The black flies (Diptera: Simuliidae) of western Massachusetts.

Frederick Randall Holbrook
University of Massachusetts Amherst

Follow this and additional works at: https://scholarworks.umass.edu/dissertations_1

Recommended Citation

This Open Access Dissertation is brought to you for free and open access by ScholarWorks@UMass Amherst. It has been accepted for inclusion in Doctoral Dissertations 1896 - February 2014 by an authorized administrator of ScholarWorks@UMass Amherst. For more information, please contact scholarworks@library.umass.edu.
THE BLACK FLIES (DIPTERA: SIMULIIDAE) OF WESTERN MASSACHUSETTS

A Dissertation Presented
by
Frederick Randall Holbrook

Approved as to style and content by:

[Signatures]

January 1967
THE BLACK FLIES (DIPTERA: SIMULIIDAE) OF WESTERN MASSACHUSETTS

A Dissertation Presented
By
Frederick Randall Holbrook

Submitted to the Graduate School of the University of Massachusetts in partial fulfillment of the requirements for the degree of
DOCTOR OF PHILOSOPHY
January 1967
Major Subject Entomology
ACKNOWLEDGEMENTS

Initially, I wish to express my profound thanks to Dr. Frank R. Shaw who, as chairman of my guidance committee, spent countless hours listening, advising, reading, re-reading, correcting and correlating without once allowing himself the indulgence of the exasperation that may have been his just due. His guidance and understanding were of great aid to me in maintaining objectivity toward my research.

My sincerest appreciation is also extended to Dr. John H. Lilly and Dr. William B. Nutting, members of my committee, and Professor Thomas J. Andrews, consultant, for their time, advice and thoughtful interest toward my research and in reading the manuscript. Members of the faculty of the Entomology and Plant Pathology Department are to be commended for the aid given me with problems in their individual areas of interest.

To Dr. B. V. Peterson and other members of the Taxonomic Section of the Canadian Ministry of Agriculture, for aid in taxonomic studies; to the Lotta Crabtree Foundation, for providing a scholarship covering two years of my work; and to Mr. E. C. Aldrich and the Massachusetts Department of Natural Resources for allowing me to use their property for my research, I extend my most heartfelt thanks.
Lastly, I wish to express my profoundest thanks and deepest appreciation to my wife, Charlotte, for maintaining a sense of calm in the midst of continuing chaos. She has had to shoulder many responsibilities not normally relegated to a wife and mother, and the success with which she has accomplished these is a tribute to her strength of character, devotion and good humor.
## TABLE OF CONTENTS

I. INTRODUCTION ......................................................... 1

II. REVIEW OF LITERATURE ............................................... 3

   Ecology and Behavior of Larvae ................................. 4
       Emergence from the egg ......................................... 4
       Attachment ...................................................... 5
       Migration ....................................................... 6
       Environmental factors .......................................... 7
       Molting .......................................................... 11
       Cocoon-spinning ................................................ 11

   Larval Feeding ...................................................... 12
       Mouthparts ....................................................... 12
       Feeding .......................................................... 14
       Food ............................................................. 15

   The Pupal Stage ..................................................... 16

   Prepupal Feeding and Spinning Cocoon ......................... 19

   Adult Behavior ..................................................... 20
       Emergence ........................................................ 20
       Dispersal ......................................................... 21
       Physical factors ............................................... 22
       Attractants ...................................................... 27

   Ovarian Development ............................................... 27

   Mating .............................................................. 27

   Oviposition ........................................................ 32
Feeding of Adults..........................34
   Adult mouthparts..........................34
   Feeding and digestion.....................36
   Host preferences..........................37
   Physical factors affecting feeding........39
Disease Relationships......................41
   Black flies as direct agents of
disease or discomfort.....................41
   Black flies as vectors....................44
Parasites and Predators....................48
   Parasites..................................48
   Predators..................................51
Rearing......................................54
Sampling.....................................56
   Immatures..................................56
   Adults......................................57
Stream Classification......................59
   Cnephia dacotensis (Dyar and Shannon).....64
   Cnephia mutata Malloch.....................67
   Prosimulium hirtipes (Fries) Complex........71
   Prosimulium magnum Dyar and Shannon........79
   Prosimulium multidentatum (Twinn)...........82
   Simulium aureum Fries.....................84
   Simulium corbis Twinn......................89
   Simulium croxtoni Nicholson and Mickel......91
   Simulium decorum Walker....................93
   Simulium gouldingi Stone...................98
Simulium latipes (Meigen) .................................. 100
Simulium parnassum Malloch .................................. 102
Simulium rivuli Twinn ........................................ 104
Simulium tuberosum (Lundstrom) .................................. 105
Simulium venustum Say ........................................ 108
Simulium verecundum Stone and Jamnback .............. 115
Simulium vittatum Zetterstedt .................................. 117
Twirnia tibblesl Stone and Jamnback .................. 124

III. STREAM CLASSIFICATION .................................. 126
Temporary Streams ........................................ 126
Permanent Streams and Rivers .................................. 127

IV. COLLECTION OF IMMATURE STAGES ....................... 130

V. SAMPLING .................................................. 132

VI. REARING IN THE LABORATORY .................................. 136

VII. REARING IN THE FIELD ..................................... 140

VIII. TAXONOMY .................................................. 142

IX. LARVAL IDENTIFICATION .................................... 145

X. KEY TO THE LARVAE OF WESTERN MASSACHUSETTS SIMULIIDAE .................................. 146

XI. CNEPHIA SPECIES ........................................... 151
Cnephia dacotensis (Dyar and Shannon) ................. 151
Cnephia mutata Malloch ........................................ 152

XII. PROSIMULIUM SPECIES ..................................... 155
Prosimulium fontanum Syme and Davies .......... 155
Prosimulium fuscum Syme and Davies ......... 158
Prosimulium magnum Dyar and Shannon .......... 161
Prosimulium mixtum Syme and Davies .......... 165
XIII.

Prosimulium multidentatum (Twinn) .................. 170
Prosimulium rhizophorum Stone and Jamnback ....... 171

XIV.

Simulium Species .................................... 173

XV.

Some Conditions Unfavorable for Larval Development .. 200

XVI.

Collection of Adults ................................ 203

XVII.

Biting Records (1965) ................................ 204

XVIII.

Summary .............................................. 206

XIX.

Conclusions ......................................... 210

Literature Cited ...................................... 211

Table I. Larval Associations .......................... 225
Table II. Stream Widths ................................ 227

Table III. Number of Collections Made at Different Stream Widths .... 228
Table IV. Substrates of Larval Simuliidae.......................... 229

Table V. Expected Maturation Periods for Larvae of some Common Species of Simuliidae in Western Massachusetts.............. 231

Table VI. Expected Maturation Periods for Larvae of some Rarer Species of Simuliidae in Western Massachusetts.............. 231

Table VII. Current Speed.......................... 232

Graphs I, II, and III.......................... 233

Plate No. 1. Hypostomal Teeth.......................... 234

Plate No. 2. Head, Anal Sclerite, and Throat Clefts.......................... 235

Plate No. 3. Larva and Pupa.......................... 236

Plate No. 4. Mouthparts of Simulium vittatum Zett.......................... 237

Plate No. 5. Stream Classification.......................... 238

Plate No. 6. Stream Classification.......................... 239

Plate No. 7. Rearing Device.......................... 240

Map I. Distribution of Cnephia mutata.................. 241

Map II. Distribution of Prosimulium fontanum.......................... 242

Map III. Distribution of Prosimulium fuscum.......................... 243

Map IV. Distribution of Prosimulium magnum.......................... 244

Map V. Distribution of Prosimulium mixtum.......................... 245

Map VI. Distribution of Simulium tuberosum.......................... 246
Map VII. Distribution of Simulium venustum.................247

Map VIII. Distribution of Simulium vittatum....................248

APPENDICES

I. Dates of Collecting Trips, Towns Visited, and Species Found........249

II. Streams Visited........................................257
I. INTRODUCTION

The black flies (Diptera: Simuliidae) are of considerable economic importance throughout much of the world, reducing the effectiveness of man, wild and domestic mammals, and birds, by their swarming and biting habits and as vectors of organisms causing serious diseases.

As population increases, and with the present trend of movement from urban to rural areas, man is exposed to attacks of insects of which he has previously been completely unaware. As his discomfort increases, demands are made upon various agencies for control measures; however, no control program should be attempted unless and until there is a basic understanding of the organism and the problems it may present.

Very little is known concerning the black fly fauna in Massachusetts, although extensive surveys have been conducted in other areas of this country and the world. Johnson (1925) lists P. hirtipes, C. mutata, S. decorum (= piscicidium), S. aureum (= bracteatum), S. meridionale and S. vittatum as occurring in this state, but records only P. hirtipes and S. aureum from western Massachusetts. Stone (1964) gives records for only three species in Massachusetts, C. dacotensis, S. johannseni and S. venustum, while Stone et al. (1965) list only S. aureum and S. venustum as definitely occurring in this state.

It is the purpose of this paper to identify the black
fly species present in the western four counties of Massachusetts (Franklin, Hampshire, Hampden and Berkshire), and to present information pertinent to their distribution, relative abundance, ecology, biology and importance to man. The intent is to form a basis of knowledge for further investigations and to provide an aid for any control programs that may be undertaken in the near future.
II. REVIEW OF LITERATURE

Introduction

Mention of black flies (Simuliidae) and their annoyance to man and animals may be found in scattered papers from the 18th to the early 20th century, but, with the discovery by Blacklock (1926) of *Simulium damnosum* as a vector of onchocerciasis in Africa, interest was focused on black fly research. Subsequently, many papers were published on the adult black flies and their habits. The advent of DDT and other organic insecticides has stimulated research in the biology, ecology and habits of larval black flies, since this is the stage that is most susceptible to control measures.

The first step in gathering information pertinent to this study was a thorough search of Biological Abstracts, the Zoological Record, the Bibliography of Agriculture, the Review of Applied Entomology (B) and the Bibliography of Onchocerciasis. Newer editions of various available publications were checked to obtain the most recent papers. The literature reviews of papers found in the journals were then checked for papers that might have been missed. Several publications of outstanding value were the Canadian Entomologist, the Canadian Journal of Zoology, the Annals of the Entomological Society of America, and state bulletins from Connecticut, Minnesota and New York.

Recent contributions on northern black fly fauna that
contain much information relevant to this study have been made by Stone and Jamnback (1955), Peterson and Wolfe (1958), Wolfe and Peterson (1959), Anderson and Dicke (1960), Davies et al. (1962) and Stone (1964). Excellent keys to the larval stages of northern black flies have been published by Wood et al. (1963) and Stone (1964).

Ecology and Behavior of Larvae

According to Johannsen (1903), Schonbauer (1795) was the first to state that immature black fly stages were found in the water. Osborn (1896) further limited the habitat by stating that the larvae are usually found in swift water. In a review, Puri (1925) quoted Webster (1887) as saying that the larvae of the Simuliidae attached themselves at depths of eight to ten feet. This has been shown to be in error, as larvae are seldom found below depths of two feet (and usually much less).

Emergence from the egg. Johannsen (1903) indicated that eggs were laid on rocks. Bradley (1935) states that Webster (1889) believed that the eggs of black flies hatched a few hours after being laid. This has been shown to be false by many authors, who have found that the eggs may be present up to ten months or more. Gambrell (1933) states that the upper eggs of the mass are generally the further advanced in development. The young larva ruptures the chorion by means of an egg-burster on the dorsal surface of the head. Fredeen (1959) describes this apparatus as a dark, prominent knob.
According to Hocking and Pickering (1954), a split is made in the most acute angle of the egg, and about twenty minutes later the larva has fully emerged.

Davies (1960) found that the first instar larvae of *Prosimulium* spp. lack head fans, but molt rather soon after emergence, with the second instar larvae possessing normal fans. Larvae of *Cnephia mutata* and *Simulium* spp. were found to have head fans in all instars.

**Attachment.** Sutherland and Darsie (1960b) state that larvae seem to be rather unselective as to substrate. Many other authors, including Davies et al. (1962) and Stone (1964), have indicated that there is a distinct preference of certain species for certain substrates.

Hora (1927), in a review on the posterior 'sucker' of the larvae, states that some people were of the opinion that this organ was indeed a true sucker, as in the leeches. He quotes Tonnoir (1925) as saying that since he found no muscles at the center of the sucker, the circle of hooklets around the edge of the sucker must be the actual attachment organs. Puri (1925) found strong muscles at the disc center, but adds that in addition to these muscles, the salivary secretions were necessary to make a tight seal. Again, the suggestion is that the hooklets were secondary in function, with suction forming the prime mechanism of attachment. Hora felt that the principal of suction was false, and that the hooks alone were the holding factor, attaching to a cluster of silken threads laid down by the larva. The large central muscle is used to
loosen the hooks when movement is required.

Puri (1925) observed the larvae to have a release thread which they can crawl back upon, once they have been forced to release their hold on a support. Hocking and Pickering (1954) further add that this silken thread is extruded from the salivary glands. Strickland (1911) felt that the release thread acted as an anchor line, to prevent the larvae from being washed completely away when the caudal sucker became detached.

Hocking and Pickering (1954) found that when the larvae moved back to their original point of attachment after having been disturbed, the posterior hooks (surrounding the sucker) were not used. The larva grasped the thread with its mandibles and moved in the manner of an inchworm, using the proleg to grasp and pull itself along. The greatest speed of movement recorded was 2.5 centimeters per second.

Migration. Phillipson (1956) and Fredeen (1959) reported that the first instar larvae were positively phototactic. I would think that this would aid the larva in obtaining a place of attachment near the surface of the water, where the water was shallow and swiftly-moving.

Jobbin-Pomeroy (1916) found that young larvae migrated more than older ones.

Fredeen et al. (1953), using larvae marked with radioactive phosphorus, discovered that migration occurred up to 520 yards from the point of release. Even at these distances, the larvae were found in large concentrations, so migration
must have been in large numbers, not just an occasional accidental release from the initial point of attachment.

**Environmental factors.** Davies and Peterson (1956) stated that larval population size depends on such things as grinding action and silting conditions of spring floods and the amount of suitable habitat available that combines sufficient food, high oxygen tension, good rate and steady volume of water flow, suitable substrate for attachment and a paucity of parasites and predators.

1. **Water flow.** Wu (1931) considered current as the most important controlling factor of larval attachment.

Jenkins (1948) found that generally Prosimulium spp. are found in fast, tumbling streams with cold, clear water, while Simulium spp. are typically found in warm, relatively slow-moving streams.

Hocking and Pickering (1954), Phillipson (1956), Peterson (1956) and Peterson and Wolfe (1958) all believed that current was the major factor controlling larval position. The first authors added that visual and tactile stimuli play important roles.

Phillipson (1956) found that in the laboratory, larvae released their hold above 111 centimeters per second of flow, and below a range of 41 to 70 centimeters per second. The greatest number remained attached between 80 and 100 centimeters per second. He also referred to Tonnoir (1925), who hinted at a relationship between current velocity and food supply, and to Zahar (1951), who considered that current kept
the mouth brushes open.

Phillipson (1957) states that according to Nielson (1950), the upper physical limit for flowing water is six meters per second, but that speeds over three meters per second rarely occur. Phillipson believes that velocity may segregate the species.

Rubtsov (1939) states that the speeds in which larvae were found varied from 15.2 to 131 centimeters per second.

Peterson (1956) found that larvae in Utah tended to concentrate where the flow was less than 177 centimeters per second. Where the larvae were in current faster than 35.4 centimeters per second, they tended to congregate on the downstream side of objects, or on the upper surfaces of leaves of aquatic vegetation. Where the current was below 35.4 centimeters per second, larvae were often found under objects, possibly to escape sediment.

According to Peterson and Wolfe (1958), a velocity of about 9.7 centimeters was preferred, but Simulium decorum occurred in water flowing over 29.5 centimeters per second. Current provides most of the energy for locomotion, and food and oxygen.

Caviaso (1962) makes the generalization that, in the Phillipines, a current of 48.1 to 65.8 centimeters per second is preferred for larval attachment.

Macan (1962) found current to be difficult to evaluate. If it were all-important, one would expect to find more species in swifter water, since this would afford a wide
range with slow speeds being found in the lee of objects and under sticks, leaves and stones. He concluded that current may be important in combination with food and oxygen.

Hocking (1960) states that he believes current to be more important than oxygen content in governing larval distribution.

2. **Oxygen content.** According to Phillipson (1956), Hubault (1927) considered oxygen concentration as the major factor controlling larval position. Phillipson, in laboratory experiments, demonstrated that larval movement was independent of oxygen concentration above 50% saturation. Below 25% saturation, the larvae could discriminate between changes in concentration with extreme sensitivity, moving toward the source of higher oxygen content.

3. **Temperature.** There seems to be a great deal of disagreement among authors as to the minimum temperature at which simuliid larvae first appear, and also the temperature range at which they develop.

Baranov (1935) found larvae and pupae in a hot spring at water temperatures of 86°F.

Rubtzov (1939) states that water temperature affects the length of life cycle. In those species having one generation per year, the mean summer temperature of the streams was found to range from 46.4 to 50°F. In those species with three generations per year, the mean summer temperature ranged from 64.4 to 68°F., with a larval stage of seven to eight months over the winter, and 20 to 30 days during the summer. He
found the threshold of larval development to be 37.4°F. This temperature agrees closely with Radzivilovskoya (1950), who states that the minimum temperature for the appearance of *P. hirtipes* is 38.7 to 41°F. According to Macan (1962), Davies and Smith (1958) state that *P. hirtipes* is a high altitude species and cannot tolerate temperatures over approximately 60°F. They also state that the larvae do not grow at the lowest winter temperatures.

Davies and Syme (1958) found larvae of *P. mixtum* and *P. fuscum* at 32.1°F., and also state that there was feeding and pupating occurring at 35.0°F.

Caviaso (1962) simply says that temperature controls larval growth, but no temperature limits were given.

Peterson and Wolfe (1958) state that development of the larvae becomes rapid once the average water temperature is above 40°F., and give a range of from 55 to 65°F. as the optimum; water over 70°F. is generally unfavorable.

Macan (1962) feels that temperature may confine some species to certain habitats by physiological requirements.

4. Other factors. Fredeen et al. (1953) found aging to be a factor in movements of the larvae, migration decreasing with age.

Fredeen and Shemanchuk (1960) consider turbidity as an important factor in the control of the size of larval population, with the number of larvae decreasing as turbidity increases.

Peterson and Wolfe (1958) state that the optimum pH for
larval development is slightly alkaline, 7.0 to 7.5, but that
development can occur between 5.8 and 8.5.

**Molting.** Tonnoir (1925), commenting on molting, observed
that the old head capsule is detached around the neck and
carried away by the current. The larva then fixes its
mandibles on a support and walks out of the old larval skin,
using its proleg.

**Cocoon-spinning.** Peterson (1958) described the cocoon-
spinning procedure of *Simulium vittatum*. He states that the
larva first probed for a suitable spot for approximately
three minutes, after moving from an exposed position to a
more protected spot. It then extended downstream as far as
possible and placed a large loose mass of silk on a leaf.
Using a continuous thread, a small mass was then laid down to
the left of the point of attachment, a third directly up-
stream, and a fourth to the right of the point of attachment.
A loose network was laid down from side to side to the right
and left longitudinal lines, starting at the point of attach¬
ment. A series of closely-packed threads was laid from one
lateral mass up over the body to the other lateral mass,
making the rim of the cocoon. The silk was then spun from the
underside of this arch to the anterior silk mass, which
became the point of the cocoon. The larva then worked from the
upstream point back to the rim, connecting the right and left
longitudinal threads. When the outside was completed, the
larva worked under the cocoon, along the outer edge, laying an
inward-projecting mass on the substrate, then widening this mass anteriorly. The floor was then spun, from the apex backward about one-half the length of the cocoon. He states that this procedure apparently differs from that for *S. venustum*, which weaves the floor first. The entire process took 40 to 60 minutes, the same as for *S. venustum*. Cocoons of smaller species, such as *S. tuberosum*, were often found in the old cases of *S. vittatum*.

**Larval Feeding**

**Mouthparts.** Puri (1925), in a paper dealing with the structure of the early stages of black flies, describes the mouthparts. The head capsule is barrel-shaped and forms an angle of about $150^\circ$ with the thorax. The antero-dorsal surface slopes downward and merges with the labrum, while the lateral and ventral sides end abruptly to give attachment to the mouth parts. The dorsal and lateral head spots mark points of attachment for muscles controlling the feeding organs.

According to Puri, the cephalic fans appear to be modified lateral parts of the labrum. The labrum is nearly semicircular and is directed downward, overhanging the mouth opening (Figure 13). The ventral wall of the labrum is continued backwards as a soft plate, the epipharynx, bounded posteriorly by a rim of hard chitin (Figure 13). This epipharynx forms the dorsal wall of the mouth opening.

The mandibles (Figure 14) are placed below the cephalic
fans and move horizontally. They are articulated to the side of the head at a point where the border of the head capsule is thickened into a strong rim. The mandibles are strongly toothed on the inner lateral margin below the apex, and to a lesser degree in other areas. Setae are present.

The maxillae (Figure 16) are situated immediately below and external to the mandibles and are shaped like a mitten, with the single-segmented palp representing the thumb. Bristles are present dorsally and ventrally, and the truncated end of the palp bears sensory papillae.

The hypopharynx (Figure 15) consists of a soft plate lying between the two maxillae, forming the floor of the mouth opening. Anteriorly it also forms the posterior border of the wide, slit-like opening of the salivary or silk glands.

The labium (Figure 17) lies ventral to the hypopharynx and forms the anterior border of the salivary opening. The body of the labium is a plate forming the floor of the salivary chamber and bearing a pair of broad, palp-like structures. The ventral wall of the labium passes backward and is connected to the ventral head capsule.

Crosskey (1960) feels that the term 'hypostomium' is correct for the structure sometimes referred to as the labium or part of the labium, because this structure is not an appendage but part of the postgenal bridge of the head capsule proper. This hypostomium bears strong teeth on its anterior edge.

The filling in of the area between the foramen magnum
and the mouth parts has been accomplished by the extension of the postgenae, although no line of union remains. The cephalic apotome (dorsal surface of the head) is not morphologically the fronto-clypeus, and he agrees with Snodgrass (1947, 1959) that there is no significance to the sutures delineating the cephalic apotome laterally, as they are merely "lines of weakness used during ecdysis."

Feeding. Stone (1964) observed that the body of the larva lies in a downstream position during feeding. The dorsal surface is toward the current and the body is then twisted so its anterior ventral portion is turned into the current. Phillipson (1956) and Peterson (1956) state that the cephalic fans are spread to strain food, and the former author states that Zahar (1951) believes that current speed keeps the brushes open. Peterson and Wolfe (1958) believe that the current provides all the energy for feeding, by carrying food and spreading the cephalic fan rays. However, Peterson (1956) and Davies et al. (1962) say that if drifting food is scarce, the larvae may scrape food from the surrounding substrate, feed on larger aquatic organisms, or become cannibalistic on smaller simuliiids. The larvae of some species (including *Twinnia tibblesi* and *Cnephia abdita*) graze in the organic silt of the stream bottom during most of their larval stages.

Puri (1925) and Tonomoir (1925) observed larvae cleaning the filaments of the cephalic fans with the mandibular bristles.
Peterson (1956) measured several specimens of *S. vittatum*, and found that the average area of the cephalic fans when in the feeding position is 1.34 square millimeters. The volume of the digestive tract averaged 0.511 cubic millimeters. In order to determine if the amount of floating food would be enough to sustain the larvae, water samples were taken with a plankton net which had a mouth opening nine and one-half inches in diameter. The net was submerged for one hour. Large pieces of debris were removed, and the remaining contents centrifuged and volumetrically measured. It was then calculated that, in two areas tested, 0.095 and 0.38 cubic millimeters of food passed through an area of 1.34 square millimeters (the area of the cephalic fans) every hour. This amount of food would fill the gut volume of 0.511 cubic millimeters in five and one-half hours in the first test, and one and one-half hours in the second. This would be an adequate food supply, as it takes over a day to digest the gut contents. Davies and Syme (1958) state that a meal may not be fully digested for one or two weeks.

**Food.** Puri (1925) found minute diatoms and Crustacea in the gut contents. Pickering (1954) states that dead larvae are often consumed. Peterson (1956) and Davies and Syme (1958) found larvae to be largely herbivorous. Fredeen (1960) states that the larvae normally feed on macroplankton, but that bacteria may be utilized if they are plentiful. Sewage can thus increase available food. Davies et al. (1962) say that the food is varied, consisting of bacteria, protozoa,
algae (many diatoms), parts of large plants and animals, and decaying organic matter, depending on what is available.

In rearing studies, Fredeen (1959, 1964) used yeast, Pablum ground to pass a 150-mesh screen, or an alga (*Leuvenia natana* Gard.). It was also found that, of the bacteria tested, *Aerobacter aerogenes* and *Escherichia coli* were better than *Bacillus subtilis*.

Anderson and Dicke (1960) found as high as 76% inorganic matter in the gut contents of *Simulium vittatum*. Davies et al. (1962) believe this may act as an aid in grinding food.

Williams et al. (1961) found that the size of particles ingested by different individuals of four species was similar, with the mean particle size ranging from 6.6 plus or minus 1.7 microns to 14.8 plus or minus 2.1 microns.

The Pupal Stage

Webster (1904) observed that the pupal period was passed in a small "pocket-shaped sack." Metcalf (1932) believed that this cocoon served merely as a method of anchoring the pupa, but Peterson (1956) states that the cocoon provides protection from swift water, floating debris and sediments that might damage the pupa.

Nicholson and Mickel (1950) state that the cocoon may be just a mass of silk, or a slipper-shaped case of intricate construction, depending on the species. Stone and Jammback (1955) found that the cocoons may be rudimentary (*Twinnia* spp.),
shapeless masses of silk (*Prosimulium* spp., *Cnephia dacotensis* and *C. mutata*), coarsely woven (*S. decorum*), or closely woven and of various shapes (other *Simulium* spp.).

Nicholson and Mickel (1950) and Stone and Jamnback (1955) often found larvae and pupae together, but Wolfe and Peterson (1958) state that pupation usually occurs out of the full force of the current on the downstream side of logs and stones.

Stone and Jamnback (1955) and Davies et al. (1962) note that the open end of the cocoon usually points downstream, but the latter authors found that sometimes positioning is more or less random. Hocking and Pickering (1954) found that 0.15 feet per second seems to be the critical water speed above which pupal cases are oriented with the open end downstream.

Fredeen and Shemanchuk (1960) found pupae of black flies in all extremes of the environment in the irrigation systems of Saskatchewan.

Puri (1925) and Rubtzov (1939) state that pupae require only high humidity for development, and the former author reared adults from pupae using only a few drops of water in a sealed jar.

Jobbins-Pomeroy (1916), Nicholson and Mickel (1950), and Stone and Jamnback (1955) believe the pupal period to be controlled by temperature.

Peterson (1956) observed smaller species to pupate within the old cocoon of larger species, weaving their cocoon entirely within the old shell. Larvae have also been observed to
utilize the cocoon left by an emerged adult. In this case, the larva does not spin its own cocoon, but simply closes off the entrance with silk and undergoes transformation.

Stone and Jamnback (1955) note that the shed head capsule of the mature larva is often found in the pupal cocoon.

Strong et al. (1934) state that the branched respiratory organs that arise from the forward lateral angles of the thorax are an adaptation for breathing in streams which may flood at one time and become dry at another. Wolfe and Peterson (1958) found a correlation between the number of respiratory filaments and the type of stream inhabited. Those species with few filaments are found in swift water, while those with many filaments are found where flow is less.

Metcalf (1932) describes the pupa. The head is bent downward and the eyes are hooded by the antennae. Between and behind the eyes the labrum, the maxillae and their palps, and the labella may be distinguished externally. The thorax is humped, and bears the tracheal gills on the lateral edges of the prothorax. The wing pads cover the sides of the pupa near its mid-length, their tips nearly meeting ventrally. Between the wing pads and the developing mouthparts lie the fore and middle leg on each side. The hind pair of legs are concealed beneath the wing pads. The abdomen is larger than in the adult, and clearly shows nine segments. Hooks are present along the lateral margin to hold the pupa in the cocoon.
Field and Law (1961) state that sexual dimorphism is expressed in the cephalic plate, a sclerite arising between the bases of the antennal sheaths and extending up over the cephalic region. This plate is shorter and broader in the female than it is in the male.

Peterson (1956) states that chironomid larvae are often found in close association with the cocoons, on them or in them, with the living pupa still present. They secrete a jelly-like mass which may lie closely appressed to the exterior of the cocoon, or may even seal off the external opening, leaving only the respiratory filaments protruding. The pupa seems to be unharmed.

Strong et al. (1934) and Davies et al. (1962) note that just before the adult is about to emerge, a bubble of air appears inside the pupal case. The latter authors indicate that a T-shaped slit appears in the dorsum of the thorax, and the fly begins to pull itself through this slit. The wings expand as this is going on, and the adult is ready to fly when it reaches the surface. Emergence requires about one minute.

Prepupal Feeding and Spinning Cocoon

Hinton (1958) refers to an early part of the pupal period, when the larval cuticle has not been shed, calling it the 'pharate' phase. He then summarizes the events taking place in _S. ornatum_ Meig. and _S. equinum_ Linn. Four days or more before the "pupa" of _S. ornatum_ spins its cocoon it moves
about and feeds like a larva, by making use of larval structures such as the mouthparts and proleg, to which it is attached only mechanically by some tonofibrillae which remain attached to the old larval cuticle. The dorsal hooks of the third and fourth abdominal segments of the pupa are visible through the larval cuticle about a day before the pupa spins its cocoon, at which time molting fluid is activated and the "previously intact endocuticle begins to dissolve." The pupa is feeding and defecating until about the time it spins its cocoon, at which time the larval mouthparts can still be manipulated. The pupa assumes the characteristic hump-backed appearance a minute or two before a split appears in the larval cuticle.

Adult Behavior

As the Simuliidae are a group of great importance, both for their biting habits and as disease carriers, much work has been done on the activities of the adults. In order to review this material in a concise and logical manner, many subheadings have been utilized. Among these are emergence, dispersal, feeding, mating, oviposition and effects of the environment.

Emergence. Coquillet (1898) noted that adult Simuliidae emerge from their cocoon in a bubble of air. Peterson (1956) observed that a split occurs from the dorsum of the thorax to the posterior end of the abdomen of the pupa. A transverse split also occurs across the dorsum of the thorax. The front
feet of the adult are the first through the opening and the insect uses them to pull itself out. The wings are frequently expanded at this time, but in many cases this occurs later.

Peterson also noted that in rearing chambers, much activity is often present several hours before emergence, for periods of time lasting about one-half hour. The pupa would move part way out of the cocoon and back, the abdomen would move both horizontally and laterally, and a bubble of air was observed to form in the thorax. He believed that this movement aided in breaking through the integument. He observed newly-emerged adults stroking the wings with their hind legs to assist unfolding. Emergence was found to take place principally before 10 a.m., and in the late afternoon.

Davies (1961) stated that the duration and scatter of adult emergence depends on the number of eggs that hatch in March and April as compared to the number of overwintering larvae.

Ide et al. (1958) reported that in 1948, 1949 and 1950 the appearance of black flies varied as much as two weeks in Manitoba, Canada, and that it could vary as much as a month. Variation was found to be at the rate of one day retardation for each degree longitude eastward, an opinion agreeing closely with Peterson and Wolfe (1958). The latter authors also calculated a retardation factor of six and one-half days per degree of latitude northward between Algonquin Park, Ontario, and Churchill, Manitoba.

Dispersal. Osborne (1896) stated that Simulid males do
not move away from the streams, but that the females do, and that the females do not return.

O’Kane (1926) observed that the adults appear to travel long distances, and Glick (1939), Rempel and Arnason (1947), Underhill (1939), Peterson and Wolfe (1958) and Anderson and Dicke (1960) indicated that wide dispersal is often influenced by winds. Hocking and Richards (1952) reported that in an area where control was applied over a radius of six miles, the percentage of *P. hirtipes* was always less toward the center, while *S. venustum* was found at the center of the control area late in the season. Davies (1952) noted that peaks of biting due to immigrating flies often occur.

**Physical factors.** There are several environmental factors which have been explored by various authors in order to explain the behavior of adult Simuliidae. Among these are temperature, relative humidity, atmospheric pressure, light, wind and color. Under normal conditions these factors interact, so that it is difficult to explain complex behavior in terms of a single factor. This has been ably pointed out by Peterson and Wolfe (1958), who observe that environmental factors work either together or antagonistically to bring about their effects on adult activity. Effects of some of the factors are covered in other sections, and will not be duplicated here.

**Temperature.** There is no close agreement among authors as to the lower temperature limit for black fly activity. Rubtsov (1939) and Twinn (1952) agree on 50°F. Wolfe and
Peterson (1960) indicate that only temperatures below 45°F affect normal activity, while Anderson and DeFoliart (1961) state that 55°F is the lower limit for adult activity.

Underhill (1940) reported that activity ceased when the temperature reached 95°F, while Wolfe and Peterson (1960) found this upper limit to be 90°F. Rubtzov (1939) stated that activities were abnormal above 84.2°F.

Although there is a certain amount of variance, most authors list the optimum range for activity as being between 65° and 85°F. Underhill (1939, 1940) listed the optimum range ornithophilic species in Virginia to be between 75° and 85°F. Davies (1952) found most flights occurred between 60° and 80°, while Rubtzov (1939) considered these limits to be 68° to 73.4°F.

Davies and Peterson (1956) observed mating to occur most often in the late afternoon and evening, when the temperature is about 70°F, although Peterson (1962) observed a mating swarm of *S. venustum* at 62°F.

Sailer (1953) noted the highest rate of biting of *S. arcticum/corbis* (he could not reliably separate the species) in Alaska to occur at 40°F. *Simulium venustum* bit at 59°F.

Downe (1957) states that digestion of a blood meal seems to speed up as the temperature increases.

Davies (1952) said that the decrease in the number of flies after peaks is due to higher temperatures and drying soil.
Relative humidity. Underhill (1940) noted that humidity is closely correlated with temperature, and adverse (high or low) readings are generally recorded at extremes of temperature, varying inversely. Underhill (1939, 1940), Rubtzov (1939), Davies (1952), Davies and Peterson (1956) and Anderson and DeFoliart (1961) all generally agree that up to a certain point, adult activity increases as the relative humidity increases.

Underhill (1940) found the peak of black fly activity to occur between 65% and 75% relative humidity. Wolfe and Peterson (1960) stated that only extremes below 25% and above 95% affect normal rhythms. Rubtzov (1939) recorded what he considered normal activity between 75% and 90% humidity. Anderson and DeFoliart (1961) found two peaks of activity, a small one one hour after sunrise and a larger one after sunset, both correlated closely with relative humidity.

Davies and Peterson (1956) point out that the saturation point of the air is one of the variables which determine whether oviposition is on objects or free in the water, and that a gentle rain stimulates oviposition.

Light. Rubtzov (1939), and Anderson and DeFoliart (1961) found that darkness suppresses adult activity when operating singly. However, Frost (1949), Peterson (1956), Hocking (1960), and Fredeen (1961) observed, by direct observation or catches in light traps, that adults are active at night.

Underhill (1939), and Anderson and DeFoliart (1961) reported that feeding most often took place in the morning and
late afternoon, but add that at certain times, feeding occurred all during the day. The latter authors noted that peaks of abundance occur earlier on cloudy days than on clear ones. Black flies are more active throughout cloudy days.

Peterson and Wolfe (1958), and Wolfe and Peterson (1960) observed that adults rested at light intensities below one foot candle, and that as light decreased, the flies moved up toward the tree tops. The latter authors believed that light is probably the major factor controlling the diurnal rhythm of *S. venustum*. Activity is suppressed also at light intensities over 25 foot candles.

Fallis and Smith (1964) stated that light may be an important factor in determining whether an adult lands on its host.

Wind. Certain information on the effects of wind has already been reported under the heading of DISPERSAL.

There are divergent opinions concerning the effects of wind on black fly activity. Wolfe and Peterson (1960), Anderson and DeFoliart (1961), and Davies (1952) state that, generally, adult activity is suppressed at wind speeds over two, five and fifteen miles per hour, respectively.

Davies (1952) found maximum activity to occur at one mile per hour, especially when the wind came from a lake or water margin. This is in general agreement with Underhill (1949), who found activity to be greatest when the wind moved only the leaves and terminal branches of trees. He also found that feeding increased when winds were from the south or west.
Davies and Peterson (1956) believe wind to be a factor in determining whether eggs are laid on objects or free in the water.

**Atmospheric pressure.** Underhill (1940), and Davies (1952) both stated that there is a close relationship between adult activity and a drop in barometric pressure. As the rate of change of the drop increases, so does activity and feeding. Underhill found that activity was greatest between 27.85 and 28.05 inches of mercury at 2000 feet. Peterson (1956) reported that in Utah several species of black flies feed on man only above 7000 feet.

**Color.** Certain information concerning color is included under the section on sampling of adult populations.

Davies (1951) stated that more flies land on dark clothing than on light clothing, the order of attractiveness being blue, brown, green, red, medium gray and white.

Fallis (1964) found that light-complexioned people are bitten more often in the morning and late afternoon, whereas dark-complexioned people are bitten more often during the middle of the day. He believed that visual stimuli, in connection with odor and tactile stimuli, might play a role in attracting black flies.

Fallis and Smith (1964) found that *S. euryadminiculum*, the only black fly known which is absolutely host-specific to loons, lands only on the dark portions of the birds, and never on the white breasts.

**Miscellaneous factors.** Underhill (1940) stated that
movement of the host seems to attract the adults. Davis and James (1957) found that *S. vittatum* males and females were attracted to putrified ground hamburger.

Davies and Peterson (1956) believe that a smooth stretch of water may aid in inducing females to oviposit directly into the water.

Downe and Morrison (1957) found that no black fly tested contained blood from more than one host, when given the choice among cows, horses, pigs and chickens.

Davies (1957) felt that age of the flies may play a role in determining the time of day when they are active, since he found the older flies more abundant later in the day. The older flies also fed more readily.

**Attractants.** Fallis and Smith (1964) showed that an ether extract from the uropygial glands of a loon, in combination with carbon dioxide, was highly attractive to *S. euryadminiculum*. Carbon dioxide alone was somewhat attractive. In conducting these experiments, it was found that visual stimuli were also important, as the attractant worked only when placed on a raised object.

Snoddy and Hays (1966?) found that more flies were attracted to a person when carbon dioxide was released under the clothing. Females of eleven species were taken in a carbon dioxide trap.

**Ovarian Development**

According to Davies (1963), Rubtzov (1955) theorized that
autogeny of many black fly species depends directly on the level of larval nutrition. Thus, a species could lay eggs before feeding if the larvae had accumulated enough nutrient to complete ovarian development, but if little nutrient had been stored, feeding would have to take place before ovarian development could occur.

Davies and Peterson (1956) observed that some *Cnephia* species seemed to contain mature eggs when they emerged, and lay them shortly thereafter. They decided that the time taken for ovarian development depends in part on the amount of larval nutrient stores available. *Simulium vittatum*, a species that developed mature eggs in the laboratory five days after emergence, was cited as an example. Other species took two or three weeks to produce mature eggs. These were found to have little or no stored nutrient, and were found to need a blood meal for ovarian development to begin. If full engorgement had taken place, development was rapid.

Davies (1958) classified the newly emerged females of twenty-four different species into the following five types:

a. Eggs mature and adults possessing reduced mouthparts (*Gymnopais* spp. and some *Cnephia* spp.).

b. Eggs half-developed, adults containing much stored nutrient, and possessing reduced mouthparts (*Cnephia emergens* and *Prosimulium alpestre*).

c. Eggs half-developed, adults containing much stored nutrient and with piercing mouthparts (*Cnephia mutata*).
d. Eggs one-fifth to one-third developed, adults usually containing much stored nutrient and possessing piercing mouthparts (some *Simulium* spp.).

c. Eggs less than one-fourth developed, adults containing little stored nutrient and possessing piercing mouthparts (*Prosimulium* spp. and some *Simulium* spp.).

Peterson and Wolfe (1958) stated that the females need protein for egg development from the blood meal or accumulated larval stores. They found that a blood meal after the first oviposition can initiate another ovarian cycle. They also noted that Simuliidae having polytrophic ovarioles and with more than two gonotrophic cycles have been recorded.

Pokó'feva (1959) found that egg maturation is at the expense of larval fat bodies in those species taking no blood meal. He reported the following three types of maturation:

a. Eggs undergo full development in the imago (*Twinnia* spp.).

b. Eggs develop up to the third follicular stage in the pupa (*Prosimulium* spp.).

c. Eggs fully-developed upon emergence of the imago (*Cnephia* spp.).

Davies (1963) disproved the theory advanced by Rubtzov (1955) (see above, page 27), by showing that *Simulium venustum* is entirely anautogenous. Anautogeny is a species characteristic, both in early and late cycles.

Fredeen (1963) showed that *Simulium arcticum* females use larval food reserves for the first ovarian cycle in the first
generation, and then seek blood for subsequent ovarian cycles. The later generations have no such larval reserve, so feeding must take place before ovarian development. Thus, autogeny or anautogeny is not a characteristic of this species, but is dependent on larval feeding.

Fredeen (1964) observed that previous ovarian cycles can be determined by the disarrangement of the ovarioles, or by retention of mature eggs.

Davies and Peterson (1956) point out that most species average 200 to 500 eggs per female. Bennett (1963) notes that Simulium rugglesi can produce 1000 to 1500 eggs in four to six feeding-ovarian cycles.

Mating. Osborn (1896) thought that copulation took place soon after emergence, since he believed that once the females had emerged and sought a meal, they did not return to the same stream.

Davies and Peterson (1956) found mating swarms to contain males of more than one species, since P. multidentatum, P. hirtipes and S. vittatum were collected in a cobweb where the wind had dispersed a swarm. They also theorized that the small size of the compound eyes and the lack of positive phototaxis of Cnephia dacotensis is probably related to the lack of a mating flight. Prosimulium hirtipes, and Simulium spp. having or suspected of having mating flights, have large compound eyes. Also the males possess large upper eye facets and small lower eye facets in the ratio of four to one. These larger upper facets may enable the males to see the small
females more readily when the females are above and ahead of them in a swarm.

These authors note that when there is a long period of time between emergence and oviposition, increased chances of fertilization occur by:

a. Mating just prior to oviposition.
b. Mating just after emergence.
c. Mating when feeding on blood.
d. Mating when feeding on nectar.

They observed that mating flights are most common in the late afternoon or evening, but that moisture, such as a fine spray, can modify this.

The mating procedure of *Simulium decorum* was described by Davies and Peterson (1956). The male approaches the female and taps with his forelegs on the apex of the wings or the tip of the abdomen. He then crawls on her back, curving the tip of the abdomen down to touch the tip of hers. Unreceptive females keep their wings closed. They found that active spermatozoa were present in the males ten minutes after emergence. Apparently mating can occur shortly after emergence, while adults are crawling on the rocks with the integument only partially hardened.

Sommerman (1958) observed the mating of *Prosimulium perspicuum* in small cages. The male seemed unaware of the female until he collided with her. The male then proceeded to seize the female in any manner, curl the tip of his abdomen under her, and move backward until the genitalia were joined.
The female remained in an upright position with all tarsi on the substrate, but the male was in various positions, side-wise with the head toward the female's head, upside down, or straight out behind her. (This is probably due to rotation of the male genitalia, a common occurrence in the lower Diptera.) The average mating time recorded was 11 minutes and 36 seconds. When the female was unreceptive, she curled the tip of the abdomen and the head under the thorax and pushed the male away with the hind tarsi.

Peterson (1962) described the movement of swarming males of *Simulium venustum*. It consisted of a triple-motioned pattern. The main movement was four to six inches straight up and down. At the same time, the whole swarm moved laterally. When a female entered the swarm, coupling occurred and the pair darted up and out of the swarm. This may be a mating dance. The eyes of the male, being divided, may be used for close contact, but in this author's opinion, it is non-specific, since males were observed trying to mate with other males. This behavior pattern was also observed in *S. vittatum*, a species which apparently can mate just prior to oviposition.

**Oviposition.** Much of the information on oviposition is included under the review of the habits of the adults of the individual species. That mentioned below is information of a more general nature.

Osborn (1896) stated that copulation and egg-laying took place shortly after emergence, since the females did not
return to the stream after seeking a blood meal.

Coquillet (1898) observed that \textit{Simulium pictipes} laid its eggs on rocks under flowing water, and Johannsen (1903) expanded this statement by saying that all the known species of \textit{Simuliidae} deposited their eggs in this manner.

Ruftzov (1939) thought that black flies oviposit only once, but as the previous section shows, this is not always the case.

Goulding and Deonier (1950) reported that in Pennsylvania, black fly eggs are rarely laid on rocks.

Davies (1952) found that oviposition in Algonquin Park, Ontario, did not take place until two to four weeks after adult emergence.

Hocking and Pickering (1954), in Labrador, erroneously concluded that eggs were apparently always laid free in the water upstream from the larval breeding place.

Davies and Peterson (1956) stated that females are common in swarms only during preoviposition or oviposition flights. The species, and factors such as wind, saturation point of the air or smooth stretches of water govern whether eggs are laid in flight or on solid objects. They report some individuals crawling as deep as twelve inches under water to oviposit. Univoltine species of \textit{Prosimulium}, \textit{Cnephia} and subgenus \textit{Eusimulium} complete egg-laying during May and June, while multivoltine \textit{Simulium} spp. lay eggs as late as October.
An evolutionary trend is proposed as follows:

a. Dropping eggs in flight: *Prosimulium* spp. and *Cnephia* spp.

b. Ovipositing through a thin film of water onto solid surfaces while in flight: subgenus *Eusimulium* of the genus *Simulium* and *Simulium pictipes*.

c. Settling and ovipositing on waterlapped surfaces at the water's edge: subgenus *Simulium* of the genus *Simulium* and *Simulium vittatum*.

Fredeen (1963) states that it may be wise to check meteorological conditions before looking for oviposition, as these may influence the habits of the females.

Feeding of Adults

The material in this section is of a general nature, as the reviews of individual species contain specific information on feeding and host preferences.

**Adult mouthparts.** Nicholson (1945) described the mouthparts of the biting black fly, *Simulium venustum*. The mouthparts include the labrum-epipharynx, mandibles, maxillae, hypopharynx, labium and the cibarial and pharyngeal pumps.

The labrum-epipharynx is triangular in cross-section, lying anterior to the other mouthparts. It has distal teeth and lateral spines.

The mandibles lie behind and at the lateral edges of the labrum-epipharynx. They lie with their inner edges over-
lapping. The food channel is thus formed by the posterior surface of the labrum-epipharynx and the anterior surfaces of the mandibles. The distal ends of the mandibles are blade-like and armored with heavy teeth, to anchor them in the wound.

The maxillae are just behind the mandibles, and are composed of the palpi, galeae and fused cardo and stipes. The galea is lanceolate, with the distal end broadened, flattened and possessing several teeth on the margin.

The hypopharynx is between the maxillae and directly behind the mandibles. It is trough-shaped, has teeth and spines on the distal margin, and bears the outlet of the salivary duct.

The labrum is posterior and serves as a sheath for the other mouthparts. Its distal labella is sensory, and serves to guide the mandibles in cutting the initial puncture.

Occupying a median and nearly vertical position in the head capsule is the cibarial pump. It is trough-shaped, with its anterior attached to the proximal ends of the labrum-epipharynx and hypopharynx.

The pharyngeal pump is located posterior to the cibarial pump, with its posterior portion extending into the occipital foramen. It is triangular in cross-section, and works together with the cibarial pump in bringing food into the digestive tract.

In non-biting species, such as *Cnephia dacotensis*, the
mandibles are thin and almost membranous at the tip, while the maxillae are only weakly sclerotized and armed with long setae. The rest of the mouthparts are sufficiently developed to allow feeding on water or nectar.

**Feeding and digestion.** Fallis (1964) observed that in feeding, the mandibles cut the initial hole and the maxillae enlarge it. The labrum-epipharynx and hypopharynx are held in place by recurved teeth, while their spines act as a sieve preventing particulate matter from entering. Once a fly has fastened the mouthparts firmly she is not easily dislodged. Flies have been observed to finish a blood meal immersed in water, emerge and fly away.

Davies and Peterson (1956) described activity during feeding of *S. venustum*. The forelegs of the female palpated the surface while site-searching. At insertion of the mandibles, the foretarsi were raised away from the skin. When ready to feed, the fly jerked back and forth with the thorax and abdomen in a pumping motion for about one and one-half minutes. The right mesotarsus and left metatarsus fastened the fly to the skin. The front tarsi were held away from the skin. The left mesotarsus was held off the skin, while the right metatarsus probed for a foothold during feeding.

Davies (1957) states that the abdomen of engorged flies returns to nearly normal size after twelve hours. Blood is then present in the midgut, but not in the crop. The peritrophic membrane is clearly visible at that time.
Downe (1957), reporting on digestion of the blood meal, defined the rate of digestion as the time it takes for a blood meal "to reach such a stage of digestion that the serum proteins no longer precipitate their specific antibodies." Engorged flies collected from horses and pigs showed very few positive reactions after 40 to 48 hours, no matter what the simuliiid species, and serum proteins were not usually detectable after 32 hours. More sensitive tests indicated that complete digestion of the blood meal occurs within 60 hours of engorgement, whereas Davies (1957) has estimated the digestion time as about 4 days.

Downe and Morrison (1957) report that of 750 engorged flies collected from a variety of hosts, none contained the blood of more than one host.

Davies (1953) fed female black flies in the laboratory on dry sucrose crystals and water. Hocking and Pickering (1954) found adults commonly feeding on flowers. Davies and Peterson (1956) discovered that nectar is stored in the esophageal diverticulum. Downes (1958) states that the blood meal does not contribute significantly to longevity, but that sugar is absolutely necessary. Peterson and Wolfe (1958) believe that both males and females use nectar as a source of energy for flight, while the females use blood as a source of protein for ovarian development.

Host preference. Shewell (1955) theorized that those black fly species possessing strongly bifid tarsal claws, are bird-feeders, or do not feed on blood at all. He states that
the overwhelming majority of the species with the simpler or minutely-toothed claw are known from mammals or from the unfeathered areas of birds.

Anderson (1956) thought that the strongly-toothed claw of the ornithophilic species was an aid to crawling through feathers.

Anderson and DeFoliart (1961) note that seven species of black flies found feeding on birds in Wisconsin all possess the strongly bifid claws.

Fallis (1964), however, notes that while this theory holds in many cases, there are instances where species with the bifid type of claw feed on man and other mammals, and species with a small claw are known as bird feeders. He quotes Crosskey (1959) that if the theory were true, then at least 80% of the black flies of the Ethiopian region must be ornithophilic.

Apparently the question has not been settled to the satisfaction of all interested parties.

The feeding habits of the species of black flies found in western Massachusetts are as follows: C. dacotensis - non-biting; C. mutata - deer, cattle and horses; P. fontanum - no records found; P. fuscum - man, horse, cattle and deer; P. magnum - man, horse, cattle, sheep; P. mixtum - man, other mammals, occasionally birds; P. multidentatum - probably mammals; P. rhizophorum - probably mammals; S. aureum - turkey, pheasant, chicken, duck and dove; S. corbis - man, horses and cattle; S. croxtoni - birds; S. decorum - man, deer, horse and
cattle; *S. mouldingi* - probably birds; *S. latipes* - man, chicken, and birds; *S. parnassum* - man and woodchuck; *S. rivuli* - probably birds; *S. tuberosum* - man, ground squirrel, cattle and horse; *S. venustum* - man, deer, dog, sheep, cattle, horse, mule, grackle, crow, blue heron; *S. verecundum* - no records found; *S. vittatum* - man, cattle, horse, sheep, pigs and moose; and *T. tibblesi* - non-biting. Sources of information for these records include Wolfe and Peterson (1958), Davies et al. (1962), Fallis (1964), and Stone (1964).

**Physical factors affecting feeding.** Underhill (1940) found temperature, relative humidity, air currents and atmospheric pressure to be important factors influencing feeding. Eighty-five percent of the flies biting did so between 75 and 85°F. Eighty percent fed between 55 and 75% relative humidity, with a peak occurring between 65 and 75%. Other factors being favorable, feeding was greatest when the wind moved only the leaves and terminal branches of trees. A drop in atmospheric pressure was associated with an increase in feeding. The more rapid the drop, the more marked the effect.

Davies (1952) correlated biting with the rate of change in atmospheric pressure. As the rate of change increases, so does biting, particularly if the pressure is dropping.

Bennett (1960), Bennett and Fallis (1960), and Anderson and DeFoliart (1961) all comment on stratification in relation to biting by certain black fly species. The second authors
state that most ornithophilic species feed at over five feet above ground level. The latter authors found that *S. aureum* shows a decided preference for roosting birds.

Peterson (1956) found barometric pressure to influence the feeding habits of some species. In Utah, *C. mutata*, *S. arcticum*, *S. tuberosum*, *S. hunteri* and *S. vittatum* rarely bit humans below 7000 feet in altitude, although other hosts were attacked.

Sailer (1953) found certain species of black flies to become active biters in Alaska only at colder temperatures, in the fall. Cloudsley-Thompson (1955) states that *S. vittatum* and *S. latipes* are pests of man in Iceland, whereas they seldom attack man in the United States.

Anderson and DeFoliart (1961) recorded little feeding between 10 a.m. and 4 p.m. on warm, clear days. There was a small peak after sunrise and a large one after sunset, both correlated with relative humidity. On warm, calm, cloudy, humid days feeding occurred all during the day, but the evening peak was still present. Feeding peaks occurred earlier on cloudy days than on clear ones.

Fallis (1964) found biting activity to be influenced by light intensity, temperature, barometric pressure, shade, and color and odor of the host. Activity was reduced during the heat of the day. Most species bit more readily in open forest or fields than in densely wooded areas. Lower light intensity was associated with increased feeding. Approximately 50°F seemed to be the lower temperature limit for most
species. Strong winds tended to lessen feeding and flight. Dark colors attracted flies more than light colors. Odor appeared to be especially significant, but visual and tactile stimuli were almost certainly important. He noted a great need to evaluate factors in the biting activity of all species of simuliiids.

DeFoliart (1965) found that biting activity and host preference may be influenced by a rapid drop in temperature.

Disease Relationships

The classification system used below is a modification of that used by Herms and James (1961).

**Blackflies as Direct Agents of Disease or Discomfort**

**Psychological effects.** According to Hocking (1952), there are three general categories in the psychological reactions of humans to the presence, annoyance and biting of black flies and other biting flies. The first of these is called the 'removal reaction.' It is invoked by the first bite received, and consists of a brushing action with the hands or an object held in the hands. This removal reaction increases as the severity of the insect attack increases, and may then be invoked simply by the landing of the insects on the skin, with no biting involved. The severest level of the removal reaction is reached when the brushing movements are made to remove non-existent insects.

The second category is that in which there is a reduction of efficiency. Under severe attack, a person reaches a stage
where almost no work can be done. This level is reached on the psychological level far quicker than simple physiological reaction can explain. "A state bordering on dementia can rapidly be reached, a condition which must be seen to be believed."

The third category is that reaction used by most animals under intense attack by biting flies. It is called 'running away', a simple name, indeed. It, in humans, is a stage beyond that of the removal reaction. One of the problems presented by this reaction is that it may achieve the exact opposite of what is intended, as running attracts, rather than avoids, some species of biting flies.

**Annoyance and blood loss.** Davies et al. (1962) quote from a journal kept by Louis Agassiz made during a trip along the north shore of Lake Superior, in 1848: "...brushing them away with branches was of no use, and even a mosquito veil proved no protection .... they alighted for a moment upon it, and then deliberately walked through...... On arriving at camp, we were speckled with blood, particularly about the forehead and back of the ears."

Harris (1852) states that "travellers and settlers ...... are very much molested by a small gnat, called the black fly....., swarms of which fill the air during the month of June."

Davies and Peterson (1956) describe *Simulium venustum* as the most important bloodsucking insect across northern Canada and Alaska, certain parts of Canada, and the northeastern United States.
Judd (1957), in a discussion of a non-biting species, *Simulium vittatum*, in Ontario, states that it was a nuisance, crawling into the ears and nose and in the crevices between the skin and clothing.

Lugger (1896) states that loss of blood can be fatal to animals. In 1874, losses of cattle in Tennessee were estimated at $500,000. Fredeen (1956) recalls that death has been attributed to anaphylactic shock. Eleven hundred cattle were killed between 1944 and 1956 in Saskatchewan. Milk production may be reduced up to 50%. Baranov (1935) states that 139,000 domestic animals were killed in 1934 in Yugoslavia, Rumania and Bulgaria.

Hocking (1952) calculates that under the severest known mosquito attack, an unclothed man could lose one-half of his blood volume in one and three-quarters hours. While biting rates of black flies are lower than those of mosquitoes, the loss of blood after feeding is greater, due to the presence of large punctures and an anticoagulant.

**Envenomization.** Lugger (1896) felt that domestic animals can be killed by black flies by the injection of a toxin. Hocking (1952) said that there is apparently a toxic enzyme present in the salivary secretions of black flies. Davies et al. (1962) mention a toxin, but do not elaborate as to its importance. Herms and James (1961) state that death seems to be due partly to a toxemia caused by the bites.

Fredeen (1956) states that, in cattle, death is probably due to a toxemia, as post mortems reveal edema in the lungs.
and serum in the body cavity.

**Allergy and immunity.** Hocking (1952) states that a reduction in the reaction of certain individuals as the black fly season progresses could be due to an immunity, or to a difference in the physiology of later generations of the flies.

Davies and Peterson (1956) observed that the early bites of black flies caused more bleeding than the later ones. Several explanations were offered. The first was that perhaps extra salivary fluid was initially stored in the esophageal diverticulum. The initial pumping action observed and the subsequent swelling of the gut with blood intake could exert pressure on the diverticulum, expressing this salivary fluid into the wound, thus adding more anticoagulant. As the season progresses, the extra salivary fluid could be replaced or diluted by nectar, thus reducing the amount of salivary fluid at the feeding site. The second explanation is that, with multiple feedings, the amount of salivary fluid present would not be as great as at the initial feeding. The third explanation is based on host immunity.

Davies et al. (1962) state that certain susceptible people, once sensitized, exhibit a severe secondary reaction, causing swelling of the lymph glands and, in some cases, more severe symptoms requiring hospitalization.

**Black Flies as Vectors**

An interesting example of time and money wasted is recorded by Herms and James (1961). They state that
Samborn (1910) ascribed the transmission of pellagra to black flies. This has since been proven to be a disease resulting from dietary deficiency, but it did succeed in generating much enthusiasm for black fly study.

**Nematoda** (Phasmida). The most important disease transmitted by black flies is onchocerciasis, caused by a filarial worm, *Onchocerca volvulus* (Leuckart). Blacklock (1926) worked out the development of the worm in *S. damnosum* Theobald, in Africa, and Strong et al. (1934) and Dalmat (1955) published significant accounts of the disease and its vectors in Central America. Herms and James (1961) calculate that about 35% of the people in the disease zones are affected. The presence of the worm in the subcutaneous tissue leads to the formation of large nodules, usually on the head and shoulders. Ocular involvement and subsequent blindness may result.

Dalmat (1955) states that black flies carry *O. gutturosa*, a cattle parasite, and Herms and James (1961) list *O. gibsoni* from cattle.

**Sporozoa.** *Leucocytozoon* spp. cause fatal infections in birds. Many of the species of these blood parasites are transmitted by black flies.

Walker (1927) found *Simulium aureum* (=*bracteatum*) attacking goslings in Canada, causing up to 100% mortality. Over 100 flies were found on the breast and abdomen of each bird. Death was attributed to blood loss, but as shown below by subsequent authors, a parasite was found to be responsible.
Wickware (1915) described *L. anatis* and found it to cause 65 to 70% mortality in young ducks. The presence of the disease during the summer months led him to suspect an insect vector. O'Roke (1930) found *L. anatis* in all ducks tested. Mortality was found to occur only in ducklings, at a level of 35%. He believed *S. venustum* to be the vector, as the disease correlated with the presence of this species. He also found sporozoites present in the outer walls of the stomach of the flies. O'Roke (1934) discovered that the range of *L. simondi* Mathis and Leger (=*L. anatis*) as synonymized by Herman (1938) coincided with that of black flies in North America.

Fallis et al. (1951) reported development of *L. simondi* in *S. venustum*, although all stages of the parasite were not found. Shewell (1955) states that the species previously thought to be the vector, *S. venustum*, is in reality *S. rugglesi*, a species of close resemblance, first found on geese in 1954. It has the strongly toothed tarsal claw associated with bird feeding, an adaptation for crawling through the feathers.

Bennett (1960) found an undescribed species (which he called *Simulium H*, pending description) involved in the transmission of *L. simondi*.

Johnson et al. (1938) recorded a disease affecting young turkey poults. Those birds which survived the initial infection became carriers. The causal agent of the disease was thought to be *L. smithi*. Underhill (1939) found the vector of
L. smithi to be S. nigropavum (= jenningsi).

Fallis et al. (1958) found ruffed grouse to be parasitized by L. bonasae, an organism less pathogenic than L. simondi. They found infective sporozoites in the salivary glands of S. aureum and S. latipes. Studies showed that the disease transmission coincided with the life cycle of these two species.

Bennett and Fallis (1960) found Leucocytozoon spp. in 70% of all birds tested at Algonquin Park, Ontario. Those birds nesting five feet or more above ground level had a higher incidence than ground-nesting species. Ornithophilic black flies most commonly feed at heights over five feet.

Virus. In 1960, Anderson et al. isolated Eastern Encephalitis Virus (EEV) from Simulium johannseni and S. meridionale, two ornithophilic species. Since S. meridionale is known to feed at least twice, it was considered to be a prospect as a biological vector of EEV among birds.

DeFoliart and Rao (1965) reported S. meridionale biting man in large numbers during October, 1964. This is a multivoltine species, occurring in more or less constant numbers during the summer and fall. The temperature during the week preceding the biting incidence averaged 5.9°C below normal. It was thought that this could have caused the change in biting habits, as such a phenomenon had previously been recorded for S. decorum, a species normally feeding on large mammals.

The importance of these discoveries has not been
evaluated, but the fact that *S. meridionale* is a possible vector of EEV and is known to feed at least twice could make it an important local factor in the transmission of this disease from birds to man.

Parasites and Predators

Parasites

Protozoa (*Sporozoa*). Strickland (1911) reported a very high percentage of larval infection by members of the Myxosporidia. Fall larvae were parasitized heavily by *Glugea* sp. and also by members of the Gregarinida.

Twinn (1939) found *Tehlohania varians* Leger (= *Nosema simulii* Lutz and Splendor, and *Glugea varians* Leger) in the abdomen of *C. mutata*, *P. hirtipes*, *P. multidentatum*, *S. gibsoni*, *S. venustum* and *S. vittatum*. The abdomens contained white, opaque masses of organisms and the integument was often semitransparent. These larvae failed to pupate.

Anderson and Dicke (1960) note that members of the Microsporidia are present in black flies in Wisconsin, but are unimportant.

Peterson (1960) found *Tehlohania* spp. in larvae in Utah.

Fungi. Twinn (1939) found *Saprolegnia parasitica* or a similar species on pupae and adults, but this may have been saprophytic.

Nematoda (*Mermithidae*). Strickland (1911) noted that nematodes of the genus *Mermis* were found in the larvae of black flies around Boston, with parasitism reaching 25%. He
and Anderson and DeFoliart (1962) found that development of the respiratory histoblast is reduced by the presence of these worms.

Jobbins-Pomeroy (1916) reports finding *Mermis* spp. in *Simulium venustum* from May until late October, as many as three or four per larva. One adult female was also found to be parasitized, resulting in reduced vitality.

Twinn (1939) found *Mermis* spp. in *Prosimulium hirtipes*, *P. multidentatum*, *S. venustum* and *S. vittatum*. The larvae were killed when the nematode left via the anus or by boring out through the integument.

Hocking and Pickering (1954) found mermithids in larvae, pupae and adults of *S. venustum*.

Anderson and Dicke (1960) state that up to eight percent of the overwintering population of *S. vittatum* is parasitized by nematodes, whereas summer populations were found parasitized up to 90% in small, muddy streams. *S. venustum* larvae were frequently parasitized from 50% to 60% under these same conditions.

Peterson (1960) collected *Hydromermis* spp. from larvae in Utah.

Anderson and DeFoliart (1962) reported on nematode parasitism in Wisconsin, by *Gasteromermis viridis* Welch and *Isomermis wisconsinensis* Welch. Species parasitized were *Crephia emergens*, *C. mutata*, *P. decemarticulatum*, *P. fuscum*, *P. gibsoni*, *P. magnus*, *P. mixtum*, *S. aureum*, *S. corbis*, *S. decorum*, *S. jenningsi*, *S. latipes*, *S. luggeri*, *S. tuberosum*,
S. venustum and S. vittatum. Normally only the larvae were attacked, but occasionally pupae and adults were infected. Death of the host occurred when the nematode bored out through the epidermis. If the host died before emergence, the nematode usually died also. Ten S. vittatum populations in small, muddy-channelled streams in August showed parasitism ranging from 49% to 93%. Gasteromermis viridis was found overwintering in S. vittatum larvae.

Phelps and DeFoliart (1964) studied Isomermis, Gasteromermis and Meromermis spp. parasitizing S. vittatum in Wisconsin. Penetration by the infective juvenile nematode is apparently accomplished by boring through the gut wall after ingestion with food. The larvae then take up residence in the haemocoal of the host. The abdomen of the host frequently becomes distended. After exit through the integument, one molt to maturity is accomplished, and eggs are laid on a form substrate.

Welch and Rubtzov (1965) state that normal nematode parasitism ranges from one to ten per cent, but is known to reach 100%.

Arachnida (Acarina). Twinn (1939) states that Hydrachnoid mites are found externally on black fly adults. Hocking and Pickering (1954) found S. venustum adults infested with hydrachnid mites.

Davies (1959) studied Hydracarina of the family Sperchonidae, possibly Sperchon jasperensis Marxhall, as parasites of adult simuliiids in Canada. The mites gain
access to the adults as they emerge from the water, and return to the water when the females return for oviposition. Species attacked were *C. dacotensis*, *C. mutata*, *S. aureum*, *S. decorum*, *S. latipes*, *S. tuberosum*, *S. venustum* and *S. vittatum*. Females were attacked more often than males. Bloodsucking species were the least infected, possibly due to the smaller amount of stored nutrient. Of the species attacked, only *S. decorum*, of secondary importance to humans in Ontario, appears to be susceptible to control by these mites.

Peterson and Davies (1960) and Peterson (1960) found members of the suborder Trambidiformes feeding on adult black flies in Algonquin Park, Ontario, and in Utah.

**Hexapoda (Hymenoptera).** Enderlein (1921) recovered two species of Braconidae, *Ademon decrescens* Nees and *Grypocampa affinis* Nees from a pupa of *S. aureum*.

Peterson (1960) reared one specimen of Scelionidae of the genus *Telonemus* from a black fly adult.

**Predators**

**Coelenterata (Hydrazoa).** Hocking and Pickering (1954) state that hydra were found feeding on black fly larvae.

**Annelida (Hirudinea).** Peterson and Davies (1960) observed Arhynchobdellida (leeches) of the genus *Haemopis* as larval predators. Borradaile et al. (1960) state that this leech is carnivorous on the aquatic larvae of insects.

**Arachnida (Araneida).** Peterson (1960) states that adult
black flies are often the victims of spiders or spider webs. Several species of spiders are common near streams on vegetation, in culverts, under bridges or on other objects. Peterson and Davies (1960) observed that the spiders either consume the flies as soon as they are trapped in the web or store them, wrapped in silk, for future consumption.

**Insecta**

**Coleoptera.** Peterson (1960) recorded Hydrophilidae of the genera *Cymbiodyta* and *Anacaena*, Dytiscidae of the genus *Agabus* and *Gyrinidae, Gyrinus natator*, as feeding on black fly larvae.

**Diptera.** Twinn (1939) found members of the Asilidae, Dolichopidae (*Dolichopus splendidulus* Lw. and *Chrysotus* sp.), Empididae and Anthomyiidae feeding on black fly imagoes. Peterson and Davies (1960) list seven genera of Empididae, three genera of Dolichopodidae, one species of Ephydridae and one species of Tendipedidae as predators of adults in Ontario. They also observed mature larvae of *S. venustum* cannibalizing first instar larvae. Peterson (1960) collected Empidids and Dolichopodids feeding on adults in Utah.

**Ephemeroptera.** Twinn (1939) lists nymphs of the genus *Heptagenia* as predators of black fly larvae.

**Hymenoptera.** Peterson and Davies (1960) observed various Formicids feeding on adult black flies in Ontario. Peterson (1960), in Utah, observed individuals of *Myrmica brevinodis, Formica obscuripes, F. fusca* and *F. neorufibarbis* pulling larvae from shallow water.
Odonata. Peterson and Davies (1960) list the genera Aeshna and Agrion as larval predators in Ontario.

Trichoptera. Twinn (1939) lists the genera Rhacophila and Hydropsyche as including important predators of black fly larvae.

Peterson and Davies (1960) state that the larvae of Hydropsyche were most prevalent, but members of the genera Cheumatopsyche, Chimarra, Neophylax and Rhacophila were also observed.

Peterson (1960), in Utah, observed members of the genera Hydropsyche, Rhacophila, Arctopsyche, Brachycentrus, Chimarra and possibly Polycentropus feeding on black fly larvae.

Fishes

Twinn (1939) listed members of the Cyprinidae, minnows, trout, the common sucker (Catastomus commersonii), the small sturgeon (Acipenser ruthensis) and the chub as larval predators.

Hocking and Pickering (1954) found Coregonus clupeaformis (Mitchell), the whitefish, feeding on the immature stages.

Peterson (1960) found a school of rainbow trout, Salmo gairdneri Richardson, feeding heavily on black fly larvae in Utah.

Aves

Hocking and Pickering (1954) state that birds apparently take a heavy toll of adult black flies. A caged white-crowned sparrow, Zonotrichia leucophrys (Forster), a common species in Manitoba, was observed to eat 54 flies (mostly S. venustum) during a five-minute period. This habit was confirmed by
observing this species in the wild.

Rearing

Many techniques have been used in the past to rear black flies in the laboratory. In all cases, mortality appears to have been high when young larvae were used.

Johannsen (1903) siphoned fresh water out of the jar as fast as it entered, thereby creating both current and aeration.

Puri (1925) used an aerator and did not have a continuous change of water. He utilized rain water, changing it occasionally as the food supply was used by the larvae. He reared adults by placing pupae in a jar with a few drops of water.

Fredeen et al. (1953), in connection with radioactive tagging experiments, used two techniques. In the laboratory, mature larvae were placed in glass jars containing water, and an air jet was used to create current. In streams, a large wooden tub was placed in the stream and filled with water. Current was supplied by a paddle wheel driven by the current of the stream outside the tub.

Hocking and Pickering (1954) used 250 cubic centimeter beakers, with air supplied through sintered glass filters; these were used because stone filters became clogged. Algae in the beakers served as food, and the larvae ate both dead larvae and microorganisms. All attempts to rear larvae from the first instar failed.

Fredeen (1959) describes three methods, each of which
has yielded success with different species.

First, a platform shaker attached to an offset cam provided water speeds up to 0.3 feet per second, when driven by a 0.5 horsepower electric motor. This method was most successful for rearing *S. vittatum*.

The second method consisted of a jar in which was placed a glass plate. The plate was positioned so that the undersurface was slanted from the bottom on one side of the jar to the top on the other side. Compressed air was driven through a fine glass tube and released so that the air bubbles flowed up the undersurface of the plate. This method provided speeds up to 1.4 feet per second. *Simulium venustum* was successfully reared using this technique.

A jar placed on a rotating platform turned by the same motor mentioned above was used for the third method; as the platform rotated, the water in turn rotated. Current was provided by introducing a stationary rod into the center of the jar. Attached to this rod was a horizontal glass plate. This plate provided resistance to the rotating water, and produced water velocity up to 4.5 feet per second, sufficient for rearing *C. dacotensis, S. aureum* and *S. decorum*.

Food provided in all three experiments was yeast, Pablum (ground to pass a 150-mesh screen) and algae (*Leuvenia natana* Gard.). Different sources of water were used, but no statement is made as to any significant differences.

Doby et al. (1959) used a vertical glass cylinder divided into two sections with a sheet of glass. A small
space was left at the bottom, into which a bent glass tube was introduced. Air bubbling through this tube and up one side of the plate created current and aeration. A muslin pocket was placed over the top of the cylinder to catch emerging adults.

Anderson and DeFoliart (1962) describe a rearing technique for *Simulium vittatum* utilizing enamel pans. Air was bubbled through porous stones to provide current and aeration. Food was given in the form of protein pellets, microorganisms in the water, and stream vegetation. No mention is made of the percentage of larvae successfully reared using this technique.

**Sampling**

**Immatures.** Fredeen et al. (1953) used radioactive phosphorus, in the form of P\(^{32}\)O\(_4\), to tag larvae of black flies, so that their movements in streams could be followed. They collected many radioactive predators from the release points, indicating that the toll of larvae was high.

Hocking and Pickering (1954) found that the number of larvae per unit length of a blade of grass was approximately proportional to the sine of the angle of the inclination to the current.

Dalmat (1955), in Guatemala, collected all immatures that could be found in one hour. These were later counted so that population changes could be determined.

Wolfe and Peterson (1958) used metal cones as substrates for larval attachment population studies. These were smooth-
surfaced, 20 centimeters in height and ten centimeters in diameter, with an apex angle of 30 degrees. The surface area was 300 square centimeters. Cones painted white were found to be superior to other colors. These devices were attached by a wire one meter in length to poles driven in the stream bottom. The larvae were found to prefer the cones to grass or rocks for attachment. Peterson and Wolfe (1958) state that the cones are useful for obtaining data on larval migration, level of infestation, growth rate, peak abundance, streams suitable for larval growth and assessing larval control methods.

Wolfe and Peterson (1959) used two methods to assess larval abundance. The first was to count the number of larvae attached to stones removed from the stream bed over a period of five minutes. Three people counted simultaneously, and the totals for each were then summed. The second method utilized pulpwood logs, four feet in length (diameter was not given) and painted white. These were anchored by rope to the shore so that they were submerged four to six inches below the surface of the water. They state that flooding was the major factor causing variation in results, as it would cause sections of the stream that had been previously unfavorable for the larvae to become favorable, and vice versa.

Adults. Frost (1949) sampled black flies in Pennsylvania with light traps. He states that females seemed to be attracted more than males.

Hocking and Richards (1952) described two methods of
estimating adult populations. One involved the number of flies landing on the front of the trousers between the waist and the knees in one minute. The other was by collecting the flies around the head by means of an insect net.

Dalmat (1955) used a twenty-minute period of time to take adult samples. The first ten minutes was allowed for the flies to assemble about the human bait. The second ten minutes was used to collect all flies that were biting.

Jamnback and Collins (1955) estimated adult populations by counting the number of flies flying about the head after the observer had been standing in one spot for a period of ten minutes. This proved to be superior to estimates made by sweeping ten times with a 12-inch insect net about the head and body.

Davis and James (1957) utilized bait traps with ground beef to attract males and females of Simulium vittatum. Beef with ample quantities of tallow placed on white paper towels was used. The white towels also seemed to help attract the flies. Putrified meat seemed superior to fresh meat.

Judd (1957) estimated populations of S. vittatum by making one sweep each day at the same station with a 12-inch insect net, from May 15 to November 15, 1956.

Wolfe and Peterson (1958) used cages to trace emergence and succession of flies. They observed, however, that this device was impractical as a control measure.

Peterson and Wolfe (1958) used a technique for assessing adult populations involving a twelve-inch square of blue serge
cloth, divided by white lines into nine squares. They waited two minutes, then counted the number of flies landing on the cloth in the next minute.

Fredeen (1961) states that Monchadski and Radzibilovskoja (1948) used one person as bait and the other as the collector. He describes an animal facsimile made of a four-legged frame with the upper two-thirds covered with dark brown plywood or dark blue denim cloth. A trap four feet high, five feet long and two feet wide was found to be the most satisfactory. A light trap collected twice as many black flies as the silhouette trap, but the catches in the latter were more representative of the attacking populations.

Stream Classification

Dalmat (1955), studying Simuliidae in Guatemala, classified streams into two basic groups, transient and permanent (sustained or perennial). Transient streams result from precipitation directly, either from rain or melting snow, and run in rather well-defined channels. Permanent streams in Guatemala have their origin in underground water that has collected in large pools and runs in channels until it reappears at the surface.

Transient streams were further classified into flashwater and temporary streams. The former are relatively unimportant, as they last from only a few hours to a matter of days, hardly long enough to support the full life cycle of any black fly species. He categorized temporary streams, however,
as lasting from two to five weeks to six months and thus capable of supporting several black fly species.

Permanent streams may result from a slight percolation of water from a set soil surface, forming tiny rivulets which later unite, or from water bubbling from the ground in the form of a rather large spring. Usually, several streams will arise from approximately the same area and altitude, since the intersection of the water table by the slope of the land is normally widespread.

Permanent streams are classified as infant, young, adolescent, mature and old. These characters do not refer to the actual geological age, but to the morphological characteristics they possess. Characteristics of a stream may vary along the course of its flow.

An infant stream varies in width from an inch to about a foot. The bottom is usually indistinguishable from the land around it. Vegetation usually consists of trailing plant parts, debris and decaying leaves. Dalmat found only anthropophilic species in these streams.

Young streams are narrow and V-shaped in cross-section. The bed is composed of sand, gravel and small stones, with occasional falls and pools. There are few tributaries, and the path is quite erratic. Vegetation is common. Anthropophilic species were found primarily.

Adolescent streams have less steep sides than young streams. There are usually many tributaries, and there are few falls, with the path taking a more meandering course, not
the zig-zag of the previous type. The bed is approximately
the same as that of young streams, with a great deal of
vegetation and dense shade. Both zoophilic and anthropo-
philic species were found in these streams.

Mature streams have a U-shaped profile, with the
immediate area being shaped by the stream itself. The water
is quite slow-moving and sandbars, beaches and floodplains
are common. Dalmat found that zoophilic species predominated
in this type of stream, but a certain number of anthropo-
philic species were found.

The old stream flows through gently rolling terrain.
There are few tributaries, these being rather large in size.
The flow is usually great, and wide beaches are found along
the banks, often wider than the stream itself. Practically
no emergent vegetation is found, and the treeline is far
removed from the water's edge. With rare exceptions, only
zoophilic species were found by Dalmat.

Wolfe and Peterson (1959) adapted Dalmat's classifica-
tion to fit the fauna of Canada. Their categories were
infant streams, permanent spring-fed forest streams, young
streams, adolescent streams, mature and old streams, and dams
and sluiceways.

Temporary streams were placed in the infant category, as
being not more than two feet in width, with no distinct bed
other than a few bare stones. Species present were Cnophia
mutata and Prosimulium hirtipes.

Permanent spring-fed forest streams were those two to six
feet in width. Species of black flies found developing in such streams were P. hirtipes, C. mutata, Simulium latipes and S. venustum.

Young streams were those permanent streams six to fifteen feet in width, with stony beds and banks, and numerous falls and rapids. Dense border vegetation was present. Species of black flies found were P. hirtipes, C. mutata, C. dacotensis, S. venustum and S. tuberosum.

Adolescent streams were small rivers, with occasional falls and many rapids and rills, a graded stony bed and a lake as a source. Species of Simuliidae present were P. hirtipes, C. mutata, C. invenusta, S. latipes, S. euryadniciculum, S. vittatum, S. venustum, S. tuberosum, S. corbis, S. decorum and S. aureum.

Mature and old streams were large rivers with great flow, rocky or sandy beds, sluggish sections and little vegetation, either in the water or along the banks. Black flies found were S. venustum, P. multidentatum, S. aureum, S. rugglesi, S. tuberosum and an undescribed species designated Simulium species M.

Dams and sluiceways were the exclusive domain of S. decorum.

Anderson and Dicke (1960) further modified stream classification for Wisconsin Simuliidae. Two main categories were designated, temporary flowing water and permanent flowing water.

Temporary flowing water was subdivided into two categories. Bog seeps are those streams usually about six inches
wide and one foot deep. Grasses are usually present. These streams are found during April and May. Drainage creeks are those temporary streams six inches to three or four feet in width, and one or two inches to a foot in depth. The bottom is composed of sand and small stones. The maximum life of these streams is about five months, drying up about mid-June.

Permanent flowing water was divided into four subcategories. Young streams are two to ten feet wide and six inches to three feet deep. The bottom is composed of gravel, rocks and boulders. There are small waterfalls interspersed along the bed of the stream, and rapids are frequent, with velocities of over three feet per second.

Old permanent streams are those three to fifteen feet wide and one to four feet deep. The bottom is composed of mostly mud, with some sand and gravel occasionally found. Vegetation is often present. These streams are found in rolling land. The water moves sluggishly at less than three feet per second.

Young rivers are those that are ten to fifty yards wide and one to five feet deep. The bottom is composed mainly of gravel and strewn with large rocks and boulders. Rapids and waterfalls are prevalent. These streams are found in forested terrain.

Old rivers are over fifty yards wide and at least ten feet deep. The bottom is composed mainly of mud. Few boulders are found and there are often dead trees and other debris in and along the banks. Black fly larvae found in
this type of water occur along the banks, clinging to vegetation or debris.

*Conephoria dacotensis* (Dyar and Shannon), 1927

**Distribution**

Smart (1945) states that this species is Holarctic. Stone (1964) lists its North American distribution as Idaho, Illinois, Iowa, Labrador, Manitoba, Massachusetts, Michigan, Minnesota, Newfoundland, New York, Ontario, Pennsylvania, Rhode Island, Saskatchewan, South Dakota and Wisconsin.

**Life History**

Stone and Jamnback (1955), Davies and Peterson (1956), Davies et al. (1962) and Stone (1964) agree that there is one generation per year.

**Egg.** Stone and Jamnback (1955), Davies and Peterson (1956) and Davies et al. (1962) found that overwintering takes place in the egg stage. The last authors state that the eggs hatch in mid-April, although a few may hatch in late autumn. Hatching was recorded in Wisconsin when the water temperature reached 41°F. Anderson and Dicke (1960) found hatching to occur at 40°F.

**Larva.** Stone and Jamnback (1955), Wolfe and Peterson (1959), Anderson and Dicke (1960) and Stone (1964) state that the larvae are found below pond or lake outlets. Anderson and Dicke (1960) also found them in temporary and permanent streams, usually with muddy bottoms, and Davies et al. (1962) collected them from streams over ten feet wide.
Dimond and Hart (1953) found larvae on May 3 in Rhode Island. Stone (1964) states that larvae are found in the spring in Connecticut. In New York, Stone and Jamnback (1956) found the larvae in May and June.

According to Anderson and Dicke (1960), the larval period lasts four to five weeks at water temperatures of 40 to 65°F. Davies et al. (1962) found this species to be highly parasitized by nematodes of the family Mermithidae (Enoplida).

**Pupa.** Dimond and Hart (1953) found pupae on May 3 in Rhode Island. Stone (1964) states that pupation occurs in May in Connecticut. In New York, Stone and Jamnback (1955) found them present in May and June. Pupae were collected in colonies in Quebec from June 7 to June 20 by Wolfe and Peterson (1959). Hocking and Richards (1952) found the first pupa in Labrador on June 19.

Stone and Jamnback (1955) say that the pupal stage lasts about eight days, and Anderson and Dicke (1960) found development to take from five to seven days.

Stone and Jamnback (1955) report finding large eggs in the pupa, and Wolfe and Peterson (1959) state the eggs mature during the pupal stage.

**Adult.** Davies and Peterson (1956) state that the adults emerge from late May to late June, with a median date of June 8 recorded over five years. Wolfe and Peterson (1959) found adults in Quebec on June 20 and 22. Davies et al. (1962) found adult emergence to be concentrated within a few days in late May and early June in Ontario. In Labrador, Hocking and
Richards (1952) recorded the first adult activity on June 19.

Davies and Peterson (1956) found a three to one ratio of females to males. They believe this to be related to the short life span of the females.

**Ovarian Development and Oviposition.** Davies et al. (1962) state that the females contain mature eggs upon emergence.

Stone (1964) states that the adults fly very little. Davies and Peterson (1956) observed that male swarms do occur, but Peterson and Wolfe (1958) say that this species has no swarms.

Hocking and Pickering (1954), Davies and Peterson (1956), Fredeen (1959), Wolfe and Peterson (1959), Davies et al. (1962) and Stone (1964) agree that mating occurs almost immediately after emergence, while crawling on objects.

Davies and Peterson (1956) report finding a ball of male flies around a female on a damp rock. Davies et al. (1962) also mention this, and add that these masses falling into the water result in high mortality.

Fredeen (1959) and Davies et al. (1962) state that oviposition occurs shortly after mating.

Wolfe and Peterson (1959) note that the eyes of the males are not differentiated into small lower ommatidia and large upper ommatidia, as is found in those species having mating flights.

Davies and Peterson (1956) and Davies et al. (1962) observed the females ovipositing by taking a short flight to the stream, dipping to the water once or twice, and then
returning to rest. Fredeen (1959), however, reports that the eggs are laid on objects at the surface of the water.

Davies (1959) found the adults to be heavily parasitized by larval Sperchonidae (Hydracarina), which gain access when the adults emerge, and correlated the extent of this parasitism (greater than in any other species observed) with the large amount of stored nutrient available.

Importance

Nicholson (1945) states that while the mandibles and maxillae of the females are not developed for bloodsucking, the other mouthparts are developed enough to allow feeding on liquids. Stone and Jamnback (1956), Downes (1958) and Stone (1964) found that the females do not feed at all.

*Cnephia mutata* Malloch, 1914

**Distribution**

Smart (1945) lists this as a Nearctic species. Stone and Jamnback (1955) and Stone (1964) record the distribution from Alaska and Labrador to California, Arkansas and Alabama. The latter author states that this species has also been found in Japan.

**Polymorphism**

Davies and Peterson (1956) recorded the unusual female to male ratio of 200:1. They found that 85% of the individuals collected in southern Ontario were in a triploid (3n) state, rather than the usual diploid (2n) condition. The theory was then advanced that this preponderance of females
and the unusual chromosomal state may have been due to parthenogenesis.

Basrur and Rothfels (1959), upon examination of the chromosome complements of the collections from southern Ontario, found the diploid forms to be bisexual, whereas the triploid forms produce only parthenogenetic females. They reasoned that this explained the unusual sex ratio. The two forms were found to intermingle in the same streams.

In further collections, Davies et al. (1962) found that 90 to 100% of the specimens collected in Ontario were of the parthenogenetic triploid form.

Life Cycle

Stone and Jamnback (1955), Davies and Peterson (1956), Wolfe and Peterson (1959), Davies et al. (1962) and Stone (1964) agree that there is one generation per year. Basrur and Rothfels (1959) theorize that while the diploid form is probably univoltine, the triploid form may not be.

Egg. Davies et al. (1962) report that this species may overwinter in the egg stage in Wisconsin, at least in temporary streams. Anderson and Dicke (1960) and Stone (1964) state that the egg stage is only one of two ways that overwintering can occur.

Larva. Anderson and Dicke (1960) and Stone (1964) found that this species can overwinter in both egg and larval stages. Dimond and Hart (1953), in Rhode Island, Stone and Jamnback (1955) and Jamnback (1956), in New York, and Davies and Peterson (1956), in Ontario, say that the larvae overwinter.
Davies et al. (1962) found the larval stage overwintering in the northern forests of Ontario.

Davies et al. (1962) found that the earliest larvae are of the diploid form, maturing in March or April, although a few may be found until early May. By mid-April, almost all larvae collected are triploid.

Dimond and Hart (1953) found large larvae in Rhode Island on March 28, and mature larvae were collected until June 14. In Connecticut, Stone (1964) collected mature larvae on March 29. Stone and Jamnback collected mature larvae in New York from late March to late May and early June. Wolfe and Peterson, in Quebec, found mature larvae in mid-May.

Stone and Jamnback (1955), Anderson and Dicke (1960) and Stone (1964) state that the larvae prefer small temporary or permanent streams with gravelly bottoms. Wolfe and Peterson (1959) collected them in shallow waters of forest streams, seepages and small permanent streams, where the flow was swift but not turbulent. Dimond and Hart (1953) report a preference for cold streams often in association with P. hirtipes.

Dimond and Hart (1953) state that the larvae show no preference as to substrate. Stone and Jamnback (1955) and Stone (1964) found them to prefer small stones, sticks and occasionally trailing grasses. Davies et al. (1962) add that the undersurface of objects is preferred.

Stone and Jamnback (1955), in New York, report that this
species makes up 20% of the larval population from November to March, after which pupation reduces it.

Twinn (1939) found the larvae to be parasitized by Protozoa. Anderson and DeFoliart (1962) state that they are parasitized by nematodes (Enoplida:Merithidae). In neither case is the extent of parasitism or death rate given.

**Pupa.** Dimond and Hart (1953) found pupae in Rhode Island on April 3. Stone and Jamnback (1955) recorded pupation in New York in late March. In Quebec, Wolfe and Peterson (1959) found pupation occurring from May 23 to the end of June. Hocking and Richards (1952) collected the earliest pupa July 9 in Labrador.

According to Davies et al. (1962), pupation occurs in crevices and under objects in the stream.

**Adults.** Dimond and Hart (1953) collected adults from April 10 to May 9 in Rhode Island. Stone (1964) took adults on April 11, and found them active until July, although never in abundance, in Connecticut. In Quebec, Wolfe and Peterson (1959) found adults from early June until August. Hocking and Richards (1952) recorded adult activity from July 9 to August 5, in Labrador.

Davies et al. (1959) found the adults are attacked by larval Sperchonidae (Hydracarina) as they emerge from the water. The parasites remain attached until oviposition.

**Ovarian development and oviposition.** Pokof'eva (1959) reports that the adult females emerge with mature eggs already present. Davies et al. (1962) state that the eggs are half-
developed on emergence, and that the females contain considerable stored nutrient.

Davies and Peterson (1956) and Davies et al. (1962) observed that the female deposits her eggs while in flight, by tapping the tip of her abdomen on the surface of the water. The former authors observed that the females flew downstream, ovipositing every foot or so for a distance of one or two yards, then returned to the upstream starting point and repeated the process.

Importance

Downe and Morrison (1957) and Anderson and DeFoliart (1961) recorded this species as feeding on horses and cattle. Davies et al. (1962) and Stone (1964) place deer on the list, the former authors adding that the ears seem to be the preferred feeding site on deer and horses.

Attacking Man

Wolfe and Peterson (1959) found that the females are not attracted to man in Quebec. Hocking and Richards (1952), in Labrador, and Stone and Jamnback (1955), in New York, found it only rarely annoying to man. Jamnback and Collins (1955) state that in New York, this species may be annoying to man in the lowlands, but is not a pest in the Adirondacks. Peterson (1956), in Utah, reports that the females attack man above an altitude of 7000 feet, and are active on warm, dark nights.

_Prosimulium hirtipes_ (Fries), 1824 Complex

Johannsen (1903) stated that the European and American
representatives of this species were identical. Rothfels (1956), however, examined the morphology of the salivary chromosomes of the *Prosimulium hirtipes* in North America and found three distinct groups. Davies (1957) demonstrated that the American forms differed from the European *hirtipes*. Syme and Davies (1958) described three species from North America, *P. fontanum*, *P. fuscum* and *P. mixtum*. They found female genitalia and the shape of the sensory vesicle of the third segment of the maxillary palp to be diagnostic characters. Mandibular and hypostomal armature was used to distinguish *P. fontanum* larvae from the other species of the complex. Davies (1961) found that the number of cephalic fan rays could be used to separate larvae of *P. fuscum* and *P. mixtum*.

**Distribution**

Smart (1945) lists *P. hirtipes* as Holarctic. Stone (1964) states that *fontanum* has been found only in Ontario and Quebec, *fuscum* in Labrador, New York, Nova Scotia, Ontario and Quebec, and *mixtum* in Labrador, Maine, Manitoba, Ohio, Ontario, Quebec and Wisconsin.

**Life History**

Stone and Jamnback (1955), Davies and Peterson (1956), Wolfe and Peterson (1959), Davies et al. (1962) and Stone (1964) agree that members of this complex have one generation per year.

**Egg.** Stone and Jamnback (1955) observed eggs on roots below a dam.

Hocking and Richards (1952) report that eggs of *hirtipes*
hatch in August in Labrador. Davies and Syme (1958) and Wolfe and Peterson (1958) state that the eggs hatch in the fall. Davies et al. (1962), however, found that the eggs of fontanum hatch in early spring.

**Larva.** O’Kane (1926), Hocking and Richards (1952), Dimond and Hart (1953), Stone and Jamnback (1955), Davies and Syme (1958), Peterson and Wolfe (1958), Wolfe and Peterson (1959) and Anderson and Dicke (1960) state that this complex overwinters as a larva.

Dimond and Hart (1953), in Rhode Island, found larvae matured on March 12. Jamnback (1956) collected larvae from November to June in New York State, and Stone and Jamnback (1955) found mature larvae in late April. O’Kane (1926) collected larvae from November to June in New Hampshire, with large (mature?) larvae occurring March 29. Davies and Syme (1958) and Davies et al. (1962) state that fuscum and mixtum larvae mature in late winter in Ontario. Wolfe and Peterson (1958) found large larvae in Quebec on May 18.

O’Kane (1926), Jenkins (1948), Jamnback (1956), Peterson and Wolfe (1958), Wolfe and Peterson (1959), and Anderson and Dicke (1960) are in general agreement that the larvae of the hirtipes complex are found in temporary or permanent streams, usually the smaller, cold streams with rocky beds and many cascades and rapids. Jenkins (1948) found this to be the only species present at high altitudes in Alaska. Hocking and Richards (1952) collected the larvae from most forest streams in Labrador. Dimond and Hart (1953) found them commonly
associated with C. mutata larvae. Davies and Syme (1958) found fuscum and mixtum larvae associated, although they and Davies et al. (1962) state that fuscum larvae are found alone in larger, more rapid streams. The latter authors also found fuscum common at outlets. Davies and Syme (1958), Davies et al. (1962) and Stone (1964) note that fontanum larvae are found in small cold streams originating from a spring or bog.

Jenkins (1948) states that hirtipes larvae are found in Alaska at an average water temperature of 43°F. and an average pH of 7.2. Although Radzivilovskoya (1950) had stated that hirtipes larvae hatch from 38.7 to 41.0°F., Davies and Syme (1958), Anderson and Dicke (1960) and Davies (1961) all found fuscum and mixtum larvae present at temperatures just above freezing, from 32.1 to 33°F. Davies and Syme (1958) thought that there was no relationship between the rate of growth and temperature, but Anderson and Dicke (1960) and Davies et al. (1962) believe that the long larval period of members of the complex may be due to low water temperature. Anderson and Dicke (1960) add food scarcity as a factor in prolonging larval growth. They found that temperatures range up to 60°F. during larval growth periods.

Dimond and Hart (1953) found that the larvae prefer rocks for attachment.

Davies and Syme (1958) observed that the larvae were mainly herbivorous. The digestive tract may be filled in one or two days, and this meal may take two weeks to digest. Growth follows an S-shaped curve.
Davies (1960) found that the first instar larva of *Prosimulium* (he thought the species to be *fuscum*) lack head fans and an anal sclerite. The larva molted within twelve hours to a larva having head fans and an anal sclerite. This indicates a relationship between this genus and *Twinnia* and *Gymnopais*, whose members lack head fans throughout the larval period.

Twinn (1939) found nematodes of the family Mermithidae present in *hirtipes* larvae, and Davies et al. (1962) found a high percentage of parasitism in *fuscum*.

**Pupa.** Dimond and Hart (1953) found pupae on April 3 in Rhode Island, and state that pupae were still abundant on May 13. According to Stone and Jamnback (1955), pupation in New York occurs from late April to the first of June. Anderson and Dicke (1960) collected pupae March 26 in southern Wisconsin, and reported that 30% of the population had pupated by April 9. Pupation was one week later in the northern part of the state. Davies and Syme (1958) and Davies (1961) state that *fuscum* and *mixtum* begin pupation in early April in Ontario. Hocking and Richards (1952) recorded pupae on June 22 in Labrador.

Davies and Syme (1958) observe that, with some variation in individual streams, the type of cocoon spun by the members of the complex can be related to the type of stream preferred. The heaviest cocoon is made by *fuscum*. It more often inhabits larger streams, and is more exposed to abrasive particles and to being torn loose from the substrate. The cocoon of *mixtum*
is usually weaker. The least amount of cocoon is typically spun by *fontanum*. Naked pupae of *fontanum* are often found on the bottom of slow streams.

Stone and Jamnback (1955) state that temperature plays a role in controlling pupation. Davies and Syme (1958) and Davies (1961) found pupation to occur at 35 and 36°F., for *fuscum* and *mxtum*, with mature larvae accumulating until the pupation threshold is reached. Dicke (1960) found pupation to occur above 40°F.

Davies and Syme (1958) state that *fuscum* often pupates in masses on rocks, while *mxtum* occurs more often on vegetation. Davies et al. (1962) note that *fontanum* pupae are often found in moss.

Anderson and Dicke (1960) found the pupal period to last six to nine days.

Adult. Frost (1949) took adult *hiertipes* in a light trap in Pennsylvania from April 4 to June 9. Dimond and Hart (1953) recorded adults on April 3 in Rhode Island. Anderson and Dicke (1960) recorded emergence on April 9 in Wisconsin. Davies et al. (1962) report that, in Algonquin Park, Ontario, *fontanum* emergence is from May 25 to August 8. Emergence of *fuscum* is from early April to early May in southern Ontario, and from early May to the end of June at Algonquin Park. Emergence of *mxtum* is from mid-April to late June at Algonquin Park, a day or two ahead of *fuscum* in those streams where both species are present. Hocking and Richards (1952) recorded adult activity from June 5 to August 20 in Labrador. Sailer
(1953) states that adults are present during July and August in Alaska.

Wolfe and Peterson (1959) report that emergence was one month later in Goose Bay, Labrador, and one month earlier in the Adirondacks, than the emergence in Quebec.

Davies and Syme (1958) found that, in Ontario, more \textit{fuscum} females are present at the end of May. The \textit{mixtum} proportion then increases and after June 6 no \textit{fuscum} were found.

Stone and Jamnback (1955) state that temperature plays a role in determining when emergence will occur.

**Ovarian development and oviposition.** Wu (1931) and Downes (1958) found that \textit{hirtipes} females develop mature eggs when maintained on sugar and water.

Davies and Syme (1958) state that \textit{fuscum} females have small fat bodies on emergence, and require a blood meal for ovarian development. However, Davies (1961) and Davies et al. (1962) found \textit{fuscum} females to be autogenous in the first ovarian cycle. These authors also say that \textit{mixtum} females are anautogenous, and the latter authors include \textit{fontanum} in this category. They found ten per cent of \textit{fuscum} females surviving to complete two ovarian cycles, while 20% of the \textit{mixtum} females do so. A few \textit{mixtum} complete three ovarian cycles, according to Davies (1961).

Johannsen (1903) believed that the eggs were laid on rocks. Davies and Peterson (1956), Davies and Syme (1958), Anderson and Dicke (1960) and Davies et al. (1962) agree that
females lay eggs in flight, by touching the tip of the abdomen to the surface of flowing water. The eggs then sink to the bottom, where moisture is present even when the streams appear to have become dry. Stone and Jamnback (1955) and Davies and Peterson (1956) also found that oviposition may occur on a network of exposed roots where water is sprayed on them by a waterfall.

Wolfe and Peterson (1959) observed oviposition in Quebec on June 1, two days after emergence. Davies and Syme (1958) state that oviposition occurs in May and June in Ontario.

Stone and Jamnback (1955), in New York, state that female *hirtipes* live about three weeks.

**Dispersal.** Anderson and Dicke (1960) and Fallis (1964) report that *mixture*, being anautogenous, disperses more than the autogenous *fuscum*. Search for a blood meal is believed to be the reason. Hocking and Richards (1952) give the flight range of *hirtipes* as two miles, but Peterson and Wolfe (1958) and Fallis (1964) feel that the adults may fly up to five miles from the point of emergence.

**Importance**

Stone and Jamnback (1955), Downe and Morrison (1957), Davies et al. (1962) and Stone (1964) list members of the complex as feeding on horses and cattle and other mammals. Downe and Morrison (1957) add pigs as a host, and Stone (1964) reports that *fuscum* has been found on deer.

Davies et al. (1962) note that *fuscum* females are
attracted to mammals only after the first oviposition.

Davies and Peterson (1956) collected adults feeding on nectar, especially blueberries (Vaccinium spp.).

Attacking Man

O'Kane (1926), Hocking and Richards (1952), Jamnback (1952), Twinn (1952), Dimond and Hart (1953), Stone and Jamnback (1955), Davies and Peterson (1956), Jamnback (1956), Peterson and Wolfe (1958), Wolfe and Peterson (1959), Anderson and Dicke (1960) and Stone (1964) all agree that members of the hirtipes complex are very annoying biters of man. Jenkins (1948) observed that they attacked only the upper parts of the body.

Frohne and Sleeper (1951) found that hirtipes was a serious problem in Alaska.

Collins and Jamnback (1953) state that they are sufficiently annoying to warrant control in New York.

Anderson and Dicke (1960) found mixtum to be a greater pest than fuscum.

Disease Relationships

Anderson and Dicke (1960) theorize that, since mixtum females live longer and have more ovarian cycles and feeding periods than the other members of the complex, they are potentially more efficient disease vectors.

Prosimulium magnum Dyar and Shannon, 1927

Distribution

Smart (1945) lists this as a Nearctic species. Stone
and Jamnback (1955) state that it is found in the Transition and Upper Austral zones from Illinois and Oklahoma to Massachusetts and Georgia. Stone (1964) adds that it has been found in Ontario, Canada.

**Life Cycle**

Stone (1964) mentions that little is known of the biology. Stone and Jamnback (1955) and Davies et al. (1962) call it an univoltine species.

**Egg.** Anderson and Dicke (1960) found the eggs buried in the sand. Davies et al. (1962) and Stone (1964) state that most of the winter is spent in the egg stage, and the latter author found the egg state to last from late spring to the following March or April.

**Larva.** Jamnback (1956) observed that the larvae were found from November to June below dams and lake outlets, but as a whole were uncommon. Anderson and Dicke (1960), in Wisconsin, found that the species often inhabited drainage creeks at a water temperature ranging from 51 to 64°F. Stone (1964) states that the larvae are found in temporary streams.

Dimond and Hart (1953), in Rhode Island, found mature larvae April 2, but never in large numbers. Stone and Jamnback (1955), in New York State, found larvae on April 8. Davies et al. (1962) say that the larvae emerge in late winter and reach maturity in late April in Ontario.

Davies et al. (1962) infer that the larvae show no preference as to substrate.
Anderson and Dicke (1962) found that the larval period lasts four to five weeks.

Anderson and DeFoliart (1962) found *Gasteromermis viridis* Welch and *Isomermis wisconsinensis* Welch (Enoplida: Merinithidae) parasitizing the larvae. Death resulted when the nematode emerged through the anus or bored out through the integument.

**Pupa.** Dimond and Hart (1953) collected pupae in Rhode Island from April 23 to May 15. Stone (1964) found pupae in Connecticut on April 21.

Anderson and Dicke (1960) state that the pupae usually are attached on the downstream end and under small rocks, but some were also found attached to dead leaves and small twigs. Davies et al. (1962) and Stone (1964) record that the pupae are often found in dense masses.

Anderson and Dicke (1960) observed that the pupal stage lasted four or five days.


Anderson and Dicke (1960) and Anderson and DeFoliart (1961) agree that this is the last of the genus *Prosimulium* to appear in the spring.
Ovarian development and oviposition. Davies et al. (1962) found that the females emerge containing much stored nutrient and sometimes with eggs nearly mature. They contain 250 or more eggs. These authors found egg deposition in Ontario in May.

Davies and Peterson (1956) and Davies et al. (1962) observed that the females deposited eggs while in flight over streams.

Importance

Anderson and DePoliart (1961) and Stone (1964) list this species as attacking man, horses, cattle and sheep. Davies et al. (1962) obtained one biting record from the ear of a horse. Anderson and DePoliart (1961) found the species attacking cattle from May 15 to May 30, and Stone (1964) records that this is a severe pest of pastured cattle.

Prosimulium multidentatum (Twinn), 1936

Distribution

Stone (1964) states that this species has been collected in Labrador, Maine, Manitoba, Ohio, Ontario, Quebec and Wisconsin.

Life Cycle

Although no definite statement is made, Wolfe and Peterson (1959) suggest that this is an univoltine species in Quebec, as they refer to it as a spring species. Davies et al. (1962) state that there is one generation per year.

Egg. Stone (1964) infers that overwintering is in the
egg stage. Davies et al. (1962) note that at least part of the population overwinters as eggs.

**Larva.** Hocking and Richards (1952) state that overwintering is in the larval stage in Labrador. Davies et al. (1962), in Ontario, found that whether the larvae hatched in early or late winter, they matured at the same time.

Hocking and Richards (1952) found that the preferred larval habitat is in small forest streams, but that they may be found in larger streams that are in flood. Wolfe and Peterson (1959) report the species as found in swiftly flowing water above falls.

Davies et al. (1962) report that mature larvae are present in April and early May in Ontario.

Davies et al. (1962) found that this species to be heavily parasitized by nematodes (Enoplida: Mermithidae).

**Pupa.** Davies et al. (1962) report pupation in late April or early May in Ontario. In Quebec, Wolfe and Peterson (1959) collected one pupa at a depth of two or three feet on June 15, along with several empty pupal cases. Hocking and Richards (1952) found the first pupa in Labrador on June 11.

**Adult.** Stone (1964) states that the adults fly in April and May in Connecticut. Davies et al. (1962) report that the peak of adult emergence in Ontario occurred about one week after that of *P. fuscum*, in a river with water temperature at 51°F.

Davies and Peterson (1956) collected adult males in a swarm with *P. hirtipes* and *S. vittatum*. 
Ovarian development and oviposition. Davies et al. (1962) state that the females emerge with partially developed eggs and large fat bodies.

Davies and Peterson (1956) found that oviposition occurs in flight, as in *P. hirtipes*.

Importance

Davies et al. (1962) theorize that the females probably feed on mammalian blood.

*Simulium aureum* Fries, 1824

Distribution

Smart (1945) considers this species to be Holarctic in distribution. Stone (1964) states that it is found as far south as Sardinia in Europe and to Guatemala in the Americas. Jamnback (1956) and Wolfe and Peterson (1959) consider it to be a rare species on the North American continent.

Species Complex

Dunbar (1959) examined the chromosomes of two collections each from southern Ontario, northern Manitoba and European Russia, and a single collection from California. On the basis of the morphology of these chromosomes, he found the 'species' to be composed of seven distinct forms, all probably worthy of species rank. He also states, however, that the possibility of geographic variance within the species cannot be overlooked. Bennett (1960), Davies et al. (1962) and Stone (1964) consider this to be a species complex.
Life Cycle

Peterson (1959) found three to four generations per year in Utah. Anderson and Dicke (1960) and Wolfe and Peterson (1959) found two generations per year in Wisconsin and Quebec. Stone (1964) states that in Connecticut there are at least two generations and perhaps more, depending on the season.

**Egg.** Anderson and Dicke (1960) and Stone (1964) report that overwintering, at least in the north, is in the egg stage. Stone and Jamnback (1955) found the incubation period during the warmer months to be eight to twelve days.

**Larva.** Jenkins (1948), Stone and Jamnback (1955), Jamnback (1956), Anderson and Dicke (1960), Fredeen and Shemanchuk (1960), Peterson (1960) and Stone (1964) agree that the larvae prefer warm, slow-moving water. Jenkins (1948) and Stone and Jamnback (1955) state that the preferred habitat is at lake outlets. Jamnback (1956) found them to inhabit shallow streams in New York. Peterson (1960) collected larvae mainly from small streams in Utah. Sutherland and Darsie (1960b) collected larvae from intermittent streams in Delaware.

Anderson and Dicke (1960) state that the larvae prefer small, rocky streams in Wisconsin. The larvae appeared when the water temperature reached 52°F, and were present as long as the temperature remained between 52 and 70°F. In Alaska, Jenkins (1948) collected them from sea level to 2500 feet, at an average pH of 7.3 and an average temperature of 56°F.

Dimond and Hart (1953) found larvae on May 8 in Rhode
island. O'Kane (1926) states that the larvae, although rare, are found from June 28 to September 16 in New Hampshire. In Wisconsin, according to Anderson and Dicke (1960), they appear in late May. Fredeen and Shemanchuk (1960) found larvae in irrigation ditches in Saskatchewan from July 12 to September 4. In Alaska, Jenkins (1948) collected larvae in late July.

Anderson and Dicke (1960) and Stone (1964) report that the preferred attachment sites are rocks and trailing grasses.

Stone and Jamnback (1955) recorded the larval period as lasting from four to five weeks, and Peterson (1959) states that the necessary time for development ranges from two to five weeks.

Anderson and DeFoliart (1962) found the larvae to be parasitized by Gasteromermis viridis Welch and Isomermis wisconsinensis Welch (Enoplida: Mermithidae), but the importance of this parasitism is not stated.

Pupa. Dimond and Hart (1953) collected one pupa in Rhode Island on September 1. Anderson and Dicke (1960) state that they are present in Wisconsin in the middle of June. In Quebec, Wolfe and Peterson (1959) recorded pupae on June 25. Hocking and Richards (1952) found the first pupa in Labrador on July 10.

According to Peterson (1959), the pupal stage lasts one week.

Enderlein (1921) reported finding Ademon decrescens Nees and Grypocampa affinis Nees (Hymenoptera: Braconidae) in the
pupa in Europe.

**Adults.** Frost (1949) took adults in a light trap in Pennsylvania on June 14. In Utah, according to Peterson, they are active from April to mid-September. Walker (1927) collected adults in Canada in July, and Wolfe and Peterson (1959) report activity in Quebec from mid-July to late August. Hocking and Richards (1952) took the first adult in Labrador on July 26.

Anderson and DeFoliart (1961) report that the adults prefer wooded areas, and Bennett (1960) states that they are most commonly found well above ground level.

Fallis and Smith (1964) found that the adults were attracted to a source of CO$_2$ placed in the forest canopy.

Davies (1959) states that the adults are parasitized by larval Sperchonidae (Hydracarina) which gain access when the adults emerge from the water. How detrimental these parasites are is unknown.

**Oviposition.** Davies and Peterson (1956) and Fredeen (1959) observed that the eggs are laid in batches on objects at the surface of the water. The former author found that the eggs may also be laid free while in flight. Stone and Jamnback (1955) state that the eggs are laid one layer thick on grass or leaves.

Davies and Peterson (1956) found egg-laying to occur from May to the end of June in Utah.

**Importance**

Davies and Peterson (1956), Peterson (1959) and Stone
(1964) agree that this species is not a pest of man. Hocking and Richards (1952) state that man is only slightly bothered in Labrador.

Walker (1927) collected *S. aureum* (= *bracteatum*) feeding on goslings. Fallis and Bennett (1958) collected them from grouse. Anderson and DeFoliart (1961) state that this species has a wide variety of hosts, and note that it possesses the large bifid claw characteristic of all ornithophilic species. They recorded females feeding on a turkey.

Anderson and DeFoliart (1961) found that this species prefers to feed on birds that are resting in trees.

**Disease Relationships**

Walker (1927) noted that goslings died following feeding by this species. He found at least 100 per bird, feeding mostly on the breast and abdomen, few on the back and none on the head. In July, younger ducks all were killed, but the older ones survived. He felt the deaths were due to loss of blood. Fallis et al. (1956) found that the deaths were due to a protozoan, *Leucocytozoon simondi*, transmitted to the ducks by female black flies beginning the last week in May.

Fallis and Bennett (1958), Fredeen and Shemanchuk (1960) and Anderson and DeFoliart (1961) found *S. aureum* females to carry *L. bonasae*, a blood parasite of ruffed grouse. The last authors also found them to carry *L. smithi* in turkeys in Wisconsin.

Bennett and Fallis (1960) believe that they are important vectors of avian trypanosomes, as infective forms were found
in the females. The species were not determined, but Bennett (1961) states that *Trypanosoma avium*, *T. paddae* and *T. gallinarum* are the species involved.

**Simulium corbis** Twinn, 1936

**Distribution**

Stone and Jamnback (1955) state that this species is found in the Hudsonian and Canadian zones. Stone (1964) lists the range as from Alaska to Utah in the west and east to New York and Maine. Jenkins (1948), Jamnback (1956) and Davies et al. (1962) report the species to be widespread but rare.

**Life Cycle**

Wolfe and Peterson (1959) found one generation per year in Quebec. Davies et al. (1962) found it to be univoltine in Wisconsin, but believe that there may be two generations in Alaska. Stone (1964) reports that the species may have multiple generations over most of its range.

**Egg.** Davies et al. (1962) and Stone (1964) share the opinion that overwintering is in the egg stage.

**Larva.** Davies et al. (1962) found larvae in mid-June in Canada.

Stone and Jamnback (1956) and Stone (1964) state that the larvae are found in small, swift rivers, but Davies et al. (1962) found that it occurs more abundantly in rivers over twenty feet in width. Wolfe and Peterson (1959) state that the larvae are found firmly attached below cascades and water-
falls, at water temperatures from 56 to 59°F.

Stone (1964) collected larvae attached to submerged wood. Wolfe and Peterson (1959) state that rocks are preferred.

Anderson and DeFoliart (1962) found the species to be parasitized by nematodes of the family Mermithidae (Enoplida). The extent or effect of this parasitism is not given.

**Pupa.** Stone and Jamnback (1955) report pupae in New York on May 22 (water temperature 53°F.) and as late as June 17. Davies et al. (1962) report one pupa on May 27 (water temperature 65°F.) at Algonquin Park, Ontario. Hocking and Richards (1952) found the first pupa in Labrador on June 16.

Stone and Jamnback (1955) found a pupa attached to a tree stem. Davies et al. (1962) report that the cocoons are attached firmly to rocks and sticks.

**Adult.** Hocking and Richards (1952) report adult activity in Labrador from July 7 to August 18.

**Ovarian development and oviposition.** Davies et al. (1962) state that the females emerge with undeveloped ovaries. Wolfe and Peterson (1959) and Davies et al. (1962) observed that the eggs are laid in flight over rapids.

**Importance**

Downe and Morrison (1957) record this species as feeding on horses and cattle. Wolfe and Peterson (1959) and Hocking and Richards (1952) state that the species is not a pest, or bothers man only slightly.
**Simulium croxtoni** Nicholson and Mickel, 1950

**Distribution**


**Life Cycle**

Davies et al. (1962) and Stone (1964) state that this species is univoltine. The former authors, however, feel that there is a possibility of two generations in Ontario.

**Egg.** Davies et al. (1962) found the larvae in temporary and permanent streams from two to fifteen feet in width. Stone (1964) states that they are found only in small streams, usually in wooded areas.

Stone (1964) found larvae in Connecticut in May, June and July. Davies et al. (1962) report that larvae are found in Ontario until mid-May.

**Pupa.** Stone and Jamnback (1955) found pupae in May and June in New York. Davies et al. (1962), in Ontario, observed pupation to occur in the second half of May. They also found mature pupae on July 10. Hocking and Richards (1952) report the first pupa on June 18 in Labrador.

**Adults.** Davies et al. (1962) report adult activity in Ontario from May 20 to late June.

Fallis and Smith (1964) report that females were attracted to a source of CO₂ placed in the forest canopy.

**Ovarian development and oviposition.** Davies et al.
(1962) state that the newly emerged females have immature eggs and much stored nutrient. They suggest that there may be two gonotrophic cycles.

Davies and Peterson (1957) record that they congregate over bodies of water, possibly for mating.

Nothing is known of oviposition habits.

Importance

Fallis (1964) believes that this is a bird feeder, as it possesses the large basal tooth on the tarsus that is associated with ornithophilic species. Davies et al. (1962) report that they are found feeding on avian blood until late June. Davies and Peterson (1957), in referring to the congregation over water, believe that this may also serve to locate ducks or other waterfowl.

Disease Relationships

Fallis et al. (1946) report that this species is a vector for *Leucocytozoon simondi*, a blood parasite of ducks, in the early part of the black fly season.

Bennett and Fallis (1956) found infective stages of unidentified trypanosomes in the females. They found the incidence to be at least 33%, but felt that it could be much higher, as the detection technique was not wholly accurate.

Bennett (1961) found that the trypanosomes (*Trypanosoma avium*, *I. paddae* and *I. gallinarum*) were transmitted to the birds when the insect defecates while feeding (posterior station development). He states that the incidence ranges from 50% to 90%.
Simulium decorum Walker, 1848

Distribution

Smart (1945) states that this is a Nearctic species. Stone (1964) records it from Alaska to Newfoundland, south to Oregon, Colorado, Arkansas and Florida. Sailer (1953) found it to be a lowland species in Alaska.

Life Cycle

Jenkins (1948) and Wolfe and Peterson (1959) state that there are two generations per year. Jones and Richey (1956), Anderson and Dicke (1960) and Davies et al. (1962) found the species to be multivoltine, with overlapping generations. Stone (1964) feels that the number of generations may depend on the latitude.

Anderson and Dicke (1960) found that the first generation lasted four weeks, and the second three weeks.

**Egg.** Wolfe and Peterson (1959), Anderson and Dicke (1960), Davies et al. (1962) and Stone (1964) agree that overwintering is in the egg stage.

Davies and Peterson (1956) found as many as 72,000 eggs per square inch at one site, on beams and cement walls.

Davies et al. (1962) found that the overwintering eggs hatch in April in Ontario. Wolfe and Peterson (1959) report that the eggs laid by the summer generation hatch within six to ten days.

Fredeen (1959) states that eggs are collected most frequently in June, July and August from objects at the
surface of the water, but that they may also be collected from the stream bed.

**Larva.** Jenkins (1948), Jamnback (1956), Jones and Richey (1956), Wolfe and Peterson (1959), Anderson and Dicke (1960), Fredeen and Shemanchuk (1960), Sutherland and Darsie (1960b), Davies et al. (1962) and Stone (1964) report similar habitats for the larval stage. These include faces of dams or other outlets of bodies of water, sticks and other objects on beaver dams, and objects below outlets of contained water. Davies et al. (1962) add that they are found in streams ranging from one to fifteen feet in width. Wolfe and Peterson (1956) note that the building of logging dams has led to the increase of this species.

Anderson and Dicke (1960) and Stone (1964) have found that larvae often occur in immense numbers in habitats such as those listed above. Wolfe and Peterson (1959) reported that the first generation was the only one to occur in such large populations.

Anderson and Dicke (1960) record that the stream velocity usually is from three to four feet per second, with temperature ranging from 58 to 69°F. Wolfe and Peterson (1959) found larvae present up to a depth of two and one half feet.

Stone (1964) found larvae in Connecticut from July 5 to September 4. Jamnback (1956) states that they may be found in New York from May to October. In New Hampshire, O'Kane (1926) collected large larvae on June 28 and again on August 20. Davies et al. (1962) collected first generation larvae during

Wolfe and Peterson (1959) observed that the newly-emerged larvae moved against the current until they reached the point where the current was greatest.

Anderson and DeFoliart (1962) found the larvae parasitized by nematodes (Enoplida: Mermithidae), but give no indication of their significance.

**Pupa.** Dimond and Hart (1953) found one pupa on May 8 in Rhode Island. Davies et al. (1962) recorded pupation occurring from mid- to late May in Ontario. In Labrador, Hocking and Richards (1952) recorded the earliest pupa on June 15.

Wolfe and Peterson (1959) found pupae to a depth of two and one-half feet.

Anderson and Dicke (1960) found the pupal period to last three to five days.

**Adult.** Stone (1964) found adults in Connecticut on May 26. Davies et al. (1962) collected them in Ontario from May to October. Johannsen (1903) refers to Lugger (1896), who found adult activity in Minnesota during June and July. Hocking and Richards (1952), in Labrador, recorded activity from June 19 to August 18.

Davies and Peterson (1956) found nematodes (Enoplida: Mermithidae) in the adults, but make no statement as to the extent or importance of this parasitism. Davies et al. (1962) state that, at times, this species seems to be controlled
by larval Sperchonidae (Hydracarina) attacking the adults as they emerge from the water.

Ovarian development and oviposition. Davies et al. (1962) state that the early females have much stored nutrient and eggs one-third to one-half grown; later females, emerging in mid-July, have the eggs less mature.

Peterson (1956) and Wolfe and Peterson (1959) observed that the adults emerge, then rest. The latter authors found that the males emerge two to three days ahead of the females.

Davies and Peterson (1956) found active spermatozoa in the males ten minutes after emergence.

According to Davies and Peterson (1956), mating can occur shortly after emergence, even before the integument hardens, while the adults are crawling on the rocks. Wolfe and Peterson (1959) and Davies et al. (1962) observed gravid females mating with newly emerged males, just prior to oviposition (which they feel takes place shortly after emergence).

Davies and Peterson (1956) observed males crawling over newly-laid eggs and dipping the tips of their abdomens, indicating the possibility of external fertilization. Mating also was observed between males and ovipositing females.

Davies et al. (1962) state that no blood meal is necessary for the first oviposition of the first generation and they recorded oviposition in Ontario from May 20 to October 9.

Davies and Peterson (1956) state that oviposition occurs
between 6:00 a.m. and 8:30 p.m. Peterson (1956), observed ovipositing females by flashlight on a warm, dark night in Utah.

Davies and Peterson (1956), Peterson (1956), Wolfe and Peterson (1956) and Davies et al. (1962) agree that oviposition occurs either while in flight or on objects at the surface of the water.

Davies and Peterson (1956) observed females ovipositing while flying upstream or at an angle to the current. The eggs were laid singly at the rate of one or two dips per trip. Many females were washed away. They believe that water pressure at the tip of the abdomen aids in oviposition.

Davies and Peterson (1956), Wolfe and Peterson (1959), and Davies et al. (1962) report that oviposition while the females are at rest takes place only where the object is sprayed with water, damp, or has a thin film of moisture over it. Davies and Peterson (1956) observed that the female probed the surface with the forelegs until a suitable surface was found. The eggs were then laid one at a time in an irregular mass.

Importance

Osborn (1896) considered this species as a pest of domestic animals. Johannsen (1903) reports that Lugger (1896) found them to show a preference for cattle. Downe and Morrison (1957) found them to feed on horses and cows. Anderson and DeFoliart (1961), Davies et al. (1962) and Stone (1964) list horses, cattle and deer as hosts, and the latter
two publications state that birds are occasionally attacked.

Attacking Man

Johannsen (1903) observed the females to be numerous and bloodthirsty in Minnesota.

Wolfe and Peterson (1959) consider that in spite of the fact that this species congregates about man, no feeding takes place.

Davies and Peterson (1956) and Davies (1959) report that this species is of minor importance biting man in Ontario.

According to Hocking and Richards (1952), the females readily attack man in Labrador.

**Simulium gouldingi** Stone, 1952

Distribution

According to Stone (1964), this species is found across the Hudsonian and Transition zones in Alaska, Manitoba, New Hampshire, New York and Pennsylvania.

Life Cycle

Davies et al. (1962) and Stone (1964) observe that this is an univoltine species.

**Egg.** Davies et al. (1962) and Stone (1964) state that overwintering occurs in the egg stage.

**Larva.** Stone and Jammback (1955) found the larvae in a few permanent streams flowing through heavily wooded areas. They were reported by Davies et al. (1962) to inhabit shallow streams, one to four feet wide, just at the edge of woods. In Connecticut, Stone (1964) collected larvae from May
through July. Stone and Jamnback, in New York, collected them from May 28 to July 2. In Ontario, Davies et al. (1962) found larvae from early May until the latter part of July.

*Simulium gouldingi* amounted to approximately eight per cent of the collections made in New York by Stone and Jamnback (1955) in June. Jamnback (1956) lists this as a rare species in New York, but states that the larvae may be locally abundant.

**Pupa.** Stone and Jamnback (1955) collected pupae in New York from June 10 to July 1. In southern Ontario, Davies et al. (1962) found pupation to begin about mid-May, at water temperatures of 50 to 60°F.

**Adult.** Davies et al. (1962) report adults flying until at least August 4 in Ontario.

**Ovarian development and oviposition.** Davies et al. (1962) state that the adult females, on emergence, have undeveloped eggs and little stored nutrient.

**Importance**

Davies et al. (1962) and Fallis (1964) observe that the females have the large bifid tarsal claw that is associated with bird-feeding. The former authors state that it has well-developed mouthparts, and is therefore presumably ornithophilic. Stone (1964) notes that nothing is known of the feeding habits.
Simulium latipes (Meigen), 1804

Distribution

Smart (1945) lists this species as Palearctic and Oriental in range. Stone (1964) gives the North American distribution from Alaska to Maine, south to California, Wisconsin and Pennsylvania. He adds that the specimens from this continent do not exactly agree with those from Europe. Davies et al. (1962) believe this to be a species complex.

Life Cycle

Stone and Jamnback (1955) recorded one generation per year in the Adirondacks, agreeing with Edwards (1920). Wolfe and Peterson (1959) found two generations in Quebec. Davies et al. (1962) state that there are two or more generations per year in Ontario. Stone (1964) considers the species to be univoltine.

Egg. Stone and Jamnback (1955) believe that S. latipes overwinters in the egg stage in the Adirondacks. Stone (1964) and Davies et al. (1962) agree with this opinion.

Larva. Wolfe and Peterson (1959) state that in Quebec, overwintering is in the larval stage, as in Great Britain. Stone and Jamnback (1955) state that larvae are found only in temporary streams in the Adirondacks. Stone (1964) found them in small semipermanent streams with rocky or gravelly bottoms. Davies et al. (1962) found the species to occur in all sorts of streams and rivers.

Wolfe and Peterson (1959) found mature larvae in several
streams at 40°F. Jenkins (1948), in Alaska, found them from sea level to 1000 feet, at an average temperature of 52°F, and average pH of 7.5.

Stone and Jamnback (1955) state that the larvae are present in May in the Adirondacks. Davies et al. (1962) found the larvae emerging in mid-April in southern Ontario. In Alaska, Jenkins (1948) found larvae in mid-June.

Anderson and DeFoliart (1962) report that the species is parasitized by nematodes (Enoplida:Mermithidae), but the importance of this parasitism is not given.

Pupa. Stone and Jamnback (1955) found that pupation takes place in June in New York. Hocking and Richards (1952) recorded the earliest pupa in Labrador on June 18.

Adult. Davies et al. (1962) state that adults are present from mid- to late May in Ontario. Hocking and Richards (1952) found adult activity in Labrador from July 19 to August 13. Sailer (1953) collected adults in the lowlands of Alaska in October.

Fallis and Smith (1964) report that the females are attracted to a source of CO₂ placed in the forest canopy. Davies (1959) found the adults to be parasitized by larval Sperchonidae (Hydracarina).

Ovarian development. Davies et al. (1962) report that the females emerge with undeveloped eggs and varying amounts of stored nutrient.

No information was found on oviposition habits.
Importance

Davies et al. (1962) and Anderson and DeFoliart (1961) state that the females feed on various birds, and have the large bifid tarsal claws of the ornithophilic species. Fallis and Bennett (1958) report feeding on ruffed grouse. Stone (1964) lists birds and cattle as hosts.

Attacking Man

Stone and Jamnback (1956) and Wolfe and Peterson (1959) state that this is not a pest of man. Stone (1964) lists man as a host, and Cloudsley-Thompson (1955) states that the females feed on man in Iceland.

Disease Relationships

Anderson (1956) found that the females carry _Ornithofilaria fallinsensis_ to birds during the early part of the black fly season.

Fallis and Bennett (1958) collected females from ruffed grouse and found them carrying infective sporozoites of _Leucocytozoon bonasae_, a blood parasite.

Bennett (1961) found this species to carry _Trypanosoma avium, T. paddae_ and _T. gallinarum_, blood parasites of birds.

_Simulium parnassum_ Malloch, 1914

Distribution

Stone (1964) states that this species is confined to the Appalachian Mountains and its foothills, from Ontario and Nova Scotia to Tennessee and Georgia.
Life Cycle

Stone and Jamnback (1955), Davies et al. (1962) and Stone (1964) agree that this species is univoltine.

**Egg.** Davies et al. (1962) states that overwintering is in the egg stage.

**Larva.** Stone and Jamnback (1955) and Stone (1964) observed that the larvae preferred cool, permanent streams, and the former authors added that they preferred heavily forested areas. Davies et al. (1962) found them in only one stream in Ontario, at 65°F.

Stone and Jamnback (1955) collected larvae on June 2 in New York. Jamnback (1956) reports that they are found in New York in June and July, but are rare. Davies et al. (1962) collected larvae in Ontario on August 4 and August 6, but believe that mature larvae must have been present prior to this date.

**Pupa.** Stone and Jamnback (1955) found pupae in New York on June 28. Davies et al. (1962) collected them in Ontario on August 4 and August 6, at a water temperature of 65°F.

**Adult.** Stone (1964) states that the adults are present in July and August in the north, and somewhat earlier in the south. Stone and Jamnback (1955) collected them from June to August 16 in New York. Davies et al. (1962) report that adults appear in Ontario in mid- to late June, and may continue into August in moist years. Hocking and Richards (1952) collected adults on August 8 and August 16 in Labrador.
Ovarian development and oviposition. Davies et al. (1962) state that the females emerge with undeveloped eggs and moderate to large amounts of stored nutrient. They have mature eggs seven days after feeding.

No reference could be found to oviposition habits.

Importance

Fuller (1940) found a female feeding on the abdominal wall of a dead woodchuck in Westboro, Massachusetts. Downe and Morrison (1957) state that it feeds on horses and cattle.

Stone and Jamnback (1955) observed that the females were annoying to man, but did not bite. Stone (1964) states that it feeds occasionally on man, but this is rare. The adults annoy man by swarming around him. Wolfe and Peterson (1959) found it to bite man in Quebec. Hocking and Richards (1952) state that it attacks man in Labrador.

Davies and Peterson (1962) state that *S. parnassum* females are aggressive biters in Algonquin Park, Ontario. They rank them as the third most troublesome black fly, following *S. venustum* and *P. hirtipes*.

Disease Relationships

Peterson and Wolfe (1958) state that *Ornithofilaria fallensis*, a blood parasite of birds, is carried by this species.

**Simulium rivuli** Twinn, 1936

Distribution

According to Stone (1964), this species has been recorded
from Connecticut, New Hampshire, Ontario and Quebec.

Life Cycle

Stone (1964) states that the larvae appear to prefer small, temporary streams that run over pebbly or stony bottoms. He collected larvae on April 11 in Connecticut. In Ontario, Davies et al. (1962) found half-grown larvae in mid-April, in water at temperatures of 47 to 49°F.

Stone (1964), in Connecticut, found pupae from April 11 to May 10. In southern Ontario, according to Davies et al. (1962), pupation occurred from late April to early May.

Davies et al. (1962) found adult emergence in Ontario in early June. They state that the females contain immature eggs and some stored nutrient. According to these authors, the adults have well-developed mouthparts, and Fallis (1964) notes that the strongly bifid claws make them suspect as bird-feeders.

*Simulium tuberosum* (Lundstrom), 1911

Davies et al. (1962) report that this is a complex of two or more undescribed species in Ontario, all probably distinct from the Palearctic form. Landau (1962) examined the morphology of the salivary chromosomes, and found four well-defined sympatric breeding units, and perhaps a fifth.

Distribution

Smart (1945) states that this species is Palearctic. Stone and Jammback (1955) list it as Holarctic. Stone (1964) gives a North American distribution from Alaska to Greenland.
and south to California, Texas and Florida.

**Life Cycle**

Wolfe and Peterson (1959) state that there are four generations per year in Quebec. Davies et al. (1962) found at least three generations in Ontario. Stone (1964) feels that there may be one to four generations per year, depending on the stream type and latitude.

**Egg.** Davies et al. (1962) and Stone (1964) agree that overwintering is in the egg stage.

**Larva.** Jamnback (1956), Wolfe and Peterson (1959), Landau (1962), Davies et al. (1962) and Stone (1964) found larvae in all types of permanent streams and rivers. Fredeen and Shemanchuk (1960) collected them in small numbers in irrigation canals in Saskatchewan and Alberta.

Dimond and Hart (1953) collected one larva in Rhode Island on September 6. Jamnback (1956) and Stone (1964) state that larvae are abundant from May to October in New York. Davies et al. (1962) found the larvae hatching in May in Ontario, while Landau (1962) states that they are common from late April to November in the same area.

Wolfe and Peterson (1959) found the third generation to be the largest in Quebec.

Sailer (1953) states that this is a lowland species in Alaska.

In Utah, Peterson (1956) found that the larvae prefer water velocities between 0.82 and 3.7 feet per second.

McComb and Bickley (1959) and Anderson and DeFoliart
(1962) found them to be heavily parasitized by nematodes (Enoplida:Mermithidae). No statements were made as to the effect on the population.

Pupa. Davies et al. (1962) collected pupae as late as October 9 in Ontario. Stone (1964) found them in September in Connecticut.

Adult. Stone (1964) reports adults active on May 15 in Connecticut. Peterson et al. (1962) state that in Ontario, they appear in late May to early June and continue into October. Sailer (1953) found them in July and August in Alaska.

Davies (1959) found larval Sperchonidae (Hydracarina) attacking the adults as they emerged from the water.

Oviposition. Wolfe and Peterson (1959) and Davies et al. (1962) found oviposition to occur in calm water. The females alighted on the surface, "poured out" a stream of ten to twenty eggs, flew, and then repeated the process. The eggs sank to the bottom.

Importance

Downe and Morrison (1957) found that in a barn, cows, horses and one chicken were attacked. Peterson (1956) collected the females on squirrels in Utah. Wolfe and Peterson (1959) and Davies et al. (1962) state that domestic animals are subject to attack.

Attacking Man

Wolfe and Peterson (1959) found them to bite man in only one locality in Quebec, in August, but believe this to
be unusual for this area. Peterson (1956) reports that they rarely attempted to bite below 7000 feet in Utah.

Anderson and DeFoliart (1961) and Davies et al. (1962) state that *S. tuberosum* does attack man. Jamnback (1952) found them to be one of the last species to attack man during the black fly season, and thought that perhaps only the first generation was attracted. Collins and Jamnback (1958) found them sufficiently annoying in New York to warrant control.

**Simulium venustum** Say, 1823

**Distribution**

Coquillet (1898) states that the range of *S. venustum* is "countrywide." In the opinion of Smart (1945), the species is Holarctic in distribution. Stone (1964) calls it one of the commonest species of Simuliidae in America.

**Life Cycle**

Conradi (1905) reported that the life history lasted five to nine weeks, depending on the breeding conditions. Peterson and Wolfe (1958) indicate that the period of time from egg to egg is approximately thirty days during the summer.

During the summer, Conradi (1905) found no distinct definition of broods, with all stages present. Three to four generations per year were reported in Illinois by Jobbins-Pomeroy (1916). In Rhode Island, Dimond and Hart (1953) calculated that there were five generations in 1952.
Twinn (1933) found three or four overlapping generations per year. Anderson and Dicke (1960) simply note that there are multiple generations. On the other hand, Stone and Jamnback (1955) and Bickley (1959) found apparently one generation per year in New York and Maryland.

**Egg.** Dimond and Hart (1953), Stone and Jamnback (1955), Davies and Peterson (1956) and Peterson and Wolfe (1958) share the view that _S. venustum_ overwinters in the egg stage. Davies et al. (1962) found that the incubation period averages four days at 75°F., six days at 65°F., and about 27 days at 45°F.

**Larva.** O'Kane (1926) found "large larvae" in New Hampshire in May, and interpreted this as meaning that the species had overwintered in the larval stage.

In describing the ideal breeding grounds, Conradi (1905) stated that the species needed a shallow, sunlit stream with the water rippling over a pebbly bottom. O'Kane (1926) added that a constant flow was important. Dimond and Hart (1953) found no preference for warm or cold streams.

Anderson and Dicke (1960), Sutherland and Darsie (1960b) and Stone (1964) agree that the larvae prefer small, permanent streams, but add that they are also found in larger streams and rivers. Stone and Jamnback (1955) found them in both large and small permanent streams. Davies et al. (1962), however, report that the larvae are more common in large, permanent streams, but are found in a wide variety of
stream sizes.

In Maryland, McComb and Bickley (1959) found larvae during April and May. In Rhode Island, Dimond and Hart (1953) report finding "third and fourth instar larvae" on April 7. Stone (1964) first found larvae in Connecticut on April 9. Stone and Jamnback (1955), in New York, found "large larvae" (presumably they meant mature larvae) first appearing during the latter half of May. Davies et al. (1962), in Ontario, observed that the larvae hatched in mid- to late April in the south, and in early May further north.

Fredeen and Shemanuchuk (1960) report that the larvae attach mainly to vegetation, but Davies et al. (1962) found them to be indiscriminate as to substrate.

Jenkins (1948), in Alaska, counted as many as 100,000 larvae per square foot.

Peterson and Wolfe (1958) record the larval period as lasting 15 to 18 days.

Anderson and Dicke (1960) report that parasitism by nematodes and sporozoa may reach 50% to 60%, but give no figures on mortality.

**Pupa.** Dimond and Hart (1953) first found pupation in Rhode Island on April 20, agreeing closely with Stone (1964), who reported pupation in Connecticut on April 21. Hocking and Richards (1952) first collected pupae in Labrador on June 13.

Jobbins-Pomeroy (1916) recorded the pupal period as
varying from five to seven days up to three weeks, depending on the temperature. Hocking and Pickering (1952) found the male pupal stage ranged from four to seven days, and the female four to nine days. According to Peterson and Wolfe (1958), the time varies from five to eight days at 55° to 60°F.

Stone and Jamnback (1955) describe the cocoon as being simple and vase-shaped with the anterior margin thickened.

**Adults.** Frost (1949) collected adult *S. venustum* in light traps from May 21 to July 3 in Pennsylvania. In Rhode Island, Dimond and Hart (1953) found the species to be prevalent all during the summer, but give no specific dates. Stone (1964) reports finding adults on May 25 in Connecticut. Adults were found flying and feeding in New York from May to early July by Stone and Jamnback (1955). Conradi (1905) reported that the species bit in early May in southern New Hampshire, and started about May 20 in the northern section. In Labrador, Hocking and Richards (1952) found adults present from June 18 to September 5. Davies and Peterson (1956) recorded feeding in late May and June in Algonquin Park, Ontario, and they and Davies et al. (1962) report continued feeding as late as mid-July, with an occasional period of activity in September and early October. In Alaska, Sailer (1953) collected adults from July to October, and classified this as a lowland species.

Anderson and DeFoliart (1961) observed that during the peak period of adult population, activity continued all
during the day.

At Algonquin Park, Ontario, Peterson (1962) observed a mating swarm on May 31, at an air temperature of 62°F.

Commenting on the longevity of the adults, Davies (1953) reports that the adults apparently can live two or three weeks, but 75% die sooner. Unfed females in the laboratory lived as long as 37 days, but this was rare. Wild flies caught before a blood meal lived longer than those which had fed, and females lived longer than males.

Ovarian development and oviposition. Davies (1963) states that the female of *S. venustum* is anautogenous, and Davies and Peterson (1956) found that they may have two gonotrophic cycles.

Oviposition was recorded by Davies and Peterson (1956); in 1947, they found the period to be from June 6 to August 22, but in 1955, they found a few females on May 21 that had retained a few mature eggs from a prior oviposition.

Jobbins-Pomeroy (1916) estimated that the females lay about 350 eggs, with the total number probably not exceeding 500.

According to Davies and Peterson (1956) and Davies et al. (1962), the eggs are laid in mats on vegetation at or just below the surface of the water, preferably glabrous green surfaces. The latter authors also add that the eggs may be several layers deep. The egg mass is hydrophilic. Egg-laying always starts at the edge of the leaf. Fredeen (1959) found eggs on all objects at or near the surface of the
water. Davies et al. (1962) found that if vegetation is lacking, the eggs may be laid in flight over the stream.

**Dispersal.** Hocking and Richards (1952) made observations in an area in Labrador that had been sprayed for a radius of six miles for black fly control. They occasionally collected flies at the center of this area, indicating a flight range of at least six miles. Peterson and Wolfe (1958) comment that in forested areas, the adults may be carried by the wind for distances up to five miles. The species has a ten mile flight range according to Fredeen (1958).

**Importance**

Osborn (1896), Johannsen (1903), Conradi (1905), Twinn (1933), Jenkins (1948), Frohne and Sleeper (1951), Jamnback (1952), Davies and Peterson (1956), Collins and Jamnback (1958) and Anderson and DeFoliart (1961) all emphasize the fact that *S. venustum* is an extremely troublesome pest. Davies and Peterson (1956), in particular, state that this "is the most important bloodsucker across northern Canada, certain parts of southern Canada, Alaska and the northeastern United States."

Osborn (1896) listed *S. venustum* as a pest affecting domestic animals, and Fredeen (1958) found that milk productivity of cattle was reduced by the feeding. Anderson and DeFoliart (1961) and Stone (1964) list man, horses, cattle, deer and sheep as being attacked, and the latter author adds that it occasionally is found on birds. Davies
and Peterson (1956) and Davies et al. (1962) say that birds are attacked only when sparsely feathered, as the females have trouble crawling through full plumage. They extend the host range to include all mammals. According to Downe and Morrison (1957), horses are attacked more often than cows, and Anderson and DeFoliart (1961) found that brown horses are more attractive than bay or white horses.

Hocking and Pickering (1954) and Davies and Peterson (1956) found the adults on flowers, and Davies (1958) showed that sugar is necessary for normal adult activity.

Attacking Man

Davies (1951) reported that this species accounted for over 90% of the black flies landing on dark clothing, and added (1952) that at Algonquin Park, Ontario, it accounted for over 80% of the species flying, landing or biting. Anderson (1956) reports that *S. venustum* is the most numerous anthropophilic black fly at Algonquin Park.

McComb and Bickley (1959) obtained two biting records in Maryland, but concluded that the adults were never abundant. Jamnback (1952), in New York, recorded data that indicated that the first generation was attracted to man, but not the subsequent generations. In one location in Alaska, Sailer (1953) found the females biting heavily at 59°F, but concluded that they are only locally important, since they were not biting elsewhere, although present.

Wolfe and Peterson (1960) found that the females prefer to feed on the back of the neck and the ears.
Disease Relationships

O'Roke (1930) considered S. venustum females to be the vector of Leucocytozoon simondi (= anatis), the causative agent of a blood disease of ducks. The same view was held by Chernin (1952), although no actual transmission was shown in either case. Shewell (1955) disproved the relationship, as he showed that although the parasite could be ingested with a blood meal, no development took place. He proved that the species carrying the disease was one resembling S. venustum.

In 1954, Anderson stated that the females of this species were the vector of Ornithofilaria fallisensis Anderson, a blood parasite of waterfowl, although no actual transmission was demonstrated. Anderson (1956) then showed that the adults could be infected with the nematodes in the laboratory, but that it did not normally transmit them in nature. Peterson and Wolfe (1958), however, say that the female of S. venustum is the vector.

Simulium verecundum Stone and Jamnback, 1955

Distribution

Wolfe and Peterson (1959) report that this appears to be a widespread species in North America. Stone (1964) gives the distribution from Alaska, Washington, Manitoba and Wyoming in the west, and from Wisconsin to Nova Scotia and south to Virginia, as well as Alabama and South Carolina.
Life Cycle

Stone and Jamnback (1955) state that this species apparently has two or three generations per year in New York. Anderson and Dicke (1960) merely state that there are multiple generations.

**Egg.** Davies et al. (1962) feel that this species probably overwinters in the egg stage. Stone and Jamnback (1955) seem to share this opinion, as they believe its biology to be similar to that of *S. venustum*.

**Larva.** Anderson and Dicke (1960) state that the larval preference is for smaller permanent or semipermanent streams, but they are also found in larger streams and rivers. Davies et al. (1962) found them to prefer streams over ten feet wide, but took them from a small stream that drained a pond.

Davies et al. (1962) report that the larvae emerge in late April to early May in Ontario. They have collected them in June in central and northern Ontario.

Anderson and Dicke (1960) note that the larvae are frequently parasitized up to 50 and 60% by nematodes (*Mermithidae: Enoplida*) and Sporozoa (*Protozoa*), but they give no mortality data.

**Pupa.** Davies et al. (1962) collected pupae in June in central and northern Ontario.

**Adult.** Stone and Jamnback (1955) and Stone (1964) state that the adults emerge somewhat later than *S. venustum*. Wolfe and Peterson (1959) believe this to be a late summer
species in Quebec. Davies et al. (1962), in Ontario, took adults in late May and June.

Wolfe and Peterson (1959) note that this is not an annoying species.

**Simulium vittatum** Zetterstedt, 1838

Davies et al. (1962) commented that the species might actually be a complex of at least two species in Ontario. Pasternak (1964) compared the larval salivary chromosome morphology of collections from Alaska, Saskatchewan, Manitoba, Wisconsin, Quebec, New York, Vermont and New Hampshire. He concluded that no siblings are present, but that the species is highly polymorphic, probably due to the exploitation of a wide range of niches.

**Distribution**

Smart (1945) states that this is an Holarctic species. Stone (1964) says that on the North American continent, the range is from Alaska to Greenland, south to Georgia and California.

**Life Cycle**

Dimond and Hart (1953) found four generations per year in Rhode Island. Stone and Jamnback (1955) state that there are at least three generations in the Adirondacks. Anderson and Dicke (1960) believe that there are four or five in Wisconsin. Wolfe and Peterson (1959) found three generations and a small fourth in Quebec, and Fredeen and Shemanchuk (1960) found four in Saskatchewan and Alberta. Jenkins (1948)
recorded two or three generations per year in Alaska. Davies et al. (1962) merely comment that this is a multivoltine species, and Stone (1964) believes that the number of generations per year depends on the latitude.

**Overwintering.** Dimond and Hart (1953) state that overwintering is in the larval stage in Rhode Island, as do Stone and Jamnback (1955) in New York, Davies et al. (1962) in Ontario, and Fredeen (1958) and Fredeen and Shemanchuk (1960) in western Canada.

Anderson and DeFoliart (1962) report that overwintering is in the egg stage in small streams.

Wolfe and Peterson (1959), Anderson and Dicke (1960) and Stone (1964) observe that overwintering can take place both as egg or larva, even in the same stream.

**Egg.** Anderson and Dicke (1960) found overwintering eggs to hatch when the temperature reached 33 to 35°F.

**Larva.** Jenkins (1948), Dimond and Hart (1953), Stone and Jamnback (1955), Jamnback (1956) and Fredeen (1958) agree that the larvae are found in streams draining ponds, lakes or swamps. Edmunds (1954) and Fredeen and Shemanchuk (1960) found them breeding in irrigation canals. Jobbins-Pomeroy (1916) and O'Kane (1926) said that they preferred streams with a small and even flow of water, and Jenkins (1948) also collected them from slow streams. Sutherland and Darsie (1960b) recovered them from rivers and large streams. Stone (1964) sums up by noting that the larvae of *S. vittatum* can occur in almost any flowing water, sometimes
in immense numbers.

Dimond and Hart (1953) found large (but not mature) larvae in Rhode Island in December, and these were still abundant April 3. O’Kane (1926) records larvae on May 24 in New Hampshire, through September 16. Anderson and Dicke (1960), in Wisconsin, collected mature larvae during the last week in April. Fredeen and Shemanchuk (1960) found larvae on April 17 in Alberta and Saskatchewan. Jenkins (1948) records larvae in early May in Alaska.

Wolfe and Peterson (1959) observed that the larvae are found initially on rocks, but move to grass and vegetation when the rocks become covered with algae. Fredeen and Shemanchuk (1960) found them only where plankton were plentiful.

Anderson and Dicke (1960) believe that the larval period is controlled by temperature. The overwintering population requires six months to develop with the temperature ranging from 32.5 to 41.0°F. During the summer, at temperatures averaging 60°F., they found the larval period to last three weeks. Wolfe and Peterson (1959) state that developmental time is 30 days. According to Davies et al. (1962), the summer generations can withstand water temperatures over 80°F.

Wolfe and Peterson (1959) found the later generations to be smaller than the first, and believed this may have been due to the high stream temperatures.

Peterson (1956) found the larvae in water flowing at
speeds ranging from 0.82 to 5.5 feet per second. At those speeds under 1.2 feet per second, they were often found under the surfaces of sticks and leaves, possibly to escape sediment. Anderson and Dicke (1960) believe that the larvae can withstand high amounts of particulate matter in the water, and up to 76% of the gut contents was found to be inorganic.

Fredeen and Shemanchuk (1960) found that of all the species studied, only _S. vittatum_ was found at high pH and extremes of salinity and dissolved oxygen, but gave no exact values.

Anderson and Dicke (1960) found five to eight per cent of the overwintering larvae to contain nematodes. Anderson and DeFoliart (1962) state that nematode (Enoplida: Mermithidae) parasitism ranges from 49% to 93% in small, muddy-channeled streams, and Fredeen and Shemanchuk (1960) report that nematode infestation is responsible for larval scarcity in some spots. Twinn (1939) and Fredeen and Shemanchuk (1960) state that the exit route of the nematodes is via the anus.

Twinn (1939) found the larvae to be attacked by _Thelohania varians_ Leger (Protozoa). Fredeen and Shemanchuk (1960) reported microsporidia of the genus _Nosema_, leeches (_Mooreobdella fervida_) and small fish attacking larvae of this species.

_Pupa_. Dimond and Hart (1953) recorded pupae as early as February 21 in Rhode Island. Stone and Jamnback (1955)
observed that pupation could, on rare occasions, occur during the winter in New York. Fredeen and Shemanchuk (1960) found pupae in all extremes of habitat from April 17 to September 30 in Alberta and Saskatchewan. In Labrador, Hocking and Richards (1952) collected the first pupa on June 7.

Stone and Jamnback (1955) and Anderson and Dicke (1960) found the pupal period to last three or four days during the summer. The latter authors found the temperature at this time to be 60°F.

Adult. Frost (1949) took adults in light traps in Pennsylvania from May 28 to September 9. Stone and Jamnback (1955) state that they are present from April to November in New York. Davies et al. (1962) observe that emergence is in mid-April in southern Ontario, and in early May at Algonquin Park. Davies and Peterson (1956) recorded adults in Ontario on May 3. Judd (1957), in Ontario, reported adult activity from May 15 to November 15. He also notes that, ninety miles eastward, they flew from April to October. Anderson and DeFoliart (1961) state that adults are present in Wisconsin from May through September. In Labrador, Hocking and Richards (1952) recorded earliest adult activity on June 12. Sailer (1953) found adults in the lowlands of Alaska from July to September.

Peterson (1956) observed that in Utah, the adults flew from the water, but in Ontario, they crawled out, then rested. Anderson and Dicke (1960) recorded adult emergence when the
water temperature was 52°F.

Davies and James (1965) report that both males and females are attracted to bait made of decaying beef.

Davies and Peterson (1956) collected males in a mating swarm with _P. hirtipes_ and _P. multidentatum_. Peterson (1962) notes that the swarming movements of the males are the same as _S. venustum_ (described elsewhere).

Davies (1959) found the adults to be attacked by larval Sperchonidae (Hydracarina) that attach themselves as the imagos emerge.

**Ovarian development and oviposition.** Davies et al. (1962) state that the early females are entirely autogenous, but that the later ones are only one per cent autogenous. Wolfe and Peterson (1959) found that a meal is not always required for oviposition initially, but subsequent ovarian cycles require blood.

Downes (1958) found that the females developed mature ovaries when fed on sugar and water. Davies and Peterson (1956) state that they develop mature eggs five days after emergence in the laboratory.

Wolfe and Peterson (1959) believe that the females probably lay about 300 eggs. Stone and Jamnback (1955) and Wolfe and Peterson (1959) observed that the eggs are laid in a very distinctive string. The former authors record that many females often lay their eggs in the same spot.

Jobbins-Pomeroy (1916) found oviposition to take place on grass blades. Fredeen (1959) states that they are laid
on objects at the surface of the water. Davies and Peterson (1956), Peterson (1956) and Davies et al. (1962) agree that while solid objects at the surface of the water are preferred, eggs may also be laid while in flight over streams. Peterson (1962) observed females ovipositing over a lake.

**Dispersal.** Wolfe and Peterson (1959) collected adults in Quebec ten miles from the nearest breeding place. Fredeen and Shemanchuk (1960) report that infestations in irrigation systems in western Canada result from gravid females flying into the area from permanent streams.

**Importance**

Edmunds (1954), Stone and Jamnback (1955), Downe and Morrison (1957), Wolfe and Peterson (1959), Anderson and DeFoliart (1961), Davies et al. (1962), Anderson and Voskul (1963) and Stone (1964) all state that cattle and horses are attacked. Downe and Morrison (1957) add pigs to the list, and indicate that horses are attacked more readily than cows. Wolfe and Peterson (1959) state that moose is a host in western Canada, and Fallis (1964) found them on the ears of sheep. Davies and Peterson (1956) comment that this species varies over the continent as to its feeding habits.

Anderson and DeFoliart (1961) state that females of *S. vittatum* feed heavily on livestock, and Fredeen (1958) and Anderson and Voskul (1963) found milk productivity to be reduced. The former author found the females feeding
even when ice formed on the streams.

Davies and Peterson (1956) collected adults feeding on nectar.

Attacking Man

Judd (1957) found that *S. vittatum* females were annoying, but did not bite. Davies and Peterson (1956) found that in Ontario, the females may occur in a dense cloud, but not bite. Stone (1964) states that they may be quite bothersome by entering the eyes, ears, mouth and nose, but that they do not bite.

Cloudsley-Thompson (1955) reports that this species is a biting pest in Iceland. Peterson (1956) found them biting man in Utah at altitudes above 7000 feet. In Canada, Davies et al. (1962) obtained two biting records, and Wolfe and Peterson (1959) recorded them as a biting species in the West.

**Twinnia tibblesi** Stone and Jammback, 1955

**Distribution**

Stone (1964) states that this species has been collected in New Hampshire, Vermont, New York and Labrador, and Davies et al. (1962) records it from one location in Ontario.

**Life Cycle**

According to Stone (1964), this is a very rare species about which little is known. He believes that it has only one generation per year. Davies et al. (1962) state that it is a univoltine species.
Egg. Stone (1964) feels that the species probably overwinters in the egg stage. Davies et al. (1962) found eggs in small numbers scattered on the bottom of cold, spring-fed streams.

Larva. Stone (1964) states that the larvae are found in small, permanent brooks. Davies et al. (1962) found them emerging in Ontario in mid-April, at water temperatures just above freezing.

Stone and Jammback (1955) record larvae in New York on April 8 and April 24.

Davies et al. (1962) found the larvae grazing in the organic silt on the bottom of streams with water temperatures below 50°F.

Pupa. Davies et al. (1962) state that pupation begins at the end of May in southern Ontario. The pupa is enclosed in a thick bag of silk on the underside of leaves and pieces of wood.

Adult. Davies et al. (1962) believe that the adults mate and oviposit within a few hours of emergence. The females possess a few large, mature eggs when they emerge. Stone (1964) notes that the short, untoothed mouthparts suggest that the females do not take blood.
III. STREAM CLASSIFICATION

As part of the preliminary investigations during 1964, attention was given to the physical characteristics of the streams and rivers in Western Massachusetts. A simple classification system, based on such criteria as stream bed, vegetation, and water speed would facilitate the description of the habitats of the various species.

Flowing water where the immature stages of Simuliidae are found falls into two natural categories, temporary and permanent. Temporary streams are those that always become dry at some time of the year; permanent streams have water present during the entire year, although flow may be reduced considerably during the summer months.

The following classification system is modified from Anderson and Dicke (1960).

Temporary Streams

Ground runoffs is a category which I have added as relevant to stream classification in Western Massachusetts. These streams are no more than three or four inches in width, and have an ill-defined course. They are usually found flowing through forested areas. The bed is composed of dead leaves, with occasional patches of sand. When dry, they leave almost no trace of their existence.

Bog seeps are defined as streams usually about six inches wide and one foot deep, with grasses usually present.
They are found in rather flat terrain. Drying is usually completed by the end of May. In Western Massachusetts, I would modify this category to include streams varying in width from a few inches up to two feet. The course is well-defined, with a bed of sand, mud or silt; few waterfalls are present, and those that occur are the result of the watercourse channeling over flat rock outcroppings. Small rocks are often found delineating the borders of these streams, and vegetation is often present, either growing from the streambed or trailing in the water.

Draining creeks are those streams varying from six inches to several feet in width, with a bed composed of sand, small pebbles and stones. During the early spring there is usually considerable flow, but drying is usually complete by mid-June, leaving a well-defined watercourse. There are many small waterfalls and rapids present, and the water depth ranges from a few inches to one or two feet.

Permanent Streams and Rivers

Old rivers need not be defined in detail, since few or no larvae were found in this situation in Western Massachusetts. Briefly, these rivers have a broad stream bed of mud and silt, well-defined shorelines, and gently sloping banks. The vegetation is usually set well back from the shoreline. There are few waterfalls, the water is often very deep, and old logs and piles of debris are frequent.

Young rivers are those varying in width from about five yards up to twenty yards. They are often very rapid, and
are found most frequently in mountain valleys. The bed is usually composed of rocks and large stones or boulders, with numerous sand and gravel banks. The borders are usually sharply defined, and cascades and rapids are frequent. Where the water is rapid, the depth may vary from a few inches at the wider points to several feet at the narrows. Vegetation in these streams is usually confined to small islands, although large trees are often present along the shoreline, forming a dense canopy over much of the water surface. An example of this type of watercourse is the Farmington River at New Boston.

Old permanent streams are rather sluggish, with widths varying from four or five feet to 15 feet, and the bed composed of sand or mud deposits. They are found in flat or gently rolling terrain. Grass is often found growing from the streambed, and vegetation on the banks is largely confined to small trees and brush. There are few waterfalls, and the surface of the water is often quite smooth. The number of locations of this type in Western Massachusetts is rather small. Examples may be found in portions of the Mill River in Amherst and Orcutt Brook in Warwick.

Young streams are usually two to ten feet wide, with depths ranging from an inch or less up to two feet or more; there are many waterfalls, and rapids are frequent. The beds of these streams are composed of sand or gravel, and larger rocks are frequently dispersed on the bottoms.
These streams are found most typically in forested, hilly terrain. Examples of this type of stream may be found on the Prescott Peninsula, Quabbin Reservation, and the Gulf Brook in Warwick.

Outlets to impounded waters is a category that must be added to any system designed to describe the streams of Western Massachusetts. This category is composed of sites below natural and artificial ponds, lakes or beaver dams. There is usually a waterfall present, although flow may be in a smooth sheet down some form of sluiceway. A large pool is often present below the impounding structure, and flow away from the foot of the pool may be considerable.

The classification system stated above is not intended to convey information about the actual age of the streams, but is merely based on their physical characteristics. Any stream may exhibit more than one of the categories at different points along its length, and may, in fact, change from one type to another over a very short distance.
IV. COLLECTION OF IMMATURE STAGES

Collections were most often made near points where roads crossed streams, as this procedure permitted more streams to be visited during each collecting trip. If divergent habitats were present, or if larvae were scarce, collections were taken from several points in the same stream. Topographic maps were consulted in order to visit streams which were not visible when driving and within easy access.

In their natural habitat, black fly larvae are easily disturbed. They release their hold on the substrate and are carried away by the current. When the substrate and attached larvae are removed from the water, the larvae are easily collected with forceps, except in the case of *Prosimulium magnum*, which grips the substrate tenaciously. Alcohol poured over these larvae was found to be effective in forcing them to release their hold.

Where possible, only mature larvae were collected. These are easily distinguished by the dark respiratory histoblasts on the thoracic pleura. Removal with the forceps minimized damage to those portions of the anatomy necessary for identification.

Larvae and pupae were preserved in 95% ethyl alcohol in two-dram vials. Collection data was recorded in pencil on small pieces of cardboard which were placed in the vial with
the larvae or pupae. Information recorded at each
collection site included date, town, name of the stream or
a brief description of its location, stream width,
substrate, and data concerning the type of stream and
surrounding topography.

Collecting trips were charted on road maps, and timed
so that no species would be missed when it appeared in any
area. Approximately 5000 miles were covered in Berkshire,
Franklin, Hampshire and Hampden counties during the period
from March through June, 1965.
V. SAMPLING

In 1964, during the course of preliminary investigations, a large population of *Simulium vittatum* was found at the outlet to Aldrich Lake in Granby. No other black fly species were found at this site, although several collections were made during the course of the spring and summer. The presence of a pure culture of a black fly species, and the proximity of the site to Amherst, presented the opportunity to study the species on a continuing basis. The owner of the property approved the use of his land and offered to help as much as possible.

The first attempt at sampling the population was made using a technique devised by Wolfe and Peterson (1958). Twenty-five metal cones of the type described on page 56 were prepared by students of the Smith Agricultural School in Northampton. In addition, metal eyelet was soldered on the apex of each cone. These cones were then spray-painted with white enamel to provide a smooth surface for larval attachment.

A ten-foot length of plastic-coated copper wire was prepared with a small loop every foot for six feet, leaving a two-foot length free at each end. A brass swivel of the type used for connecting fishing lures to a line was attached in each of the loops. A small clip attached to the swivel was then hooked to the eyelet in the tip of a white cone.
This technique was initially tested at Aldrich Lake. The free ends of the wire were attached to rocks, which held the cones close to the stream bottom, where the larvae were found attached to rocks or debris. Checks made every three or four days over a three-week period indicated that *S. vittatum* larvae avoided the cones, but could be found on rocks or debris that were in contact with them.

The value of the cones was also assessed in smaller streams on the Prescott Peninsula, Quabbin Reservoir, New Salem. The species of Simuliidae present in these streams had not yet been identified, as no mature larvae were present. Three streams, ranging in width from three to 12 feet, were selected for study. Six cones were placed in each stream in the same manner as had been used at Aldrich Lake.

Larvae of *Prosimulium mixtum*, *Simulium venustum* and *S. tuberosum* seemed to show some preference for the cones. There was great difficulty in evaluating changes in the level of infestation, however, since the amount and depth of water in the streams varied considerably, with the cones becoming partly or totally exposed at various times.

No conclusion can be drawn as to the over-all usefulness of these cones as a sampling technique, as they were tested on such a limited basis. They may be useful in larger streams where the water levels have less fluctuation, or in locations where daily observation is possible, but I believe the difficulties described above would limit their usefulness.
In the second method devised to sample black fly larval populations strips of plasterer's lath 1.75 inches wide, 0.75 inches thick and 14.25 inches long were used. These dimensions closely approximate the 300 square centimeters surface area of the metal cones, when only the upper and lateral surfaces of the wood pieces are considered. Two strips of lead flashing were attached to the bottom surface of the wooden strips, to insure that they would sink in the streams. The wooden strips were attached to lengths of plastic-coated wire in the same manner as were the metal cones.

The sampling devices were tested at the outlet to Aldrich Lack and in two streams on the Prescott Peninsula. Larvae of _S. vittatum_ at the former site attached themselves to the strips in very small numbers, preferring rocks and debris; larvae in the streams on the Prescott Peninsula seemed to show no preference for them, but were found to be most frequent when the devices were in direct contact with other natural substrates. The problems encountered with the wooden strips were the same as with the cones, plus the fact that the eyelets used to attach them to the wire sometimes pulled out of the end of the lath and the current washed them away.

The third technique, which was subsequently used in the survey, was designed to sample the larvae directly from their natural substrate. A wire was formed into a circle so that the inside area closely approximated 300 square
centimeters. A sample was taken by choosing several rocks from the stream, selecting one that seemed to be most representative of the population, placing the ring on the rock and collecting all larvae encompassed by the ring. The specimens were preserved in vials containing 95% ethyl alcohol for future counting.

The main advantage of this technique is that it does not depend on an artificial substrate for larval attachment; however, the selection of the sample is quite subjective. Tremendous numbers of *S. vittatum* larvae were present at Aldrich Lake, in the spring of 1965, so that collecting a sample took a considerable amount of time. The larvae had to be collected with forceps, one or two at a time, as scraping or brushing them from the surface damaged the larger larvae and destroyed the smaller ones, and individual collection was necessary for counting the total number of larvae present. Time for sample collecting was also limited by other duties.
Attempts to rear larvae of the Simuliidae in the laboratory failed, although three different techniques were attempted. A large water bath was available, equipped with a temperature control device so that constant water temperatures could be maintained by placing containers partially submerged in the water. The temperature could be varied by placing the containers at different distances from the cooling source, or by varying the setting of the temperature control mechanism, a large coil containing a refrigerant. Water was circulated past this coil by draining from one end of the water bath as much water as was pumped in at the other end. The water bath was divided into a series of compartments with holes in the walls of each compartment to provide flow and maintain water depth.

Larvae were transported to the laboratory in jars placed in a metal container filled with ice water to prevent the water from becoming too warm en route from the collection site. In all cases, larvae arrived in the laboratory in seemingly good condition.

The first rearing attempts were made using four-ounce baby food jars to hold the larvae. Current and aeration were supplied by means of a Marco 25 aerator, manufactured by the J. B. Maris Company. Air was pumped through rubber tubing and released into the jars through porous stone air-breakers,
one per jar. The air flow was regulated by a metal clamp applied to the hose just before it entered the jar. Six jars could be used simultaneously with this technique. The first series of tests ended after one week, when all the larvae in the jars died. It was thought that perhaps this resulted from autointoxication, so in subsequent tests the water in the jars was changed every three days. The water used was taken from the stream from which the larvae were collected and stored in a refrigerator.

The only result obtained from three tests with this apparatus was the pupation of one mature larva of the genus Prosimulium. The adult never emerged, and the pupa later became covered by a mass of fungus.

The second attempt, a modification of the technique described by Doby et al. (1959), was made with 150 cc test tubes. A glass plate, cut to fit snugly in the tube and to leave about one inch of space at the top, separated each tube into two compartments. When filled with water, the two-compartments were connected only at the top and rounded bottom of the tubes. A one millimeter glass tube with the end drawn to a fine point and then bent into a U-shape was inserted beneath the glass partition. Air forced through this tube by the Marco 25 aerator provided aeration and created a current which flowed in a continuous circle around the glass plate.

Larvae of *Simulium vittatum* were used as test animals for these experiments. Ten larvae were introduced into each
of six tubes, which were immersed in the water bath at the same temperature as was recorded in the stream where the larvae were collected. When first introduced, the larvae attached themselves to the first surface with which they came in contact. They later moved close to or upon the opening of the glass tube from which the air bubbles were flowing. All the larvae in these and subsequent trials with this equipment died within a week, with no noticeable development taking place.

Evaporation of water from the test tubes was the greatest problem encountered during these experiments. This left the upper portion of the glass plate exposed, stopping circulation from one compartment to the other. After the death of the larvae, the water in the tubes became cloudy and the dead larvae became covered with mats of fungus. As this fungus did not appear until after the larvae were dead, it was probably saprophagous, as mentioned by previous authors.

The third set of experiments was conducted using 600 cc cylindrical battery jars as containers. A piece of wood one inch wide was cut to fit snugly across the diameter of the bottom of the jar. A plastic tube sealed at one end was fastened to this strip, and holes were drilled through the upper surface of the tube at intervals of one-half inch. The tube was connected to the Marco 25 aerator. A glass plate 13 cm wide and 16 cm long was placed in the jar so that it slanted from one side of the jar at the bottom to the other side at the top. The air forced through the holes of
the plastic tubing bubbled up the plate, creating aeration and current.

Twenty _S. vittatum_ larvae were introduced into each of two battery jars, and the water in the jars was changed every two days. In three successive experiments, no larvae survived more than nine days.

Food for all the experiments described above consisted of yeast, Pablum and powdered skim milk. Fredeen (1959, 1964) used yeast and Pablum, and Anderson and DeFoliart (1962) used ground protein pellets.

The reasons for the failure of these rearing techniques can only be conjectured. Autointoxication may have played a role in the small containers, especially when the water was only infrequently changed. Oxygen should have been sufficient, as the aerator was kept in continuous operation. Temperatures were maintained as close as was possible to those recorded in the streams where the larvae were collected.
VII. REARING IN THE FIELD

After attempts to rear black fly larvae in the laboratory had failed, it was decided to attempt confinement of the larvae in their natural habitat in such a way as to retain all cast skins. It was hoped to make associations of all larval instars by this means. Simulium vittatum was selected as a test animal, since this species was already undergoing field study, and was readily available in large numbers.

In order to retain larvae for study, a device was necessary to hold them and yet not remove them from their natural habitat. A compartmented holding cage was designed, containing sections of glass tubing which could be covered at both ends with 25-mesh monofilament nylon to allow water circulation but prevent the larvae from escaping.

Plate No. 7 shows a photograph of the holding case. Materials used were one-eighth inch fiberboard and wooden strips 14 inches long, one and three-quarters inches wide and three-quarters of an inch thick. Two wooden strips were used as top and bottom with grooves cut on one side at intervals of one and three-eighths inches center to center along the length of each strip. Fiberboard separators one and one-quarter inches long and one and one-eighths inches wide were fitted into the grooves, resulting in ten compartments. A strip of fiberboard 14 inches long and one
inch wide was nailed to the back of the cage, to prevent the glass tubes from being washed away by the current. A moveable wire was fastened across the front of the cage, to hold the glass tubes and at the same time allow their removal.

This device was a success from the standpoint of rearing larvae; however, no cast skins were recovered from any of the tubes. It is not known whether they disintegrated, were washed from the tubes, or were eaten by the confined larvae. Mature larvae pupated in the tubes, but no adults emerged.

A drawback of this rearing device was that the fine mesh used to prevent larval escape also trapped large amounts of silt and sand. At each visit the tubes had to be removed from the holding compartments and carefully rinsed in water to remove the accumulation. The silt seemed to have no effect on the larvae, but may have affected the respiration of the pupae.
VIII. TAXONOMY

Four genera and 21 species of Simuliidae were identified from the material collected in Western Massachusetts during 1965. The genus *Twinnia* is represented by one very rare species, *T. tibblesi*. The genus *Cnephia* is represented by two species, *C. dacotensis* and *C. mutata*. Six species of *Prosimullum* were collected: *P. fontanum, P. fuscum, P. magnum, P. mixtum, P. multidentatum* and *P. rhizophorum*. The remaining twelve species found are in the genus *Simulium*; these are *S. aureum, S. corbis, S. croxtoni, S. decorum, S. gouldingi, S. latipes, S. parnassum, S. rivuli, S. tuberosum, S. venustum, S. verecundum* and *S. vittatum*.

Various anatomical structures are used for the separation of the immature stages of the genera and species of simuliiids. A generalized lateral view of a larval black fly, modified from Stone (1964), is shown in Figure 11, and a dorsal view of the pupa and cocoon of *S. vittatum* in Figure 12.

*Twinnia tibblesi* is a very distinctive species, as the larvae lack the protruding cephalic fans which are so conspicuous in all other species found in Western Massachusetts. The anal sclerite, usually X-shaped (Figure 7), is distinctly Y-shaped.

Larvae of the genus *Prosimullum* are readily distinguished by the fact that the proximal two segments of the antennae
are pale and nearly transparent, while the distal two segments are dark and clearly visible. Larvae of *Cnephia* and *Simulium* possess antennae which are uniformly pale in color throughout their length. The cervical sclerites are not visible in *Prosimulium*, being enclosed by the postocciput. The apical abdominal gills, when visible, are a simple trilobed structure. The cocoon of the pupae is a loosely-woven structure, with an irregular, ill-defined anterior margin. The pupa possesses no strong terminal dorsal abdominal hooks.

The genus *Cnephia* may be separated from *Prosimulium* by the antennal characters given above, and the presence of visible cervical sclerites, not enclosed by the postocciput. Differentiation from the members of the genus *Simulium* is based on less prominent characters. The abdominal gills are simple, as in *Prosimulium* species. Ventral abdominal papillae on segment 8 are lacking, although this is true of some members of the *Simulium*. *Cnephia mutata* possesses a strongly tri-lobed central tooth on the hypostomium, as in the *Prosimulium*; however, the lateral teeth are borne on two large sclerotized lobes that protrude beyond the median tooth. The hypostomium of *C. dacotensis* bears many small, irregular teeth, as does the hypostomium of many *Simulium* larvae. The cocoons of *Cnephia* species resemble those of *Prosimulium*, and the pupae have no strong dorsal terminal abdominal hooks.

Larvae of the *Simulium* may be separated from *Prosimulium*
by the antennal characters previously stated, and the readily visible cervical sclerites. The rectal gills usually have digitally compound lobes. The cocoons of *Simulium* pupae have very well-defined anterior margins and the pupae possess large dorsal terminal abdominal hooks.

Characters for the separation of the species of the Simuliidae of Western Massachusetts are given in the accompanying key.
IX. LARVAL IDENTIFICATION

Larvae were identified with the aid of larval keys by Wood et al. (1963) and Stone (1964). The former key was more useful, as it contained more characters to separate difficult or closely related species. Stone's key does not differentiate between some species, for example, *S. venustum* and *S. verecundum*. Identifications of certain specimens were verified by Dr. B. V. Peterson of the Canadian Ministry of Agriculture.

The larvae were positioned on a small piece of absorbent cotton in a watch glass containing 95% ethyl alcohol. This cotton kept the larvae stationary for viewing characters at angles that otherwise would have been impossible.

Dissection of the maxillae and the labio-pharyngeal complex was usually necessary, as their setae, bristles and coloration formed a background that made observation of the hypostomal teeth impossible. An insect pin with a small hook at the end was inserted into the opening of the salivary canal; when removed, the maxillae and labio-pharyngeal complex usually came out easily.

It was sometimes necessary to dissect the integument surrounding the anal sclerite, as the dorsal arms are often obscured.
X. KEY TO THE LARVAE OF WESTERN MASSACHUSETTS SIMULIIDAE
(Modified from Wood et al. (1963) and Stone (1964))

1. Head fans absent; anal sclerite Y-shaped... .......................... Twinnia tibblesi.
   Head fans present; anal sclerite X-shaped......................... 2

2. Basal two segments of antennae colorless, distal two segments darkly pigmented; postocciput nearly complete dorsally, enclosing cervical sclerites.............................. (Prosantirium)........ 3
   Basal two segments of antennae at least partly colored, distal two segments rarely of a contrasting dark color; postocciput with a wide gap dorsally, not enclosing cervical sclerites.......................... (Fig. 5)........ 8

3. Median tooth of the hypostomium the longest, the lateral teeth subequal in length or decreasing in length outwardly (Fig. 1 and 4); maxillary palp about twice as long as width at base; abdomen gradually expanded posteriorly.......................... 4
   Median tooth of the hypostomium, at most, about as long as longest lateral teeth, the lateral teeth not decreasing outwardly (Fig. 2, 3 and 5); maxillary palp two and one-half to three times as long as width at base; abdomen abruptly expanded at segment five....... 5

4. Tips of secondary projections of median tooth about equal in length to tips of outer lateral teeth but shorter than tips of the longest sublateral teeth (Fig. 1); vertical sclerotization of lateral plate of proleg heavy, well-developed, extending basally more than one-half the length of apical segment of proleg; head capsule dark brown; body rather uniformly brownish-gray with pale, intersegmental bands........
   Tips of secondary projections of median tooth at least as long as tips of longest lateral teeth (Fig. 4); vertical sclerotization of lateral plate of proleg light, not well-developed, usually extending basally much less than one-half the length of apical segment of proleg; head capsule pale yellow to brownish-yellow; body pale whitish to gray, darker dorsally, with rather broad, pale, intersegmental bands........ P. multidentatum
5. Antero-lateral head spots (Fig. 6) distinctly yellow; respiratory histoblast with slender filaments arising from a swollen, club-like base. \( P. \) rhizophorum

Antero-lateral head spots dark; respiratory histoblast with slender filaments arising from a slender, parallel-sided base. \( P. \) fontanum

6. Outer lateral teeth of hypostomium distinctly longer than sublateral teeth which are of equal length (Fig. 2); antero-dorsal arms of anal sclerite each with a postero-medially directed apodeme, these arms longer than postero-ventral arms (Fig. 7); head capsule medium brown; body light brown. \( P. \) fuscum

Lateral teeth of hypostomium of equal length or slightly decreasing in length inwardly (Fig. 3 and 5); length of arms of anal sclerite variable, but antero-dorsal arms without apodemes; head color and body color variable. \( P. \) mixtum

7. Lateral teeth of hypostomium decreasing slightly in length inwardly (Fig. 5); antero-dorsal arms of anal sclerite shorter than postero-ventral arms, or arms subequal; large grayish-brown species with pale brown head capsule. \( P. \) fuscum

Lateral teeth of hypostomium usually of equal length, occasionally decreasing in length inwardly (Fig. 3); antero-dorsal arms of anal sclerite considerably longer than postero-ventral arms; smaller brown species with dark brown head capsule. \( P. \) mixtum

8. Abdomen with a single ventral transverse bulge on segment eight; postgenal cleft narrow and shallow, of an acutely-pointed, inverted V-shape (Fig. 8). \( C. \) mutata

Abdomen without a ventral transverse bulge on segment eight, but sometimes with two ventral tubercles; postgenal cleft wider and deeper (if cleft small, then squared in shape). \( C. \) mutata

9. Abdomen (segment eight) with two large ventral tubercles, their length one-third to one-half the width of the abdomen at their points of attachment (Fig. 11); antennae usually noticeably longer than stalk of head fan; postgenal cleft not pointed apically, may be short or long and bulbous; suboesophageal ganglion and epidermis in postgenal cleft not distinctly blackish (\( S. \) in part).
Abdomen without ventral tubercles, or these inconspicuous and reduced in length to less than one-sixth the width of the abdomen at their points of attachment; length of antennae variable; postgenal cleft variable; suboesophageal ganglion and/or epidermis in postgenal cleft often distinctly blackish (*Simulium*, in part). \textsuperscript{14}

10. Postgenal cleft small, quadrate, its length (from posterior tentorial pit to anterior margin of cleft) one-fifth or less the length of the head between posterior tentorial pit and hypostomal teeth. \textsuperscript{11}

Postgenal cleft larger, one-third or more the length of the head between posterior tentorial pit and hypostomal teeth, with rounded apex, usually broadest at about the midpoint of its length. \textsuperscript{12}

11. Median hypostomal tooth equal to, or shorter than longest lateral tooth; body pigment green...*S. rivuli*

Median hypostomal tooth longer than lateral teeth; body pigment of two contrasting colors, in alternating bands of reddish-brown and greenish-gray...*S. aureum*

12. Pigmented area anteroventral to eye absent, or not larger than area encompassed by eye...*S. gouldingii*

Pigmented area anteroventral to eye large, more than twice the area encompassed by eye. \textsuperscript{13}

13. Dorsal background pigment of head extended forward beyond bases of antennae as a dark median stripe; length of postgenal cleft one-third or more the distance from posterior tentorial pit to hypostomal teeth. \textsuperscript{13}

Dorsal background pigment of head not extended beyond antero medial spot; length of postgenal cleft one-quarter or less the distance from posterior tentorial pit to hypostomal teeth. \textsuperscript{13} *S. latipes*

14. Postgenal cleft subquadrate, apical margin straight or rounded; anal gill with three simple lobes, these occasionally with minute, secondary tubercles. \textsuperscript{15}

Postgenal cleft long and bulbous, or sharply pointed apically; anal gill with digitally compound lobes. \textsuperscript{16}

15. Second segment of antenna uniformly pale yellow, without white band near tip; pale brown species; hypostomal teeth short, not well-developed; abdomen
gradually expanded posteriorly...........C. dacotensis

Second segment of antenna with a whitish band near tip; grayish to blackish species; hypostomal teeth longer, well-developed; abdomen abruptly expanded at segment eight.........................S. vittatum

16. Postgenal cleft a narrow, straight-sided, inverted V-shape, not narrowing posteriorly, extending about one-third the distance to the hypostomal teeth (Fig. 9); head capsule brown, with indistinct, brown head spots

..........................S. parnassum

Postgenal cleft a bulbous, inverted V-shape (Fig. 10); length of postgenal cleft variable; head capsule and head spots variable in color.......................17

17. Antennae long, nearly entire distal two segments extending beyond apex of stalk of head fan; suboesophageal ganglion or epidermis in postgenal cleft distinctly blackish; abdomen blackish.............18

Antennae short, at most extending only slightly beyond apex of stalk of head fan; suboesophageal ganglion and epidermis in postgenal cleft not blackish; abdomen not blackish.......................19

18. Postgenal cleft with a distinct, narrow, apical extension extending almost to base of hypostomium (Fig. 10); cephalic apotome with distinct, dark spots, posterior portion with a narrow, dark, fulvous area extending less than one-half the length of the head; suboesophageal ganglion pale, epidermis in postgenal cleft blackish; head fan with about 50 rays....S. corbis

Postgenal cleft without a narrow, apical extension, shorter; dark spots, fulvous area broader, extending one-half or more the length of the head; suboesophageal ganglion distinctly blackish, epidermis in postgenal cleft usually pale; head fan usually with less than 40 rays..........................S. tuberosum

19. Infuscation around head spots narrow, not extending beyond inner edges of antero-lateral spots; antennae not longer than stalk of head fan; arms of anal sclerite narrowly fused medially..............S. decorum

Infuscation around head spots wider, extending beyond outer edges of antero-lateral head spots; antennae slightly longer than stalk of head fan; arms of anal sclerite fused medially.......................20
20. Lateral plate of proleg lightly sclerotized, faintly visible; head fan with more than 52 rays; postgenal cleft not bordered by a fulvous band......S. verecundum

Lateral plate of proleg heavily sclerotized, conspicuous; head fan with less than 48 rays; postgenal cleft bordered by a narrow, fulvous band.......S. venustum
XI. CNEPHIA SPECIES

Cnephria dacotensis Dyar and Shannon

Collection Records (1965)


Pupae: Wales - May 21.

Biological Information

Cnephria dacotensis is apparently quite a rare species in Western Massachusetts. It was found in large numbers at only one location, in Wales.

Larvae were collected from mid-April to the latter part of May. This would indicate that C. dacotensis is a univoltine species, agreeing with observations of Stone and Jamback (1955) in New York State.

Davies et al. (1962) state that, in Ontario, overwintering usually occurs in the egg stage, with hatching occurring in mid-April, although a few eggs may hatch the previous fall. Overwintering probably occurs in the egg stage in Western Massachusetts, with hatching occurring in late February and early March.

All three collections were made below outlets to impounded water; these were small ponds, with outlets ranging from two to five feet in width, and with slow current.

At two collection sites the larvae and pupae were found attached to rocks, but in Wales, where a large
population was found, the larvae were collected from nearly every submerged object below the dam.

As seen in Table I, the species found in association with the larvae of *C. dacotensis* were *P. mixtum* (twice) and *P. magnum* (once). Both are common species during early spring. Although *S. vittatum* larvae are most often found below outlets to impounded water, they were not collected with *C. dacotensis*. The physical environment appeared to be favorable at the time of year when *C. dacotensis* was collected, but other factors, such as cessation of water flow, lack of food, or some other chemical factor may have prevented *S. vittatum* from occupying these niches.

*Cnephia mutata* (Malloch)

Collection Records (1965): See Map I


Leyden - May 18, Northampton - April 27, Wendell - April 8.

Biological Information

Cnephia mutata is a common early spring species of black fly in Western Massachusetts. It is usually found in small numbers, even in the most favorable of habitats.

The earliest mature larvae of this species were found in Ware on March 31. Elsewhere, however, they were not found until early April. The early date of larval maturation suggests that this species overwinters in the larval stage, as recorded by Stone and Jamnback (1955), in New York, and by other previous authors. The first pupae were not collected until April 8.

The larvae of C. mutata are common in temporary drainage creeks and bog seeps, and in young permanent streams. Only one collection came from a stream over 12 feet in width, and, as can be seen in Graph II, over 75% were found in streams six feet or less in width. This indicates a definite preference for small streams.

No preference was noted as to site of larval attachment; the larvae seemed to utilize any substrate available. Where grass trailed in the streams, they were most often found on the undersurface of the blades, but, in the only large population found, the larvae were observed on leaves, twigs, logs, mossy rocks and even bottles and cans.

The time of year when C. mutata larvae are present indicates that cold water is preferred. They were found at
extremes of current speed, ranging from the slight flow in bog seeps to swiftly-moving water below lake outlets.

The larvae of C. mutata were most often found in areas which were open to the sun, with little or no large vegetation along the stream banks to form a canopy over the streams. They were found quite often in streams flowing through open meadowland, or in larger streams with small trees and shrubs present along the banks.

Eight species of Simuliidae were found in association with the larvae of C. mutata; these and their frequencies are shown in Table I. The greatest number of associations was recorded with P. mixtum (14). This is to be expected, as both are early spring species that overwinter as larvae and prefer the same type of streams, although P. mixtum is also found in larger streams. Other early spring species collected with C. mutata were P. magnum, P. rhizophorum, P. fuscum and T. tibblesi. All are often found in small streams. Simulium venustum and S. latipes, two late spring species, were also collected with C. mutata larvae. These associations occurred when the population of C. mutata was declining, and the populations of these last two species was rising.
XII. PROSIMULIUM SPECIES

Prosimulium fontanum Syme and Davies

Collection Records (1965): See Map II


Biological Information

Prosimulium fontanum is a fairly common mid-spring species of Simuliidae in Western Massachusetts. It never occurs in large populations, as do some other members of the hirtipes complex.

Mature larvae were first collected on April 7, at two locations in Bernardston. Davies and Syme (1958), in Ontario, reported that of the members of the hirtipes complex P. fuscum matured first, followed two or three days later by P. mixtum,
with \( P. \) \textit{fontanum} appearing last. In Western Massachusetts, in 1965, \( P. \) \textit{mixtum} appeared in the latter part of March, followed a week later by \( P. \) \textit{fuscom}, and then, after another week, by \( P. \) \textit{fontanum}.

Davies et al. (1962), state that, at Algonquin Park, in northern Ontario, the larvae of \( P. \) \textit{fontanum} hatch in early spring. According to Hopkins Bioclimatic Law, this could be translated to late winter in Western Massachusetts, probably during late February or early March. \textit{Prosimulium magnum} larvae, which are known to hatch in late winter in Western Massachusetts, mature at approximately the same time as do the larvae of \( P. \) \textit{fontanum}.

As can be seen in Graph I, 60% of the collections of \( P. \) \textit{fontanum} larvae were taken from streams four feet or less in width, and over 70% from streams six feet or less in width. Temporary drainage creeks and young permanent streams were preferred, although larvae were occasionally collected from bog seeps or young rivers.

Graph I shows that \( P. \) \textit{fontanum} is more often found in small streams than are the closely related species, \( P. \) \textit{mixtum} and \( P. \) \textit{fuscom}. Table II shows the mean stream width to be less than five feet for \( P. \) \textit{fontanum}, and over seven feet for \( P. \) \textit{mixtum} and \( P. \) \textit{fuscom}. In addition, Table III indicates that over 13% of the \( P. \) \textit{fontanum} larvae came from streams less than one foot in width; about 1.5% of the \( P. \) \textit{mixtum}, and no \( P. \) \textit{fuscom}, larvae were present in such streams.

The streams from which \( P. \) \textit{fontanum} were most often
collected were found in relatively flat, forested terrain, in valleys. The larvae were usually present where the water flowed rather rapidly over the stream bed at a depth of only a few inches. A good deal of shade was usually provided by the forest canopy.

Approximately 73% of the larval collections were taken from rocks, and 27% from substrates of organic origin. It is interesting to note that all the collections from vegetation were made during May and June, although this species is found throughout much of the month of April. Apparently, the larvae move to vegetation as it becomes available in late spring.

As shown in Table I, eleven species of Simuliidae were found in association with the larvae of *P. fontanum*. One reason for this large number is the extended period during which the larvae are present, spanning both the early and late spring species. The most frequent early spring species associated with *P. fontanum* were *P. mixtum*, *P. magnum* and *P. fuscum*. These species are frequently found in small forest streams, and the habitats of all four species overlap considerably. Of the other early spring species, *P. rhizophorum* and *C. mutata* were found on one occasion each. The low incidence of the latter is a bit surprising, as it is often found in small streams, although it seems to prefer more sunlight than do the larvae of *P. fontanum*. Of the late spring species, the most frequent associations were with *S. tuberosum* and *S. venustum*. Both species are quite variable
in habitat selection. Other late species found were S.ouldinghi, S. verecundum, S. latipes and S. parnassum.

The pupae of P. fontanum are often found imbedded in moss on rocks. The silken portion of the cocoon in such situations is minimal, but, by incorporating bits of the moss, the pupa is well-protected. In slower streams, the cocoon may be reduced to a few threads at the tip of the abdomen.

*Prosimulium fuscom* Syme and Davies

**Collection Data (1965):** See Map III


Biological Information

Prosimulium fuscum is a fairly common species of the hirtipes complex in Western Massachusetts. Distribution is widespread, but large populations were not found at any location in 1965.

This species undoubtedly overwinters in the larval stage, because mature larvae were found as early as March 28. This information agrees with that of Davies and Syme (1958) and other authors.

Prosimulium fuscum is an univoltine species. Mature larvae were present from late March through the third week in May. One generation would be expected, as this is characteristic of the members of the genus Prosimulium.

Maturation of the larvae of this species occurs a few days later than in the closely related species, P. mixtum. It is interesting to note, however, that P. mixtum larvae may be found for about a month after the populations of P. fuscum have disappeared from the streams.

This species was found in temporary drainage creeks and bog seeps, and in permanent streams classified as young permanent streams, young rivers and outlets to impounded water. Widths of these streams ranged from one foot to 25 feet.

The habitats of P. fuscum larvae are very much like those of P. mixtum immatures, with a few exceptions. No fuscum larvae were found in streams under one foot or over 25 feet in width, while mixtum larvae were taken from streams
ranging from a few inches to 40 feet in width. As can be seen in Table II, there was little difference in the mean width of the streams inhabited by the two species; however, the standard deviation was much smaller for *fuscum*, 5.1 feet, as compared with 7.6 feet for *mixtum*. This indicates that *P. fuscum* has a narrower range of stream preference than *P. mixtum*.

Table III shows the various stream widths at which *P. fuscum* larvae were collected, and Graph I shows a comparison of the percentages of the larvae of the two species at different stream widths. A smaller percentage of *P. fuscum* larvae were found in the small streams than were those of *P. mixtum*. This, with the information in Tables II and III, indicate that the larvae of *P. fuscum* prefer larger streams than do the larvae of *P. mixtum*.

Approximately 25% of the 39 collections of *P. fuscum* were made at pond outlets, a habitat not often utilized by *P. mixtum*.

The streams in which *P. fuscum* was found are classified as temporary drainage creeks, larger young permanent streams, and small young rivers. All have stream beds composed of stones, rocks and gravel, and are found primarily in hilly, forested terrain.

Forty-three records were obtained of the substrate from which the larvae of *P. fuscum* were collected. Eighty-six per cent of all larvae taken were found on rocks, indicating a strong preference for substrates of inorganic origin.
Only six species of Simuliidae were found associated with the larvae of *P. fuscum*, considerably less than the number recorded for other members of this genus. The most common associations were with the early or mid spring, univoltine species, as may be seen in Table I. *Prosimulium fontanum*, *P. mixtum*, *P. magnum* and *C. mutata* are all species preferring small streams. Since *P. fuscum* was collected rather frequently at pond outlets, it was expected to be found in association with *S. vittatum*, a species preferring outlets from impounded water. The only late spring species found in association with the larvae of *P. fuscum* was *S. venustum*, on one occasion. This association occurred when the population of *P. fuscum* was declining, and that of *S. venustum* rising.

*Prosimulium magnum* Dyar and Shannon

**Collection: Records (1965):** See Map IV


**Biological Information**

*Prosimulium magnum* is a common species of black fly in Western Massachusetts. It is widely distributed, and may occur in great numbers under favorable conditions.

Davies et al. (1962) and Stone (1964) have stated that this species spends most of the winter in the egg stage, with hatching occurring late in winter. Observations in Pelham made in 1964 and 1965 support this statement. During late February and March, weekly or bi-weekly collections were taken from a small stream about two miles west of Pelham center on the Amherst Road. In the second week in March, small larvae were collected that were very different in appearance from those previously observed. All other larvae seen were of a distinct club-shape, with the abdomen abruptly expanded at segment 5; these new larvae had the
abdomen gradually expanded posteriorly, so that they appeared more like a baseball bat. These new larvae also clung to the substrate much more firmly than the other species present. The area on the stones to which they were confined was a straight line at right angles to the current on the upstream surface. These larvae were later identified as P. magnum. The body shape and tenacious hold on the substrate were later used as a reliable means of field identification for this species.

Prosimulium magnum is a univoltine species in Western Massachusetts, mature larvae being commonly found from mid-April to the last of May.

Larvae were found in both temporary and permanent streams; temporary drainage creeks, young and old permanent streams, young rivers and outlets to impounded water were the habitats utilized. The largest populations occurred below pond outlets, especially where the water flowed away from the impounding structure without forming a deep pool. Anderson and Dicke (1960) and Stone (1964) stated that this species preferred temporary streams, but this does not seem to be the case in Western Massachusetts.

As shown in Table III, the larvae of P. magnum were found in streams ranging from one to 40 feet in width. Graph II shows that 65% of the larvae were collected from streams six feet or less in width, and 75% from streams eight feet or less in width. The mean stream width, as indicated in Table II, was 7.8 feet, slightly more than the
mean stream width for other members of this genus.

The larvae were most often found in that portion of the stream where the current was swiftest, and the water quite shallow. The preferred site was on the upper surface of the substrate, where the water broke over the upstream edge.

Larvae and pupae were found in both heavily forested and open situations, indicating that light intensity may not be important to the immature stages of this species.

Table IV shows that the larvae of *P. magnum* were found on substrates of inorganic origin 71% of the time, indicating a strong preference for stones and rocks. There was, however, a marked increase from April to May (from two to 27 per cent) of larvae collected on vegetation. This indicates that the larvae will move from rocks to vegetation as it becomes available in the spring. Vegetation is not commonly found in drainage creeks and young permanent streams, sites from which this species was most often collected.

The pupae of *P. magnum* are quite distinctive, due to the large number of respiratory filaments that branch from the central stalk in a dense oval clump. The bases of the filaments are usually encased in the cocoon, which is unusual in that it is enclosed at the anterior end. The shed head capsule and cast integument of the mature larva are often found inside the cocoon. The cocoons frequently occur in dense masses on the downstream ends or crevices of stones and rocks, and thus protected from the current.
Table I shows the species of black flies that were found in association with the larvae of *P. magnum*, and the frequencies of each. One reason for the large number of associations is that *P. magnum* is present during the middle portion of the black fly season, from mid-April to the end of May, thus overlapping with the early and late spring species.

Of the early spring species, associations were recorded with the greatest frequency with *P. mixtum* (29 occasions). Both *P. mixtum* and *P. magnum* are common in small forest streams. Eight other early spring species were recorded: *P. fontanum*, *P. fuscum*, *P. rhizophorum*, *P. multidentatum*, *C. dacotensis*, *C. mutata*, *S. vittatum* and *T. tibblesi*. These species are found in habitats ranging from bog seeps and drainage creeks to outlets to impounded water. The diversity of habitats occupied by *P. magnum* is accented by these associations. Of the late spring species, *S. venustum* and *S. tuberosum* were found in association with *P. magnum* larvae with the greatest frequencies. Both are common species with a wide range of habitat preference. Other late spring species collected were *S. corbis* and *S. verecundum*.

*Prosimulium mixtum* Syme and Davies

Collection Records (1965): See Map V

Larvae: Amherst - April 28. Ashfield - April 7, May 12 (3). Becket - May 2 (4), May 5 (2). Belchertown - April 1, April 20 (2), May 7 (2), May 17. Bernardston -
April 8, May 18 (2). Blandford - March 28, May 2 (3).
Great Barrington - April 6. Hancock - April 25 (2), May 23.


**Biological Information**

*Prosimulium mixtum* is an extremely common early spring species of black fly in Western Massachusetts. One hundred and eighty-one collections were made, far more than for any other species.

Overwintering of this species occurs in the larval stage in Western Massachusetts. Mature larvae were collected from March 23 to May 30, although the greatest number of collections occurred from early April to mid-May. This is an univoltine species, as are all other members of this genus collected in Western Massachusetts.

The habitats of *P. mixtum* larvae covered a wide range of temporary and permanent streams, including bog seeps and temporary drainage creeks, young and old permanent streams, young rivers, and occasionally outlets to impounded water. They are most common in drainage creeks and young permanent
As shown in Table III, the width of streams from which *P. mixtum* larvae were taken ranged from a few inches to 40 feet. Graph I shows that about 50% of the collections were made in streams four feet or less in width, and over 70% from streams eight feet or less in width. This indicates that the larvae prefer small streams. The mean stream width, shown in Table II, was approximately 7.4 feet, compared with 7.3 feet for *P. fuscum*, and 5.0 feet for *P. fontanum*, two closely related species; however, Graph I shows that, while the means of stream widths for *P. mixtum* and *P. fuscum* were approximately the same, *P. fuscum* larvae were less common in very small streams. *Prosimulium fontanum* was more commonly collected in streams under four feet in width than either *P. fuscum* or *P. mixtum*.

The largest river in which *P. mixtum* larvae were collected was the Farmington River, at New Boston, near Route 57. Flood conditions prevented collecting more than a few feet from shore, but larvae were found to be fairly common on several large boulders that had been used to shore up a bridge. The larvae were confined to a small area where the current broke over the upstream surface of the boulders. No larvae were found on the sides of boulders with the upper surface exposed above the water.

In small streams, larvae were often found covering the entire upper surface of submerged rocks or stones; however, no larvae were found on the lateral surfaces, although
pupation often occurred in these locations.

Table IV shows that 71% of the larval collections were made from inorganic substrates. In the drainage creeks and young permanent streams most often frequented by *P. mixtum* larvae, vegetation is not usually found in the early spring. Collection records indicate, however, that where vegetation is present, the larvae show no preference for any particular substrate. In sites with extremely heavy larval populations, every available substrate may be matted with larvae.

The larvae were most common in swift water flowing over a stream bed at a depth of one to six inches. They may be observed easily from above the surface.

Thirteen species of Simuliidae were found in association with the larvae of *P. mixtum*. The reasons for this large number are the extreme variability of this species in habitat selection, and the length of time that the larvae may be found, from late March to the end of May, so that overlapping occurs with the late spring species.

Table I shows the frequencies of the associations of other black fly species with *P. mixtum*. *P. magnum*, *C. mutata* and *P. fontanum* were the early spring species most commonly found. All three show a marked preference for small streams, as do *P. mixtum* larvae. Only four associations were recorded with the closely related species, *P. fuscum*. This species prefers larger streams, and is more common at luslets to impounded water than are *P. mixtum* larvae. Other early spring species found with *P. mixtum* larvae were *P. rhizophorun,*
P. multidentatum, C. dacotensis, S. vittatum and T. tibblesi. The most common late spring species found with P. mixtum larvae were S. venustum and S. tuberosum. Both species have a wide habitat range, and are often found in young permanent streams. Other late spring species recorded were S. verecundum and S. latises.

Prosimulium mixtum adults were recorded biting more often than any other black fly species. The bites were not painful, and little swelling or itching developed. Annoyance, on the other hand, was great at nearly every collection site. The adults swarmed around the head, and often landed and crawled into the orifices of the head and under the clothing. They were often inhaled by the investigator!

Prosimulium multidentatum (Twinn)

Collection Records (1965)


Pupae: None.

Biological Information

Prosimulium multidentatum was a rare species in Western Massachusetts in 1965. From the few collections made, overwintering apparently takes place in the egg stage, since mature larvae were found from early to mid-May. This agrees with statements by Davies et al. (1962) and Stone (1964). This is probably a univoltine species, as recorded by Peterson (1959) and others.
The collections of *P. multidentatum* larvae were taken from two young permanent streams and one young river. These had stream beds of gravel and small stones, with little or no vegetation present. The larvae were collected from stones in shallow, swift water.

The young streams were three and four feet in width and the young river, where two collections were made, varied from 20 to 35 feet in width. Deciduous and evergreen trees formed the vegetation along the banks.

Four species of black flies were found in association with the larvae of *P. multidentatum*, as shown in Table I. *Prosimulium mixtum* and *P. magnum* are both early spring, univoltine species often collected from young permanent streams. The late spring species found with *P. multidentatum* larvae were *S. venustum* and *S. tuberosum*, two species which are variable in habitat selection.

*Prosimulium rhizophorum* Stone and Jamnback

**Collection Records (1965)**


Pupae: None.

**Biological Information**

*Prosimulium rhizophorum* is a rare species of the *hirtipes* complex. The collection records indicate that, in Western Massachusetts, overwintering occurs in the egg stage, since
no mature larvae were found until early May.

No larvae of this species were collected after May 28, so this is probably an univoltine species, as are all other members of this genus in Western Massachusetts.

The larvae were found in one temporary and five permanent streams, and in one stream which was probably permanent, but became dry in June, possibly due to a drought year in 1965. These streams were classified as drainage creeks and young permanent streams.

Table III shows that five of the seven collections were made in streams one foot or less in width. Only seven collections were made, but it appears that the larvae prefer small streams.

_Prosimulium rhizophorum_ larvae were collected about equally from substrates of organic and inorganic origin, as shown in Table IVa, indicating no particular preference for substrate.

As shown in Table I, four species of black flies were found in association with the larvae of _P. rhizophorum._ _Prosimulium fontanum, P. mixtum, P. magnum and C. mutata_ are all early spring, univoltine species that prefer small streams such as the ones in which _P. rhizophorum_ larvae were found.
XIII. **SIMULIUM SPECIES**

*Simulium aureum* Fries

**Collection Records (1965)**


Shelburne - June 27. Southwick - May 9, June 27.
Warwick - June 15.

**Biological Information**

*Simulium aureum* was a rather rare species in Western Massachusetts in 1965, although its distribution was widespread. Mature larvae were collected during the second week of May in the southern part of the state, but were not found until June along the northern border.

The late appearance of the mature larvae indicates that overwintering takes place in the egg stage. According to Peterson (1959), Stone (1964) and others this is a multivoltine species, with at least two generations per year.

The few collection records available make inferences about this species difficult. All the streams from which mature larvae were taken were of the old permanent type, with muddy or sandy bottoms and a slow current. All the streams occurred in rather flat terrain, with swamps and boggy areas interspersed along their lengths. Grass or aquatic plants were growing in the stream bed, and of the
six larval collections made, four were from aquatic vegetation, giving an indication of a preference for substrates of organic origin.

The widths of the streams, as shown in Table III, varied from a few inches to 15 feet. Shallowness of the streams and the presence of vegetation seemed more consistent than stream width.

Much of the surface area of all the streams from which *S. aureum* was collected was open to direct sunlight, as the vegetation along the banks was composed of small trees and bushes.

As shown in Table Ia, six species of Simuliidae were recorded in association with the larvae of *S. aureum*, all members of the genus *Simulium*. The most common associations were with *S. vittatum* and *S. venustum*. The former species is quite variable as to habitat, but is often found in small numbers in old permanent streams; the latter species is more often found in young permanent streams, but may be found in old permanent streams, as well. Other late spring species found were *S. tuberosum*, *S. verecundum*, *S. latipes* and *S. croxtoni*. While *S. aureum* larvae were present during the time that early spring members of the genus *Prosimulium* are to be found, no associations were recorded, due to the preference of members of *Prosimulium* for temporary and young permanent streams with colder water and faster current and in a forested situation.
Simulium corbis Twinn

Collection Records (1965)


Pupae: Bernardston - May 18.

Biological Information

Simulium corbis is apparently a rare species in Western Massachusetts; it was found in very small numbers in 1965. The small number of collections makes it difficult to be specific concerning the life cycle and habitat of this species. The April 18 collection indicates that this species probably overwinters in the egg stage, as recorded by Davies et al. (1962) and Stone (1964), with hatching occurring in late winter. The species may be multivoltine, as it was collected over quite a span of time, although previous authors have disagreed on this point.

As shown in Table III, the widths of the streams from which larvae of this species were collected was quite variable. All were permanent streams (young streams and young rivers) with rocky beds, many falls and rapids and with swift currents. The larvae were collected in shallow water where the current flowed rapidly over the substrate. As shown in Table IV, larvae were collected from both organic and inorganic substrates, although little vegetation was present in the streams.

As shown in Table Ia, three species were found in association with the larvae of S. corbis. Prosimulium magnum
larvae were collected at all three locations; this species seems to prefer permanent streams with a rapid current. *Simulium venustum*, found on two occasions, and *S. tuberosum*, collected once, are both quite variable in habitat selection.

**Simulium croxtoni** Nicholson and Mickel

Collection Records (1965)


Biological Information

*Simulium croxtoni* is apparently a relatively rare species in Western Massachusetts. Mature larvae were collected from late May through June, indicating that this species overwinters in the egg stage. Davies et al. (1962) and Stone (1964) infer that this species is univoltine.

All the collections of this species were made from old permanent streams or outlets to impounded water. As shown in Table III, stream widths ranged from a few inches up to eight feet.

Table VII shows that the four larval collections of *S. croxtoni* were made in streams with a slow or moderate current. All these streams had beds composed of mud and sand, with grass growing from the stream bed. The larvae were collected from substrates of both organic and inorganic origin.

The water temperature in the streams where the larvae
of this species were found was noticeably higher than that of forest streams. The terrain over which the streams flowed was quite flat, and swamps and ponds were frequent. This spreading of the stream bed subjects the water to considerable warming by the sun. At the points of collection, however, trees and shrubs along the banks of the streams created a good deal of shade.

Larvae of four species of black flies were collected with those of *S. croxtoni*, each at a different site, as shown in Table Ia. *Simulium vittatum* was collected at a pond outlet, a favored site for that species. *Simulium decorum* was taken once on a dam face, where the current was quite swift, and so was not taken from the same habitat as was *S. croxtoni*, which was found below the dam. *Simulium aureum* was found in a small, warm, slow stream in Shelburne. *Simulium venustum* was associated with *S. croxtoni* in a collection taken in a stream with moderate current speed.

*Simulium decorum* Walker

**Collection Records (1965)**


**Biological Information**

*Simulium decorum* seems to be a relatively common species
in Western Massachusetts, although all collections made were confined to the eastern side of the Berkshire Range. The collection records indicate that overwintering takes place in the egg stage, as reported by Wolfe and Peterson (1959) and others. There are apparently several overlapping generations per year, as reported by Jenkins (1948) and subsequent authors.

The larvae of S. decorum occupy a very restricted habitat, being found almost exclusively on dam faces, spillways and sluiceways, and occasionally on rocks or debris just below such a location. In this limited niche they are often found in tremendous numbers, covering the substrate like a carpet.

As shown in Table VII, the current speed where the larvae of S. decorum was found was either moderate or swift. The water is usually quite warm, as it is subjected to the sun as it spreads out above the impounding structure.

The peculiar habitat of this species made larval collection by the usual method impossible. They were usually found on large, permanent structures which could not be removed from the water, so that the only method that could be used was to divert the water around them. Two boards, one foot long and six inches wide, were nailed together to form a V. The device could be positioned so that the point of the V faced upstream and the larvae to be collected were enclosed by the arms of the device. By pressing the device against the substrate, the water was made to flow around the
larvae, leaving them in such a situation as to be easily collected with forceps. At sites where little water was flowing, a cupped hand could be used to divert the water.

Four species of Simuliidae were found in association with the larvae of *S. decorum*, as shown in Table Ia. None of the associations occurred on the dam faces, but were either below the dams or on organic matter in a sluiceway. *Simulium vittatum* and *S. tuberosum* were collected on three occasions each. The former species prefers outlets to impounded water, and the latter species is quite variable in habitat selection. *Simulium venustum* and *S. verecundum* were each found on one occasion.

It is interesting to note that *S. decorum* apparently has been able to invade a habitat that is essentially free from competition from other black fly species; such an adaptation is certainly of great survival value.

*Simulium gouldingi* Stone

**Collection Records (1965)**

Florida - June 27 (3).

Pupae: Florida - June 27.

**Biological Information**

*Simulium gouldingi* appears to be a rather rare species of ornithophilic black fly in Western Massachusetts. Mature larvae were found from mid-May through June, indicating that this species overwinters in the egg stage, as recorded by
Davies et al. (1962) and Stone (1964). These authors report this to be an univoltine species.

The immature stages of *S. gouldingi* were collected from young permanent streams varying in width from a few inches up to eight feet (Table III) and flowing through forested areas. As shown in Table VII, all collections were made in streams with a moderate current. The stream bed contained many small stones, and vegetation was common, growing from the bottom and trailing from the banks. Collections were made from both inorganic and organic substrates, as shown in Table IVa, but the small numbers prevent inferences as to the preferred attachment sites.

As shown in Table Ia, five species were found in association with the larvae of *S. gouldingi*. *Prosimulium fontanum*, a late member of that genus known to prefer small permanent streams, was collected on three occasions. *Simulium tuberosum* and *S. venustum* are late spring species that have a wide range of habitat preference. *Simulium verecundum* and *S. parnassum* were recorded on one occasion each.

*Simulium latipes* (Meigen)

Collection Records (1965)


Pupae: None.
**Biological Information**

*S. latipes* is apparently a rather uncommon species of black fly in Western Massachusetts. Mature larvae were collected from mid-May through June, indicating that this species overwinters in the egg stage, with hatching occurring in early to mid-spring. According to previous authors, there are one or two generations per year.

The collection records indicate that *S. latipes* larvae prefer small young permanent forest streams with a moderate current (Table VII) and rather warm water. Only two collections were made from streams over two feet in width (Table III), these being shallow with rocky beds and grasses trailing in the water.

Table IVa shows that both inorganic and organic substrates were utilized for attachment, although there seems to be a slight preference for the latter, particularly late in the black fly season. Two of the collection records from inorganic substrates were made at the outlets to small ponds, where no inorganic substrates were available.

Table Ia shows that eight species of black flies were collected in association with the larvae of *S. latipes*. Three early to mid-spring, univoltine species that prefer small streams in forested situations were found: *P. fontanum*, *P. mixtum*, and *C. mutata*. Of the late spring species, *S. venustum*, a species with a wide habitat preference, was collected with the highest frequency, and *S. vittatum*, *S. tuberosum*, *S. verecundum* and *S. aureum* were found.
associated with *S. latipes* larvae on one occasion.

*Simulium parnassum* Malloch

**Collection Records (1965)**


Pupae: None.

**Biological Information**

*Simulium parnassum* appears to be a rare species of black fly in Western Massachusetts. Mature larvae were first collected in mid-June, the latest of any species, so this species almost certainly overwinters in the egg stage. The three collections were quite scattered, indicating a rather wide range, although all were found east of the Berkshire Range.

The streams from which the larvae of *S. parnassum* were collected were all young permanent forest streams, six feet or less in width (Table II), and with moderate currents (Table VII). The heavy shade of the forest canopy kept the water in the streams rather cool. All larvae collected were taken from rocks (Table IVa).

As shown in Table I, *P. fontanum*, *S. gouldingi*, *S. venustum* and *S. tuberosum* were the four species of black flies found in association with the larvae of *S. parnassum*. The first three of these species were collected from a stream six inches wide flowing at high altitude through a forest in Florida.
Simulium rivuli Twinn

Collection Records (1965)

Larvae: Mount Greylock Reservation - May 23.

Pupae: None.

Biological Information

Simulium rivuli is apparently a very rare species in Western Massachusetts. The one collection was made from a very small temporary drainage creek approximately two-thirds of the way up the southeast side of Mount Greylock. The larvae were found on a small stone (Table IVa) in a stream three inches wide that flowed rapidly (Table VII) down the side of a large rock outcropping.

The late appearance of the mature larvae suggest that *S. rivuli* overwinters in the egg state; however, at the altitude where the larvae were found, snow and ice are present much later in the spring than in other lower portions of Western Massachusetts, so this date may be misleading. Davies et al. (1962) and Stone (1964) have hinted that this species has one generation per year. This is certainly true at the location in which it was collected, as this stream was revisited in mid-June, and no water was present. The short life of the stream would prevent multiple generations.

Simulium tuberosum Twinn

This species, as previously mentioned, has been found, as a result of studies of the salivary chromosomes, to be a species complex; however, it must at present be treated as
one species, since no external morphological studies have been published.

Collection Records (1965): See Map VI


Simulium tuberosum is apparently one of the most common late spring species of black flies in Western Massachusetts. Mature larvae were collected in early May in the southern portion of the state, and in mid-May along the Vermont border, indicating that overwintering is in the egg stage. According to Wolfe and Peterson (1959) and others, there may be one to four generations per year.

Mature larvae of *S. tuberosum* were found in all types of permanent streams, in some temporary streams, and at outlets to impounded water. As this is a multivoltine species, a preference for permanent streams would be expected. As shown in Table VII, the larvae were found in streams with slow, moderate and fast current, although over half of the collections were taken from streams classified as moderate. Water temperatures varied greatly, from cool forest streams to the warm water at pond outlets. The larvae were usually found where the water flowed shallowly over the stream bed, except when trailing grasses were utilized as a substrate; the larvae were then found on the undersurface of the grass blades which were floating on the surface of the water. As shown in Table IVa, both inorganic and organic substrates were used as attachment sites. During May, rocks were the most commonly used, but in June, the numbers were more nearly equal on rocks and grass.
Table III shows that the stream widths from which the larvae of *S. tuberosum* were collected ranged from a few inches up to 40 feet. Table II shows that the mean stream width, 9.4, is the largest of any of the species collected, an indication of the wide range of habitat selection present in this species.

As shown in Table Ia, 13 black fly species and 86 individual associations were recorded with the larvae of *S. tuberosum*, indications of the wide range of habitats occupied by the larvae of this species. Almost half of these associations involved *S. venustum*, the most prevalent late spring species of black fly, and one possessing nearly as wide a habitat range as does *S. tuberosum*. *Prosimulium fontanum*, *P. mixtum*, *P. multidentatum*, *P. magnun*, *S. corbis* and *S. vittatum* were the early or mid-spring species found with *S. tuberosum*. Other late spring species were *S. decorum*, *S. verecundum*, *S. aureum*, *S. latipes*, *S. Gouldingi* and *S. parnassum*.

*Simulium tuberosum* adults were not collected biting man in Western Massachusetts, but this species has been recorded as a pest and vicious biter in other areas.

*Simulium venustum* Say

Collection Records (1965): See Map VII

Savoy - June 17, June 27. Sheffield - May 5.
Shelburne - June 27. Shutesbury - May 14, June 15.
Windsor - June 27.

Biolofical Information

Simulium venustum appears to be a very common and widely distributed late spring species of black fly in Western Massachusetts. Mature larvae were collected from early May throughout the remainder of the black fly season (Table V), indicating that this species overwinters in the egg stage, with hatching occurring in the spring.

Anderson and Dicke (1960) and others have reported this species to be multivoltine; however, Jamnback (1955) and Bickley (1959) reported only one generation in New York and Maryland. Data collected during 1965 indicate that this species is multivoltine in Western Massachusetts, as larvae and pupae are present throughout the summer months.

The larvae of S. venustum are most often found in young and old permanent streams and in young rivers. Table III shows that the widths of streams from which mature larvae were collected ranged from a few inches up to 30 feet, and Table II indicates the mean width of stream to be 6.8 feet. Graph III shows that over 65% of the collections of S. venustum larvae were made in streams under six feet in width, and nearly 80% from streams 10 feet or less in width.

Larvae were found inhabiting both warm and cold streams in open farmland and in forested terrain, although the largest populations were found below outlets to impounded water. The larvae were indiscriminate as to substrate selection (Table IVa), being collected 55 times from inorganic substrates and 61 times from organic substrates. At one
collection site, near a dump, larvae were collected from rusty cans, bottles, wooden crates and even paper. Below a pond near the center of Rowe, a very heavy population was found on a jumble of logs, sticks and boards, and larvae were also observed on tree roots and on the rock outcropping that formed the stream bed.

Sixteen species of black flies were recorded in association with the larvae of S. venustum, as shown in Table I, an indication of the variation of habitat selection of this species. Of the early spring species, P. mixtum was found on seven occasions, S. vittatum six times, C. mutata twice and P. fuscum once. Associations with these species occurred when their populations were declining, resulting in low association frequencies. Mid-spring species found with S. venustum were P. fontanum (nine times), P. magnum (13 times), P. multidentatum (once) and S. corbis (twice). The largest number of associations (39) was recorded with S. tuberosum, another late spring species with a wide range of habitat selection. Other late spring species found were S. aureum (four times), S. croxtoni (once), S. decorum (once), S. gouldingi (three times), S. latipes (three times), S. parnassum (once) and S. verecundum (three times).

Adult S. venustum were collected biting man on only one occasion, which seems unusual, as this species is known as a fierce biter over most of the northern portion of the North American continent. They were found to be very annoying,
however, flying about the head in large numbers, and entering the nose, mouth, eyes and ears, and crawling under the clothing.

**Simulium verecundum** Stone and Jamnback

**Collection Records (1965)**


**Biological Information**

*Simulium verecundum* does not seem to be a particularly common species in Western Massachusetts, although it is widely distributed. Larvae were found in large numbers on only one occasion, below a reservoir outlet in Belchertown.

The late appearance of the larvae of this species indicates that overwintering takes place in the egg stage, as recorded by Stone and Jamnback (1955) and Davies et al. (1962). As shown in Table V, larvae were commonly collected from mid-May throughout the remainder of the black fly season. This is probably a multivoltine species in Western Massachusetts, as recorded by Stone and Jamnback (1955) in New York, and by Davies et al. (1962) in Ontario.

The larvae of *S. verecundum* were found in young and old permanent streams, and outlets to impounded water with stream widths varying from a few inches up to eight feet (Table III).
This is in contrast to statements by Davies et al. (1962) that this species prefers streams over 10 feet in width.

Ten of the 14 collections made were taken below pond outlets and swamps. This indicates a preference for warm water, as the spreading out of the stream bed in these locations would subject the water to warming by the sun.

Larvae were collected eight times from organic substrates, and eight times from inorganic substrates, as shown in Table IVa, indicating a lack of preference as to substrate. In very small streams, however, the larvae were most often found on the undersurfaces of grass blades drifting near the surface of the water.

As shown in Table Ia, 10 species of black flies were found in association with the larvae of *S. verecundum*. The most common association was with *S. vittatum*, an early spring multivoltine species that prefers outlets to impounded water. The only other early association was found with *P. mixtum*, a species that is present until late May.

Mid-spring species found associated with *S. verecundum* larvae were *P. fontanum* and *P. magnum*, each on two occasions. The most frequent late spring species found were *S. venustum* and *S. tuberosum*, both possessing a wide range of habitat selection. Other late spring species recorded were *S. aureum*, *S. decorum*, *S. gouldingii* and *S. latipes*. 
Simulium vittatum Zetterstedt

Collection Records (1965): See Map VIII


Biological Information

Simulium vittatum is a rather common early spring species of black fly in Western Massachusetts. In the most preferred habitats, the immature stages may be found in tremendous numbers.

Overwintering may occur in the egg or larval stage, as recorded by Wolfe and Peterson (1959) and others. In February of 1966, at a time when fifth instar larvae were present, several clusters of newly-hatched larvae were found in the same stream, at Aldrich Lake in Granby. This variability of overwintering would seem to be of great survival value to the species.
This species was studied during 1965 and 1966 at Aldrich Lake in Granby. The first mature larvae appeared on February 23, at a water temperature of 35°F. They were found in the greatest numbers in mid-March, and pupation was first recorded on March 15, at a water temperature of 37°F.

This is a multivoltine species in Western Massachusetts, since larvae, pupae and adults were found throughout the spring, summer and fall. The number of generations per year is difficult to assess, because of overlapping of stages during the summer months, but there are probably at least four, and perhaps five. Previous authors have found that development of the immature stages may be completed in as little as four weeks.

The larvae of S. vittatum were found in old permanent streams and outlets to impounded water. The latter of these is the most preferred, 17 of the 29 larval collections being made at such sites. In the old permanent streams, larvae were found in small numbers, but at outlets, the populations may reach tremendous proportions, so that every available substrate is matted with them. The overwintering generation is the largest, although another small peak occurs in the fall.

Larvae and pupae were found at varying water depths, from a few inches in old permanent streams to two feet or more below pond outlets. The early spring generation is found at greater depths than are the subsequent generations. At Aldrich Lake, the first generation was present until late
April, at water temperatures ranging from 33 to 50°F. This cold water would hold more oxygen than would the warmer waters during the summer; also, a greater volume of water is present at this time, and current over the stream bed is greater than during the summer. These factors would permit the immature stages to maintain themselves at greater depths during the first generation than in subsequent generations.

During the summer generations, the water temperature ranged from 60°F. up to 85°F., indicating that this species possesses a broad tolerance, as stated by Fredeen and Shemanchuk (1960), and shown by chromosome studies of Pasternak (1964).

As shown in Table IVa, the larvae of *S. vittatum* were found on both organic and inorganic substrates. Observations at Aldrich Lake indicate that the early spring generation prefers rocks, but that the subsequent generations may be found on any substrate available to them. This is also borne out by Table IVa, which shows that larvae were more often found on rocks during April and May, but were taken from both types of substrates in nearly equal numbers in June.

Table VII shows that *S. vittatum* shows little preference as to current speed, the larvae being found in slow, moderate and fast currents. This again indicates that great variability is present in this species.

The mature larvae of the overwintering generation of *S. vittatum* were observed to be approximately twice the size of the mature larvae of the summer generations. Wolfe and
Peterson (1956) attribute this size differential to stream temperature, but Anderson and Dicke (1960) stress that the larval period of the overwintering generation is approximately six times that of the summer generations, giving a longer period for growth.

A few of the S. vittatum larvae collected at Granby were observed to contain nematodes, presumably Mermithidae. The abdomens of the infected larvae were greatly distended, and the nematodes could be seen through the translucent cuticle. No data were taken as to the percentage of parasitism or its affect on the population. Many Trichoptera of the genus Rhyacophila were observed where S. vittatum larvae were numerous.

Ten species of Simuliidae were found in association with the larvae of S. vittatum, as shown in Table I. Of the early spring species, P. mixtum was found three times and P. fuscum twice. Prosimulium magnum, a mid-spring species, often found at pond outlets, was found on four occasions. The most common of the late spring species was S. venustum, a species with a wide habitat preference. Other late spring species found were S. aureum, S. croxtoni, S. decorum, S. latipes, S. tuberosum and S. verecundum. With the exception of S. decorum, these associations were found in small old permanent streams with much vegetation growing from a muddy bed.

Adults of S. vittatum were collected as late as November 26, 1965, at an air temperature of 56°F. They were
observed alighting and crawling on the blue hood and rear
dock of the author's automobile, although none were found
on the cream-colored top. These data correspond to observa-
tions made by Davies (1951) that blue is the most attractive
color to black flies and white the least attractive.

Oviposition by females of *S. vittatum* was observed in
May, 1966, at Aldrich Lake. The females alighted on a solid
object, turned, and backed into the water, laying eggs at a
depth of about one inch below the surface of the water.
Several dead females were recovered attached to egg masses
they had apparently deposited. Several egg masses were
found on the lower surface of a board which was maintained
in a very moist condition by spray from a small cascade.
Females were observed performing a vertical dance below this
board, but no oviposition was observed.

During the week of October 19 through October 26, 1965,
annoyance by females of *S. vittatum* was observed for the
first time, although no bites were received. The owner of
the property, however, reported having been severely bitten
by black flies during that week. DeFoliart and Rao (1965)
reported that the normally ornithophilic species,
*S. meridionale*, will bite man after a period of cold weather.
This may also be the case with *S. vittatum*, as no other
species of black fly was known to be present at the Aldrich
Lake collection site.
XIV. **TWINNIA SPECIES**

*Twinnia tibblesi* Stone and Jamnback

Collection Records (1965)

Larvae: Belchertown - April 17, May 6.


**Biological Information**

*Twinnia tibblesi* was an extremely rare species of black fly in Western Massachusetts in 1965. It was collected from one small, spring-fed stream near an antique shop on Route 202 west of Belchertown.

Davies et al. (1962) and Stone (1964) have stated that this species overwinters in the egg stage. The former authors recorded hatching in mid-April in Algonquin Park, Ontario. According to Hopkin's Bioclimatic Law, hatching would thus occur during late February or early March in Western Massachusetts.

Larval development of black flies has been reported by several authors as requiring as little as three to four weeks, particularly in the multivoltine summer species. If this rapid development could take place in a cold adapted species, then *T. tibblesi* would certainly be able to overwinter in the egg stage, hatch in late winter, and complete larval development by mid-April.

No larvae were found after May 6, although weekly or bi-weekly collection trips were made to the Belchertown site.
during the remainder of May and June. Larvae were again found, however, in April of 1966. *T. tibblesi* is therefore a univoltine species in Western Massachusetts, as reported by Davies et al. (1962), in Ontario, and Stone (1964), in Connecticut.

The site at which the larvae were found is classified as a young permanent stream. At the point of collection, no trees or shrubs grew along the stream banks. Approximately one hundred yards upstream, near the spring which was the source of the stream, the banks were lined with trees which formed a heavy canopy over the stream bed. No *T. tibblesi* larvae were found in this location.

The immature stages of *T. tibblesi* were collected from small stones in the stream bed, and no more than one larva or pupa was found per stone. They were readily observed from above the surface of the water, as the habitat occupied was out of the main current. The larvae were always observed to be in a C-shaped position.

The lack of a gregarious nature, the still water habitat, and the peculiar position of the larva make this species quite distinct from other black fly species found in Western Massachusetts. All three habits may be explained by the feeding mechanism of the larvae of *T. tibblesi*. As mentioned previously, the larvae lack head fans, and cannot strain food carried by the current. Food gathering is accomplished by scraping the surrounding substrate with the mandibles. The larvae are thus not dependent on the current,
and may move to a new habitat. The characteristic shape of the larva is necessary for gathering food, and the solitary habit insures that enough food is available for completion of larval development.

Table I indicates the species of black flies which were found occupying different habitats in the same stream with *T. tibblesi*. *Prosimulium fuscum*, *P. mixtum* and *C. mutata* are all univoltine, early spring species often found in young permanent streams.
XV. SOME CONDITIONS UNFAVORABLE FOR LARVAL DEVELOPMENT

There are many factors that interact to produce a suitable habitat for black fly larvae, among them water temperature, current speed, oxygen content, water depth, suitable substrate and sufficient food supply.

An instance of natural control was found in a large young permanent stream, the Walker Brook, which flows along Route 20 between Becket and Huntington and is a tributary of the Westfield River. This stream was first visited early in April, when small larvae, probably members of the $E$. hirtipes complex, were found in abundance. Later in the month, when the stream was revisited, no larvae could be found and the water was discolored with large quantities of silt and sand. The source of this disturbance was found to be a section of a hillside along the stream, which had eroded and was slowly sliding into the water, releasing large quantities of soil. Above the point of this erosion, larvae were frequent.

Apparently, as mentioned by Davies and Peterson (1956), the grinding action of the soil particles carried by the water had either killed or dislodged the larvae. By the latter part of May, when the erosion had ceased and the water was again clear, mature larvae of $S$. venustum and $S$. tuberosum, which had overwintered as eggs and hatched after the damaging action of the soil particles had ceased
to be a factor, were collected in large numbers.

Several streams, either large young streams or young rivers, were found to be so polluted with chemicals or excreta that no larvae could survive. An example of chemical pollution was found in the West Branch of the Westfield River in Huntington. There was at least one large paper mill in this area, and during the working week, the water of the river was a peculiar greenish color. This apparently had such an effect on the larvae that they could not survive, although there were many areas along the river that appeared to be favorable habitats for both early and late spring black fly species.

Extreme pollution as a controlling agent was found in the Mill River in Williamsburg and Northampton, the Manhan River in Westhampton and the Miller's River in Orange, Wendell and Erving. Both chemicals and excreta are poured into these young rivers in large quantities, and no determination could be made as to which had the greatest effect. Fredeen (1960) stated that sewage may increase black fly populations by increasing the amount of food present, so perhaps the chemical pollutants were responsible for the absence of larvae.

Another result of pollution was found in parts of the Housatonic River, which flows in a southward direction through most of Berkshire County. In this river, larvae may be found in certain areas, but are absent from apparently favorable situations for most of its length. An examination
of the substrates available in this river has led me to the tentative conclusion that the larvae have been forced out of the environment by competition of other organisms for attachment sites. Every available rock or piece of submerged debris in most of the areas of the river is covered with a thick layer of algae, other microorganisms and organic matter that is poured into the river by the communities through which the river passes. It appears that the larvae cannot obtain a hold on the substrate with their ring of posterior hooks, and are thus eliminated. This would seem to be a relatively minor benefit of stream pollution.

No black fly larvae were collected from either the Deerfield or Connecticut Rivers. The Deerfield River has several sites, particularly in Charlemont and Shelburne, which would appear to be favorable habitats for the larvae, and no explanation is given for their absence. The Connecticut River, however, is a large, slowly-moving river with very few good sites for black fly larvae to develop. It is rather deep at most points, the bottom is composed of mud, and there is very little vegetation either growing from the river bed or trailing in the water.
XVI. COLLECTION OF ADULTS

Adult black flies were usually present all during the day, although their numbers were quite small from about 10:00 a.m. to four or five p.m. The peak period of black fly activity took place during the evening, for about two hours prior to darkness. On cloudy days, more activity was noted during the day, but the peak was still present during the evening. Adults were not observed to fly on rainy or cold days.

During unfavorable flight periods, adults were found in large numbers resting on the upper surfaces of culverts and low bridges, and could be easily collected with a twelve inch sweep net. Many Chironomidae and Tipulidae were also collected from these locations.

Larger bridges were avoided as resting places, probably due to the high amount of light present, the air currents, and the lower humidity found in these locations, as opposed to the small culverts and bridges.

Adults were also collected flying about the head or biting. The flying females were collected by sweeping about the head and upper body with a 12-inch sweep net. The biting adults were collected by inverting an empty two dram vial over the feeding insect. All adults captured were preserved in 75% ethyl alcohol.
XVII. BITING RECORDS (1965)

Prosimulium fuscum, P. mixtum and Simulium venustum were collected biting man in Western Massachusetts. The first two species are univoltine early spring species, while the latter is a multivoltine late spring species. The latter two species were also the ones most frequently collected in the larval stage. The biting records are as follows:


The only instance of severe biting was recorded on May 16, when all three species were present. The location is a heavily wooded gully, and the stream itself was extremely favorable to black fly larvae, since they were present in such proportions as to cover the substrate like a carpet. Clouds of adults were present, biting and flying about the
head and upper portion of the body, so that hundreds could be collected with one or two sweeps with a net. All other biting records obtained were isolated instances.

Immunity may be responsible for the small number of biting records obtained. Herms and James (1961) point out that "individuals differ vastly in their attractiveness or non-attractiveness to insects," and add that the factors causing the differences are not well-understood. At times when the author was completely free from annoyance, other people were observed to be severely bitten and distracted by the presence of the adults.

Those bites that were received were not painful and disappeared in a day or two. This is in sharp contrast to descriptions of other authors, who report intense reactions to black fly bites.
As very little was known about the species of Simuliidae present in Western Massachusetts, and nothing was available concerning their ecology and biology in the area, a study was instituted in 1964 in order to form a framework for future research. Techniques of collecting and sampling were developed during 1964, rearing (unsuccessful) was attempted, a system of stream classification was established, and a search of available pertinent literature undertaken. The data upon which this paper is based were gathered during the black fly seasons of 1964, 1965 and 1966.

In the course of these investigations, four genera and 21 species of Simuliidae were found in Western Massachusetts: *Cnephia dacotensis* and *Cnephia mutata*; *Prosimulium fontanum*, *P. fuscum*, *P. magnum*, *P. mixtum*, *P. multidentatum* and *P. rhizophorum*; *Simulium aureum*, *S. corbis*, *S. croxtoni*, *S. decorum*, *S. gouldingi*, *S. latipes*, *S. parnassum*, *S. rivuli*, *S. tuberosum*, *S. venustum*, *S. verecundum* and *S. vittatum*; and *Twinnia tibblesi*.

All members of the genera *Prosimulium*, *Cnephia* and *Twinnia*, and *Simulium croxtoni*, *S. gouldingi* and *S. parnassum* are univoltine in Western Massachusetts; all other *Simulium* species are multivoltine, possibly having from two to five generations per year.

The prevalence of the species of black flies in Western Massachusetts based on frequency of collection was as follows:
Prosimulium mixtum and S. venuatum, the two most common species, are also the two species most often reported attacking man. The former, an univoltine early spring species, is found biting during April and May, while the latter, a multivoltine late spring species, appears in May and is present during the remainder of the summer, although biting is reported most frequently by the first generation.

The nine most common species listed under (3) are primarily pests of mammals; the other species are known to feed on either birds or nectar.

The species of black flies found may be classified according to the manner of overwintering and the time of appearance of mature larvae during the black fly season (Table V). The early spring species, Cnephia mutata, P. fuscum, P. mixtum and S. vittatum, overwinter as partly developed larvae, and are found as mature larvae from late March into early April; the mid-spring species, C. dacotensis, P. fontanum, P. magnum, P. multidentatum, P. rhizophorum, S. corbis and T. tibblesi, hatch from overwintering eggs in late winter, with mature larvae appearing during the middle
of April; and the late spring species, *S. aureum*, *S. croxtonii*,
*S. decorum*, *S. gouldinsi*, *S. latipes*, *S. parvassum*,
*S. tuberosum*, *S. venustum* and *S. verecundum*, overwinter as
eggs, hatch in the spring and develop to mature larvae from early May through June.

The early and mid-spring species are commonly found in both temporary and permanent streams, but the late spring species prefer permanent streams.

The larvae of the early and mid-spring species were more often found on inorganic substrates, while the larvae of the late spring species were common on both inorganic and organic substrates.

Illustrations of the more important taxonomic structures, and keys to larvae of the species found in Western Massachusetts have been included.

Although three different techniques were used in attempts to rear black fly larvae in the laboratory, none proved successful. A method of successfully rearing larvae in their natural habitat using a compartmented holding device is described.

The collection sites of the immature stages of black flies have been classified using physical characteristics of the streams. Temporary flowing water was classified as ground runoffs, bog seeps or drainage creeks, and permanent streams were classified as young permanent streams, old permanent streams, young rivers, old rivers or outlets to impounded water.
Sampling techniques using metal cones and pieces of wooden lath were attempted, but fluctuations in water levels and larval preferences for other substrates limited their usefulness. A technique using a wire ring and sampling larvae directly from their natural habitat was used.

Where possible, only mature larvae were collected, as younger larvae could not be reliably classified. Larvae were collected with forceps and preserved in 95% ethyl alcohol. Special techniques for collecting were devised where necessary.

Adults were collected when biting, by sweeping around the head or in vegetation, or from under culverts and low bridges during the heat of the day.
XIX. CONCLUSIONS

1. For the first time, there are now definite records of the species, distribution (both seasonal and geographical), ecology and relative abundance of Simuliidae in Western Massachusetts.

2. Four genera and 21 species of black flies were collected and identified during the course of these investigations.

3. An attempt has been made to associate the distribution of each species with the environment in which it occurs.

4. The two most common species, Prosimulium mixtum, an early spring univoltine species, and Simulium venustum, a late spring multivoltine species, are the black flies that most frequently attack man.

5. An association can be made between the stage in which the species of Simuliidae overwinter and the occurrence of mature larvae in the spring. This in turn affects the time of emergence of the adult stage and the resulting annoyance to man.

6. The use of artificial sampling devices as substrates for larvae is limited by the fluctuation of water levels and the preferences of larvae for natural substrates.

7. Large numbers of black fly adults were found resting on the upper surfaces of culverts and low bridges during the heat of the day.


Anderson, R.C.


Baranov, N.

Basrur, P.K.


Bennett, G. F.

Bennett, G. F. and A. M. Fallis.

Blacklock, D. B.


Bradley, G. H.

Browne, S. G.

Burton, G. F.

Caviaso, B. L.

Chamberlain, J. C.
Chernin, E.

Cloudsley-Thompson, J.L.


Conradi, A.F.

Coquillet, D.W.

Corbet, P.S.

Crosskey, R.W.

Dalmat, H.T.

Dampf, A.

Davies, D.M.


Edmunds, L.

Edwards, F.W.

Fallis, A.M.

Fallis, A.M., R.C. Anderson and G.F. Bennett.

Fallis, A.M. and G.F. Bennett.
1958. Transmission of Leucocytozoon bonasa Clarke to ruffed grouse (Bonasa umbellus L.) by the black flies Simulium latipes Mg. and Simulium aureum Fries. Can. J. Zool. 36(4);533-539.


Field, G. and W. Law.

Fredeen, F.J.H.


1963. Oviposition in relation to the accumulation of bloodthirsty black flies (Simulium (Gnus) arcticum) prior to a damaging outbreak. Nature 200(4910):1024.


Fredeen, F.J.H. and J.A. Shemanchuk.


Freund, J.E.

Frohne, W.C. and D.A. Sleeper.

Frost, S.W.

Fuller, H.S.

Gambrell, F.D.
Goulding, R.L. Jr. and C.C. Deonier.  

Hagen, H.A.  

Harris, T.W.  

Herman, C.M.  

Hers, W.B. and M.T. James.  

Hinton, H.E.  

Hocking, B.  


Hora, S.L.  


Ide, F.P., C.R. Twinn and D.M. Davies.  
Jamnback, H.


Jamnback, H. and D.L. Collins.

Jamnback, H. and A. Stone.

Jenkins, D.W.

Jobbins-Pomeroy, A.W.

Johannsen, O.A.

Johnson, C.W.


Jones, C.M. and D.J. Richey.
1956. Biology of the black flies of Jasper County, South Carolina, and some relationships to a Leucocytozoon disease of turkeys. J. Econ. Entomol. 49:121-123.

Judd, W.W.

Krafchick, B.
Landau, H.


Lugger, O.

Macan, T.T.

Malloch, J.R.

McComb, C.W. and W.E. Bickley.

Metcalf, C.L.

Metcalf, C.L. and V.E. Sanderson.

Nicholson, H.P.

Nicholson, H.P. and C.E. Mickel.

O'Kane, W.C.

O'Bole, E.C.

Osborn, H.  

Pasternak, J.  

Peterson, B.V.  


Peterson, B.V. and D.M. Davies.  


Phelps, R.J. and G.R. DeFoliart.  

Phillipson, J.  

Polof'eva, K.K.
1959. The types of maturation of eggs in the non-blood-sucking species of black flies (Diptera, Simuliidae).
Biol. Abs. 35 (E):33232. (Abstr.)

Puri, I.M.

Rothfels, K.H.
J. Hered. 47:113-122.

Rubtzov, I.A.
Appl. Entomol. (B) 34:42-44. (Abstr.)

Sabrosky, C.W.

Sailer, R.I.

Shewell, G.E.
1955. Identity of the black fly that attacks ducklings
87(8):345-349.

1956(1958). Classification and distribution of Arctic
10(1):635-643.

Smart, J.


1945. The classification of the Simuliidae (Diptera).

Snoddy, E.L. and K.L. Hays.

Sommerman, K.M.
1958. Two new species of Alaskan Prosimulium, with notes
on related species (Diptera:Simuliidae). Entomol. Soc.
Stains, G.S. and G.F. Knowlton.

Stone, A.


Strickland, E.H.


Sutherland, D.W. and R.F. Darsie, Jr.


Syme, P.D. and D.M. Davies.

Tonnoir, A.L.

Twinn, C.R.


Underhill, G.W.
1939. Two simuliiids found feeding on turkeys in Virginia. J. Econ. Entomol. 32(6):765-768.


Walker, G.P.

Welch, H.E. and I.A. Rubtzov.

Wickware, A.B.


Wolfe, L.S. and D.G. Peterson.


<table>
<thead>
<tr>
<th></th>
<th>dacotensis</th>
<th>mutata</th>
<th>fontanum</th>
<th>fuscum</th>
<th>magnum</th>
<th>mixtum</th>
<th>multidentatum</th>
<th>rhizophorum</th>
<th>corbis</th>
<th>sculda</th>
<th>latipes</th>
<th>parmassum</th>
<th>tuberosum</th>
<th>venustum</th>
<th>verecundum</th>
<th>rittatum</th>
</tr>
</thead>
<tbody>
<tr>
<td>C. dacotensis</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1 2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>C. mutata</td>
<td>-</td>
<td>- 1 3 4 14</td>
<td>- 3 1</td>
<td>- 2</td>
<td>- 2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>P. fontanum</td>
<td>- 1 5 9 10</td>
<td>- 1 3 1 11</td>
<td>9 2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>P. fuscum</td>
<td>3 5 3 4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>P. magnum</td>
<td>1 4 9 3 29</td>
<td>1 2 1 3</td>
<td>- 8 13 2 4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>P. mixtum</td>
<td>2 1 4 10 29</td>
<td>2 2 1</td>
<td>- 1 9 7 2 3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>P. multidentatum</td>
<td>-</td>
<td>-</td>
<td>- 1 2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>P. rhizophorum</td>
<td>- 3 1 2 2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>T. tibblesi</td>
<td>- 1 1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Numbers refer to collections of species simultaneously at a site.
TABLE I (Cont'd). Larval Associations

<table>
<thead>
<tr>
<th></th>
<th>mutata</th>
<th>fontanum</th>
<th>fuscum</th>
<th>magnum</th>
<th>mixtum</th>
<th>aureum</th>
<th>decorum</th>
<th>croxtoni</th>
<th>decorum</th>
<th>gouldingi</th>
<th>latipes</th>
<th>parnassum</th>
<th>tuberosum</th>
<th>venustum</th>
<th>verecundum</th>
<th>vittatum</th>
</tr>
</thead>
<tbody>
<tr>
<td>S. aureum</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S. corbis</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>2</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S. croxtoni</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S. decorum</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S. gouldingi</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S. latipes</td>
<td>2</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S. parnassum</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S. tuberosum</td>
<td>-</td>
<td>11</td>
<td>8</td>
<td>9</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>9</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>S. venustum</td>
<td>2</td>
<td>9</td>
<td>1</td>
<td>13</td>
<td>7</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>9</td>
<td>3</td>
</tr>
<tr>
<td>S. verecundum</td>
<td>-</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>-</td>
<td>4</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>S. vittatum</td>
<td>-</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>-</td>
<td>4</td>
<td>-</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>-</td>
<td>3</td>
<td>6</td>
<td>4</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>
TABLE II. Stream Widths

<table>
<thead>
<tr>
<th>Collections</th>
<th>Mean Stream Width (Feet)</th>
<th>Maximum Stream Width (Feet)</th>
<th>Minimum Stream Width (Feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C. dacotensis</td>
<td>3</td>
<td>-</td>
<td>5</td>
</tr>
<tr>
<td>C. mutata</td>
<td>33</td>
<td>4.3</td>
<td>20</td>
</tr>
<tr>
<td>P. fontanum</td>
<td>45</td>
<td>5.0</td>
<td>20</td>
</tr>
<tr>
<td>P. fuscum</td>
<td>39</td>
<td>7.3</td>
<td>25</td>
</tr>
<tr>
<td>P. magnum</td>
<td>61</td>
<td>7.8</td>
<td>40</td>
</tr>
<tr>
<td>P. mixtum</td>
<td>181</td>
<td>7.4</td>
<td>40</td>
</tr>
<tr>
<td>P. multidentatum</td>
<td>4</td>
<td>-</td>
<td>35</td>
</tr>
<tr>
<td>P. rhizophorum</td>
<td>8</td>
<td>-</td>
<td>12</td>
</tr>
<tr>
<td>S. aureum</td>
<td>5</td>
<td>-</td>
<td>15</td>
</tr>
<tr>
<td>S. corbis</td>
<td>3</td>
<td>-</td>
<td>25</td>
</tr>
<tr>
<td>S. croxtoni</td>
<td>5</td>
<td>-</td>
<td>8</td>
</tr>
<tr>
<td>S. decorum</td>
<td>15</td>
<td>-</td>
<td>15</td>
</tr>
<tr>
<td>S. gouldingi</td>
<td>5</td>
<td>-</td>
<td>8</td>
</tr>
<tr>
<td>S. latipes</td>
<td>8</td>
<td>-</td>
<td>6</td>
</tr>
<tr>
<td>S. parnassum</td>
<td>3</td>
<td>-</td>
<td>6</td>
</tr>
<tr>
<td>S. rivuli</td>
<td>1</td>
<td>-</td>
<td>0.25</td>
</tr>
<tr>
<td>S. tuberosum</td>
<td>84</td>
<td>9.4</td>
<td>40</td>
</tr>
<tr>
<td>S. venustum</td>
<td>96</td>
<td>6.8</td>
<td>35</td>
</tr>
<tr>
<td>S. verecundum</td>
<td>14</td>
<td>4.5</td>
<td>8</td>
</tr>
<tr>
<td>S. vittatum</td>
<td>29</td>
<td>8.3</td>
<td>30</td>
</tr>
<tr>
<td>T. tibblesi</td>
<td>1</td>
<td>-</td>
<td>1.5</td>
</tr>
</tbody>
</table>
TABLE III.
Number of collections made at different stream widths

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>C. dacotensis</strong></td>
<td>-</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>C. mutata</strong></td>
<td>11</td>
<td>5</td>
<td>5</td>
<td>6</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>P. fontanum</strong></td>
<td>13</td>
<td>6</td>
<td>8</td>
<td>5</td>
<td>3</td>
<td>6</td>
<td>3</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>P. fuscum</strong></td>
<td>2</td>
<td>3</td>
<td>7</td>
<td>12</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td><strong>P. magnum</strong></td>
<td>6</td>
<td>6</td>
<td>15</td>
<td>13</td>
<td>6</td>
<td>3</td>
<td>5</td>
<td>2</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td><strong>P. mixtum</strong></td>
<td>24</td>
<td>19</td>
<td>47</td>
<td>25</td>
<td>15</td>
<td>16</td>
<td>22</td>
<td>4</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td><strong>P. multidentatum</strong></td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>P. rhizophorum</strong></td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>S. aureum</strong></td>
<td>2</td>
<td>1</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>S. corbis</strong></td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td><strong>S. croxtoni</strong></td>
<td>3</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>S. decorum</strong></td>
<td>2</td>
<td>-</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>S. gouldingi</strong></td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>S. latipes</strong></td>
<td>4</td>
<td>2</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>S. barnassum</strong></td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>S. rivuli</strong></td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>S. tuberosum</strong></td>
<td>9</td>
<td>7</td>
<td>11</td>
<td>16</td>
<td>6</td>
<td>10</td>
<td>13</td>
<td>5</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td><strong>S. venustum</strong></td>
<td>15</td>
<td>7</td>
<td>23</td>
<td>18</td>
<td>7</td>
<td>6</td>
<td>14</td>
<td>4</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td><strong>S. verecundum</strong></td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>S. vittatum</strong></td>
<td>3</td>
<td>2</td>
<td>7</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>6</td>
<td>1</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td><strong>T. tibblesi</strong></td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
TABLE IV.
SUBSTRATES OF LARVAL SIMULIIDAE

<table>
<thead>
<tr>
<th>Species</th>
<th>April</th>
<th>May</th>
<th>June</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I*</td>
<td>II**</td>
<td>I</td>
</tr>
<tr>
<td>C. dacotensis</td>
<td>1</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>C. mutata</td>
<td>11</td>
<td>5</td>
<td>11</td>
</tr>
<tr>
<td>P. fontanum</td>
<td>17</td>
<td>2</td>
<td>20</td>
</tr>
<tr>
<td>P. fuscum</td>
<td>30</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>P. magnum</td>
<td>19</td>
<td>2</td>
<td>36</td>
</tr>
<tr>
<td>P. mixtum</td>
<td>68</td>
<td>23</td>
<td>77</td>
</tr>
<tr>
<td>P. multidentatum</td>
<td>-</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td>P. rhizophorum</td>
<td>-</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td>T. tibblesi</td>
<td>1</td>
<td>-</td>
<td>1</td>
</tr>
</tbody>
</table>

*Inorganic substrates.
**Organic substrates.

The numbers refer to the number of collections made from inorganic or organic substrates during the months.
<table>
<thead>
<tr>
<th>Species</th>
<th>April</th>
<th>May</th>
<th>June</th>
</tr>
</thead>
<tbody>
<tr>
<td>S. aureum</td>
<td>-</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>S. corbis</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>S. croxtoni</td>
<td>-</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>S. decorum</td>
<td>-</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>S. gouldingi</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>S. latipes</td>
<td>-</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>S. parnassum</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>S. rivuli</td>
<td>-</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>S. tuberosum</td>
<td>-</td>
<td>73</td>
<td>21</td>
</tr>
<tr>
<td>S. venustum</td>
<td>-</td>
<td>43</td>
<td>47</td>
</tr>
<tr>
<td>S. verecundum</td>
<td>-</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>S. vittatum</td>
<td>11</td>
<td>2</td>
<td>5</td>
</tr>
</tbody>
</table>
### Table V.

**Expected maturation periods for larvae of some common species of Simuliidae in western Massachusetts**

<table>
<thead>
<tr>
<th>March</th>
<th>April</th>
<th>May</th>
<th>June</th>
</tr>
</thead>
<tbody>
<tr>
<td>S. vittatum</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P. mixtum</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P. fuscum</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. mutata</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P. fontanum</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P. magnum</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S. decorum</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S. tuberosum</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S. venustum</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S. verecundum</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table VI.

**Expected maturation periods for larvae of some rarer species of Simuliidae in western Massachusetts**

<table>
<thead>
<tr>
<th>March</th>
<th>April</th>
<th>May</th>
<th>June</th>
</tr>
</thead>
<tbody>
<tr>
<td>C. dacotensis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T. tibblesi</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S. corbis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P. rhizophorum</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P. multidentatum</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S. aureum</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S. latipes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S. gouldingi</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S. croxtoni</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S. parnassum</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Species</td>
<td>Slow</td>
<td>Medium</td>
<td>Fast</td>
</tr>
<tr>
<td>--------------</td>
<td>------</td>
<td>--------</td>
<td>------</td>
</tr>
<tr>
<td>C. dacotensis</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>C. mutata</td>
<td>4</td>
<td>14</td>
<td>12</td>
</tr>
<tr>
<td>P. fontanum</td>
<td>1</td>
<td>26</td>
<td>18</td>
</tr>
<tr>
<td>P. fuscum</td>
<td>18</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>P. magnum</td>
<td>24</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>P. mixtum</td>
<td>8</td>
<td>67</td>
<td>103</td>
</tr>
<tr>
<td>P. multidentatum</td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>P. rhizophorum</td>
<td>5</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>S. aureum</td>
<td>4</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>S. corbis</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>S. croxtoni</td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>S. decorum</td>
<td>4</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>S. gouldingi</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S. latipes</td>
<td>2</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>S. parnassum</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S. rivuli</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>S. tuberosum</td>
<td>15</td>
<td>49</td>
<td>20</td>
</tr>
<tr>
<td>S. venustum</td>
<td>26</td>
<td>51</td>
<td>17</td>
</tr>
<tr>
<td>S. verecundum</td>
<td>7</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>S. vittatum</td>
<td>9</td>
<td>15</td>
<td>6</td>
</tr>
<tr>
<td>T. tibblesi</td>
<td>2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Numbers refer to the speed of the current in a stream at the time when a collection was being made.
PLATE NO. 1

Figure 1. Hypostomal teeth of *Prosimulium magnum*.
Figure 2. Hypostomal teeth of *Prosimulium fontanum*.
Figure 3. Hypostomal teeth of *Prosimulium mixtum*.
Figure 4. Hypostomal teeth of *Prosimulium multidentatum*.
Figure 5. Hypostomal teeth of *Prosimulium fuscum*.
PLATE NO. 2

Figure 6. Cephalic apotome of larva, showing head spots.
al - antero-lateral head spots.
am - antero-medial head spots.
pl - postero-lateral head spots.
pm - postero-medial head spots.

Figure 7. Anal sclerite of P. fontanum.
a - apodeme.
ad - antero-dorsal arms.
pv - postero-ventral arms.

Figure 8. Ventral view of head capsule of C. mutata, showing shape of throat cleft.

Figure 9. Ventral view of head capsule of S. parnassum, showing shape of throat cleft.

Figure 10. Ventral view of head capsule of S. corbis, showing shape of throat cleft.
Figure 11. Larva of Simuliidae.
A - Antenna.
AG - Anal gill.
AS - Anal sclerite.
CF - Cephalic (head) fan.
CS - Cervical sclerite.
LP - Lateral plate of proleg.
RH - Respiratory histoblast.
VP - Ventral abdominal papilla.

Figure 12. Pupa of *Simulium vittatum*.
C - Cocoon.
P - Pupa.
RF - Respiratory filaments.
PLATE NO. 4

MOUTH PARTS OF *Simulium vittatum* Zett.

Figure 13. Labrum-epipharynx
Figure 14. Mandible
Figure 15. Hypopharynx
Figure 16. Maxilla
Figure 17. Labium
PLATE NO. 5

Photograph 1 - Ground Runoff
Photograph 2 - Drainage Creek
Photograph 3 - Bog Seep
Photograph 4 - Drainage Creek
Photograph 5 - Small Young Permanent Stream
Photograph 6 - Large Young Permanent Stream
PLATE NO. 6

Photograph 7 - Small Old Permanent Stream
Photograph 8 - Large Old Permanent Stream
Photograph 9 - Stream with Young Permanent and Old Permanent Habitats in Close Proximity
Photograph 10 - Young River
Photograph 11 - Outlet to Impounded Water
Photograph 12 - Outlet to Impounded Water
PLATE NO. 7

Rearing device
MAP I.
Distribution of Cnephia mutata
MAP II.
Distribution of
Prosimulium fontanum
MAP III.

Distribution of
Prosimulium fuscum
MAP V.
Distribution of
Prosimulium mixtum
MAP VI.
Distribution of
Simulium tuberosum
MAP VII.
Distribution of
Simulium venustum
APPENDIX I.

The following is a list of the dates upon which collecting trips were made, the towns in which mature larvae were found, and the species found in them.

March 28 - Blandford (P. fuscum, P. mixtum), Chesterfield (P. mixtum), Otis (P. mixtum).

March 30 - Chesterfield (S. decorum), Northampton (P. fuscum), Westhampton (P. fuscum), Williamsburg (P. fuscum).

March 31 - Conway (P. fuscum), Gilbertville (P. mixtum), Pelham (P. magnum - not mature), Shutesbury (P. fuscum), Ware (C. mutata).

April 1 - Belchertown (P. mixtum), Ludlow (S. vittatum).

April 2 - Ware (C. mutata).

April 4 - Windsor (P. fuscum), Worthington (P. fuscum).

April 5 - Granville (P. mixtum), New Boston (P. mixtum).

April 6 - Egremont (S. vittatum), Great Barrington (P. mixtum), Northampton (C. mutata), Pittsfield (P. fuscum), Richmond (P. fuscum), Stockbridge (P. mixtum and S. vittatum).

April 7 - Ashfield (P. mixtum), Bernardston (P. fontanum), Conway (P. fuscum), Leyden (P. fuscum and P. mixtum).

April 8 - Hawley (P. fontanum), Northfield (P. fuscum), and P. fontanum), Shelburne (P. fuscum and P. mixtum),
Warwick (P. mixtum and C. mutata), Wendell (C. mutata), and Whately (P. mixtum).

April 9 - South Hadley (P. mixtum).

April 11 - Becket (P. fuscum, P. fontanum and P. magnum).

April 13 - Cheshire (S. vittatum), Cummington (P. fontanum), and Windsor (P. mixtum).

April 14 - Charlemont (P. fontanum and P. mixtum), Rowe (P. fontanum and P. mixtum), and Shelburne (P. fontanum, P. mixtum and P. magnum).

April 15 - Amherst (P. fuscum and S. vittatum), South Hadley (P. mixtum, P. magnum and S. vittatum).

April 16 - Granville (P. mixtum, P. magnum and C. dacotensis), New Boston (P. mixtum), Otis (P. fuscum and C. mutata) and Southwick (P. mixtum and C. mutata).

April 17 - Hawley (S. vittatum), Pelham (P. fontanum and P. magnum) and Shutesbury (P. mixtum).

April 18 - Charlemont (P. mixtum), Colrain (P. magnum and S. corbis) and Warwick (P. fuscum, P. fontanum and P. mixtum).

April 19 - Otis (P. mixtum), and Warwick (P. fuscum, P. mixtum and C. mutata).

April 20 - Belchertown (P. mixtum), Bondsville (P. fuscum and P. fontanum), Ware (P. fuscum, P. fontanum, P. magnum, P. mixtum and S. vittatum).

April 21 - Ashfield (P. fontanum), Buckland (P. fuscum and P. mixtum), Charlemont (P. mixtum), Chesterfield
April 22 - South Hadley (S. tuberosum, S. venustum), Ware (P. magnum, P. mixtum and S. vittatum).

April 23 - South Hadley (S. vittatum) and Sunderland (P. mixtum).

April 24 - New Salem (P. mixtum) and Pelham (P. mixtum).

April 25 - Berkshire (S. vittatum), Cheshire (P. mixtum), Florida (P. mixtum), Hancock (P. magnum and P. mixtum), Hawley (P. mixtum), Lanesboro (P. mixtum) and New Ashford (P. mixtum).

April 27 - Chesterfield (P. mixtum), Cummington (P. fuscum and P. mixtum), Huntington (P. fuscum and P. mixtum), Northampton (C. mutata), Westhampton (P. fuscum and P. mixtum) and Worthington (P. mixtum).

April 28 - Amherst (P. mixtum), Gill (P. mixtum), Leverett (P. fuscum, P. magnum and P. mixtum), Montague (P. mixtum), Northfield (P. mixtum), Shutesbury (P. fuscum and S. vittatum) and Wendell (P. mixtum and C. mutata).

May 1 - Pelham (P. mixtum).

May 2 - Becket (P. fuscum, P. magnum, P. mixtum and C. mutata), Blandford (P. magnum, P. mixtum, C. dacotensis), Bonny Riggs Corners of Becket (P. fuscum), Chesterfield (P. mixtum), Huntington (P. magnum and P. mixtum), Montgomery (P. fuscum, P. mixtum and P. rhizophorum), Otis (P. magnum and P. mixtum), Russell (P. mixtum), Tyringham (P. magnum and P. mixtum), Westfield (P. fuscum) and Westhampton (P. mixtum).
May 4 - Hardwick (P. magnum, P. mixtum and S. venustum), New Salem (P. magnum, P. mixtum and C. mutata), Otis (P. rhizophorum and C. mutata), Ware (P. magnum, P. mixtum, S. venustum, S. verecundum and S. decorum).

May 5 - Becket (P. mixtum), Dalton (P. mixtum), Hinsdale (P. mixtum), Huntington (P. mixtum), Mill River (P. mixtum, P. multidentatun and S. tuberosum), New Marlboro (P. mixtum, C. mutata and S. venustum), Sheffield (P. mixtum, P. magnum, C. mutata and S. venustum) and Washington (P. mixtum and C. mutata).

May 6 - Belchertown (P. magnum, S. venustum and T. tibblesi), Chesterfield (S. decorum), Gill (P. magnum), Granby (P. fontanum, P. magnum, C. mutata and S. venustum), Ludlow (S. venustum and S. tuberosum), Pelham (P. mixtum), Shutesbury (P. fontanum, P. magnum, P. mixtum and C. mutata), South Hadley (P. mixtum).

May 7 - Belchertown (P. magnum, P. mixtum and C. mutata).

May 9 - Granville (P. fontanum, P. mixtum, S. tuberosum and S. venustum), Great Barrington (S. tuberosum and S. venustum), New Marlboro (P. mixtum), Pittsfield (P. magnum, S. tuberosum and S. venustum), Richmond (P. mixtum), Sandisfield (P. mixtum and S. venustum), Sheffield (P. mixtum and C. mutata), Southampton (S. aureum), Southwick (S. venustum) and Windsor (P. fontanum and P. mixtum).

May 10 - Pelham (P. mixtum, P. rhizophorum, C. mutata, S. venustum and S. tuberosum).

May 14 - Leverett (P. fontanum, P. magnum, and P. mixtum), New Salem (P. magnum) and Shutesbury (P. mixtum, S. decorum and S. venustum).

May 16 - Adams (S. tuberosum and S. venustum), Cheshire (P. mixtum), Chesterfield (S. tuberosum and S. verecundum), Hinsdale (S. tuberosum), Lanesboro (S. vittatum), Peru (P. mixtum and S. venustum), Savoy (P. magnum, P. mixtum), Williamsburg (P. mixtum), Windsor (P. magnum, P. mixtum and P. multidentatum) and Worthington (P. fuscum, P. fontanum and P. mixtum).


May 19 - Buckland (P. magnum and S. venustum), Charlemont (P. mixtum, S. tuberosum and S. venustum), Cummington (S. venustum), Hawley (P. mixtum and S. venustum), Monroe Bridge (P. fuscum and P. mixtum),
Plainfield (S. venustum), Rowe (P. mixtum and S. venustum), Williamsburg (P. magnum, S. tuberosum and S. venustum) and Zoar (P. mixtum).


May 21 - Belchertown (S. venustum), Brimfield (P. fontanum and P. magnum), Hampden (P. fuscum, P. fontanum, P. magnum, P. mixtum, S. tuberosum and S. venustum), Ludlow (S. vittatum and S. venustum), Monson (S. tuberosum and S. venustum) and Wales (C. dacotensis).


May 26 - Northfield (P. mixtum, S. tuberosum and S. venustum) and Warwick (P. magnum, P. mixtum, S. decorum, S. venustum and S. verucundum).

May 28 - Pelham (P. magnum, P. rhizophorum, S. verucundum and S. vittatum).
May 30 - Becket (*S. decorum*, *S. tuberosum* and *S. venustum*), Chester (*P. fontanum*, *P. mixtum*, *S. tuberosum*, and *S. venustum*), Chesterfield (*S. tuberosum*, *S. venustum* and *S. vittatum*), Hinsdale (*P. fontanum* and *S. venustum*), Huntington (*S. tuberosum* and *S. venustum*), Middlefield (*S. latipes*, *S. tuberosum*, *S. venustum* and *S. verecundum*), Peru (*S. venustum* and *S. verecundum*), Washington (*S. venustum*), Williamsburg (*S. tuberosum* and *S. venustum*), and Worthington (*S. tuberosum*).

May 31 - Ashfield (*P. fontanum*, *S. tuberosum* and *S. venustum*), Conway (*S. tuberosum* and *S. venustum*), Deerfield (*S. tuberosum* and *S. venustum*) and Williamsburg (*S. venustum*).

June 7 - Leeds (*S. tuberosum*), Northampton (*S. decorum*).

June 9 - Becket (*S. latipes* and *S. venustum*), Blandford (*S. tuberosum*), Cummington (*S. gouldingi*, *S. tuberosum*, and *S. venustum*), Otis (*P. magnum*, *S. aureum*, *S. corbis*, *S. croxtoni*, *S. tuberosum*, *S. venustum*, *S. verecundum* and *S. vittatum*), Peru (*P. fontanum*, *S. tuberosum*, and *S. verecundum*) and Russell (*S. tuberosum*).

June 11 - Ashfield (*S. aureum*, *S. latipes*, *S. venustum* and *S. vittatum*) and Goshen (*S. decorum*, *S. parnassum*, *S. tuberosum*, *S. venustum* and *S. vittatum*).

June 12 - Granby (*S. vittatum*).

June 15 - Leverett (*S. parnassum* and *S. venustum*), Montague (*S. tuberosum* and *S. venustum*), Shutesbury (*S. tuberosum*, *S. venustum* and *S. vittatum*) and Warwick
(S. aureum, S. decorum, S. furculatum (?) and S. vittatum).

June 17 - Ashfield (S. tuberosum and S. venustum), Belchertown (S. vittatum), Charlemont (P. fontanum), Cummington (S. tuberosum), Hawley (S. venustum and S. decorum), Plainfield (S. tuberosum and S. vittatum) and Savoy (P. fontanum, P. mixtum, S. tuberosum, S. venustum and S. latipes).

APPENDIX II.

Summary of streams visited including town and location of stream.

Adams: Drowned Land Brook; Hoosic River.

Amherst: Hop Brook; Fort River; Plum Brook; Mill River; Cushman Brook; Pulpit Hill Pond outlet.

Ashfield: South River; Creamery Brook; East Brook; Chapel Brook; Twining Brook; North Branch, Swift River; Swift River; Upper Branch; Bassett Meadow River; Cole Meadow Brook (two branches); junction of Route 112 and 116 and Cape Street; Route 112 and 116 one mile east of Spruce Corners; junction Route 116 and Cummington Road.

Becket: Walker Brook; Spark Brook; West Branch Walker Brook; Palmer Brook; Shaker Mill Brook; Shaw Pond tributary; October Mountain Road; near Eagles Nest sign on Route 20.

Belchertown: Roaring Brook; Broad Brook; Hop Brook; Hill Brook; Jabish Brook; Bachelor Brook; Scarborough Brook; Route 202 west of center, by antique shop; 1.5 miles north of Bondsville, Route 181.

Berkshire (Lanesboro): Muddy Brook.

Bernardston: Falls River; Shattuck Brook; Couch Brook; Route 5, Vermont line; one mile south of center beneath Route 91 overpass.

Blandford: Benton Pond outlet; Peeble Brook; Route 23,
beaver dam; Route 23, two miles from Russell line; junction of Route 23 and Granville Road, below dam; Route 23, just west of center.

Bondsville: Lily Pond outlet; 0.5 miles south of Bondsville, Route 181.

Brimfield: Wales Brook.

Buckland: Clark Brook; Clesson Brook.

Charlemont: Mill Brook; Maxwell Brook; Avery Brook; Patch Brook; Todd Brook; Steele Brook; Rice Brook; Trout Brook; Cold River; Hartwell Brook; Wilder Brook; Oxbow Brook; Route 2, two miles west of center.

Cheshire: Gore Brook; Collins Brook; Kitchen Brook; Hoosic River; Penniman Brook; McDonald Brook; Dry Brook.

Chester: Sanderson Brook; Walker Brook; Austin Brook; Blair Brook; 0.5 miles west of Sanderson Brook, Route 20; Huntington Road, Westfield River tributary.

Chesterfield: Dead Branch; Page Brook; Scout Pond outlet; Meekin Brook; Rocky Brook; Thayer Brook; Dead Branch tributary; Whistle Brook; West Branch; Otis Wait Brook; East Branch Westfield River.

Colrain: West Branch North River; East Branch North River; Spur Brook; Johnson Brook; Green River; Taylor Brook.

Conway: Roaring Brook; Pumpkin Hollow Brook; Poland Brook; South River; Johnny Bean Brook; Mill River; Bear River; Schneck Brook; Route 116 just east of center.

Cummington: Swift River; North Branch Swift River; Westfield River; Kearney Brook; Childs Brook; Meadow Brook;
Bartlett Brook; Alder Meadow Brook; Route 112 one mile from Route 9.

Dalton: Wahconah Falls Brook; Housatonic River; Hathaway Brook.

Deerfield: Mill River.

Easthampton: Hannum Brook.

Egremont: Hubbard Brook; Karner Brook; Route 41 1.5 miles south of South Egremont.

Erving: Keyup Brook; Schoolhouse Brook.

Florida: Cold River; White Brook; Whitcomb Brook; Green River; Staples Brook; Tower Brook; Reed Brook; junction of Route 2 and Strykers Road; Route 2 at the Eastern Summit.

Gill: Fall River; one mile west of center on Turners Falls Road.

Goshen: Sears Meadow Brook; Highland Lake outlet; West Branch Mill River; Rogers Brook; Swift River; East Brook; Route 9, two miles south of center.

Granby: Aldrich Lake outlet; Bachelor Brook; Ingraham Brook; Stony Brook; junction of Route 116 and Amherst Road.

Granville: Munn Brook; Dickinson Brook; Seymour Brook; Hubbard River; Potash Brook; Trumbly Brook; Valley Brook; Pond Brook and two tributaries; at center.

Great Barrington: Green River; Hubbard Brook; Long Pond Brook; Housatonic River; Williams River; Fountain Pond Brook; Muddy Brook; Route 23 two miles east of center.

Greenfield: Wheeler Brook; Smead Brook.
Hadley: Fort River; two temporary streams 3.5 miles south of center, Route 47.

Hancock: Kinderhook Creek; Whitman Brook; West Branch Green River; Bentley Brook; Rathburn Brook; Gardner Hollow Brook; at North Hancock.

Hampden: Temple Brook; junction of Monson and Wilbraham Roads; 0.5 miles from Monson line.

Hawley: Hallockville Pond outlet; King Brook; Chickley River; Bozrah Brook; Potash Brook; North Brook; Route 8A, 0.5 miles north of West Hawley; Route 8A, 2.5 miles north of West Hawley.

Heath: Avery Brook; Mill Brook; West Branch Brook; West Branch, North River; Burrington Brook; Vincent Brook; Tissdale Brook; Davenport Brook; Taylor Brook; Carley Brook.

Hinsdale: East Branch Housatonic River; Cady Brook.

Huntington: Pond Brook; Roaring Brook; Little River; Sykes Brook; junction Route 112 and County Road; Route 20, Norwich Bridge; 0.5 miles southeast of Worthington line, Route 20.

Lanesboro: Berkshire Pond outlet; Town Brook; Secum Brook; Bentley Brook; Route 8, 0.5 miles north of Pittsfield line.

Lee: Greenwater Brook; Washington Mountain Brook.

Leverett: Long Plain Road; Cranberry Pond outlet; Leverett Pond outlet stream; Ryans Hill Brook; Cushman Brook; Roaring Brook; Doolittle Brook; Sawmill River; Spaulding Brook; Williams Brook; Red Brook; Gardner Brook;
0.5 miles west of North Leverett at M&M Trail sign.

Leyden: Hibbard Brook; Brandy Brook; Shattuck Brook; on Brattleboro Road; Colrain Road 0.5 miles east of Green River; Colrain Road, beaver dam.

Ludlow: Broad Brook; Route 21 at center.

Middlefield: Factory Brook; Tuttle Brook; Glendale Brook; Geer Brook.

Monroe: Phelps Brook; Dunbar Brook.

Monson: Chicopee Brook; Norcross Brook; Twelve-mile Brook.

Montague: Sawmill River; Goddard Brook.

Monterey: Konkapot River; Lake Buel tributary; Swann Brook; 0.25 miles east of junction of Route 23 and Corashire Road; Konkapot River tributary 1.25 miles west of center; Lake Garfield tributary near Hupi Road and Route 23.

Montgomery: Sacket Brook; Meadow Brook; Roaring Brook; Crow Brook; Shatterack Brook.

Mount Greylock Reservation: Mitchell Brook; East Branch; 0.5 miles below summit on west side.

New Ashford: Green River; East Brook; Thompson Brook.

New Marlborough: Mill River; Konkapot River; at Brewer's Limestone Farm; Umpachene River; 0.5 miles east of center.

New Salem: Swift River tributaries; Moosehorn Brook; Bow Brook; Hop Brook and one tributary; Prescott Brook; Thurston Brook; West Branch Swift River; Route 202, one mile west of center; 0.5 miles north of center on Wendell Road.
Northampton: Bassett Brook; Parsons Brook; Mill River; Roberts Brook; Pine Grove Golf Course; Rocky Hill Pond outlet.

Northfield: Fourmile Brook; Mill Brook; Route 63 to Hinsdale; junction Routes 10 and 63; Warwick Road one mile east of center.

Orange: West Branch, Tully River; Cheney Brook; Poor Farm Brook; Orcutt Brook; Moss Brook; West Brook.

Otis: Hop Brook; Spectacle Pond Brook; Benton Brook; Dimmocks Brook; Wheeler Brook; Thomas Brook; Farmington River, West Branch; junction Routes 8 and 23; junction Route 8 and Harrington Road.

Pelham: Harris Brook; Jabish Brook; Buffum Brook; Amethyst Brook.

Peru: Trout Brook; Fuller Brook; Kilburne Brook; Ashmere Lake tributary; Route 143 east of center.

Pittsfield: Shaker Brook; Jacoby Brook; Mount Lebanon Brook; Pontoosuc Lake outlet; West Branch Housatonic River.

Plainfield: Mill Brook; Meadow Brook; North Branch Swift River; Hallockville Pond tributary, Route 8A and 116.

Richmond: Furnace Brook; Sleepy Hollow Brook; at center; one mile south of center.

Rowe: Tuttle Brook; Pelham Brook; Potter Brook; Shipper Brook; Sam Rice Brook; Lord Brook; County Brook; Taylor Brook; pond outlet at center.

Russell: Bradley Brook; Pond Brook; 1.25 miles southeast of center, Route 20; Route 23 near junction of Route 20.
Sandisfield: Silver Brook; Buck River; West Branch Farmington River; Thorp Brook.

Savoy: Gulf Brook; Bog Brook; Black Brook; Phelps Brook; Horsefords Brook; Manning Brook; Cold River; Center Brook; Westfield River; Savoy Hollow Brook; Drowned Land Brook.

Sheffield: Bear Rock Stream; Willard Brook; Fawn Lake outlet; near Bartholomews Cobble.

Shelburne: Hinsdale Brook; North River; Hawkes Brook; Dragon Brook and one tributary; Allen Brook; High Ledge Brook; Sluice Brook; two miles east of Shelburne Falls; 2.5 miles east of Shelburne Falls.

Shutesbury: Lake Wyola outlet; Atherton Brook; Cobb Brook; Camel Brook; Dean Brook; Junction Route 202 and Prescott Road; one mile west of center; Roaring Brook and tributaries.

South Hadley: Bachelor Brook; Stony Brook; Elmer Brook; Dry Brook; Leaping Well Brook; Smith Brook; Lower Pond outlet.

Southwick: Kellog Brook; Great Brook; Pearl Brook; Tuttle Brook; Shurtleff Brook; Munn Brook.

Stockbridge: Agawam Brook; Kampoosa Brook.

Sunderland: Gunn Brook; Dry Brook; Route 47, one mile north of center; Route 47, two miles north of center.

Tolland: Taylor Brook; Richardson Brook.

Tyringham: Hop Brook; Crystal Brook; Camp Brook; Merry Brook.
Wales: Walse Brook; Delphi Brook.

Ware: King Brook; Beaver Brook; Swift River; Flat Brook; at Ware Center; 0.3 miles on Route 32 north of junction with Route 20; at Torcotte Airport; one mile south of Gilbertsville on Route 32; Peppers Mill Pond tributary.

Warwick: Mountain Brook; Darling Brook; Orcutt Brook; Kidder Brook; Rum Brook; Black Brook; Tully Brook; Grace Brook; Moss Brook; Bass Pond outlet; along Northfield Road; one mile east of Sheomet Lake on Athol Road.

Washington: Depot Brook and one tributary.

Wendell: Middle Branch, Swift River; Whetstone Brook; Osgood Brook; Plympton Brook; West Branch Swift River; Bowens Pond outlet; brook from Sibleys Swamp on Jennison Road; 1.25 miles from center on East Road.

Westfield: Arm Brook; Meadow Brook.

Westhampton: Roberts Meadow Brook; North Branch Manhan River; Loudville Brook; Manhan River; Lyman Brook; Rive Brook; Dead Branch; Turkey Brook; Edwards Pond outlet; .25 miles east of junction of Route 66 and Southampton Road.

West Stockbridge: Williams River; Crane Lake Brook; Route 41, at Williamsville.

Whately: Ground Brook; Potash Brook; West Brook; Roaring Brook; Sunkpot Brook; two tributaries to the Northampton Reservoir.

Williamsburg: Mill River; Meekin Brook; Beaver Brook; Joe Wright Brook; West Brook; Bradford Brook; Potash Brook.
Williamstown: Roaring Brook; Sweet Brook; Hemlock Brook; Flora Glenn Brook; Paull Brook; Hoosic River; Buxton Brook; West Branch Green River and tributaries.

Windsor: Hume Brook; Weston Brook; Westfield Brook; Windsor Brook; Tyler Brook; Steep Bank Brook; Westfield River; 1.25 miles north of center, Route 8A.

Worthington: Tower Brook; West Branch Westfield River and tributaries; Bronson Brook; Steven Brook, Wards Stream; Watts Stream; Middle Branch Westfield River; Whitside Brook; Little River.