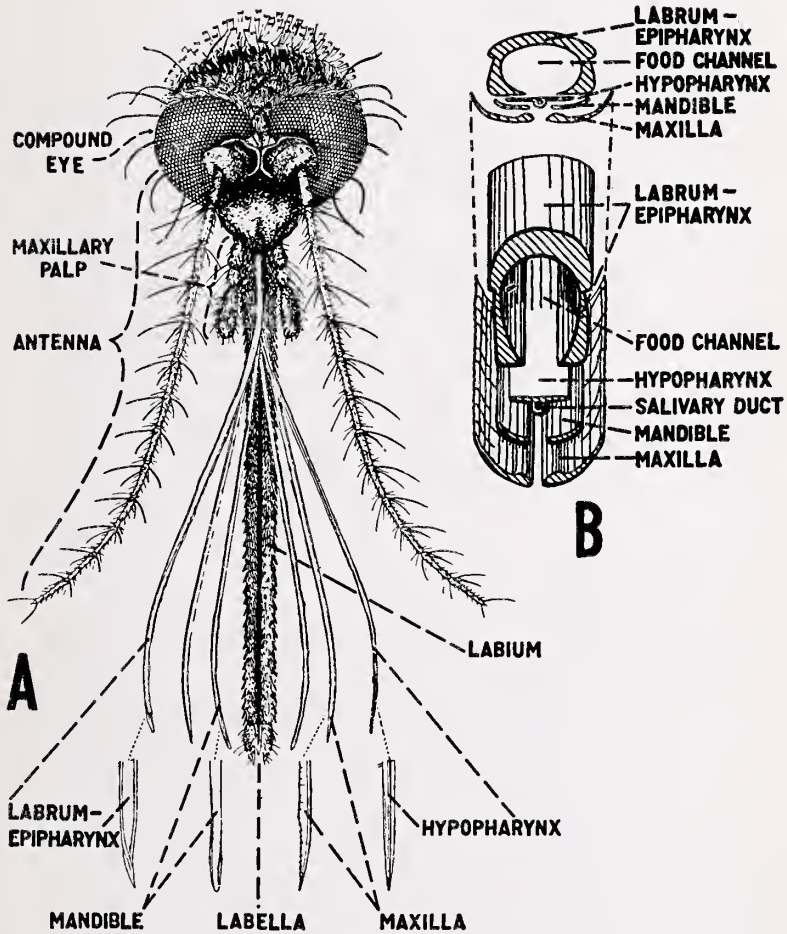

Figure 6 The organs with which the mosquito bites; piercing-sucking mouth parts as found in the female mosquito. *A* Front or dorsal view of the head and mouth parts with the stylets spread out of the labium and their tips more enlarged below. *B* Cross section and isometric projection of the stylets as described by Howard, Dyar and Knab. Much enlarged. (From Metcalf and Flint, Destructive and Useful Insects)

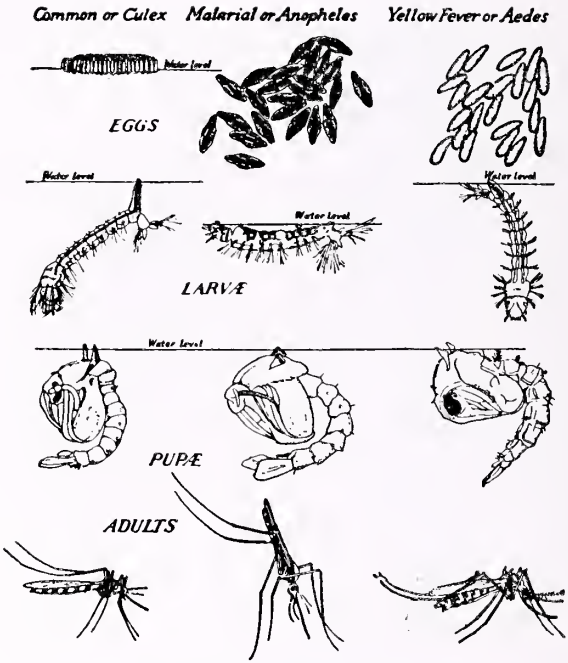

Figure 7 The various stages of development of three important species of mosquitoes, showing egg, larval, pupal and adult forms of each: in the left column the common house mosquito; in the center column the malarial mosquito; and in the right column the yellow fever mosquito. (From Metcalf and Flint, Destructive and Useful Insects; after Pieper and Beauchamp)

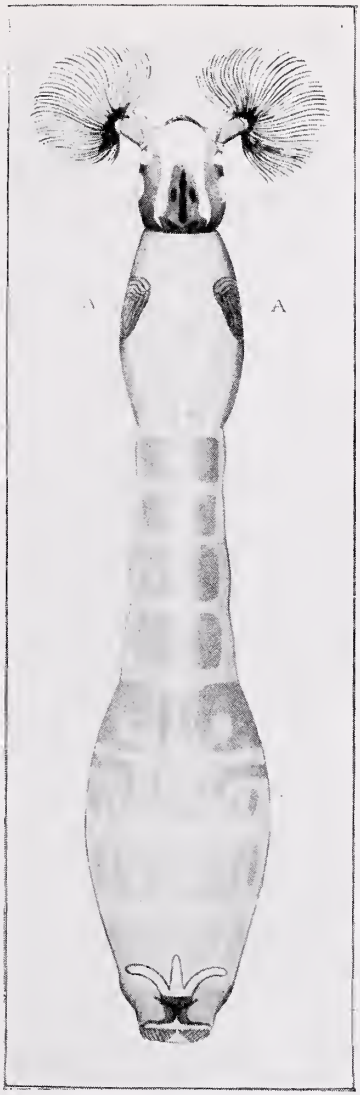

Figure 8 Larva of a black fly, *Simulium bracteatum*, dorsal view, showing the mouth fans in expanded position near the upper end of the head with the slender antennae crossing their bases; also at (*A*) the filaments or respiratory processes, which are to be used in the pupal stage, developing underneath the skin of the larva; near the posterior end at the bottom of the figure the three-lobed gills; and at the extreme end the anal sucker, with its rows of hooks, used in maintaining the position of the larva in the swift water. (From Jobbins-Pomeroy, U.S.D.A. Bul. 329)

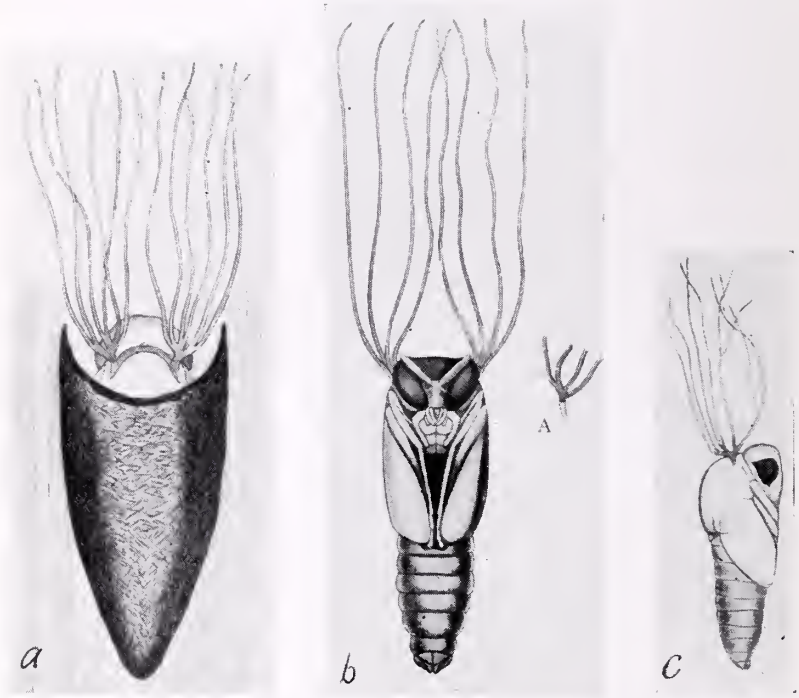

Figure 9 *a* The pupa stage of the black fly, *Simulium venustum*, in its cocoon or resting stage, dorsal view, showing the respiratory filaments with which the pupa gets oxygen from the water. *b* Pupa of a black fly, *Simulium bracteatum*, removed from its cocoon, ventral view, showing the long respiratory filaments with which the pupa gets oxygen, the developing eyes, antennae, mouth parts, legs and wings. *c* Pupa of a black fly, *Simulium jenningsi*, removed from its cocoon, side view. (From Jobbins-Pomeroy, U.S.D.A. Bul. 329)

Note for each species the characteristic number of branches of the respiratory organs.

Figure 10 Where black flies come from. Larvae of black flies clinging to a stone which has been lifted from beneath the swift water current at the outlet of a mountain lake. One such stone bore 2880 larvae of the black fly.

Figure 11 Larvae, pupae and empty cocoons of black flies fastened to the surface of a rock from beneath the swift current of a mountain stream. Some 1500 black flies developed on this stone in the summer of 1929.

Figure 12 The kind of wild mountain stream in which black fly larvae thrive and from which flies emerge.

Figure 13 Black flies do not develop in all streams. A stream on Blue mountain, apparently well suited for the breeding of black flies, was found to be entirely free from them, possibly due to the heavy pollution from residences upstream.

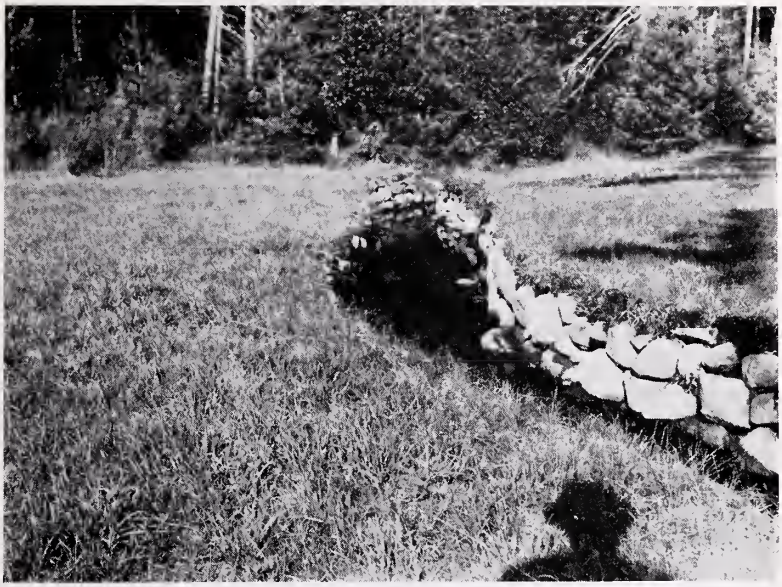

Figure 14 Black flies do not require large streams in which to develop. Black flies were breeding in this small sluggish stone-walled stream in the dooryard of one of the most exclusive camps in the Adirondacks.

Figure 15 This small stream through one of the Adirondack golf courses was grossly infested with black fly larvae.

Figure 16 This charming brooklet in the dooryard of an Adirondack hotel contained black fly larvae at the rate of 300 to the square foot.

Figure 17 Water may apparently be too warm for black fly larvae to grow in it. In this very stony brook no black fly stages were found in the main stream. A little side brook of much colder water, at the point indicated by the figure, yielded many black fly larvae.

Figure 18 Black flies may live in streams which dry up entirely during a part of the year. Cocoons of black flies were found on the stones in the bed of this stream near Chapel pond, while the bed of the stream was entirely dry.

Figure 19 The outlets from lakes and ponds like this are frequently grossly infested with black fly stages.

Figure 20 The water that flows over beaver dams furnishes an ideal breeding place for black flies.

Figure 21 Larvae of the stable fly were found breeding in heaps of grass clippings from golf courses, which had been piled at the edge of the woods and allowed to become water soaked and fermenting, following rain.

Figure 22 Where mosquitoes come from. A neglected watering trough by the side of a road. Thousands of mosquitoes, larvae and pupae, were found in this water.

Figure 23 A cemented ditch along the margin of a golf course, due to improperly constructed drainage, holds water throughout the summer and serves as a breeding place for thousands of mosquitoes.

Figure 24 A bog in which mosquito larvae, and another kind which we believe to be punkies, were found developing in pitcher plants.

Figure 25 Mosquitoes often develop in the immediate dooryard of camp or dwelling. In this catch basin beneath the wash-stand, mosquito larvae were swarming in the water.

Figure 26 Mosquitoes were found developing in considerable numbers in the rock holes along stream beds.

Figure 27 A sheltered cove near a marsh and lake where deer flies were especially annoying.

Figure 28 Mosquitoes, deer flies and possibly punkies may breed in extensive swampy areas surrounding lakes.

CONTROL OF BITING FLIES IN THE ADIRONDACKS

By C. L. Metcalf D.Sc.

Field Entomologist, New York State Museum

AND

W. E. Sanderson B.S.

Field Naturalist, New York State Museum

CONTENTS

The primary object of this investigation has been to devise methods of alleviating suffering from blood sucking flies about human habitations in the Adirondacks. The following suggestions are made in the belief that, if followed out, they will prevent much of the acute suffering that visitors and residents in the Adirondacks experience from these pests. The recommendations are largely ones that the Adirondack people themselves have discovered or which have been found to be effective under local conditions. Our function has been to gather the information and assemble it for the use of all. Our thanks as authors are due to the very many friends of the project, who have contributed freely of their experience.

GENERAL RELIEF FROM BITING FLIES

How to dress in fly time. For those who do not leave the immediate vicinity of buildings, customary clothing may serve; but if one attempts to play golf, to go fishing or hiking, or to camp out, it is imperative to be dressed for the occasion. To experience the greatest possible freedom from fly annoyance the body must be covered as completely as possible with two thicknesses of cloth. Long-sleeved, full-length underwear of silk or other light material is desirable, if the weather will permit. Indeed, most persons will prefer to be slightly overdressed than to suffer punishment from the flies. Short trousers, low-necked gowns and bare or thinly clad legs have no place in the mountains in the fly season.

One must avoid any break or hole in the clothing, as a tear in shirt, hose or trousers, or a gap made by failing to secure all buttons or laces. Black flies and punkies will pour into such openings, and the tender skin may be poisoned by their bites, much more seriously than the hardened skin of face or hands.

Mosquitoes will bite even through thick clothing where it is tightly pressed to the skin. Consequently the looser the clothing the greater freedom from these pests. The use of belts rather than suspenders has been wisely recommended by Dunn (1925) because the latter hold the shirt close to the body, while a belt helps to prevent the flies from gaining entrance at the waist.

The clothing must be tightly secured at the neck, wrists and ankles to prevent black flies and punkies crawling inside. A large handkerchief about the neck or a closely buttoned collar serves admirably. The sleeves should be closely buttoned at the wrists or, better still, the vent or placket may be stitched up and the wristbands closed with elastic.

Loose trousers should be tied or secured by boot tops or long hose.

A pair of long silk hose reaching well above the knees, if worn next the skin under trousers, hunting-pants or golf knickers, and heavy, close-knit hose drawn on over the bottoms of the trousers will effectually exclude these pests, and form the essential double layer of clothing about and below the knees without increasing discomfort even in hot weather. Stable flies will, however, bite through two pairs of heavy hose. Where this pest is prevalent, shoes of more than ankle height afford welcome protection, and boots reaching nearly to the knees will almost completely outwit it.

When the flies are prevalent it may be necessary to cover the face and hands, or use "dope" to keep the flies away. Gloves may be used

for the hands, and head nets or veils to protect the head or ears. As the deer flies are more active around the hair and crown of the head, some head covering will mitigate their annoyance.

Head nets are uncomfortable and very few persons will submit to the interference with vision and the hampering of activity and breathing that they cause. They are of course a perfect protection if properly secured at the hatband and neck. For deer flies the ordinary bee-net or veil similar to those used by beekeepers, is fine enough. For mosquitoes a black bobbinet of 20 mesh to the inch was found thoroughly effective. For black flies the material should be 30 mesh to the inch, while for punkies 50 mesh to the inch would be necessary for perfect protection. For the latter purpose the grit gauze or bolting cloth, recommended for screening doors and windows, will be found to permit the maximum possible ventilation and visibility. The cloth should be black for best vision. If black cloth of the proper mesh can not be procured, the material may be dyed black.

Nets may be easily made. A rectangle of cloth about 24 x 48 inches of the proper mesh, should have each long edge folded under, three-fourths to one inch, and stitched on a sewing machine. Into the tube so formed, a piece of flat or round elastic about 18 to 20 inches long is passed with the aid of a blunt needle or a safety pin. The two remaining short edges of the rectangle are then double-folded together and stitched to form a cylinder about 16 inches in diameter and 20 to 24 inches long. The ends of the elastic cord may be tied or sewed together, adjusting one to fit snugly over the hat band and the other over the collar or shoulders.

A window of celluloid or better, a noninflammable transparent film made of cellulose-acetate, may be inserted in the bobbinet for greater clarity of vision, by using zinc oxide tape to hold the transparent material and sewing the bobbinet to the tape.

Selecting sites for camp, home and resort. Much can be done in selecting a camp or home site by locating in situations where attacks will be least severe and extensive. These biting flies, like most Diptera, have a particular antipathy for a wind or breeze. One of the natural physical conditions of which man may take advantage to alleviate suffering from these pests is the maximum circulation of air.

In locating a camp, cottage, hotel or resort site, the owner would do well to choose a point where prevailing winds will work to his advantage. Frequently there is a choice of shores or exposure on a lake, of sites at different elevations, and of a site among trees and brush or one in open terrain. Other factors being equal, the site which will be swept by the prevailing winds or breezes, preferably

from a lake, which is not too closely smothered by trees and brush, and which is well exposed to the sun, will give the greatest natural freedom from plagues of biting flies. As these pests hide in damp places in long grass and underbrush, one should select a high, dry, sandy soil, if possible. The general tendency of the inexperienced camper to locate right down by the water's edge is bad from the standpoint of fly attack.

Dunn (1925) points out that small islands with few trees and a mile or more from the shores of the larger lakes, are often remarkably free from mosquitoes. The only place which we found in the course of the summer's work that has the reputation of being always free from black flies is such an island in one of the Fulton lakes (figure 29). The same author warns against pitching camp in the grassy yards of old lumber camps, where punkies often lurk in myriads, or near dams on streams or the outlets of lakes, which are ideal breeding places for black flies.

It must not be supposed that these insects will not bite in a breeze or in the sunshine, for the authors have been bitten in the full sunlight and with a fairly stiff breeze blowing, on the tops of Mt. Marcy, Whiteface and McIntyre. The general experience, however, is that their attacks are more common and voracious in the shelter of trees and brush and when and where atmospheric humidity is high.

So common is this experience that a widespread opinion exists among Adirondack residents that black flies "breed" in the brush and fallen leaves, and punkies in the grass. Certainly the former has no basis in fact and probably neither statement is correct. It seems certain that these situations serve merely as shelters or retreats for the adult or winged fly in either case; that is, they are roosting places but not nesting or breeding sites. They, therefore, have no bearing on the total number of flies developed in any area, but they may well determine the regions of greatest annoyance or of maximum freedom from the adult or winged biting stage.

The relation between vegetative covering and abundance of flies suggests a possible connection between the evaporating power of the air under various conditions and the prevalence of flies, that should receive careful attention. We studied a place on one of the lakes where the trees were completely cleared out for one-fourth to one-third mile around the building and where underbrush and weeds were closely cut for at least a hundred feet in every direction, so that the living quarters were thoroughly exposed to sun and wind. Within a mile is a similar resort that is "smothered" by trees, with grass and weeds grown up close all around, and with underbrush covering the

bank between the veranda and the lake. The testimony given by residents of each resort is that black flies were of no importance in the former place and very bad in the latter but that punkies were very annoying at both stations. We know of no connection between the presence of trees, underbrush, grass, weeds and fallen leaves and the abundance of flies, except as they afford roosting places for the flies, or affect the evaporating power and velocity and directions of air currents (figures 30, 31).

In case the camp or home site is established, much relief can be gained by cleaning out the brush, keeping the grass cut close, covering paths with sand, and seeing that all areas drain properly and are opened up to receive the benefit of the breezes. The local situation should be studied and advantage should be taken of all conditions that may afford relief.

Use of tents and screens. It is difficult to keep a tent absolutely free from these bloodsucking insects. Nevertheless, when one is obliged to spend the night in the open, in fly country, a properly erected tent makes the difference between comfort and misery, and if a period of some time is to be spent camping, adequate protection in the tent may be the only way of making conditions endurable. The tent must be absolutely free from all holes and tears. Special attention should be given to chinking up the small holes which adjoin the ropes used to support the tent. A complete floor of cloth, securely fastened to the sides of the tent, or a floor-cloth extending inward a foot or more from the edge of the tent, all the way around, is essential to keep out flies and mosquitoes. A fine mesh bobbinet curtain of about 30 squares to the inch should cover the gap in front of the tent and should be cut full enough to be slack and to allow a foot or more to be turned in at the bottom. For real comfort a window opening, similarly covered with bobbinet, should be provided in the side of the tent opposite the entrance, to give adequate ventilation. If protection is desired from punkies, the bobbinet, or better, the bolting cloth screens should be finer, and should have at least 50 mesh to the inch.

When the tent is erected, a quantity of clean, dry sand or other earth, and several stones or other smooth objects, should be placed on the floor cloth to hold it in position.

When the tent has been pitched one should insist that every one stay out of it except when it is absolutely necessary to enter. Before one enters to retire, the front of the tent should be thoroughly brushed to drive away any mosquitoes or punkies which may be resting upon it. The clothing of each person should similarly be vigor-

ously brushed to dislodge mosquitoes and punkies. Entrance should then be made as quickly as possible and the front bobbinet curtain should be secured with stones and sand to make it completely pest-tight. Finally, a search should be made with a flash light or torch for any mosquitoes or other flies which may be on the inside of the tent. If these are all disposed of and the work of fly-proofing the tent has been thoroughly done at every step, a night of complete rest and immunity from the biting flies may be enjoyed.

Where large tents are used as sleeping quarters for a number of persons, floor cloths and bobbinet screens are not likely to prove satisfactory because of the frequent entrance to the tent. In such cases it will probably be more satisfactory for each individual to have a bed-net of fine enough mesh to keep out the pests, as stated above; namely, 20 mesh to the inch or finer for mosquitoes, and 50 to the inch for punkies. These may be supported over the bed by means of strings or crossed sticks resting on an upright forked stick driven into the ground at each corner of the bed. The lower edge must be securely tucked under the mattress or bedding, after one has retired, in order to make certain that not the slightest opening is left for the pests to crawl through.

Effect of underbrush, water, humidity, sunlight, breezes. All who have a choice will do well, in the fly season, to select trails that lead along breezy, elevated places and to avoid loitering near swamps or bogs or in damp, low locations. Especially on days of high humidity and in cloudy weather one may well refrain from going into thickets or among underbrush where the pests are in hiding. During the punkie season it is well not to venture out in the early morning during cloudy weather, or in the evening, when these pests are the most active. During the height of the black fly season, keeping close to cleared, sunny, open and breezy camp sites during the daytime may be the only protection some persons will need from these most annoying pests. Where deer flies are abundant, simply staying out of the low, swampy, wooded areas where they may be, is easier than attempting to ward them off. Knowing the habits of the different pests, those who are on vacation or at leisure may intelligently take advantage of these varied habits to gain the greatest freedom from attack.

By an intelligent study of the seasonal and daily cycles of the biting flies we believe that the transient and occasional visitor to the Adirondacks may easily plan his trips and time his activities so as to avoid the major part of the cause for complaint that is otherwise sure to arise.

If camping trips, fishing trips, canoe trips or hiking parties are planned, the height of the black fly season must be avoided, unless other methods of protection are very carefully worked out.

Beach parties, dances, dinners, bridge parties, even conventions which are scheduled for the evening hours and which are conducted entirely indoors would, however, probably be better planned during the black fly season than later when punkies are abundant, since the black flies are not at all troublesome at night nor indoors.

There is not a single kind of these flies that bites during the entire 24 hours. With a little care, therefore, one may plan occasional activities so as to avoid places where the flies are most prevalent; or if necessary to go there, arrange for a time when that kind of fly is quiescent, and, in effect, absent.

When one is caught without adequate protection, by swarms of black flies, mosquitoes or punkies, temporary relief may sometimes be secured by retreating to the center of a lake. In taking to the lake, one should steer directly into the wind upon leaving the shore, even although this may be out of the desired course, and paddle or row as rapidly as possible to windward for several hundred yards. By that time the flies will generally have been left behind and the desired course may be resumed. If one rows slowly or with the wind, especially on a warm, muggy day or evening, the persistently biting flies may follow the boat across the lake.

If retreat to a lake is not possible, the next best place is some wind-swept elevation above the shelter of trees and surrounding hills.

Use of smoke and smudges. A time-honored control measure for flies is smoke. Tobacco smoke gives a measure of relief, but it is totally inadequate when flies are very abundant. Smudges made by burning green grass, leaves, punky wood or even old leather, over a bed of coals, are effective although not pleasant. In many places in the Adirondacks smudge pots are regularly attended throughout the fly season. A galvanized pail or iron kettle or any similar vessel may be used or the fire may be built on the clean soil or rocks. A good bed of coals made by burning a large quantity of dry wood or other fuel is essential. The larger the bed of coals, the longer the smudge can be made to last. The green material is placed over such live coals and a dense smudge or smoke is formed. One may then sit as close to the smoke as necessary to escape the flies. Frequently such smudges are built regularly in front of tents or cottages and about the verandas of hotels, dance halls and similar places. Those constructed in portable pails may be shifted to produce the smoke screen where it is most desired, even carried into tents to drive out

the pests by directing the smoke from the back of the tent toward the opening. In using smudge pails one should always insulate the bottom of the receptacle and use all necessary precautions to prevent accidental fires.

Instead of the stifling smoke made from the materials listed above, equally good results may be secured by burning pyrethrum or incense. The oil from pyrethrum is highly toxic to insects but has little if any effect on man. Howard recommends molding the powder into cones, drying them in the oven and then burning like punk by igniting the tip of the cone. Certain kinds of incense will given thorough protection from flies without the unpleasantness of ordinary smoke. Pyrethrum and incense are, of course, rather expensive materials.

Large smudges may be used advantageously to afford protection to horses and other domestic animals.

Use of "dope" and repellents. Some natives claim to be immune to the attack of these pests, but for the most part even hardened woodsmen seek relief during the height of the fly season by the use of various chemicals applied to the skin. The woodsman generally uses a mixture of oil of tar and lard, beginning with a rather high percentage of lard and gradually increasing the oil of tar as the skin becomes hardened to it. This is usually continued until it has formed a perfect glaze on the skin, being renewed day after day, often without washing any of it off at night.

The camper and vacationist now have a choice of a large number of repellents less irritating to the skin and more pleasant to use, nearly all of which have some merit. He may buy one of the ready prepared commercial "dopes" of unknown composition, or he may make his own repellents from formulas or recipes, some of the best of which are given below. None of them is entirely satisfactory. One may be assured that in buying the patent, commercial and ready-prepared "dope" one is paying a big price for repellents that are no more effective than some of the home-made compounds. The requisites of a good "dope" are (1) effectiveness, (2) harmlessness to the skin and (3) lasting qualities. Desirable additional qualities are nonstaining properties and ease of removal. Dunn, in his very practical paper already cited, advises that an ounce a day for each person is the minimum amount that should be provided, when one is out away from habitations in the midst of the fly season.

Instead of applying repellents directly to the skin it is sometimes a more satisfactory arrangement to fasten a handkerchief or piece of cloth across a small forked stick in the shape of a fan, saturate the cloth with one of the repellents or "dopes" and use it like a fan by waving it about the face and hands to drive the flies away.

We quote the following recipes with a few notes on the properties of each.

No. 1	Oil of Cassia	1 ounce
	Camphorated Oil	2 ounces
	Vaseline	3 ounces

Recommended by Bacot and Talbot (1919).

No. 2	Oil of Citronella	3 ounces
	Spirits of Camphor	1 ounce
	Oil of Tar	1 ounce
	Oil of Pennyroyal	¼ ounce
	Castor Oil or Tallow	4 ounces

Recommended by Dunn (1925), who advises that for sensitive skins the last item should be increased to five or six ounces. The use of castor oil gives a lotion; of tallow a salve.

No. 3	Oil of Citronella	1 ounce
	Spirits of Camphor	1 ounce
	Oil of Cedar	½ ounce

Recommended by Howard and Bishopp (1928).

No. 4	Vaseline	2 ounces
	Oil of Peppermint	1 ounce
	Oil of Cassia	2 ounces

Recommended by Bacot and Talbot (1919).

The principal objection to repellents or "dopes" is the shortness of the time during which they are effective after being applied. Most of the "dopes" have to be renewed every 20 or 30 minutes. They are consequently useless, or nearly so, for protection while sleeping.

Working on the principle of binding or tying up the essential oils, such as citronella, cassia and pennyroyal, with a heavy base that would prevent their rapid evaporation, George L. Hockenyos of the University of Illinois, perfected the following dope-salve which one of us tried extensively during the summer of 1929 against black flies, punkies and mosquitoes with gratifying results. A single application lasted for hours. Paper or cloths impregnated with it and placed about the face upon retiring retain the odor of the oils, apparently undiminished the following morning. It is recommended that others try this mixture.

No. 5	Vaseline	1 ounce
	Beeswax	1 ounce
	Medium hard paraffin	1 ounce

Melt together over a gentle fire; cool until the mixture is just fluid; then stir in the following:

Oil of Cassia	1 gram
Oil of Citronella	2 grams

Remedies for bites. After one has been bitten by any of these flies, the most important advice that can be given and followed is "Don't scratch." If friction must be applied one should use the palm of the hand or a moistened piece of soap, which gives equal relief

without the danger of infection that attends breaking the skin with the finger nails. Physicians are emphatic in their statements that the fatal and tragic cases of fly bites are almost invariably due to secondary infection rather than to the poison injected by the mouth parts of the flies.

Various lotions that have a cooling, soothing effect are the most important medication that can be prescribed. No internal treatment seems to be known that in any way alleviates the suffering. Several prominent Adirondack physicians have kindly told us the lotions which their experience has indicated to be most effective and have given their permission to quote them here:

Camphor and benzoated lard
Sweet spirits of niter
Aqueous solution of aluminum acetate
Hexyresorcinal, S. T. 37
Household ammonia
Borated vaseline

Any one of these lotions may be applied freely to the inflamed itching skin. The sooner it can be used upon a bite the greater the measure of relief. Holding a hot lamp as close as may be borne to the bitten area is recommended to give relief. Household ammonia seems one of the most universal remedies to allay the itching. Boric acid powder dusted over the bitten areas has been found very helpful. The ointment with this powder incorporated in it, known as borated vaseline, is one of the most healing and soothing remedies, especially for children who object to the smart of the ammonia if the bite has been scratched raw.

SPECIAL SUGGESTIONS FOR CONTROL OF BITING FLIES

Control of black flies. The heaviest breeding areas of black flies have uniformly been found where water flows rapidly over or around obstructions of any kind that cause a churning, whirling or foaming of the water—the conditions usually spoken of as rapids. The outlets of lakes, the rapids below dams, the spill over beaver dams and similar spots are usually grossly infested with black fly larvae and pupae.

Two measures of control suggest themselves:

1 The water over a dam should have a sheer, unobstructed drop into a deep pool reinforced at the bottom to prevent destructive erosing. Most Adirondack dams have been constructed after a type useful in floating logs and consist of a gradual slope or spillway through which the water rushes rapidly. Frequently these spillways

are roughened by spikes and splinters that catch leaves, sticks and trash and thus form places of attachment for innumerable black fly larvae. In nine cases out of ten the need for facilitating logging operations has passed.

2 Since black flies require a constant flow of water, we recommend that the outlets from dams be always in duplicate, or a larger number if possible, and that throughout the year water be flowed alternately at three to five-day intervals through different valves while the others be allowed to dry up completely.

We have found that larvae on rocks or other obstructions, when the water flow is stopped, crawl slowly down to the moist surface beneath and, becoming trapped there, may perish in a few hours. Consequently any larvae that might develop in such outlets from lakes and ponds, or float down and lodge there from breeding areas higher up stream, will be killed by alternating the flow so that each outlet undergoes a period of drying up at frequent intervals. In many cases the overflow water from lakes is allowed to take the roughest possible course over stones, logs, discarded building materials, trees and underbrush. Jobbins-Pomeroy (1916) has shown that eggs of the black fly, *Simulium venustum,* if dried for two days do not hatch. Other species are supposed to be able to survive in the egg stage, when the stream bed dries up completely.

When one can see in late summer and autumn literally millions of black fly larvae developing in favorable sites such as those described, for the next spring emergence, one is ready to apply direct measures of destruction. The clearing out of obstructions in streams near hotels, golf courses, camps, clubs and private cottages; removing brush, logs, sticks, stumps and stones that form the ripples and waterfalls, and deepening and narrowing channels will reduce the numbers of flies that can develop in these breeding areas (Weed '04, O'Kane '26).

Where the larvae are developing on the smooth stone bottoms of streams flowing over rock outcrops, or over obstructions that can not be removed, the use of stiff-bristled stable brooms to remove the masses of larvae will do much to prevent the excessive breeding of these pests near living quarters.

Suggestions for the control of punkies. Punkies, stable flies and mosquitoes, unlike black flies and deer flies, come into dwellings and habitations of all kinds.

The general opinion prevails that punkies can not be screened out. To test the practicability of screening we made some tests with silk bolting cloth and grit gauze of various degrees of fineness from 22 to 62 threads to an inch.

The punkies readily passed through the 34 and 36-mesh gauze. They passed through gauze of 40 and 42 meshes to the inch with some difficulty. One passed through 44-mesh gauze after a few minutes and another only after 10 or 12 minutes. Fifty per cent of those inclosed by 48-mesh screen escaped in three or four hours. In no case did the insects pass a bolting cloth with 50 meshes to the inch, although a good many found their way through a brass strainer cloth that measures 50 meshes in one direction by 40 in the other. We believe that any cloth or screen with 50 meshes to the inch will exclude all female punkies of the species, *Culicoides biguttatus* Coq. The bolting cloth or grit gauze, on account of the cleanness of the threads, admits a maximum of air and light. It is expensive, but for tent windows or screening the doors and windows of cottages where punkies are prevalent, the owner will probably find it a good investment. It will enable him to have a light and, especially if an electric fan is available, to live in complete comfort so far as punishment from punkies is concerned.

It is suggested that all who have the opportunity try the effect of electric fans on the adult punkies. Their dislike for a breeze makes it seem possible that a high degree of protection from punkies may be afforded by the draft from an electric fan, placed so as to direct the breeze toward the face or head, or toward the entrances to the room.

Suggestions for the control of stable flies. According to Bishopp ('26), who has studied the stable fly intensively, this species breeds chiefly in straw stacks and especially in oats straw. He states that accumulations of weeds and bunches of grass in open fields are not infested.

In our work in the summer of 1929 we found the insect sometimes abundant in the grass clippings from golf greens and fairways that had been piled up in the edge of the adjoining woodland, where they became soaked by rains and, fermenting, formed ideal feeding places for the larvae (figure 21).

A survey of the surroundings led us to believe that in many cases these clippings were the chief source of this tormenting pest about certain of the mountain resorts. In places where no livestock is kept it is difficult to find any other accumulation of green or fermenting vegetation exposed to rain and sun, that would seem to be responsible for the plagues of stable flies.

The remedy, so far as these clippings are concerned, is exceedingly simple. If they are simply scattered about or not piled up sufficiently to form a heating fermenting mass, the flies will not

develop in them. At the same time *all* accumulations of straw, hay, manure and grain that are exposed to rain or other moisture, should be eliminated by scattering very thinly, or by burning, or, if neither of these measures is practicable, by chemical treatment. The larvae may be destroyed and breeding of this pest, as well as of the house fly, prevented, by wetting the manure, straw, garbage or other fermenting material with borax dissolved at the rate of one pound of borax in 25 gallons of water, and using enough of the solution evenly applied to wet all parts of the mass.

Special control methods for mosquitoes. There is apparently some species of mosquito to lay its eggs in every sort and sized body of still water. The first step in reducing their numbers and gaining protection from them is to give attention to those breeding areas close to human habitations. An unsuspected breeding place within the bounds of a dooryard may often furnish a continuous supply of blood-thirsty mosquitoes, that are supposed by the inhabitants to come from some distant and mysterious swamp.

All food cans and other discarded vessels of every kind should either be mashed flat, melted in an incinerator, or have several holes punched in the bottom so they cannot hold water.

Eaves-troughs and gutters on buildings should be inspected to make sure they drain evenly and completely.

Water barrels or catch basins of every kind should be screened or treated chemically as described below; otherwise they are nearly certain to invite development of mosquitoes in hordes.

The grounds along roads, railroads and every other site of excavation should be examined and any depressions that hold water after rains should be filled in, or drained or oiled periodically. In one case a small water hole, excavated with dynamite to be a source of drinking water, was found within ten days to be swarming with mosquito larvae.

Swamps, bogs, ponds and puddles that cannot be filled or drained may, when they have been shown by a competent investigator to be infested and a source of trouble, be treated every ten days with oil.

There are two primary ways of applying the oil. One is to apply from above with bucket and dipper, or with a knapsack or other type of sprayer from the shore or from a boat. The resulting film of oil should be renewed systematically every ten days. If oiling can be done under well-organized competent direction to insure that the oil will not be poorly applied, or renewals neglected, this is probably the best method. Another method is to saturate sawdust with oils, and sink weighted cloth sacks or bags of the

oil-bearing sawdust in the water to be protected. The sawdust gives off the oil slowly and such treatments require less labor and attention. Even in this case, however, inspections should be made every week or two to make sure that the surface is receiving the essential thin but unbroken film of oil.

One Adirondack community has used dried hardwood sawdust (a by-product of a local sawmill) soaked in locomotive fuel oil or waste crank-case oil for safeguarding nearby standing water from mosquitoes. For rain barrels and cisterns, borax at the rate of two and one-half ounces to a gallon of water is recommended by Matheson (1929) as effective in preventing mosquito breeding. Such water is excellent for washing purposes but should not be used for drinking. In using oil or chemicals in control measures, one must always take into consideration the possibility of injuring fish or other aquatic life.

The treatment of larger areas such as swamps and bogs is one requiring organized community or governmental action. Each individual can, however, following the suggestions made above, make sure that his mosquito enemies are not being reared in or about his own household.

The use of smudges, headnets, repellent dopes and screening, as previously described, are additional control measures useful against mosquitoes under certain conditions.

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Figure 29 An island in one of the lakes of the Fulton chain, less than a mile from mainland, which is said to be entirely free from biting flies. Such sites may sometimes be chosen for camps to escape torment from flies.

Figure 30 Hotels, clubhouses and camp sites should not be too closely smothered with trees and underbrush.

Figure 31 Open, sunny sites for hotels, clubhouses and camps help to lessen the severity of attack by biting flies.

Figure 32 Black fly larvae and pupae often attach to floating vegetation. In this case on Fall stream millions of young black flies were fastened to the slightly submerged leaves of the sedges in the swift current.

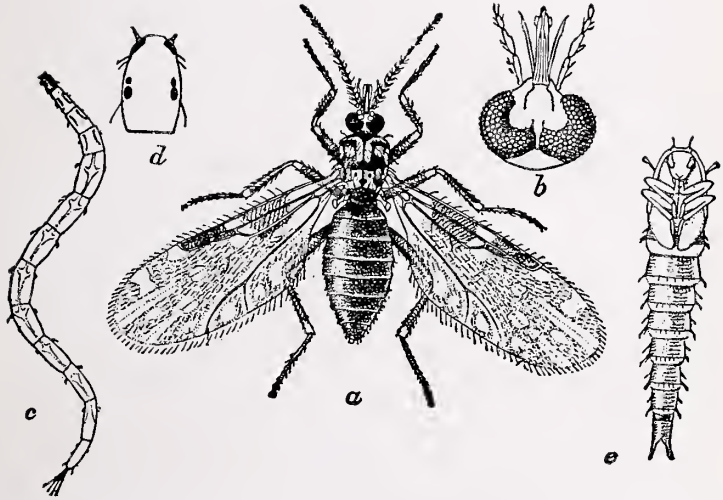

Figure 33 A punkie or midget, *Culicoides guttipennis* (Coq.). *a*, adult, 15 times natural size; *b*, head of adult, more enlarged; *c*, larva; *d*, head of larva; *e*, pupa, (After Pratt).

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