1-1-1953

Blackfly control investigations.

Hugo Andrew Jamnback
University of Massachusetts Amherst

Recommended Citation

Jamnback, Hugo Andrew, "Blackfly control investigations." (1953). *Doctoral Dissertations 1896 - February 2014*. 5853.
https://scholarworks.umass.edu/dissertations_1/5853

BLACKFLY CONTROL INVESTIGATIONS

JAMNBACK - 1953

BLACKFLY CONTROL INVESTIGATIONS

Hugo Jamnback

Thesis submitted in partial fulfillment of
the requirements for the degree of
Doctor of Philosophy
University of Massachusetts, Amherst.
1953.

TABLE OF CONTENTS

SECTION IV. THE EFFECTS OF STREAM TREATMENT FOR BLACKFLY LARVAL CONTROL ON OTHER WILDLIFE

INTRODUCTION

The basic purpose of this study was to investigate a blackfly control program being carried out in the Town of Webb in the Adirondacks. The primary objectives in this study were; evaluation of existing control procedures, development of more effective and less costly methods of control, and determination of the effects of a large scale, repeated blackfly control operation on stream fauna.

A study of the taxonomy and biology of the species of Simuliidae present in the Adirondacks was necessary in order to properly evaluate the effectiveness of the control program and to develop better methods of control.

A study of the effects of annual blackfly control operations on stream fauna other than blackfly larvae involved the development of sampling equipment and techniques and stream population studies over a period of three years.

The information secured in this study is presented in four sections dealing respectively with the taxonomy, biology, and control of the Simuliidae, and the effects of stream treatments on stream fauna other than blackfly larvae.

SECTION I. TAXONOMY*

SUPRASPECIFIC CLASSIFICATION OF THE SIMULIIDAE FOUND IN NEW YORK

The early classifications of Simuliidae have been well discussed in Smart's (1945) catalog and in Vargas' (1945) monograph dealing with the family. The differences of opinion (see below) seem to be more in according rank to the groups within the family than in separating or delimiting the different groups. The more important recent taxonomic papers are summarized below. (The concepts of Enderlein, Edwards, and Rubtzov are taken from Smart's (1945) paper.)

Enderlein published numerous taxonomic papers from 1921 to 1927 dividing the family into 7 subfamilies and 50 genera. Workers have, in general, not followed his lead in splitting the Simuliidae to this degree.

Edwards (1931) divided the Simuliidae into 2 genera, *Parasimulium* and *Simulium*. The genus *Simulium* was divided to form 7 subgenera: (*Prosimulium*), (*Cnephia*), (*Gigantodax*), (*Austrosimulium*), (*Eusimulium*), (*Morops*), and (*Simulium*). Later (1934), he indicated

---

*Tables in each section numbered independently.

that the last 3 subgenera could be regarded as one, (Simulium) (restricted).

Twinn (1936) followed Edwards' (1931) classification.

Smart (1945) divided the Simuliidae into 2 subfamilies, the Parasimuliinae and the Simuliinae. The former is composed of the genus Parasimulium, and the latter the genera Prosimulium, Cnephia, Austrosimulium, Gigantodax, and Simulium. The genus Simulium (restricted) includes the subgenera (Simulium), (Eusimulium), and (Morops).

Rubtzov (1940) divided the Simuliidae into 5 genera, Parasimulium, Prosimulium, Gigantodax, Austrosimulium, and Simulium. According to Rubtzov, the genus Prosimulium is divided into 2 subgenera, (Prosimulium) and (Helodon); the genus Simulium is divided into 17 subgenera including (Simulium), (Eusimulium), and (Neosimulium).

Vargas (1945) divided the family into 2 genera, Parasimulium and Simulium, with no subgenera.

Nicholson and Mickel (1950) followed Smart (1945) fairly closely but did not divide the genus Simulium into subgenera.

Stone (1951, personal communication) noted that he considers *Prosimulium*, *Cnephia*, and *Simulium* to be valid genera. He divides the genus *Simulium* into the subgenera (*Simulium*), (*Eusimulium*), and (*Neosimulium*).

In addition to the above mentioned genera, the genus *Gymnopais* (first described from Alaska by Stone in 1952) has been found in New York.

The supraspecific classification for the Simuliidae of New York used in this report is as follows:

Family

Simuliidae

Subfamily

Simuliinae

Genus 1. *Gymnopais*
2. *Prosimulium*
3. *Cnephia*
4. *Simulium*
Subgenera a. (*Simulium*)
b. (*Eusimulium*)
c. (*Neosimulium*)

SPECIES OF SIMULIIDAE FOUND IN NEW YORK

Gymnopais *sp*., undescribed.

Prosimulium *hirtipes* (Fries), 1824. Mon. Simul. Suec. 1: 17.

P. sp. 14, undescribed.
P. magnum D&S, 1927. Proc. U.S.N.M. 69: 6.
?P. multidentatum Twinn, 1936. Can. J. Res. D. 14: 106-108

Cnephia dacotensis (D&S), 1927. Proc. U.S.N.M. 69: 20-21.
C. mutata (Malloch), 1914. U.S.D.A. Ent. Bull., Tech. Ser. 26: 20-21
C. sp. 1, undescribed.
C. sp. 2, undescribed.

Simulium (Simulium) venustum Say, 1823. Jour. Acad. Sci. Phila. 3: 28.
S. (S.) decorum Wlk., 1848. Cat. Brit. Mus. Dipt. 1: 112.
S. (S.) jenningsi Malloch, 1914. U.S.D.A. Ent. Bull., Tech. Ser. 26: 41-43.
S. (S.) tuberosum (Lündstrom), 1911. Acta Fauna Flora Fenn. 34: 14.
S. (S.) parnassum Malloch, 1914. U.S.D.A. Ent. Bull., Tech. Ser. 26: 36-37.
S. (S.) corbis Twinn, 1936. Can. Jour. Res. D. 14: 147-148.
S. (S.) croxtoni N&M, 1950. Univ. Minn. Agr. Expt. Sta. Tech. Bull. 192: 41-42.
S. (S.) pictipes Hagen, 1880. Proc. Bost. Soc. Nat. Hist. 20: 305-307.
S. (S.) fibrinflatum Twinn, 1936. Can. Jour. Res. D. 14: 141-142.
S. (S.) sp., undescribed.

S. (Neosimulium) vittatum Zett., 1838. Ins. Lapp. Descripta, pp. 803.

S. (Eusimulium) aureum Fries, 1824. Monog. Simul. Suec. 1: 16.
S. (E.) gouldingi Stone, 1952. Proc. Ent. Soc. Wash. 54: 90-91.
S. (E.) latipes (Meigen), 1804. Klassif. Beschr. Europ. Zweifl. Ins., pp. 96.
S. (E.) pugetense (D&S), 1927. Proc. U.S.N.M. 69: 23.

LARVAL KEYS

REVIEW OF THE LITERATURE

The first larval key including species of Simuliidae found in New York was published by Johannsen in 1903. For taxonomic characters he used the structure of the anal gills, pattern of the head capsule, shape and number of teeth of the submentum, number of epicranial spines, presence or absence of setae or bristles on the mandibles and maxillary palps, the number of fan rays on the cephalic fan, and the color and size of the larvae.

Malloch published a key in 1914 modified from Johannsen's (1903) key.

Some of the species found in New York are included in Edwards' (1920) key to the British species of Simuliidae. In addition to characters used by Johannsen (1903), Edwards used the presence or absence of ventral papillae, segmentation of the antenna, and the number of hooks on the anal ring as "key" characters.

Other workers, including Puri (1925), Johannsen (1934), and Smart (1944), have published larval keys containing some of the species of Simuliidae found in New York using various combinations of the above mentioned characters.

In addition to the taxonomic characters listed above, De Foliart (1951), in an unpublished key to species, used the throat cleft which varies in size and shape between species and is relatively constant within a species. De Foliart (loc. cit.) also constructed generic and subgeneric keys for New York species based on a limited number of species. He used relative lengths of the *small teeth* (middle group of De Foliart) of the mandible, presence or absence of tooth-like spira posterior to the upper arm of the anal cross-piece (anal armature of De Foliart). These characters appear not to be of generic significance when a larger number of species are considered. All previously published larval keys take the specimen directly to species without distinguishing between generic and specific characters.

It is interesting to note that the classification based on adult characters appears to be a natural one since the species of Simuliidae found in New York may be divided into existing genera using larval characters. Even the subgenera of *Simulium* namely (*Simulium*), (*Eusimulium*), and (*Neosimulium*) show larval differences that are fairly consistent within each subgenus.

Larval characters found to be of value in separating the genera include the shape and number of the teeth of the submentum and the shape and number of the teeth and serrations on the inner subapical margin of the mandible. Gymnopais differs markedly from the other genera found in New York in shape of the head capsule, length of the fan rays, shape of the mandible, and other structures.

LARVAL KEY TO GENERA OF SIMULIIDAE

1. Fan rays very short, less than one-third the length of antennae. Head capsule strongly convex on lateral margin (Pl. 4, fig. 4). Teeth of submentum blunt (pl. 2, fig. 1). Distal teeth of mandible blunt (pl. 4, fig. 1) .... Gymnopais

   Fan rays long, longer than antennae. Head capsule slightly convex on lateral margin. Teeth of submentum pointed. Distal teeth of mandible pointed 2

2. Antenna with segments 1 and 2 colorless, segments 3 and 4 dark brown to black (pl. 5, figs. 2-3). Throat cleft a subrectangular notch, two to three times as wide as deep (pl. 3, fig. 2). Median tooth of submentum trifid (pl. 2, figs. 2, 3). Anal gills with three simple lobes .... Prosimulium

   Antennae with segments 1 and 2 yellow to brown, segments 3 and 4 rarely dark brown. Throat cleft neither subrectangular notch nor two to three times as wide as deep. Median tooth of submentum single. Anal gills either three simple or three compound lobes 3

3. Submentum with large and subequal outer and median teeth and three smaller subequal intermediate teeth on each side (pl. 2, fig. 7). Anal gills with three compound lobes (except S. aureum) .... Simulium

Submentum not as above (pl. 2, figs. 4, 5, 6). Anal gills with three simple lobes .... Cnephia

LARVAL KEY TO PROSIMULIUM SPECIES

1. Antennae about one-third as long as distance from point of insertion to posterior margin of head capsule. Teeth of submentum gradually decrease in length from median to lateral. Inner subapical margin of mandible with about eight serrations, mostly large. Length of maxillary palps two times width at base 2

Antennae about one-half as long as distance from point of insertion to posterior margin of head capsule. Teeth of submentum do not gradually decrease in length from median to lateral. Inner subapical margin of mandible with twelve or more serrations, mostly small. Length of maxillary palps three times width at base 3

2. Anal hooks 10-13 per row. Mandibles with small teeth having relative lengths 16:14:25 distad to basad. Serrations on inner subapical margin of mandible larger (pl. 6, fig. 4) .... P. multidentatum

Anal hooks 15-16 per row. Mandibles with small teeth having relative lengths 2:1:3 distad to basad. Serrations on inner subapical margin of mandible smaller (pl. 6, fig. 3) .... P. magnum

3. Head capsule with distinct dark brown anterolateral head spots. Submentum with trifid tooth shorter than all others; intermediate teeth subequal in length to outer teeth. Pupal respiratory organ with 16 filaments arising from three main branches. Inner subapical margin of mandible with about twelve serrations (pl. 6, fig. 1) .... _P. hirtipes_

Head capsule with distinct yellow anterolateral head spots. Submentum with median trifid tooth larger than all other large teeth; intermediate teeth shorter than outer teeth (pl. 2, fig. 2). Pupal respiratory organ with 16 setiform short filaments arising from stumplike base. Inner subapical margin of mandible with usually about seventeen serrations (pl. 6, fig. 2) .... _P. sp. 14_

LARVAL KEY TO _CNEPHIA_ SPECIES

1. Abdominal segment 5 projecting ventrally far beyond segment 4. Head spots light. Paired ventral papillae present. Throat cleft U-shaped, rounded apically. Submentum with concave anterior margin, with teeth very small (pl. 2, fig. 5).. _C. sp. 1_

Abdominal segment 5 not projecting ventrally far beyond segment 4. Head spots dark. Paired ventral papillae absent. Throat cleft usually not rounded apically. Submentum not as above 2

2. Throat cleft a shallow V-shaped notch (pl. 3, fig. 3). Submentum with large lateral teeth, long slender median tooth, apical margin not smoothly concave (pl. 2, fig. 4). Antennae long, nearly as long as distance from point of insertion to posterior margin head capsule (pl. 5, fig. 4) .... _C. mutata_

Throat cleft U-shaped with flattened apex. Submentum with small teeth, median largest, apical margin smoothly concave (pl. 2, fig. 6). Antennae short, slightly less than half as long as distance from point of insertion to posterior margin head capsule (pl. 5, fig. 6) .... C. dacotensis

LARVAL KEY TO SIMULIUM SPECIES

1. Anal lobes absent or small and inconspicuous. Throat cleft either pointed apically or suboesophageal ganglion distinctly black or both. Head spots light or dark 2

Anal lobes conspicuous. Throat cleft usually not pointed apically. Suboesophageal ganglion not distinctly black. Head spots dark 7

2. Suboesophageal ganglion not distinctly black. Abdomen not black 3

Suboesophageal ganglion distinctly black. Abdomen mostly black 5

3. Head spots dark obscure. Throat cleft V-shaped extending 1/3 distance from posterior margin of head capsule to teeth of submentum (pl. 3, fig. 5) .. .. S. parnassum

Head spots light. Throat cleft bulbous 4

4. Infuscation around head spots not extending beyond inner edge of anterolateral spots. Light yellow area present just anterior to apex of throat cleft on epicranial plate. Anal cross piece narrowly fused medially (pl. 6, fig. 7). Mature specimens 8-10 mm. long .... S. decorum

Infuscation around head spots extending to outer edge of anterolateral spots. Light yellow area absent on epicranial plate just anterior to apex of throat cleft. Anal cross piece broadly fused medially. Mature specimens 6-7 mm. long .... S. venustum

5. Throat cleft bowed V-shaped, extending one-half distance to teeth of submentum (pl. 3, fig. 4). Antennae uniformly yellow except for ventral light area on first segment. Anal hooks with 11-15 per row. Mature larvae 5.5 mm. long .... S. tuberosum

Throat cleft not as above. Antennae with light spot on venter of second segment (on distal half). Anal hooks with 18-27 per row. Mature larvae 9-11 mm. long 6

6. Submentum with large median tooth extending far beyond lateral teeth (pl. 2, fig. 8). Second antennal segment with bilobed ventral light spot (pl. 5, fig. 7). Anal gills with three lobes bearing numerous large dorsal accessory lobes. Throat cleft extending half way from posterior margin of head capsule to apex of submentum. Anal hooks with 127-135 rows ...... S. pictipes

Submentum not with large median tooth extending far beyond lateral teeth. Second antennal segment with single lobed ventral light spot (pl. 5, fig. 8). Anal gills with three lobes bearing small ventral accessory lobes. Throat cleft extending slightly more than one-fourth distance from posterior margin to apex of submentum (pl. 3, fig. 6). Anal hooks with 67-88 rows .... S. vittatum

7. Throat cleft more or less flattened on anterior margin (pl. 3, fig. 7). Anal gills three simple lobes. Inner subapical margin of mandible with two serrations, anterior one two times as long as posterior. Mature larvae with four pupal filaments .... *S. aureum*

   Throat cleft rounded on anterior margin. Anal gills made up of three compound lobes. Inner subapical margin of mandible with five serrations typically; large anterior serration is more or less flat on anterior margin and forms angle of about 90 degrees with margin, followed by 2-4 small anteriorly pointing serrations. Mature larvae with four or six filaments 8

8. Antennal segment length ratios 4.2:3.6: 3.0:0.6 (pl. 5, fig. 9). Mature larvae with six filaments .... *S. gouldingi*

   Antennal segment length ratios 4.7:6.2: 2.9:0.5. Mature larvae with four pupal filaments 9

9. Larvae present in streams in early spring (March in Adirondacks). 4 long and 1-2 short epicranial setae on each side .... *S. pugetense*

   Larvae present in streams in late spring and summer (May and June in the Adirondacks). 1-3 long and 1-2 short epicranial setae on each side ...... *S. latipes*

LARVAL DESCRIPTIONS

REVIEW OF THE LITERATURE

Descriptions or figures of the immature stages of Simuliidae were published as early as 1774 (Eichhorn). Osten Sacken summarized the efforts of earlier workers in 1870. This early work, while of historical interest, dealt with the Simuliidae as a group with little attempt to distinguish species.

Riley (1887) included some of the earliest taxonomic descriptions and figures of species found in the United States (*C. pecuarum* and *S. meridionale*). Lugger (1896) gave an early description of a species found in New York, *S. vittatum* (descr. as *S. tribulatum*), with figures of the larva, pupa, and pupal case.

The first comprehensive series of larval descriptions of species found in New York was given by Johannsen in 1903. He described and figured the larvae of *S. pictipes*, *S. venustum*, *S. jenningsi* (descr. as *S. venustum* var. *a*), *S. vittatum*, *S. decorum*, (descr. as *S. piscicidium*), and *Prosimulium sp*. (descr. as *P. hirtipes*).

Later workers who described larvae of species found in New York include Emery (1913), Hungerford (1913), Strickland (1913), Malloch (1914), Jobbins-Pomeroy (1916), Edwards (1920), Puri (1925), O'Kane (1926), Ritcher (1931), Johannsen (1934), Johannsen (1934), Underhill (1944), and De Foliart (1951).

GENERAL DESCRIPTION

A general description of larval characters found to be of taxonomic value in identifying species of blackflies found in New York is given to orient the reader. Taxonomic characters are described, located, and evaluated in more detail than would be desirable in the generic and specific descriptions. Since the descriptions are not intended to be complete anatomical studies, there are many structures which may be of taxonomic value, that have not been considered here. As examples, the arrangement of setae and bristles on the mandibles and maxillae, the structure of the hypopharynx, prementum, or labrum may be cited.

For a more detailed treatment of larval anatomy consult Puri's (1925) excellent study of the larvae of S. decorum (descr. as S. nölleri).

The head capsule is made up of two sclerites, the dorsal frontoclypeus and the lateral and ventral *epicranial plate*. The frontoclypeus is quite uniform in color except for the *head spots* and infuscations. The head spots occur at the point of insertion of muscles attached to the head capsule. In some species, the area around the head spots may be infuscated. Since the location of the head spots on the frontoclypeus is quite constant in most of the species studied, they may be divided into four categories based on their locations: the *anterior median group*, the *posterior median group*, and the paired *anterior lateral* and *posterior lateral groups* (see pl. 4, figs. 3-5). In some species, the head spots are light against a dark background, in others dark against a lighter background. The epicranial plate is less uniform in color than the frontoclypeus. Often the lateral portion is somewhat darker than the ventral. There are a series of muscle attachment points along the posterolateral margin of the epicranial plate. Three spots may be visible, arranged in an irregular line on each side, extending from near the posterolateral margin to a point below the eye. In some species there is a single lateral spot on each side of the venter slightly anterior to the anterior margin of the throat cleft.

The throat cleft is located on the postero-ventral margin of the epicranial plate. It may vary in shape, width, and depth between species (pl. 3, figs. 1-9).

The suboesophageal ganglion is located just ventrad of the digestive tract. It can usually be seen just under the epidermis in the general region of the throat cleft. It is a distinct black in some species and either white or light brown in others (pl. 3, figs. 4-5).

The submentum bears heavily sclerotized teeth on the anterior margin. These are fused to the anteromedian margin of the epicranial plate. The shape, size, and number of teeth of the submentum are slightly variable but nevertheless furnish good generic and sometimes specific characters. The degree of serration of the lateral margins of the submentum is also of some value in distinguishing species (pl. 2, figs. 1-8).

There are two series of setae which appear to originate near the lateral margins of the submentum. Actually, as was pointed out by Puri (1925), they originate on the epicranial plate just ventrad of the submentum. Earlier workers described these as submental or labial setae. These setae will be referred to as epicranial setae in the larval descriptions. The number of setae and the distance from the outermost tooth of the submentum to the anteriormost seta on the same side are of some taxonomic value.

The mandibles of many species have been well described by Puri (1925). There are a series of teeth and serrations on the distal portion of the mandible which are of some value in identifying genera, subgenera, and species. Puri divided these teeth into four groups. There are three large, black apical teeth which are quite similar in most species. The basad tooth is about two times as large as the upper two. Basad of the apical teeth there is a series of small teeth on the ventral surface of the mandible. The first three of these are similar in appearance to the apical teeth but are usually much less heavily pigmented. They project clearly beyond the inner edge of the mandible and are not overlapped by other teeth. Their relative lengths vary between species but are fairly constant within each species.

Basad of these three teeth the small teeth series is continued by less distinctly visible teeth which gradually decrease in size from anterior to posterior. This series of teeth is overlapped by a submarginal row of <u>bristle-like teeth</u> which begin just basad of the third tooth of the small tooth series. The first tooth of this series is usually longer than the third tooth of the small teeth series. The bristle-like teeth decrease gradually in size from anterior to posterior since all but the first three teeth of the small teeth series overlap the bristle-like teeth, it is difficult to determine the number and size of either of these series without clearing, staining, and examining a number of specimens under oil immersion. The edge of the inner subapical margin of the mandible may bear <u>serrations</u> (tooth-like processes of Puri, 1925). These serrations are quite variable, even within a species, but the basic pattern usually remains recognizable.

The <u>antennae</u> are generally 4-segmented. (Some authors have considered segments 1 and 2 as a single compound segment.) Segment 3 bears two small spine-like distal processes. Segment 4 is very short and pointed apically. The pigmentation and the total length of the antennae are characters of some taxonomic value. The segment length ratios are somewhat variable within species but have some taxonomic value (pl. 5, figs. 1-10).

The cephalic fans are complex paired structures of uncertain homology located laterad of the antennae. The number of fan rays is quite variable within a species, but the average number for a species often varies from that of other species. In *Gymnopais sp.* the fan rays are very short; in other genera the fan rays are always longer than the antennae.

The maxillae are rounded apically, bearing numerous setae and bristles. The maxillary palps are single segmented and bear stout apical bristles.

The thorax is somewhat stouter than the first few abdominal segments. In mature specimens, the developing pupal filaments can readily be seen just under the epidermis on each side of the prothorax. These filaments may be removed for study as an aid in identifying larvae. A single median ventral proleg arises from the prothorax (although the base appears to extend into the mesothorax as a ventral thickening). This proleg terminates distally in rows of radially arranged hooks, similar in appearance to the anal hooks.

The *abdomen* is 8-segmented. The segments usually increase gradually in diameter from anterior to posterior with segment 7 the stoutest.

The *ventral papillae* of the abdomen are paired conical projections from the lateroventral portion of the eighth abdominal segment. These may be conspicuous as in *S.* (*Eusimulium*) *spp.*; small and indistinct as in *S.* (*S.*) *venustum*; or totally lacking as in *P. hirtipes* and most of the other species found in New York.

The *anal gills* are projections of the ventral wall of the rectum (Headlee, 1906). When retracted they lie completely within the rectal cavity. The rectal opening is located just anterior to the anal cross-piece on the dorsum of the eighth abdominal segment. The anal gills may consist of three simple lobes (*Gymnopais*, *Prosimulium*, and *Cnephia*) or be made up of three compound lobes (all *Simulium* species found in New York except *S.* (*E.*) *aureum*). *S.* (*N.*) *vittatum* is distinguished by having very small ventral accessory lobes.

The anal hooks are located at the posterior end of the terminal abdominal segment. These hooks are arranged in a series of radially arranged parallel rows. The number of rows and the number of hooks per row, while difficult to count, are sometimes of use in taxonomy.

The anal cross-piece is located just anterior to the anal hooks of the eighth abdominal segment. It consists of two sclerotized pieces. Each piece is broadly U-shaped with the arms of one directed to the right and of the other to the left. These arms are joined medially forming an X-shaped structure. The comparative lengths of the upper and lower arms and the presence or absence of lightly sclerotized areas adjoining or between the arms are of some value in determining species although these may vary somewhat within a species (pl. 6, figs. 7-9).

GYMNOPAIS LARVAE

Since the larva of only one species of *Gymnopais* is known to the author, separation of generic and specific characters is, of necessity, somewhat arbitrary. Characters probably of generic value are as follows.

The head capsule is strongly convex along the lateral margin, being widest just behind the eyes when viewed dorsally or ventrally. The width decreases to about one-half maximum at the point of insertion of the mandibles. The position of the head spots and the shape of the frontoclypeal plate are quite different from those of other genera of Simuliidae, as might be expected since the shape of the head capsule is quite different in Gymnopais.

The submentum consists of nine main teeth. The median tooth is more or less trifid. There are smaller teeth between the main teeth, but these often are not readily visible unless examined under oil immersion. The teeth are unusual in being rounded apically instead of pointed as are the teeth of the submentum in other genera of Simuliidae. This genus resembles Prosimulium in the grouping of the teeth and the presence of small intermediate teeth.

The mandibles have blunt apical and subapical teeth. The posterior teeth are somewhat more pointed and narrower than the anterior ones.

The maxillary palps are dark brown except for a white apex which bears small bristles.

Each cephalic fan bears very short and inconspicuous fan rays which are one-third to one-half as long as the antennae.

Ventral papillae are lacking. The anal gills are made up of three simple lobes.

Gymnopais sp. Larvae

Not previously described.

Description

Pl. 2, fig. 1 submentum; pl. 3, fig. 1 throat cleft; pl. 4, fig. 1 mandible, fig. 4 head capsule, pl. 5, fig. 1 antenna; pl. 6, fig. 8 anal cross-piece.

Mature specimens 8 mm. long. Head capsule with distinct dark brown to black head spots; infuscation around head spots lacking; median posterior group of head spots present, just anterior to these, paired mediolateral spots are present on each side; two pairs of anterolateral spots present, single anteromedian spot visible just distad of anterolateral spots; epicranial plate with dark posterolateral spots, suborbital series and single lateroventral spot present on each side. Throat cleft absent, posteroventral margin of head capsule irregular. Submentum with median trifid tooth and outermost teeth shorter than intermediate teeth; with lateral margins serrate. Two long epicranial setae present on each side, appearing to arise from near lateral margins of submentum. Distance from apex of outermost tooth of submentum to anteriormost epicranial seta on same side slightly less than distance between outermost teeth. Mandibles with teeth not differentiated as in other genera; with eight apical and subapical blunt teeth followed by six bristle-like teeth; inner subapical margin with three small serrations. Antennae relatively short, about one-third as long as distance from point of insertion to posterior margin of head capsule; segment length ratios base to apex, 1.2:3.2:2.5:0.5; segments 1 and 2 clear, segments 3 and 4 dark brown. Each cephalic fan with about 36 rays. Length of maxillary palps slightly more than two times width at base. Pupal respiratory organs each with sixteen filaments arising from three main branches. Abdomen of preserved specimens dark mottled brown; widening laterally with greatest width between segments 5 and 6. Anal cross-piece well sclerotized, lacking lightly sclerotized areas between arms; with ventral arms fused and dorsal arms separate forming Y; dorsal arms slightly shorter than ventral arms. Anal hooks about 10 per row; 54 rows.

PROSIMULIUM LARVAE

Mature specimens are 6 to 10 mm. in length depending on the species. The head capsule has slightly convex lateral margins. The head spots are brown and the area around the heat spots is not infuscated. The anterior and posterior median groups are usually a distinct dark brown and are separated by a moderately wide isthmus. There are two pairs of anterolateral head spots on each side. These may be dark brown or distinctly light yellow depending on the species. The posterolateral head spots are dark brown in all species. The spots on the epicranial plate are either indistinct brown or not apparent.

The throat cleft is two to three times as broad as deep. The apical margin is transverse and the lateral margins slope slightly outward from anterior to posterior.

The suboesophageal ganglion is usually not distinct. It may be brownish at times but is never a distinct black.

When examined under high power, the teeth of the submentum appear to be made up of a series of large teeth with very small to moderately sized teeth between them. The outer tooth on each side and the median trifid tooth are plainly visible even under low power. There are two or three large intermediate teeth between the median tooth and the outer teeth on each side. The lateral margins of the submentum are wavy or serrate distally but are relatively smooth for most of their length.

The epicranial setae appear to arise from near the lateral margins of the submentum on each side. There are 2-4 long setae and a variable number of short setae arranged in an irregular line on each side.

The distance from the apex of the outermost tooth of the submentum to the anteriormost epicranial seta on the same side is slightly less than the distance between the outermost teeth.

The mandibles have small teeth with the third tooth longest and the second shortest. The inner subapical margin of the mandible usually has between eight and seventeen serrations. The most distal of these is larger than the others. There is apparently considerable variation in the size and number of these serrations both between and within species.

The *antennae* are 4-segmented and quite short. They are, at most, slightly more than half as long as the distance from the point of insertion to the posterior margin of the head capsule. Segments 1 and 2 are colorless; segments 3 and 4 are dark brown to black.

The *cephalic fans* are much longer than the antennae. There are usually 30-40 rays on each fan.

The length of the *maxillary palps* is two to three times their width at the base. They are dark brown except for a white apex which bears small bristles.

The *abdomen* of preserved specimens is grayish to brownish with light intersegmental areas. *Ventral papillae* are absent. The *anal gills* consist of three simple lobes. The *anal cross-piece* is well sclerotized with the areas between arms lightly sclerotized. The dorsal arms are longer or subequal in length to the ventral arms. The *anal hooks* are made up of 75-95 rows with 11-16 hooks per row.

Prosimulium hirtipes Larvae

Previous Descriptions and Figures

1903. Johannsen, (see P. sp.)

1911. Strickland, (see P. sp.)

1920. Edwards, (see P. sp.)

1925. Puri, (see P. sp.)

1934. Johannsen (see P. sp.)

1951. De Foliart, P. hirtipes. Unpublished thesis, Cornell Univ., pp. 54-55 (description); 87, pl. 1 (frontoclypeus); 89, pl. 3 (throat cleft); 90, pl. 4 (antenna); 92, pl. 6 (submentum); 94, pl. 8 (mandible, distal); 96, pl. 10 (anal cross-piece).

Description

Pl. 3, fig. 2 throat cleft; pl. 5, fig. 2 antenna; pl. 6, fig. 1 inner subapical margin of mandible, fig. 9 anal cross-piece.

Mature specimens 6-8 mm. long. Head capsule with distinct dark brown anterolateral head spots. Throat cleft three times as broad as deep. Submentum with outermost teeth slightly longer than median trifid tooth; with three intermediate teeth, between median and outer on each side, subequal in length to outer teeth; with innermost of these slightly smaller than others; lateral margins of submentum wavy but not serrate distally. Usually two long and two short epicranial setae present on each side. Mandibles with small teeth having relative lengths 2:1:3 distad to basad; inner subapical margin of mandible with about twelve serrations, mostly small. Antennae relatively short, slightly more than half as long as distance from point of insertion to posterior margin head capsules; segment length ratios base to apex 3.3:4.6:4.7:0.5; width of first two segments approximately 0.16 their combined length. Each cephalic fan with 30-40 fan rays. Length of maxillary palps about three times width at base. Pupal respiratory organs each with sixteen filaments arising from three main branches. Anal cross-piece well sclerotized, dorsal arms longer than ventral arms. Anal hooks 9-14 per row; about 77 rows.

Prosimulium sp. 14 Larvae

Previous Descriptions and Figures

1926. O'Kane, Prosimulium sp. N. H. Exp. Sta. Tech. Bull. 32: 21 (description).

Description

Pl. 2, fig. 2 submentum; pl. 6, fig. 2 inner subapical margin of mandible.

Mature specimens 7 mm. long. *Head capsule* with distinct light yellow *anterolateral head spots*. *Throat cleft* three times as broad as deep. *Submentum* with median trifid tooth longer than others; with outer lateral teeth nearly as long as median; with two intermediate teeth, between median and outer on each side, distinctly shorter than outermost teeth and innermost, third intermediate tooth much smaller, lateral margins of submentum wavy but not serrate distally. Usually three long and one or two short *epicranial setae* present on each side. *Mandibles* with *small teeth* having relative lengths 13:8:21 distad to basad; inner subapical margin of mandible generally with about seventeen *serrations*, mostly small. *Antennae* relatively short, slightly more than half as long as distance from point of insertion to posterior margin of head capsule; segment length ratios base to apex 5.0:6.9:6.3:0.6; width of first two segments approximately 0.16 their combined length. Each *cephalic fan* with about 37 fan rays. Length of *maxillary palps* about three times width at base. *Pupal respiratory organs* each with sixteen short, setiform pupal filaments arising from stumplike base. *Anal cross-*

piece well sclerotized, dorsal arms slightly longer than ventral arms. *Anal hooks* 11-14 per row; about 78 rows.

Prosimulium magnum Larvae

Previous Descriptions and Figures

1951. De Foliart, *P. magnum*. Unpublished thesis, Cornell Univ., pp. 55-56 (description); 92, pl. 6 (submentum).

Description

Pl. 6, fig. 3 inner subapical margin of mandible.

Mature specimens 9-11 mm. long. *Head capsule* with distinct dark brown *anterolateral head spots*. *Throat cleft* about two and one-half times as wide as deep. *Submentum* with median trifid tooth longer than all others; other teeth gradually decrease in length from median to outermost teeth; lateral margins of submentum serrate distally. Usually two long and two short *epicranial setae* present on each side with points of insertion regularly spaced. *Mandibles* with *small teeth* having relative lengths 2:1:3 distad to basa; inner subapical margin of mandible with about eight *serrations*, mostly large. *Antennae* short, about one-third as long as distance from point of insertion to posterior margin head capsule; segment length ratios base to apex 3.0:4.5:4.8:0.6; width of first two segments approximately 0.19 their combined length. Each cephalic fan with about 45 fan rays. Length of maxillary palps slightly more than two times width at base. Pupal respiratory organs with about 26 filaments. Abdomen with median ventral bulge often present on segment 7. Anal cross-piece well sclerotized, dorsal arms subequal in length to ventral arms. Anal hooks 15-16 per row; about 92 rows.

Prosimulium multidentatum Larvae

Not previously described

This species is apparently very rare in the Adirondacks. One pupa, probably of this species, was collected in 1950. Dr. A. Stone (U.S.N.M.) sent 6 specimens of larvae believed to be this species for study. These came from White Sulphur Springs, West Va., dated 4.V.41 and were determined by Stone.

Description

Pl. 2, fig. 3 submentum; pl. 5, fig. 3 submentum; pl. 6, fig. 4 inner subapical margin of mandible.

Specimens available were not mature since they lacked well developed pupal filaments. These larvae averaged 7.5 mm. in length.

Head capsule with distinct dark brown anterolateral *head spots*. *Throat cleft* slightly more than two times as broad as deep. *Submentum* with median trifid tooth longer than all others; other teeth gradually decrease in length from median to outermost teeth; lateral margins of submentum serrate distally. Usually two long and one short *epicranial setae* present on each side with points of insertion regularly spaced, a second small seta often present posterior to these. *Mandibles* with *small teeth* having relative lengths 16:14:25 distad to basad; inner subapical margin with about eight serrations, mostly large. *Antennae* short, slightly more than one-third as long as distance from point of insertion to posterior margin head capsule; segment length ratios base to apex 2.2:3.5:3.5:0.6; width of first two segments about 0.18 their combined length. Each cephalic fan with 35-37 *fan rays.* Length of *maxillary palps* about two times width at base. *Pupal respiratory organs* each with 23-28 filaments. Abdominal segment 7 with median ventral bulge. *Anal cross-piece* moderately sclerotized, dorsal and ventral arms subequal in length. Anal hooks 10-13 per row; 82-90 rows.

Prosimulium sp. A. Larvae

Previous Descriptions and Figures

1903. Johannsen, *S. hirtipes*. N. Y. State Mus. Bull. 68: 363-364 (description); Pl. 34, figs. 3-9, 11, 12 (maxilla and maxillary palp, submentum, antenna, mandible, habitus, ventral aspect head capsule, fan ray, habitus, posterior end abdomen, anal hooks).

1911. Strickland, *S. hirtipes*. Biol. Bull. 21: Pl. 1, fig. 2a-c (head spots recently moulted larvae); Pl. 3, fig. 8a, 8b (full grown parasitized larva of *S. hirtipes* measuring 11 mm., average size mature larva *S. hirtipes* measuring 8.5 mm.).

1912. Garman, *C. pecuarum*. Kent. Agr. Expt. Sta. Bull. 159: 20, fig. 5 (habitus); 21, fig. 6 b,d,f,g', g'', h,i,n (cephalic fan rays, maxilla and maxillary palp, mandible ventral, mandible dorsal, distal end mandible, submentum, antenna, prementum).

1914. Malloch, *P. hirtipes*. U.S.D.A. Ent. Bull., Tech. Ser. 26: 19-20 (description); Pl. 3, figs. 3,6 (submentum, maxilla and maxillary palp); Pl. 6, figs. 3,7 (antenna, portion of ray of mouth fan).

1920. Edwards, *S. hirtipes*. Bull. Ent. Res. 11: 245-246 (description from Johannsen, 1903 and Malloch, 1914); 220, fig. 2g (submental teeth) (after Malloch, 1914); 220, fig. 3g (antenna) (after Johannsen, 1903).

1925. Puri, *S. hirtipes*. Parasit. 17: 359-361 (description); 360, figs. 20A-E (dorsal aspect head capsule, antenna, distal end mandible, submentum, submental teeth).

1934. Johannsen, *P. hirtipes*. Cornell Univ. Agr. Expt. Sta. Mem. 164: 59-60 (description); Pl. 24, fig. 211 (submentum).

Prosimulium sp. Larvae

Descriptions and/or figures of larvae supposedly *P. hirtipes*, by Johannsen (1903, 1934), Strickland (1911), Malloch (1914), Edwards (1920), and Puri (1925) are based, at least in part, on misdetermined specimens. The larval descriptions fit *P. multidentatum* better than any other species. However, these authors note that the pupae of the species in question has about 60 respiratory filaments while the pupae of *P. multidentatum* have 23-28 respiratory filaments.

For the present, I consider these descriptions to be based on a species closely related to *P. multidentatum* but unknown to me.

Cnephia Larvae

Considering the morphological homogeneity of larvae of the other genera of Simuliidae, the variation in structures between species of *Cnephia* is remarkable. The only structure that is similar in the three species of *Cnephia* found in New York is the anal gills which are made up of three simple lobes. These species may belong to three different genera, but until further studies are made they are provisionally retained in the genus *Cnephia*.

Mature specimens are 6 to 11 mm. long depending on the species. The head capsule has slightly convex lateral margins. The head spots may be either light or dark and may or may not be surrounded by a dark infuscation. An isthmus may or may not be distinguishable. Two pairs of anterolateral head spots are present on each side. A lateral spot on each side of the venter just anterior to the anterior margin of the throat cleft may or may not be present depending on the species.

The throat cleft varies from a small V-shaped notch to a deep U-shaped cleft depending on the species.

The suboesophageal ganglion is colorless or light brown except in one species in which it is tinged with black.

The submentum is very different in each of the three species. The anterior margin varies from concave with a few small teeth, to straight with twelve fairly even teeth and a slightly enlarged median tooth, to one with an elongate median tooth and large lateral teeth.

There are usually 2-3 long and a variable number of short epicranial setae present forming an irregular line on each side, appearing to arise from near the lateral margins of the submentum.

The distance from the apex of the outermost tooth of the submentum to the anteriormost epicranial seta on the same side compared to the distance between the outermost teeth is highly variable between species of Cnephia.

The relative lengths of the small teeth of the mandible are different between species. The degree of serration of the inner subapical margin of the mandible is also of some taxonomic value.

The antennae vary from very short to very long depending on the species. Usually segments 1 and 2 are clear ventrally and light yellow dorsally with segments 3 and 4 mostly yellow.

The cephalic fans are of normal length; that is, much longer than the antennae. There are usually 41-68 fan rays on each fan.

The length of the maxillary palps ranges from two and one-half to almost four times the width at the base depending on the species. They are dark brown with a white apex. There are small apical bristles present.

The abdomen varies from deep brown to yellow in color and has light intersegmental areas. It may be "normal" in shape (i.e., slightly bulbous posteriorly) or may be abruptly enlarged ventrally. Paired ventral papillae may be present or absent, if present they are directed posteriorly. The anal gills are made up of three simple lobes. The anal cross-piece may be present or absent. The anal hooks consist of about 61-69 rows of radiating hooks with 7-18 hooks per row.

Cnephia dacotensis Larvae

Previous Descriptions and Figures

1951. De Foliart, C. dacotense. Unpublished thesis, Cornell Univ., pp. 57-58 (description); 92, pl. 6 (submentum).

Description

Pl. 2, fig. 6 submentum; pl. 5, fig. 6 antenna

Mature specimens 11 mm. long. Head capsule with distinct brown head spots, with brown infuscation around head spots; median row lacks distinct isthmus between anterior and posterior groups, consists of about eleven irregularly placed spots. Throat cleft extending slightly more than one-fourth distance from posterior margin of head capsule to anterior margin of submentum; with anterior margin variable, flattened to slightly arched; widest at posterior margin. Suboesophageal ganglion colorless to light brown, never black. Submentum with six small teeth on each side of a slightly larger median tooth; with anterior margin, at most, slightly concave; with lateral margins serrate distally. Usually two long and one short epicranial setae present on each side. Distance from apex of outermost tooth to anteriormost seta on same side slightly less than distance between outermost teeth. Mandibles with small teeth having relative lengths 15:11:17 distad to basad; inner subapical margin with long thin tooth-like serration followed by 1-3 smaller serrations which are followed by a small cleft. Antennae short, slightly less than half as long as distance from point of insertion to posterior margin head capsule; segment length ratios base to apex 1.5:3.6: 3.4:0.4; general color light yellow, uniform. Each cephalic fan with 41-49 rays. Length of maxillary palps about two and one-half times width at base. Pupal respiratory organs each with about 30 filaments. Abdomen of preserved specimens mottled brown with light intersegmental areas; with maximum thickness at posterior margin of segment 7. Ventral papillae lacking.

Anal cross-piece well sclerotized, area between dorsal arms lightly sclerotized; dorsal arms slightly shorter than ventral arms. Anal hooks 11-17 per row; about 61 rows.

Cnephia mutata Larvae

Previous Descriptions and Figures

1931. Ritcher, Undescribed species no. 2. Ent. News 42: 243-244 (description); Pl. 6, figs. 1-3, 5, 6 (mandible, maxilla and maxillary palp, anal gills and anal hooks, and cross-piece, antenna, submentum).

1934. Johannsen, Simulium sp. A. Cornell Univ. Agr. Expt. Sta. Mem. 164: 61 (description); Pl. 24, fig. 212 (submentum).

1951. De Foliart, C. mutata. Unpublished thesis, Cornell Univ., pp. 56-57 (description); 87, Pl. 1 (frontoclypeus); 89, Pl. 3 (throat cleft); 90, Pl. 4 (antenna); 92, Pl. 6 (submentum); 94, Pl. 8 (mandible, distal); 96, Pl. 10 (anal cross-piece).

Description

Pl. 2, fig. 4 submentum; pl. 3, fig. 3 throat cleft; pl. 4, fig. 5 head capsule; pl. 5, fig. 4 antenna.

Mature specimens 6 mm. long. Head capsule with distinct dark brown head spots, lacking infuscation around head spots; with about five anterior and four posterior median head spots widely separated by a yellow isthmus; with single lateral spot on each side of venter of head capsule slightly anterior to the anterior margin of throat cleft. *Throat cleft* small V-shaped notch extending less than one-fifth distance from posterior margin of head capsule to tip of longest submental tooth. *Suboesophageal ganglion* never a distinct black, may be brownish at times. *Submentum* with nine teeth (excluding processes beyond two large lateral teeth), outermost teeth large and broad with small tooth on inner slope of each side, one or two additional small teeth present on each side of long narrow median tooth which is shorter than large lateral teeth; lateral margins with distal serrations, medially wavy. Two to three long *epicranial setae* and a variable number of short setae present on each side. Distance from apex of outermost tooth of submentum to anteriormost seta on same side slightly greater than distance between outermost teeth. *Mandible* with small teeth having relative lengths 8:5: 15, with teeth 1 and 2 almost obscured by apical teeth; inner subapical margin with 7-12 serrations, distal ones larger than basal. *Antennae* long, slightly more than distance from point of insertion to posterior margin head capsule; segment length ratios base to apex 5.2:4.8:4.0:0.5; yellowish with pigmentation somewhat heavier on dorsal margin, with segments 3 and 4 darker than segments 1 and 2. Each cephalic fan with about 54 fan rays. Length of maxillary palps slightly more than three times width at base. Pupal respiratory organs each with 12 filaments arising from two main branches. Abdomen on preserved specimens with brownish and yellowish areas, with light intersegmental areas; median ventral bulge on segment 8. Anal cross-piece well sclerotized, area between arms not sclerotized; ventral arms longer than dorsal arms. Anal hooks 11-13 per row; about 60 rows.

Cnephia sp. 1 Larvae

Not previously described.

Description

Pl. 2, fig. 5 submentum; Pl. 5, fig. 5 antenna.

Mature specimens 7.5 mm. long. Head capsule with distinct yellow to white head spots, with dark infuscation around head spots; anterior median group separated from posterior median group by wide dark-brown *isthmus*; *posterolateral spots* obscure. *Throat cleft* U-shaped, rounded apically, slightly narrowed posteriorly; extending about one-third distance from posterior margin of head capsule to teeth of submentum. *Suboesophageal ganglion* light except near anterior margin where tinged with black. *Submentum* with deeply concave anterior margin; with small median tooth, two small intermediate teeth, and a single large outer tooth on each side; lateral margins wavy but not serrate distally. Usually three long *epicranial setae* on each side. Distance from apex of outermost tooth of submentum to anteriormost seta on same side one-fourth distance between outermost teeth. *Mandibles* with *small teeth* broader and more heavily pigmented than in other species, having relative lengths 13:11:9; inner subapical margin smooth except for single small *serration*. *Antennae* long, almost as long as distance from point of insertion to posterior margin head capsule; segment length ratios base to apex 5.7:8.4:1.8:0.5; segment 1 clear ventrally, pigmented yellow dorsally, segment 2 mostly clear yellow dorsally near base, segments 3 and 4 light yellow. Each cephalic fan with 68 rays. Length of maxillary palps slightly less than four times width at base. Pupal respiratory organs each with eight filaments. Abdomen of preserved specimens mottled brown with light intersegmental areas; segment 5 projecting abruptly ventrally about one-fourth width of preceding segment, following segments taper posteriorly. Ventral papillae present, directed posteriorly. Anal cross-piece absent or not sclerotized. Anal hooks 7-8 per row; about 69 rows.

Simulium Larvae

Mature specimens are 5.5 to 11 mm. in length depending on the species. The head capsule has slightly convex lateral margins. The head spots may be either light or dark and the region around the spots infuscated or not depending on the species; venterolateral spots may or may not be present on the epicranial plate depending on the species. The size and shape of the throat cleft may be V-shaped, U-shaped, or bulbous arrowhead shaped depending on the species.

The suboesophageal ganglion may be a distinct black or light brown to white depending on the species.

The submentum is very similar in most species of *Simulium*, consisting of nine teeth, the outer and median are usually subequal and the three intermediate teeth on each side much smaller and subequal. The lateral margins of the submentum are more or less serrate.

The epicranial setae appear to arise from near the lateral margins of the submentum forming an irregular line on each side. There are 1-7 long setae and a variable number of small setae on each side.

The distance from the apex of the outermost tooth of the submentum to the anteriormost epicranial seta on the same side is slightly more or less than the distance between the outermost teeth.

The mandibles have small teeth with the distalmost one largest and the next two nearly equal in size. The inner subapical margin of the mandible is quite variable. Species in the subgenus (*Simulium*) typically have a double serration, the anterior portion of which is about two times longer than the ventral. The anterior and posterior processes may be so separated as to look like two single serrations, or there may be one or two adventitious serrations. In the subgenus (Eusimulium), three species have a large anterior serration followed by 2-4 small serrations, while S. (E.) aureum has the double serration typical of (Simulium).

The length, segment ratios, and pigmentation of the antennae vary between species.

The cephalic fans are of normal length, that is, much longer than the antennae. There are usually 38-59 rays per fan.

The length of maxillary palps is two and one-half to four times the width at the base. They are yellow to brown except for a white apex. There are small bristles present on the apex.

The abdomen of preserved specimens ranges from mottled gray to black depending on the species. Ventral papillae are present and conspicuous in (Eusimulium), and absent or inconspicuous in all other species found to date. The anal gills are made up of three compound lobes except in S. (E.) aureum.

The anal cross-piece is well sclerotized with or without areas between arms lightly sclerotized. The ventral arms are subequal to or longer than the dorsal arms. The anal hooks consist of 60-135 rows of radiating hooks with 9-27 hooks per row.

Simulium (S.) venustum Larvae

Previous Descriptions and Figures

1903. Johannsen, S. venustum. N. Y. State Mus. Bull. 68: 381 (description); Pl. 37, figs. 1, 3, 6 (maxillary and maxillary palp, labrum, submentum).

1912. Garman, S. venustum. Kent. Agr. Expt. Sta. Bull. 159: 13-15 (description); 13, fig. 1 (habitus); 16, fig. 3c, d', d'', f, g', g'', h, i (ventral aspect head capsule, maxilla and maxillary palp dorsal and ventral views, antenna, dorsal aspect mandible, ventral aspect mandible, distal end mandible, submentum).

1912. Forbes, S. venustum. State Entom. of Ill. 27th Report, p. 45, figs. 19, 20 (habitus) (one from Garman, one based on misdetermined specimen).

1914. Malloch, S. venustum. U.S.D.A. Ent. Bull. Tech. Ser. 26: 44 (description).

1916. Jobbins-Pomeroy, S. venustum. U.S.D.A. Bull. 329: Pl. 4, figs. 4, 9 (dorsal aspect head capsule, anal gills and cross-piece); 13, fig. 5 (submentum); 14, fig. 8 (antenna); 16, fig. 12 (mandible); 16 (description mandible); 18, fig. 15 (tracheal system).

1920. Edwards, S. venustum. Bull. Ent. Res. 11: 232-233 (description); 218, fig. 1 g (dorsal aspect head capsule).

1925. Puri, S. venustum. Parasit. 17: 347 (description); 348, fig. 13A-E (dorsal aspect head capsule, antenna, distal end mandible, lateral aspect posterior end abdomen, submentum).

1925. Seguy, S. Austeni. Faune de France 12: 22, fig. 40 (dorsal aspect head capsule).

1934. Johannsen, S. venustum. Cornell Univ. Agr. Expt. Sta. Mem. 164: 63-64 (description); Pl. 24, fig. 213 (anal gills).

1951. De Foliart, S. (S.) venustum. Unpublished thesis, Cornell Univ., pp. 58-60 (description); 88, Pl. 2 (frontoclypeus); 89, Pl. 3 (throat cleft); 91, Pl. 5 (antenna); 93, Pl. 7 (submentum); 94, Pl. 8 (mandible, distal); 96, Pl. 10 (anal crosspiece).

Description

Pl. 3, fig. 4 submentum; Pl. 4, fig. 3 head capsule.

Mature specimens 6 to 7 mm. long. Head capsule with distinct light yellow head spots; with dark infuscation around median head spots and median posterior infuscation present; infuscation extending to outer margins of anterolateral head spots or beyond; with median anterior and posterior groups separated by narrow isthmus; with anterolateral and posterolateral head spots present and distinct in most specimens. Epicranial plate fumeous brown, lacking light yellow area just anterior to throat cleft. Throat cleft bulbous arrow-head shaped;

width and depth subequal; pointed apically; widest about one-third distance from posterior margin to apex. *Suboesophageal ganglion* light. *Submentum* with nine main teeth; outermost and median largest and subequal; with three intermediate teeth on each side much smaller, outermost of these slightly larger than others; lateral margin serrate distally. Usually three long and one short *epicranial setae* present on each side. Distance from apex of outermost tooth of submentum to anteriormost epicranial seta on same side subequal to distance between outermost teeth. *Mandibles* with *small teeth* having relative lengths 12:9:8 distad to basad; inner subapical margin usually with a large double tooth or two single teeth, anterior portion two times as long as posterior. Antennae moderately long, about two-thirds as long as distance from point of insertion to posterior margin of head capsule; segment length ratios base to apex 5.9:6.7:5.8:0.5; uniformly light yellow except for light basal area on venter of first segment. Each *cephalic fan* with about 51 rays. Length of maxillary palps almost three times width at base. *Pupal respiratory organs* each with six filaments. Abdomen of preserved specimens dirty gray to brown with light intersegmental areas. Ventral papillae inconspicuous or absent. Anal gills consisting of three compound lobes. Anal cross-piece well sclerotized, areas between arms lightly sclerotized; ventral arms longer than dorsal arms. Anal hooks 9-15 per row; 60-75 rows.

Simulium (S.) decorum Larvae

Previous Descriptions and Figures

1903. Johannsen, S. piscicidium. N. Y. State Mus. Bull. 68: 382 (description); Pl. 37, figs. 2, 5 (prementum, submentum).

1920. Edwards, S. subornatum. Bull. Ent. Res. 11: 227 (description); 218, figs. 1c (dorsal aspect, head capsule) 220, figs. 2b, 3b (submental teeth, antenna).

1925. Puri, S. nölleri. Parasit. 17: 303-330 (description); 305, fig. 1A-C (dorsal, ventral, and lateral aspect head capsule); 311, fig. 2A-C (rectal scales, dorsal view posterior end abdomen, anal hooks); 312, fig. 3 (setal plan of body); 314, fig. 4A-C (oesophageal valve, portion of dorsal vessel, portion of oesophagus wall); 329, fig. 5A-C (first stage larvae; cluster of eggs, egg burster, portion head capsule dorsal aspect); Pl. 8, figs. 1-10 (lateral aspect head capsule saggital section, internal anatomy lateral aspect, ventral view heart, dorsal view anterior portion alimentary canal, lateral view larva, muscular system of body, tracheal system larva, developing male genital organs, posterior and larva showing muscles); Pl. 9, figs. 11-30 (dorsal view cephalic fan, ventral view cephalic fan, filament cephalic fan, antenna, distal end antenna, dorsal view left mandible, ventral view left mandible, ventral view left maxilla, dorsal view left maxilla, distal portion right mandible, ventral view labrum, dorsal view labrum, ventral view prementum, lateral view hypopharynx and prementum, apex of prementum, dorsal view hypopharynx and prementum, ventral view submentum, distal end submentum, labrum, lateral view thoracic proleg).

1934. Johannsen, S. piscicidium. Cornell Univ. Agr. Expt. Sta. Mem. 164: 63 (description).

1950. Hennig, M. noelleri. Akademie-Verlag 2: 375, fig. 186 (dorsal aspect head capsule, schematic).

1951. De Foliart, S. (S.) decorum. Unpublished thesis, Cornell Univ., pp. 62-63 (description); 88, Pl. 2 (frontoclypeus); 89, Pl. 3 (throat cleft); 91, Pl. 5 (antenna); 92, Pl. 6 (submentum); 95, Pl. 9 (mandible, distal); 96, Pl. 10 (anal crosspiece).

Description

Pl. 6, fig. 7 anal cross-piece.

Mature specimens 8 mm. long. Head capsule with light head spots; dark infuscation around median row forming H-shaped dark area on posterior two-thirds of frontoclypeus with horizontal line formed by moderately wide isthmus between anterior and posterior median groups; medium posterior infuscation also present; infuscation not extending lateral beyond inner edge of anterolateral group; with anterolateral and posterolateral head spots obscure light; epicranial plate fumeous brown with light yellow area just anterior to apex of throat cleft, widening gradually anteriorly, extending to anteroventral margin head capsule. Throat cleft bulbous; slightly deeper than wide at base; pointed apically; widest about one-third distance from posterior margin to apex; extending about one-half of distance from posterior margin of head capsule to teeth of submentum. Suboesophageal ganglion light, never distinctly black. Submentum with nine main teeth; outermost and median largest and subequal; three intermediate teeth on each side much smaller; outermost of these slightly larger than others, usually 3-4 long (epicranial setae) and 1-2 short present on each side; lateral margin serrate distally. Distance from apex of outermost tooth of submentum to anteriormost epicranial seta on same side slightly less than distance between outermost teeth. Mandibles with small teeth having relative lengths 20:13:14 distad to basad; inner subapical margin with large double tooth, anterior portion two times as long as posterior. Antennae slightly more than one-half as long as distance from point of insertion to posterior margin head capsule; segment length ratios base to apex 4.0: 5.6:4.7:0.5; uniformly yellow except for light basal area on venter of first segment. Each *cephalic fan* with about 50 rays. Length of *maxillary palps* about two and one-half times width at base. *Pupal respiratory organs* each with 8 filaments. *Abdomen* of preserved specimens dirty gray to brown with light intersegmental areas. *Ventral papillae* absent or indistinct. *Anal cross-piece* well sclerotized, areas between arms not sclerotized; ventral arms longer than dorsal arms. *Anal hooks* 9-16 per row; about 74 rows.

Simulium (S.) jenningsi Larvae

Previous Descriptions and Figures

1903. Johannsen, *S. venustum* var. *a*. N. Y. State Mus. Bull. *68*: 381 (description); Pl. 37, figs. 9, 10, 12, 13, 14 (anal gills, prementum, labrum, mandible, submentum).

1914. Malloch, *S. jenningsi*. U.S.D.A. Ent. Bull. Tech. Ser. *26*: 42 (description, quoted from Johannsen, 1903); Pl. 3, fig. 1 (mandible).

1916. Jobbins-Pomeroy, *S. jenningsi*. U.S.D.A. Bull. *329*: 14-15 (description); Pl. 4, figs. 3, 5 (dorsal aspect head capsule, anal gills and cross-piece); 14, figs. 7, 9 (antenna, submentum).

1934. Johannsen, *S. jenningsi*. Cornell Univ. Agr. Expt. Sta. Mem. *164*: 62 (description).

1934. Johannsen, *S. venustum* var. *a*. Cornell Univ. Agr. Expt. Sta. Mem. *164*: 64 (description).

1944. Underhill, *S. nigroparvum*. Va. Agr. Expt. Sta. Tech. Bull. *94*: 3-4 (description); 5, fig. 2, 1-A, 1-B, 2-A, 2-B, 2-C, 3-A, 4-A, 5-A, 5-B, 5-C, 5-D, 6-A, 6-B, 7-A, 7-B, 8-A, 8-B, 9-A, 10-A, 10-B, 10-C, 10-D (dorsal and ventral aspect thorax and abdomen, dorsal aspect head capsule, lateral margin throat cleft, antenna, fan ray, mandible dorsal aspect, distal end, lateral aspect submentum, maxilla and maxillary palpus dorsal and ventral aspect, anal hooks and cross-piece, anal gills, pupal filaments from larva).

1951. De Foliart, *S.* (*S.*) *jenningsi*. Unpublished thesis, Cornell Univ., pp. 61-62 (description).

Description (adapted from Underhill (1944) and others)

Mature specimens 5-5.5 mm. long. *Head capsule* with distinct dark *head spots*; wide *isthmus* between *anterior* and *posterior median groups*. *Throat cleft* bulbous; slightly deeper than wide at the base; pointed apically; widest about one-half distance from posterior margin to apex; extending slightly less than one-half distance from posterior margin head capsule to teeth of submentum. *Suboesophageal ganglion* never distinctly black. *Submentum* with nine main teeth; outermost and median largest and subequal; three intermediate teeth on each side much smaller and subequal; lateral margins serrate distally.

Usually 3 long and 1 short epicranial setae present, forming irregular line on each side, appearing to arise from near lateral margins of submentum. Distance from apex of outer tooth of submentum to anteriormost epicranial seta on same side slightly more than one-half distance between outermost teeth. Mandibles with small teeth having relative lengths 7:6:4 distad to basad; inner subapical margin with large double tooth, anterior portion two times as long as posterior. Antennae segment length ratios 1.35:1.3:1.1:0.1. Each cephalic fan with 38-42 rays. Length of maxillary palps slightly more than three times width at base. Pupal respiratory organs each with 10 filaments. Abdomen light to moderately yellowish-brown, often with a slight green and sometimes red tinge. Anal gills made up of three compound lobes. Anal cross-piece well sclerotized, areas between arms lightly sclerotized; ventral arms two times longer than dorsal arms. Anal hooks 12-14 per row; 68-70 rows.

Simulium (S.) tuberosum Larvae

Previous Descriptions and Figures

1920. Edwards, S. tuberosum. Bull. Ent. Res. 11: 234 (description).

1925. Puri, S. tuberosum. Parasit. 17: 346-347, (description); 346, fig. 12A-E (head capsule dorsal aspect, antenna, distal end mandible, lateral aspect posterior end, submentum).

1951. De Foliart, S. (S.) tuberosum. Unpublished thesis, Cornell Univ., pp. 60-61 (description); 91, Pl. 5 (antenna); 93, Pl. 7 (submentum); 94, Pl. 8 (mandible, distal).

Description

Pl. 3, fig. 5 throat cleft.

Mature specimens 5.5 mm. long. Head capsule with obscure dark head spots; triangular shaped infuscation, base extending full width across posterior of frontoclypeal plate, becoming narrower anteriorly forming a blunt point about one-half distence from posterior margin of head capsule to apex of labrum. Throat cleft bowed V-shaped, deeper than broad at the base; pointed apically; widest about one-fourth distance from posterior margin to apex; extending about one-half distance from posterior margin of head capsule to teeth of submentum. Suboesophageal ganglion distinctly black. Submentum with nine main teeth; outermost and median largest and subequal; three intermediate teeth on each side much smaller and subequal; usually 3-4 long and 1-2 short *epicranial setae* present on each side, lateral margin serrate distally. Distance from apex of outermost tooth of submentum to anteriormost epicranial seta on same side slightly less than distance between outermost teeth. *Mandibles* with *small teeth* having relative lengths 14:8:6 distad to basad; inner subapical margin with large double tooth, anterior portion two times as long as posterior. *Antennae* long, as long as eight-tenths the distance from point of insertion to posterior margin head capsule; segment length ratios base to apex 6.0:6.4:4.5:0.5 (Puri, 1925, reported 5 segments); uniformly yellow except basal area of venter of first segment is light. Each *cephalic fan* with about 38 fan rays. Length of *maxillary palps* slightly less than three times width at base. *Pupal respiratory organs* each with six filaments. *Abdomen* of preserved specimens black with broad white intersegmental areas; with segments 7 and 8 lightened ventrally. *Ventral* *papillae* inconspicuous or absent. *Anal gills* made up of three compound lobes. *Anal cross-piece* well sclerotized, areas between arms not sclerotized; ventral arms longer than dorsal arms. *Anal hooks* 11-15 per row; about 72 rows.

Simulium (S.) parnassum Larvae

Previous Descriptions and Figures

1951. De Foliart, *S.* (*S.*) *parnassum*. Unpublished thesis, Cornell Univ., pp. 63-64 (description); 89, Pl. 3 (throat cleft); 92, Pl. 6 (submentum).

Description

Pl. 3, fig. 6 throat cleft.

Mature specimens 6-7 mm. long. *Head capsule* with indistinct brown *head spots*; no infuscation around head spots; *epicranial plate* fumeous. *Throat cleft* deep V-shaped notch with straight anteriorly converging edges; extending about one-third distance from posterior margin of head capsule to teeth of submentum. *Suboesophageal ganglion* light, never distinctly black. *Submentum* with nine main teeth; outermost and median largest and subequal; three intermediate teeth on each side much smaller, outermost of these slightly larger than others; lateral margins serrate distally. Usually

3-4 long and 1-2 short *epicranial setae* present on each side. Distance from apex of outermost tooth of submentum to anteriormost epicranial seta on same side slightly less than distance between outermost teeth. *Mandibles* with *small teeth* having relative lengths 20:12:9 distad to basad; inner subapical margin with either large double tooth, two single teeth, or some combination of the two, quite variable. *Antennae* almost as long as distance from point of insertion to posterior margin head capsule; segment length ratios 5.9:7.0:4.1:0.5; uniformly yellow except for light area on venter of segments 1 and 2. Each *cephalic fan* with about 32 rays. Length of *maxillary palps* slightly less than three times width at base. *Pupal respiratory organs* each with six filaments. *Abdomen* of preserved specimens mottled brown with faint white intersegmental lines. *Ventral papillae* absent or indistinct. *Anal gills* made up of three compound lobes. *Anal cross-piece* well sclerotized, areas between arms not sclerotized; ventral arms longer than dorsal arms. *Anal hooks* about 13 per row; about 77 rows.

Simulium (S.) pictipes Larvae

Previous Descriptions and Figures

1903. Johannsen, S. pictipes. N. Y. State Mus. Bull. 68: 376 (description); Pl. 36, figs. 1-6 (mandible, maxilla and maxillary palp, submentum, prementum, labrum, cross-section of prementum).

1906. Headlee, S. pictipes. Amer. Nat. 40: 877, fig. 1A-C (habitus, anal gills).

1912. Garman, S. pictipes. Kent. Agr. Expt. Sta. Bull. 159: 22, fig. 7 (habitus); 24, fig. 8, a,c, e,f,g,h,i,j,k,l (dorsal aspect head capsule, ventral aspect head capsule, maxillary palp, antenna, mandible, distal end mandible, submentum, proleg, anal hooks, anal gills, lateral aspect posterior end abdomen).

1912. Forbes, S. pictipes. 27th Report State Entom. Ill., p. 41, fig. 12 (habitus) (from Garman).

1914. Malloch, S. pictipes. U.S.D.A. Ent. Bull., Tech. Ser. 26: 57 (description); Pl. 3, figs. 4, 5 (submentum, cephalic fan).

1916. Jobbins-Pomeroy, S. pictipes. U.S.D.A. Bull. 329: Pl. 4, figs. 1, 8 (dorsal aspect head capsule, anal gills and cross-piece); 15, fig. 10 (antenna); 17, fig. 14 (submentum).

1934. Johannsen, S. pictipes. Cornell Univ. Agr. Expt. Sta. Mem. 164: 62-63 (description); Pl. 24, figs. 208, 209, 215 (submentum, habitus, antenna).

1934. Smart, S. pictipes. Can. Ent. 66: 63, fig. 2 (habitus).

1951. De Foliart, S. (S.) pictipes. Unpublished thesis, Cornell Univ., pp. 64-65 (description).

Description

Pl. 2, fig. 8 submentum; Pl. 5, fig. 7 antenna.

Mature specimens 11 mm. long. Head capsule dark brown with indistinct dark head spots; median row gradually increasing in width giving appearance of elongate triangle, isthmus narrow. Throat cleft with subparallel sides from about one-half distance to apex, distinctly more convergent beyond, ending in an apical point; extending about one-third distance from posterior margin of head capsule to tip of submentum; about as broad as deep. Suboesophageal ganglion distinctly black. Submentum with median tooth much larger than outer teeth; outer teeth larger than three intermediate teeth on each side, outermost of these slightly larger than others; lateral margins serrate distally. Usually with 6-7 long and 3-4 short epicranial setae present on each side. Distance from apex of outermost tooth of submentum to anteriormost epicranial seta on same side is slightly less than the distance between outermost teeth. Mandibles with small teeth having relative lengths

35:34:30 distad to basad; inner subapical margin with large double tooth, anterior portion two times as long as posterior. Antennae slightly less than one-half as long as distance from point of insertion to posterior margin head capsule; segment length ratios base to apex 3.3:5.3:2.7: 0.5; segment 1 dark brown, segment 2 dark brown except for distinctive light area on ventral portion extending from 0.4-0.8 distance from base of segment to apex, segments 3 and 4 dark brown. Each cephalic fan with about 59 rays. Length of maxillary palps slightly less than four times width at base. Pupal respiratory organs each with nine filaments. Abdomen of preserved specimens mottled black with some light areas, indistinct light intersegmental lines present; segments 6 and 7 with median ventral bulge. Ventral papillae absent. Anal gills consisting of three compound lobes. Anal cross-piece well sclerotized, areas between arms not sclerotized; ventral arms longer than dorsal arms. Anal hooks 18-27 per row; 127-135 rows.

Simulium (N.) vittatum Larvae

Previous Descriptions and Figures

1887. Lugger, S. tribulatum. Second Rept. Entom. Minn., p. 179, fig. 147 (habitus).

1903. Johannsen, S. vittatum. N. Y. State Mus. Bull. 68: 385-386 (description); Pl. 35, figs. 2, 3 (submentum, mandible).

1912. Forbes, S. vittatum. 27th Report State Entom. Ill., p. 48, fig. 25 (habitus).

1913. Emery, S. vittatum. Kans. Univ. Sci. Bull. 8: 347-348 (description).

1913. Hungerford, S. vittatum. Kans. Univ. Sci. Bull. 8: 368-369 (description).

1914. Malloch, S. vittatum. U.S.D.A. Ent. Bull., Tech. Ser. 26: 55 (description from Johannsen, 1903).

1916. Jobbins-Pomeroy, S. vittatum. U.S.D.A. Bull. 329: Pl. 4, figs. 2, 6 (dorsal aspect head capsule, anal gills and cross-piece); 15, fig. 11 (antenna); 17, fig. 13 (submentum).

1934. Johannsen, S. vittatum. Cornell Univ. Agr. Expt. Sta. Mem. 164: 64 (description); Pl. 24, fig. 218 (antenna).

1951. De Foliart, S. (N.) vittatum. Unpublished thesis, Cornell Univ., pp. 68-69 (description); 88, Pl. 2 (frontoclypeus); 89, Pl. 3 (throat cleft); 91, Pl. 5 (antenna); 93, Pl. 7 (submentum); 95, Pl. 9 (anal cross-piece).

Description

Pl. 3, fig. 7 throat cleft; Pl. 4, fig. 2 mandible; Pl. 5, fig. 8 antenna; Pl. 6, fig. 6 inner subapical margin of mandible.

Mature specimens 9 mm. long. *Head capsule* with dark brown *head spots*; narrowly infuscated around *median row*, *anterolateral* and *posterolateral head spots*, with narrow *isthmus* between *anterior* and *posterior median groups*; degree of pigmentation quite variable; *epicranial plate* fumeous brown. *Throat cleft* widest at posterior margin, apex varies from blunt point to nearly flattened; two times as wide as deep; extending slightly more than one-fourth distance from posterior margin of head capsule to tip of labrum. *Suboesophageal ganglion* distinctly black. *Submentum* with nine main teeth; outermost and median largest and subequal; three intermediate teeth on each side smaller, outermost of these slightly larger than others; lateral margins serrate. Usually 4-5 long and 1-2 short *epicranial setae* present on each side. Distance from apex of outermost tooth of submentum to anteriormost epicranial seta on same side slightly more than one-half distance between outermost teeth. *Mandibles* with *small teeth* having relative lengths 20:14:17 distad to basad; inner subapical margin with large double tooth, anterior portion two times as long as posterior. *Antennae* slightly more than one-half as long as distance from point of insertion to posterior margin head capsule; segment length ratios base to apex 3.1:4.6:4.0:0.5; segment 1 brown except for basal ventral light spot, segment 2 brown except for distinctive single lobed light area on ventral portion extending 0.5 to 0.7 distance from base to apex, segments 3 and 4 uniformly brown. Each *cephalic fan* with about 50 rays. Length of *maxillary palps* slightly more than three times width at base. *Pupal respiratory organs* each with 16 filaments. *Abdomen* of preserved specimens mottled black with light intersegmental areas. *Ventral papillae* absent. *Anal gills* consisting of three compound lobes (small ventral auxiliary lobes). *Anal cross-piece* well sclerotized, areas between arms lightly sclerotized; ventral arms subequal or slightly longer than dorsal arms. *Anal hooks* 18-24 per row; 67-88 rows.

Simulium (E.) aureum Larvae

Previous Descriptions and Figures

1913. Strickland, *S. bracteatum*. Jour. Morph. *24*: 45-46 (description); 95, Pl. 1, figs. 1-7 (antenna, dorsal aspect, head capsule, mandible, hypopharynx, maxilla and maxillary palp, submentum, submental teeth); Pl. 5, fig. 1 (habitus).

1916. Jobbins-Pomeroy, S. bracteatum. U.S.D.A. Bull. 329: 13-14 (description); Pl. 3, fig. 7 (habitus); Pl. 4, fig. 7 (anal gills and cross-piece); 13, figs. 3, 4 (antenna and submentum); 14, fig. 6 (row of anal hooks).

1920. Edwards, S. aureum. Bull. Ent. Res. 11: 242-243 (description); 218, fig. 1k (head capsule dorsal aspect).

1925. Puri, S. aureum. Parasit. 17: 354-355 (description); 355, fig. 17A-E (dorsal aspect head capsule, antenna, distal end mandible, submentum, submental teeth).

1925. Seguy, S. aureum. Faune de France 12: 22, fig. 48 (dorsal aspect head capsule).

1934. Johannsen, E. aureum. Cornell Univ. Agr. Expt. Sta. Mem. 164: 60 (description).

1951. De Foliart, S. (E.) aureum. Unpublished thesis, Cornell Univ., pp. 65-66 (description); 87, Pl. 1 (frontoclypeus); 89, Pl. 3 (throat cleft); 90, Pl. 4 (antenna); 93, Pl. 7 (submentum); 94, Pl. 8 (mandible, distal); 96, Pl. 10 (anal cross-piece).

Description

Pl. 3, fig. 8 throat cleft.

Mature specimens 7 mm. long. Head capsule with dark head spots; infuscation very light or absent; isthmus narrow between anterior and posterior median groups; epicranial plate fumeous brown lacking ventrolateral spots. Throat cleft U-shaped; width and depth subequal; apex flat or slightly upcurved medially; lateral margins nearly subparallel diverging slightly from posterior to anterior. *Suboesophageal ganglion* never distinctly black. *Submentum* with nine main teeth, outermost and median largest and subequal; three intermediate teeth on each side much smaller, outermost of these slightly larger than others; lateral margins serrate distally with distalmost serration large and pigmented. Usually three long and 1-2 short *epicranial setae* present on each side. Distance from apex of outermost tooth of submentum to anteriormost epicranial seta on same side subequal to distance between outermost teeth. *Mandibles* with *small teeth* having relative lengths 14:11:13 distad to basad; inner subapical margin with two single teeth, anterior one to two times as long as posterior. *Antennae* about three-fourths as long as distance from point of insertion to posterior margin head capsule; segment length ratios base to apex 6.2:7.0:3.9:0.6; uniformly yellow except segment 1 slightly darker than others. Each *cephalic fan* with about 45 rays. Length of *maxillary palps* slightly more than three times width at base. *Pupal respiratory organs* each with four filaments. Abdomen of preserved specimens mottled brown with light intersegmental areas. Ventral papillae conspicuous. Anal gills made up of three simple lobes. Anal cross-piece well sclerotized, areas between arms lightly sclerotized; ventral arms slightly longer than dorsal arms. Anal hooks about 11 per row; about 60 rows.

Simulium (E.) gouldingi Larvae

1951. De Foliart, S. (E.) species 1. Unpublished thesis, Cornell Univ., pp. 67-68 (description); 87, Pl. 1 (frontoclypeus); 90, Pl. 4 (antenna); 94, Pl. 8 (mandible, distal); 96, Pl. 10 (anal cross-piece).

Description

Pl. 1, fig. 1 habitus; Pl. 5, fig. 9 antenna.

Mature specimens 6.5 mm. long. Head capsule with dark head spots; infuscation very light or absent; isthmus wide between anterior and posterior median groups; epicranial plate fumeous with ventero-lateral spots present, one on each side of the epicranial plate at about the level of the apex of the throat cleft. Throat cleft U-shaped, slightly narrowed posteriorly and rounded apically; about as wide as deep; extending about one-third distance from posterior margin of head capsule to teeth of submentum. Suboesophageal ganglion never distinctly black. Submentum with nine main teeth, outermost and median largest and subequal; three intermediate teeth on each side much smaller, median one of these smallest, other two subequal; lateral margins serrate distally with distalmost serrations large and pigmented. Usually 2-3 long and 1-2 short epicranial setae present on each side. Distance from apex of outermost tooth of submentum to anteriormost epicranial seta on same side subequal to distance between outermost teeth. Mandibles with small teeth having relative lengths 12:7:10, inner subapical margin with a large anterior serration which is more or less flat on the anterior margin and forms an angle of about 90 degrees with the margin, followed by 2-4 small anteriorly pointing serrations. Antennae almost as long as distance from point of insertion to posterior margin head capsule; segment length ratios base to apex 4.2:3.6:3.0:0.6; uniformly yellow except for slightly darkened third segment. Each cephalic fan with about 53 rays. Length of maxillary palps three times width at base. Pupal respiratory organs each with six filaments. Abdomen of preserved specimens mottled brown with light intersegmental areas. Ventral papillae conspicuous. Anal gills consist of three compound lobes. Anal cross-piece well sclerotized, areas between arms lightly sclerotized; ventral arms slightly longer than dorsal arms. Anal hooks about 10 per row; 50-60 rows.

Simulium (E.) latipes Larvae

Previous Descriptions and Figures

1920. Edwards, S. latipes. Bull. Ent. Res. 11: 239 (description); 218, fig. 1j (head capsule, dorsal aspect); 220, fig. 2e (submental teeth); 220, fig. 3d (antenna).

1925. Puri, S. latipes. Parasit. 17: 352 (description); 353, fig. 16A-E (dorsal aspect head capsule, antenna, distal end mandible, lateral view posterior end abdomen, submentum).

1925. Seguy, S. latipes. Faune de France 12: 22, figs. 46, 53 (dorsal aspect head capsule, antenna).

1944. Smart, S. latipes. Freshwater Biol. Assoc. Brit. Emp., Sci. Publ. 9: 47, figs. 16c, 17j (lateral aspect posterior end abdomen, dorsal aspect head capsule) (from Puri, 1925 and Edwards, 1920).

Description

Pl. 3, fig. 9 throat clefts; Pl. 6, fig. 5 inner subapical margin of mandible.

Mature specimens 6.5 mm. long. *Head capsule* with dark brown *head spots*: no infuscation on frontoclypeal plate around head spots; anterior and posterior median groups separated by moderately broad *isthmus*; *epicranial plate* fumeous brown with *venterolateral spots* present. *Throat cleft* U-shaped, slightly narrowed posteriorly and rounded apically (somewhat flattened on some specimens); about as wide as deep; extending about one-third distance from posterior margin of head capsule to teeth of submentum. *Suboesophageal ganglion* never distinctly black. *Submentum* with nine main teeth, outermost and median largest and subequal; three intermediate teeth on each side much smaller, outermost of these slightly larger than others; lateral margins serrate distally with distalmost serrations large and pigmented. Usually 1-3 long and 1-2 short *epicranial setae* present on each side. Distance from apex of outermost tooth of submentum to anteriormost epicranial seta on same side slightly more than distance between outermost teeth. *Mandibles* with *small teeth* having relative lengths 10:6:8, inner subapical margin with a large anterior serration which is more or less flat on the anterior margin, followed by 2-4 small anteriorly pointing serrations. Antennae almost as long as distance from point of insertion to posterior margin head capsule; segment length ratios base to apex 4.8:6.2:2.9:0.6; uniformly yellow except for lightened ventral portion of segment 1. Each cephalic fan with about 45 rays. Length of maxillary palps slightly more than three times width at base. Pupal respiratory organs each with four filaments. Abdomen of preserved specimens mottled light brown with light intersegmental areas. Ventral papillae conspicuous. Anal gills made up of three compound lobes. Anal cross-piece well sclerotized, areas between arms lightly sclerotized; ventral arms slightly longer than dorsal arms. Anal hooks about 10 per row; about 80 rows.

Simulium (E.) pugetense Larvae

Not previously described.

Description

Pl. 5, fig. 10 antenna.

Mature specimens 7 mm. long. Head capsule with dark brown head spot; infuscation absent;

isthmus wide between *anterior* and *posterior median groups*; *epicranial plate* fumeous with *ventrolateral spots* present, one on each side of the epicranial plate at about the level of the apex of the throat cleft. *Throat cleft* U-shaped, slightly narrowed posteriorly and rounded to slightly pointed apically; about as wide as deep; extending about one-third distance from posterior margin of head capsule to teeth of submentum. *Suboesophageal ganglion* never distinctly black. *Submentum* with nine main teeth, outermost and median largest and subequal; three intermediate teeth on each side much smaller, median one of these smallest, other two subequal; lateral margins serrate distally with distalmost serrations large and pigmented. Usually four long and 1-2 short *epicranial setae* present on each side. Distance from apex of outermost tooth of submentum to anteriormost epicranial seta on same side slightly less than the distance between outermost teeth. *Mandibles* with *small teeth* having relative lengths 12: 9:11 distad to basad; inner subapical margin with large anterior serration which is more or less flat on anterior margin and forms angle of about 90 degrees with margin, followed by 2-4 small anteriorly pointing serrations. *Antennae* almost as long as distance from point of insertion to posterior margin head capsule; segment length ratios base to apex 4.7:6.2:2.9:0.5; uniformly yellow except for lightened ventral portion of segment 1. Each *cephalic fan* with about 37 rays. Length of *maxillary palps* slightly more than three times width at base. *Pupal respiratory organs* each with four filaments. *Abdomen* of preserved specimens mottled brown with light intersegmental areas. *Ventral papillae* conspicuous. *Anal gills* consist of three compound lobes. *Anal cross-piece* well sclerotized, areas between arms usually lightly sclerotized; ventral arms slightly longer than dorsal arms. *Anal hooks* 11-13 per row; about 77 rows.

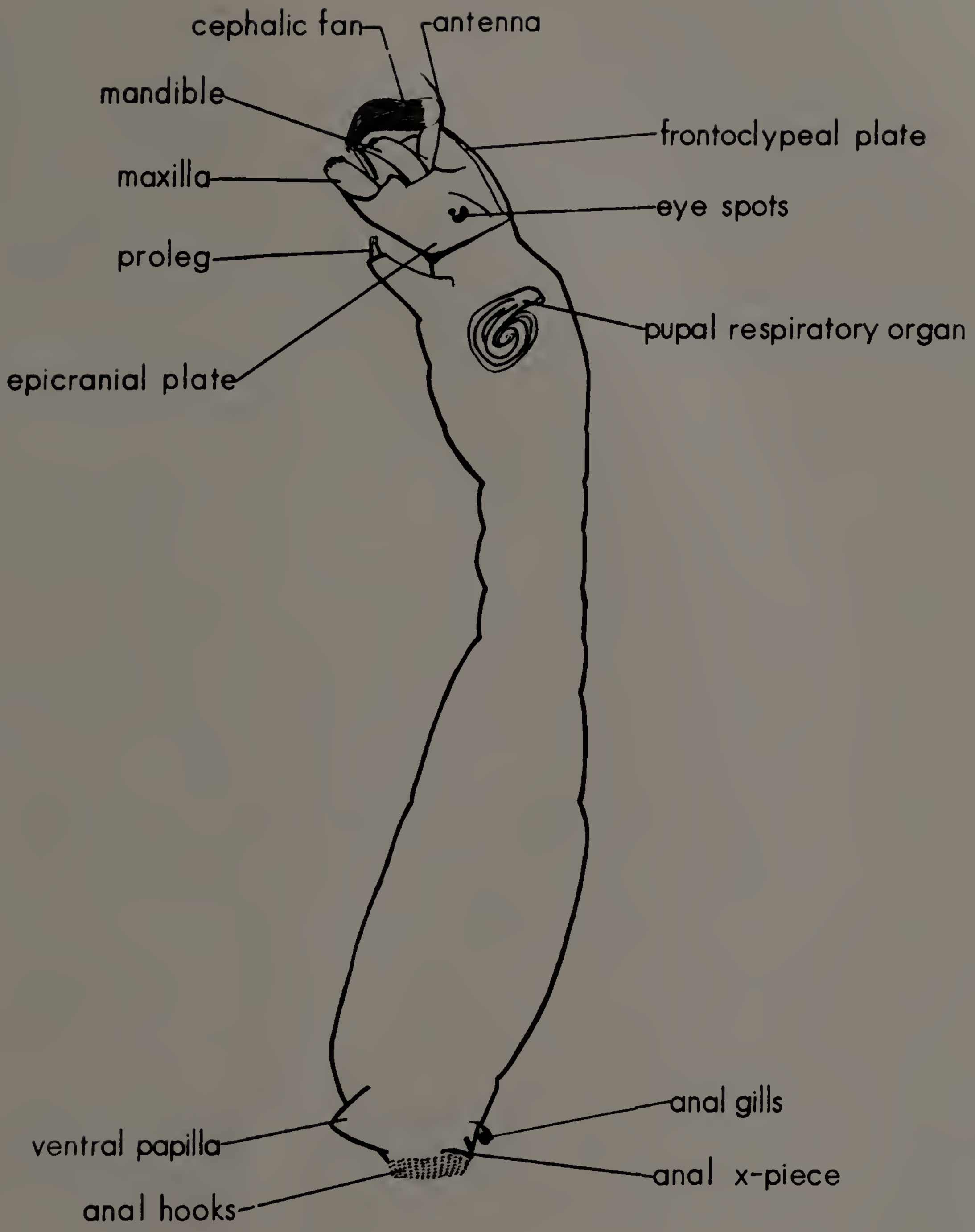
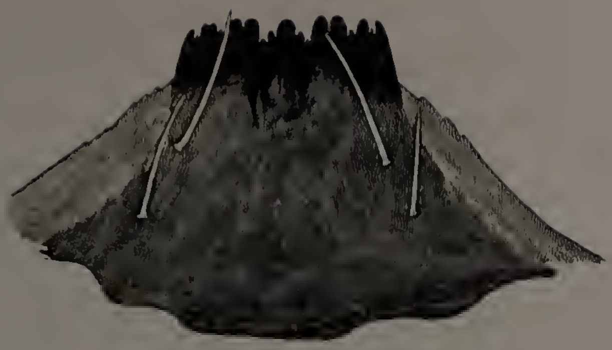
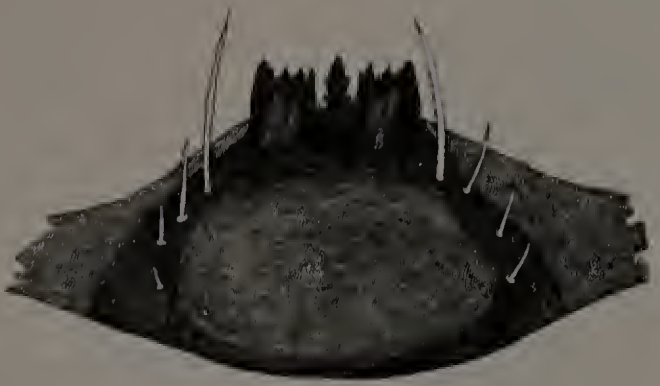


Plate 1. fig.1. Lateral view of S.gouldingi larva

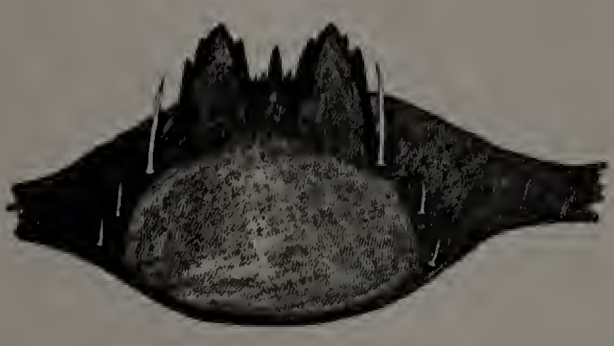


1 Gymnopais sp.



2 Prosimulium sp. 14

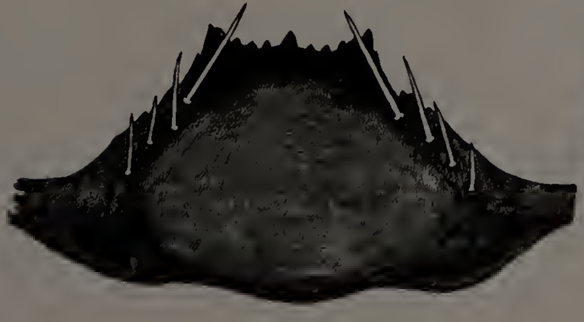
3 P.multidentatum



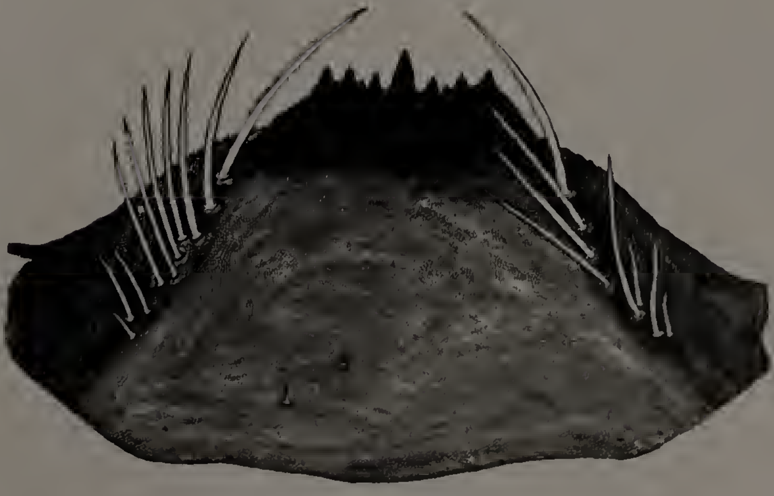
4 C.mutata

5 Cnephia sp.1

6 C.dacotensis



7 S.venustum



8 S.pictipes

Plate 2. figs. 1–8. Submenta

1 Gymnopais sp.

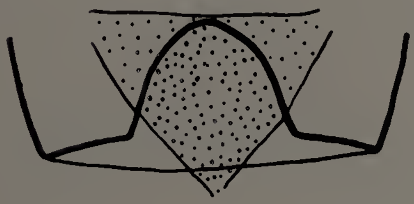
2 P. hirtipes

3 C.mutata

4 S.venustum

5 S.tuberosum

6 S.parnassum



7 S.vittatum

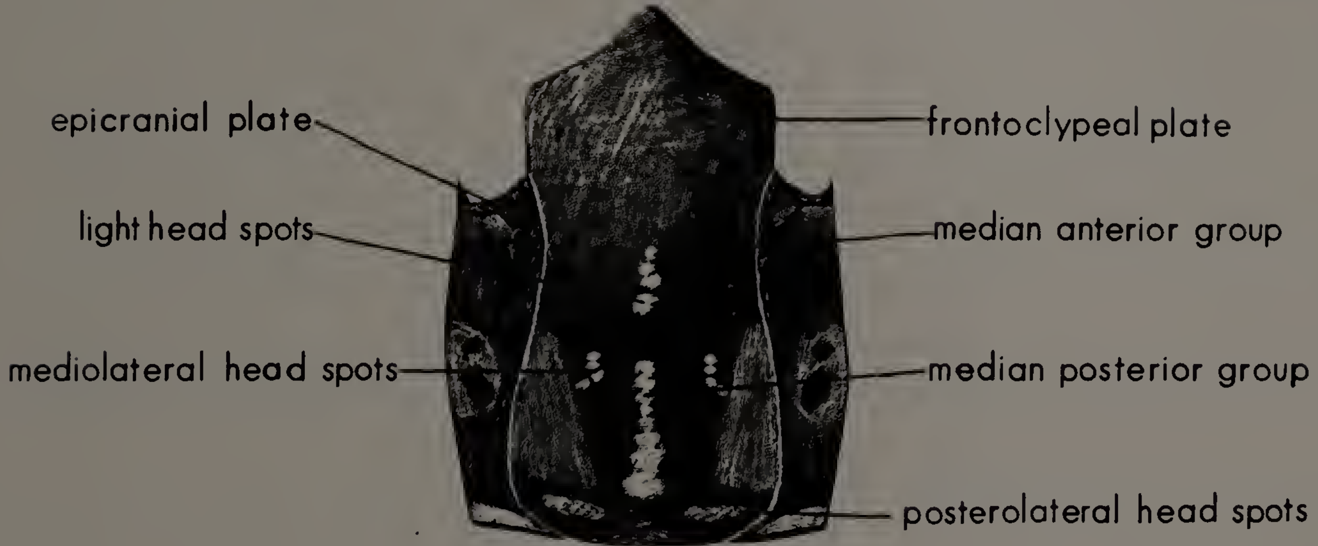
8 S.aureum

9 S.latipes

Plate 3. figs. 1–9. Throat clefts

1 Gymnopais sp.

2 S.vittatum



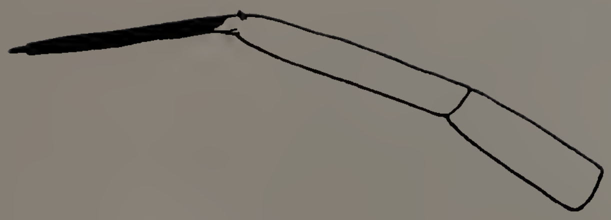
3 S.venustum

4 Gymnopais sp.

5 C.mutata

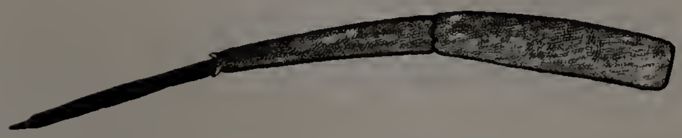
Plate 4. figs.1-5 Head capsules and mandibles

1 Gymnopais sp.



2 P.hirtipes

3 P.multidentatum



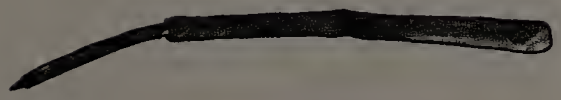
4 C.mutata

5 Cnephia sp.1

9 C.dacotensis

7 S.pictipes

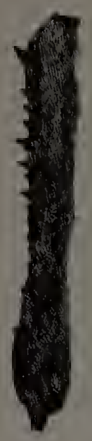
8 S.vittatum



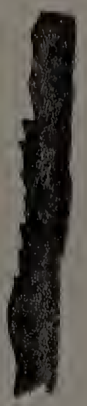
9 S.gouldingi

10 S.pugetense

Plate 5. figs.1-10. Antennae



1 P.hirtipes



2 P. sp. 14

3 P.magnum

4 P.multidentatum

5 S.latipes

6 S.vittatum

7 S.decorum

8 Gymnopais sp.

9 P.hirtipes

Plate 6. figs. 1–9. Inner subapical margins of mandibles and anal x-piece

SECTION II. BIOLOGY*

GENERAL BIOLOGY OF SIMULIIDAE

The egg-laying habits of most species of blackflies are poorly known. Some species lay their eggs in masses on grass trailing in the water (e.g., _S_. _venustum_), some drop the eggs singly into streams (_S_. _arcticum_; Fredeen _et_ _al_., 1951), and some lay their eggs in long strings (_S_. _vittatum_). A female _S_. _maculatum_ was observed 9 to 12 inches below the water surface encased in an air bubble, presumably ovipositing (Britten, 1915). Comstock (1949) has observed _S_. _pictipes_ laying eggs on rocks beneath a thin sheet of water. Oviposition of species observed generally took place in the late afternoon or early evening (Fredeen _et_ _al_., 1951) (Jobbins-Pomeroy, 1916). However, Gambrell (1933) reports that oviposition of _S_. _pictipes_ was observed between 9 and 11 A.M. Nicholson and Mickel (1950) reported observing mating by _C_. _dacotensis_ from 9:30 A.M. until noon without any indication of decrease in activity.

The eggs of species tested by Jobbins-Pomeroy (1916), Wu (1931), and Smart (1934) were not resis-

*Tables in each section numbered independently.

tant to prolonged desiccation. The eggs are whitish to light orange in color when first laid. As the become older they darken, becoming nearly black shortly before emergence of the larvae. The egg is flattened subtriangular in lateral aspect, ranging in size from 0.20 to 0.40 mm. The number of eggs laid by blackflies varies from about 200 to 450.

The incubation period of the eggs varies greatly depending on the species involved, the time of year, and the temperature of the water. It varies from a probable minimum of 2.5 days to a maximum of about 7 months.

The larvae of blackflies are found only in running water (with the exception of an African species found on lake edges; Hargreaves, (1932). Some species are found primarily in large rivers (C. pecuarum, S. arcticum, S. reptans, and S. jenningsi are Holarctic representatives of such species). It is interesting to note that all of these large river species may be pests of economic importance at times. Some species are found in both large and small permanent streams (S. venustum,

S. tuberosum, S. gouldingi). Other species are more catholic in their distribution, being found in large or small temporary or permanent streams (P. hirtipes, C. mutata). Still other species are found almost exclusively below lake outlets, dams, or large pools (S. vittatum, S. decorum, S. aureum, C. dacotensis, and P. magnum). S. pictipes larvae were found only in swift water, permanent streams having sedimentary rock bottoms. S. latipes has been found only in small temporary streams.

The larvae of species studied by Puri (1925), Edwards (1920), Baranov (1935), and Cameron (1922), moult six times before pupation. Mature larvae range from 5-12 mm. in length depending on the species and somewhat on the time of year. The duration of the larval period depends on the species, the temperature of the water, the season, and the amount of food available. De Foliart (1951) reported a minimum larval developmental period of 12 days in the summer. P. hirtipes, C. mutata, and S. vittatum overwinter as larvae in the Adirondacks. Most of the other species found in this area probably overwinter in the egg stage (although overwintering eggs have not been found) and emerge as larvae in the spring or summer.

The pupae are found attached to the substrata in the same situations where larvae are found. The larvae weave silken pupal cases which may be small and rudimentary (*Gymnopais sp.*), shapeless masses of silk (*Prosimulium spp.*, *Cnephia dacotensis* and *C. mutata*), coarsely woven cocoons (*S. pictipes*, *S. decorum*), or closely woven cocoons of various shapes (*S. parnassum*, *S. venustum*, *S. tuberosum*, *Eusimulium spp.*). Usually the pupal case has the open end facing downstream. The pupa may or may not have well-developed hooks on the posterior end of the abdomen. It always has paired pupal filaments which arise from the prothorax. The filaments on both sides are similar in shape, number, and arrangement (with occasional adventitious filaments). The number, type of branching, thickness, and texture of the filaments are useful in determination of species. The length of the pupal stage depends on water temperature and the species involved. Two days to three weeks or more have been reported.

The feeding habits of the adults of most species of *Simuliidae* are not known. The females of some species are known to feed on mammals, birds, or both. The females are blood suckers. Both males and females have been kept alive for long periods when fed sugar-water or soaked raisins. Friederichs (1921) kept *S. maculatum* alive for a maximum of 23 days on sugar-water in a large cage. Wu (1931) kept adults of *S. vittatum* and *S. jenningsi* alive for 5-6 days on a diet of water, and up to 18 days with sugar solutions or soaked raisins. At least two species (*C. dacotensis*, Krafchich, 1942; Nicholson, 1945) and *P. alpestre* (Dorogostajskij *et al.*, 1935; Nicholson, 1945) do not feed as adults. According to Jobbins-Pomeroy (1916), *S. venustum* requires a blood meal for the development of the eggs. Cameron (1922) reported that *S. arcticum* (descr. *S. simile*) also requires a blood meal. Wu (1931) reported that *S. venustum* apparently requires a blood meal while *S. vittatum* does not.

Because of the expense and large personnel required, few flight range studies of blackflies have been carried out. Dalmat (1950, 1952) and Dalmat and Gibson (1952) in Guatemala reported flight ranges of marked specimens of *S. metallicum*, *S. ochraceum*, and *S. callidum* up to 9.7 miles although most of the species were collected at distances of less than 4 miles. Twinn (1952) reported that radioactive phosphorus (P^{32}) is being used in studies of the dispersal and flight range of blackflies in Saskatoon.

Flight range studies based on the distance from the nearest known breeding areas are less reliable because the flies may have migrated from streams further away or from closer but unknown breeding areas. However, the flight ranges of species which pass the immature stages in large rivers can be determined fairly accurately. Cameron (1922) reported taking *S. arcticum* (descr. as *S. simile*)in large numbers 12-15 miles from the nearest known breeding area. Baranov (1937) records *S. colombaschensis* (descr. as *S. columbaczense*) being collected 60-160 miles from the nearest known breeding places. Underhill (1944) reports taking *S. jenningsi* (descr. as *S. nigroparvum*) in large numbers 10 miles from the nearest known breeding area and in smaller numbers 20-30 miles away. Wanson and Henrard (1945) have collected *S. damnosum* regularly 12 miles from the nearest known breeding place. Gibbins (1934) and Wanson (1950) reported collecting *S. damnosum* 30-50 miles from the nearest known breeding area. Rempel and Arnason (1947) report collecting *S. arcticum* 50 miles from the breeding area, with an indicated range of 80-90 miles.

It is more difficult to determine the flight range of species which pass the immature stages in smaller (and usually more numerous) streams. Edwards (1920) reports taking *S. venustum* 2 miles and *S. ornatum* 1 mile from the nearest known breeding area. Jobbins-Pomeroy (1916) collected *S. johannseni* and *S. forbesi* 5-6 miles from the nearest known breeding place.

Judging from the literature dealing with blackfly control studies (Goldsmith *et al.*, 1949; Prevost, 1948b; Travis, 1949; Wilson *et al.*, 1949; Brown, *et al.*, 1951; Hocking and Richards, 1952), *P. hirtipes* and *S. venustum*, the common pests in much of the United States, Canada, and Alaska, have flight ranges of at least several miles.

Complicating factors in evaluating these data are: lack of knowledge of control efficiency; recently emerged adults; incomplete knowledge of flight habits; direction and strength of prevailing winds; physical barriers; and effects of crowding.

In the Adirondacks, excellent control of _P. hirtipes_ was achieved inside of a sprayed area of about 175 square miles. Few adults of this species were observed within 1-2 miles of the edge of the control area. It was not possible to even approximate the flight range of _S. venustum_ and _S. tuberosum_ since there was some emergence of these species inside of the control area before the second treatment.

Reasons for the reported differences in flight ranges of large river species in contrast to small river and stream species are not known. However, Baranov (1934, 1937) reports active migration of _S. colombachensis_ (descr. as _S. reptans columbaczense_ and _S. columbaczense_) from over-crowded areas in search of food and the formation of large migratory swarms which fly or are carried long distances.

BLACKFLY LARVAL POPULATION FLUCTUATIONS

In 1950, slightly fewer than 3000 blackfly larvae were collected. In 1951, almost 6000 were collected, and in 1952, about 12,000 larvae were collected. Collections were made from April to September in 1950 and 1951 and from Marchto September in 1952.

Collections were made from most of the accessible streams in the town of Webb and many streams near Inlet, Raquette Lake, Blue Mt. Lake, and Long Lake. These collections were more or less proportional to the numbers of larvae present (for details of larval population estimate method, see Control Section, page 138). In 1950 and 1951, all collecting stations were visited once each week. In 1952, the Forestport area was included in studies (but treated separately in analyses of population fluctuation data), therefore collection stations were visited once during each ten day interval.

The collections for each year were divided into bimonthly groups to determine the seasonal fluctuation of larval populations of the various species of blackflies (see tables 1-4). Analyses of these data are presented under the biologies of the individual species.

There is a surprising uniformity in the larval population fluctuations during these three years. These years were reported to be "bad" blackfly years by the natives in the Adirondacks outside of the control area.

Table 1. Seasonal fluctuations of blackfly larval populations in the Central Adirondacks - 1950 (in per cent)

Date	hirt.	mut.	ven.-tub.	vit.	gould.	aur.	unident.	Total
April								
4-7	70.0	14.7	0.8	14.5	-	-	-	599
26-30	80.0	16.5	0.8	2.8	-	-	-	356
May								
1-15	24.6	39.6	26.2	1.2	-	-	8.4	569
16-31	69.1	9.6	18.0	3.5	-	-	0.8	256
June								
1-15	35.7	1.3	52.0	1.8	9.2	-	-	229
16-30	6.6	0.3	81.2	-	10.7	0.3	1.0	300
July								
1-15	0.6	-	85.0	6.3	2.5	-	5.6	160
16-31	-	-	99.0	0.1	-	-	-	96
August								
1-15	-	-	83.4	1.9	-	8.3	-	314
Total								2879

The column headings for this and the following tables are abbreviations of the specific names of larvae. The full names are as follows: hirt. = *hirtipes*; mut. = *mutata*; ven. = *venustum*; tub. = *tuberosum*; vit. = *vittatum*; gould. = *gouldingi*; parn. = *parnassum*; aur. = *aureum*; dec. = *decorum*; dac. = *dactense*; lat. = *latipes*; magn. = *magnum*; crox . = *croxtoni*; *Cnephia sp.1*= *pine creek species*.

Table 2. Seasonal fluctuations of blackfly larval populations in the Central Adirondacks - 1951 (in per cent)

Date	hirt.	mut.	ven.-tub.		vit.	gould.	parn.	aur.	dec.	undet.	Total
April											
1-7	72.5	27.5	-	-	-	-	-	-	-	-	512
22-30	65.7	30.3	1.7	2.3	-	-	-	-	-	-	300*
May											
1-7	53.4	25.6	17.3	-	3.7	-	-	-	-	-	300
15-31	48.3	4.2	40.2	5.1	0.5	0.4	-	-	-	1.2	755
June											
1-14	7.5	0.9	52.4	24.5	0.3	5.0	9.1	0.3	-	-	755
15-30	0.8	-	44.8	41.6	-	3.5	8.5	0.6	-	0.2	484
July											
1-14	-	-	64.7	30.0	-	0.4	3.3	1.0	0.6	-	659
15-31	-	-	25.1	68.9	-	1.0	2.2	2.2	0.9	-	1016
August											
15-31	-	-	15.6	76.4	-	-	-	4.4	3.6	-	705
Totals											5486

*210 C. mutata collected in 5-minute samples from 1 stream (OF #38). Of these 100 not included in calculations to partially offset bias due to disproportional sampling.

Table 3. Seasonal fluctuations of blackfly larval populations in the Central Adirondacks - 1952 (in per cent)

Date	hirt.	mut.	ven.	tub.	vit.	gould.	parn.	aur.	dec.	dacot.	lat.	magn.	undet.	Total
Nov. 1951														
22-29	78.6	20.5	-	-	0.9	-	-	-	-	-	-	-	-	461
March														
1-15	78.4	21.5	-	-	0.1	-	-	-	-	-	-	-	-	475
15-31	86.2	8.1	-	-	5.7	-	-	-	-	-	-	-	-	173
April														
1-15	75.0	18.2	-	-	6.8	-	-	-	-	-	-	-	-	660
16-30	65.8	19.4	0.5	-	14.3	-	-	-	-	-	-	-	-	623
May														
1-15	45.0	16.6	27.5	4.7	0.1	0.2	-	-	-	1.0	2.4	2.5	-	803
16-31	20.3	3.0	47.4	17.0	2.6	0.7	-	0.5	-	0.2	8.3	-	-	570
June														
1-15	2.2	-	56.5	15.5	11.4	8.3	-	-	-	0.3	5.8	-	-	636
16-30	1.0	-	36.1	35.4	0.1	5.6	2.0	5.9	12.9	-	0.3	-	0.7	746
July														
1-15	-	-	47.9	40.1	4.8	2.7	3.4	1.0	0.1	-	-	-	-	703
16-31	-	-	28.4	69.2	-	0.13	0.2	0.13	2.0	-	-	-	.07	1471
Aug.														
1-15	-	-	43.0	50.0	-		-	1.0	6.0	-	-	-	-	925
16-31	-	-	12.6	62.9	-		-	0.5	24.0	-	-	-	-	183
Totals														8429

Table 4. Seasonal fluctuations of blackfly larval populations in the Forestport area - 1952* (in per cent)

Date	hirt.	mut.	ven.	tub.	vit.	aur.	dec.	lat. or gould.	lat.	c.sp.	puget.	crox.	Total
March													
16-31	58.1	33.2	2.9	-	2.6	-	0.3	-	-	2.9	-	-	313
April													
1-15	59.7	13.3	13.8	-	-	8.6	-	-	-	-	4.6	-	196
16-30	30.7	15.0	48.4	5.9	-	-	-	-	-	-	-	-	339
May													
1-15	1.8	0.7	96.8	0.7	-	-	-	-	-	-	-	-	274
16-31	0.6	-	79.5	1.9	18.0	-	-	-	-	-	-	-	156
June													
1-15	-	-	94.2	-	2.9	-	-	-	2.9	-	-	-	103
16-30	-	-	84.6	4.8	4.5	4.5	-	-	-	-	-	1.6	418
July													
1-15	-	-	75.6	20.4	-	3.5	-	-	0.3	-	-	-	284
16-31	-	-	86.4	7.0	-	5.7	-	0.9	-	-	-	-	229
August													
1-15	-	-	90.3	9.7	-	-	-	-	-	-	-	-	204
16-31	-	-	81.6	5.7	0.9	0.5	11.3	-	-	-	-	-	212
Totals													2728

*Excluding Otter Lake area streams

BIOLOGIES OF THE INDIVIDUAL SPECIES

NOTES ON THE BIOLOGY OF *Gymnopais* *sp*.

Larvae of the genus *Gymnopais* have been collected in Alaska (Stone, 1952), Labrador (Hocking and Richards, 1952), from Vermont (Coher, personal communication), and from New York by the author. This species has not been found previously in New York. Larvae of one species of this genus were found in a small, temporary inlet to 6 Mile Creek in Brooktondale, N. Y., on April 8, 1952. Collections from the same stream on April 24, 1952 (by S. Moore, Cornell Univ.) and on April 30, 1952 had no larvae or pupae of this species. There is probably only one generation per year. Little is known of the biology of this species. Other species found in this stream are *P*. *hirtipes*, *C*. *mutata*, and *P*. *sp*. *14*.

NOTES ON THE BIOLOGY OF *Prosimulium* *hirtipes*

To the knowledge of this author, the eggs of *P*. *hirtipes* have not been previously described. Smart (1936, 1944) mentions that the oviposition habits of this species are now known, but that negative information indicates that they do not lay their eggs in masses. Several theories have been advanced to explain the difficulty in finding *P. hirtipes* eggs during the summer. It has been hypothesized that the adults may aestivate during the summer and lay their eggs in the fall or that females may lay their eggs singly, dropping them into the water instead of laying them in masses attached to the substrata as many blackflies do. (Recently, Fredeen *et al.*, (1951) reported that *S. arcticum* females lay their eggs singly by dropping them into the water). It is also possible that gravid *P. hirtipes* females may imbed the eggs in moist soil or vegetation with their unusually well developed ovipositors. Any one of these methods could account for the appearance of *P. hirtipes* larvae, in the autumn, in streams that recede greatly or dry up almost completely during the summer.

On May 15, 1951, 8 gravid female *P. hirtipes* were collected flying over a small dam below a beaver pond (2nd Okara outlet). Each of the females was filled with well-developed, apparently mature eggs. The eggs collected from these females were more or less ovoidal. They differed from typical Simuliid eggs in not being subtriangular in outline. Three of the females were dissected. There was an average of 263 eggs in each of the abdomens. The eggs averaged 0.360 mm. in length and 0.159 mm. in width at the widest point. In 1952, numerous annoying female _P_. _hirtipes_ adults were dissected and the ovaries examined. Most of the ovaries contained immature eggs. One, collected on May 9, 1952, was full of apparently mature eggs; others, collected on May 9, 19, 28, 1952, had one or two mature eggs and an otherwise empty pair of ovaries. From this evidence it would seem that the eggs are laid during the early part of the summer instead of in the fall. However, actual oviposition by this species was not observed. Since Simuliid eggs (at least some species) are not resistant to prolonged desication, the eggs must be either dropped into the streams while they are still running (being carried by the current into protected niches where the ground remains damp all summer) or oviposited into moist earth, leaves or other vegetable matter.

Strickland (1911), stated that P. hirtipes larvae were first found in November near Boston, Mass. O'Kane (1926) reported that P. hirtipes larvae were found in New Hampshire streams in early November in 1923 after being absent during the summer. According to De Foliart (1951), P. hirtipes larvae first appeared in Adirondack streams in mid-October, 1950. Collections made in December, 1950 and November, 1951 were examined and P. hirtipes larvae ranging in size from 1-7 mm. found (with a mode of about 4 mm.). Larvae of this species were found during the winter and early spring in large numbers, making up about 80% of the total blackfly larval population. P. hirtipes larvae declined rapidly in numbers from April until June, when only a few could be found (tables 1-3). However, some were found as late as mid-July. At first it was hypothesized that there might be a partial second generation which appeared in the streams as larvae in late June and early July. Matheson (1950) states that P. hirtipes frequently has two generations per year in the Adirondacks. However, Strickland (1913), Smart (1944), Davies (1950), Jenkins (1948), and De Foliart (1951) indicate that there is only one generation per year. Johannsen (1934) states that there is only one generation per year but his determination of the larvae of this species is subject to question.

To determine the number of generations per year in the Adirondacks, all P. hirtipes larvae collected from November, 1951 through June, 1952 were measured. Small larvae (1-2 mm.) were found as late as June 5. However, there was no apparent appearance of a second generation of larvae of this species in any of the streams as indicated by a sudden large increase in the number of small larvae. It seems probable that the small larvae found in April, May, and June were due to late hatching of eggs laid the previous summer. This information is important to consider when planning a control program since proposed fall treatments after the appearance of P. hirtipes larvae in the streams would not be as effective as spring treatments because many of the larvae would be in the highly resistant egg stage. By treating the streams in the spring after almost all of the eggs have hatched, more effective control may be obtained.

P. hirtipes larvae pupate, for the most part, between late April and the first week in June depending on the temperature of the stream (see table 6). The period of most abundant adult emergence of this species was between May 15 and 30 during 1950, 1951, and 1952. Adults were not annoying until about 1 week after emergence. They were annoying from mid-May to early June. The duration of their life and their habits, except for annoying humans, are little known. Judging from the period that they are annoying to man, the decline in larval populations and emergence of adults, it is probably only about three weeks (see graph 1).

P. hirtipes has been reported attacking man, cattle, a pony, and other animals. (Bromley, 1952; Davies, 1950; De Foliart, 1951; Dyar and Shannon, 1927; Edwards, 1915; Edwards *et al.*, 1939; Frost, 1949; Hocking and Richards, 1952; Jamnback, 1952; Jenkins, 1948; Johannsen, 1934; Malloch, 1914;

Smart, 1936, 1944; and Twinn, 1936.)

NOTES ON THE BIOLOGY OF *Prosimulium sp. 14*

O'Kane (1926) reported finding larvae and pupae of this species in temporary streams in late May and in June in New Hampshire.

Larvae and pupae of *P. sp. 14* were found only in the Caroga Lake and Brooktondale, N. Y. areas. The larvae are quite similar in appearance to those of *P. hirtipes*. Larvae were collected near Caroga Lake from a small, temporary stream which flows into Stink Lake Outlet crossing route 10 near Pole NYP 333. Larvae were collected on April 18, 1952, larvae and pupae April 29, 1952, and larvae and pupae May 6, 1952. Larvae were also collected from a small, temporary stream which crosses route 29A one-half mile west of Irving Pond Outlet on April 18, 1952. Larvae and pupae were collected from this stream May 6, 1952.

One pupa was taken from a small temporary inlet to 6 Mile Creek in Brooktondale April 8, 1952.

There is probably only one generation per year. According to Stone (personal communication, 1952), neither the males nor the females can be separated from those of *P. hirtipes*. It is not known whether or not this species is homophilic.

NOTES ON THE BIOLOGY OF *Prosimulium magnum*

There is one generation per year of *P. magnum* in the Adirondacks. Larvae and pupae were collected at Eaton Pond Outlet on May 6, 1952. Larvae were collected from a stream near the junction of route 13 and Eastlawn Road in Ithaca April 8, 1952, and from Pack Forest Lake Outlet, Warrensburg (by D.L.C.) May 8, 1952. This species is not present in large enough numbers to be annoying in the Adirondacks. It is probably more plentiful in the lowlands.

NOTES ON THE BIOLOGY OF *Prosimulium multidentatum*

P. multidentatum is said to overwinter in the larval stage in small forest streams and larger streams in flood (Hocking and Richards, 1952). It was not collected in the Adirondacks. These authors report that the species is not annoying to man. Larvae and pupae were found on April 29, 1935 near Ottawa; emergence of adults had commenced on May 8 and was practically complete by May 14 (Twinn, 1936). No signs of larvae were found through the summer (*ibid*).

NOTES ON THE BIOLOGY OF *Cnephia dacotensis*

C. dacotensis was found only rarely in the Adirondacks. Larvae and pupae were present only in warm pond or lake outlets such as Lily Pad Pond Outlet and Big Otter Lake Outlet. It is found only in May or June in the larval or pupal stage, probably overwintering as an egg. Nicholson and Mickel (1950) report that in Minnesota larvae are found in April, with adults emerging in May; and that it may spend most of the summer and winter in the egg stage. Davies (1950) reported that the adults emerge in June in Ontario.

According to Nicholson and Mickel (1950) the pupae require about eight days to complete development. Large and apparently well developed eggs are present in the mature pupae of the females. Copulation takes place immediately after emergence (Nicholson and Mickel, 1950). The females do not feed as adults (Krafchick, 1942; Nicholson, 1945).

NOTES ON THE BIOLOGY OF *Cnephia mutata*

The larvae of *C. mutata* are found in temporary or permanent streams. They are most numerous in sandy bottom streams with few rocks and pebbles and with abundant trailing grass. This species overwinters in the larval stage in the Adirondacks. In November and December it makes up about 20 per cent of the total blackfly larval population. This percentage remains relatively constant until about March when it begins to decline due to pupation and appearance of larvae of other species. Larvae may be found until late May or early June. Adults have been collected from rocks or grass on stream edges in May. Data collected in the Adirondacks support Davies' (1950) statement that there is one generation per year. The adults are usually not homophilic, at least in the Central Adirondacks. They have been caught in collections of annoying adults in the Forestport area and Bozenkill, Delanson, N. Y. (by D.L.C.). Davies (1950), Hocking and Richards (1952), and Frohne and Sleeper (1951) report that this species is rarely annoying to man.

NOTES ON THE BIOLOGY OF *Cnephia sp. 1*

C. sp. 1 was found only in Pine Creek in the Forestport area on March 21, 25, and on April 4, 1952 in the larval stage. Pupae were found on April 4 and 10, 1952. At the point where larvae and pupae of this species were collected the stream is about 20 feet wide. It has a coarse sand bottom with large rocks. At the time of the collections, the stream was about 1.5 feet deep. This species probably overwinters in the larval stage. There is probably only one generation per year.

NOTES ON THE BIOLOGY OF *Simulium* (*S.*) *venustum*

During the summer, *S. venustum* females are known to lay their eggs in masses on grass trailing in the water, on sticks, and on rocks. The number of eggs laid by females averaged 349 in studies made by Jobbins-Pomeroy (1916). Davies (1950) reported that the number of eggs laid by *S. venustum* females averaged 435. It has been reported that this species overwinters as a larva in New York (Forbes, 1912). This is not true in the Adirondacks. However, Twinn *et al.*, (1948) report that it overwinters as a larva in the vicinity of Ottawa. In most of the areas studied, however, the larvae are absent from streams during the winter.

The eggs are between 0.21 and 0.26 mm. in length (Wu, 1931; De Foliart, 1951). The incubation period during the summer is 7-11 days (McBride, 1870; Wu, 1931; Malloch, 1914); De Foliart (1951) reported that the incubation period is probably about 5 days during the summer. In the Adirondacks, the first larvae appear during the last part of April. By June they may be the dominant species in the stream. The larvae are said to require four weeks (McBride, 1870) to over 7.5 weeks (Wu, 1931) for maturation. De Foliart (1951) reported that the larval stage was completed in as few as 12 days in rearing troughs during the summer. Field observations indicate that about 2 weeks may suffice during warm weather. The pupal stage has been recorded lasting from 84 hours (Jobbins-Pomeroy, 1916) to three weeks (McBride, 1870). De Foliart (1951) reported that the pupal stage required as few as 4 days during the summer.

Edwards (1920) states that *S. venustum* (descr. as *S. austeni*) has only 1 generation per year; Matheson (1950) 2 generations per year; Smart (1944) 2 or more generations per year; Jenkins (1948) 2-3 generations per year; Forbes (1912) 3 generations per year; Davies (1950) 3 generations per year; Twinn (1933), and Jobbins-Pomeroy (1916) 3 generations per year. De Foliart (1951) reported that there were 5-6 generations or peaks of emergence in 1950 in the Adirondacks.

In the Adirondacks, adults may be annoying from the last week in May until the first week in July. There are at least 3 and possibly 4 generations of *S. venustum* per year during the period from late April to September. The data are obscured by overlapping generations. Since adults emerge during the entire summer it is difficult to see why *S. venustum* should not be annoying for the whole summer (see graph 2). It may be that only the first generation is homophilic, or that there are two species mixed, one of which is homophilic and the other not.

The above problem becomes somewhat complex because *S. tuberosum*, another annoying species (in some areas) is present and the females of these two species cannot be readily differentiated. Smart (1944) distinguishes between females of these species in the following way:

> "Face black, shining like the front;
> legs mainly black .... *S. tuberosum*
>
> Face grey; legs more or less extensively pale .... *S. venustum*"
> (and some other species)

Stone (1952) distinguishes between females of these species in the following way:

> "Hairs on stem vein and base of costa
> pale ...... *rubtzovi* Smart; *venustum* Say
>
> Hairs on stem vein and base of costa
> dark .... *tuberosum* (Lund.)"

In addition to the above characters, it was noted that *S. tuberosum* is often smaller and darker than *S. venustum*. In the Adirondacks, typical specimens of both species could be distinguished using Stone's characters. However, there were many specimens which appeared to be intermediate between the two species.

In studying the larvae of *S. venustum*, it was noted that some of the specimens had distinct red bands and some were entirely white. When collections of the larvae were grouped into half-month periods it was noted that both red and white larvae were present in a 1:1 ratio in June but that the white larvae increased to 6:1 and 8:1 ratios in July and August respectively (see graph 4). When it is considered that the over-all S. venustum population declined during the course of the summer and that the red-banded larval portion of this population declined in particular, it can be seen that a plausible explanation for the lack of annoying S. venustum adults in the late summer exists if the annoying adults come only from larvae with red bands. If these larvae are not genetically distinct from the white larvae it seems necessary to hypothesize that only first generation S. venustum are homophilic.

No morphological differences between the red-banded and the white larvae were found. Nicholson and Mickel (1950) have noted and figured two types of S. venustum male genitalia. Reared males from pupae in streams having only red or white larvae have been collected and will be examined to determine whether these differences can be correlated with the red-banded and white larvae.

Man, horses, mules, dogs, ducks, and domestic animals have been reported as being attacked by *S. venustum* (Cameron, 1922; Davies, 1950; De Foliart, 1951; Dyar and Shannon, 1927; Frohne and Sleeper, 1951; Frost, 1949; Hall and Wigdor, 1918; Hearle, 1938; Hocking and Richards, 1952; Jamnback, 1952; Jenkins, 1948; Johannsen, 1903; 1934; Jobbins-Pomeroy, 1916; Johnson *et al.*, 1938; Nicholson, 1945; Nicholson and Mickel, 1950; O'Roke, 1934; Petersen, 1924; Reeves, 1910; Smart, 1944; Stokes, 1914; Twinn, 1933, 1936; Twinn *et al.*, 1948).

NOTES ON THE BIOLOGY OF *Simulium decorum*

The eggs of *S. decorum* are laid in large masses, especially on dams and near lake outlets or below large pools. Females of this species are often found imbedded in masses of eggs. Apparently more than one female lays its eggs in a single area to form a large egg mass. According to De Foliart (1951) the eggs require from less than 4 to 7 days to hatch at 70° F. ± 1°.

Larvae of S. decorum were found almost invariably on dams, at lake outlets, or below large pools in the Adirondacks. They were present in large numbers during the latter part of the summer, especially after the first two weeks in June. They were very numerous in these restricted breeding areas. Sometimes larvae of this species will entirely cover parts of the face of a concrete dam or twigs on a beaver dam. De Foliart (1951) reported that the larval stage lasts 12-16 days during warm weather. Davies (1950) reported that there are two generations per year. Puri (1925) stated that pupae of S. decorum (descr. as S. nölleri) require 5 days at 16 degrees C. or 13-15 days at 3.8 degrees C. for maturation. De Foliart (1951) reported that the pupal stage lasted 3-4 days at summer temperatures.

S. decorum is not a pest species of man in the Adirondacks. There are a few records of this species annoying man and cows (De Foliart, 1951; Dyar and Shannon, 1927; Hocking and Richards, 1952; Lugger, 1896; Nicholson and Mickel, 1950).

NOTES ON THE BIOLOGY OF *Simulium jenningsi*

S. jenningsi is generally rare in the Adirondacks. However, adults were collected in some numbers in the Forestport area. Searches for the larvae in this area were unsuccessful. Empty pupal cases were found August 27, 1952 in Little Woodhull Creek which was not sampled earlier in the season because it appeared to flow too slowly to have blackfly larvae. It is about 75 feet wide with a maximum depth of more than 6 feet and a flow rate of about 0.3 foot per second. The pupal cases were found on twigs at a depth of three to four feet. This species is annoying to humans (but has not been taken biting) in the Adirondacks. It is a late summer pest, being found in July and August. Underhill (1944) reported that in Virginia no larvae of *S. jenningsi* (descr. as *S. nigroparvum*) are present in the streams in the winter but that they are abundant in the summer, being found first in March. He further reported that there are three generations per year and that the life cycle lasts about 6 weeks in that area. Larvae are found chiefly in large creeks and rivers (Underhill, 1944; Johnson *et al.*, 1938). Nicholson and Mickel (1950) state that the pupal stage of this species (descr. as *S. j. luggeri*) is completed in 2-4 days at about 25 degrees C. under laboratory conditions.

Underhill (1944) states that *S. jenningsi* (descr. as *S. nigroparvum*) adults have been collected 20-30 miles from known breeding places and were present in large numbers 10 miles from the nearest known breeding areas. Johnson *et al.*, 1938, state that adults have been taken 5-6 miles from the nearest known breeding place.

This species is recorded attacking turkeys, horses, mules, cattle, and "mammals" (Jobbins-Pomeroy, 1916; Johnson *et al.*, 1938; Malloch, 1914; Nicholson and Mickel, 1950; Underhill, 1939, 1940, 1944).

NOTES ON THE BIOLOGY OF *Simulium tuberosum*

Little is known of the life cycle or habits of *S. tuberosum*. Smart (1944) and Davies (1950) report that there are possibly two generations per year. Studies of the size of larvae and the larval populations indicate that there are at least three and probably four generations per year in the Adirondacks. De Foliart (1951) stated that there were probably four generations in 1950. The data are somewhat obscured because of overlapping generations, however. This species probably overwinters in the egg stage although overwintering eggs have not been found. The first generation larvae reach peak numbers toward the end of May, the second toward the end of June, and the third toward the end of July. There is probably one more generation in August. Larvae begin emerging from the eggs in early May, somewhat after the first S. venustum are found. This species becomes the dominant larva found in Adirondack streams in the latter half of August or early in July. It is found in all types of permanent streams. Judging from larval and pupal population fluctuations, this species either is not annoying in the Adirondacks or is only homophilic in the first generation (see graph 3). It seems quite possible that the former is true, although many of the annoying adult females collected have the dark hairs on the base of the costa and on the stem vein that are said to be typical of *S. tuberosum*.

S. tuberosum has been reported attacking man, horses, domestic animals, and "mammals" (Davies, 1950; De Foliart, 1951; Edwards, 1915; Edwards *et al.*, 1939; Jamnback, 1952; Hocking and Richards, 1952; and Smart, 1944).

NOTES ON THE BIOLOGY OF *Simulium parnassum*

S. parnassum larvae were first collected in 1950 by De Foliart (1951). Larvae of this species are found in only a few streams in the Adirondacks. The larvae were found in June and July in 1951 and 1952. Streams in which immature stages of this species were found include Bear Brook (where it was the dominant species during June, 1951), Aedes Brook, and rarely in Pancake Brook and FT #1. There is apparently only one generation per year in the Adirondacks.

The adults of *S. parnassum* are annoying to humans in the Adirondacks but have not been collected biting. Dyar and Shannon (1927) and Hocking and Richards (1952) have stated that this species attacks man.

NOTES ON THE BIOLOGY OF Simulium pictipes

S. pictipes was found only rarely in the Adirondacks. Larvae and pupae were found on June 15, 1952 (by D.L.C.) in Fall Brook which flows into the Moose River near Porter, N. Y., and on June 27, 1952 in the Black River Canal between Port Leyden and Boonville on Route 12. Larvae and pupae were found only in streams having sedimentary rock bottoms. Larvae were especially numerous on flat rocks where the water is swift and shallow above small falls. The larvae are unusual in often being found in "colonies" which look like black moss. These "colonies" are often only a few inches in diameter, appearing to be larvae hatched from a single egg mass. Adults were not collected.

In 1934, Smart reported on studies of the biology of this species in and around Ithaca, N. Y. He reported that the egg is ovoid but without the marked triangulate shape usually associated with the ova of Simuliidae. The eggs averaged 0.37 x 0.22 x 0.20 mm. Oviposition was effected through a thin film of water or the eggs were laid where the surface was wet with spray. The incubation period of the eggs is 2.5 to 5 days at 25 degrees C. Desiccation of the eggs results in mortality. The larvae require 4-6 weeks to mature and pupate but the period can be prolonged by reducing the food supply. The pupae require 4.5 days to mature at 2.5 degrees C. The adults copulate immediately after emergence. Observations indicate that the females lay eggs about a week later. There are at least four and probably five generations per year. _S_. _pictipes_ overwinters in the larval stage.

Other workers who have studied this species agree fairly well with Smart's observations. These include Coquillet (1898), Forbes (1912), and Gambrell (1933).

Gambrell (1933) noted that oviposition took place between 9 and 11 a.m. as a general rule. However, one swarm was detected ovipositing at about 9 p.m. It was also noted that a single female laid between 150 and 200 eggs.

S. *pictipes* has been reported attacking horses, mules, and moose (Jobbins-Pomeroy, 1916; Malloch, 1914; Nicholson and Mickel, 1950). It has not been reported attacking humans.

NOTES ON THE BIOLOGY OF *Simulium corbis*

S. *corbis* larvae have not been described. Empty pupal cases of this species were collected on May 31, 1950 at the dam of Shaw Pond Outlet in Long Lake, N. Y. Repeated collections at this point and in neighboring streams later in 1950 and in 1951 and 1952 produced no more pupae of this species. Since the larvae are not known, it is possible (but not likely) that some of the larvae collected from this stream and determined as other species were incorrectly identified. There are some indications that this species is more abundant in the lowlands (Coher, 1952, personal communication).

NOTES ON THE BIOLOGY OF *Simulium fibrinflatum*

S. *fibrinflatum* have not been described. Three pupae were found by Coher (1952,personal communication) in a small stream near Altona, N. Y. on June 17, 1952.

NOTES ON THE BIOLOGY OF Simulium vittatum

The biology of S. vittatum has been fairly completely studied, probably owing to the ease with which large numbers of eggs, larvae, or pupae can be collected from readily accessible areas. The eggs are said to be between 0.27 and 0.3 mm. in length (De Foliart, 1951); 0.25 mm. (Wu, 1931). Malloch (1914) reported that eggs take 9-15 days to hatch while Wu (1931) reported that they require only 4-5 days. These eggs are not resistant to desiccation according to Wu (1931). Larvae of this species are found on dam faces, below lake outlets, and below large pools. The species over-winters in the larval stage. De Foliart (1951) noted that the duration of the larval stage is influenced by the amount of food available. Pupation, however, may occur even during the winter, although this is quite rare. During the summer pupation occurs in 3-4 days (De Foliart, 1951). Adults have been collected flying about on warm days when there was still ice on the lakes and snow on the ground.

S. vittatum lays its eggs in characteristic strings joined by a gelatinous substance. Dead females are often found partially buried in the egg masses. Apparently, numerous females lay their eggs in the same spot. The larvae are often so numerous that they appear like a black mossy covering on the dam face. At least three generations per year have been observed in the Adirondacks during the course of a summer. From field observation, it seems probable that there are at least four generations per year. De Foliart (1951) reported three or more generations per year in the Adirondacks. Davies (1950) stated that there are probably two generations per year in Ontario, while Jenkins (1938) stated that there are 2-3 generations per year in Central Alaska. The females probably lay about 300 eggs each. (300-320 according to Wu, 1931.) The pupae require about 4 days for adult emergence (Wu, 1931).

S. vittatum is rarely annoying to man in the Adirondacks although larvae can be found in large numbers below dams, at lake outlets, and below large pools. It has, however, been reported attacking man, horses, domestic animals, and "mammals" (Cameron, 1922; Davies, 1950; Dyar and Shannon, 1927; Emery, 1913; Frost, 1949; Hocking and Richards, 1952; Knowlton, 1935; Knowlton and Maddock, 1944; Jobbins-Pomeroy, 1916; Longstaff, 1932; Lugger, 1896; Malloch, 1914; Twinn, 1936).

NOTES ON THE BIOLOGY OF *Simulium aureum*

The eggs of *S. aureum* are 0.21-0.26 mm. in length (De Foliart, 1951). They are laid on trailing grass or leaves and deposited in a neat, compact mass one layer deep, all of the eggs standing on end and covered by a thick layer of gelatinous material. The incubation period of the eggs is 8-12 days according to Malloch (1914). The larval period is said to be 4-5 weeks (Puri, 1925). They are found in warm streams in the Adirondacks, especially at lake outlets such as Bald Mt. Pond Outlet. Jenkins (1948) reported that this species is found in warm, slow-moving lake outlets in Alaska. Jobbins-Pomeroy (1916) reported 5-6 generations per year in South Carolina. Pacuad (1942) reported two generations per year in Europe, Edwards (1920) reported the same in the British Isles, as did Davies (1950) in Ontario and Forbes (1912) in Illinois. In the Adirondacks there are probably two generations per year.

This species is not a pest in the Adirondacks. Edwards (1920) and Cameron (1922) (descr. as S. bracteatum) reported that there is no evidence of blood-sucking in this species. It has been reported attacking goslings (Smart, 1944; Bequaert, 1938). Hocking and Richards (1952) state that this species is rarely annoying.

NOTES ON THE BIOLOGY OF Simulium gouldingi

Larvae of S. gouldingi have only been found in a few permanent streams flowing through heavily wooded areas in the Adirondacks. Streams in which this species was found include Wheeler Creek, High Rock Pond Outlet, and Aedes Brook. A few larvae were found in May, June, and July. In June, 1952 about 8% of the total number of blackfly larvae collected were of this species. There is probably only one generation per year. De Foliart (1951) also reported that there is probably only one generation per year.

Nothing is known of the egg-laying or adult feeding habits of this species. Adults were not taken in collections of annoying blackflies.

NOTES ON THE BIOLOGY OF *Simulium latipes*

S. latipes is not a common species in the Adirondacks. Larvae were found only in temporary streams which continue to flow until at least mid-May or June. Edwards (1920) reported that this species overwinters in the larval stage. In the Adirondacks, larvae were not found until May, 1952, although frequent collections were made in this stream earlier in the season. In the Adirondacks, this species probably overwinters in the egg stage. Larvae are first found in May and the major portion of pupation takes place in June. Since *S. latipes* larvae closely resemble those of *S. pugetense*, and to a lesser extent *S. gouldingi* and *S. aureum*, caution should be taken in determining this species. Edwards (1920) stated that there is probably one generation per year. This agrees with observations made in the Adirondacks.

Although Edwards reported in 1915 that *S. latipes* was not a pest species, in 1920 he reported instances of its being annoying to man. Smart (1944) reported that this species was a pest. Hocking and Richards (1952) reported that this species is not a pest in Labrador. *S. latipes* is not a pest in the Adirondacks. However, it is not present in large numbers. A few females of the (*Eusimulium*) group which may be *S. latipes* were collected along with other species of annoying adults.

NOTES ON THE BIOLOGY OF *Simulium pugetense*

S. pugetense is very rare in the Adirondacks. It was found only in the Forestport area in Crystal Brook. This is a small spring-fed stream with a bottom of fine sand, dead leaves, twigs, and some grass. Larvae and pupae were collected during the first two weeks in April but were not found thereafter.

Jenkins (1948) reports that the larvae are found in cold waterfalls and mountain streams in

Alaska. Hocking and Richards (1952), report that this species is found in small forest streams and in rather larger streams while in flood. They state that this species apparently overwinters in the larval stage. Well grown larvae can be found early in May in Labrador, according to these authors. There is probably only one generation per year. Davies (1950) recorded two generations per year (descr. as *S. costatum*). Grenier (1945a) recorded three generations per year (descr. as *S. costatum*) (ex Davies, 1950).

Davies (1950); Edwards *et al.*, (1939); Smart (1944) recorded this as a severe blood sucker. Hocking and Richards (1952) noted that *S. pugetense* was rarely annoying.

REPORTS OF THE OLD FORGE WEATHER STATION

Table 5, p. 121, presents temperature and rainfall data taken at the Old Forge Weather station, abstracted from reports of the U.S.D.C. Weather Bureau publications (U.S. Dept. Commerce, 1950, 1951, 1952). Since the temperatures, precipitation, and blackfly populations were quite

Table 5. Climatology-Old Forge USDC Weather Bureau

Average Monthly Temperatures

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1949	23.1	25.0	27.7	41.4	53.1	66.8	68.6	66	54.7	50.8	30.8	23.6	44.3
1950	27.0	16.6	-	-	53.6	60.4	64.9	63.3	53.8	48.0	36.3	19.9	-
1951	19.2	21.6	29.3	41.6	53.7	60.3	65.1	62.9	-	46.6	27.9	-	-
					Total Monthly Precipitation								
1949	3.68	3.48	2.34	4.71	1.93	2.06	-	6.58	4.91	1.69	3.62	4.47	-
1950	5.06	3.36	-	-	1.71	3.62	3.74	4.32	4.53	2.53	6.32	3.52	-
1951	4.32	5.12	4.25	-	1.71	4.27	5.56	3.43	-	-	-	-	-

similar for 1950, 1951, and 1952 no conclusions could be drawn from these data for the present. If similar data are collected during an unusually cold or dry season, it may be possible to study the effect of these factors on blackfly populations.

THE RELATIONSHIP BETWEEN WATER TEMPERATURE AND THE APPEARANCE OF ANNOYING BLACKFLIES

General observations in 1950 seemed to indicate that there was a relationship between the temperature of a stream and the time of emergence of the overwintering larvae of *P. hirtipes*. It also seemed likely that the date of emergence of *S. venustum* and *S. tuberosum* larvae from the (probably) overwintering eggs was influenced by stream temperatures.

The water temperatures of 15 streams were taken at intervals of approximately one week in 1951. The mean temperatures for the season were calculated from data collected between the third week in May and the last week in July. During this period there was a fairly consistent trend toward increasing temperatures, with some fairly wide deviations.

The mean temperatures of these streams during this period varied from 52 degrees F., in a small, narrow, spring-fed stream flowing into Raquette Lake to 69.9 degrees F. in the outlet from Bald Mountain Pond. The mean temperature of all the streams checked during this period was 59.8 degrees F.

There is apparently a relationship between the temperature of the water and the time when *P. hirtipes* larvae were last found in a stream. In general, the higher the mean temperature of the stream, the earlier in the season the *P. hirtipes* pupate and emerge (see table 6). There was no readily apparent relationship between the mean temperature of a stream and the date of emergence of *S. venustum* larvae from the overwintering eggs.

On theoretical grounds, it would seem reasonable to assume that the active *P. hirtipes* larvae would have a higher metabolic rate than the more or less quiescent eggs of *S. venustum* and

S. tuberosum, and therefore would be more sensitive to differences in water temperature.

In 1952, control operations were extended to other areas and it was not possible to check individual streams more than once every two weeks. It was felt that these inspections were not frequent enough to secure data correlating water temperatures with pupation of *P. hirtipes* or egg hatching of *S. venustum* and *S. tuberosum*. In 1952, temperature readings in individual streams at 2-week intervals indicated that stream waters remained relatively constant (at near 32 degrees F.) in March. Water temperatures began rising in April and increased (with fluctuations) through July. They began decreasing in August.

On a practical basis, for use in control work, these data indicate that a control supervisor can use a few of the warmest streams as checks to time treatment for the control of *P. hirtipes*. Treatment should be made as soon as there are indications of imminent pupation in these warm streams.

The timing of treatments for the control of

S. venustum and *S. tuberosum* based on water temperature data secured by recording temperatures at weekly intervals is impractical because of the lack of correlation between water temperature and hatching of the eggs. Numerous streams must be examined when determining the time to treat streams to control these larvae.

In 1952, it was noted that the larvae of *S. venustum* and *S. tuberosum* often hatch first at lake outlets, pond outlets, or below large pools. Larvae at these points may begin pupating before larvae from other parts of the same stream emerge from the egg. This complicates control procedures since more than one application becomes necessary for good control. This phenomenon of differential hatching time and maturation of *S. venustum* and *S. tuberosum* average larvae in the early spring may be due to very slight temperature differences or to a "critical" temperature which is necessary to initiate hatching, although, in very few cases could these be demonstrated.

Differences in the larval population fluctuations between the Adirondacks proper and the warmer and lower Utica Valley to the south are shown by a comparison of the time and rate of *P. hirtipes* larval population decline and *S. venustum* larval population increase (see graph 5). The Town of Forestport lies partly inside of the mountainous area of the Adirondacks and partly in the Utica Valley. The area around the village of Forestport, which is in the valley, was studied in some detail. It is located about 22 miles south of Old Forge at an elevation of 1200-1300 feet, compared to 1800-2300 feet in the Town of Webb area.

Table 6. Relation of Water Temperature to Development of Annoying Blackflies

Stream	Mean Temperature	Order of dates last P.hirtipes larvae found	Order of dates last S.venustum larvae found	Order of dates last S.tuberosum larvae found
Bald Mt. Pond Outlet	69.9	1a	*	*
Safford Pond Outlet	66.9	*	7	8
N. Branch, Indian Brook	65.4	2	1	-
Indian Brook	63.1	3	6	5
Salmon River	63.1	5	8b	10
Pole OF #38	59.6	4	2	-
Otter Lake Inlet	59.1	6	3	4
Bottle Brook	59.0	1b	8c	1
3rd Lake Creek	58.9	*	5	9
Bear Brook	57.4	*	8d	6
Wheeler Creek	57.2	7	4a	2
Loon Brook	56.7	*	*	*
High Rock Pond Outlet	54.7	10	4b	3
Aedes Brook	54.4	9	9	7
Raquette Inlet	52.0	8	8	10a

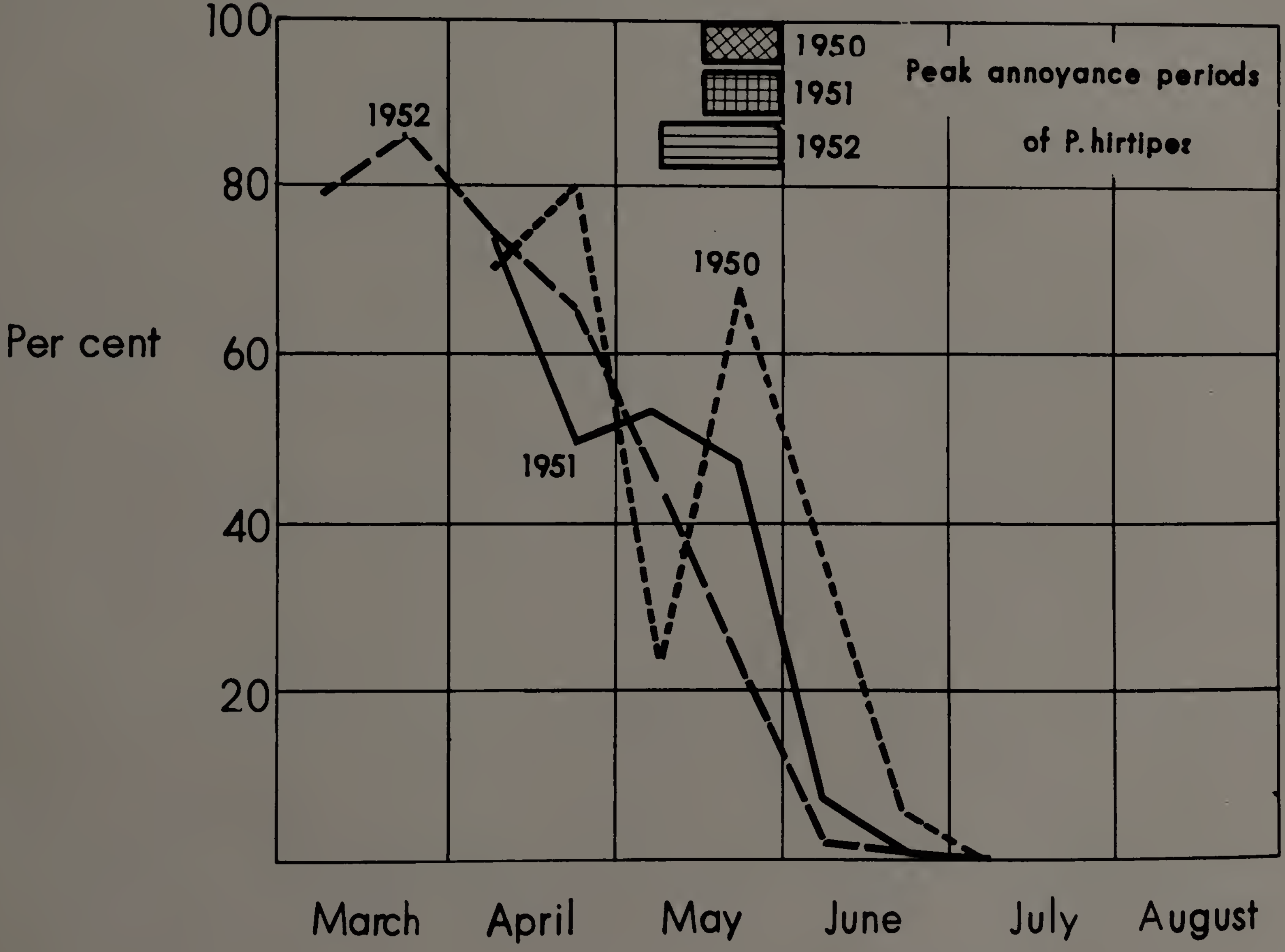
*Stream treatments interfered with the collection of data.

The last larvae of P. hirtipes were collected from these streams between April 3 and June 6, 1951. The first larvae of S. venustum were found between April 29 and June 6, 1951. The first larvae of S. tuberosum were found between May 17 and June 27, 1951.

GRAPH 1.

Seasonal larval population fluctuations of P. hirtipes in Old Forge area 1950, 1951, and 1952

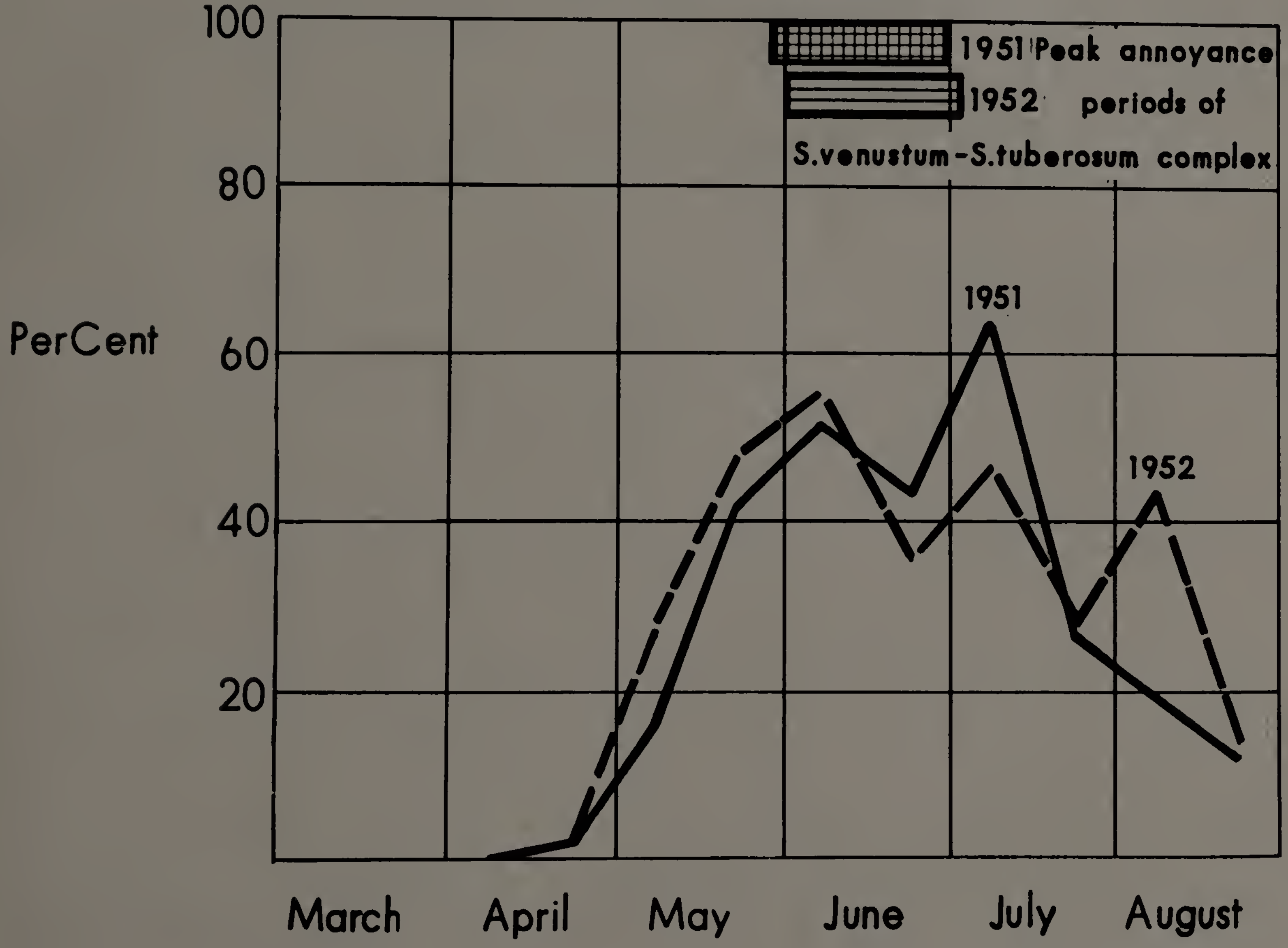
(Based on per cent of P. hirtipes larvae in collections for each half month period.)



GRAPH 2.

Seasonal larval population fluctuations of S.venustum in Old Forge area 1951 and 1952.

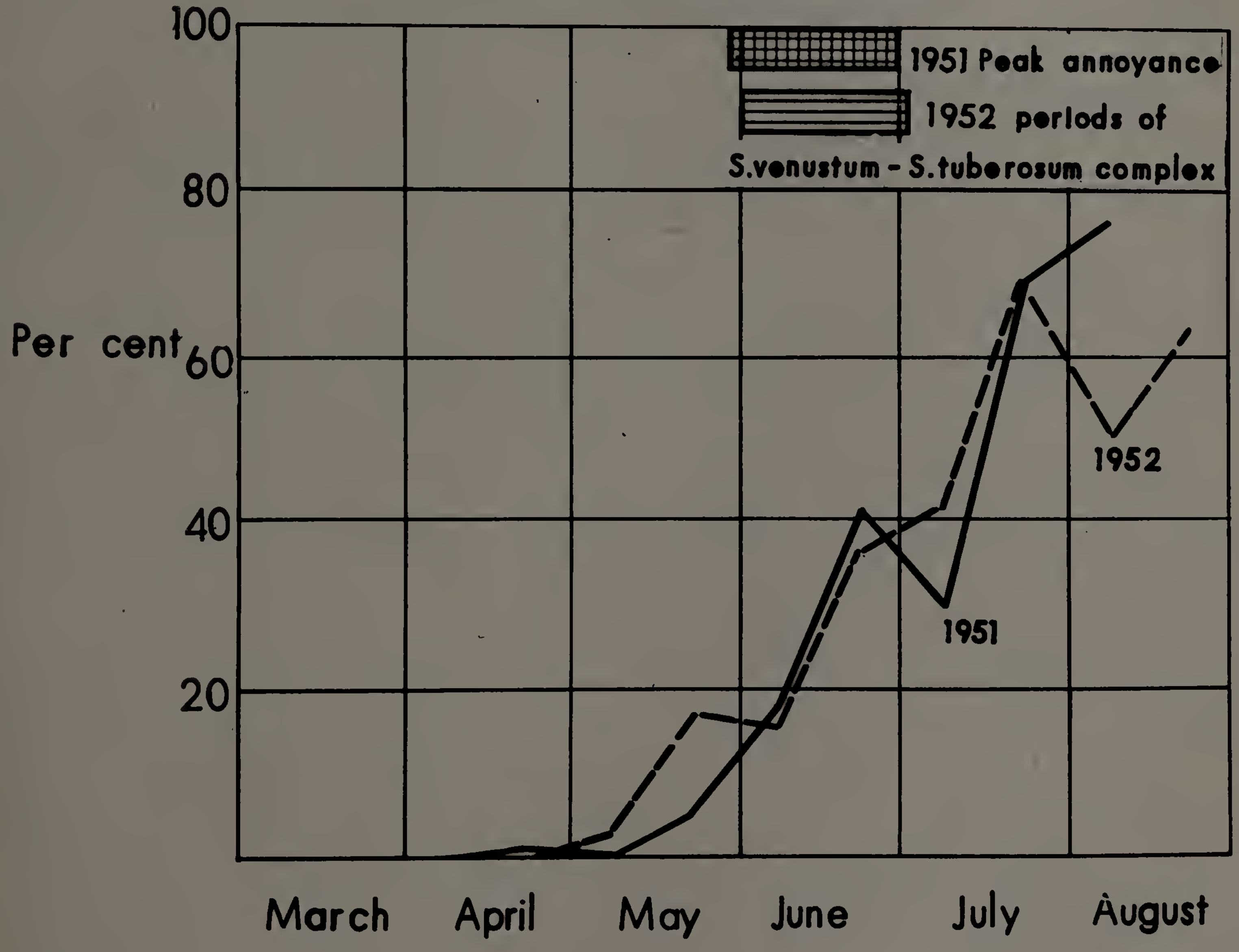
(Based on per cent of S.venustum larvae in collections for each half month period.)



GRAPH 3.

Seasonal Larval Population Fluctuations of S.tuberosum
in Old Forge Area 1952 1951 and 1952

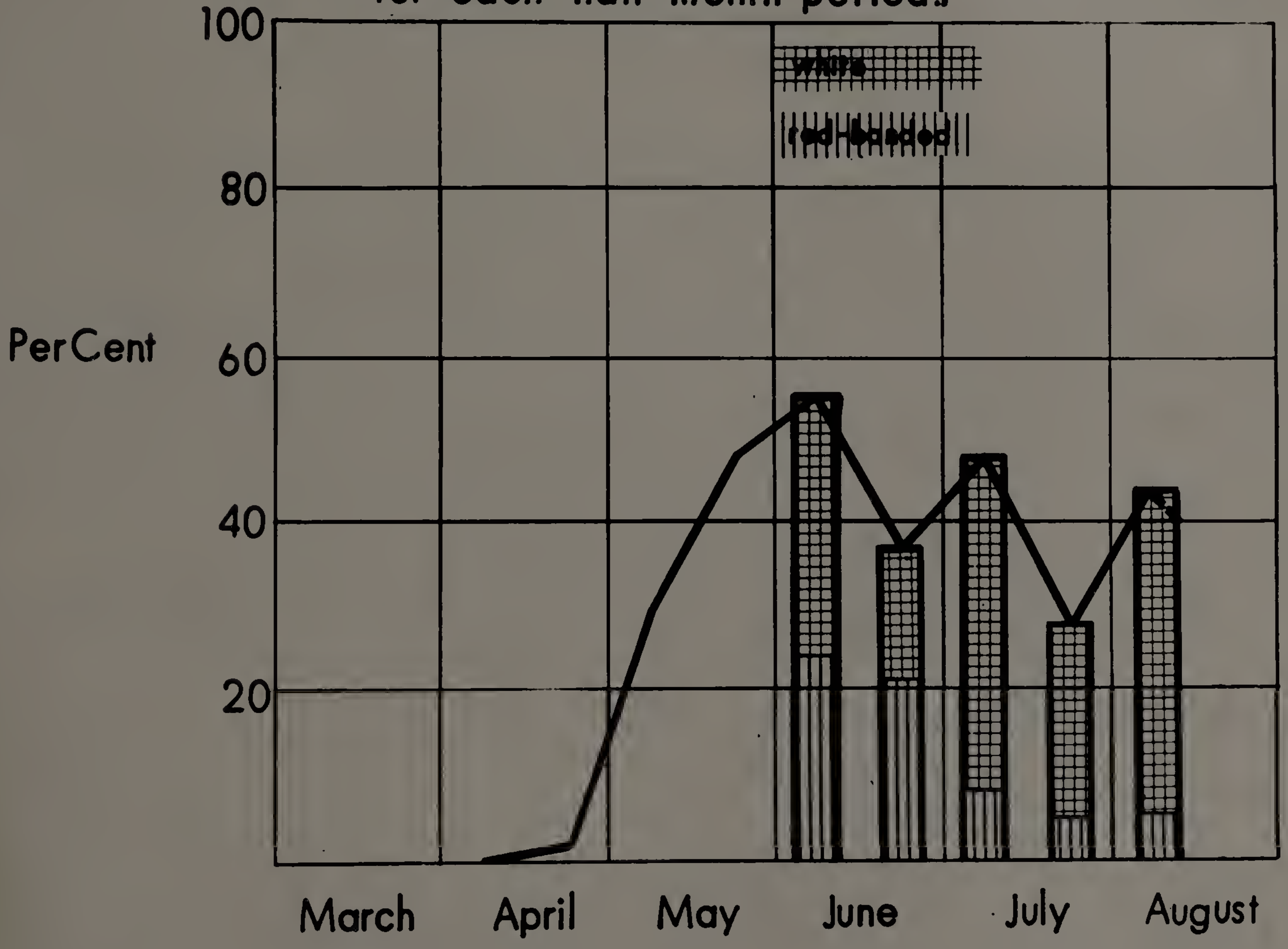
(Based on per cent of S.tuberosum larvae in collections
for each half month period.)



GRAPH 4.

Seasonal larval population fluctuations of red-banded and white S.venustum larvae in Old Forge 1952

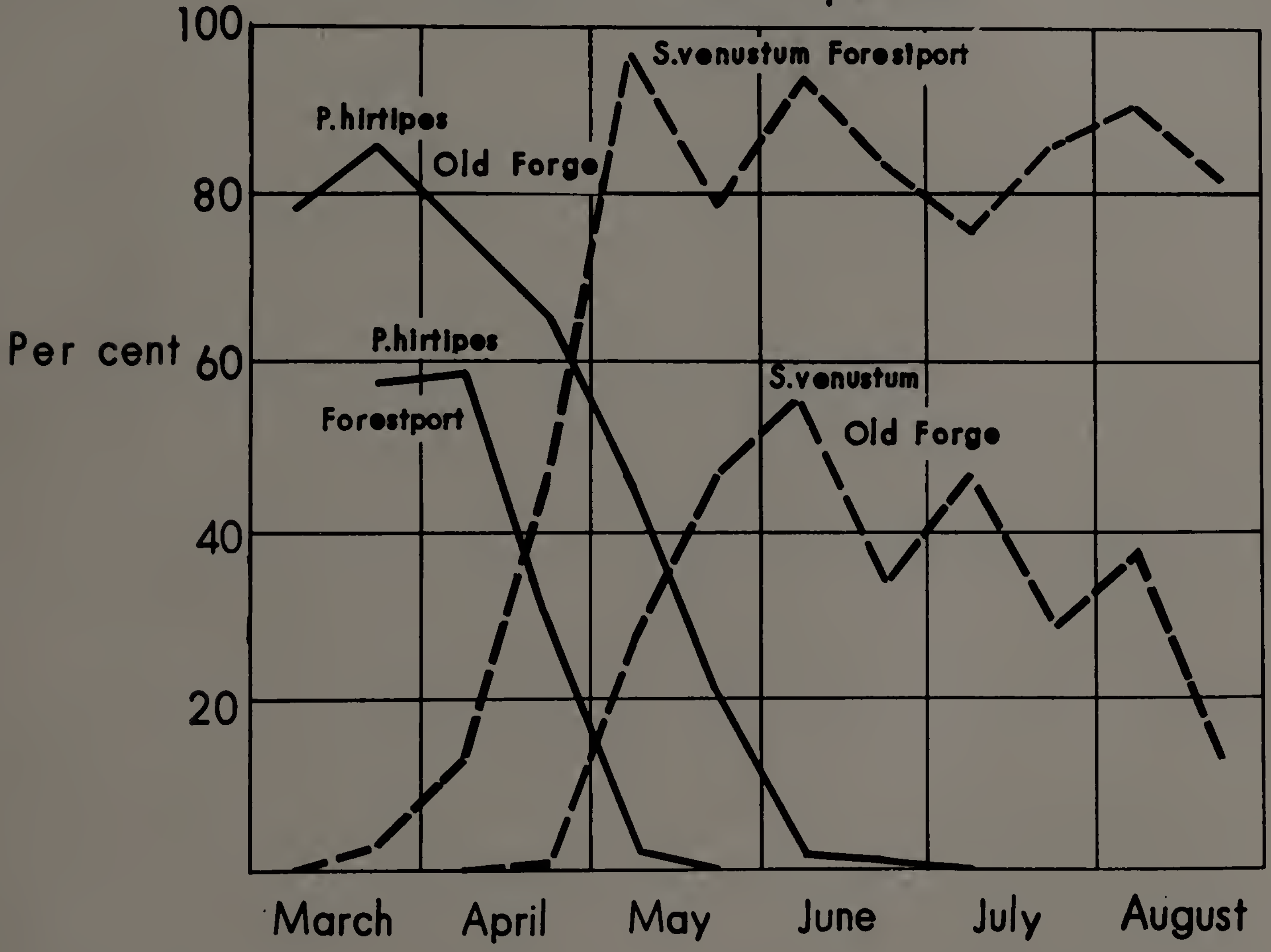
(Based on per cent of larvae of these species in collections for each half month period.)



GRAPH 5.

Seasonal larval population fluctuations of P.hirtipes and S.venustum in Old Forge and Forestport areas compared 1952

(Based on percent of each of these forms in collections for each half month period.)



SECTION III. CONTROL*

ECONOMIC IMPORTANCE OF SIMULIIDAE

Blackflies are important economic pests for several reasons; some species bite and otherwise annoy man, some attack domestic animals, and some are vectors of disease.

Twenty-three species of blackflies have been collected in New York during 1950, 1951, and 1952. Of these species, only 9 have been caught in collections of adults annoying man. *Prosimulium hirtipes* is, by far, the most annoying bloodsucker. *Simulium venustum* and possibly *S. tuberosum* are the next most common biters. (The females of these two species could not be distinguished from each other with certainty.) They are, at times, even more annoying than *P. hirtipes* because of their habit of swarming about the head and crawling into the eyes, ears, nose, and mouth. Other species were caught much less commonly in net collections of adults annoying man. However, in some localities they were definitely annoying. Control measures might be desirable where there is an abundance of one or more of these species. These are *S. parnassum*,

*Tables in each section numbered independently.

S. decorum, *S. jenningsi*, *S. sp.*, *Cnephia mutata*, and *C. sp.*

There is great variation in the response of different individuals to blackfly bites. According to Dr. R. Lindsay, a physician in Old Forge who has had considerable experience in dealing with the effects of their bites, some people are nearly immune while others suffer immoderately from a few bites. In most persons, the bite produces a typical allergic reaction. Around the wound there appears a pruritic urticarial wheal of varying intensity. With additional bites there is an increase in reaction. The whole area may become hot, and edematous. At times the bites may raise large blisters.

Along with these local reactions, there is a general reaction varying in intensity with the number of bites and the sensitivity of the individual. Headache, fever, nausea, and adenitis may occur. This condition is generally of short duration, usually 48 hours or less. It leaves no after-effects except for the glandular enlargement which slowly subsides.

The most important result of blackfly bites is possible secondary infection. Commonly, scratching of the bites produces skin infections varying from a simple pustule to a deep cellulitis. In regions where the flies are abundant, children are frequently seen with a mass of purulent, scabrous lesions of the scalp.

Early writers have stated that blackflies may, at times, cause human deaths (Riley, 1887; Buck, 1888; Webster, 1904). However, none of the later literature mentions deaths of humans due to blackfly bites.

From the foregoing discussion, it can readily be seen that pests such as these, if present in large numbers, could easily have an adverse effect on businesses depending on tourists.

In regions where livestock are of economic importance blackflies cause injury more or less regularly if present even in moderate numbers. This injury may involve loss of milk production, weight loss, abortion, worry, and (in the case of draft animals) loss of work time. At irregular intervals, blackflies become so numerous that they kill many domestic animals. These outbreaks often occur for several years in succession in a given area. According to Forbes (1912), when domestic animals are lightly attacked the condition of the victim is not particularly threatening. The animal apparently then becomes partially immune to later attacks. If heavily attacked, fatigue, failure of the appetite, drooping head, trembling, high fever and rapid pulse may become apparent. Later the pulse becomes feeble and death appears after a few hours. According to Schmidt (1916), animals attacked in large numbers die within one to two hours, while less serious cases are characterized by loss of appetite, abortion, marked depression, and blindness. According to Schoenbauer (1795), the nasal passages and the bronchial tubes and their ramifications may be filled with flies.

The Mississippi valley blackfly, Cnephia pecuarum, was reported "bad," killing numerous animals, in 1861-1864, 1866, 1868, 1872, 1873, 1874, 1881, 1882, 1884, 1885, 1886 (Riley, 1887). Dyar and Shannon (1927) note that C. pecuarum was not bad between the series of years following the Civil War up to 1927. Bradley (1935b) reported that 1927, 1928, 1931, and 1934 were bad blackfly years. In 1931, it was reported that 1000 mules were killed in Arkansas alone due to the activities of this fly.

In the Balkans, the so-called Golubatz fly, Simulium colombacensis, takes a heavy toll of domestic animals. In 1923, 16,474 domestic animals were recorded as killed in certain parts of Roumania (Ciurea and Dinuflescu, 1924). In 1934, a bad blackfly year, about 13,900 domestic animals were killed in Jugoslavia, Bulgaria, and Roumania (Baranov, 1935).

Undetermined species of blackflies killed cattle and severely injured sheep in parts of Germany in 1918, 1919, and 1920 (Rupert, 1920). Simuliidae are also, at times, pests of sheep in Australia (Roberts, 1940).

In Saskatchewan, successive outbreaks of the blackfly *S. arcticum* in 1944, 1945, and 1946 caused heavy livestock losses, killing 600 farm animals in 1946 alone (Rempel and Arnason, 1947).

Simulium griseicolle has been reported killing turkeys in northern Sudan (Garside and Darling, 1951).

Although blackflies are not known to be vectors of any diseases in the Adirondacks, they are important disease vectors in some parts of the world. They are known vectors of filarial and sporozoan diseases and suspected vectors of certain bacterial diseases.

The filarial parasite of man *Onchocerca volvulus* Leuk. is widespread in Africa, occurring along the west coast from Sierra Leone to the Congo Basin and east to southern Sudan, Uganda, Nyassaland, and Kenya (Belding, 1942). Microfilaria of *O. volvulus* were first found in the blackfly *Simulium damnosum* (Blacklock, 1926). In Guatemala, *O. volvulus* was first found parasitizing humans by Robles (1919). It has also been found in southern Mexico (Hoffman, 1930) where it is transmitted by _S._ _callidium_ (descr. as _S._ _mooseri_), _S._ _metallicum_ Bellardi, and _S._ _ochraceum_ Wlk. Another species of _Onchocerca_, _O._ _gutterosa_ Neum., a parasite of cattle in England, is carried by _S._ _ornatum_ Meig. (Steward, 1937).

Several species of the sporozoan _Leucocytozoon_, which is the causative agent of a malaria-like disease of ducks, are carried by blackflies. _L._ _simondi_ Mathis and Leger is transmitted to ducks by _Simulium_ _venustum_ (O'Roke, 1934). _Leucocytozoon_ _smithi_ (Laveran and Lucet) is transmitted to poultry by _S._ _occidentale_ Townsend (Skidmore, 1932). Johnson _et_ _al_. (1937) reported that _S._ _jenningsi_ Mall. is a vector of a species of _Leucocytozoon_ attacking turkeys. Twinn (1933) reported that _S._ _venustum_ is the vector of a _Leucocytozoon_ attacking ducks in eastern Canada. In Minnesota, ducks and turkeys have been found infected with species of _Leucocytozoon_. Three proven vectors of the disease in this area are _S._ _venustum_, _S._ _occidentale_, and _S._ _jenningsi_ (Nicholson and Mickel, 1950).

Parker (1934) demonstrated that tularemia could be experimentally transmitted by Simulium decorum (descr. as S. decorum katmai). De Oliveira, Castro, and Mariano (1947) demonstrated the presence of leprosy bacilli in adults of an undetermined species of Simuliidae.

It would seem highly probable that blackflies may also be purely mechanical vectors of other relatively resistant bacteria such as anthrax bacilli, staphylococci, and streptococci.

DEVELOPMENT OF BLACKFLY CONTROL IN THE TOWN OF WEBB

The first study of the blackfly control problem in the Adirondack region was made in 1929 (Metcalf and Sanderson, 1931; Metcalf, 1932; Metcalf and Sanderson, 1932). It was initiated by Dr. R. D. Glasgow, then State Entomologist, at the request of a large number of Adirondack businessmen. The general conclusion of this study was that little could be done to control blackflies economically with the materials and methods then available.

In the fall of 1947, the Hotel Association of the Town of Webb, after a particularly bad blackfly season, set up a Committee on Blackfly Elimination, which went to Albany to confer with Dr. Glasgow. At that time, Dr. Glasgow felt that with newly developed materials and methods, local control of blackflies would be possible, practical, and financially profitable from the point of view of the inhabitants of the area.

Before large scale control measures could be undertaken it was necessary that legislation permitting these measures be enacted. The Town of Webb Committee on Blackfly Elimination was instrumental in having "An act to amend the public health law in relation to mosquito and insect control," introduced and passed in the state legislature. This bill was vetoed by the governor because of certain ambiguities. In March, 1948, a modified bill with the same title (Bill 2531, Int. 2333) was introduced into the legislature, passed, and signed by the governor. This new law amended the public health law of New York by adding a new section (Section 21-d, Chapter 577) that reads as follows:

"21-d. Mosquito and insect control. "The board of health of a town or village may take all necessary and proper steps for the control of mosquitoes, flies, blackflies, punkies, ticks, and other insects detrimental to health within their jurisdiction which may require community action for their destruction or control.

"2. This act shall take effect immediately."

The Committee, with the advice and active participation of the State Entomologist's office, proceeded to arrange for helicopter fogging, the first step in a comprehensive blackfly control program now five years old. Since then, larval control measures have been adopted which (combined with ground fogging) have proved more effective and less expensive than helicopter fogging. These will be described in some detail on the following pages.

METHODS USED IN ESTIMATING LARVAL BLACKFLY POPULATIONS

Most workers dealing with larval control in field experiments have not made numerical counts. Generally only the degree of infestation (i.e., very heavy, heavy, moderate, light, or nil) and the subsequent reduction presumably due to treatment was noted. This method is probably adequate for most control work since effective control requires nearly complete elimination of blackfly larvae. However, in biological studies more refined methods of estimating larval populations seem to be indicated.

Garnham and McMahon (1947), Prevost (1947), Hocking *et al*. (1949), and Gjullin *et al*. (1949a, 1949b) did not make numerical counts.

More recent workers have attempted to use more objective methods. Goulding and Deonier (1950) made counts of larvae per attachment unit. These units were considered to be individual rocks 3 to 10 inches across, blades of grass 6 inches long, or leaves 2 to 5 inches across. When larvae were very dense the number per square inch or foot was calculated. Gjullin *et al.* (1950) estimated larval populations per rock. Hocking and Richards (1952) counted the number of larvae per rock, twig, or square inch depending on where and in what numbers larvae were found.

In the Adirondacks, both quantitative and qualitative counts were made in each stream examined. Since the work being carried out included both biology and control studies it was felt that numerical data would be easier to analyze than notes on the degree of infestation. Methods developed for making counts were essentially similar to those of Goulding and Deonier (1950) and Hocking and Richards (1952). The number of larvae found on 10 attachment units was recorded. An attachment unit was defined as a stone 3 to 10 inches in diameter, a single blade of grass, a twig, or a leaf. Experience indicated that the number of larvae on each of these kinds of substrata were comparable. Only units collected from locations that experience had shown to be "good blackfly spots" in the streams were sampled. When populations were unusually large, counts of those attached in what appeared to be representative areas of one square inch were made. In studying the effectiveness of blackfly control operations, samples of the numbers and kinds of organisms coming downstream during a period of 5 minutes before and at intervals after spraying were taken. These were called "5 minute samples." They were made by placing the square foot bottom sampler in a swift part of the stream for 5 minutes, thus catching a representative sample of the organisms being carried downstream during this period. The method was essentially the same as that used by Hoffman and Surber (1945).

HAND APPLICATION OF LARVICIDES

LITERATURE REVIEW

Perhaps the earliest reported attempts to control blackflies experimentally with larvicides were made in 1886. Riley (1887) attempted to reduce blackfly larval populations by stream treatments using freshly burned lime, emulsions of kerosene, powdered pyrethrum, carbon bisulphide, powdered cocculus indicus, and tobacco soap. He reported some kill of larvae but his experiments indicated that it is nearly, if not quite, impossible to reduce blackfly larval populations by killing them in streams in the early spring because of the large amounts of toxicants required. He suggested that treatments might be effective when the water is low. He also suggested removing all logs, sticks, and leaves to reduce larval blackfly populations.

Weed (1904) reported that blackfly larvae were eliminated from short sections of streams treated with either heavy, non-miscible or light "soluble" Phinotas oil.* He also reported that blackfly larvae could be killed by brushing them from the substrata with stiff brooms. Sanderson (1910) also reported that Phinotas oil was an effective larvicide. Reeves (1910) suggested the use of stiff brooms to brush larvae from their attachment points as a control measure.

In 1926, O'Kane found that the heavy,

---

*Further specifications not given: it was supplied by Phinotal Oil Co., New York, N. Y.

insoluble Phinotas oil was less effective than the light soluble oil. In the first attempt to give a quantitative estimate of the amount of larvicide required for blackfly elimination, he reported that an amount sufficient to give the water a solid-white appearance for 5 minutes was effective in eliminating blackfly larvae for short distances.

Rubtzov et al. (1934) were perhaps the first workers to report exact dosages used in stream treatments. They used 80 different emulsions which were tested by dipping larvae, enclosed in glass tubes with muslin covered ends, for varying periods into larvicide. The tubes were then placed in a stream and the dead larvae counted in 24 hours. In these field tests xylol was the best larvicide tested, killing all larvae at a dosage of 1 part to 200 parts water dipped for 3 - 3.5 minutes. Kerosene required a concentration of 1:100 when larvae were dipped for 3 minutes. A sharp drop in toxicity of kerosene was noted at 0 degrees C. and a sharp rise above

15 degrees C. In a stream treatment test, kerosene was effective at 1:100 but was quickly absorbed by vegetation. It was noted that heavy oils were less effective than light oils. Laboratory tests of nicotine, calcium arsenite, paris green, sodium fluoride, and sodium fluosilicate were also made. Paris green killed all larvae at a concentration of 1:1000 for 5 minutes.

In the foregoing experiments the use of oils, non-organic insecticides, and mechanical control measures were all demonstrated to be effective in reducing blackfly larval populations. However, no large scale control programs were initiated, presumably because of the expense, difficulties, and injury to stream fauna inherent in any of the above-mentioned methods.

The outstanding pioneer work of Fairchild and Barreda (1945) in Guatemala was undoubtedly responsible for the beginning of modern blackfly control work. They found that dosages of as little as 0.1 ppm of DDT emulsion applied over a 60-minute period would effectively destroy blackfly larvae for long distances (up to 10 kilometers).

They experimented with the use of plaster of Paris blocks, sponge gourds, and sacks of sawdust impregnated with larvicides, then placed in streams to gradually release the insecticide. Since that time, much experimental work has been carried out using various insecticides and methods of application in an effort to find easy and inexpensive methods of reducing blackfly larval populations.

Garnham and McMahon (1947) in Kenya made an experimental test using 5% DDT in kerosene with cutting oil. Dripped into a stream over a 35-minute period it eliminated blackfly larvae. The calculated dosage was 0.2 ppm for 35 minutes. When checked two weeks later, blackfly larvae were eliminated below the treatment point and only dead pupae were found. Larvae and pupae were abundant at this time above the treatment point. Encouraged by the success of this experiment, the authors experimentally treated all streams in an area of 65 square miles to eradicate S. neavei, a vector of onchocerciasis in the area. The nearest breeding ground outside of the control area was 6 miles away across a range of hills and in another watershed. Fifteen per cent DDT emulsifiable concentrate and 20% para para DDT in toluene and soap and other DDT formulations were used in these treatments. The larvicide was applied with drip cans. Dosages varied from 1.3 to 34.6 ppm for 30 minutes (with some "token" treatments). The treatments were repeated 10 times at 10-day intervals and then every two weeks and finally every month for an over-all period of five months. Intensive collections were made for six months after the final treatment. No S. neavei adults were found inside of the control area during this period.

Prevost (1947) in Canada reported that streams treated with DDT-impregnated blocks at concentrations of 0.1-0.005 ppm for 48 hours were completely freed of larvae.

Hocking et al. (1949) in Canada found that DDT in fuel oil, wettable powder suspension, or as an emulsion gave good control with dosages of 0.1 ppm for 15 minutes when poured, dropped, or sprayed into a stream. Gamma BHC gave 50% control when used at the rate of 0.1 ppm for 15 minutes and a high percentage of control at 0.2 ppm for 15 minutes. Fuel oil alone was ineffective at 1.7 ppm for 15 minutes. Chlordane and toxaphene were poor larvicides at the concentrations tested. *S. venustum* larvae were in the majority during the testing period.

Gjullin *et al.* (1949a) in Alaska reported that DDT in acetone suspension caused complete detachment for 150 yards or more when applied at the rate of 0.3 ppm for 15 minutes. DDT in fuel oil was effective when applied at the rate of 0.4 ppm for 15 minutes, DDT in kerosene at 0.3 ppm for 15 minutes, and DDT emulsion at 0.7 ppm for 15 minutes. Application was made using gallon aspirator bottles with a calibrated rate of discharge. Toxaphene and gamma BHC were less effective than DDT. Chlordane was not effective at 0.5 ppm for 15 minutes. Dimethyl phthalate, n-butyl mesityl oxide oxalate, 2-ethyl-1, 3 hexanediol, mono- and dimethyl-naphthenes, fuel oil, and kerosene were ineffective at the concentrations tested.

Travis (1949) in Alaska reported that DDT, TDE, and methoxychlor were about equally effective as blackfly larvicides. The most practical method of treatment was considered to be DDT in fuel oil applied at the rate of 0.4 ppm. The time of application was not noted. "Parathion was more effective than other materials but not sufficiently superior to warrant its use in streams where fish are present." BHC, chlordane, and toxaphene were found to be inferior to DDT as blackfly larvicides.

Kindler and Regan (1949) in New Hampshire treated 200-foot stream sections experimentally with larvicides. They found that DDT emulsion at 0.05 ppm, TDE emulsion at 0.2 ppm, and 12% gamma BHC at 0.2 ppm all applied over a 10-minute period were good larvicides. Pyrethrins, chlordane, and acetone alone were very poor larvicides. Blackfly larvae were nearly all eliminated from 5 miles of stream treated at mile intervals with 0.2 ppm of TDE emulsion for 10 minutes. Larvae used in these experiments were _P. hirtipes_ and _S. venustum_.

Curtis (1949) reported effective blackfly larval control in British Columbia using 10% DDT emulsifiable concentrate at 0.5 ppm (duration of treatment and effective distance not noted in review).

Hocking (1950) in Canada reported that 15% parathion wettable powder at 0.2 ppm for 15 minutes gave good control but gave no control at 0.033 ppm for 15 minutes. Ten per cent DDT in fuel oil gave good control at 0.1 and 0.07 ppm for 15 minutes. Dieldrin at 0.2 ppm for 15 minutes gave excellent results against P. hirtipes. When used as a wettable powder poor results were reported. Aldrin was a poor larvicide used as an emulsifiable concentrate, wettable powder, or in fuel oil. Methoxychlor used as a powder gave good control. Trichlorobenzene gave poor control. Gamma BHC was poor when used as an emulsion but gave good control when used as a wettable powder at the rate of 0.2 ppm for 15 minutes or in fuel oil at the rate of 0.1 ppm for 15 minutes. The larvicide was introduced into the stream by a variety of methods in these tests. It was dropped in with a medicine dropper, poured in with a graduate, or dribbled in with a special dispenser. Species involved in these tests were *P. hirtipes*, *S. arcticum*, *S. tuberosum*, *S. latipes*, *P. onychodactylum*, *P. sp. j.*, *Cnephia sp. g.*, *Cnephia sp. d.*, and *P. decemarticulatum*. Quoting an unpublished report of Twinn, Hocking reported that 5% DDT in kerosene applied at the rate of 0.14 ppm for 10 minutes gave good control in a large river for 20 miles below the treatment point. Many larvae were present at the time of treatment and pupae of *S. arcticum*, *S. venustum*, and probably *S. pugetense* and *S. decorum* were collected.

Twinn (1952) reported that the Saskatchewan River was almost entirely cleared of *S. arcticum* larvae for a distance of 117 miles when treated with DDT in fuel oil at the rate of 0.1 ppm for 15 minutes.

Hocking and Richards (1952) reported that 42 streams in Labrador were treated by hand from the ground and 7 from boats. The desired dosage in these tests was 0.1 ppm DDT (in fuel oil and auxiliary solvent) applied to the stream over a 15-minute period. The insecticide was dribbled directly into the streams in most cases. Two streams were experimentally treated with sand-filled muslin bags containing absorbed DDT. No larvae were found in the treated streams checked after treatment. However, the number of streams checked was not noted. Nineteen described and 6 undescribed species of blackflies were collected in the treatment area.

There is some disagreement in the above papers concerning minimal dosages, best method of application, best form of the larvicide, and the relative toxicity of the larvicides to blackflies. However, there is a general agreement on some of the broader aspects of larval control. These points are as follows:

1. DDT proved to be the best blackfly larvicide of those tested. It should be used in oil solution or as an emulsifiable concentrate at dosages between 0.1 and 0.4 ppm for 15 minutes. When blocks are used, a dosage of 0.005 ppm or less for 48 hours was effective (see page 195).

2. Larvicides are effective for longer distances at relatively lower concentrations in large rivers than in small streams.

3. Less work was done using lindane, TDE, dieldrin, and parathion but available data indicate that these are effective blackfly larvicides.

4. Limited field tests of chlordane, toxaphene, dimethyl phthalate, n-butyl-mesityl oxide oxalate, 2-ethyl-1,3-hexandiol, mono- and dimethyl-naphthenes, aldrin, trichlorobenzene, pyrethrins, acetone, fuel oil, kerosene, nicotine, calcium arsenite, paris green, sodium fluoride, and sodium fluosilicate indicate that these are poor blackfly larvicides (as applied) when compared to those previously mentioned.

EXPERIMENTAL WORK IN THE ADIRONDACKS

It seems probable, judging from the conflicting results reported in the literature and experienced in the Adirondack work, that there are several important factors in addition to larvicide and the amount applied that have a bearing on the effectiveness of stream treatments. Large streams and rivers apparently require proportionately less insecticide than smaller streams. Furthermore, the effective distance is greater in these large streams and rivers than in smaller ones. This may be because larger streams usually have proportionately less area of contact with the stream bed and the larvicide is not "adsorbed" as quickly. It is also generally true that larger streams have fewer pools and beaver dams to impede flow.*

Another possible factor of some importance is the age of the larvae since there is some evidence that younger larvae are less resistant than older larvae both in the Adirondack work and in the literature (Gjullin, *et al*. 1950; Rubtzov and Vlasov, 1934; and Kindler and Regan, 1949).

Rubtzov and Vlasov (1934) reported that a rise in temperature increased the toxicity of various emulsions; kerosene showed a sharp drop in toxicity at about 32° F. and a sharp rise above

---

*The hindrance of water flow due to these pools and dams and to filtration through leaves or sand has been called *impedition* in this paper.

59° F. Results of stream treatments by Gjullin et al. (1950) may have been influenced by low water temperatures, at least winter and early spring applications of larvicide were less successful than summer treatments. Results in the Adirondacks are somewhat contradictory. Travis (personal communication) reported poor larval control when DDT was applied to a stream by hand sprayer during the winter. However, Cascade Brook was treated (see p. 163) on March 14, 1952 when the water temperature was 32° F. with excellent results.

Finally there is a possibility of error in evaluating treatments due to the natural decline in larval populations. This decline is, at times, quite rapid. This is especially noticeable during the early spring emergence of overwintering larvae. Not only is it essential to make counts both above and below the treatment point, but the biology of the species being controlled must also be known. If, as often happens, the treatment is made just below a lake outlet the species above the treatment point may be different from those below the treatment point and the normal seasonal declines in larval populations might occur at different times.

In the following section, streams treated in the Adirondacks will be described along with larvicide used, method of treatment, dosage, species present in the larval stage at the time of treatment, effectiveness of treatment, time required for "repopulation" with blackfly larvae and species "repopulating" the stream. Following this a brief summary of the treatments and effectiveness will be given in tabular form.

The dosage of larvicide in experimental tests was calculated in the following way. The width and depth of a stream were measured. In the area these measurements were made the rate of flow was determined by finding the time necessary for a block of wood to flow 10 feet. The average figure for three trials was used. The average rate of flow was considered to be two-thirds of the maximum rate (Hocking _et al._, 1949). The number of ounces of water flowing by the treatment point during the period of application was then compared to the number of ounces of larvicide applied during that time. The figures thus derived were then standardized in terms of parts of insecticide per million parts of water (ppm).

Wheeler Creek flows into 7th Lake, crossing routes 28 and 365 about 4 miles north of Inlet, N. Y. It is a long, relatively permanent stream averaging about 11 feet in width, 1.25 feet in depth, and flows at the rate of about 2.5 feet per second in the spring. The bottom is made up largely of sand and gravel with numerous small and large stones. There is little vegetation in the stream bed although long grass trails in the water in some places. During the summer, the amount of water flowing in it decreases to a few inches in depth, a few feet in width, and the rate of flow decreases to well under 1 f.p.s. For the most part, the stream flows through deep forest with occasional large grassy clearings. Prosimulium hirtipes, Cnephia mutata, Simulium venustum, S. tuberosum, S. gouldingi, and S. aureum larvae have been collected from this stream.

Wheeler Creek was treated on May 7, 1950 with one-half block DDT-impregnated plaster of Paris.* The dosage was calculated to be approximately 0.0005 parts per million of emulsifiable DDT released during a period of approximately 24 hours. The block was placed in swift running water about 1 mile above routes 28 and 365. At the time of treatment, _P_. _hirtipes_ and _C_. _mutata_ larvae were present in the stream. The larval population was fairly heavy and quite uniform, ranging from 100 to 200 per 10 unit. Larvae were found only rarely below the treatment point for a checked distance of 1 mile at the end of the treatment period. There was no decrease in the number of larvae found above the treatment point. Larvae were found only rarely below the treatment point until 52 days after treatment when some small _S_. _venustum_ and _S_. _tuberosum_ larvae were found. When rechecked 60 days after treatment,

---

*Each DDT-impregnated plaster of Paris block contained 1.8 ounces of DDT.

the number of larvae present had increased to above pretreatment population levels. It should be noted that this stream was treated before the emergence of S. venustum and S. tuberosum, yet larvae of this species were not found below the treatment point until June 28 but were found above the treatment point on May 22. Since the stream appears to be more or less uniform along the treated and untreated area and since S. venustum and S. tuberosum larvae appeared at about the same time above and below the treatment point in 1951 and 1952, it seems reasonable to assume that DDT-impregnated blocks used in the manner and at the dosages described above have ocicidal or residual action.

In 1951, Wheeler Creek was not treated until June 7 when S. venustum, S. tuberosum, and S. gouldingi larvae were present in the stream. At the time of treatment the flow was 1.4 f.p.s., the width 3.5 feet, and the depth .25 foot in the arc measured. A block of TDE-impregnated plaster of Paris* was used in the treatment. The

---

*Each TDE-impregnated plaster of Paris block contained 1.1 ounce of TDE.

calculated dosage was 0.008 ppm for 48 hours. Before treatment, blackfly larvae were numerous all along the observed portion of the stream (150 - 200 per 10 units). Two days after treatment, the larval population above the block and three-quarters of a mile below the block were approximately the same. Blackfly larvae were, however, rare for 0.5 mile below the treatment point. Beyond 0.5 mile there was a rapid increase in the number of larvae. The population three-quarters of a mile below the treatment point was 150 per 10 units. Larval populations in the affected portion of the stream remained lower than above the block site until 42 days after treatment when 400 larvae per 10 units were found in all portions of the stream examined.

In 1952, Wheeler Creek was treated with 7 ounces of 20% emulsifiable lindane applied by hand-sprayer at the rate of 0.33 ppm for 20 minutes. *S. venustum*, *S. tuberosum*, *S. gouldingi*, and a few *P. hirtipes* larvae were collected from the stream on June 5, the day treated. The flow was 0.5 f.p.s., the width 7 feet, and the depth

1.5 feet at the spot checked. The average population from the culvert 1 mile below the treatment point to above the treatment point was 100 per 10 units. The stream was checked 5 days after treatment and no reduction was noted even a short distance below the treatment point. Because of this unexpected failure to reduce larval populations, a second treatment was made on June 18 using 7.5 ounces of 20% DDT in oil solution. Flow was 0.67 f.p.s., the width 6 feet and the depth 0.58 feet at the time of treatment. _S_. _venustum_, _S_. _tuberosum_, and _S_. _gouldingi_ larvae were present. A calculated dosage of 0.80 ppm was applied over a 20-minute period. There were 100 to 150 larvae per 10 units above the treatment point and 20 to 30 1 mile down. The stream was checked 2 days later. There were no larvae for 0.2 mile below the treatment point but no reduction beyond that point.

The relative failure of experimental treatments in 1951 and 1952, even with heavy dosages of larvicide, can probably be ascribed to late treatments when the stream was relatively low. As the stream becomes lower the amount of contact area (i.e., water with stream bed) becomes proportionately greater hence adsorption of the insecticide is probably more rapid. Furthermore, the impedition of flow due to pools, beaver dams, and areas of slow water becomes more pronounced.

High Rock Pond Outlet is a long permanent stream crossing route 28 and 365 about 6.5 miles north of Inlet, N. Y. It flows into the upper end of 7th Lake. In the spring it averages about 17 feet in width, 0.75 feet in depth, and has a flow of 2.5 f.p.s. The bottom is made up of fine sand and mud near 7th Lake; further upstream the bottom is coarse sand with small and large stones. There is relatively little aquatic vegetation in the stream although the rocks become covered with "slime" during part of the summer. This stream flows for the most part through deep woods although the lower end is somewhat marshy. Species of blackflies found in this stream include *P. hirtipes*, *C. mutata*, *S. venustum*, *S. tuberosum*, *S. gouldingi*, and *S. parnassum*.

High Rock Pond Outlet was treated on May 11, 1950 with 1 block of DDT-impregnated plaster of Paris. Dosage was calculated to be about 0.001 ppm for 24 hours. Before treatment larval blackfly populations averaged about 60 per 10 units all along the length of the stream checked. No larvae were found below the treatment point (except for a short distance immediately below) until 48 days after treatment for a checked distance of 1.25 mile. Species present at the time of treatment were P. hirtipes and C. mutata. Larval populations above the treatment point increased during May to a maximum of 1000 per 10 units on June 15. Thereafter the larval populations fluctuated from 500 per 10 units to rare (that is, 1 or less per 10 units) until mid-August when observations were discontinued.

High Rock Pond Outlet was treated again in 1951 with 1 block of TDE-impregnated plaster of Paris on May 24. At the time of treatment the stream was 11 feet wide, 0.25 foot deep and was flowing at the rate of 1.25 f.p.s. at the point checked. The calculated dosage was 0.003 ppm for 48 hours. Before treatment there were 50 larvae per 10 attachment units below the treatment point and about 150 per 10 units above. Species present in the larval stage at the time of treatment were P. hirtipes and S. venustum. After treatment, there was no reduction but rather a small increase both 1 mile below and above the block site. Larvae were rare for one-eighth mile below the treatment point but gradually increased in numbers to 20-30 per 10 attachment units about three-quarters mile below the treatment point. Larval populations were similar above and below the treatment point 40 days after treatment.

In 1952, High Rock Pond Outlet was treated on June 18 when the flow was 1.5 f.p.s., the width 3.5 feet, and the depth 0.5 feet. Twelve ounces of 24% emulsifiable dieldrin were poured into the stream over a 20-minute period to give a calculated dosage of 1.36 ppm for 20 minutes. Species present at the time of treatment were S. venustum, S. tuberosum, and a few P. hirtipes. Larval populations before treatment were fairly uniform at about 500 per 10 units except in areas where slimy rocks were found. No larvae were found below the treatment point for a checked distance of 1 mile 2 days after treatment. There was no reduction in larval populations above the treatment point. There was no "repopulation" below the treatment point for the rest of the summer (last checked August 13).

As was the case in Wheeler Creek stream treatment late in the season, using TDE-impregnated block had little effect on blackfly larvae. This is probably due to increased area of contact between the water and the stream bottom (proportionately) and to increased impedition of flow. A heavy dosage of dieldrin (1.36 ppm for 20 minutes) however, did eliminate larvae from the stream in 1952 even though treatment was made when the water was relatively low.

Cascade Brook flows from Cascade Lake into Moss Lake in the Big Moose area of the Town of Webb. It crosses the Big Moose Road about 1.8 miles from Eagle Bay. The upper half of the stream is obstructed by many old and new beaver dams. There are many areas of slow or still water here. The lower portion has relatively uninterrupted flow.

The bottom along the upper portion is mainly mud and fine sand while along the lower portion it is coarse sand with numerous rocks in some areas. Trailing grass was fairly abundant in some sections. Species found in this stream include P. hirtipes, C. mutata, S. venustum, and S. tuberosum. At the time of treatment, March 14, 1952, there was snow on the ground and ice along the edges of the stream. The water temperature was 32° F. P. hirtipes was the only species collected at the time of treatment. The flow was 1.1 f.p.s., the width 9 feet, and the depth 0.67 foot. Six ounces of 25% DDT emulsifiable concentrate were applied with a hand sprayer over a 20-minute period. The calculated dosage was 0.28 ppm for 20 minutes. Before treatment, the larval population was fairly heavy and uniform, about 500 per 10 units along the lower half of the stream. Treatment was applied 1 mile above Moss Lake. Three days after treatment no larvae were found below the treatment point for a checked distance of 1 mile. The population of blackfly larvae above the treatment point remained constant. There was no repopulation below the treatment point until 37 days after treatment when small S. venustum larvae were found.

Cascade Brook was treated again on June 3, 1952 when 6 ounces of 20% lindane emulsifiable concentrate were applied with a hand sprayer. At the time of treatment, the flow was 1.4 f.p.s., the width 11 feet, and the depth 0.67 foot. The calculated dosage was 0.15 ppm for 20 minutes. At the time of treatment, larval populations were spotty, averaging about 20 per 10 units both above and below the treatment point. Species present in the larval stage at the time of treatment were S. venustum, S. tuberosum, and P. hirtipes, (the latter two being rare). Two days later no black-fly larvae were found below the treatment point for a checked distance of one-half mile. There was no reduction above the treatment point. Repopulation with S. tuberosum and a few S. venustum was noted 6 days after treatment.

Cascade Brook is an example of a stream with very little impedition (i.e., pools, dams, or areas of still water) in the treated portion. It is also a stream that does not become low during the summer. Accordingly it would be expected that relatively low dosages would be effective even when the treatment is applied fairly late in the season. The data summarized above indicate that this is the case.

Salmon River crosses routes 10 and 28N a few miles north of Blue Mt. Lake, N. Y. The stream has a coarse sand bottom with little vegetation. Many large stones are present. There are several pools at the lower end of the checked portion of the stream. Species of blackflies collected from this stream include *P. hirtipes*, *S. venustum*, *S. tuberosum* and *S. aureum*. On August 15, 1951, this stream was treated using 3.7 ounces of 10% DDT in oil solution. The rate of flow was 1.7 f.p.s., the width 20 feet, and the depth 0.5 foot. Larvae were numerous, averaging 500 per 10 units, along the observed section of the stream. Species present at the time of treatment were *S. venustum* and *S. tuberosum*. The calculated dosage was 0.03 ppm for 20 minutes. Two days after treatment the stream had increased about 6 inches in depth due to heavy rains. Examination was difficult but no larvae could be found except immediately below the treatment point. Thirteen days after treatment there were still about 500 per 10 units above the treatment point. Below the treatment point larvae were rare, gradually increasing to 50 per 10 units one-half mile downstream.

Salmon River was treated again on July 17, 1952 with 10 ounces of 20% emulsifiable lindane poured from a graduate over a 20-minute period. At the time of treatment, the flow was 1.25 f.p.s., the width 24 feet, and the depth 0.83 feet. The calculated dosage was 0.1 ppm for 20 minutes. Only _S_. _venustum_ and _S_. _tuberosum_ larvae were found in the stream at the time of treatment. Before treatment larval populations averaged 100-150 per 10 units both above and below the treatment point. The larval population below the treatment point was reduced to rare for a checked distance of one-half mile after treatment. There was apparently some normal reduction in blackfly larval populations above the treatment point to 50 per 10 units 2 days after treatment. When rechecked 14 days later after treatment, the population both above and below the treatment point was 500 per 10 units.

A second treatment was made on August 4, 1952 using 1.6 ounces of DDT in 50% dust (in talc) applied over a period of 20 minutes. At this time, the flow was 1.25 f.p.s., the width 15 feet, and the depth 0.67 foot. The calculated dosage was 0.16 ppm for 20 minutes. The larval population was very heavy and uniform both above and below the treatment point at 1000 per 10 units. Species present in the larval stage were _S. tuberosum_ and a few _S. venustum_. Two days after treatment, no larvae were found below the treatment point until below the first large pool (about 0.4 mile below treatment point). Below the pool several rocks had 100 larvae each with an average population of 200 per 10 units. By August 25, the population below the treatment point had reached 500 per 10 units (_S. venustum_ and _S. tuberosum_). Above the treatment point there was some apparent natural decline although there were still about 300 per 10 units 2 days after treatment.

Salmon River is another example of a large stream with relatively little impedition or decline in the volume of flow during the summer. Accordingly we find that low dosage of the insecticides used were quite effective.

Bear Brook is located between Raquette Lake and Blue Mt. Lake, N. Y. It crosses routes 28 and 365 north of Raquette Lake flowing into the Marion River near Utowana Lake about 7 miles from Blue Mt. Lake. The stream has a coarse sand and pebble bottom with numerous large stones. Species found in this stream include P. hirtipes, C. mutata, S. venustum, S. tuberosum, and S. parnassum. It was treated on July 22, 1952 with 10 ounces of 25% emulsifiable TDE. At the time of treatment the flow was 2 f.p.s., the width 6 feet, and the depth 0.75 foot. The calculated dosage was 0.35 ppm for 20 minutes. At the time of treatment, the larval population was made up of S. tuberosum and S. venustum and was fairly uniform at 200 per 10 units. Treatment was applied by pouring the larvicide from a graduate into turbulent water one-half mile above the road over a 20-minute period. Larval populations were reduced to very rare (that is, only an occasional larva found) for a checked distance of three-quarters of a mile below the treatment point. There was no noticeable reduction above the treatment point. "Repopulation" with small S. tuberosum larvae was noted 34 days after treatment. At that time the population of blackfly larvae was fairly uniform at 150 per 10 units both above and below the treatment point.

Here is another stream with relatively large volume of flow and little impedition. Probably a smaller dosage would have been equally effective.

Aedes Brook is located on the Moose River Fire Trail about 3.5 miles from Big Otter Lake. The stream is about 2 feet wide and 0.17 feet deep at the culvert under the fire trail road in June. The flow is about 1.33 f.p.s. The bottom is made up of coarse sand, small stones, and a few larger stones. There are numerous pools with leaves and other decaying organic matter on the bottom. Water flows from some of these pools through debris and sand which probably exert a filtering action. This stream flows down a steep grade for most of its length although the grade becomes much less steep near its entrance into South Inlet. In 1950, it was treated May 27 with one-third block of DDT-impregnated plaster of Paris. At this time the stream was 5 feet wide, 0.33 feet deep, and was flowing at the rate of 2.5 f.p.s. The calculated dosage was 0.003 ppm for 24 hours. Species found in this stream include *P. hirtipes*, *C. mutata*, *S. venustum*, *S. tuberosum*, *S. gouldingi*, *S. aureum*, and *S. parnassum*. Species present at the time of treatment were *P. hirtipes*, *C. mutatum*, and *S. venustum*. Before treatment larval populations averaged 60 per 10 units. Larvae were eliminated for a distance of one-half mile below the treatment point. Beyond this point, the effect of the treatment diminished from 100% effective to non-effective in about 100 yards. The relatively poor results are presumed to be due to the pools, dams, still water, and the relatively large amount of contact area per unit volume of water. In the section of the stream where larvae were eliminated no repopulation was noted on June 27, 1950, the last date checked.

In 1952, Aedes Brook was treated June 24 with 2 ounces of 20% DDT solution applied with a hand sprayer over a 20-minute period. The calculated dosage, 1.22 ppm for 20 minutes reduced larval populations of S. venustum, S. tuberosum, S. parnassum, and S. aureum from 300 per 10 units to 0 for one-half mile. There was "great reduction" for 200 feet more and no noticeable reduction beyond that point.

In spite of heavy treatments applied to this stream the larvicide was only effective for one-half mile. This is apparently another example of impeded flow and large contact area.

Second Okara Outlet flows from Second Okara Lake into the Middle Branch Moose River near Minehaha crossing routes 28 and 365 about 4 miles south of Thendara, N. Y. It varies greatly in width, depth, and rate of flow along its length. In the spring it averages about 8 feet in width, 0.42 feet in depth, and has a flow of about 2 f.p.s. The bottom is made up of fine and coarse sand with areas of small and large rocks. There are some beaver dams and several stretches of still water. In these areas the bottom is muddy. Species of blackflies collected from this stream include P. hirtipes, C. mutata, S. vittatum, S. venustum, S. tuberosum, and S. decorum. This stream was treated November 22, 1951 with 2.6 ounces of 20% DDT in oil solution. Application was made just before the outlet of Second Okara Lake using a hand sprayer. The calculated dosage was 0.1 ppm for 20 minutes. A spot check one-half mile below the treatment point before treatment indicated a larval population of about 350 per 10 units. Seven days after treatment the larval population one-half mile below the treatment point was 100 plus per 10 units (observed by D.L.C.). Blackfly larvae present at the time of treatment were P. hirtipes, C. mutata, and a few S. vittatum.

A second treatment was made in this stream on March 26, 1952. Six ounces of 25% emulsifiable DDT were applied over a 20-minute period using a hand sprayer. Species present at the time of treatment were P. hirtipes, C. mutata, and S. vittatum. The calculated dosage was 0.31 ppm for 20 minutes. Larval populations before treatment were not uniform in the spots checked. Just below the dam 400 per 10 units were noted while 1 mile downstream about 100 per 10 units were counted. One week after treatment, no larvae were found at check points one-half mile, 1 mile, and 2 miles below the dam. Larval populations just below the dam, above the treatment point, were 100 per 10 units. Some pupation was noted at this time.

This stream has a great deal of impedition to flow during the summer but treatment was made in March during the spring break-up when water was high and impedition low. No larvae were found in this stream below the treatment point until 78 days after treatment when small *S. venustum* larvae were found.

Townsend Pond Inlet is a small temporary stream in the Big Moose area. It emerges as a small trickle about one-third of a mile from Townsend Pond. During the spring it is about 2 feet wide, 0.5 foot deep, and has a flow of 1.2 f.p.s. The nature of the stream bottom varies along its length. The upper portion is shallow and rocky with alternate small pools and falls. The bottom here is composed of leaves and other decaying vegetation. Further downstream, the bottom becomes sandy with many small stones. Near Townsend Pond it becomes narrower and deeper and has a fine sand bottom. Only _P_. _hirtipes_ and _C_. _mutata_ larvae have been collected from this stream. The only species collected at the time of treatment was _P_. _hirtipes_. Larvae were found on grass trailing in the water, on stones, leaves and twigs. The stream was treated on April 29, 1950 with 1 block of DDT-impregnated plaster of Paris for a calculated dosage of 0.01 ppm for 48 hours. Before treatment the larval population both above and below the treatment point was about 60 per 10 units. Larvae were not found below the treatment point for the rest of the season or in 1951 and 1952, although larvae were present above the treatment point. However, this stream diminished in size early in the summer (last part of May) and existed only as a series of small, discontinuous pools by June 20, 1950.

Nursip _Brook_ is another small, temporary stream about one-half mile long. The bottom consists, for the most part, of sand with some stones. There are several pools along its course where the bottom is made up of leaves and mud. The stream crosses routes 28 and 365 between Wheeler Creek and High Rock Pond Outlet. At the sampling point the flow was 2.5 f.p.s., the width 4 feet, and the depth 0.5 foot. It is somewhat narrower and deeper than this on the average. This stream was treated with one-third block DDT-impregnated plaster of Paris on May 11, 1950. The calculated dosage was 0.002 ppm for 24 hours. Since the treatment was made upstream from the road about one-half mile at a point beyond which conditions were unsuitable for the larvae, no checks could be made above the point of treatment. At the time of treatment only _P. hirtipes_ larvae were collected from the stream. Larval populations below the treatment point were 50 per 10 units before treatment and 0 at the end of the treatment period. No larvae were found in this stream for the rest of 1950. In 1951 _P. hirtipes_, _C. mutata_ were found in May and early June and _S. aureum_, _S. tuberosum_, and S. gouldingi later in June.

In 1952 numbers of blackflies were about the same below the treatment point as in 1950 before the treatment.

Townsend Pond Outlet is a small stream flowing from Townsend Pond into Big Moose Lake Outlet. It crosses the Big Moose Road just before the turnoff to the Higby Club about four miles from Eagle Bay. The stream bottom is made up mainly of coarse sand and pebbles with some larger stones. The level of the stream declines from about 4 feet to 1 foot in width and correspondingly in depth and rate of flow, during July and August but there is almost always some flow. Species collected from this stream include P. hirtipes, C. mutata, and S. tuberosum. This stream was treated on April 28, 1950 with 1 block of DDT-impregnated plaster of Paris. At the time of treatment, the stream was 4 feet wide, 0.5 foot deep, and had a flow of 1.5 f.p.s. The calculated dosage was 0.005 ppm for 48 hours. Species present at the time of treatment were P. hirtipes and C. mutata. The stream was treated just below the outlet of Townsend Pond.

The larval population averaged about 15 per 10 units but larvae were more numerous just below the pond. After treatment no larvae were found for a checked distance of 1 mile below the treatment point. Above the block site there were 60 larvae per 10 units. No larvae were found below the treatment point in the stream until July 18, 1952, when *S. tuberosum* larvae were found.

Indian Brook crosses the Moose River Fire Trail about 1 mile from the beginning of the trail. The stream flows through open country for the most part although there are fairly thick shrubbery growths (probably alder) along sections of the stream. The bottom is made up mostly of fine sand with sections of coarser sand with some pebbles and stones. There are numerous new and old beaver dams and consequently many areas of still water. The flow, at the point measured, was approximately 1.4 f.p.s., the width 7 feet and the depth 1.5 feet. In many places the water is much deeper. The stream was treated on May 27, 1952 with 2 ounces of 20% emulsifiable lindane applied by hand sprayer about 500 yards above the fire trail. The larvae here were very numerous and pupation was well under way. The species involved was S. venustum. Further downstream, the larvae were not as well developed. This is probably due to the fact that treatment was made just below a beaver pond (see p. 225). The calculated dosage was 0.034 ppm for 20 minutes. Larval populations before treatment averaged about 20 per 10 units for 1.5 miles below the treatment point although they tended to be somewhat heavier below small beaver pools. The stream was checked 2 days after treatment. There was no apparent reduction in larval populations. The stream was therefore treated again, this time with 4 ounces of emulsifiable lindane sprayed into the stream over a 20-minute period. Two days after this second treatment larvae were rare for slightly over one-quarter mile below the treatment point. Further downstream there was no apparent reduction. The calculated dosage of the second treatment was 0.068 ppm for 20 minutes.

Relatively low dosages were used in this experiment but judging from other experiments they should have been sufficient to reduce larval blackfly populations. This lack of effectiveness is probably due to the numerous pools in the stream.

Kincaid Road Stream flows across Kincaid Road, in the Forestport area about one-quarter mile from the North Lake Road. It originates from a spring a short distance above the road and flows into Little Woodhull River. This stream was treated on May 22, 1952 with one-quarter block of DDT-impregnated plaster of Paris. At the time of treatment the flow was 2.5 f.p.s., the width 1 foot, and the depth 0.25 feet, giving a calculated dosage of 0.01 ppm for 24 hours. The total length of the stream was about one-quarter mile. The stream flowed in a relatively regular channel with little impedition of the flow. The bottom is made up of coarse sand with pebbles in some sections and mud in others. The larval population was made up of *S. tuberosum* and *S. gouldingi* at the time of treatment. There were about 100 per 10 units before treatment and none 11 days after treatment. Since the treatment was applied as far upstream as possible no checks were made above the treatment point. Larvae were eliminated for a checked distance of one-quarter mile until 67 days after treatment when small *S. tuberosum* larvae were found in the stream.

Gulf Creek crosses the Bellingertown Road about 1.25 miles from Forestport Station. Just above the road it flows over a dam from a small pond. The stream bottom in this section is rocky with a coarse sand base and very little vegetation. Further downstream the bottom is made up of fine sand. Species found in this stream include *P. hirtipes*, *C. mutata*, *S. vittatum*, *S. venustum*, *S. tuberosum*, and *S. decorum*. This stream was treated March 21, 1952 with 2 lindane-impregnated plaster of Paris blocks, each containing one-tenth the amount of lindane (0.18 ounce) as was used in making DDT-blocks. The stream was 2.5 feet wide, 0.75 foot deep, and had a flow of 2 f.p.s. at the time of treatment. The calculated dosage was 0.002 ppm for 24 hours. Species present at the time of treatment were *P. hirtipes*, *C. mutata*, and *S. vittatum* just below the dam and *P. hirtipes* and *C. mutata* further downstream. Before treatment (just below the dam) the larval population was estimated to be 500 per 10 units along the checked length of the stream. After treatment larval population three-quarters of a mile below the treatment point was still 200 per 10 units.

A second treatment was made April 4, 1952 during the spring run-off using a DDT-impregnated block. At this time, the stream was 4 feet wide, 0.83 feet deep, and had a flow of 3 f.p.s. The calculated dosage was 0.003 ppm for 24 hours. At the time of treatment _P. hirtipes_ and _C. mutata_ were present three-quarters of a mile below the treatment point. The larval population was reduced from 200 per 10 units three-quarters of a mile below the treatment point to "rare" 6 days later. Above the treatment point there was a normal seasonal decline to about 60 per 10 units. No repopulation of the treated section of the stream was noted until _S. venustum_ and _S. tuberosum_ larvae were found 73 days after treatment.

Meadow Stream, Lower Road, crosses the lower road (which branches from the Bellingertown Road three-quarters of a mile from Forestport Station heading south) about 2 miles from Forestport Station. Just above the road is a small dam and pond. Below the road the stream is 1 foot wide, 0.67 feet deep, and flows at the rate of 2.0 f.p.s. It has a fine sandy bottom with much grassy vegetation. This stream flows into Kayuta Lake three-quarters of a mile from the lower road. Species collected from this stream included *C. mutata*, *C. vittatum*, *S. venustum*, *S. tuberosum* and *S. aureum*. This stream was treated May 19, 1952 with 0.5 ounce of 20% DDT emulsifiable concentrate giving a calculated dosage of 0.09 ppm for 20 minutes. Larvae present at the time of treatment were *S. venustum* and *S. tuberosum*. The population was a uniform 100 per 10 units down to Kayuta Lake. The flow was uninterrupted along a well-defined channel with no pools or dams below the treatment point. The treatment was applied using a small hand sprayer over a 20-minute period. Larval populations remained fairly constant before and 3 days later above the treatment point but larvae were eliminated for a checked distance of three-quarters of a mile below the treatment point. Reinfestation with S. venustum and S. tuberosum larvae was noted on June 30, 51 days after treatment.

Inlet to Pine Creek crosses North Lake Road 2.75 miles from Forestport Station. The stream has a fine sand and mud bottom with numerous twigs and leaves in the water. The stream is 3 feet wide, 0.5 foot deep, and has a flow of 1.8 f.p.s. Species of blackflies found in this stream include P. hirtipes, C. mutata, S. venustum, S. aureum, S. latipes, and S. croxtoni. It was treated on May 8, 1952. At the time of treatment only S. venustum larvae were present. The stream was treated with 1 ounce of 20% emulsifiable DDT 100 yards above North Lake Road just below a large beaver dam. At the time of treatment the population was 1500 per 10 units with some pupation noted. The stream was checked for about 400 yards below the treatment point. The calculated dosage was 0.09 ppm for 20 minutes applied by hand sprayer. The stream was examined 5 days after treatment and no larvae were found below the treatment point. However, 11 days after treatment small S. venustum larvae were found.

Pine Creek crosses the Bellingertown Road about 2.25 miles from Forestport Station and crosses the lower road about 1.5 miles from it. This stream has a coarse to fine sand bottom with little vegetation in most places. In a few sections there are rock riffles but the stream is predominantly a deep water sand bottom stream. The lower end flows through rather swampy country into Kayuta Lake. Species collected from this stream include *P. hirtipes*, *C. mutata*, *C. sp. 1*, *S. venustum*, and *S. tuberosum*. At the time of first treatment it was 6 feet wide, 1.25 feet deep, and had a flow of 2.5 f.p.s. at the point measured. It was treated March 21, 1952 using 16 ounces of 25% emulsifiable DDT applied over a 20-minute period using a hand sprayer. The treatment was applied just below the Bellingertown Road Bridge. The population before treatment above the treatment point was 50 per 10 units and below 1.75 miles 100 the length of stream between these points was not examined. Blackflies present in the larval stage at the time of treatment were *P. hirtipes*, *C. mutata*, and *C. sp. 1*. The calculated dosage was 0.27 ppm for 20 minutes. There were no larvae below the treatment point 4 days after treatment at the check point 1.75 miles downstream from the treatment point. There was no decrease in larval populations above the treatment point. In this case the larvicide passed through 3 large, successive beaver dams, an aggregate area of at least one-quarter linear mile of slow water. The first repopulation was noted at the lower checkpoint 56 days after treatment when small larvae (*S. venustum* and *S. tuberosum*) were found.

A second treatment was made on August 4, 1952 when the flow was 2.86 f.p.s., the width 8 feet, and the depth 0.67 foot. The stream was treated with 10 ounces of 25% emulsifiable TDE. The larvicide was poured into the water at the same point as the March application. The calculated dosage was 0.2 ppm for 20 minutes. At the time of treatment *S. venustum* and *S. tuberosum* larvae were present. Larvae above the treatment point were very numerous on grass (2000 per 10 units) and about the same on rocks just above the culvert crossing under the lower road 1.75 miles downstream. Two days after treatment there were no larvae 1.75 miles below the treatment point and no reduction above the treatment point. Very small S. venustum larvae were found 16 days after treatment below the treatment point.

Inlet to Split Rock Creek flows into Split Rock Creek just above routes 28 and 365 about one-quarter mile south of Gull Lake Outlet. This small stream is about 1.33 feet wide, 0.33 feet deep, and has a flow of 1.2 f.p.s. It has a fine sand bottom with areas of heavy "grassy" vegetation. Species collected from this stream include P. hirtipes, C. mutata, S. venustum, S. aureum, and undetermined species of Eusimulium. The stream was treated with 4 ounces of 20% emulsifiable lindane applied with a hand sprayer over a 20-minute period. The calculated dosage was 1.89 ppm for 20 minutes. Treatment was applied on June 13, 1952 when S. venustum was the only species present in the larval stage. The treatment was applied one-fifth mile above the point where the inlet enters Split Rock Creek. Before treatment the larval population was quite uniform at about 80 per 10 units. Three days after treatment no larvae were found below the treatment point. The next time the stream was examined, 24 days after treatment, *S. venustum* larvae were found.

Inlet to Independence River is located about 1 mile northeast of Independence Lake, the water reservoir for the Town of Webb. The stream was fairly low when examined having a flow of 1.1 f.p.s. It was 6 feet wide, and only 0.17 feet deep. The stream has a coarse gravel bottom with numerous rocks and much mossy vegetation. Near Independence River the flow becomes less and the bottom sandy with clumps of grass. The stream was treated on August 7, 1952 one-fifth of a mile above an old lumber road. Four ounces of Rohm and Haas emulsifiable TDE-like compound (Q-137) were poured in over a 20-minute period. The calculated dosage was 1.13 ppm for 20 minutes. At the time of treatment the larval population was made up of *S. tuberosum* and *S. venustum*. Before treatment larval populations were about 20 per 10 units along the upper part of the stream with somewhat fewer larvae in the slower water near Independence River. Three days after treatment no larvae were found below the treatment point for a checked distance of one-quarter mile. No check could be made above the treatment point because the rocks there were very mossy and the water low. The stream was examined again 14 days later and no larvae found below the treatment point.

Gull Lake Outlet flows into the Middle Branch of Moose River about 1 mile above the junction of the Middle and South Branches. It was 5 feet wide and 0.42 feet deep, with a flow of 2.5 f.p.s. The upper portion of the stream flows under large boulders down a steep grade. It flows underground for long distances. Further downstream the grade is much less and the bottom is sandy in spots and muddy with much decaying matter in other spots. It often disappears for a distance and then reappears. Further downstream the stream bottom becomes better defined, there is more trailing vegetation and the bottom is made up of fine sand with large and small stones. This stream was treated on November 23, 1951 with 1 block of DDT-impregnated plaster of Paris three-quarters of a mile above the Moose River in the upper portion above several sections of underground flow. No larvae were noted before treatment for one-half mile below the treatment point. Just above the culvert crossing under routes 28 and 365 and for one-quarter mile down to the Moose River, P. hirtipes larvae were found, about 100 per 10 units. The stream was not checked for 6 days after treatment but the block probably disintegrated in about 48 hours, giving a calculated dosage of 0.003 ppm for 48 hours. There was no apparent reduction in blackfly larvae when the stream was checked 6 days after treatment.

Gull Lake Outlet was treated a second time on April 4, 1952. Five ounces of 20% DDT solution were sprayed into the stream with a hand sprayer over a 20-minute period to give a calculated dosage of 0.24 ppm for 20 minutes. The treatment was applied one-quarter mile above Middle Branch Moose River and below any sections of underground flow. Before treatment larval populations varied from 50 per 10 units below route 28 to 20 per 10 units above route 28. Only P. hirtipes larvae were found before treatment. No larvae were found in the stream 2 days after treatment. There was no "repopulation" with blackfly larvae until August 8, 1952 when S. tuberosum larvae were found.

Eaton Pond Outlet flows from Eaton Pond into Long Lake, near the village of Long Lake. This stream was 6 feet wide, 0.833 feet deep, and had a flow of 5 f.p.s. at the point checked. For the most part the stream is much wider and slower. This stream was treated on May 24, 1950 with two-thirds of a DDT-impregnated block, giving a calculated dosage of 0.0008 ppm for 24 hours. The effect of this treatment is difficult to evaluate because sampling spots above and below the treatment point are not strictly comparable. The treatment point was just below Eaton Pond Dam. As many as 10,000+ blackfly larvae per stone were noted on and just below the dam. There were few larvae present one-third mile below the treatment point even before treatment. Larval populations above the block site increased from 550 per stone to a maximum of 10,000+ per stone on July 10. One hundred yards below the treatment point, larvae were present in numbers up to 500 per stone before treatment. They were not observed here for 47 days after treatment.

Species found in this stream in 1950 were *P. hirtipes, S. venustum*, *S. aureum*, *S. tuberosum* and *P. magnum*. The species found in large numbers on and just below the dam was *S. decorum*.

SUMMARY - LARVAL CONTROL BY HAND APPLICATION METHODS

There is considerable variation concerning required dosages in previous reports of effective blackfly larvicides. From examination of the literature and from the results of field work in the Adirondacks it seems probable that factors important in determining the effectiveness of a larvicide have been neglected. In general, the larger the stream, the less larvicide (proportional to the amount of water) is required. Further, the larger the stream, the longer the effective distance of the larvicide. Conversely, very small streams apparently require larger proportionate dosages and these are effective for shorter distances. The factors probably making for this difference are:

1. The greater area of contact of the water and the stream bed (per unit volume of water)

in the smaller streams and hence more chance for adsorption of the insecticide by organic matter.

2. Smaller streams in the Adirondacks are generally made up of numerous small pools connected by sections of running water or have alternate pools and small falls. The woodland pools often have many small natural dams made up of branches and leaves through which the water filters. This impedition is apparently very important in determining the effectiveness of a larvicide.

3. Even the larger streams approach the condition of the smaller streams as the summer progresses due to the decrease in water levels. The combination of large area of contact and impedition have an important bearing on the degree of effectiveness of a larvicide.

From table 1, p. 195, it can be seen that DDT-impregnated plaster of Paris blocks effectively reduced blackfly larval populations for checked distances up to 1.25 miles in large, relatively unimpeded streams when dosages of 0.0005-0.001 ppm for 24 hours were applied. Smaller but relatively unimpeded streams were cleared of larval blackflies for distances up to 1 mile using dosages of 0.003 ppm for 24 hours to 0.01 ppm for 24 hours. Much heavier dosages were required for control in small impeded streams. The distance that control was effective in small streams was difficult to ascertain since most of these streams were relatively short but available data indicate that the distance is much shorter than in unimpeded streams.

DDT used in the form of solution or emulsifiable concentrate was effective in unimpeded streams of any size at concentrations of 0.09-0.31 ppm for 20 minutes but was not effective, even with much higher dosages (up to 1.22 ppm), in impeded streams.

TDE and lindane used as impregnated plaster of Paris blocks, in solution, or as emulsifiable concentrate exhibited approximately the same order of toxicity as DDT.

Dieldrin was tested only once. The stream in which it was used was moderately impeded at the time of treatment. A heavy dosage of 1.36 ppm for 20 minutes cleared larvae from the stream (table 2).

Table 1. Dosages used in experimental stream treatments using indicated methods. (Symbols explained on next page.)

Dosage ppm	Time	Distance controlled (in miles)	Duration effect (in days)	Species controlled	Stream	Relat. Imped.	Treat-ment Date
A. DDT-impregnated plaster of Paris blocks							
0.0008	24 hrs.	0.33*	47	*hirt.*,*ven.*	Eaton Pond Out.	1	5/24/50
0.0005	24 "	1.0*	52	*hirt.*,*mut.*	Wheeler Creek	1	5/7/50
0.001	24 "	1.25*	48	*hirt.*,*mut.*	High Rock Pond Out.	1	5/11/50
0.003	24 "	0.75*	73	*hirt.*,*mut.*	Gulf Creek	1	4/4/52
0.002	24 "	0.5*	!	*hirt.*	Nursip Brook	3	5/27/50
0.003	24 "	0.5	!	*hirt.*,*mut.*,*ven.*	Aedes Brook	2.5	5/27/50
0.003	48 "	0.0	0	*hirt.*	Gull Lake Out.	3.5	11/23/51
0.005	48 "	1.0*	!	*hirt.*,*mut.*	Townsend Pond Out.	1.5	4/28/50
0.01	24 "	0.33*	67	*tub.*,*gould.*	Kincaid Rd. Str.	1.5	5/22/52
0.01	48 "	0.33*	!	*hirt.*,*mut.*	Townsend Pond In.	3	4/28/50
B. Emulsifiable DDT sprayed or poured into stream							
0.09	20 min.	1.0*	11	*ven.*,*tub.*	Lower Rd. Mead.Str.	1	5/19/52
0.09	20 "	0.24*	11	*ven.*	Inlet Pine Creek	1.5	5/8/52
0.27	20 "	1.75*	56	*hirt.*,*mut.*,*C.sp.1*	Pine Creek	2	3/21/52
0.28	20 "	1.0*	37	*hirt.*,*mut.*	Cascade Brook	1	3/14/52
0.31	20 "	2.0*	78	*hirt.*,*mut.*	2nd Okara Outlet	1	3/26/52
C. DDT in oil solution sprayed or poured into stream							
0.03	20 "	0.5*	13	*ven.*,*tub.*	Salmon River	1	8/15/51
0.1	20 "	0.0	0	*hirt.*,*mut.*,*vit.*	2nd Okara Outlet	2	11/23/51
0.24	20 "	0.25*	126	*hirt.*	Gull Lake Outlet	2	4/4/52
0.80	20 "	0.2	-	*ven.*,*tub.*,*gould.*	Wheeler Creek	3	6/18/52
1.22	20 "	0.5	-	*ven.*,*tub.*,*aur.*,*parn.*	Aedes Brook	3	6/24/52
D. 50% DDT dust sifted into stream							
0.16	20 min.	0.5*	21	*ven.*,*tub.*	Salmon River	1	8/4/52

Table 2. Experimental stream treatments using insecticides other than DDT

Dosage ppm	Time	Distance controlled (in miles)	Duration effect (in days)	Species controlled	Stream	Relat. Imped.	Treat-ment Date
A. TDE-impregnated plaster of Paris blocks							
0.003	48 hrs.	0.13	40	*hirt.*,*ven.*	High Rock Pond Out.	3	5/24/51
0.008	48 "	0.5	42	*ven.*,*tub.*,*gould.*	Wheeler Creek	3	6/7/51
B. Emulsifiable TDE sprayed or poured into stream							
0.20	20 min.	1.75*	16	*ven.*,*tub.*	Pine Creek	2	8/4/52
0.35	20 "	0.75*	34	*ven.*,*tub.*	Bear Brook	1	7/22/52
C. Lindane-impregnated plaster of Paris blocks							
0.002	24 hrs.	0.0	0	*hirt.*,*mut.*,*vit.*	Gulf Creek	1	3/21/52
D. Emulsifiable lindane sprayed or poured into stream							
0.034	20 min.	0.0	0	*ven.*	Indian Brook	3	5/27/52
0.068	20 "	0.25	-	*ven.*	Indian Brook	3	5/29/52
0.1	20 "	0.5*	14	*ven.*,*tub.*	Salmon River	1	7/17/52
0.15	20 "	0.5*	6	*ven.*,*tub.*,*hirt.*	Cascade Brook	1	6/3/52
0.35	20 "	0.0	0	*ven.*,*tub.*,*gould.*, *hirt.*	Wheeler Creek	3	6/5/52
1.89	20 "	0.2*	-		Inlet Split Rock Cr.	2	6/13/52
E. Emulsifiable dieldrin sprayed into stream							
1.36	20 min.	1.0*	!	*ven.*,*tub.*,*hirt.*	High Rock Pond Out.	3	6/18/52

*Last checked distance.
! No blackfly larvae found for the rest of the season.
Relative impedition-arbitrary figure based on amount of obstruction to flow:
1 equals little; 2 equals moderate; 3 equals great.

BLACKFLY LARVAL CONTROL USING AIRCRAFT

LITERATURE REVIEW

The reduction of blackfly larval populations using aircraft to apply insecticides to streams is a relatively new technique. While this method may be more expensive than hand application of larvicides, it also has certain advantages. Rapid, easy treatment of streams in inaccessible areas is possible. There is less chance that streams will remain untreated, there is less danger of too heavy dosages of insecticide, rapid treatment of large areas is possible, and the whole control operation can be more closely supervised.

In 1949, Hocking _et_ _al_., while primarily interested in mosquito control experiments, observed the effects of air treatment on blackfly larvae. A C-47 plane was used to apply a 5% DDT fuel oil solution at a mean concentration of 0.26 pounds per acre over one-half mile of streams. Later a dosage of 0.48 pounds per acre was applied over one of these streams above the area treated in the first experiment. No pupae were present at the time of treatment. Larvae were present in large numbers before the treatments and were totally absent a few days after treatment. S. venustum larvae were predominant in the streams at the time of treatment.

Travis (1949) reported that DDT in fuel oil and auxiliary solvent, when applied at the rate of 0.1 pound per acre caused complete detachment for one-half mile downstream when one 100-foot swath was flown across a stream. When 400-2400 foot swaths were flown there was larval detachment for 1-2.5 miles downstream.

In 1948, Gjullin et al. (1949b) used C-47 and L-5 aircraft to treat streams from the air. A 20% DDT solution containing fuel oil and auxiliary solvent was used. The C-47 laid down swaths about 800 feet in width delivering 0.1 pound DDT per swath acre. Under these conditions, a single swath flown directly across a stream resulted in 100% larval detachment for an average distance of over 2 miles downstream. Two successive swaths were flown over each of two streams with no increase in the distance of 100% detachment. In one case, three successive swaths were flown over a river with 100%

detachment downstream for only 1 mile.

The spray application equipment of an L-5 was calibrated to deliver 0.2 pound of DDT in 20% solution with a swath width of 100 feet. When 1 swath was flown across a stream there was 100% detachment for 2 miles below. In these experiments, if more than one swath was applied, each covered the sam section of stream. It was noted that the larvicide was over 90% effective for a long distance below the point where it ceased being 100% effective. The 800-foot swath width at 0.1 pound per acre was 92% effective 3.5 miles, 81% at 4 miles, 70% at 5 miles, and 58% effective at 7.5 miles below the treatment point. Species involved in these experiments were *P. onychodactylum*, *S. arcticum*, *S. vittatum*, *S. corbis* and the *S. venustum*-*S. vandalicum* (= *tuberosum*) complex. There were no discernible species differences in susceptibility to the larvicide.

Gjullin *et al.* (1950) attempted to eliminate overwintering larvae from Alaskan streams using 20% DDT in fuel oil and auxiliary solvent applied by aircraft. Treatment of Little Solomon Creek on May 5 at the rate of 0.1 pound per acre (based on a swath width of 800 feet) caused no reduction in larval populations in 24 hours. The stream was sprayed again with an additional swath with no reduction noted 300 feet downstream. In sharp contrast, after similar applications during the summer of 1948, complete detachment of larvae below the treatment points for 1.5-2.5 miles were recorded.

On May 7, Naknek River and tributaries were treated in the same way for 30 miles upstream at intervals of about 1 mile. Twenty-four hours later, all small larvae were detached but there was no apparent reduction in numbers of large larvae. On June 25, the streams were re-sprayed; larval populations were high before treatment. Spraying was carried out in a 12-24 m.p.h. wind. Nearly complete elimination of larvae from these streams was reported.

Arnason et al. (1948) used a 12% DDT solution dissolved in 1 part Velsicol AR-50 and 9 parts fuel oil with 0.5% Triton X-100 emulsifier and 0.5% Williams Red Dye added. Larvae involved were S.

arcticum, an important livestock pest in parts of Canada. The South Saskatchewan River was treated with 0.13 ppm for 36 minutes. Larvae of *S. arcticum* were almost completely eliminated from the river for a checked distance of 17 miles below the treatment point and there were some indications that the treatment was effective for 90 miles. The North Saskatchewan River was treated at the rate of 0.07 ppm for 34 minutes. Blackfly larvae were apparently unharmed by this treatment.

It should be pointed out that both of these rivers are large and deep (with volumes of 35,200 and 63,900 c.f.s. respectively). A total of 1160 pounds of DDT were used in treatment of these two rivers alone.

Twinn (1950) reports that in an experimental treatment of the Saskatchewan River larvae were practically eliminated for 117 miles when treated at the rate of 0.1 ppm for 15 minutes with DDT.

Goulding and Deonier (1950) checked streams for blackfly larvae before and after application of 12% DDT in kerosene and xylene applied at the rate of 1 pound per acre by aircraft. In one area, 8 stations on 6 streams were examined. Populations ranged from fewer than 1 to 9 per unit before treatment. No larvae were found at these check points after treatment. In another area, 27 stations in 10 streams were examined. Here larval populations varied from fewer than 1 per rock to 200 per square inch. These were apparently eradicated by treatment except at one station where 1.1 larvae per unit were found 60 days later. It was noted that larvae were dislodged for a distance of 0.75 mile beyond the area actually treated in one stream which had 0.25 mile of its length inside the control area. Breeding continued in check area streams although instances of natural decrease in larval populations were noted.

Hocking and Richards (1952) supervised the treatment of 27 streams with 10% DDT solution in fuel oil and auxiliary solvent applied by helicopter. The larvicide was dispersed through a 30-foot rubber hose one-half inch in diameter with a 6-foot length of metal pipe at the lower end. The whole affair dangled from the helicopter during application of the larvicide. The calculated dosage in all treatments was approximately 0.1 ppm for 15 minutes.

The area was not checked completely after treatment but no larvae were found in the streams checked. As part of the same control program, the Hamilton River was treated, using a C-47. The plane flew 30 feet above the river crossing it obliquely on a one-half mile track. A 15.4% DDT solution was used and a dosage of 0.1 ppm for 15 minutes applied. A total of 403 pounds of DDT was used to treat this river with a flow of 72,000 c.f.s. No larvae were found below the treatment point after treatment.

APPLICATION OF LARVICIDES FROM AIRCRAFT IN THE ADIRONDACKS

The first application of larvicide from the air in the Adirondacks was made in 1950, in the Town of Webb (Travis et al., 1951). A trapezoidal plot approximately 12 miles in length and 3 miles in width was treated on an experimental basis. The plot was located in a relatively inaccessible area to the west of the population centers of Old Forge and Big Moose. The area is heavily wooded but the foliage had not developed at the time of spraying. (see map 1).

The plot was sprayed in the late evening of May 2 and the early morning of May 3, 1950. The spray consisted of 20% DDT, 20% fuel oil, and 60% auxiliary solvent. The aircraft used was a helicopter provided with a pressure spray system equipped with 2 nozzles which delivered 0.35 gallon each per minute at 60 pounds pressure. Flight was 25 feet or more above the tree tops. By flying approximately 60 m.p.h., a dosage of 0.1 pound of actual DDT per swath acre was delivered. The term swath acre is used in calculations instead of the average per acre dosage because the latter term is misleading when applied to applications made in swaths that do not overlap or touch. Since there are 43,560 square feet in an acre, a flight distance of 435.6 feet would cover 1 swath acre. The concentration of DDT in this swath would be relatively high and the concentration between swaths low since only a few of the lighter particles would be carried beyond the swath limits. Swaths were flown parallel to the long axis of the plot (see figure), the plot being laid out in such a way as to cross most of the streams in the area at right angles. The distance between swath centers was one-quarter mile, the width of the swaths about 100 feet. Wind conditions were favorable, being no more than 5-10 m.p.h. during the last two swaths and less during the others. Good inversion prevailed except during the last two swaths, when, due to air movement, the conditions were isothermic. A total of 140 gallons of 20% DDT solution were used to swath-spray an area of approximately 36 square miles.

Eighteen observation stations were established at random across the width of the plot, scattered from one end to the other. Blackfly larval populations were sampled at these stations by counting or estimating the number of larvae per square foot of surface of rocks and vegetation. Pretreatment populations in 16 of the streams ranged from 50-100 per square foot and in the other 2 streams only 15-25 per square foot.

_P_. _hirtipes_ constituted 74% of the population, _C_. _mutata_ 24%, and _S_. _venustum_ the remaining 2%. Most of the larvae were in the last instar except at one station, where they had begun to pupate. Four days after treatment, no blackfly larvae could be found at 7 of the 18 stations. At two stations control was estimated to be better than 95%. One station showed no reduction and one station only 50% reduction. The estimated total reduction for all 18 stations was 85%. The two streams showing little or not reduction in larval populations were short brooks running between and parallel to the swaths. Because some of the short streams and sections of streams near pond outlets did not receive sufficient DDT to eliminate the blackfly larvae, it was decided that the distance between swath centers should be decreased from one-quarter mile to one-eighth mile in 1951. In this way, it was believed that the reduction in blackfly larval populations could be increased to over 95%.

In 1951, approximately 90 square miles in the Town of Webb were sprayed from the air (Collins et al., 1952). The area treated by aircraft was increased about 2.5 times over that of 1950 (see map 2). The spraying was carried out on April 29, 30, and May 1, 1951 using two small fixed-wing planes (Piper Cubs). Each of these planes had a pressure spraying system with spray booms extending parallel to the lower surface of the wings. Each of the planes had two spray nozzles (Tee-jet) calibrated to deliver 0.35 gallon of spray per nozzle per minute at 60 pounds tank pressure. The planes were capable of carrying between 25 and 30 gallons of solution per trip. Cruising at 60 m.p.h., at an altitude of approximately 150 feet, spray swaths of about 100 feet in width were laid down.

The area treated included most of that treated in 1950 plus an area around Twitchel Lake north of Big Moose Lake, a section of the south shore of the Fulton Chain stretching from Little Moose Lake to the Herkimer-Hamilton county line and extending about 1.5 miles inland. About 79 square miles of this area were treated at the rate of 0.017 pound of DDT per swath acre using a solution containing approximately 3.2% DDT in fuel oil and auxiliary solvent. The remainder of the area was sprayed at the rate of 0.1 pound of

DDT per acre using a 20% DDT solution containing fuel oil and auxiliary solvent. After field investigation had shown that only about 72.4% eradication was achieved at 11 check points scattered throughout the control area when the lighter dosage was employed (table 3), supplementary swaths were made over the lightly sprayed area. A special effort was made, at this time, to spray over streams instead of laying down a regular pattern of swaths at one-eighth mile intervals.

Checks made shortly after the supplementary spraying indicated that there was a reduction of 90% in numbers of blackfly larvae in the 11 check streams. Examination of these streams two to three weeks later showed that the reduction remained approximately the same. In 6 untreated streams checked at the same times there was an over-all increase in the number of blackfly larvae during this period (table 4). Data gathered by Collins near Twitchell Lake indicated that control operations were not entirely successful in this area. It was sprayed May 1 at the rate of 0.1 pound DDT per swath acre. No observations were made here before treatment. After treatment, many larvae (estimates not made) were found alive although there were indications that a large reduction in blackfly larval populations had taken place. Many dead larvae were observed and numerous silken threads were found without larvae at the ends. Collins noted that most of the surviving larvae were nearly ready to pupate. It has been suggested by Rubtzov and Vlasov (1934), Kindler and Regan (1949), and Gjullin _et_ _al_. (1950) that mature larvae may be more resistant than young larvae. The "poor kill" obtained in this area may be attributed to the fact that the mature larvae were resistant to the dosages used.

Five-minute samples in a stream treated at the rate of 0.017 pound DDT per swath acre indicate that the effect of this treatment is of relatively short duration (table 5). An increase in the number of blackfly larvae being carried downstream became apparent about one hour after treatment. They reached their peak numbers in about 0.5 hours and declined to "normal" in slightly more than 3 hours. The number of other arthropods being carried downstream did not increase after treatment. The average number both before and after treatment was less than 1 per sample.

It was noted that the streams which did not receive effective dosages of DDT in 1950 were only slightly more successfully treated in 1951, even though the swath interval was cut in half. In view of the greater expense in applying swaths at one-eighth mile intervals instead of one-quarter mile intervals and the fact that the success of the control operation in 1950 was only slightly less than the one in 1951 it would seem practical to use one-quarter instead of one-eighth mile swaths.

Treatment was made somewhat late in 1951 even though the treatment dates were a few days before those in 1950. There was fairly extensive pupation at time of treatment in many of the streams. This failure to treat before _P. hirtipes_ pupation was reflected in increased counts of annoying _P. hirtipes_ adults inside the control area in mid-May.

At the time of treatment P. hirtipes made up 65.7% of the larval population, C. mutata 30.3%, S. venustum 1.7%, and S. tuberosum 2.3%.

In 1952, the area treated from the air was about double that treated in 1951. About 175 square miles in the Town of Webb were sprayed by aircraft. This included the areas sprayed from the air in 1950 and 1951 and also those treated with blocks during these years (see map 3). A solution of about 18.4% DDT was made up using Sovacide and fuel oil in 1:1 ratio as solvents. Spraying was started on the morning of April 16 using the same equipment under the same conditions as were used in 1951. Spraying was started about two weeks earlier than in 1951 to avoid losses in effectiveness of treatment due to pupation. A light wind was blowing at the beginning of the treatment. It increased steadily in velocity during the morning so that spray operations were halted at about 11 a.m. Since the planes were exposed overnight, a heavy frost on the wings prevented the start of spraying operations until 9 a.m. Because some P. hirtipes pupation was noted it was

Table 3. Reduction of blackfly larvae population in streams treated by aircraft with DDT in oil solution, 1951.
(Treatment #1 at the rate of 0.017 lb. per swath acre.)
(Treatment #2 at the rate of 0.1 lb. per swath acre.)

Stream	Blackfly larval populations*		
	Before	After #1	After #2
2nd Okara outlet	70	30	0
Indian Brook	2000	150	0
North Branch Ind. Brook	1000	rare	0
Safford Pond Outlet	70	0	0
1st Little Safford inlet	150	50	30
2nd Little Safford inlet	150	50	30
3rd Lake Creek	20	rare	0
Pole OF #38 Stream	50	20	0
Pole CYNP #861 Stream	30	10	-
Old Forge Dam	100	30	0
FT #4	400	200	200

*Units used are number of larvae per 10 attachment units.

Table 4. Blackfly larval populations in untreated streams before and after treatment, 1951.

Stream	Blackfly larval populations*	
	Before treatment date	After treatment date
Otter Lake inlet	50	50
Nursip Brook	10	10
High Rock Pond outlet above		
block site (1950)	30	250
below " (")	30	50
Split Rock Creek inlet	300	150
Bottle Brook	100	50
Townsend Pond inlet above		
block site (1950)	80	160

*Units used are number of larvae per attachment units.

Table 5. Five-minute samples taken from a stream treated by aircraft, 1951.
(Treated at the rate of 0.017 lb. DDT per acre.)

Time	Number of blackfly larvae
12:35 p.m.	2, 2
1:05 p.m.*	-
1:35 p.m.	7
2:05 "	68
2:35 "	108
3:05 "	47
3:35 "	30
4:05 "	20
4:35 "	7
5:05 "	1

*Plane passed about 800 feet upstream at 1:05 p.m. The spray was visible and could be smelled.

decided that the spraying should proceed as swiftly as possible. A single coarse nozzle was used to replace the two fine nozzles on each plane so that a coarser particle would be emitted allowing spraying operations at higher wind velocities than would be feasible for the finer jet nozzles. On April 17, the use of the single coarse nozzle was initiated and was continued for the rest of the treatment. Treatment was continued during periods of calm, slight, and moderate wind during the mornings and evenings of April 17 and 18. Spraying was completed in the Town of Webb area on the morning of the 19th.

A total of 1440 pounds of technical DDT were used together with 400 gallons of Sovacide and 400 gallons of fuel oil. A concentration of 18.4% DDT in the solution was used. The solution was applied at the rate of 32 gallons per 24 linear miles or 1.33 gallons per linear mile. Since there are 12.12 swath acres per flight mile (considering the swath width to be 100 feet) a calculated dosage of 0.11 pound of DDT per swath acre was applied. If the concentrations used in 1952 were converted to average per acre basis, the dosage would be 0.0144 pound per acre.

The swath pattern was flown following lines drawn on a USGS map so that most of the streams in each of three areas were crossed at right angles. Two Piper Cubs with spray booms and attachments, the same as were used in 1951, were used for the application of the insecticide. Since these planes were flying at an altitude of about 150 feet, an Aeronca without spray equipment flying at an altitude of about 2000 feet was used to guide the low-flying planes. From 2000 feet it was possible to pick out landmarkers which were not visible to the low flying planes.

After the spray treatment flying strictly according to swath pattern was completed, there was some supplementary spraying over streams in "bad" fly-producing areas between Indian Brook and Middle Settlement Creek, along the south shore of the Fulton Chain, and areas along the north and south shores of Big Moose Lake.

The over-all results of the air treatment in 19 check streams scattered throughout the control area indicate that there was an over-all reduction of 84% in blackfly larvae populations (see table 6). Fifteen of the streams were completely cleared of larvae, there was a 99% reduction in one stream, and no control in three streams. Two of the streams showing no control are short, narrow streams, one being a lake outlet (checked just below the lake) and the other a spring-fed stream which runs underground just above the check point. The third stream is a long, relatively wide stream (6 feet). In other streams not checked before treatment to determine larval populations 7 had no larvae after treatment and 2 had some larvae.

Five minute samples were taken in Indian Brook before and after treatment in 1952. A great increase in the number of live blackfly larvae being carried downstream was noted one hour after treatment (see table 7). Samples were not taken one day after treatment but a five minute sample taken two days after treatment indicated that few larvae were being carried downstream at that time.

Table 6. Reduction of blackfly larval populations in streams treated by aircraft with DDT in 1952 in the Town of Webb.

Stream	Blackfly larval populations Before treatment	After treatment
Pancake Brook	50	0
Pancake Jr. Brook	40	40
3rd stream on Fire Trail	70	0
FT #4	200	0
Indian Brook proper	5000	50
North Branch Indian Brook	200	0
Bald Mt. Pond Outlet	50	50
OF #144, stream, Big Moose	50	rare
Dart Inlet	400	0
Townsend Pond Inlet	80	0
Townsend Pond Outlet	1000	0
OF #38 stream, South Shore	10	rare
OF #31 stream, South Shore	150	rare
OF #3 stream, " "	400	0
Indian Brook, South Shore	200	0
Cascade Brook	500	rare
2nd Little Safford Inlet	20	0
Split Rock Creek	300	300
3rd Lake Creek	20	0
West Pond Outlet	-	60
Russian Lake Outlet	-	0
Gull Lake Outlet	-	0
Merriam Lake Outlet	-	0
North Bay Stream	-	0
Andes Creek	-	0
Sisters Outlet	-	0
Haymarsh Outlet	-	20
Aedes Brook	-	0

Table 7. Five-minute samples, 1952.

Indian Brook.

Aircraft passed almost one-quarter mile to one side of the observation point. The next swath was just on the other side of the stream. The slight but steady breeze was blowing so that most of the material from the second swath probably did not fall into the stream in question. First swath passed at 9:45 a.m.

Time		No. of blackfly larvae
April 16	8:05 a.m.	21
"	8:45 "	21
"	9:05 "	28
"	9:45 "	17
"	10:45 "	1600*
"	11:15 "	3200
"	11:45 "	2400
"	12:15 p.m.	2400
"	12:45 "	800
"	12:50 "	600
"	1:15 "	1000
April 18	10:00 a.m.	12

*Numbers from 10:45 to 1:15 estimated by Travis, Collins, Jamnback.

Forestport area - aircraft application of larvicide, 1952

The Forestport area including human population centers in Forestport, Forestport Station, and northward to Otter Lake was treated. In all about 75 square miles were covered. Because of the shape of the township, the area treated was about 18 miles long and 4 miles wide. Thus the maximum distance from untreated adjoining areas was about 2 miles. In some cases population centers were much closer to the non-treated areas. The application was made on April 19-20, 1952 using the same spray equipment as was used in the Town of Webb. Seventeen per cent DDT in fuel oil and auxiliary solvent was applied at the rate of about 0.11 pound per swath acre. Swath centers were one-quarter mile apart. Ten streams checked before and after treatment showed a reduction of only 63%. This was probably due to the fact that winds were moderate to high during spraying. The area was resprayed one week later, using topical application instead of a swath pattern. The result of these combined operations was a 96% reduction in larval populations (table 8).

Table 8. Forestport. Reduction of blackfly larvae in streams treated by aircraft with DDT - 1952.

Stream	Blackfly larval populations	
	Before treatment	After treatment
Inlet to Pine Creek	300	0
Pine Creek	150	0
Inlet to Gulf Creek	200	0
Gulf Creek	1000	0
Middle Road Meadow Stream	100	10
Lower Road Meadow Stream	70	0
N. Forestport, 1st stream	150	0
N. Forestport, 2nd stream	200	10
Norton Road, Otter Lake	150	rare
Pole 667, Otter Lake	50	10

Summary - Aircraft and Control

Conclusions drawn from the results of three years of stream treatment using aircraft for blackfly larval control are as follows:

1. Calculated larval population reductions of about 85% were obtained by application of 0.1 pound DDT in oil solution per swath acre with swath centers one-quarter mile apart (with some supplementary spraying). Since the calculation of effectiveness of treatment is based on the per cent reduction in blackfly larval populations in each of the checked streams, and since only small

streams were missed, the actual percentage reduction of blackfly larvae is greater than 85%.

2. When DDT solution is sprayed at the same rate in swaths with centers one-eighth mile apart (with some supplementary spraying) about 90% control was obtained.

3. In mountainous areas, a swath pattern should be followed because of the many small, temporary streams which contain _P_. _hirtipes_ larvae. Modifications of the swath pattern, for example, flying around rather than over high mountains, makes some supplementary spraying advisable.

4. Special care should be taken to treat lake and pond outlets since annoying blackflies often breed in large numbers at these points.

5. Good results were obtained using a 20% DDT in solution (fuel oil and auxiliary solvent). Use of more dilute solutions means more gallons applied and consequently more landings, takeoffs, refills of insecticide, refueling, and flying time, which is uneconomical.

6. Spray should be applied from aircraft only during periods of calm or _very_ _low_ winds.

Early morning or evening are usually the best times for treatment.

THE EFFECTIVENESS OF BIOLOGICALLY TIMED LARVAL TREATMENTS IN CONTROLLING ANNOYING BLACKFLIES

Since the eggs and pupae are more resistant than larvae, the time of application to secure maximum effectiveness in reducing blackfly populations is critical (Prevost, 1947; Hocking *et al.*, 1949; Twinn, 1950; Hocking 1950; and others).

Data gathered in 1950 and 1951 indicated that two separate stream treatments are necessary to control annoying blackflies in the Adirondacks (Jamnback, 1952). The first treatment reduces overwintering larval populations of *P. hirtipes* and the second *S. venustum* and *S. tuberosum* larvae, which do not appear in the streams as larvae until later in the spring.

The early spring of *P. hirtipes*, treatment may be applied in March or early April, in the Adirondacks, preferably as soon as possible after the spring run-off. A treatment in the fall after *P. hirtipes* larvae appear in the streams would probably not be as effective as the early spring treatment because biological studies indicate that

P. hirtipes larvae emerge from eggs both in the fall and during the winter (see biological section). For maximum effectiveness a spring treatment seems indicated.

Since blackfly pupae are more resistant to larvicides than larvae, the early spring treatment should be made before any appreciable pupation occurs. In 1950, the treatment was carried out May 3 and 4. Some pupation was noted before treatment. In 1951, treatment was made between April 29 and May 1. Even though this treatment took place a few days earlier than in 1950 there was extensive *P. hirtipes* pupation before treatment. In order to obtain the maximum effectiveness in 1952, treatment was applied as soon after the spring run-off as feasible. Since the aircraft used in spraying operated from the local golf course it was necessary to wait until the snow melted and the ground became firm enough for light aircraft. Treatment was made April 16-20, before any appreciable *P. hirtipes* pupation was noted.

In the Town of Forestport, which lies about 20 miles south of the Town of Webb, treatment was made on April 20 and 21 and another application was made a week later (see aircraft spraying - Forestport). There was some pupation at the time of treatment but it was not extensive.

The second stream treatment each year is aimed at reducing the larval populations of *S. venustum* and *S. tuberosum*. These species probably overwinter in the egg stage. Since the eggs are relatively resistant to insecticides, it is necessary to wait until the larvae emerge before treatment. In streams where repeated observations were made at intervals of approximately one week (1951) it was noted that *S. venustum* and *S. tuberosum* larvae were first found between May 15 and June 6 (table 9) in most of the streams. In five of 47 streams examined in 1951, larvae of these species were present before May 15.

In 1952, *S. venustum* and *S. tuberosum* larvae were found only in small numbers until May 14 or later with the bulk of the first generation appearing in streams between May 14 and May 28 as in 1951 (table 11). An exception to this general rule was the Forestport area where *S. venustum* and *S. tuberosum* larvae were found in most of the streams by late April.

Most of the streams were treated with the second treatment between May 27 and June 1, 1951. In 1952 treatment was applied during the last week in May and the first week in June. These treatments probably killed the majority of *S. venustum* and *S. tuberosum* larvae in the control area. However, in many cases there was localized pupation in some streams and portions of streams before treatment. This was especially noticeable below large stretches of still water, behind beaver dams, or at lake outlets. Apparently larvae emerge from the eggs earlier and develop more rapidly in these situations probably because this water is slightly warmer than other portions of the streams. Because of this, there is no one time when the first generation *S. venustum* and *S. tuberosum* are present as larvae in all of the streams. Consequently, there is no one time when treatment can be made which will kill almost all the larvae in all of the streams. Ideally the proper method of treatment would be to treat the warmer sections of streams first and the cooler streams or parts of streams later. Using the volunteer method in the Adirondacks this is impossible because the treatments must be made during the "busy" period when the hotels are preparing for the summer. In the past a compromise has been made and the streams treated when larvae of these species are present in most of the streams. Unfortunately, there is fairly extensive pupation before this time and *S. venustum* and *S. tuberosum* adults were annoying for a short period at the beginning of their "normal" period of activity. A possible solution to this problem would be the use of aircraft over a period of approximately two weeks during the "critical" period. These aircraft could treat lake outlets, areas of still water in streams, and beaver dams during the first part of the period and other streams and areas of streams during the latter part of the "critical" period. While this method would be initially more expensive there would probably be less necessity for the use of ground fogging which is relatively inefficient and expensive so that the final cost would probably not be much greater and the control much more effective.

When the second treatment was applied *S.*

venustum and *S. tuberosum* were not found, after treatment, in these streams until June 20 or later, in 1951 (table 10). In 1952, most streams were not repopulated with *S. venustum* and *S. tuberosum* until late June or July (table 12).

Since *S. venustum* larvae require an average of about 17 days in the summer to mature (De Foliart, 1951), larvae found June 20 would not pupate until about July 7. The pupal period would require about four days more. Adults would not emerge until about July 11 after the "blackfly season" is over. It appears that only the first generation adults of *S. venustum* and *S. tuberosum* are homophilic (discussed in detail in biological section) so that it is not necessary to apply control measures to the subsequent generations that year.

Table 9. The appearance of first generation *S. venustum* and *S. tuberosum* larvae in untreated streams and in streams treated to eliminate *P. hirtipes* larvae - 1951

Stream	Treatment date for *P. hirtipes* control	*S. venustum*-*S. tuberosum* larvae first found
Otter Lake inlet	none	May 15
Bottle Brook	none	May 17
High Rock Pond outlet	none	May 17
Wheeler Creek	none	May 24
Aedes Brook	none	May 25
Raquette Lake inlet	none	June 5
Nursip Brook	none	June 26
North Branch of Indian Brook	April 29	May 19
Safford Pont outlet	May 1	May 22
2nd Okara outlet	April 29	May 28
Bear Brook	May 1	May 29
Cascade Brook	May 1	June 6
Third Lake Creek	May 1	May 21
Constable Creek	May 1	May 22
Indian Brook	April 29	May 25
Pole OF #38 stream	May 1	May 28
Salmon River	May 21	June 5
Loon Brook	May 1	0
Dart Inlet	May 1	0
Bald Mt. Pond outlet	May 1	0
Townsend Pond outlet	May 1	0

Table 10. The reappearance of *S. venustum* and *S. tuberosum* larvae in streams after treatment to eliminate the first generation larvae of these species - 1951.

Stream	Treatment date for *S. venustum* and *S. tuberosum* control	*S. venustum* and *S. tuberosum* larvae found after treatment
Third Lake Creek	June 1	June 27
Constable Creek	May 27	June 20
Indian Brook	June 5	-
Pole OF #38 stream	June 1	July 19
Salmon River	June 1	June 28
Loon Brook	May 27	July 16
Dark Inlet	May 27	July 20
Bald Mt. Pond outlet	June 1	July 26
Townsend Pond outlet	May 27	0

Table 11. The appearance of first generation S. venustum and S. tuberosum larvae in untreated streams and in streams treated to eliminate P. hirtipes larvae - 1952.

Stream	Treatment date for P. hirtipes control	S. venustum and S. tuberosum larvae first found
Bottle Brook	none	May 16
High Rock Pond outlet	none	May 28
Wheeler Creek	none	May 16
Aedes Brook	none	May 23
Raquette Lake Inlet	none	May 28
Big Otter outlet	none	May 9
South Inlet	none	May 6
Inlet to South Inlet	none	May 6
2nd Big Otter Inlet	none	May 23
1st Big Otter Inlet	none	May 23
Big Stone Stream	none	June 10
Split Rock Creek	none	April 22
Eaton Pond Outlet	none	May 6
Shaw Pond Outlet	none	May 6
N. Branch Indian Brook	April 16-20	May 23
Indian Brook	"	May 14
Cascade Brook	March 14	May 20
3rd Lake Creek	April 16-20	May 15
Constable Brook	"	May 27
OF #31	"	May 23
OF #38	"	May 23
Bald Mt. Pond outlet	"	May 16
Purgatory Creek	April 20-21	May 22
1st stream N. F'port	"	April 23
Crystal Brook	"	April 23
Bellingertown Rd. 1st Stream	"	April 10
Lower Rd. Meadow Stream	"	May 13
Gulf Creek Lake Inlet	"	April 10
Gulf Creek	April 20-21	April 19
Inlet Pine Creek	April 20-21	April 10
Pine Creek	April 20-21	May 19
Kincaid Rd. Stream	April 20-21	May 22

Table 12. The reappearance of *S. venustum* and *S. tuberosum* larvae in streams after treatment to eliminate the first generation larvae of these species - 1952.

Stream	Treatment date for *S. venustum* and *S. tuberosum* control	*S. venustum* and *S. tuberosum* 2nd generation larvae found
Indian Brook S. shore	May 27-June 2	June 26
2nd Okara Outlet	March 26	June 12
Gull Pond Outlet	April 4	August 8
Pancake Creek	June 1-7	July 1
Townsend Pond Outlet	1950	July 18
Wheeler Creek plus 1	1950	July 2
High Rock Pond outlet	none	July 2
Loon Brook	June 1-7	July 17
Bear Brook	June 1-7	July 2
Salmon River	June 1-7	July 17
3rd Lake Creek	May 21-30	June 12
Bald Mt. Pond Outlet	"	June 23
Cascade Brook	June 3	June 9
Dart Inlet	?	Aug. 8
Constable Brook	June 1-7	June 19
Purgatory Creek	May 21-30	June 16
1st stream N. F'port.	May 21-30	Aug. 4
Crystal Brook	"	June 10
Meadow Stream, lower rd.	May 19	June 16
Gulf Creek	April 20-21	June 16
Pine Creek	April 20-21	June 30
Kincaid Rd. stream	May 22	July 28

DURATION OF EFFECTIVENESS OF STREAM TREATMENTS

Garnham and McMahon (1947) succeeded in eradicating S. neavei from an area of 65 square miles. However, this was due to repeated treatments over a long period in an isolated area rather than to long term duration of effect of larvicides.

Prevost (1947) reported that blackfly larvae were eliminated from streams treated with DDT (in alcohol or acetone with emulsifier added) dripped in over a 24-hour period. One year later, in April and May, 1947, the same streams were re-examined and no blackfly larvae found except above the treatment point and immediately below it.

In other experiments (April and May, 1947) Prevost treated streams with DDT-impregnated plaster of Paris blocks obtaining concentrations of 0.1 - 0.005 ppm for 48 hours. Larvae were eliminated from these streams and did not reappear during the period of observation (June to November of the same year). Prevost reported that these streams had contained blackflies only in the larval stage. In streams containing both larvae and pupae, or eggs, larvae, and pupae (June, 1947) larvae reappeared a few weeks after treatment. Prevost did not mention the species of blackflies involved in this work. Later, in correspondence with Dr. Twinn (1948), Prevost noted that the species involved were primarily _S_. _vittatum_ and _S_. _venustum_.

Goulding and Deonier (1950) state that most of the streams treated at the rate of 1 pound DDT per acre (kerosene and xylene mixture) in 1946 and 1947 had no larvae in 1948. The biologies of the species involved are not associated with the treatments. The species present were, however, noted. These included _S_. _venustum_, _S_. _vittatum_, and _C_. _dacotensis_ as the predominating species, with small numbers of _P_. _hirtipes_, _P_. _magnum_, _S_. _decorum_, and _S_. _pugetnse_ (descr. as _S_. _costatum_) present.

These reports seem to indicate that, under certain conditions, a single stream treatment may have a prolonged effect.

Work carried out in the Adirondacks dealt with two distinct groups of blackflies. _P_. _hirtipes_ and _C_. _mutata_ make up the early spring group. These overwinter in the larval stage. The majority of these larvae pupate and emerge as adults during the last half of May.

The later spring and summer group presumably overwinter in the egg stage. Larvae of these species are found in the streams during the last half of May or later in the season, depending on the species. This group includes *S. venustum* and *S. tuberosum*, important pests of man. The less important pests of man (in the Adirondacks), *S. parnassum*, *S. decorum*, and *S. jenningsi* also emerge during the late spring or summer. *S. vittatum* is intermediate between the two groups since it overwinters in the larval stage and is also present in the streams later in the summer. It is the only species found in the Adirondacks that overwinters in the larval stage and that also has more than one generation per year.

Both Prevost's and Goulding and Deonier's work involved the use of relatively heavy dosages of DDT. These dosages involved extensive injury of other stream fauna. In work carried out in the Adirondacks dosages were much lighter except for a few experimentally overdosed streams. Dosages of

0.001-0.0005 ppm for 24 hours were considered ideal when DDT-impregnated plaster of Paris blocks were used. When DDT solutions or emulsifiable concentrates were sprayed or poured into the streams, dosages of 0.1-0.3 ppm over a 20-minute period were considered ideal. These dosages reduced larval populations of blackflies almost 100 per cent without causing extensive injury to other stream fauna.

It was not possible to treat streams at any time of the year when no blackfly eggs were present because eggs of some species are present at all times in permanent Adirondack streams. Furthermore, there was a limited amount of pupation before treatments in 1950, 1951, and 1952. Therefore, it might be expected, according to Prevost's observations, that there would be no long term duration of effect. This has proved to be the case in experiments carried out in permanent streams in the Adirondacks (see table 13).

Table 13. A comparison of larval blackfly populations in streams treated for three consecutive years. (Samples taken before treatment for *S. hirtipes* control in 1951 and 1952.)

Treated Streams	Numbers of Larvae 1951	1952
Stream OF #38	30	10-
3rd Lake Creek	20	20
FT #4	400	200
Bald Mt. Pond Outlet	300	50
Old Forge Dam	1000	1000
Split Rock Creek	20	80
Okara Pole 861	30	100
Cascade Brook	10	40
Constable Creek	50	0**
Wheeler Creek	0	30
Loon Brook	50	120
Bear Brook	100	200
Eaton Pond Outlet	-	200
2nd Minnow Pond Outlet	-	30
High Rock Pond Outlet	30	0
Stream OF #31	-	140
Stream OF #3	-	375
Indian brook (south shore)	-	125
FT #3	0*	70
Gull Pond Outlet	-	50
Indian Brook	1500	10,000!
North Branch, Indian Brook	100	150
Dart Inlet	-	400
Pancake Brook	-	500
Pancake Jr. Brook	-	40

*Stream treated in fall of 1950 with DDT-impregnated plaster of Paris block by De Foliart.

**Stream treated in the fall of 1951 when rotenone used in Constable Pond to kill fish.

! Approximation.

From the foregoing table, it can be seen that there is no significant difference in the populations of blackfly larvae before treatment in 1951 and 1952 even though these streams were treated between samplings. These streams were treated with moderate dosages of larvicides (i.e., where no extensive injury to other stream fauna was noted).

In streams experimentally treated with heavy dosages in 1950 and not treated at all in 1951 or in 1952 until after counts were made, there was some apparent year-to-year duration of effect of the larvicide (table 14).

Table 14. A comparison of the larval blackfly populations in streams treated with a high dosage of larvicide in 1950. (Samples taken before pupation of _P. hirtipes_.)

Stream	Numbers of Larvae 1950	1951	1952
Nursip Brook			
above treatment point	50	-	-
below treatment point	50	rare	0
Townsend Pond Inlet			
above treatment point	60	80	80
below treatment point	60	0	0
Townsend Pond Inlet			
above treatment point	20	50	750
below treatment point	20	0	0

Since moderate dosages do not give a long term duration of effect even though larvae are eliminated from the stream and since heavy dosages do cause a long term duration of effect, it seems likely that this effect is due to residual action of the larvicide.

In most of the experimental treatments made in the Adirondacks, moderate dosages of larvicide to reduce P. hirtipes populations had no effect on the overwintering (presumably) eggs of S. venustum and S. tuberosum. Exceptions to this were noted when DDT-impregnated blocks were used. S. venustum and S. tuberosum larvae were not found in these streams until late June or early July whereas they appeared in mid-May to early June in other streams the same year (see table 1).

For the next two years they appeared in these streams (which were not treated to control P. hirtipes populations for these two years) in mid-May or early June. Whether the non-appearance of first generation S. venustum and S. tuberosum larvae in these streams in 1950 was due to residual or ovicidal action of the larvicide or to other factors was not determined. Dosages of up to 0.314 ppm of DDT emulsifiable concentrate for 20 minutes and application of DDT in oil solution by aircraft did not have this effect.

From these data the following conclusions have been drawn: Stream treatment using moderate dosages of DDT has no apparent year-to-year effect on blackfly larval populations. Heavy dosages may cause a year-to-year effect.

Treatment of streams with DDT to eliminate *P. hirtipes* larvae may have some effect on overwintering eggs of *S. venustum* and *S. tuberosum* when DDT-impregnated plaster of Paris blocks are used t0 apply moderate dosages. Emulsifiable concentrate (DDT) or DDT in oil solution applied in moderate dosages does not have this effect.

Further studies may reveal that it is possible to eliminate larvae of annoying species of blackflies from streams with a single treatment without excessive injury to other stream fauna. This would involve either residual or ovicidal action against blackflies in the egg stage during the treatment period. The evidence gathered to date indicates that this can be accomplished by long periods of exposure to low concentrations of the larvicide rather than short periods of exposure to high concentrations.

METHODS USED IN ESTIMATING ANNOYING ADULT BLACKFLY POPULATIONS

Most workers dealing with annoying blackflies have stressed the difficulties in making reliable population estimates (Collins, 1948; Prevost, 1948; Wilson *et al.*, 1949; Goldsmith *et al.*, 1949; and others). There have been three main methods used in estimating annoying adult populations. These are the sweep method, the landing rate count, and the visual count method.

The sweep count may be made in two ways. Sometimes sweeps are made continuously over a certain period of time, generally 1 minute (Collins, 1948). The other method involves making a certain number of sweeps about the head and body, generally 10 or some multiple of 10 (Goulding and Deonier, 1950; Hocking and Richards, 1952).

The landing rate on the front of the trousers between the waist and knee during 1 minute while facing half-way between down-wind and away from the sun was used by Hocking and Richards (1952) and by Brown *et al*. (1951).

The estimation method consists of estimating the number of blackflies around the head after standing still or walking around slowly for a certain length of time (Collins, 1948; Prevost, 1948; Wilson *et al*., 1949). Goulding and Deonier (1950) used a modification of this method; counting the adults passing between the observer and a distant object during the period of several minutes.

Biting rates have been used (Garnham and McMahon, 1947) but have not proved too satisfactory.

Most of the workers referred to above have used more than one of these methods. Collins (1948) used both the sweep method and the estimation method. Goulding and Deonier (1950) used the sweep method and the estimation method. Hocking and Richards (1952) used the sweep method and landing rates. Where labor is cheap and plentiful, populations of annoying species have been estimated in flyboy hours (Garnham and McMahon, 1947). These are, presumably, the number of flies a native "boy" can catch in one hour.

The estimation method was used in the Adirondacks. An estimate was made of the number flying about the head and body after the observer had remained in one spot for 10 minutes. Since this method is necessarily somewhat subjective it was checked at frequent intervals using the sweep method. Ten directed, continuous sweeps with a 12-inch diameter hand-net were made about the head and body. The catch in 10 sweeps multiplied by 5 generally gave a good approximation of the estimated population unless there were fewer than 2 or more than an estimated 30 adults flying about the head and body. In these cases the 10 sweeps appeared to give a less accurate figure than the population estimate. Another method tested, but not adopted for routine use, was sweeping about the head and body for 1 minute using a small hand-net. Approximately the same number of flies was caught by this method as was estimated flying about the head and body. When the populations were very small or large this method appeared to be less reliable than the estimation method.

Factors such as cyclical changes in the activity of the blackflies during the course of the day, changes in direction and velocity of the wind, changes in barometric pressure, relative humidity, or cloudiness may influence the activities of blackfly populations. The relative personal attraction, in the case of more than one worker, may be an important factor in estimation of adult population. Further, day to day changes may affect blackfly populations at a single check point. These short-term population fluctuations, due to the habits of the blackflies and local conditions, complicate evaluation of the degree of success of a control program. The influence of these factors can be reduced by making repeated observations at randomly selected times at the check points. To further reduce error due to short term population fluctuations, only data gathered during the "peak periods of annoyance" for the species being controlled were used in evaluating the results of a control program. In this way, the highly variable counts made during the gradual buildup and decline of annoying blackfly adult populations did not complicate evaluation of the control.

To determine the "peak annoyance period" of the most important pest species, i.e., *P. hirtipes* and the *S. venustum-S. tuberosum* group, it was assumed that the number of annoying adults collected was proportional to the number present. Therefore, more flies would be collected during the worst part of the blackfly season than during periods when fewer blackflies were around. In 1951 and 1952, there was a particular effort to collect in numbers more or less proportional to the numbers of annoying flies present at the time counts were made. The period during which approximately 90% of the total number of annoying *P. hirtipes* were collected was designated as the peak annoyance period of *P. hirtipes*. In like manner, the period during which 90% of the *S. venustum-S. tuberosum* group were collected was designated as the peak annoyance period of the *S. venustum-S. tuberosum* group. As a further check, the population estimates were analyzed. It was found that more than 90% of the population estimates were made during the peak annoyance periods as determined by numbers of annoying flies collected.

At the beginning of the 1950 control program, little was actually known about the annoying species of blackflies present in the Adirondacks. It was known that P. hirtipes and S. venustum were severe pests of man at certain times of the year. The relative numbers of these species and of other annoying species, their time of emergence, and periods of annoyance were known only in a general way. No regular collections of annoying adults had been made during an entire blackfly season.

Data collected in 1950, 1951, and 1952 indicate that P. hirtipes is annoying primarily during the last two or three weeks of May and that adults of the S. venustum-S. tuberosum group are annoying from the last of May to early July. Table 15 gives, in the form of percentages, the relative numbers of the major annoying species collected in the Adirondacks during the "blackfly seasons" in 1950, 1951, and 1952. Other species were found only rarely in collections of annoying adults in the Town of Webb and other areas in the Adirondacks. However, in the Forestport area, at the edge of the

Adirondacks, which is lower in elevation and more level than the Adirondacks, C. mutata was annoying, at times, early in the spring. S. jenningsi was a pest species during August. It was not collected while biting but was definitely homophilic, landing on the face, neck, and especially in the ears.

C. mutata was not annoying in most of the area of the Adirondacks studied although larvae are present in large numbers in the spring. It was annoying at times in the Forestport area. A collection of annoying adults made on the Bozenkill, Delanson, N. Y., by Collins on May 11, 1952 was made up of 27 C. mutata and 2 P. hirtipes.

S. parnassum larvae were found in large numbers in one stream in 1951 although they were generally rare in the Adirondacks. In this area they were quite annoying, suggesting that this may be a pest species in areas where it is common.

S. vittatum is a reported pest of humans in some areas, but the adults are rarely attracted to humans in the Adirondacks. Larvae of this species are present in large numbers on dam faces, near pond outlets, and below large pools.

The above data indicate that cautions should be used in beginning a control program in an unstudied area. A knowledge of the species present and species found to be annoying to man <u>in that area</u> is essential. Species show some apparent variability in feeding habits from area to area. Whether this is due to physiological races, differances in climate, availability of favored hosts, or to a failure to separate closely similar species with different habits is not known. Probably the safest method of procedure is to collect annoying adults during the year previous to the first control operations, noting time of emergence, peak annoyance periods, and types of streams in which the larvae of the species are found.

Table 15. Collections of annoying blackflies taken in the Central Adirondacks showing the percentage changes in the annoying species present in 1950, 1951, and 1952. (Expressed as per cent of total number caught for each half month period.

Date	P. hirtipes			S.venustum-S.tuberosum			Other Species			Total No. Collected		
	1950	1951	1952	1950	1951	1952	1950	1951	1952	1950	1951	1952
May												
1-15	100	1	91.6	0	-	0	0	-	8.4*	22	-	59
16-31	72.6	71.9	68.2	27.4	25.2	24.2	0	2.9	7.6*	179	345	157
June												
1-15	17.3	3.9	4.8	80.8	94.6	93.8	1.9	1.5	1.4	208	204	161
16-30	12.8	0	4.4	85.4	98.7	88.0	1.8	1.3	7.6**	266	155	159
July												
1-15	5.0	1.5	0	95.0	94.1	97.2	0	4.4	2.8	21	68	37

*Mostly *C. mutata* adults from the Forestport, N. Y. area. This species is not bothersome in the Old Forge-Big Moose area or in areas to the north of the Town of Webb. Larvae of this species and adults are, however, numerous in these areas.

**Mostly *S. jenningsi* which was somewhat annoying to humans in July and August in the Forestport area but not elsewhere in the Central Adirondacks.

ADULTICIDES - A LITERATURE REVIEW

Area treatment, using adulticides, is a relatively new method of reducing annoying blackfly populations. It has generally proved to be less effective and more expensive than larval control measures, especially for large scale work. However, the extensive use of fogging and, to a lesser extent, spraying in experimental adult blackfly control studies justifies its inclusion in a control paper. This is especially true because of the possibility that improved techniques of application and new insecticides may make adulticiding more effective and less costly.

One of the earliest reports that brought this method of treatment to the attention of entomologists was Monroe et al. (1943). They reported that blackflies were very sensitive to pyrethrum aerosols in closed chamber tests.

In 1946, Glasgow and Collins reported on experimental work with TIFA machines used at Old Forge and Blue Mt. Lake for blackfly adult control. About 60 acres of the Thendara Golf course were fogged with 5% DDT in fuel oil. Ten of these acres were fogged intensively at the rate of 2 pounds per acre and the rest at the rate of about 0.2 pound per acre. The effectiveness of these treatments in reducing adult populations was not reported although it was noted that blackflies were killed by these applications.

In 1947 (Travis, 1949) 1/2-mile-square plots were treated using DDT fog applied by heat generated aerosols. Applied under nearly perfect conditions there was no immediate kill apparent. There was some indication that the treatments were insufficient to kill adult blackflies.

Prevost (1948b) reported that TIFA's when used in small areas, afforded scarcely any relief. Some relief was noted for 24 hours when 70 acres were treated. A truck-mounted Mistona D-6 fogging machine was used to apply DDT in oil solution in experiments near Mt. Tremblant. Dr. Prevost stressed the difficulties in evaluating control effectiveness and the apparent variability in effectiveness of fogging. According to Prevost, there is little residual effect when a TIFA is used. (Some of his report is based on observed controloperations in the Old Forge area.)

Collins (1948) reporting on the work in the Town of Webb indicated that satisfactory blackfly control was achieved when the area was treated with 15% DDT solution dispersed as fog by helicopter and truck-mounted TIFA. An area of 6000 acres was treated three times (with a few exceptions) in a season. The ground machine was used primarily in controlling local increases in blackfly populations between helicopter foggings. The helicopter cruised at about 10 m.p.h. just above the tree tops in order to force the fog down to the ground with the powerful downdraft produced by the rotor. In experimental treatments, caged flies were killed by the fog when the cages were in the open. However, when the cages were placed under leaves, the blackflies were unharmed. A calculated dosage of 0.27 pound per acre was used in the helicopter fogging program.

Goldsmith et al. (1949), using ground-operated spraying equipment, treated two test plots 118 and 130 acres in size. A dosage of 0.35 pound of DDT per acre was applied using a 5% fuel oil solution (weight/volume). A reduction of 99.8% in numbers of annoying blackflies was noted 24 hours after treatment. After 48 hours infiltration was noted and 4 days after treatment counts were very high. When small plots (1-2 acres) were treated using knapsack sprayers, there was a temporary reduction of blackflies. Heavy populations reinfested the area within 15 minutes to 1 hour. A dosage of 2 quarts per acre with a 30-foot swath interval was used. Pyrethrum and pyrethrum-DDT aerosol bombs, DDT-nicotine, and BHC smoke bombs were also ineffective in small areas.

Wilson _et_ _al_. (1949), treated 64 acres using a modified Besler generator mounted on a vehicle. In the first treatment, 0.53 miles of road front were treated at a calculated dosage of 0.21 pound per acre. The DDT was in the form of a 6% solution dissolved in fuel oil and auxiliary solvent. The area was extended to 0.7 mile of road front on the second day. During the treatments an air movement across the road and into the area to be treated aided in the dispersal of fog. During the treatment period good inversion prevailed. Blackflies were found to be annoying 15 hours after the first treatment and a great many were present after the second. In 10 experimental treatments no satisfactory 24 hour protection was obtained, even with fronts up to one-half mile.

In 1950, Twinn reported that preliminary studies indicated that aerosols have a definite value in reducing blackfly populations under suitable conditions. A test of smoke generators containing 6% gamma BHC, drawn on a vehicle at the rate of 1-2 m.p.h., giving a calculated dosage of about 0.01 pound per acre over 250 acres was considered ineffective. In 1952, Twinn reported that aerosols from thermal generators, when emitting particles of a mass median diameter particle size 10-20 u, at the rate of 20 gallons per hour from a vehicle traveling 1-2 m.p.h., were effective in reducing blackfly populations under suitable meterological conditions (i.e., with inversion and wind velocities of 2-3 m.p.h. in relatively open country or greater velocities in wooded area).

Brown _et_ _al_. (1951) noted that adult blackflies were killed by DDT spray applied at the rate of 0.165 pound per acre. Nineteen square miles were treated with 4.2% (wight/volume) DDT in fuel oil and auxiliary solvent. Swaths were flown 200 yards apart and at variable heights, depending on the wind velocity. Under these conditions, control inside of the control area was incomplete. Two weeks after treatment there were 50% as many flies inside the control area as outside; three weeks after treatment, 60%, and four weeks after treatment, 80%. In another area, 2.6 square miles were treated with the same dosage (?). The landing rate here was 1.4 before treatment, 1.3 just after treatment, and 0.4 14 hours later. In another area there was complete disappearance of adults after spraying 2.3 square miles (due "partially to natural conditions") and a 50% decrease the next morning (compared to the previous morning).

Since the area used by Brown et al. (1951) in his adult control experiments was the center of a 200-square mile larval control experiment (Hocking and Richards, 1952), in which larvae were nearly eliminated from checked streams for a distance of approximately 8 miles from the center between

June 2-29, caution should be used in evaluating this control data.

RESULTS OF THE TOWN OF WEBB CONTROL PROGRAM, 1950

In 1950, there was little known about the species found in the Adirondacks which were actually annoying to humans. Blackfly control was directed against blackflies in general. Because of this, too few population estimates were made by the author during the period of peak annoyance of *P. hirtipes* in 1950. Control of this species was carried out using DDT-impregnated plaster of Paris blocks to treat streams in and around Old Forge-Thendara, Big Moose, and along the north and south shores along the first four lakes of the Fulton chain. A helicopter was used to treat about 36 square miles of inaccessible territory to the west of Old Forge-Thendara. These larval control measures were carried out during the last week of April and the first week of May. Results of this treatment combined with adult fogging with helicopter and the use of 2 truck-mounted TIFA's are summarized below.

Table 16. Peak annoyance period of P. hirtipes - May 16-31, 1950

Areas	Average estimated population per observation
Old Forge-Thendara	0.5
Big Moose	0
Marginal	1.7
Outside of Control	11.8

Total number of observations - 28

Since only 28 estimates of adult populations were made during this period, there may be some doubt as to the validity of the averages. However, notes taken during this period indicate that there was marked relief from fly annoyance inside of the control area and that flies were very bad outside of the control area.

Because of a lack of knowledge of the species involved there was no attempt made to control larvae of the S. venustum-S. tuberosum group. Any control must be ascribed to the use of helicopter and ground fogging for adult control. Adult population counts are summarized for the peak annoyance period of S. venustum- and S. tuberosum as follows:

Table 17. Peak annoyance period of S. venustum and S. tuberosum, June 2-July 6, 1950

Areas	Average estimated population per observation
Old Forge-Thendara	1.3
Big Moose	5.5
Marginal	6.8
Outside of Control	5.5

Total number of observations - 131

The Old Forge-Thendara area was treated by both helicopter and truck-mounted TIFA. The numerous roads in the area facilitated good coverage with the ground machine. Control in this area using only fog as an adulticide was fair. The Big Moose area was not treated during this period with helicopter. A lack of roads made thorough fogging with a truck-mounted TIFA difficult. There was no apparent control in this area during the S. venustum-S. tuberosum peak period of annoyance (except possibly locally for short periods).

1951

In 1951, about 90 square miles around Old Forge-Thendara, along the north and south shore, and to the west of Big Moose were treated with DDT larvicide applied by aircraft. The Big Moose area streams were treated with blocks put in by volunteers. Treatment was applied during the last few days of April and the first few days of May. At the time of treatment, fairly extensive P. hirtipes pupation was noted in the warmer streams. Three truck-mounted TIFA's were used to fog local "hot spots" (i.e., localized increases in annoying blackfly populations). A helicopter was not used for adult fogging in 1951. Population counts made during the peak P. hirtipes annoyance period are summarized below.

Table 18. Peak annoyance period of P. hirtipes - May 16-31, 1951

Areas	Average estimated population per observation*
Old Forge-Thendara	0.3
South Shore	3.6
Big Moose	8.2
Marginal	9.0
Outside of Control	6.7

Total number of observations - 68

*No observations made before May 16, 1951.

Control was better than expected in the Old Forge-Thendara region. It was felt that the extensive P. hirtipes pupation before larviciding would reduce the effectiveness of the control measure. The probable explanation of the good control is extensive use of TIFA's. Control in the less accessible south shore area was poorer. In the Big Moose area there was no apparent control, probably because of the following factors: late treatment, a gradual diminution of enthusiasm required of volunteers treating remote streams in difficult terrain, and the lack of roads to facilitate extensive use of the truck-mounted TIFA machines.

Streams were treated with blocks from May 27 - June 1 in the Town of Webb to reduce larval populations of _S. venustum_ and _S. tuberosum_. The reduction in larval populations is reflected in the reduced populations of annoying adults during the peak annoyance period of _S. venustum_ and _S. tuberosum_ as summarized below.

Table 19. Peak annoyance period of _S. venustum_ and _S. tuberosum_, May 27-June 28, 1951

Areas	Average estimated population per observation
Old Forge-Thendara	0
South Shore	0.5
Big Moose	1.7
Marginal	1.2
Outside of Control	5.3

Total number of observations - 186

Control during this period was good, especially when compared with the same areas in 1950 during the peak annoyance period of S. venustum and S. tuberosum.

1952

In 1952, about 175 square miles were treated with larvicide applied from aircraft during the period from April 16 - 20. The area treated included Old Forge-Thendara, North Shore, South Shore, and Big Moose. In addition to these areas, part of the Town of Forestport was treated April 19-20 and again a week later. A total of 75 square miles were treated in this area. Population counts made during the peak annoyance period of P. hirtipes are summarized below.

Table 20. Peak annoyance period of P. hirtipes, May 6-30, 1952

Areas	Average estimated population per observation
Old Forge-Thendara	0.4
South Shore	0.5
Big Moose	0.5
Marginal	2.1
Outside of Control	11.0
Forestport	0.5

Total number of observations - 112

Control during the peak annoyance period of *P. hirtipes* was excellent in all areas.

Streams in the towns of Webb and Forestport were treated during the last week in May and the first week in June with DDT-impregnated blocks. Treatment in the Big Moose area was made too late for optimum control. The following table summarizes the population counts made during the peak annoyance period of *S. venustum* and *S. tuberosum*.

Table 21. Peak annoyance period of *S. venustum* and *S. tuberosum*, June 2-July 2, 1952

Areas	Average estimated population per observation
Old Forge-Thendara	0.3
South Shore	0.2
Big Moose	2.4
Marginal	3.6
Outside of control	17.0
Forestport	1.4

Total number of observations - 187

Control was excellent considering the heavy population of annoying flies outside of the control area during this period. As usual, truck-mounted TIFA's fogged local "hot spots" in the Town of Webb. No fogging was done in the Forestport area.

SUMMARY

CONTROL OPERATIONS 1950-1952

From the preceding data it might be inferred that the Old Forge-Thendara area is normally less bothered with blackflies than the Big Moose area. Unfortunately, no data were collected with regard to this point before control operations began. However, numerous townspeople in Old Forge have talked of the days before control when they were unable to work in gardens, walk short distances, stand outside, or do any work outside in the village due to the blackflies. Bleeding and raw scalps were commonplace among the children. Therefore, it would seem that while there may be differences in normal adult blackfly populations in different sections of the Town of Webb, all areas were "bad" during the blackfly season. Therefore, all differences following control can probably be safely ascribed to differences in control measures.

During the three years that observations concerning the effectiveness of control operations were made, there were six opportunities to evaluate the success of different control methods.

Adult control alone was used during the *S. venustum*-*S. tuberosum* peak annoyance period in 1950. Control was fairly good where both helicopter and truck-mounted TIFA were used and where there were many roads through the area. In the area where only a TIFA was used and roads were poor, there was no apparent control (except locally and for short periods of time.).

A combined larval and adult control program was carried out during the *P. hirtipes* annoyance period in 1950. Results of the combined operations were excellent in all areas. Larval control was carried out using DDT-impregnated plaster of Paris blocks; adult control by helicopter and TIFA fogging. Blocking for larvae combined with the use of truck-mounted TIFA's was carried out during the peak annoyance periods of *S. venustum* and *S. tuberosum* in 1951 and 1952. Control was good during these periods. In one area, streams were blocked in 1951 to reduce *P. hirtipes* populations after extensive pupation had occurred. There was no apparent control even though TIFA's were used for adult control. However, there were few roads in this area.

Larval control using aircraft combined with the use of TIFA's for adulticiding worked excellently in 1951 and 1952 against annoying P. hirtipes adults. The use of aircraft for larviciding with no supplementary adult control was carried out in Forestport in 1952, during the P. hirtipes period. Blocks only were used during the S. venustum-S. tuberosum group annoyance period in this area in 1952. Control during both periods was good.

EXPENSES OF THE TOWN OF WEBB CONTROL PROGRAM

Expenses of the control program are itemized in table 22. The success of the control program in 1948 and 1949 was not as thoroughly studied in 1948 and 1949 as 1950-1952. However, indications are that every year the over-all control has become more effective, primarily because of the more effective treatment methods. The use of the expensive helicopter fogging was discontinued after 1950.

If, for purposes of calculation, the cost of three TIFA's and a town truck is depreciated over the 5 years of active control effort, a cost of about $12,230 per year is obtained. However, a more reasonable yearly cost ($9360) would be obtained by using an average of the last two years' (1951 and 1952) expenses (including 20% of the total cost of the TIFA's and truck for each of these years). The toal area in which control was carried out during the last three years has varied little. During this pèriod a greater and greater proportion of the control area has been treated by aircraft for control of _P. hirtipes_ larvae.

It should be noted that control operations carried out in 1951 and 1952 included to applications for the control of _P. hirtipes_ and _S. venustum_ respectively. In spite of this, expenses for these years were less than for previous years.

Perhaps the major remaining item on which money could be saved is in the use of the TIFA ground machines. They are apparently effective for a limited time in limited areas. There was a tendency to use them for _psychological purposes_ when no fogging was necessary. This is expensive because of the cost of DDT, solvent, operator time, and unnecessary use of the TIFA's.

An average of about 3856 pounds of DDT per year was used for the period from 1948-1951 (see table 23).

Table 22. Expenses for blackfly control Town of Webb - 1948-1952

From the Annual Report of F. W. Burdick, Supervisor of the Town of Webb.

1948 - Town General Fund, Fly Control

Trucking oil and DDT	$158.75
Expenses	146.53
Labor	269.19
Bell Aircraft Corp.	4916.67
Socony Vacuum Corp.	500.00
Geigy Co., Inc.	1383.13
Spray outfit	54.90
Total	$7429.17

In addition, about $4000.00 was donated by hotel owners for publicity and ferry time. The helicopter contract with Bell Aircraft at $50.00 per hour included ferry time. Total flight time 120 hours including publicity and ferry time.

Total cost about $11,400.00 for 1948.

1949 - Health Fund, Fly Control

Truck	$1000.00
Payroll	1773.00
Sovacide and DDT	4375.54
Fuel gas and supplies	494.92
Helicopter and crew	6000.00
Legal	27.20
Labor and repairs	14.18
Hose	296.00
Total	$13980.84

The cost of 3 TIFA fog applicators was not included under health fund disbursements. It was included under the General Improvement Bond account at about $1500 each.

TIFA's	$5723.94

The helicopter contract called for 100 hours minimum guarantee at $60.00 per hour. About 70 hours of this were actually spent fogging.

Table 22, continued

1950 - Health Fund, Fly Control

DDT and Sovacide	$2,866.08
Helicopter and crew	6,000.00
TIFA crews	1,888.50
General expenses	275.57
Total	$11,030.15

A jeep pickup truck brought primarily to carry a TIFA cost $1,800.00. It is used as a town truck during the rest of the year. The helicopter was used as in 1949, 100 hours guaranteed at $60.00 per hour.

1951 - Health Fund, Fly Control

DDT, Sovacide, plaster of Paris, twine	$3,471.97
Spraying contract	2,500.00
Payroll	3,692.84
General expenses	204.48
Total	$9,869.29

1952 - Health Fund, Blackfly Control

DDT, Sovacide, plaster of Paris, twine	$2,345.40
Spraying contract	2,854.40
Payroll	1,930.73
General expenses	216.40
Total	$7,346.93

Table 23. Amount of DDT in pounds used by the Town of Webb for blackfly control in 1948-1952.

Year	lbs. left from preceding year	lbs. purchased	Total lbs. on hand	lbs. used
1948	0	4730	4730	3530
1949	1200	3600	4800	3600
1950	1200	4220*	5420	3442
1951	1978	4570*	6548	4850
1952	2900	2100	5000	-

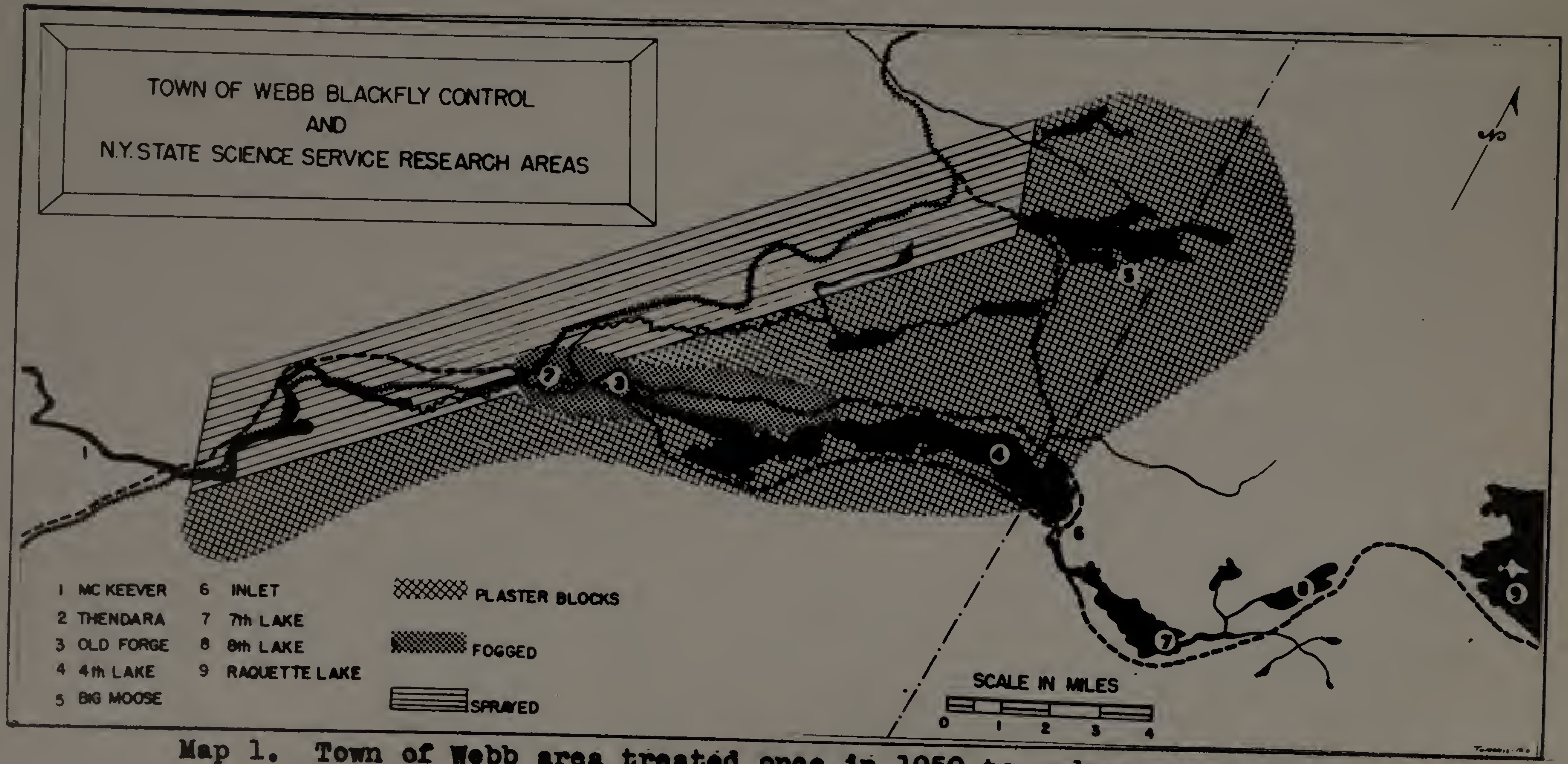
The underlined figures are approximations.

*Includes 2 barrels of 25% emulsifiable DDT per year, equals 220 pounds DDT per year, for making blocks.

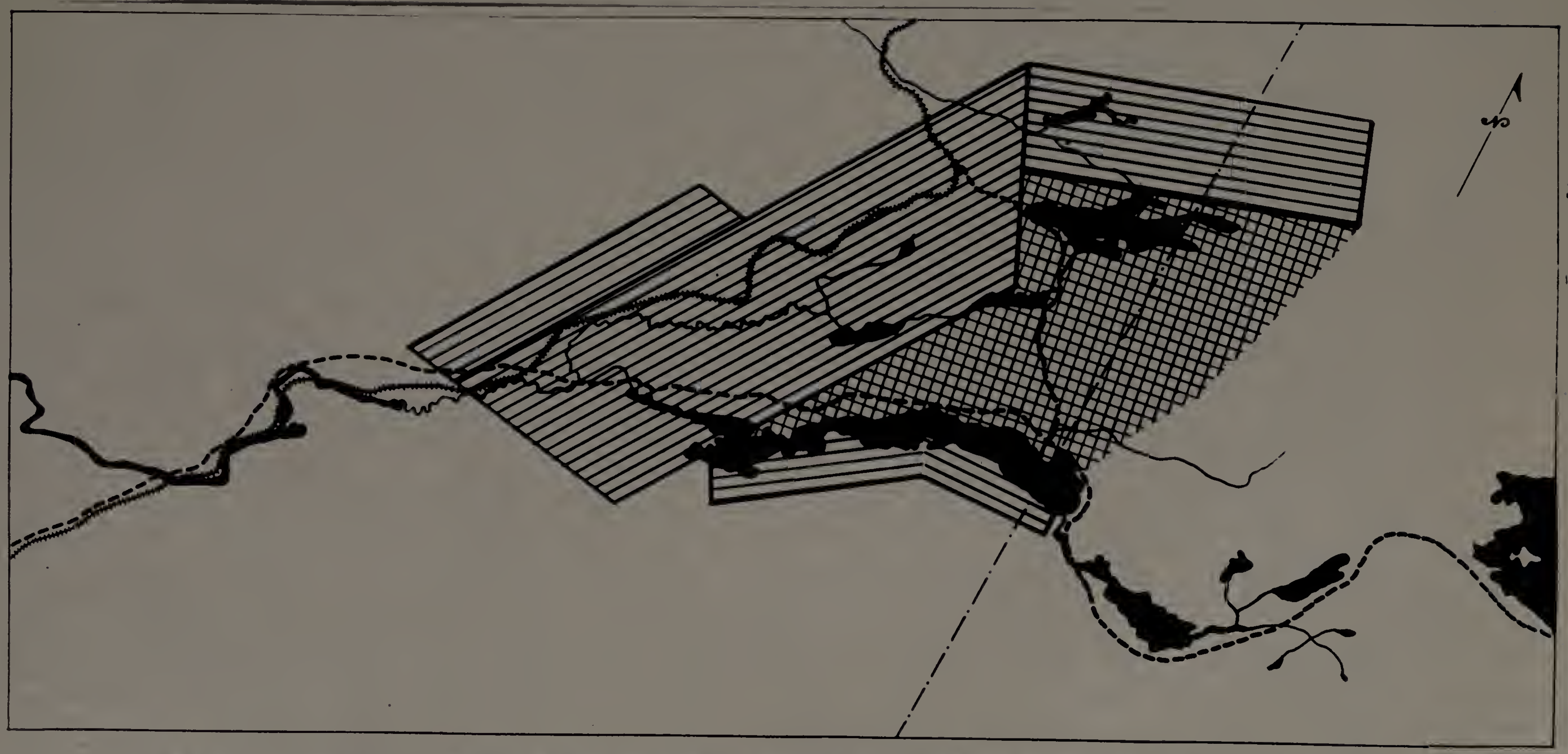
AMOUNT OF DDT IN EACH PLASTER OF PARIS BLOCK

Since the Town of Webb formula for making DDT-impregnated blocks was the same as that of Prevost (1948a) except that the quantities involved were increased five-fold, it was assumed that five times as many blocks would be made using the Town of Webb formula. Calculations of dosages were made on this assumption in 1950. In 1951, experimental blocks using TDE instead of DDT were made by the author and it was found that the amount of plaster of Paris indicated in Prevost's formula was insufficient to make four blocks 12 inches by 3 inches by 3/4 inch. In checking with the men who actually made the blocks in Old Forge and Big Moose, it was found that only 12 blocks of the above dimensions were being made instead of the calculated 20 blocks. Therefore, instead of having 1.1 ounces of DDT in each block, as was calculated in 1950, there were 1.8 ounces of DDT in each block. The actual dosages in 1950 were, therefore, somewhat higher than was indicated by the figures in the 1950 progress report. The following table reveals the 1950 figures for experimental treatments, as given in 1950, and the corrected figures for these treatments.

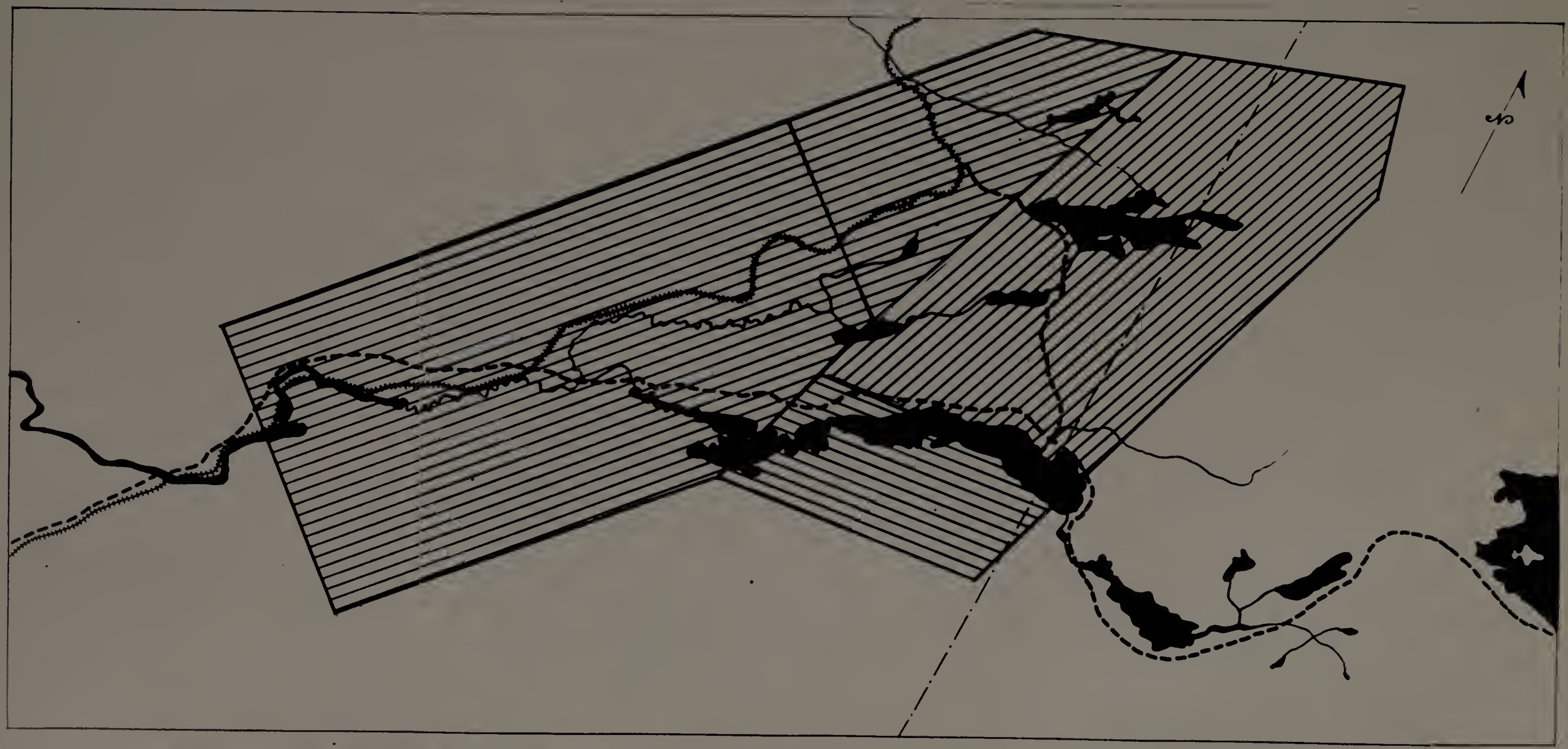
1950 report figures	corrected report figures
0.006 ppm for 48 hours	0.01 ppm
0.004 ppm for 24 hours	0.0068 ppm
0.002 ppm for 24 hours	0.0033 ppm
0.0006 ppm for 24 hours	0.001 ppm
0.0005 ppm for 24 hours	0.0008 ppm
0.0003 ppm for 24 hours	0.0005 ppm



Map 1. Town of Webb area treated once in 1950 to reduce populations of *P.hirtipes*.



Map 2. Town of Webb area treated twice in 1951 to reduce populations of *P.hirtipes* and the *S.venustum*-*S.tuberosum* complex.



Map 3. Town of Webb area treated twice in 1952 to reduce populations of *P.hirtipes* and the *S.venustum*-*S.tuberosum* complex.

SECTION IV. EFFECTS OF STREAM TREATMENTS FOR BLACKFLY LARVAL CONTROL ON OTHER WILDLIFE *

THE EFFECTS OF DDT ON MAMMALS, BIRDS, REPTILES, AND AMPHIBIANS

Because of the great toxicity of DDT to insects, there has been some apprehension as to its possible effects on both invertebrates and vertebrates. Laboratory tests have shown DDT to be toxic, in varying degrees, to vertebrates (Orr and Mott, 1945; Coburn and Treichler, 1946; Ellis et al., 1944, and others). The effects of large scale applications of DDT on wildlife under field conditions have also been studied by some workers (see below).

Since dosages used in the Adirondacks were much lower than those reported to be injurious to vertebrates, no experimental studies dealing with the effects of DDT on wildlife were carried out in this area. A review of the literature dealing with the effects of DDT on vertebrate wildlife is presented to summarize available information on this topic.

*Tables in each section numbered independently.

Mammals

Large scale applications of as much as 6 pounds of DDT in oil solution per acre have produced no apparent injury to mammals (Coburn and Treichler, 1946; Cottam and Higgins, 1946; Ericksen, 1947; Goodrum *et al.*, 1949; Speirs, 1949; Adams *et al.*, 1949; Mackie, 1949; Stickel, 1946, 1951). Not until dosages of 100 pounds per acre were applied were symptoms induced in chipmunks, mice, shrews, or bats (Mackie, 1949; ref. from Brown, 1951).

Birds

Dosages of DDT in oil solution applied at the rate of 5 pounds or more per acre (or frequently repeated slightly lower dosages) are detrimental to many species of birds (Cottam and Higgins, 1946; Hotchkiss and Pough, 1946; Robbins and Stewart, 1949; Speirs, 1949). Dosages of 3 pounds of DDT per acre of less apparently caused little or no injury to birds (Cottam and Higgins, 1946; Hotchkiss and Pough, 1946; Stewart *et al.*, 1946; Ericksen, 1947; Kendeigh, 1947; Adams *et al.*, 1949; Goodrum *et al.*, 1949). Mitchell (1946) reported that DDT in oil solution applied at the rate of 5 pounds per acre had no apparent effect on eggs or nestlings.

Reptiles and Amphibians

DDT in oil solution applied at the rate of 1 pound per acre or more may, under some conditions, injure some species of reptiles and amphibians. Water snakes and amphibians in shallow pools seem to be particularly susceptible (Cottam and Higgins, 1946; Goodrum *et al.*, 1949). High concentrations have been used, in some cases, without apparent injury to reptiles or amphibians (Cottam and Higgins, 1946; Tiller and Cory, 1947; Stickel, 1951).

THE EFFECTS OF DDT ON STREAM FISH

DIRECT EFFECTS

Judging from the literature, 1 pound of DDT in oil solution per acre is about the upper limit which can be applied without extensive injury to trout (Surber, 1946; Surber and Friddle, 1946; Evendon, 1947; Adams *et al.*, 1949). Fallfish, bluegills, common shiners, common suckers, golden shiners (Surber, 1946) cottoids, mountain suckers, and black bullheads (Adams *et al.*, 1946) are apparently somewhat more susceptible than trout.

Studies of the effects of stream treatment for blackfly control of fish populations have been made by some workers. Garnham and McMahon (1947) reported some fish kill in experiments using high dosages of DDT emulsion (up to 35.6 ppm for 30 minutes) in Kenya.

In trough tests, Cope, Gjullin, and Storm (1947) reported that blackfly larval control was effective at dosages well below the limits of tolerance of the fish tested. Fingerlings of silver and king salmon exhibited the same order of tolerance as rainbow trout. Dolly Varden trout of the same size group were slightly more resistant to emulsions than rainbows. Rainbow trout were disabled by DDT emulsions applied at the rate of 8 ppm for 15 minutes and killed or rendered helpless by 12 ppm for 24 hours. When DDT solution was used rainbow trout were not disabled by concentrations of less than 35 ppm for 15 minutes.

Kindler and Regan (1949) reported that good blackfly control was obtained using DDT emulsifiable concentrate applied at the rate of 0.2 ppm for 10 minutes. Small trout were only slightly affected by this treatment when concentrations of 1 ppm for 10 minutes were used. They were severely affected by 2 ppm for 10 minutes. Larger fish were affected at 3 ppm for 10 minutes and some fish were killed at 5 ppm for 10 minutes.

Arnason et al., (1949) using DDT solution with emulsifier and dye added, noted no injury to several species of fish placed in live boxes for study during treatment of the South Saskatchewan River. Blackfly larvae were eliminated by this treatment for at least 17 miles below the point of application. Field observation of the North Saskatchewan River, which was treated at the rate of 0.176 ppm for 15 minutes using the same formulation, indicated that there was no injury to fish. However, blackfly larval populations were not greatly affected by this treatment, either. In other tests, DDT did not apparently injure common river fish at concentrations of as high as 25 ppm for 30 minutes.

Gjullin et al. (1949a), reported that DDT in fuel oil was completely effective against blackfly larvae at 0.4 ppm for 15 minutes and was not injurious to trout at 10 ppm for 15 minutes (highest tested dosage). Trout were unaffected by DDT-acetone solution at 0.3 ppm for 15 minutes while blackfly larvae were eliminated by this treatment.

Hocking et al., (1949) in field observations, noted no injury to fish in a stream treated with DDT in oils solution at the rate of 0.176 ppm for 15 minutes.

Curtis (1949) noted that DDT emulsifiable concentrate effectively reduced blackfly larval populations while trout fry could withstand dosages nearly four times as great without harmful results and nearly eight times as great with only slight mortality.

Hocking (1950) reported that jackfish (Esox lucius), suckers, and trout did not suffer any visible or permanent injury from single dosages of DDT up to 600 ppm-min. (probably 40 ppm for 15 minutes) in tank tests. Some symptoms in jackfish were noted at 100 ppm-min. (probably 6.7 ppm for 15 minutes). The 50 LD of sticklebacks was reached at 150 ppm-min. (probably 10 ppm for 15 minutes).

Twinn (1950) reported that 30% DDT-methylated naphthalene concentrate was applied to the South Saskatchewan River at the rate of 0.39 ppm for 24 minutes and 0.113 ppm for 16 minutes. These concentrations killed large numbers of fish. Twinn noted that, unlike fuel oil or kerosene, this preparation was heavier than water. It was observed being carried along the bottom in droplet form. Results of analyses of stomach contents of fish killed by the treatment indicate that they had been killed by swallowing globules of the DDT concentrate.

INDIRECT EFFECTS

In evaluating the indirect effects of stream treatment on fish due to reductions in fish food it is necessary to know the feeding habits of the fish involved. Most of the studies of stomach contents of rapid stream fish have dealt with the Salmonidae (both trout and salmon) since they are the most important game and commercial fish in these streams.

Food eaten by these fish is made up, to a large extent, or arthropods (Ricker, 1930 and others). The numbers of the various kinds of arthropods found in fish stomachs depend on the kinds of arthropods and the number of each kind available. Hess and Rainwater (1939), Leonard (1941), Hess and Swartz (1941), and Allen (1941a, b), have reported that the relationship is not directly proportional. The relative proportions of the different groups are dictated by food preferences of the fish, and the location and availability of the food organisms.

As the fish increase in size, the diet changes (Ricker, 1934; Metzelaar, 1928, 1929; and Clemens, 1928). Midges, *Canthocamptus* (a Copepod), *Entomostraca*, and other smaller arthropods, are found in the stomachs of small trout (about 1 inch); larger insects including mayflies, stoneflies, caddisflies, and some Chironomids are found in the stomachs of larger fish (about 5 inches); crayfish and fish are found in the stomachs of the larger trout (Ricker, 1934).

There are also seasonal changes in diet. In the winter almost all of the food is made up of aquatic organisms (Ricker, 1934; Needham, 1930; Lord, 1930). In the summer half or more of the food is aquatic in origin and half terrestrial in origin (Lord, 1930; Dimick and Mote, 1934; Surber, 1933).

As these studies indicate and as Muttkowski (1929) reported, trout are "opportunists" where food is concerned. That is, a decline in one kind of food is compensated for by increased consumption of other types of food. Adams _et al_. (1949), reported a change in diet of trout in a stream heavily treated with DDT, this change being due presumably to decreases in "preferred" types of food. A temporary decline in the number of arthropods of aquatic origin available as food in the spring or summer would be compensated for by increased surface feeding on arthropods either of terrestrial origin or those migrating from other streams or lakes. On the other hand, an overdosage of larvicide in the fall greatly reducing stream arthropod populations during the fall and winter, would have an indirect adverse effect on fish since few or no arthropods other than those present in the stream would be available.

Blackfly larvae may, at times, make up a substantial proportion of the fish diet in rapid streams (Dimick and Mote, 1934; Leonard, 1941; Allen, 1941b; Idyll, 1942). Other workers report that blackfly larvae may make up only an insignificant proportion of the fish food (White, 1930; Chapman and Quistorff, 1938; Cope _et_ _al_., 1947; Gjullin _et_ _al_., 1949; Hocking, 1950). Differences have been noted in the number of blackfly larvae found in the stomachs of different species of trout in the same streams (Idyll, 1942) and the same species in different streams (Allen, 1941). Blackfly larvae have been found in large numbers in a few trout collected from a given stream while other trout have nearly or absolutely no blackfly larvae (Leonard, 1941, and others). Because of the omnivorous diet of trout, a great reduction in the number of blackfly larvae available as trout food is probably not detrimental to fish, providing that there is sufficient other food available.

Surber (1946) fed blue gills with flies killed by DDT with no mortality. However, four out of thirty brook trout fed heavily on insects paralyzed by DDT died. In 1947, Ginsburg reported that mosquito larvae killed by DDT in ethanol were not toxic to goldfish. In laboratory tests, (Langford, 1949) flies and trout fingerlings were exposed or injected with DDT in oil solution or as a technical powder. *Semotilus atromaculatus*, *Perca flavescens*, and *Salvelinus fontinalis* were killed by these treatments. In field tests, minnows which fed heavily on insect larvae and nymphs killed by DDT were apparently unaffected.

From these limited data it would appear probable that fish are not affected by feeding upon insects killed by DDT unless the insects are killed by contact with large amounts of the insecticide. This is not the case in streams treated to reduce blackfly larval populations.

THE EFFECTS OF DDT ON STREAM ARTHROPODS OTHER THAN BLACKFLY LARVAE

SAMPLING ARTHROPOD STREAM POPULATIONS

Before taking up the effects of stream treatment for blackfly larval control on other aquatic arthropods, it would be well to consider the methods used in gathering and evaluating such data.

Most quantitative stream studies have stressed the difficulties in obtaining representative samples and in determining the size of the sampling error. Various types of samplers have been used. In deep rivers, especially those with muddy bottoms, dippers and Petersen dredges (Richardson, 1921a, 1921b, 1928), dip nets and Ekmann (sic.) dredges (Ludwig, 1932), Birge-Ekman bottom samplers, and box samplers (Jonasson, 1948), sagnets and shovel nets (Percival and Whitehead, 1929) have been used. In shallower streams, square foot boxes, hand screens, and strainers were used by Needham (1928, 1934). Hoffman et al. (1946) used square foot area cylinders and Ide (1940) used a square yard emergence trap.

In 1934, a group of limnologists including H. S. Davis, P. R. Needham, A. S. Hazzard, and E. Surber adopted a standard method of sampling using an easily portable square foot sampler (Surber, 1937). Many workers, especially in the United States and Canada, have adopted the use of this square foot sampler (with occasional slight modifications).

This square foot sampler is essentially similar to that used in the Adirondack studies that are reported in this paper.

The square foot sampler used in the Adirondacks was made of iron. The base has inner dimensions of 1 foot on each side of the four sides and is made up of four pieces of angle iron welded together to form a square. Each flange of the angle iron is 1.75 inches in width. At the one end of the base two vertical pieces of lighter and narrower angle iron are welded, one on each side. These are each 1 foot in length and are joined together at the top by a transverse piece of light angle iron slightly more than 1 foot in length (giving inner dimensions of 1 foot both horizontally and vertically). The flanges of the vertical and transverse posterior pieces are arranged so as to form a lip around which the hem of the net may be firmly fastened by passing a wire through the hem and drawing it tight around the flanges of the upright and transverse, pieces of angle iron. The vertical pieces of angle iron are strengthened by oblique straps of iron on each side. These are welded to the base near the other end and to the vertical pieces near the apex on each side. A triangular piece of copper screen was fastened to each side of the sampler to prevent macroscopic organisms from flowing around the edges of the net. The entire sampler, with the exception of the copper screening and net, was painted with red lead to prevent rusting. The net used to capture the dislodged organisms was made of nylon (see text fig. 1).

To take a square foot sample, the sampler was pressed firmly into the bottom of a riffle. Stones enclosed by the square foot were then examined for closely clinging orgnaisms which were removed before the stones were discarded. The remaining gravel, silt, sand, or debris was then thoroughly agitated so that most of the arthropods in the square foot area were washed into the net. This technique was standardized as much as possible in an attempt to obtain consistent results.

After the organisms in the square foot were washed into the net the sampler was removed from the stream and the organisms washed from the net into a

Text figure 1. Square foot bottom sampler.

white enamel tray containing water. The organisms were then picked out, while still alive, and placed into a vial containing preserving fluid. It was easier to remove the arthropods in the field while they were still alive and moving than preserving the entire contents of the net and sorting the material later in the laboratory.

The use of a square foot sampler has some disadvantages. It is not possible to sample pool bottoms effectively since water movement is required to carry the organisms into the net. It is difficult to use the sampler on soft or mucky bottoms or where there are numerous rocks. Finally, the number of organisms collected from a single square foot sample may take several hours to sort where organisms are very numerous.

The number of organisms found in a single stream will vary greatly depending on the type of bottom (sand, stone, mud, etc., Behning, 1928; Percival and Whitehead, 1929; Pate, 1932, 1933, 1934; Lastochkin, 1945; Pennak and Van Gerpen, 1947; Jonasson, 1948). Fortunately, mountain streams, such as occur in the Adirondacks, apparently have fewer organisms per unit area than lowland streams (Pennak and Van Gerpen, 1948).

Because of the time involved in sampling and sorting, the distances between stations, and the annoyance caused by blackflies, as a general rule only one sample was taken at each station on any one day. Since only one sample was taken at any one time, there was some question as to the degree of reliability of the sample as an estimate of the population of the area of the stream sampled.

The studies of Mottley *et al.* (1938) and Leonard (1939) indicate that caution should be used inevaluating stream populations based on a SMALL NUMBER of unit area samples. Thirty-five samples taken by eight individuals (Mottley *et al.*, 1938) in a single stream were analyzed. The mean number of specimens per 1000 square cm. was 161.9, the standard deviation was 94.1 and the standard error was 15.9. This is a very great variation indicating the need for caution in evaluating data derived from square foot samples.

A series of five samples taken by Leonard

(1939) from a single stream varied from 574 to 1118 in the number of individuals taken. A series of ten samples taken from another stream varied from 520 to 983 in numbers of individuals.

Series of riffle samples taken in Adirondack streams indicate that there is considerably less variation than reported by these workers. It should be noted, however, that the number of organisms found in samples in the Adirondacks is much less than reported by either of these workers.

For purposes of quantitative comparisons, the number of arthropods included in counts excludes all supraneuston, blackfly, and midge larvae, all pupae, and all other arthropods as small or smaller than large stream copepods. Supraneuston were excluded because of the ease with which they could jump out of the collecting tray; blackfly larvae were excluded because of this unusual habitat preferences and "contagious" distribution; midge larvae were excluded because they ranged in size from near microscopic to large, making selection of macroscopic fauna more subjective than desirable; pupae were excluded because of the difficulty in determining the effect of stream treatment on organisms in this stage; other organisms as small or smaller than large copepods were excluded because of the difficulties in sorting small specimens in the field.

Experience derived from three years of stream sampling indicate that it is important for the person sampling to be familiar with the stream fauna being sampled (as was noted by Hoffman et al., 1946). Even in very homogeneous appearing areas of a stream, small pockets of leaves, a few twigs, or an eddy may influence greatly the number of organisms found in that particular square foot sample. In a given riffle, when a series of samples are taken the bottom should be relatively uniform, the depth, rate of flow, and distance from the margins of the stream should be similar for each sample.

For purposes of calculation it was assumed that there was a random distribution of arthropods in the homogeneous area of the riffle being tested. It was also assumed that the mean of four square foot samples gave a true picture of the arthropod fauna in a homogeneous riffle of the stream. Since four samples were taken in a series of streams with different sized arthropods populations it was necessary to assume that the variances of the samples in all tests were constant and independent of the size of the sample.

The standard deviation (SD) was calculated from the pooled variance of 21 tests of 4 samples each (see table 1). The standard deviation thus obtained seems to be the most practical estimate of the amount of variation to be found in single observations.

With this estimate of population standard deviation it becomes possible to infer with 95% probability that the true mean is included in the number of arthropods taken in a single sample plus or minus two standard deviations (where 2 is the "t" value for 63 degrees of freedom, i.e., n(k-1). In this case the number of arthropods in a single square foot sample plus or minus 5.6 will be 95% likely to include the true number of organisms in the homogeneous area of the stream being tested.

Table 1. Replicates of square foot riffle samples taken in Adirondack streams

No. of Arthropods per Sample	Mean ($\bar{x}$)	Deviations	Sum of squared deviations
0,0,1,3.	1.00	1,1,0,2.	6.00
1,1,2,4.	2.00	1,1,0,2.	6.00
1,1,2,4.	2.00	1,1,0,2.	6.00
3,5,5,6.	4.75	1.75,0.25,0.25,1.25.	4.75
6,8,8,9.	7.75	1.75,0.25,0.25,1.25.	4.75
7,8,11,12.	9.50	2.50,1.50,1.50,2.50.	17.00
7,10,12,12.	10.25	3.25,0.25,1.75,1.75.	16.75
9,10,12,15.	11.50	2.50,1.50,0.50,3.50.	21.00
13,14,16,16.	14.75	1.75,0.75,1.25,1.25.	6.75
14,14,15,17.	15.00	1.00,1.00,0.00,2.00.	6.00
16,17,17,19.	17.25	1.25,0.25,0.25,1.75.	4.75
13,18,18,21.	17.50	4.50,0.50,0.50,3.50.	33.00
17,21,22,23.	20.75	3.75,0.25,1.25,2.25.	20.75
15,22,24,25.	21.50	6.50,0.50,2.50,3.50.	61.50
19,21,24,30	23.50	4.50,2.50,0.50,6.50.	69.00
19,24,25,26.	23.50	4.50,0.50,1.50,2.50.	29.00
20,21,23,33.	24.25✓	4.25,3.25,1.25,8.75.	106.75
23,24,28,28.	25.75	2.75,1.75,2.25,2.25.	20.75
23,27,28,29.	26.75	3.75,0.25,1.25,2.25.	20.75
33,34,35,37.	34.75	1.75,0.75,0.25,2.25.	8.75
43,46,48,48.	46.25	3.25,0.25,1.75,1.75.	16.75
		TOTAL	486.75

$$\mathrm{SD} = \sqrt{\frac{d^2}{n(k-1)}}$$

$$= \sqrt{\frac{486.75}{63}}$$

$$= \sqrt{7.73}$$

$$= 2.8$$

Qualitative studies of the possible changes in the composition of stream fauna were made in several ways:

Arthropods collected in square foot sampler were identified to family or genus depending on the group involved.

Five-minute samples were taken by placing the square foot sampler in a swift portion of the stream for five minutes. At the end of this period the sampler was removed and the contents of the net collected. This method is similar to that used by Hoffman and Surber (1945). Samples were taken before, during, and after treatment.

Finally, qualitative studies based on field observations were made in some of the smaller streams where the stream bottom could be readily observed.

The data derived from these qualitative studies are analyzed beginning on page

LITERATURE REVIEW

Hoffman and Surber (1945) studied the effects of aircraft application of 1 pound of DDT (as wettable powder) per acre on invertebrate fauna. Square foot samples were taken before and after treatment both above and below the treatment point. Survival of as few as 26% of the invertebrates was noted in some areas. Immature Trichoptera, Ephemeroptera, and coleopterous adults (Elmidae) were found to be susceptible while most of the large carnivorous Plecoptera naiads, Elmidae larvae, and immature Megaloptera were not affected. No Odonata naiads were collected in stream samples before treatment but a few were collected in samples taken after treatment. Five-minute samples of the organisms being carried downstream indicated that 90% of the affected invertebrates were carried downstream during the first three hours.

Hoffman et al. (1946), reported that square foot riffle sample studies in a temporary stream indicated reductions of as high as 92% of the invertebrate fauna of a stream treated by aircraft with 4-5 pounds of DDT per acre. In a larger stream (10 feet wide and 10 inches deep), treated by aircraft with the same dosage, reductions of as high as 90% of the stream invertebrate fauna were noted. A third stream (6 feet wide and 6 inches deep), treated in the same way, had reductions of up to 87% of the stream invertebrate fauna. When a wide, deep stream (60 feet wide and 20 inches deep) was treated with 2 pounds DDT solution per acre applied by aircraft, there was no reduction which could be attributed to DDT.

Hoffman and Merkel (1948) reported that square foot samples taken in streams treated in 1945 with 1 pound of DDT in oil solution indicated a 90% reduction in invertebrate fauna a short time after treatment. One year later there was still a 39% reduction. Annelids, Mollusca, Odonata, Coleoptera, Hydracarina, and Megaloptera were little affected. Plecoptera, Diptera, Ephemeroptera, and some Trichoptera were severely affected. A stream treated by aircraft with 1 pound DDT in oil solution per acre showed a maximum reduction of 94% in a stream 7-15 feet wide and varying from a few inches to several feet in depth. Another stream was sprayed with 1 pound DDT (as wettable powder) per acre with a maximum reduction in population of 74%.

One year later the invertebrate population was greater than before treatment. This stream was then resprayed with 1 pound DDT in oil solution per acre with a maximum reduction of 90% in invertebrate fauna.

Goodrum _et_ _al_. (1949), reported that aerial application of 2 pounds of DDT (probably in oil solution) per acre over tidal mashes resulted in practically complete elimination of the abundant fiddler crabs. No immediate effect was noted on snails and mussels.

Adams _et_ _al_. (1949), studied streams treated by aerial application using 1 pound DDT in solution per acre. Square foot samples indicated that stream populations were reduced from 84 invertebrates before treatment to 3 invertebrates two weeks after treatment. Five weeks after treatment 3 invertebrates per square foot were counted and 9 weeks after treatment there were 47 per square foot. Populations in a nearby untreated stream showed no decrease during this period. In the heavily treated stream Oligochaetes, Hydracarina, Coleoptera, and Crustacea survived the treatment while Plecoptera, Ephemeroptera, Trichoptera, and

Diptera did not.

Savage (1949) noted that Odonata, Sialids, Mollusca, Copepoda, and Cladocera were strongly resistant to stream treatment with DDT. Gerridae, Gyrinidae and some Trichoptera were more sensitive.

Blackfly control workers have studied the effects of DDT on other stream fauna at dosages commonly used for blackfly larval control.

Garnham and McMahon (1947) treated two streams in Kenya 13 times over a six-month period at concentrations varying from 1.3 ppm or less to 35.6 ppm for 30 minutes using DDT emulsion. Immediately after the final treatments only leeches, crabs, and snails were found in the streams. Many types of aquatic life had returned to the treated streams 3 months after the last application. Aquatic life found at this time included: Ephemeroptera, Odonata, Culicidae, Corixidae, Gyrinidae, and Hydrometridae.

Prevost (1947) noted that emulsifiable DDT, when applied to a stream at the rate of 0.1 ppm for 24 hours, killed a great number of larvae (other than blackfly larvae).

Hocking et al. (1949), found 2600 specimens of 37 different families, only two of which it was desirable to kill in a collection of detritus at the edge of a stream previously treated with 0.48 pound DDT in oil solution per acre. (This includes adults and immature forms, both aquatic and non-aquatic.) An oil solution of DDT applied by hand sprayer at a concentration of 0.1 ppm for 30 minutes was used to treat two other streams. Cross stream screens were used to collect insects affected by the treatment. Complete counts were not made, because of the great amount of material collected in this way. Random counts indicated that an unusually large number of Crustacea were affected. Immature Plecoptera, Ephemeroptera, Trichoptera, Tipulidae, Simuliidae, Chironomidae, Empididae, Dytiscidae, and Dytiscid adults were noted in the collection.

Arnason et al. (1949), found that DDT in oil solution with emulsifier added, sprayed at the rate of 0.13 ppm for 36 minutes caused an 86.2% reduction (in arthropods other than blackfly larvae) 1.25 miles downstream and a 6.9% reduction 17 miles downstream. The population of arthropods other than blackfly larvae per square foot is given but the method of obtaining these figures is not stated.

Gjullin _et al_. (1949a), in field tests with caged caddisfly larvae, determined that no deaths were attributable to the insecticides tested at (or near) the minimum dosages needed to give complete blackfly larval control. Caddislfy larvae were not injured by DDT in fuel oil applied at the rate of 10 ppm for 15 minutes or 5 ppm DDT emulsion for 15 minutes.

Hocking (1950) experimentally used screens of different sizes to sample organisms being carried downstream due to treatment for blackfly larval control. A wide variety of organisms were caught but no qualitative or quantitative studies were attempted.

QUANTITATIVE STUDIES OF STREAMS IN THE ADIRONDACKS

In the Adirondacks, several methods of stream treatment were employed. DDT-impregnated plaster of Paris blocks and aircraft applications of DDT in oil solution were used in large scale treatments. Experimental stream treatments using various insecticides applied by hand sprayer or poured into the stream were made also.

In these studies, each stream will be considered individually. The dates of treatment, insecticide used, dosages used, and the effectiveness of each treatment in reducing blackfly larval populations will be given (where known). Each table is followed by a brief analysis of the data for each stream.

Descriptions of the streams and details of the treatment and effectiveness in reducing blackfly larval populations are given in the control section.

Aedes Brook

Aedes Brook was treated for the first time May 29, 1950 with one-third block of DDT-impregnated plaster of Paris (table 2).

Table 2. Periodic riffle samples of arthropod populations: Aedes Brook

	Numbers of arthropods taken		
Date	above*	1 mile below*	blackfly larval control
May 27, 1950	-	44	
May 28	41	50	
May 29, Treated, DDT block, 0.003 ppm for 24 hrs.			
May 30	24	28	GOOD
June 8	21	14	
June 14	21	16	
June 21	19	57	
June 27	10	-	
July 9	-	27	
Aug. 18, 1951	-	39	
April 17, 1952, Treated, Aircraft, 0.1 # DDT/swath acre			
May 1	-	53	?GOOD**
June 24	-	44	
June 24, Treated, DDT sol., 1.22 ppm for 20 min.			
June 26	-	19	GOOD
July 11	-	31	
July 23	-	29	
Aug. 15	-	33	

*Location with reference to treatment point.

**Not checked before treatment.

Since the larvicide was not effective in reducing populations of the highly sensitive blackfly larvae one mile below the treatment point (with the possible exception of aircraft application) all changes in population at this point were probably due to factors other than stream treatment. The fluctuations noted here are probably due to "normal" seasonal changes in arthropod populations (i.e., mass emergence, mass hatching, lowering of the stream, other similar factors and sampling error). The population changes in this stream were given first to aquaint the reader with the magnitude of population fluctuations in a "normal" stream population as indicated by single square foot samples.

Wheeler Creek

Wheeler Creek is outside of the regular blackfly control area. It was treated for the first time May 7, 1950 with one-half DDT-impregnated plaster of Paris block (table 3).

Table 3. Periodic riffle samples of arthropod populations: Wheeler Creek

	Numbers of arthropods taken			Blackfly Larval control
Date	above*	1/8 mile below*	1 mile below*	
May 7, 1950	-	-	-	
May 7, Treated, DDT block, 0.0005 ppm for 24 hrs.				GOOD
May 11	-	-	18	
May 22	22	-	12	
May 29	-	-	14	
May 30	107	-	-	
June 9	56	-	41	
June 15	53	-	48	
June 20	17	-	50	
June 28	32	-	49	
July 6	88	-	73	
July 17	64	-	29	
Aug. 1	78	-	12	
May 17, 1951	22	-	20	
June 7	24	44	56	
June 7, Treated, TDE block, 0.008 ppm for 48 hrs.				GOOD
June 9	32	4,4	36	
June 18	28	4,8	44	
June 26	120	8	40	
July 3	48	8	56	
July 12	68	-	20	
July 18	32	20	36	
July 26	104	24	16	
Aug. 27	36	-	-	
June 5, 1952	27	-	50	
June 5, Treated, Lindane emulsif., 0.35 ppm for 20 min.				POOR
June 10	17	-	40	
June 18	48	-	57	
June 18, Treated, DDT solution, 0.80 ppm for 20 min.				POOR
June 20	113	-	36	
July 1	129	-	66	
July 15	89	-	24	
July 23	19	-	-	
Aug. 1[illegible]	-	-	32	
Aug. 13	14	-	8	

*Location with reference to treatment point.

Table 4. Yearly averages of periodic riffle samples or arthropod populations: Wheeler Creek

Date	Numbers of arthropods taken Above*	 1 mile below*
1950	57.4	34.3
1951	60.0	38.0
1952	61.4	37.6

*Location with reference to treatment point.

It seems probable that blackfly larval control was poor in 1951 and 1952 in Wheeler Creek because of the high degree of impedition (see control section p. 152) at the time of treatment. There seems to be no significant difference between arthropod populations 1 mile below the treatment point in 1950 when the blackfly larvae were nearly completely eliminated and in 1951 and 1952 when the control was not effective at this point.

The arthropod population 1/8 mile below the treatment point shown an decline in numbers, presumably due to treatment in 1951. At the time of treatment, the stream was low. Blackfly larvae were greatly reduced for a distance of only 1/2 mile. The reduction in stream arthropods was only temporary in nature.

When normal population fluctuations and the size of the sampling error are considered, the differences in numbers of arthropods above and 1 mile below the treatment point during these treatments do not seem to be significant. The numbërs of arthropods per square foot sample taken after treatments in 1950, 1951, and 1952 are averaged in table 4.

High Rock Pond Outlet

High Rock Pond Outlet is outside of the regular blackfly control area. It was treated for the first time on May 11, 1950 with 1 block of DDT-impregnated plaster of Paris (table 5).

Table 5. Periodic riffle samples of arthropod populations: High Rock Pond Outlet.

Date	Numbers of arthropods taken Above*	1/8 mile below*	1 mile below*	1¼ mile below*	Blackfly larval control
May 11, 1950	-	-	7,13	-	
May 11, Treated, DDT block, 0.001 ppm for 24 hrs.					GOOD
May 22	9	-	8	12	
May 29	37	-	6	5	
June 5	18	-	7	-	
June 9	37	-	-	9	
June 15	37	-	14	9	
June 20	19	-	3	9	
June 28	58	-	10	16	
July 6	46	-	7	4	
July 17	24	-	9	11	
Aug. 1	63	-	16	8	
Dec. 28	-	-	20	-	
April 8, 1951	8	-	-	-	
May 17	17,21,22,23	-	22	-	
May 24	24	-	23,27,28,29	-	
May 24, Treated, TDE block, 0.003 ppm for 48 hrs.					POOR
May 26	24	15	24	-	
June 1	15	8	18	-	
June 7	15,22,24,27	17	16	-	
June 18	13	3	28	-	
June 26	13	5	19	-	
July 3	32	8	24	-	
July 11	22	10	37	-	
July 18	31	13	39	-	
July 25	50	12	43	-	
Aug. 24	26	17	18	-	
June 18, 1952	19	-	103	-	
June 18, Treated, Dieldrin, 1.36 ppm for 20 min.					GOOD
June 20	106	-	4,3	-	
July 2	99	-	6	-	
July 15	83	-	10	-	
July 30	44	-	12	-	
Aug. 13	26	-	11	-	

*Location with reference to treatment point.

The water was low at the time of treatment in 1951 and 1952 and the impedition correspondingly high.

Arthropod populations above and 1mile below the treatment point were similar in 1951, the year that blackfly larval control was not effective. The arthropod populations in 1950 and for part of 1952 were apparently reduced by the treatment. It should be noted that the dosage used in the 1952 treatment with dieldrin was far in excess of that which would be normally used in control work.

An index of the arthropod populations above and below the treatment point as indicated by an average of all the square foot samples taken after treatment each year is given in table 6.

Table 6. Yearly averages of periodic riffle samples of arthropod populations: High Rock Pond Outlet

Date	Numbers of arthropods taken	
	Above*	1 mile below*
1950	33.3	10.8
1951	24.8	26.6
1952	71.6	8.6

*Location with reference to treatment point.

Indian Brook

Indian Brook was treated for 3 years in succession with DDT solution applied by aircraft. In 1950 and 1952, the distance between swath centers was one-quarter mile. In 1951, the distance between swath centers was one-eighth mile (table 7).

Table 7. Periodic riffle samples of arthropod populations: Indian Brook

Date	Numbers of arthropods taken Below*	Blackfly larval control
April 30, 1950	41	
May 3	64	
May 3, Treated, aircraft, DDT solution 0.1#/swath acre		GOOD
May 9	43	
May 20	18	
May 30	10	
June 8	48	
June 14	8	
June 27	45	
Aug. 3	60	
April 29, 1951	10	
April 29, Treated, aircraft, DDT solution, 0.1#/swath acre		GOOD
May 15	11	
May 31	33	
June 8	24	
June 22	20	
July 2	23	
April 12, 1952	78	
April 17	38	
April 17, Treated, aircraft, DDT solution, 0.1#/swath acre		GOOD
April 21	44	
May 3	28	
May 14	29	
May 23	21	
May 27, Treated, Lindane emulsif., 0.034 ppm for 20 min.		POOR
May 29	44	
May 29, Treated, Lindane emulsif., 0.068 ppm for 20 min.		POOR
May 31	18	
June 9	36	
June 24	16	
July 11	16	
July 23	19	
Aug. 14	235	

*Location with reference to treatment point.

Indian Brook was treated at or near the source by aircraft. It was therefore not possible to take samples above the point of treatment. There was no apparent reduction in arthropods as indicated by square foot samples due to any of the treatments individually or to combined treatments.

Other streams treated primarily with DDT solution applied by aircraft

Two small temporary streams near Indian Brook on the Big Moose Fire trail were treated by aircraft on the same dates and in the same manner as Indian Brook in 1950, 1951, and 1952.

In FT #3 blackfly larvae were eliminated in all cases by the treatment. The stream was heavily treated with a DDT-impregnated plaster of Paris block in the winter of 1950 by De Foliart. Information regarding the date of treatment and the dosage involved is not available.

While few samples were taken in this stream, there was no apparent indication of year-to-year decline in arthropod populations due to stream treatments (table 8).

Table 8. Periodic riffle samples of arthropod populations: Stream FT #3

Date	Numbers of arthropods taken Below*	Blackfly larval control
April 30, 1950	15	
May 3,	Treated, Aircraft, DDT solution, 0.1#/swath acre	GOOD
Dec. ,	Treated, DDT block, dosage unknown	?GOOD**
April 29, 1951,	Treated, Aircraft, DDT solution, 0.1#/swath acre	none present
May 15, 1951	29	
April 12, 1952	88	
April 17,	Treated, Aircraft, DDT solution, 0.1#/swath acre	GOOD
April 21	50	
May 14	22	

*Location with reference to treatment point.

**No samples taken before treatment.

FT#4 was treated by aircraft as mentioned above. In this stream, aircraft treatment was unsuccessful in 1950 and 1951 in reducing blackfly larval populations. It seems likely that this was due to the small size, shortness, and location of the stream. (It runs parallel to and about half-way between swath centers.) On March 15, 1952, 0.5 pound of 3% DDT dust was applied with a hand duster to the snow over a distance of 100 feet parallel to the stream in a swath 13 feet wide. At the time of application, the snow was over 2 feet in depth.

On April 12, 1952, the snow was still 1 foot deep along the margins of the stream. The snow was almost gone by April 16, the date of aerial application of larvicide. There was no apparent reduction in blackfly larval populations until after the aerial application of DDT (table 9).

Table 9. Periodic riffle samples of arthropod populations: FT #4

Date	Numbers of arthropods taken Below*	Blackfly larval control
April 30, 1950	17	
May 3, Treated, aircraft, DDT solution, 0.1#/swath acre		POOR
May 3	13	
April 29, 1951, Treated, aircraft, DDT solution, 0.1#/swath acre		POOR
March 15, 1952, Treated, DDT dust on snow, 0.5# 3%		POOR
April 17, Treated, aircraft, DDT solution, 0.1#/swath acre		GOOD
May 3	115	

*Location with reference to treatment point

While few samples were taken in this stream, there is no evidence of a year-to-year decline in arthropod populations due to stream treatment.

Second Okara Outlet

The Second Okara Outlet was treated by aircraft application of DDT solution in 1950, 1951, and

1952. In 1950 and 1951 there was nearly complete elimination of blackfly larvae from the stream. In 1952, blackfly larvae had been eliminated before treatment by aircraft (table 10).

Table 10. Periodic riffle samples of arthropod populations: Second Okara Outlet

	Numbers of arthropods taken		Blackfly larval control
Date	Above*	1½ miles below*	
May 2, 1950,	Treated, aircraft, DDT solution, 0.1#/swath acre		GOOD
May 5	29	-	
May 6	20	-	
April 30, 1951	18	-	
May 1,	Treated, aircraft, DDT solution, 0.1#/swath acre		GOOD
May 5	7	-	
May 15	9,11	-	
June 16	-	33,34,35,37	
June 27	-	43,46,48,48	
Nov. 22	59	43	
Nov. 22,	Treated, DDT solution, 0.1 ppm for 20 min.		POOR
Nov. 23	-	50	
Nov. 24	-	26,27	
Nov. 29	-	27	
March 26, 1952	-	54	
March 26,	Treated, DDT emulsif., 0.31 ppm for 20 min.		GOOD
April 3	-	42	
April 17,	Treated, aircraft, DDT solution, 0.1#/swath acre		GOOD
April 22	-	30	
May 8	-	56	
May 31	-	14	
June 26	-	18	
July 11	-	16	
Aug. 8	-	25	
Aug. 19	-	81	

*Location with reference to treatment point.

This stream was treated on five separate occasions. Three of these treatments greatly reduced blackfly larval populations. The 1952 aircraft application would probably have been effective but larvae had been eliminated by an earlier treatment in the same year. There was no apparent year-to-year reduction in numbers of stream fauna. There were, however, temporary fluctuations which are probably not attributable to the larvicides.

Gull Lake Outlet

Gull Lake Outlet was treated for the first time on November 3, 1951 with 1 DDT-impregnated plater of Paris block (table 11).

Table 11. Periodic riffle samples of arthropod populations: Gull Lake Outlet

Date	Numbers of arthropods taken 1/4 mile below*	Blackfly larval control
Nov. 3, 1951,	Treated, DDT block, 0.003 for 48 hrs.	POOR
April 4, 1952	30	
April 4,	Treated, DDT solution, 0.24 ppm for 20 min.	GOOD
April 11	15	
April 22	29	
May 8	20	
May 31	83	
Aug. 19	11	

*Location with reference to treatment point.

There was no significant reduction attributable to the stream treatments. The decline in August is probably correlated with the normal season diminution of flow of this stream. The sample taken on April 11 was shortly after the spring run-off which may have reduced the fauna somewhat.

Cascade Brook

Cascade Brook was treated experimentally by Glasgow in May, 1949 (unpublished report). A series of tests were carried out, using one-half a DDT-impregnated plaster of Paris block and an emulsified solution of pyrethrins. Glasgow reported little apparent injury to stream fauna due to block treatments. Cross-stream nets placed below the point of treatment indicated that there was extensive injury to stream fauna due to treatment with emulsifiable pyrethrins. These insecticides were applied above the point where square foot bottom samples were taken in 1951 and 1952 (table 12).

Table 12. Periodic riffle samples of arthropod populations: Cascade Brook

Date	Numbers of arthropods taken below*	Blackfly larval control
May 1949,	Treated, DDT blocks and pyrethrins emulsif., dosage unknown	
May 1950,	Treated, DDT blocks, dosage unknown	GOOD
June,	Treated, DDT blocks, dosage unknown	GOOD
May 6, 1951	8	
March 14, 1952	20	
March 14,	Treated, DDT emulsif., 0.28 ppm for 20 min.	GOOD
March 17	29	
March 24	38	
April 18,	Treated, aircraft, DDT solution, 0.1#/acre	none present
May 5	14	
May 24	23	
June 3	15	
June 3,	Treated, emulsif. lindane, 0.15 ppm for 20 min.	GOOD
June 5	28	
June 19	15	
July 3	28	
July 17	17	
July 29	12	
Aug. 14	29	

*Location with reference to treatment point.

In 1949, the stream was heavily treated with emulsifiable pyrethrins, causing extensive, although apparently temporary, injury to the stream fauna.

Since only one square foot sample was taken before 1952 it was not possible to ascertain whether or not there was any year-to-year decline in arthropod populations. Treatments applied in 1952 had little, if any, effect on the stream populations of arthropods other than blackfly larvae.

Constable Creek

Constable Creek flows from Constable Pond for a distance of about two miles into Big Moose Lake. About 3/4 mile upstream from Big Moose Lake, Mays Pond Outlet joins Constable Creek. In the spring it is about 20 feet wide and a foot deep.

This stream has been treated for 4 years in succession (table 13).

Table 13. Periodic riffle samples of arthropod populations: Constable Creek

Date	Numbers of arthropods taken Below*	Blackfly larval control
May 1949, Treated, DDT blocks, dosage unknown		-
April 1950, Treated, DDT blocks, dosage unknown		GOOD
May 2	10	
May 20	15	
April 1951, Treated, DDT blocks, dosage unknown		GOOD
May 16	11	
May 1951, Treated, DDT blocks, dosage unknown		GOOD
May 22	3,5,5,6	
June 12	2	
Aug. 23	31	
Sept. 1951, Treated, Rotenone, dosage unknown		?GOOD**
March 22, 1952	7	
April 18, Treated, aircraft, DDT solution, 0.1#/swath acre		none present
May 5	20	
May, Treated, DDT blocks, dosage unknown		GOOD
May 27	12	
July 7	8	
July 29	12	
Aug. 14	17	

*Location with reference to treatment point.
**Not checked before treatment.

This stream has been repeatedly and sometimes heavily treated. If it is assumed that there was no great reduction in stream fauna due to the 1949 treatments, there was no apparent year-to-year effect on stream populations. The greatest reduction in stream fauna which is probably attributable to stream treatment occurred May to June, 1951. This was the second treatment of the year. The water was lower than during the early spring treatment. There was probably a considerable overdosage because it was the general practice to use the same number of blocks during both the early spring (high water) and early summer (lower water) treatments.

Salmon River

Salmon River was treated for the first time by volunteers from Blue Mt. Lake in 1950. Samples were not taken at that time (table 14).

Table 14. Periodic riffle samples of arthropod populations: Salmon River

Date	Numbers of arthropods taken Above*	 1/2 mile below*	Blackfly larval control
May 1950, Treated, DDT blocks, dosage unknown			GOOD
April 1951, Treated, DDT blocks, dosage unknown			GOOD
June 28	19,21,24,30	-	
Aug. 15	14,14,15,17	10	
Aug. 15, Treated, DDT solution, 0.03 ppm for 20 min.			GOOD
Aug. 17	30	29	
Aug. 28	20	40	
April 1952, Treated, DDT blocks, dosage unknown			GOOD
July 17	23,23,26,30	0.0,1,3	
July 17, Treated, Lindane emulsif., 0.1 ppm for 20 min.			GOOD
July 19	16	7	
July 31	23	7	
Aug. 4	22	10	
Aug. 4, Treated, 50% DDT dust, 3.2 oz., 0.16 ppm for 20 min.			GOOD
Aug. 6	16	20	
Aug. 25	19,24,25,26	7,8,11,12	

*Location with reference to treatment point.

The reason for the scarcity of arthropods below the treatment point on July 17, 1952 is not known. The last treatment previous to this sample was in April 1952 so that the low population is probably not attributable to stream treatment. There was no apparent decling in arthropod populations from year to year attributable to stream treatments.

Eaton Pond Outlet

Eaton Pond Outlet was treated for the first time on May 24, 1950, using a DDT-impregnated plaster of Paris block. Blackfly larvae were eliminated below the treatment point for a checked distance of one-third mile. Unfortunately the populations of arthropods above and below the treatment point are not strictly comparable since the treatment point was located just below a dam at Eaton Pond. The fauna below lake outlets is usually much more numerous than further downstream, with Rhyacophilidae and Philopotamidae especially numerous (table 15).

Table 15. Periodic riffle samples of arthropod populations: Eaton Pond Outlet

Date	Numbers of arthropods taken Above	100 ft. below*	1/3 mile below*	Blackfly larval control
May 24, 1950	35	18	20	
May 24,	Treated, DDT block, 0.0008 ppm for 24 hrs.			GOOD
May 25	-	34	48	
May 31	50	32	4,7	
June 12	51	17	9	
June 26	34	61	147	
July 10	57	61	73	
July 20	125	-	50	
Aug. 4	232	-	29	
Aug. 28	160	-	-	

*Location with reference to treatment point.

No samples were taken from this stream in 1951 or 1952. There was little apparent change in arthropod populations in 1950 due to stream treatment except for a short period at the lower check station. This reduction was, however, temporary in nature and may have been due to factors other than stream treatment.

Gulf Creek

Gulf Creek was treated for the first time in 1952 (table 16).

Table 16. Periodic riffle samples of arthropod populations: Gulf Creek

Date	Numbers of arthropods taken Above*#	3/4 mile below*	Blackfly larval control
March 21, 1952	46	15	
March 21, Treated, Lindane blocks, 0.002 ppm for 24 hrs.			POOR
March 25	-	16	
April 4, Treated, DDT block, 0.003 ppm for 24 hrs.			GOOD
April 10	31	8	
April 19	57	8	
April 19, Treated, aircraft, DDT solution, 0.1#/swath acre			none present
May 1	36	2	
May 19	9	3	
June 30	-	4	
Aug. 20	47	4	

*Location with reference to treatment point.

#Below point of treatment by aircraft application.

There was some apparent reduction in stream arthropod population below the treatment point possibly attributable to treatment with both DDT blocks and aircraft application.

Pine Creek

Pine Creek was treated for the first time in 1952 (table 17).

Table 17. Periodic riffle samples of arthropod populations: Pine Creek

Date	Numbers of arthropods taken above*#	1 3/4 miles below*	Blackfly larval control
March 21, 1952	55	84	
March 21,	Treated, DDT, emulsif., 0.27 ppm for 20 min.		GOOD
March 25	-	53	
April 19	32	4,4	
April 19,	Treated, aircraft, DDT sol. 0.1#/ swath acre		none present
April 23	17	-	
May 1	36	16	
May 19	106	7	
Aug. 4	50	20	
Aug. 4,	Treated, TDE emulsif., 0.20 ppm for 20 min.		GOOD
Aug. 6	35	20	
Aug. 20	45	24	

*Location with reference to treatment point.

#Below point of treatment by aircraft application.

There was a great reduction in stream populations after the first treatment. Although there was little reduction four days after treatment the populations declined greatly thereafter. This decline is probably partially attributable to stream treatment. The aircraft application of DDT and the application of emulsifiable TDE apparently had little effect on arthropod populations as indicated by square foot samples.

Loon Brook

Loon Brook was not treated experimentally and so has not been described in the control section. The estimated width (at the point sampled) was about 20 feet; the depth varied greatly during the season but was about 1.5 feet in the spring. The rate of flow in the spring was probably more than 2.5 feet per second. This stream originates on the northern slopes of Blue Ridge and flows for a distance of about 6 miles into Utowana Lake. It crosses routes 28 and 365 about 3.5 miles from the village of Blue Mt. Lake.

Loon Brook was treated for the first time in 1950 from Blue Mt. Lake by volunteer workers (table 18).

Table 18. Periodic riffle samples of arthropod populations: Loon Brook

Date	Numbers of arthropods taken Below*	Blackfly larval control
May 1950, Treated, DDT blocks, dosage unknown		GOOD
April, 1951, Treated, DDT blocks, dosage unknown		GOOD
May 21	31	
June, Treated, DDT blocks, dosage unknown		GOOD
Aug. 15	26	
April, 1952, Treated, DDT blocks, dosage unknown		GOOD
June, Treated, DDT blocks, dosage unknown		GOOD
Aug. 18	9,10,12,15	

*Location with reference to treatment point.

Too few samples of the arthropod fauna in Loon Brook were taken to determine population fluctuations each season. However, there was no apparent year-to-year decline in population.

Dart Inlet

Dart Inlet flows from Big Moose Lake into Dart Lake, a distance of about 1 1/4 miles. This stream was sampled near the point where Townsend Pond Outlet flows into Dart Inlet. It is a large, permanent stream over 50 feet in width and 0.5-1 foot or more in depth, depending on the season. The bottom of the stream is made up of small rocks and gravel in the sampling area. There are numerous large rocks further upstream.

Dart Inlet was treated for the first time by volunteers in 1949 (table 19).

Table 19. Periodic riffle samples of arthropod populations: Dart Inlet

Date	Numbers of arthropods taken	Blackfly larval control
	Below*	
May 1949, Treated, DDT blocks, dosage unknown		GOOD
May 1950, Treated, DDT blocks, dosage unknown		Good
June 20,	5	
Dec. 28,	6	
April 1951, Treated, DDT blocks, dosage unknown		GOOD
May 18,	13,14,16,16	
June, Treated, DDT blocks, dosage unknown		GOOD
June 5,	1	
July 13,	6,8,8,9	
Aug. 2,	8	
Nov. 23,	6	
March 17, 1952	23	
April 1, Treated, DDT blocks, dosage unknown		GOOD
May 5	2	
May 20	7,10,12,12	
June 19	13,18,18,21	
July 18	6	
Aug. 8	16,17,17,19,20,21, 23,33	

*Location with reference to treatment point.

Although no samples were taken before treatment in 1949, it would appear that there was a considerable reduction in the number of riffle inhabiting stream organisms present after treatment in 1950 and later. It was learned, in 1952, that, in addition to the treatmented noted in table 19, 5 gallons of emulsifiable 20% DDT was poured into the stream each spring. It was also learned that all the DDT-plaster residue from making blocks was thrown into the stream. It is therefore to be expected that the stream population would have been reduced a great deal because of these treatments.

Streams OF #31 and OF #38

Two streams crossing the South Shore Road 2 1/4 and 2 3/4 miles from Old Forge near Poles OF #31 and OF #38 respectively will be considered together since they were both treated in the same ways at approximately the same times. These streams were treated once with DDT blocks in 1950 and probably once in 1949 (table 20).

Table 20. Periodic riffle samples of arthropod populations: OF #3 and OF #31

Date	Numbers of arthropods taken		Blackfly larval control
	Below OF#3*	Below OF#31*	
May 1950, Treated, DDT blocks, dosages unknown			GOOD
April 1951, Treated, DDT blocks, dosages unknown			GOOD
May 1, Treated, aircraft, DDT solution 0.1#/swath acre			GOOD
April 11, 1952	31	6	
April 18	32	5	
April 18, Treated, aircraft, DDT solution 0.1#/swath acre			GOOD
May 2	36	32	
May 23	33	84	
May, Treated, DDT blocks, dosages unknown			GOOD
July 8	2	4	
Aug. 13	-	9	
Aug. 15	18	7	

*Location in reference to treatment point.

It seems that there was no apparent injury to stream fauna when DDT solution was applied by aircraft. There was some apparent injury when DDT-impregnated plaster of Paris blocks were used.

Nursip Brook

Nursip Brook is outside of the regular control area. It was treated for the first time May 11, 1950 with one-third block of DDT-impregnated plaster of Paris. Blackfly larvae were eliminated from the treated portion of the stream by the treatment. There was no subsequent repopulation in 1950.

Larvae of *P. hirtipes*, *C. mutata*, *S. tuberosum*, and *S. gouldingi* were collected from this stream below the treatment point in 1951 and 1952, (table 21).

Table 21. Periodic riffle samples of arthropod populations: Nursip Brook

Date	Numbers of arthropods taken 1/2 mile below*	Blackfly larval control
May 11, 1950	43	
May 11, Treated, DDT block, 0.002 ppm for 24 hrs.		GOOD
May 12	7	
May 22	3	
May 29	3	
June 9	1	
March 26, 1952	11	

*Location with reference to treatment point.

There was a great decrease in the number of riffle inhabiting arthropods in this stream immediately after, and presumable due to, treatment. The number of arthropods present almost two years after treatment was still less than before treatment. However, samples in May and March may not be strictly comparable.

Townsend Pond Outlet

Townsend Pond Outlet was first treated in 1949 by volunteers using DDT-impregnated plaster of Paris blocks (table 22).

Table 22. Periodic riffle samples of arthropod populations: Townsend Pond Outlet

Date	Numbers of arthropods taken 1 mile below*	Blackfly larval control
May, 1949, Treated, DDT blocks, dosage unknown		--
April 28, 1950, Treated, DDT block, 0.005 ppm for 48 hrs.		GOOD
May 4	5	
June 2	27	
Aug. 23, 1951	8	
Nov. 23	3	
March 17, 1952	6	
April 18, Treated, aircraft, DDT solution, 0.1#/swath acre		GOOD
July 3	35	
Aug. 14	13	

*Location with reference to treatment point.

Although only a few samples were taken from this stream, the evidence indicates that there was a considerable temporary decline due to stream treatment in 1950.

Field Observations

General field observations on the effect of treatment on stream fauna were difficult to make in large streams because of their depth, width, and speed of flow which made observations difficult. In small streams, observations of the effect of treatment on aquatic arthropods could be made by watching the organisms in the stream before and after treatment.

QUALITATIVE STUDIES IN ADIRONDACK STREAMS

Square Foot Riffle Samples

Different streams in the same area, although they may appear to be very similar, often have dissimilar arthropod faunas. However, it is possible to make some generalizations concerning the fauna of various types of Adirondack streams. Small, temporary streams have Plecoptera of the families Leuctridae and Nemouridae as the dominant groups. Larger and more permanent streams often have Ephemeroptera with one or more of the following genera as the dominant group: Ephemerella, Paraleptophlebia, Habrophlebia, or Stenonema. Plecoptera of the families Leuctridae, Nemouridae, and Perlidae may also be present in large numbers in these streams. Portions of streams just below lakes or ponds usually have Trichoptera of the families Hydropsychidae and Philopotamidae as the dominant forms, with Coleoptera of the family Psephenidae often present in relatively large numbers.

The arthropods collected in square foot riffle samples were identified to family, or to genus where possible. However, the collections were too small to have any qualitative significance when divided further than orders. All of the square foot riffle samples taken in treated streams were combined in 1950 and 1952 in order to see whether there were any gross compositional changes in the arthropod fauna of streams which had been treated 3-4 years in succession for the control of blackfly larvae. Unfortunately, most of these streams were treated once, in 1949, before sampling began in 1950. Comparisons of arthropod populations in treated and untreated streams or portions of streams in the same area in 1950 and later, however, indicated that there was no significant difference between treated and untreated streams either in number or kinds of arthropods present.

It may be argued that figures derived from combining all of the square foot samples taken during the period from March to September in 1950 and 1952 have little significance since the populations of many of the groups present fluctuated greatly during the sampling periods because of factors other than stream treatment. Furthermore, each stream has its own characteristic fauna and the streams were treated in different ways. However, it seems to the author, that by combining all samples taken each year a better idea of the "average" stream riffle fauna in a given area can be obtained than by taking samples in any one or any few streams. Since more small, temporary streams were sampled in 1950 (in connection with treatments using high concentrations of larvicide) than in 1952, more Plecoptera and fewer Ephemeroptera were collected in 1950. The data for 1950 and 1952 are summarized in table 23.

Except for the somewhat higher percentage of Plecoptera and lower percentage of Ephemeroptera in 1950 compared to 1952 there are no apparent large scale compositional changes in the stream riffle fauna. In a few heavily treated streams there were apparent increases in the more resistant Neuroptera and Hydracarina (table 24). While

Table 23. Types of riffle inhabiting arthropods in Adirondack streams, based on periodic riffle samples*

Order	Percentages of totals from all streams 1950	1952
Plecoptera	55.3	36.4
Ephemeroptera	10.9	27.3
Odonata	1.0	2.8
Trichoptera	16.7	14.3
Neuroptera	0.8	4.0
Coleoptera	2.6	4.1
Diptera	11.5	9.2
Lepidoptera	0.1	-
Hydracarina	0.7	1.5
Decapoda	0.4	0.4

*Total numbers of specimens examined and classified: 6622 in 1950 and 5349 in 1952. Forestport streams not included in totals because area is faunistically different from the Central Adirondacks.

Table 24. Types of riffle inhabiting arthropods in exceptionally heavily treated streams in 1952, based on periodic riffle samples.

Order	Percentages of totals from stream** High Rock Pond Outlet	Dart Inlet	Constable Creek
Plecoptera	70.4	13.6	10.9
Ephemeroptera	1.6	19.1	33.7
Odonata	-	5.6*	3.3
Trichoptera	5.0	28.4	14.1
Neuroptera	-	25.9*	16.3*
Coleoptera	6.3	0.9	-
Diptera	10.1	6.5	18.5
Lepidoptera	-	-	-
Hydracarina	5.6*	0.9	-
Decapoda	1.0	6.5*	-

*Unusually high percentages when compared with 1952 averages from all streams combined.

**Total number collected from High Rock Pond Outlet 575, total from Dart Inlet 324, and total from Constable Creek 92.

it seemed that these increases were not only relative but absolute (i.e., an actual increase in numbers), sufficient data were not available to demonstrate this. At any rate, these differences are not significant in the over-all average.

In contrast to these general averages for all streams in 1950 and 1952, the faunal composition of three heavily treated streams in 1952 is given in table 24.

It may seem to be rationalization to consider small percentage changes in Odonata, Neuroptera, Hydracarina, or Decapoda as significant while much larger deviations from the average occur in Plecoptera, Ephemeroptera, Trichoptera or Diptera. However, the number of specimens in the latter orders fluctuated greatly from stream to stream while the number of specimens of the former orders were present in small numbers in many streams but were never dominant in untreated streams.

Five-minute samples

A description of the technique used in taking five-minute samples is given on page of this section, and their use in studying effects of treatment on blackfly larvae is given in the control section (page 140).

Five-minute samples were taken in OF #38 on April 30, 1951 before and after application of DDT oil spray by aircraft. During a period of 3.5 hours after treatment, five-minute samples were taken every half hour beginning one-half hour after treatment. These samples were compared to samples taken before treatment. Few organisms were caught in five-minute samples taken before treatment. A total of 285 organisms were taken after treatment. Of these, 280 were blackfly larvae and 5 were other aquatic arthropods.

Five-minute samples were taken in Indian Brook on April 17, 1952 before and after application of DDT oil solution by aircraft. During a period of 3.5 hours after treatment, five-minute samples were taken every hour. A total of about 10,518 organisms were collected (aliquot estimates made of large samples). All but one of these organisms were blackfly larvae.

These five-minute samples are further strong evidence that blackfly larvae are more susceptible to DDT than other stream arthropods, and therefore, that blackfly larvae can be cleared from streams by dosages that will not affect most other organisms.

Field Observations

Townsend Pond Inlet

Riffles in Townsend Pond Inlet were too small to sample using regular square foot riffle samples. It was treated on April 29, 1950 with 1 DDT-impregnated plaster of Paris block. The calculated dosage was 0.01 ppm for 48 hours. Blackfly larvae were eliminated from the treated portion of the stream and were not found in 1951 or 1952 below the treatment point. This was obviously a very heavy overdose. Five minutes after treatment began, Plecoptera were seen drifting helplessly in the current. They could be seen coming from the normal habitats, under leaves, sticks, and stones into the open. Their movements appeared to be uncoordinated and swimming was erratic. Their bodies arched upwards and many drifted downstream venter upwards collecting in large numbers in pools and eddies. A pool sampled April 29, 1950 before treatment had 40 arthropods per square foot. On May 1, 1950, two days after treatment, a square foot sample of pool bottom about 200 feet below the treatment point contained approximately 16,400 arthropods, mostly Plecoptera (Leuctridae and Nemouridae) all dead or dying. Most of these Plecoptera were found dead and decaying 11 days later. Forty-eight hours after treatment began many Tipulids were noted crawling about in the pools. Many Limnophilids had lost their cases and were lying helplessly on the pool bottom, occasionally moving their legs and twisting their bodies in a very feeble manner. Many of the smaller Trichoptera were dead in 48 hours. The larger Trichoptera, the Tipulidae and the Plecoptera were almost all dead 11 days later.

Nursip Brook

Nursip Brook was intentionally overdosed May 11, 1950 with 0.002 ppm DDT emulsion for 24 hours. Square foot riffle samples taken one-third of a mile below the treatment point indicate that the entire arthropod stream population was eradicated, with the exception of Hydracarina and Decapoda. A single live Plecopteran was found here 11 days after treatment. None were found after this date until June 28, 1950.

Before treatment 41 Plecoptera were collected in a square foot riffle sample. Pool samples taken below the treatment point at this time indicated that there were over 300 Plecoptera per square foot of pool. At this time, all the Plecoptera were alive although they showed the effects of DDT poisoning. Eleven days after treatment, about one-third of those collected from the pool bottom were dead. Eighteen days later, many dead Plecoptera were observed and collected here. Many live and apparently normal Plecoptera were collected in pool samples 29 days after treatment.

The fact that many of these insects affected by DDT survived is of interest because it was previously believed that all arthropods obviously affected by the DDT, and being helplessly carried downstream by the current were either dead or dying.

North Branch Indian Brook

Observations in the North Branch of Indian Brook, a small stream (about 3 feet wide and 8 inches deep) before, during, and after treatment with DDT solution by aircraft on April 17, 1952 revealed large numbers of blackfly larvae but very few other organisms being carried downstream by the current after treatment. None were seen before treatment. They were carried, by the current, into backwaters and to the bottom of pools. All of the larvae examined one day later were alive and apparently uninjured. Two days after treatment some of the larvae were still alive but many were dead. Five days after treatment all of the blackfly larvae were dead and mold could be seen growing on the dead masses of blackfly larvae. A sample of one of these masses of dead larvae included 134 dead blackfly larvae, 6 live Chironomidae larvae and 10 small live crustaceans.

SUMMARY - EFFECTS ON OTHER STREAM FAUNA

All available data indicate that blackfly larval populations may be greatly reduced or eliminated from streams without apparent injury to other stream fauna. Instances where injury did occur usually were directly traceable to "overdoing," that is, dosages considerably above those required to effect the desired blackfly reduction.

Stream treatment with DDT in oil solution applied by aircraft at the rate of 0.1 pound per swath acre (with swath centers either one-eighth or one-fourth mile apart) was the method found least injurious to other arthropods. Under these conditions, no injury to arthropods other than blackfly larvae could be discovered while the overall blackfly larval population was reduced more than 85 per cent.

When DDT-impregnated plaster of Paris blocks were used, concentrations of 0.001-0.0005 ppm for 24 hours were successful in greatly reducing blackfly larval populations while causing little or no reduction in the populations of other stream arthropods.

When DDT emulsifiable concentrate or oil solution was applied by hand sprayer or poured into a stream, dosages of 0.1-0.3 ppm for 20 minutes (depending on the size of the stream) proved to be effective in greatly reducing blackfly larval populations with slight or no reductions in populations of other stream arthropods.

Within the recommended range of dosages for treatment with DDT-impregnated plaster of Paris blocks or application of DDT by hand sprayer or pouring there may be injury unless the following precautions are observed:

Small streams (less than 10 cubic feet per second) require proportionately higher dosages than larger streams. Either 0.001 ppm for 24 hours using blocks or 0.3 ppm for 20 minutes will probably give good control without causing extensive injury to other stream arthropods. In these streams applications of larvicide must be made at shorter intervals (see control section, p. 192).

Medium sized streams (10-40 cubic feet per second) may be treated with proportionately lighter dosages without decreasing the effectiveness of the control.

Large streams (over 40 cubic feet per

second) may be successfully treated with DDT blocks using 0.0005 ppm for 24 hours or with 0.1 ppm for 20 minutes using a hand sprayer or pouring. Higher dosages in medium sized or large streams may cause extensive stream injury.

Large scale stream treatments in the Adirondacks repeated one to two times per year for 3 to 4 years had little or no apparent effect on populations of stream arthropods other than black-fly larvae. Neither the size of the population nor the composition of the arthropod stream fauna was affected by these treatments, except in a few streams that were overdosed.

REFERENCES CITED*

Adams, L., Hanavan, M., Hosley, N., and Johnston,D.
1949. The effects on fish, birds, and mammals of DDT used in the control of forest insects in Idaho and Wyoming.
Jour. Wildlife Manag. 13: 245-254.

Allen, K. R.
1941a. Comparison of bottom faunas as sources of available fish food.
Trans. Amer. Fish. Soc. 71: 275-283.

1941b. Studies on the biology of the early stages of the salmon (Salmo salar). 2.
Jour. Anim. Ecol. 10: 47-76.

Arnason, A.P.A., Brown, A.W.A., Fredeen, F.J.H., Hopewell, W.W., and Rempel, J.G.
1949. Experiments in the control of Simulium arcticum Mall. by means of DDT in the Saskatchewan River.
Sci. Agr. 29: 527-537.

Baranov, N.
1935. Contribution to the knowledge of Simulium reptans columbaczense. (In Serbian).
Vet. Arhiv 5: 58-96, 97-140.
(Ref. from R.A.E. (B) 23: 161).

1937. Contribution to the knowledge of the Golubatz fly. V. (Study of the epidemiology of the fly in 1936). (In Serbian).
Vet. Arhiv 7: 229-276.
(Ref. from R.A.E. (B) 25: 249).

Behning, A.
1928. Das leben der Wolga.
Die Binnengewasser, 5. Stuttgart
(Ref. from Jonasson, 1948).

---

*Plates and figures cited only in references of taxonomic interest.

Belding, D. L.
1942. Textbook of clinical parasitology.
D. Appleton-Century Co., N. Y., pp. 888.

Bequaert, J.
1938. The black-flies, or Simuliidae, of the Belgian Congo.
Amer. Jour. Trop. Med. 18: 116-136.

Blackflock, D. B.
1926. The development of *Onchocerca volvulus* in *Simulium damnosum*.
Ann. Trop. Med. 20: 1-48, 203-218.

Bradley, G. H.
1935a. The hatching of eggs of the southern buffalo gnat.
Science 82: 277-278.

1935b. Notes on the southern buffalo gnat, *Eusimulium pecuarum* (Riley) (Diptera: Simuliidae).
Proc. Ent. Soc. Wash. 37: 60-64.

Britten, H.
1915. A note on the oviposition of *S. maculatum* Mg.
Ent. Monthly Mag. 51: 170-171.

Bromley, S.
1952. Notes on Stamford bloodsucking flies.
Ent. News 63: 97-100.

Brown, A.W.A.
1951. Insect control by chemicals.
John Wiley and Sons, Inc., N. Y., pp. 817.

Brown, A.W.A., Thompson, R.P., Twinn, C.R., and Cutkomp
1951. Control of adult mosquitoes and black flies by DDT sprays applied from aircraft.
Mosq. News 11: 75-84.

Buck, A. E.
1888. Buffalo-gnats attacking man.
Insect Life 1: 60-61.

Cameron, A. C.
1922. The morphology and biology of a Canadian cattle-infesting black fly, Simulium simile Mall. (Diptera: Simuliidae).
Dom. Can. Dept. Agr. Bull. 5: 2-26.

Chapman, W. and Quistorff, E.
1938. The food of certain fishes of north central Columbia River drainage, in particular, young chinook salmon and steelhead trout.
Wash. State Dept. of Fish., Biol. Rept. 37A: 1-14.

Ciurea, T. and Dinuflescu, G.
1924. Ravages causes par la mouche de golubatz en Roumanie; ses attacques contre les animaux et contre l'homme.
Ann. Trop. Med. Parasit. 18: 323-342.

Clemens, W. A.
1928. Food of trout from the streams of Oneida Co., New York State.
Trans. Amer. Fish. Soc. 58: 183-197.

Coburn, D. R. and Treichler, R.
1946. Experiments on toxicity of DDT to wildlife.
Jour. Wildlife Manag. 10: 208-216.

Collins, D. L.
1948. Blackfly control: Experiments with the use of a DDT oil fog applied by helicopter. (Unpublished manuscript, pp. 51).

Collins, D. L., Travis, B. V., and Jamnback, H.
1952. The application of larvicide by airplane for control of blackflies.
Mosq. News 12: 75-77.

Comstock, J.
1949. An introduction to entomology. Ninth edition, revised.
Comstock Publ. Co., Inc., Ithaca, N.Y., pp. 1064.

Cope, O. B., Gjullin, C. M., and Storm, A.
1947. Effect of some insecticides on trout and salmon in Alaska with reference to blackfly control.
Trans. Amer. Fish. Soc. 77: 160-177.

Coquillet, D. W.
1898. The buffalo-gnats of the United States.
U.S.D.A. (N.S.) Bull. 10: 66-69.

Cottam, C. and Higgins, E.
1946. DDT and its effect on fish and wildlife.
Jour. Econ. Ent. 39: 44-52.

Curtis, L. C.
1949. The effect of DDT emulsions on trout fry.
Proc. Ent. Soc. B. C. 45: 31-32.
(Ref. from R.A.E. (B) 39: 90).

Dalmat, H. T.
1950. Studies on the flight range of certain Simuliidae, with the use of aniline dye marker.
Ann. Ent. Soc. Amer. 43: 537-545.

1952. Longevity and further flight range studies on the blackflies (Diptera, Simuliidae), with the use of dye markers.
Ann. Ent. Soc. Amer. 45: 23-37.

Dalmat, H. T. and Gibson, C. L.
1952. A study of the flight range and longevity of blackflies (Diptera, Simuliidae) infected with *Onchocera volvulus*.
Ann. Ent. Soc. Amer. 45: 605-612.

Davies, D. M.
1950. A study of the black fly population of a stream in Algonquin Park, Ontario.
Trans. Royal Can. Inst. 28: 121-160.

De Foliart, G. R.
1951. The life histories, identification and control of blackflies (Diptera: Simuliidae) in the Adirondack Mountains.
(Unpublished thesis, Cornell Univ., pp. 98).

Dimick, R. E. and Mote, D. C.
1934. A preliminary survey of the food of Oregon trout.
Sta. Bull. Ore. Agric. Exp. Sta. 323: 1-23.

Dorogostajskij, V., Rubtzov, I., and Vlasenko, N.
1935. Notes on the taxonomy, biology and geographical distribution of black flies in East Siberia.
Mag. de Parasit. de l'Inst. Zool de l'Acad. des Sci. de l'U.R.S.S., Leningrad 5: 107-204.
(In Russian with English summary.)
(Ref. from Nicholson and Mickel, 1950).

Dyar, H. G. and Shannon, R. C.
1927. The North American two-winged flies of the family Simuliidae.
Proc. U.S.N.M. 69(10): 1-54, pls. 1-7.

Edwards, F. W.
1915. On the British species of Simulium. I. The adults.
Bull. Ent. Res. 6: 23-42, figs. 1-6.

1920. On the British species of Simulium. II. The early stages; with corrections and additions to part I.
Bull. Ent. Res. 11: 211-246, figs. 1-7.

1931. Simuliidae. In Diptera of Patagonia and South Chile based mainly on material in the British Museum (Natural History).
Part II-Fasc. 4: 121-154, text figs. 7-13.

1934. The Simuliidae (Diptera) of Java and Sumatra.
Archiv. f. Hydrobiol., Suppl. 13: 92-138.

Edwards, F. W., Oldroyd, M. A., and Smart, J.
1939. British blood-sucking flies.
Wm. Clowes and Sons, Ltd., London and Beccles, pp. 156.

Eichhorn, J. C.
1774. Naturgesch. d. Kleinsten Wasserthiere.
Danzig, Tab. VII.
(Ref. from Osten Sacken 1870).
(Date of publication noted as 1776 in Hagen (1862) and Horn and Schenkling (1928-1929).

Ellis, M.M., Westfall, B. A., and Ellis, M. D.
1944. Toxicity of dichloro-diphenyl-trichloroethane (DDT) to goldfish and frogs.
Science 100: 477.

Emery, W. T.
1913. Morphology and biology of *Simulium vittatum* and its distribution in Kansas.
Kans. Univ. Sci. Bull. 8: 323-362, pls. 38-42.

Ericksen, A. B.
1947. Effects of DDT mosquito larviciding on wildlife, part II. Effects of routing airplane larviciding on bird and mammal populations.
U.S.P.H. Rept. 62: 1254-1262.

Evendon, J. C.
1947. Hazards of DDT spraying against forest insects.
Rept. Tussock Moth Control Coop. Proj. U.S.D.A.
(Ref. from Brown, 1951.)

Fairchild, G. B. and Barreda, E. A.
1945. DDT as a larvicide against *Simulium*.
Jour. Econ. Ent. 38: 694-699.

Forbes, S. A.
1912. On black flies and buffalo gnats (Simulium) as possible carriers of Pellagra in Illinois.
In 27th Rept. State Entom. Ill.: 21-55, figs. 1-25.

Fredeen, F.J.H., Rempel, J. G., and Arnason, A. P.
1951. Egg laying habits, overwintering stage, and life cycle of *Simulium arcticum* Mall. (Diptera: Simuliidae).
Can. Ent. 83: 73-76.

Friederichs
1921. Untersuchungen über Simuliiden (Teil II). Zeitschr. f. angew. Entomol. 6: 61-83. (Ref. from Wu, 1931).

Fries
1824. Monog. Simul. Sueciae. In Dissert. Academica: "Observationes entomologicae". 1: 5-20, figs. 6-7. (ref. from Osten Sacken, 1870).

Frohne, W. C. and Sleeper, D. A.
1951. Reconnaissance of mosquitoes, punkies, and blackflies in southern Alaska. Mosq. News 11: 209-213.

Frost, S. W.
1949. The Simuliidae of Pennsylvania (Dipt.). Ent. News 60: 129-131.

Gambrell, L. A.
1933. The embryology of the black fly, Simulium pictipes Hagen. Ann. Ent. Soc. Amer. 26: 641-671.

Garman, H.
1912. Simulidae. In Preliminary study of Kentucky localities in which Pellagra is prevalent. Kent. Agr. Expt. Sta. Bull. 159: 12-26, figs. 1-8.

Garnham, P.C.C. and McMahon, J. P.
1947. The eradication of Simulium neavei Roubaud, from an onchocerciasis area in Kenya colony. Bull. Ent. Res. 37: 619-627.

Garside, J. S. and Darling, H. S.
1951. Death of turkeys from attack by Simulium griseicolle Becker in the northern Sudan. Bull. Ent. Res. 42: 583-584.

Gibbins, E. G.
1934. Further studies on Ethiopian Simuliidae.
Trans. R. Ent. Soc. London 82: 51-97.

Ginsburg, J. M.
1947. Results from feeding mosquito larvae killed by DDT to goldfish.
Jour. Econ. Ent. 40: 275-276.

Gjullin, C. M., Cope, O. B., Quisenberry, B. F., and Du Chanois, F. R.
1949a. The effect of some insecticides on black fly larvae in Alaskan streams.
Jour. Econ. Ent. 42: 100-105.

Gjullin, C. M., Sleeper, D. A., and Husman, C. N.
1949b. Control of blackfly larvae in Alaskan streams by aerial applications of DDT.
Jour. Econ. Ent. 42: 392.

Gjullin, C. M., Cross, H. G., and Applewhite, K. H.
1950. Tests with DDT to control black fly larvae in Alaskan streams.
Jour. Econ. Ent. 43: 696-697.

Glasgow, R. D.
1949. Blackfly studies May 4-6, 1949. A preliminary report.
(Unpublished manuscript, pp. 4)

Glasgow, R. D. and Collins, D. L.
1946. The thermal aerosol fog generator for large scale application of DDT and other insecticides.
Jour. Econ. Ent. 39: 227-235.

Goldsmith, J. B., Husman, C. N., Brown, A.W.A., McDuffie, W. C., and Sharp, J. F.
1949. Exploratory studies on the control of adult mosquitoes and black flies with DDT under arctic conditions.
Mosq. News 9: 93-97.

Goodrum, P., Baldwin, W. P., and Aldrich, J.
1949. Effect of DDT on animal life of Bull's Island, South Carolina.
Jour. Wildlife Manag. 13: 1-10.

Goulding, R. L. and Deonier, C. C.
1950. Observations on the control and ecology of blackflies in Pennsylvania.
Jour. Econ. Ent. 43: 702-704.

Grenier, P.
1945a. Observations biologiques sur Simulium costatum Fried. (Diptera) I. L'hibernation.
Bull. Soc. Path. Exot. 37: 363-374.
(Ref. from R.A.E. (B) 35: 62.)

1945b. Les diapauses primaires et l'echelonnement des eclosions chez les simulies.
Bull. Soc. Ent. Fr. 49: 119-124.
(Ref. from R.A.E. (B) 34: 208.)

Hagen
1862. Bibliotheca Entomologica.
Leipzig. pp. 512.

Hagen, H. A.
1880. A new species of Simulium with a remarkable nympha (sic) case.
Boston Soc. Nat. Hist. Proc. 20: 305-307.

Hall, M. C. and Wigdor, M.
1918. Notes on the Acanthocephalid and Arthropod parasites of the dog in North America.
Jour. Amer. Vet. Med. Assoc. 53: 493-500.

Hargreaves, H.
1932. Report of the government entomologist, of the laboratories division of the agricultural department, upon investigations of medical interest undertaken during the year 1932.
Ann. Med. Sanit. Rept. Uganda, pp. 86-90.
(Ref. from R.A.E. (B) 22: 83-84.)

Hart, C. A.
1912. (See Forbes, 1912.)

Headlee, T. J.
1906. Blood gills of Simulium pictipes.
Amer. Natur. 40: 875-885, figs. 1-4.

Hearle, E.
1938. Insects and allied parasites injurious to livestock and poultry in Canada.
Dom. Canada, Dept. Agr. Publ. 604, Farmers' Bull. 53: 1-108.

Hennig, W.
1950. Melusinidae (Simuliidae). In Die larvenformen der Dipteren.
Akademie-Verlag, Berlin. Teil 2: 374-394, figs. 186-196.

Hess, A. D. and Rainwater, J. H.
1939. A method for measuring the food preference of trout.
Copeia 3: 154-157.

Hess, A. D. and Swartz, A.
1941. The forage ratio and its use in determining the food grade of streams.
Trans. 5th N. A. Wildlife Conf., pp. 162-164.

Hocking, B.
1950. Further tests of insecticide against blackflies (Diptera: Simuliidae) and a control procedure.
Sci. Agr. 30: 489-508.

Hocking, B. and Richards, W. R.
1952. Biology and control of Labrador blackflies (Diptera: Simuliidae).
Bull. Ent. Res. 43: 237-257.

Hocking, B., Twinn, C. R., and McDuffie, W. C.
1949. A preliminary evaluation of some insecticides against immature stages of blackflies. (Diptera: Simuliidae).
Sci. Agr. 29: 69-80.

Hoffman, C. C.
1930. Investigationes sobre la transmission de la onchocercosis de chiapas.
Ann. Inst. Biol. Univ. Mexico 1: 59-62.
(Ref. from R.A.E. (B) 18: 213.)

Hoffman, C. H. and Surber, E. W.
1945. Effects of wettable DDT on fish and fish food organisms in Black Creek, West Virginia.
Trans. Amer. Fish. Soc. 75: 48-58.

Hoffman, C. H., Townes, H. K., Sailer, R. I., and Swift, H. H.
1946. Field studies of the effect of DDT on aquatic insects.
U.S.D.A., Bur. of Ent. and Pl. Quar. E-702: 1-20.

Hoffman, C. H. and Merkel, E. P.
1948. Fluctuations in insect populations associated with aerial applications of DDT to forests.
Jour. Econ. Ent. 41: 464-473.

Horn, W. and Schenkling, S.
1928-1929. Index Litteraturae Entomologicae.
Berlin, pp. 1426.

Hotchkiss, N. and Pough, R. H.
1946. Effect on forest birds of DDT used for gypsy moth control in Pennsylvania.
Jour. Wildlife Manag. 10: 202-207.

Hungerford, H. B.
1913. The anatomy of Simulium vittatum.
Kans. Univ. Sci. Bull. 3: 365-382, pls. 43-45.

Ide, F. P.
1940. Quantitative determination of the insect fauna of rapid water.
Publ. Ont. Fish. Res. Lab. 59, Univ. of Toronto Studies 47: 1-20.

Idyll, C.
1942. Food of rainbow cutthroat, and brown trout in the Cowichan River system.
B. C. Jour. Fish. Res. Bd. Canada 5: 448-458.

Jamnback, H.
1952. The importance of correct timing of larval treatments to control specific blackflies (Simuliidae).
Mosq. News 12: 77-78.

Jenkins, D. W.
1948. Ecological observations on the blackflies and punkies of central Alaska.
Mosq. News 8: 148-155.

Jobbins-Pomeroy, A. W.
1916. Notes on five North American buffalo gnats of the genus Simulium.
U.S.D.A. Bull. 329: 1-48, text figs. 1-15, pls. 1-5.

Johannsen, O.
1903. Simuliidae. In Aquatic insects in New York State.
N. Y. State Mus. Bull. 68: 336-388, pls. 33-38.

1934. Simuliidae. In Aquatic Diptera Part I. Nemocera, exclusive of Chironomidae and Ceratopognidae.
Cornell Univ. Agr. Expt. Sta. Mem. 164: 56-64, pl. 24 (in part).

Johnson, E. P., Underhill, G. W., Cox, J. A., and Threlkeld, W. L.
1938. A blood protozoon of turkeys transmitted by Simulium nigroparvum (Twinn).
Amer. Jour. Hyg. 27: 649-665.
(Ref. from R.A.E. (B) 26: 188.)

Jonasson, P. M.
1948. Quantitative studies of the bottom fauna of the river Susaa.
Reprint from Kaj Berg: Biological studies on the river Susaa, Folia Limnologica Scandinavica 4: 204-287.

Kendeigh, S. C.
1947. Bird population studies in the coniferous forest biome during a spruce budworm outbreak.
Dept. Lands and Forests, Ont., Biol. Bull. 1: 1-100.

Kindler, J. B. and Regan, F. R.
1949. Larvicide tests on blackflies in New Hampshire.
Mosq. News 9: 108-112.

Knowlton, G. F.
1935. Simuliids annoy livestock.
Jour. Econ. Ent. 28: 1073.

Knowlton, G. F. and Maddock, D. R.
1944. Snipe flies in Utah.
Jour. Econ. Ent. 37: 119.

Krafchick, B.
1942. The mouthparts of blackflies with special reference to Eusimulium lascivum Twinn.
Ann. Ent. Soc. Amer. 35: 426-434.

Langford, R. R.
1949. Forest spraying and some effects of DDT. The effect of DDT on freshwater fishes.
Dept. Lands and Forests, Ont. Biol. Bull. 2: 19-37.

Lastochkin, D.
1945. Achievement in Soviet hydrobiology of continental waters.
Ecol. 26: 320-
(Ref. from Jonasson, 1948.)

Leonard, J. W.
1939. Comments on the adequacy of accepted stream bottom sampling technique.
Trans. 4th N. A. Wildlife Conf., pp. 288-295.

1941. Some observations on the winter feeding habits of brook trout fingerlings in relation to natural food organisms present.
Trans. Amer. Fish. Soc. 71: 219-227.

Longstaff, T. G.
1932. An ecological reconnaissance in west Greenland.
Jour. Anim. Ecol. 2: 119-142.

Lord, R. F.
1933. Type of food taken throughout the year by brook trout in a single Vermont stream with special reference to winter feeding.
Trans. Amer. Fish. Soc. 63: 182-197.

Ludwig, W.
1932. A limnological study of the bottom invertebrates of the Hocking River.
Ohio Biol. Surv. 5: 223-
(Ref. from Jonasson, 1948.)

Lugger, O.
1896. Buffalo-gnats, Black-flies.
In Second Report of the Entomologist of Minnesota. Univ. Minn. Agr. Expt. Sta., pp. 172-182.

Lundström, C.
1911. Beiträge zur kenntnis der Finlands. VII. Melusinidae (Simuliidae).
In Acta Societatis pro Fauna et Flora Fennica 34: 1-23, figs. 26.
(Ref. from Jobbins-Pomeroy, 1916).

Mackie, R. E.
1949. The effect of DDT on mammals.
Dept. Lands and Forests, Ontario Biol. Bull. 2: 63-70.

Malloch, J. R.
1914. American black flies or buffalo gnats.
U.S.D.A. Ent. Bull., Tech. Ser. 26: 1-72, pls. I-VI.

Matheson, R.
1950. Medical Entomology, 2nd Edition.
Comstock Publ. Co., Inc., Ithaca, N. Y., pp. 612.

McBride, S.
1870. The so-called webworm of young trout.
Amer. Ent. 2: 365.

Meigen, J.
1804. Klassifikazion und Beschreibung der Europäischen zweiflügligen Insekten. (Diptera Linn.) 1: 94-97.
(Ref. from Smart, 1945.)

Metcalf, C. L.
1932. Blackflies and other biting flies of the Adirondacks.
N. Y. State Mus. Bull. 289: 5-58.

Metcalf, C. L. and Sanderson, W. E.
1931. Black flies, mosquitoes and punkies of the Adirondacks.
N. Y. State Mus. Circ. 5: 1-38.

1932. Control of biting flies in the Adirondacks.
N. Y. State Mus. Bull. 289: 59-79.

Metzelaar, J.
1928. The food of the rainbow trout in Michigan.
Trans. Amer. Fish. Soc. 58: 178-182.

1929. The food of the trout in Michigan.
Trans. Amer. Fish. Soc. 59: 146-152.

Mitchell, R. I.
1946. Effects of DDT spray on eggs and nestlings of birds.
Jour. Wildlife Manag. 10: 192-194.

Monroe, H.A.U., Briand, L. J., Delisle, R., and Smith, C. C.
1943. Some experiments with the pyrethrum aerosol under Canadian conditions.
Ent. Soc. Ont. R. 74: 43-44.

Mottley, C., Rayner, H. and Rainwater, J.
1938. The determination of the food grade of streams.
Trans. Amer. Fish. Soc. 68: 336-343.

Muttkowski, R. A.
1929. The ecology of trout streams in Yellowstone National Park.
Bull. N. Y. State Coll. Forestry, Roosevelt Wildlife Ann. 2: 155-224.

Needham, P. R.
1930. Studies of the seasonal food of brook trout.
Trans. Amer. Fish. Soc. 60: 73-86.

Nicholson, H. P.
1945. The morphology of the mouthparts of the non-biting blackfly *Eusimulium dacotense* D.&S. as compared with those of the biting species *Simulium venustum* Say (Diptera: Simuliidae).
Ann. Ent. Soc. Amer. 38: 281-297.

Nicholson, H. P. and Mickel, C. E.
1950. The black flies of Minnesota (Simuliidae). Univ. Minn. Tech. Bull. 192: 1-64, figs. 1-32.

O'Kane, W. C.
1926. Black flies in New Hampshire. N. H. Agr. Expt. Sta. Bull. 32: 1-23, figs. 1-6, photographs p. 5, 7.

de Oliveira Castro, G. M. and Mariano, J.
1944. Transporte e inoculacoa de baciles de lepra pelos mosquitoes. Mem. Inst. Osw. Cruz. 41: 511-524.

O'Roke, E. C.
1934. A malaria-like disease of ducks caused by Leucocytozoon Anatis (sic) Wickware. Mich. Univ. School Forestry and Conserv. Bull. 4. (Ref. from Nicholson and Mickel, 1950.)

ORR, L. W. and Mott, L. O.
1945. The effects of DDT administered orally to cows, horses and sheep. Jour. Econ. Ent. 38: 428-432.

Osten Sacken, R.
1870. On transformation of Simulium. Amer. Ent. 2: 229-231, figs. 145-147.

Parker, R. R.
1934. Recent studies of tick-borne disease made at the United States Public Health Service at Hamilton, Montana. (Proc. Pan. Pacific Sci. Congr. 5: 3367-3374.) (Ref. from R.A.E. (B) 23: 140.)

Pate, V.S.L.
1933. Studies on fish food in selected areas. N. Y. Cons. Dept. Suppl. 22nd Ann. Rept. 1932: 130-156.

1934. Studies on the fish food supply in selected areas of the Raquette watershed. N. Y. Cons. Dept. Suppl. 23rd Ann. Rept. 1933: 136-157.

Pennack, R. W. and Van Gerpen, E. D.
1947. Bottom fauna production and physical nature of substrate in a northern Colorado trout stream.
Ecol. 28: 42-48.

Percival, E. and Whitehead, H.
1929. A quantitative study of the fauna of some types of stream bed.
Jour. Ecol. 17: 282-

Petersen, A.
1924. Bidrag til de Danske Simuliers naturhistorie.
D. Kgl. Danska Vid. Selsk. Skr. Nat. Math Afd. 8: 237-341.
(Ref. from Smart, 1944.)

Prevost, G.
1947. Eradication of black fly larvae (Simulium spp.) for a long term by the use of DDT at a critical time.
Read at Limnological Soc., A.A.A.S., Dec. 29, 1947, Chicago, Ill. (mimeographed), pp. 6.

1948a. Directions for using DDT in plaster in the eradication of blackfly larvae.
Montreal, Que. (mimeographed), pp. 5.

1948b. Observations on insecticidal fogging as a method of controlling black flies.
Symposium on black flies, Sept. 29, 1948, Big Moose, N. Y. (mimeographed), pp. 11.

Puri, I. M.
1925. On the life history and structure of the early stages of Simuliidae (Diptera, Nematocera). Parts I, II.
Parasitology 17: 295-369, text figs. 1-21, pls. 8-9.

Reeves, C. D.
1910. A remedy for the blackfly pest in certain streams of the southern peninsula of Michigan.
Mich. Acad. Sci. Rept. 12: 77-78.

Rempel, J. G. and Arnason, A. P.
1947. An account of three successive outbreaks of the black fly, Simulium arcticum, a serious livestock pest in Saskatchewan.
Sci. Agr. 27: 428-445.

Richardson, R. E.
1921a. The small bottom and shore fauna of the middle and lower Illinois River and its connecting lakes, Chillicothe to Grafton: its valuations; its sources of food supply; and its relation to the fishery.
Ill. Nat. Hist. Surv. 13: 363-522.

1921b. Changes in the bottom and shore fauna of the middle Illinois River and its connecting lakes since 1913-1915 as a result of the increase, southward, of sewage pollution.
Ill. Nat. Hist. Surv. 14: 33-75.

1928. The bottom fauna of the middle Illinois River 1913-1925. Its distribution, abundance, valuation, and index value in the study of stream pollution.
Bull. Ill. Nat. Hist. Surv. 17: 391-475.

Ricker, W. E.
1930. Feeding habits of speckled trout in Ontario water.
Trans. Amer. Fish. Soc. 60: 64-72.

1934. An ecological classification of certain Ontario streams.
Publ. Ont. Fish. Res. Lab. 49: 114-265.

Riley, C. V.
1887. Buffalo gnats.
In U.S. Com. Agr. Rept. for 1886, pp. 492-517.

Ritcher, P. O.
1931. An undescribed species of Simuliid larva and the corresponding pupa.
Ent. News 42: 241-246, figs. 1-6.

Robbins, C. S. and Stewart, R.
1949. Effects of DDT on bird population of scrub forest.
Jour. Wildlife Manag. 13: 11-16.

Roberts, F.
1940. The insect parasites of sheep.
Queensland Agr. Jour. 53: 530-546.
(Ref. from R.A.E. (B) 29: 2.)

Robles, R.
1919. Onchocercose humaine au Guatemala produisant la cecite et "l'erysipele du littoral" (Erisipela de la costa).
Bull. Soc. Path. Exot. 12: 442-460.
(Ref. from R.A.E. (B) 7: 159-160.)

Rubtzov, I. A.
1940. Fauna de l'U.R.S.S. Insectes Dipteres. 6. Family Simuliidae.
Moscow Inst. Zool. Acad. Sci. U.R.S.S. (N.S.) 23: pp. 533, figs. 93.
(Ref. from Vargas, 1945 and Zoo. Record 82: 96.)

Rubtzov, I. A. and Vlasov, N. A.
1934. An experiment in applying emulsions for the control of black flies (In Russian).
Arb. ost-Sibir. St. Univ. 2: 51-79.
Ref. from R.A.E. (B) 23: 117.)

Ruppert
1920. Beobachtungen uber Schadwirkungen von Kriebelmücken bei Schafen in der Umgebung von Friesack (Mark).
Deutsche Tierarztl. Wochenschr. 28: 579-580.
(Ref. from R.A.E. (B) 9: 36.)

Sanderson, E. D.
1910. Controlling the blackfly in the White Mountains.
Jour. Econ. Ent. 3: 27-29.

Savage, J.
1949. Aquatic invertebrates: mortality due to DDT and subsequent re-establishment.
Dept. Lands and Forests, Ont. Biol. Bull. 2: 39-47.

Say, T.
1823. Descriptions of dipterous insects of the United States.
Jour. Acad. Nat. Sci., Phila. *3*: 9-54, 73-104.
(Reprinted Le Conte, J. L., 1891. *In* The complete writings of Thomas Say on the Entomology of North America *2*: 51-52.)

Schmidt, M.
1916. Durch die Kolumbacser Mücken hervorgerufene er krangungen.
Deut. Tierärtzl. Wchnschr. *24*: 247-248.
(Ref. from Nicholson and Mickel, 1950.)

Schoenbauer, J. A.
1795. Geschicte de Schädlichen Kolumbatczer Mücken, pp. 1-100.
(Ref. from Riley, 1887.)

Seguy, E.
1925. Simuliidae. *In* Fauna de France *12*: 20-42, figs. 32-105.

Skidmore, L. V.
1932. *Leucocytozoon smithi* infection in turkeys and its transmission by *Simulium occidentale* Townsend.
Aentbll. f. Bakt. Abt. I. *125*: 329-335.
(Ref. from Nicholson and Mickel, 1950.)

Smart, J.
1934. Notes on the biology of *S. pictipes*.
Can. Ent. *66*: 62-66, figs. 1-4.

1936. Notes on the Simuliidae occuring at Fortingal, Perthshire.
Scot. Nat. *217*: 22-26.
(Ref. from R.A.E. (B) *24*: 118.)

1944. The British Simuliidae with keys to the species in the adult, pupal and larval stages.
Freshwater Biol. Assoc. Brit. Emp. *9*: 1-57, figs. 1-17.

1945. The classification of the Simuliidae (Diptera).
Trans. Roy. Ent. Soc. Lond. *95*: 463-532.

Speirs, J. M.
1949. The relation of DDT spraying to the vertebrate life of the forest.
Dept. Lands and Forests, Ont. Bio. Bull. 2: 141-158.

Steward, J. S.
1937. The occurrence of Onchocerca gutturosa Neumann in cattle in England, with an account of its life-history and development in Simulium ornatum Mg.
Parasitology 29: 212-219.

Stewart, R. E., Cope, J. B., Robbins, C. S., and Brainerd, J. W.
1946. Effects of DDT on birds at the Patuxent Research Refuge.
Jour. Wildlife Manag. 10: 195-201.

Stickel, L. F.
1946. Field studies of a Peromyscus population in an area treated with DDT.
Jour. Wildlife Manag. 10: 216-218.

Stokes, J. H.
1914. A clinical, pathological and experimental study of the lesions produced by the bite of the "black fly" (Simulium venustum).
Jour. Cut. Dis., Incl. Syph.: 751-769, 830-856.

Stone, A.
1949. A new genus of Simuliidae from Alaska.
Proc. Ent. Soc. Wash. 51: 260-267.

1952. The Simuliidae of Alaska.
Proc. Ent. Soc. Wash. 54: 69-96, figs. 1-4.

Strickland, E. H.
1911. Some parasites of Simulium larvae and their effects on the development of the host.
Biol. Bull. 21: 302-334, pls. 1-5.

1913. Further observations on the parasites of Simulium larvae.
Jour. Morph. 24: 43-94, text figs. 1-2, pls. 1-6.

Supervisor, Town of Webb
1948. Annual Report.

1949. Annual Report.

1950. Annual Report.

1951. Annual Report.

1952. Annual Report.

Surber, E. W.
1937. Rainbow trout and bottom fauna production in one mile of stream.
Trans. Amer. Fish. Soc. 66: 193-202.

1946. Effects of DDT on fish.
Jour. Wildlife Manag. 10: 183-191.

Surber, E. W. and Friddle, D.D.
1946. Relative toxicity of suspension and oil formulations of DDT to native fishes in Back Creek, West Virginia.
Trans. Amer. Fish. Soc. 76: 315-321.

Tiller, R. E. and Cory, E. N.
1947. Effects of DDT on some tidewater aquatic animals.
Jour. Econ. Ent. 40: 431-433.

Travis, B. V.
1949. Studies of mosquito and other biting insect problems in Alaska.
Jour. Econ. Ent. 42: 451-457.

Travis, B. V., Collins, D. L., De Foliart, G., and Jamnback, H.
1951. Strip spraying by helicopter to control blackfly larvae.
Mosq. News 11: 95-98.

Twinn, C. R.
1933. The blackfly, *S. venustum* Say, and a protozoon disease of ducks.
Can. Ent. 65: 1-3.

Twinn, C. R.
1936. The blackflies of eastern Canada (Simuliidae, Diptera).
Can. Jour. Res. D 14: 97-150, figs. 1-15, pl. 1.

1950. Studies of the biology and control of biting flies in northern Canada.
Arctic 3: 14-26.

1952. A review of studies of blood-sucking flies in northern Canada.
Can. Ent. 84: 22-28.

Twinn, C. R., Hocking, B., McDuffie, W. C., and Cross, H. F.
1948. A preliminary account of the biting flies at Churchill, Manitoba.
Can. Jour. Res. D 26: 334-357.

Underhill, G. W.
1939. Two simuliids found feeding on turkeys in Virginia.
Jour. Econ. Ent. 32: 765-768.

1940. Some factors influencing feeding activity of Simuliidae in the field.
Jour. Econ. Ent. 33: 915-917.

1944. Blackflies found feeding on turkeys in Virginia (*Simulium nigroparvum* Twinn and *Simulium slossonae* Dyar and Shannon).
Tech. Bull. Va. Agr. Exp. Sta. 94: 1-32, figs. 1-15.

U.S. Department Commerce Publication
1950. Climatological data, New York. Annual summary 1949, 61: 298-310.

1951. Climatological data, New York. Annual summary 1950, 62: 344-356.

1952. Climatological data, New York. Annual summary 1951, 63: 304-318.

Vargas, L.
1945. Simulides des Nuevo Mundo.
Inst. Salub. y Enferm. Trop., Monog. 1: 1-241, pls. 1-10.

Walker, F.
1848. List of the specimens of dipterous insects in the collection of the British Museum 1: 112.
(Ref. from Vargas, 1945.)

Wanson, M.
1950. Contribution a l'etude de l'Onchocercose Africaine humaine (problemes de prophylaxie a Leopoldville).
Ann. Soc. Belge Med. Trop. 30: 667-863.

Wanson, M. and Henrard, C.
1945. Habitat et comportement larvaire du *Simulium damnosum* Theobald.
Rec. Trav. Sci. Med. Congo Belge 4: 113-121.
(Ref. from R.A.E. (B) 36: 146-148.)

Webster, F. M.
1904. The suppression and control of the plague of buffalo gnats in the valley of the lower Mississippi River, and the relations thereto of the present levee system, irrigation in the arid west and tile drainage in the middle west.
Proc. 25th Ann. Meet. Soc. Prom. Agr. Sci., pp. 53-72.

White, H. C.
1930. Some observations on the eastern brook trout (*S. fontinalis*) of Prince Edward Island.
Trans. Amer. Fish.Soc. 60: 101-108.

Weed, C. M.
1904. Experiments in destroying black flies.
N. H. Agr. Exp. Sta. Bull. 112: 133-136.

Wilson, C. S., Applewhite, K. H., and Redlinger, L. M.
1949. Heavy ground aerosol generators for the control of adult biting insects in Alaska.
Mosq. News 9: 91-101.

Wu, Yi Fang
1931. A contribution to the biology of Simulium (Diptera).
Mich. Acad. Sci. Arts and Letters 13: 543-599.

Zetterstedt, J. W.
1838. Insecta Lapponica 3: 802-803.
(Ref. from Smart, 1945).

ABSTRACT

This paper, dealing with an investigation of blackfly control, is divided into four sections dealing respectively with the taxonomy, biology, and control of Simuliidae, and the effects of stream treatment on stream fauna.

In the taxonomic section generic and specific descriptions of blackfly larvae are given. Descriptions of the larval stage of eighteen of the twenty-three species of blackflies found in New York are given, four of these descriptions being new. Keys to the genera and species of blackfly larvae found in New York are also given.

In the biological section seasonal larval population fluctuations and the biologies of the individual species are described. Special emphasis is given to the biologies of the most important annoying species *Prosimulium hirtipes*, *Simulium venustum*, and *Simulium tuberosum*.

In the control section various aspects of blackfly control including economic importance, development of control programs, methods of application of insecticides, and experimental control studies are set forth in some detail. Control methods used in the Adirondacks include stream treatments using DDT-impregnated plaster of Paris blocks and application of DDT solution by aircraft.

The final section deals with the effects of stream treatment on wildlife with special reference to stream arthropods. Methods of sampling and the data obtained are considered in detail. When properly applied, using correct dosages, stream treatments which eliminated or greatly reduced blackfly larval populations were not injurious to most other stream fauna.

ACKNOWLEDGEMENTS

First and foremost, the author would like to express his gratitude to Dr. D. L. Collins, State Entomologist of New York, and to the State of New York for making this study possible by employing him as "temporary entomologist" for a total of more than fifteen months before, during, and after the "blackfly season" in 1950, 1951, and 1952.

Thanks are also due to the thesis committee headed by Dr. F. Shaw and composed of the additional members Doctors L. Bartlett, J. Hanson, W. Nutting, and R. Trippensee for carefully, patiently, and critically reading and correcting errors in this thesis.

The author sincerely appreciates the financial assistance provided by the Lotta Crabtree Estate in the form of a Lotta Crabtree Fellowship for 1952-1953.

The author is indebted to Dr. A. Stone, U.S. National Museum, who determined many specimens and provided unpublished taxonomic information which materially aided the author in writing this thesis.

The author also appreciates the time and effort freely donated by Professor S. Russell in determining appropriate statistical techniques to be used in evaluating the results of stream studies.

Dr. G. De Foliart (formerly of Cornell University) was of great assistance in introducing the author to the study of Simuliidae and his friendship and cooperation is greatly appreciated.

The people of the Town of Webb were both friendly and helpful in providing laboratory space and whole-hearted cooperation during a very pleasant three years.

Finally, the author would like to thank the New England New York Interagency Committee, U.S. Public Health Service for making available material and records of collections made in New York.

APPROVED:

Frank R. Shaw

L. M. Bartlett

W. B. Nutting

J F Hanson

R. E. Trippensee

DATE May 12, 1953