# THE SIMULIIDAE OF INSULAR NEWFOUNDLAND AND THEIR DYNAMICS IN SMALL STREAMS ON THE AVALON PENINSULA

DAVID JAMES LEWIS

# THE SIMULIIDAE OF INSULAR NEWFOUNDLAND AND THEIR DYNAMICS IN SMALL STREAMS ON THE AVALON PENINSULA

by

David James Lewis

A THESIS

submitted in partial fulfillment
of the requirements for the degree of

Master of Science

Department of Biology
Memorial University of Newfoundland

St. John's, Newfoundland

April, 1973

# ABSTRACT

Three genera and twenty-one species of simuliids are recorded from Newfoundland, viz., three species of *Prosimulium*, two of *Cnephia*, and sixteen of *Simulium*. *S. croxtoni*, *S. excisum*, and *S. gouldingi* are new records for Newfoundland. A key to the simuliids of insular Newfoundland is provided for the mature larvae, pupae, males, and females.

Sampling of 212 streams across Newfoundland indicated that species of *Prosimulium* and *Cnephia* overwinter as larvae, and species of *Simulium* overwinter as eggs. *P. fuscum*, *P. mixtum*, and *S. venustum* were the most abundant mammalophilic species, while *S. latipes* was the most abundant ornithophilic species.

Nine species of simuliids were found in the complex of streams in Pickavance Creek and its six tributaries. Pickavance Creek is a small, shallow, permanent stream about 16 km west of St. John's.

Sampling in the Pickavance Creek area was accomplished using 10 x 10 x 0.8 cm ceramic tiles. These facilitated collecting of specimens and were of convenient area for population density studies.

The effects of the following factors on simuliid larval and pupal populations have been investigated: rate of flow, temperature, depth, substrate, light, shade, drift, water chemistry, parasites and predators.

The seasonal succession of simuliids in Newfoundland is similar to that in other regions of North America, but it occurs later in the year in Newfoundland. The number of generations of multivoltine

species of simuliids is usually less in Newfoundland due to the short summer. Apart from these two differences, the habits and biology of Newfoundland simuliids are similar to those of other areas on the continent, and the insular habitat apparently does not affect the ecology and bionomics of these blackflies.

## TABLE OF CONTENTS

# TABLES

# FIGURES

# ACKNOWLEDGEMENTS

I wish to express my deepest appreciation to Dr. Gordon F. Bennett for suggesting this study, and for his helpful guidance throughout its course.

My appreciation is also extended to Professor J. Phipps for his time, advice, and thoughtful interest toward my research and for reading the manuscript.

Thanks are extended to Dr. Douglas M. Davies, Department of Biology, McMaster University, Hamilton, for identification and confirmation of some simuliid species encountered in this study, and also to Dr. Stephen M. Smith, Department of Biology, University of Waterloo, Waterloo, for confirmation of identified specimens and invaluable hints on aspects of biology and morphology of blackflies.

Thanks are also extended to the following persons associated with the Department of Biology, Memorial University of Newfoundland: Mr. B. A. Ebsary, for identification of blackfly parasites; Mr. Ebsary and Mr. R. F. Coombs for permission to quote unpublished data; and Mr. Roy Ficken, photographer, for his assistance in the preparation of the plates. Thanks are also due to the staff of the Interlibrary Loans Division, Henrietta Harvey Library, Memorial University of Newfoundland, who obtained literature pertinent to this study.

I wish to thank the Government of Newfoundland, the National Research Council of Canada, and Memorial University for financial assistance throughout the course of this study.

Finally I wish to express my appreciation to my wife, Ivy, for her patience, assistance on several field trips, and the typing of this thesis.

# INTRODUCTION

Blackflies have a world wide distribution, but their degree of annoyance and capacity as vectors varies from place to place. Stone (1964) indicated that there are about 1,300 species of blackflies, some of which have been shown to transmit parasitic protozoa, nematodes, and viruses. However, it is not their capacity to transmit pathogens that makes them of importance in Canada, but their role as nuisance pests of man and livestock. Blackflies tend to be rather sparse in tropical and subtropical areas, but reach maximum densities under boreal and sub-tundra conditions. The current economic trend in Canada to develop and exploit the sparsely-populated northern regions brings man and his endeavours into the center of some of the densest simuliid populations known. Continued development of these areas by man, then, requires control of these biting fly pests. Efficient control requires detailed knowledge of the biology and bionomics of the target insect in the specific environment under consideration.

Most studies on simuliids are of a taxonomic nature, and relatively little is known of their biology and how it varies from one area to another for a single species. This is particularly true for insular Newfoundland, where the majority of the work done on simuliids has been to record the presence or absence of certain species. The purpose of this study, therefore, was to determine which species of simuliids occur in Newfoundland, and to present information on their biology, dynamics and distribution on the Island. Particular effort was made to compare the life cycles of the species occurring here with the cycle of the same species in other regions of North America.

# REVIEW OF LITERATURE

## Classification

Classification of the Simuliidae is highly controversial as shown by the differing opinions of Rubtsov (1956), Shewell (1958), Smart (1945), and Stone (1965). Most taxonomic works have been compiled for localized areas. The more important keys to the various stages include Abdelnur (1968), Davies *et al.* (1962), Nicholson and Mickel (1950), Peterson (1960, 1970), Sommerman (1953), Stains and Knowlton (1943), Stone (1952, 1964), Stone and Jamnback (1955), Stone and Snoddy (1969), Vargas *et al.* (1945), and Wood *et al.* (1963) for the North American species; L. Davies (1966, 1968), Edwards (1920), Grenier (1953), Obeng (1965), Puri (1925b), Rubtsov (1956), and Smart (1944) for the European and Asian species; Mackerras and Mackerras (1948, 1950, 1952, 1955) and Tonnoir (1925) for the Australian region; Crosskey (1960, 1967) for Africa and the Middle East; Edwards (1934) for Sumatra; Dalmat (1955) for Guatemala; Perez (1971) for Venezuela; Wygodzinsky and Coscaron (1970) and Coscaron and Wygodzinsky (1972) for other South American regions; Smart and Clifford (1965) for Papua and New Guinea; and Smart and Clifford (1968) for the species of Sabah.

## Life History

Generalized life history of blackflies has been summarized by a variety of North American workers, including Jamnback (1969), Jamnback *et al.* (1971), and Jobbins-Pomeroy (1916). Davies *et al.* (1962), Nicholson and Mickel (1950), Stone (1964), Stone and Jamnback (1955), and Stone and Snoddy (1969) have presented information on the general biology of blackflies.

## Eggs

According to Puri (1925a), Schönbauer (1795) discovered that the immature stages of *Simulium* are found in running water. Jobbins-Pomeroy (1916), Johannsen (1934), Malloch (1914), Marr (1962), Puri (1925a), and Wu (1930) reported that freshly laid eggs are white in color and turn to dark brown as development progresses. Davis (1971), Gambrell (1933), Smart (1934b), and Stone and Jamnback (1955) agreed with this, and with Abdelnur (1968), Davies (1950), Davies and Peterson (1956), and L. Davies (1954) made measurements of the eggs of various species of blackflies. Jobbins-Pomeroy (1916), Smart (1944), and Wu (1930) presented evidence to indicate that eggs are not resistant to desiccation, but Peterson and Wolfe (1958) showed that eggs may undergo a summer or a winter diapause. Jobbins-Pomeroy (1916), Smart (1934a, 1934b), Wenk and Raybould (1972), and Wu (1930) indicated that incubation may last only a few days, while Stone (1964) and Stone and Jamnback (1955) reported that the incubation period may be more than seven months. Definite egg-diapause has been demonstrated by Fredeen (1959a, 1959b) and Fredeen *et al.* (1953). Wood and Davies (1966) conducted experiments to break the egg diapause. Gambrell (1933) gave an account of the embryology of *Simulium pictipes* Hagen; Craig (1969) described the embryology of the larval head; and Davis (1971) gave a detailed account of the hatching mechanism of *Simulium*. Hatching was considered only briefly by Davies *et al.* (1962), Hocking and Pickering (1954), Puri (1925a), Smart (1934b), and Wu (1930).

## Larvae

The first instar larvae are characterized by the presence of an "egg-burster" on the mid-dorsal region of the head capsule. The structure and use of the "egg-burster" has been described by Davies (1949), Davies *et al.* (1962), Davis (1971), Puri (1925a), and Smart (1934a). Anatomical features of the larvae have been described by many authors, particularly in taxonomic works. Detailed external anatomy has been studied by Jobbins-Pomeroy (1916), Johannsen (1934), Malloch (1914), Puri (1925a), Sacken (1870), Stone (1964), Stone and Jamnback (1955), and Wood *et al.* (1963). Chance (1970a) gave a detailed account of the functional morphology of the larval mouthparts. Dorier (1945) described the head capsule and Crosskey (1960) considered the larval characters and their taxonomic value. Internal anatomy of the various systems include studies by Jobbins-Pomeroy (1916), Puri (1925a), Smart (1934b), and Taylor (1902). The feeding mechanism of larvae has been described by Peterson (1956) and Smart (1944). Observations by Hocking and Pickering (1954) agree with those of Smart. Rate of feeding has been studied by Ladle *et al.* (1972), and the diet of larvae by Burton (1971b), Davies (1949), Davies *et al.* (1962), Emery (1913), Fredeen (1960, 1964b), Jobbins-Pomeroy (1916), Kellogg (1901), Peterson (1956, 1962a), Peterson and Davies (1960), Puri (1925a), and Rees and Peterson (1953). The size of particulate material which may be ingested has been determined by Williams *et al.* (1961a).

Larvae are attached to the substratum by posterior hooks which are embedded in silk secreted by the labial glands. The attachment mechanism is discussed by Field (1961), Hora (1927, 1928), Peterson and Wolfe (1958), Puri (1925a), Smart (1934b), Tonnoir (1923b), and Wu (1930). Locomotion is accomplished by a looping movement similar to that of a geometrid caterpillar, or by drifting downstream on a strand of silk secreted by the larva. The larva is also able to make some progress by means of the mouthparts and the proleg, with the abdomen unattached to the substratum. Locomotion and migration have been observed and considered in detail by Hora (1928), Jobbins-Pomeroy (1916), Marr (1962), Nicholson and Mickel (1950), Peterson and Wolfe (1958), Puri (1925a), Smart (1934b), Tonnoir (1923b), Travis (1967), and Wu (1930). Peterson and Wolfe (1958) reported that migration occurred during the night. Yakuba (1959) indicated that rapid rise in water level might stimulate migration. Locomotion and migration are directly related to organic drift. Hynes (1970a), in reviewing the ecology of stream insects, considered drift and emphasized that the importance of drift may have been over stressed because the loss to the fauna by drift may be very small or insignificant, and also because of the limited knowledge of upstream movement. Waters (1972) reviewed the drift of stream insects and Clifford (1972) included *Simulium* in his study of drift. Harrison (1966) reported that blackfly larvae were one of the first organisms to recolonize a stream after drought.

The duration of the larval stage varies with the water temperature and the growth rate varies in different species. Peterson and Wolfe (1958) showed that development is related to stream temperature. Smart (1934a) indicated that the larval stage of *S. pictipes* lasted for four to six weeks, and Malloch (1914) generally agreed with this. Smart (1934b) showed a 7 to 10 week period for *S. ornatum* Meigen; Marr (1962) indicated five days or more for *S. damnosum* Theobald, depending on the temperature; Wanson and Henrard (1945) indicated five days for *S. damnosum;* and Davies and Syme (1958) showed a six to seven month larval stage for *P. mixtum* Syme and Davies and *P. fuscum* Syme and Davies.

L. Davies (1961) stated that development continued throughout the winter in ice-covered streams, but Davies and Syme (1958) could find no correlation between stream temperature and growth rate. Marr (1962) believed that the availability of food is important for determining the duration of the larval stage. Food supply, substrate, current velocity, volume of flow, depth, light, and various other physical and chemical conditions have been shown to affect the abundance and distribution of larvae. Carlsson (1967), Chutter (1968), Dalmat (1955), Fredeen and Shemanchuk (1960), Grenier (1949), Peterson and Wolfe (1958), Phillipson (1956, 1957), Sommerman *et al.* (1955), Wu (1930), and Zahar (1951) considered one or several of these factors. Dalmat (1955) and L. Davies and Smith (1958) indicated an altitudinal distribution. Certain species have been shown to have habitat preferences: this has been discussed by Davies and Syme (1958), Grenier (1949), Hocking and Pickering (1954), and Wolfe and Peterson (1959). Pentelow (1935) indicated that geological structure, distribution of water plants, and the hardness of the water may be important factors affecting distribution of larvae and pupae. Bradt (1932), Kuzoe (1969), and Wolfe and Peterson (1959) reported that heavy rains and floods influence larval abundance and distribution. Wolfe and Peterson (1959) also indicated that logging and fires tend to decrease larval density. Nielson (1950) reported that pollution increases the numbers of simuliid larvae. Bequaert (1934), Smart (1944), and Wolfe and Peterson (1959) showed that larvae are positively phototaxic.

Larvae and pupae of some blackfly species live as epizoites on crabs and mayfly larvae. Lewis (1965) believes that the crabs probably carry the immature stages to safety from possible desiccation and turbulent currents. Phoresy in blackfly larvae is discussed by Berner (1954), Burton (1971a), Corbet (1962), Crosskey (1965), Disney (1969a, 1971a, 1971b, 1971c, 1971d), Edwards (1928), Freeman (1954), Germain and Grenier (1967), Germain *et al.* (1966), Grenier *et al.* (1965), Lewis and Disney (1969), Lewis *et al.* (1960, 1969), and McMahon (1952).

According to Puri (1925a), Meinert (1886) reported that Horvarth (1884) thought there were four larval instars and that Tömösváry (1892) and Aigner-Abafi (1903) reported that there were five. Species studied by Cameron (1922), Davies (1949), Edwards (1920), Harrod (1964), Puri (1925a), Smart (1934b), and Terterjan (1957) were shown to have six instars. Crosskey (1960) believed that six instars is probably universal in the family. Davies *et al.* (1962) suggested that the number of instars may vary from four to seven in many species. Grenier and Feraud (1960) and Johnson and Pengelly (1969) reported seven instars for *S. damnosum* and *S. rugglesi* Nicholson and Mickel respectively. Jobbins-Pomeroy (1916) and Puri (1925a) described larval ecdysis in detail. Last stage larvae, or the pharate pupa of Hinton (1958), spin silk for the pupal stage. The formation of the cocoon has been described by Burton (1966), Puri (1925a), Tonnoir (1923a), and Wu (1930). Burton (1966) described larval ecdysis after completion of the cocoon. Jobbins-Pomeroy (1916), Peterson (1956), Tonnoir (1923a), and Wu (1930) considered the pupation process in detail. Disney (1969b) stated that pupation occurs mainly by day.

## Pupae

According to Emery (1913), *Simulium* pupae are yellowish brown in color when first formed and later darken as development progresses.

Anatomical descriptions of pupae have been presented by Johannsen (1934), Puri (1925a), Smart (1943b), Stone (1964), and Stone and Jamnback (1955).

The duration of the pupal period varies with temperature according to Nicholson and Mickel (1950), Puri (1925a), Smart (1943b), and Zahar (1951). Barnley (1952) showed a 5-day pupal stage, Johannsen (1934) 2 days to a week or more, Newstead *et al.* (1907) 2 to 6 days, Smart (1934a) 4.5 days, and Smart (1934b) 3.75 to 12 days. Burton and McRae (1965), Crisp (1956), Kuzoe (1969), and Marr (1962), all working with *S. damnosum* at different temperatures, found the pupal period to be 10 to 11, 10 to 13, 3, and 8 to 9 days respectively. Marr (1962) suggested that the difference in time of pupal development from 2 to 4 days might be a matter of sex differentiation.

Taylor (1902) considered the tracheal system of the pupa in detail. Wolfe and Peterson (1959) and Rubstov (1956) indicated that there is a correlation between the number of pupal respiratory filaments and the character of the stream. Since pupae do not feed or move, many factors which affect larvae do not apply to the pupal stage. Carlsson (1967) reported that temperature, oxygen, and inorganic and organic drift may influence the pupal stage. Movement of the pupa within the cocoon prior to adult emergence has been observed by Jobbins-Pomeroy (1916) and Peterson (1956). Peterson believed this sometimes violent motion of the pupa may aid in rupturing the pupal skin. Adult emergence has been described in detail by Burton (1966) and to a lesser extent by Newstead *et al.* (1907), Peterson (1956), Smart (1934a), and Tonnoir (1923b). Disney (1969b) showed that the timing of adult eclosion is influenced by the stream temperature on the day of eclosion. Marr (1962) observed that emergence occurred chiefly in the evenings and only occasionally in the mornings. Burton (1966), Cameron (1922), Coquillet (1898), Jobbins-Pomeroy (1916), Peterson (1956), Smart (1934b), Tonnoir (1923b), and Wu (1930) observed the adult to take flight almost immediately upon reaching the water surface. However, Emery (1913) and McBride (1870) indicated that the adult stayed on the surface or held on to some object to dry the wings before actually flying.

## Adults

Davies *et al.* (1962), Edwards (1915), Forbes (1912), Jobbins-Pomeroy (1916), Stone (1964), and Stone and Jamnback (1955) have given general descriptions of adult blackflies. Jobbins-Pomeroy (1916) and Smart (1935) described internal anatomy. Emery (1913) and Hungerford (1913) discussed in detail the anatomy of *S. vittatum* Zetterstedt females. Freeman (1950) considered male genitalia and Gibbins (1938), Kellogg (1899), Krafchick (1942), and Nicholson (1945) discussed adult mouthparts.

Fallis (1964), reviewing feeding and related behaviour of adult females, considered feeding preferences, biting sites and activities, size and digestion of blood meal, longevity, flight range, and feeding and climate. Downes (1970) and Wenk and Raybould (1972) have conducted further studies related to the feeding of adult simuliids. Field *et al.* (1967) induced *S. vittatum* to feed on various animals. Carlsson (1967), Dalmat (1954, 1955), L. Davies (1957b), Peterson and Wolfe (1958), Underhill (1940, 1944), Wolfe and Peterson (1959, 1960), and Zahar (1951) have indicated that environmental conditions influence blackfly activity. Davies (1952) demonstrated that flight, attraction, and landing and biting activities are influenced by environmental conditions. Ussova and Kulikova (1958) indicated that temperature, light, wind, and relative humidity influence the frequency of attack. Fallis (1964) suggested that all adults which feed on blood may be considered as pests. He reviewed the importance of blackflies as pests and recorded instances of fatality and economic losses caused by blackflies. Halgoš and Jedlička (1971) recorded blackflies attacking horses in Bratislava. Bennett *et al.* (1972), Bradbury (1972), Davies (1951), and Peschken and Thorsteinson (1965) presented data illustrating the visual orientation of adults to color. L. Davies (1961) and Lewis (1960) have sorted adult flies into two age groups, the parous and the nulliparous, by changes in the ovary, including the presence or absence of follicular relics. Fredeen (1964a) discussed this method and its significance. Downes (1969) reviewed mating and swarming, Field *et al.* (1967) induced copulation in *S. vittatum*, and Wenk and Raybould (1972) studied the mating of the "Kibwezi" form of *S. damnosum* in the laboratory.

There are various stages of egg development as shown by autogenous and anautogenous species of simuliids. Chutter (1970) and Davies and Peterson (1956) suggested that ovarian development is dependent on nutrients available and also on the temperature at which the larvae grew. Peterson and Wolfe (1958) suggested that the stage of egg development at emergence may vary within the species. Cameron (1922), Davies and Syme (1958), Downes (1965, 1970), and Downes *et al.* (1962) also considered aspects of ovarian development. Abdelnur (1968), Chutter (1970), and Davies and Peterson (1956) recorded numbers and dimensions of oocytes in newly emerged flies. Parthenogenetic populations have been shown to exist by Davies (1950), L. Davies (1954), and Downes (1965). Carlsson (1962) has shown that most individuals of *Prosimulium ursinum* Edwards fail to emerge from the pupa in northern Norway, but on disintegration of the pupa the eggs are released into the stream and hatch the following spring. Davies and Peterson (1956) suggested that oviposition behaviour is variable in some species and quite rigid in others. Grenier (1949) showed that some species oviposit on the surface of water, some on a support at the surface, others enter the water, and others drop their eggs while in flight. Britten (1915), Davies (1949, 1950), Fredeen *et al.* (1951), Jobbins-Pomeroy (1916), Peterson (1956, 1959b), Smart (1934a), Webster (1889), and Wu (1930) have also observed oviposition. Davies and Peterson (1956) indicated that environmental factors influence oviposition. Wolfe and Peterson (1959) and Peterson and Wolfe (1958) observed oviposition occurring mostly in the late afternoon until twilight, Hocking and Pickering (1954) observed oviposition taking place during the evenings of warm days, and Gambrell (1933) indicated oviposition occurred chiefly in the morning. Bradley (1935) and Nicholson and Mickel (1950) obtained oviposition in the laboratory. Wenk and Raybould (1972) and Wood and Davies (1966) were able to induce oviposition. Davies and Peterson (1956) indicated that females may lay 200-500 eggs, and as many as 800 in a single gonotrophic cycle, depending on the species.

## Vectors

Fallis (1964) reviewed the importance of blackflies as vectors.

Since then, Baker (1970) and Barrow *et al.* (1968) considered the transmission of *Leucocytozoon sakharoffi* Sambon by *Simulium angustitarse* Lundstroem and *L. simondi* (Mathis and Leger) by *S. rugglesi* respectively. Bennett (1970) showed the development of *Trypanosoma avium* Danilewsky complex in four species of ornithophilic blackflies. Eichler (1971) studied the behaviour of *S. ornatum* in relation to transmission of *Onchocerca gutturosa* Neumann. Barreto *et al.* (1970) and Duke *et al.* (1972) also discussed onchocerciasis.

## Cytology

Studies in cytology have shown that many of the single species of earlier taxonomy in reality consisted of several rather similar or sibling species. Cytological studies use the banding pattern of the giant chromosomes that are found in the salivary gland cells of blackfly larvae. Rothfels and Dunbar (1953) started cytological research with blackflies and since that time it has also been carried out by Basrur (1962), Basrur and Rothfels (1959), Dunbar (1958, 1959, 1966a, 1966b, 1967, 1969), Landau (1962), Ottonen (1966), Ottonen and Nambiar (1969), Pasternak (1964), Rothfels (1956), and Rothfels and Basrur (1962).

## Physiology

Physiology of blackflies has been somewhat neglected. Apart from ovarian development already considered, Downe and Morrison (1957) studied the rate of digestion of blood meals using precipitin tests, and Hinton (1959) studied the larval chromatocytes and their function at metamorphosis and the origin and development of the indirect flight muscles. Mansingh *et al.* (1972) considered oligopause hibernation in blackflies, and Yang and Davies (1968a, 1968b, 1968c) studied trypsin invertase, and amylase activity. Teshima (1972) examined DNA-DNA hybridization in several species of blackflies. Ultrastructural physiological studies have been conducted by Liu and Davies (1971, 1972a, 1972b, 1972c, 1972d, 1972e).

### Rearing

Adult blackflies have been reared without difficulty from immature stages in the laboratory. Studies on rearing include those by Dalmat (1955), Doby *et al.* (1959), Fredeen (1959a), Hall and Harrod (1963), Hartley (1955), Hocking and Pickering (1954), Puri (1925a), Raybould (1967), Smart (1934b), Tarshis (1968b, 1971), Thomas (1946), Wood and Davies (1965), and Wright (1957). Wenk (1965) and Wenk and Raybould (1972) have had success with mating, feeding, and oviposition in *S. damnosum*.

### Sampling

The device needed to sample a population of blackfly larvae or pupae is determined by the type of substrate selected by them. Carlsson (1962) used wooden boards; Curtis (1968) made use of white hardboard strips; Disney (1972) suspended in streams lengths of cord which had mango leaves tied in it at intervals; Doby *et al.* (1967) used polythene tapes; Johnson and Pengelly (1966) used metal cones; Peterson and Wolfe (1958) used white metal cones; and Phillipson (1956) used plastic cones. Wanson and Henrard (1945) made use of nets, wooden floats, and sealed tins; Williams and Obeng (1962) also used polythene tapes; Wolfe and Peterson (1959) used white plates and metal cones; Zahar (1951) used white tiles; and for convenience Disney (1970) used palm fronds, and Tarshis (1965, 1968a) used lengths of fabric for collecting large numbers of larvae and pupae. Maitland (1964) and Maitland and Penney (1967) sampled gravel or small boulders with a shovel sampler, and Chutter (1968) sampled individual stones. Holbrook (1967) used a plasterer's lath, and Ladle *et al.* (1972) used a unique apparatus for sampling immature stages of blackflies on *Ranunculus* plants. Many of these devices were designed for estimating population density, while others were used strictly to facilitate collecting.

Other methods have been used to study adult populations. Davies (1950), Davies and Syme (1958), and Hocking and Richards (1952) used emergence traps. Abdelnur (1968), L. Davies (1955), Davies and Williams (1962), and Fredeen (1961) used light traps. Anderson and DeFoliart (1961) and Bennett (1960) employed baited traps, and Fredeen (1961) used silhouette traps. L. Davies (1963) and Hocking and Richards (1952) sweep-netted. Davies (1951), Hocking and Richards (1952), and Peterson and Wolfe (1958) have presented methods of estimating adult density.

### Parasites and Predators

Jenkins (1964) produced a bibliography which included parasites and predators of blackflies up to 1962. Laird (1971) continued this bibliography combining literature from 1963-1967. Many authors have since discussed parasites and predators in ecological studies but those papers specifically related to parasitism and predation include Bengston and Ulfstrand (1971), Frost (1970), Frost and Manier (1971), Frost and Nolan (1972), Jamnback (1970), Lichtwardt (1967), Manier and Maurand (1966), Maurand (1967), Moss (1970), Reichle and Lichtwardt (1972), Snoddy (1967, 1968), Snoddy and Chipley (1971), and Williams and Lichtwardt (1971).

## Control

McMahon (1967) reviewed the available literature on the control of *Simulium* vectors of onchocerciasis in Africa, and Chance (1970b) reviewed the chemical control methods for blackfly larvae. Other papers which have not been considered by these authors or which have been published since include Brown *et al.* (1951), Burton *et al.* (1964), Conradi (1905), Jamnback and Means (1966), Jamnback and West (1970), Metcalf and Sanderson (1932), Noamesi (1962), Quelennec (1962, 1970), Quelennec and Ovazza (1968), Quelennec *et al.* (1970), Travis (1966, 1968), Travis *et al.* (1967, 1970), and Weed (1904a, 1904b). Gross *et al.* (1972) undertook studies on radiation of blackflies to develop methods of control, based on the "sterile-male" technique. DeFoliart (1951b) compared the effectiveness of several repellents against blackflies and determined the average protection time for each repellent tested.

## MATERIALS AND METHODS

Pickavance Creek (Figs. 1 and 2) was the immediate research area and was studied from late April to early September, 1970 and late April, 1971 through to the end of October, 1972. Scattered collections were made in the winter of 1970-71. Normally, collections were made weekly, and fortnightly when weekly collections could not be made. Other collections included a trans-Island survey conducted in late May, 1972 and collections on various parts of the Island during 1970-72. Including the Pickavance Creek area, a total of 212 streams were sampled either once or several times, depending on the geographical location. The distribution of these streams on the Island is indicated in Fig. 3. In Appendix A, a more detailed description and location of the streams is given. Descriptions of the first 99 streams have the following format: stream number; map number; military grid reference; name of stream or location; T, I, or P, depending on whether the stream is temporary, intermittent or permanent (the temporary streams are not illustrated on the maps); depth (cm) at which immatures were collected; average width (m) of the stream; and species obtained from that stream. Streams 100 to 212 have all of this data except for the widths and depths. All map numbers and grid references are from the Canadian National Topographic Series 1:50,000.

### Pickavance Creek Research Area

Pickavance Creek is about 16 kilometers west of St. John's on the Trans Canada Highway (Stream 206 in Appendix A). It is a permanent stream approximately 1,200 meters in length and varies from 2 to 4 meters in width. The depth ranges from 10 to 100 centimeters in June.

The stream moves rapidly in the spring and fall, but rather sluggishly in midsummer because the gradient is not steep. The bed consists of mud in occasionally interspersed pools, and all sizes of rocks up to 70 centimeters in diameter. Portions of the stream are completely exposed to sunlight, while other regions are somewhat shaded. Eleven sampling areas were chosen to provide as many different habitats as possible within the same stream (Fig. 2). Table I contains a description of these 11 areas, and the current ranges and averages may be found in Fig. 4. The dominant streamside vegetation of these areas is contained in Appendix B.

There are six other creeks or trickles which flow into Pickavance Creek (A Creek), and these also have been studied. They have been designated B, C, D, E, F and G creeks (Fig. 2). B and C creeks are permanent roadside trickles which run parallel with the Trans Canada Highway and which flow into Pickavance Creek where it crosses under the highway. D is also a roadside trickle into which E, F and G empty. D creek does not flow directly into Pickavance Creek, rather, it flows into a bog-like area which empties into Pickavance Creek at several locations near site 11. E is a temporary drainage creek which empties a forest bog. F and G also drain a woodland bog, but F is temporary and G is permanent. B, C, E and F creeks have been sampled in one area only, and D and G creeks have been sampled in two areas. Descriptions of these sampling areas may be found in Table I, and the current velocities are to be found in Fig. 4. The dominant streamside vegetation of each of these sampling areas is contained in Appendix B.

Table I. Site descriptions in the Pickavance Creek area

| Site | Dist. from source (m) | Width (m) | Depth (cm) | Substrate | Shade* | Max. rock diam. (cm) | Comments |
|---|---|---|---|---|---|---|---|
| A-1 | 400 | 1.5 | 25.0 | rocks, boulders | complete | 60.0 | Stream 206 in Appendix A |
| A-2 | 439 | 1.0 | 15.0 | rocks** | partial | 15.0 | Outflow of small pool 2 m in length |
| A-3 | 456 | 0.8 | 25.0 | rocks, twigs, branches | partial | 15.0 | |
| A-4 | 493 | 1.2 | 13.0 | rocks | partial | 40.0 | |
| A-5 | 512 | 1.0 | 20.0 | rocks, boulders | complete | 60.0 | Base of 1 m waterfall |
| A-6 | 521 | 1.5 | 15.0 | rocks, boulders** | nil | 70.0 | Outflow of 2 m pool |
| A-7 | 543 | 1.5 | 18.0 | rocks, boulders | partial | 70.0 | |
| A-8 | 607 | 1.0 | 10.0 | rocks, pebbles** | nil | 40.0 | Entrance of culvert, at base of 90 m pool |
| A-9 | 625 | 0.8 | 12.0 | rocks | complete | 20.0 | Middle of 2.4x36 m culvert |
| A-10 | 664 | 1.5 | 15.0 | rocks | partial | 15.0 | |
| A-11 | 803 | 1.5 | 15.0 | rocks | nil | 20.0 | Stream empties into Paddys Pond 396 m from this site |
| B | | 0.15 | 6.0 | rocks | complete | 12.0 | Stream 207 in Appendix A |
| C | | 0.20 | 10.0 | rocks, grasses | partial | 15.0 | Stream 208 in Appendix A |
| D-1 | | 0.25 | 10.0 | rocks | nil | 10.0 | Stream 209 in Appendix A |
| D-2 | | 0.20 | 12.0 | rocks | partial | 15.0 | |
| E | | 0.15 | 8.0 | sand, pebbles, rocks | partial | 12.0 | Stream 210 in Appendix A |
| F | | 0.15 | 6.0 | rocks, grasses | nil | 8.0 | Stream 211 in Appendix A |
| G-1 | | 0.20 | 6.0 | rocks, grasses | nil | 12.0 | Stream 212 in Appendix A |
| G-2 | | 0.15 | 6.0 | log | complete | - | Outflow of small pool dammed by 12 cm log |

*Shade due to shoreline vegetation - see Appendix B for dominant vegetation in the collecting areas.

**Trailing vegetation abundant in summer.

## Field and Laboratory Procedures

Larvae and pupae are usually found in flowing water. Species are known to vary in the types of streams which they inhabit, so habitats varying from very small, temporary roadside trickles to large permanent streams and rivers, were sampled. The immature stages of blackflies have been collected from all sizes of rocks, trailing vegetation, twigs, logs, and other assorted debris which may have been naturally or unnaturally introduced into streams. Several species were often found in the same stream. Larvae and pupae were collected by removing them with forceps from the substrate. In the Pickavance Creek study area, 10 x 10 x 0.8 cm. ceramic tiles were the usual substratum. These tiles were gray in color and in many areas resembled the color of the stony substrate. They were easily positioned on the stream bottom and just as easily retrieved. These tiles facilitated collecting, since larvae could be scraped off with any sort of smooth, straight, rigid object (e.g. plastic ruler). Obviously, if pupae were found on the tile, these required more care in removal. The tile surface area (100 $cm^2$) was also convenient for population density studies. Two series of tiles were painted and placed on the stream bottom to demonstrate possible color preference, and another series of four tiles was placed at various depths on a clamp stand for studies of depth preference.

Larvae were preserved in 95 percent alcohol in the field and determined in the laboratory using a dissecting microscope. Mature larvae are distinguished by the presence of the blackened pupal respiratory organ developing in the thoracic region of the larva. The number of filaments of the respiratory organ (histoblast) is specific, and quite often it was dissected from the larva and placed in glacial acetic acid to aid in identification. Usually the acid would cause the coiled histoblast to straighten out. Pupae were carefully removed from the substrate and, if found on vegetation, that portion of the vegetation with the pupa was cut away. They were placed in petri dishes containing moist filter paper and brought back to the laboratory for emergence. In the laboratory, pupae were reared individually in shell vials. Each vial was 9 x 30 mm, ¼ dr, and in each was placed a strip of filter paper which stood in a small amount of water. A cotton plug prevented the emerging adult from escaping. Several hours after emergence the adults were either pinned or preserved in 70 percent alcohol with the associated pupal skin. Newly emerged females were kept for 4 or 5 days in the laboratory for studies of ovarian development. The flies were fed with either a 5 percent sucrose solution or water was applied to the cotton plug. The adults were later dissected in 0.9 percent saline and a drop of detergent. The detergent causes the fly to be wetted quickly, it causes the oocytes to swell and to be easily separated, and it prevents the saline from forming inconvenient separate drops during dissection on the microscope slide. Following dissection, these females were preserved in 70 percent alcohol.

Frequently, the head capsule and the shed skin of the mature larva can be found within the cocoon of the pupa and this may aid species identification. Also, by rearing individual pupae, an association of the pupal skin with the adult can be established.

Eggs were often collected on trailing vegetation; these were collected and placed in a petri dish with moist filter paper. Generally, these eggs hatched in 2 to 3 days. The first instar larvae were then preserved in 95 percent alcohol.

During the course of this study, various physical and chemical factors were measured. Depth and width measurements were made with a meter stick; temperatures were measured with a Centigrade thermometer; and current velocity was measured with an Ott propellor-driven current meter.[1] Chemical analyses, which included tests for ammonia, carbon dioxide, chlorides, calcium, dissolved oxygen, hardness, magnesium, nitrate, pH, phosphate, silica, and sulfide were conducted in the field using a LaMotte chemical analysis kit.[2]

---

[1] A. Ott. Kempten-Allgaen, Hydraulic Laboratory.

[2] LaMotte Chemical Products Co., Chestertown, Md.

# RESULTS AND DISCUSSION

## THE NEWFOUNDLAND SPECIES OF SIMULIIDAE

The general classification of the Simuliidae is still in a state of flux, because very little work has been done on a universal scale to bring the various taxonomic studies together, and there is still considerable lack of knowledge about the immature stages and life histories. In 1905 only a single genus was recognized, but presently at least 11 genera and many subgenera are recognized (Stone and Snoddy, 1969).

Three genera and nine subgenera are now recorded from Newfoundland and the purpose of the key is to make possible the identification of the Newfoundland species of Simuliidae. The key is based on those by Davies *et al.* (1962), Peterson (1970), and Wood *et al.* (1963). Because not all stages of all species were collected, and since the missing stages are probably similar to those of other regions of Canada, they are included in the key for completeness. Keys have been constructed for male and female adults, pupae, and mature larvae. Mature larvae are distinguished by the presence of the blackened histoblast (pupal respiratory organ) laterally located on the larval thorax.

### Variability of Characters

Intraspecific variation has been observed in the Newfoundland Simuliidae, particularly the larval stages. Generally, mature larvae of all species are about 7 mm in length, but in one stream (Stream 126 in Appendix A) larvae of *Prosimulium fuscum* Syme and Davies, *P. mixtum* Syme and Davies, *Cnephia mutata* Malloch, and *C. dacotensis* Dyar and Shannon were about 10 mm long. The reason for this is unknown, especially since very little is known about the stream itself.

The anal sclerite appears variable, particularly in the *P. fuscum/mixtum* complex, and may not be a reliable character in the separation of these two species. *P. fuscum* sometimes has an anal sclerite which resembles that of *P. mixtum*, and vice versa. The postgenal cleft is normally a rigid character, but in *Simulium corbis* Twinn it varies in its depth. The rectal gills and ventral tubercles, when present, are not always visible, and while this may be due to methods of preservation, it is still a difficult character to use. The abdominal pigmentation of *S. venustum* Say and *S. verecundum* Stone and Jamnback often varies from stream to stream or generation to generation in the same stream and this is thought to be due to the diet of the larvae. *C. mutata* is a species with stable characters, and may be recognized without any difficulty from the first or second instar.

Several forms of aberrations or abnormalities other than variation were observed in the course of this study. These were mainly found in the eye spots, but abnormalities were also observed in head-spots, hypostomial teeth, abdominal pigmentation and in one adult male *S. venustum*. On several occasions the eye spots of all species at the Pickavance Creek area were observed to be slightly dislocated, that is, located to one side of the clear area in the head capsule. Smart and Clifford (1965) also reported that the eye spots may be abnormally shaped or absent in larvae that appeared to be otherwise perfectly normal. Several specimens of *P. fuscum/mixtum*, *C. mutata*, *S. latipes* (Meigen), *S. venustum* and *S. tuberosum* Lundstrom were found to be lacking eye spots altogether, and specimens of *P. fuscum/mixtum* and

*S. latipes* were observed to have eye spots on one side of the head only, and these were not always in the clear region of the head capsule. The first specimens of "blind" larvae were found at Site A-9 (the culvert under the Trans Canada Highway) and it was thought that this dark habitat may have had some relation with the occurrence of larvae with no eye spots. Several specimens of *P. fuscum/mixtum* were found to have semi-clear head spots, which are the regions of muscle attachment. One immature specimen of *P. fuscum/mixtum* was found to have two complete and apparently identical sets of hypostomial teeth on the hypostome and this had no relation with larval ecdysis. One medium-sized specimen of *S. venustum* was found to have its median tooth absent in such a way that there was a deep V-shaped cleft in the hypostome. All the larvae in a collection of *S. venustum* from one stream were found to have a large triangular pigmented area laterally located on each side of the eighth abdominal segment. This was found only in *S. venustum* and only in one stream. An adult male *S. venustum* which was reared from a pupa in the laboratory was found to have emerged with five normal legs and a vestigial sixth. All of these aberrations are assumed to be genetic, although it is not known how various chemical, physical or biotic parameters of streams may affect the immature stages of blackflies.

## Key to the Genera of Newfoundland Simuliidae

### Adults

1\. Costa with fine hairs, spinules absent; radial sector forked apically; calcipala and pedisulcus absent . . . . . . . . . . . . . . . *Prosimulium*

Costa with spinules interspersed with fine hair; radial sector unbranched; calcipala and pedisulcus usually present . . . . . . . . . . . . 2

2. Basal cell present; length of vein R not less than one-third distance from base of radial sector to wing apex, with hair dorsally; calcipala often reduced; second hind tarsal segment without pedisulcus or very shallow . . *Cnephia*

Basal cell absent or incomplete; length of vein R less than one-third distance from base of radial sector to wing apex, with or without dorsal hair; calcipala usually well developed; second hind tarsal segment usually with distinct, deep pedisulcus . . . . . . . . . . . . . *Simulium*

### Pupae

1. Cocoon irregular, shapeless, without a well-defined anterior margin; abdomen with two long terminal hooks . . . . . . . . . . . 2

Cocoon well developed, variously shaped, with a well-defined anterior margin; abdomen without two long terminal hooks. . . . . . . . . *Simulium*

2. Respiratory filaments arising from a rounded knob on a short petiole. . . . . . . . . *Cnephia*

Respiratory filaments not arising from a rounded knob on a short petiole . . . . . . *3*

3. Respiratory filaments 12 . . . . . . . . . *Cnephia*

Respiratory filaments 16 or more. . . . . . *Prosimulium*

### Larvae

1. Basal two segments of antenna colorless, distal two segments darkly pigmented; postocciput nearly complete dorsally, enclosing cervical sclerites; secondary fan with few rays, forming a flat triangular fan when open . . . . . . *Prosimulium*

Basal two segments at least partly colored, distal two segments usually same color as basal two; postocciput with a wide dorsal gap, not enclosing cervical sclerites; secondary fan with many rays, forming a cupped fan when open . 3

2. Hypostomium with outerlateral and median teeth large and subequal and three smaller subequal intermediate teeth on each side; rectal gill usually with three compound lobes . . . . . *Simulium*

Hypostomium not as above; rectal gill with three simple lobes . . . . . . . . . . . *Cnephia*

## Key to the Species of *Prosimulium*

### Females

1. Ovipositor lobe short, truncate or broadly rounded distally, not reaching anal lobe, abdomen appears truncate or rounded posteriorly; anteromedial corner of lobe not produced nipple-like; spermatheca with small differentiated circular area, or none, at junction with spermathecal duct; claw with conspicuous basal or subbasal tooth. . . . . . . . . . *pleurale*

   Ovipositor lobe long, pointed or narrowly rounded distally, reaching or extending beyond anal lobe; abdomen appears pointed posteriorly; anteromedial corner produced nipple-like; spermatheca with large, differentiated circular area at junction with spermathecal duct; claw simple or with small inconspicuous subbasal tooth. . . . . . . . . . . . . . . 2

2. Genital fork arm with a subquadrate terminal plate, with a short, broad, rounded or bluntly pointed, inner distal process. . . . . . . . *fuscum*

   Genital fork arm with a triangular or subtriangular terminal plate, with a long, slender, sharply pointed process. . . . . . . . . . *mixtum*

### Males

1. Pleuron with small patch of hairs anterior and posterior to pleural membrane; body of ventral plate deeply cleft, H-shaped; median sclerite Y-shaped, its stem and basal portion of arms heavily sclerotized, remainder of arms membranous and prolonged so that they project posteriorly and ventrally beyond margin of ventral plate; distimere thin, pointed, bearing 1 subterminal and 2 terminal spines; plate of endoparameral organ dorsally with a spine that curves ventrally and posteriorly to meet tip of distimere . . . . . . . . . . . . . . *pleurale*

   Pleuron without small patches of hair on either side of pleural membrane; body of ventral plate not deeply cleft or H-shaped; median sclerite variable but arms not prolonged; distimere variable; endoparameral organ dorsally expanded plate-like but not as a curved meeting tip of distimere . . . . . . . . . . . . . . 2

2. Lip of ventral plate long and slender, in terminal view . . . . . . . . . . . . . *mixtum*

Lip of ventral plate short and broader, in terminal view . . . . . . . . . . . . . *fuscum*

Pupae

1. Respiratory organ with 16 filaments. . . . . 2

Respiratory organ with 26 filaments. . . . . *pleurale*

2. Respiratory organ laterally broad, as wide or wider as long; three primary trunks separating from base so that all are equally visible, lateral trunk not obscured by other two . . . *fuscum*

Respiratory organ laterally narrow, longer than wide; lateral primary trunk usually more divergent from dorsal trunk than from ventral trunk so that the ventral trunk is usually obscured. . . . . . . . . . . . . . *mixtum*

Larvae

1. Lateral plate of proleg narrow lying parallel to bases of apical hooks with, at most, a weak indication of vertical portion; postgenal cleft deep . . . . . . . . . . . *pleurale*

Lateral plate of proleg broad with a well-developed vertical portion; postgenal cleft shallow . . . . . . . . . . . . . . . 2

2. Outerlateral and sublateral hypostomial teeth of nearly equal height; cephalic fan with 27-37 rays; anterodorsal arms of anal sclerite one-third longer than posteroventral arms; first posterolateral head spot absent . . . . *mixtum*

Outerlateral hypostomial teeth higher than sublateral teeth, which are nearly equal in height, or decreasing in height inwardly; cephalic fan with 37-46 rays; anterodorsal arms of anal sclerite equal to, or slightly longer, than posteroventral arms; first posterolateral head spot present. . . . . . *fuscum*

## Key to the Species of *Cnephia*

### Females

| | | |
|---|---|---|
| 1. | Tarsal claws simple . . . . . . . . . . . | *mutata* |
| | Tarsal claws long, slender, each with a small subbasal tooth . . . . . . . . . . . . | *dacotensis* |

### Males

| | | |
|---|---|---|
| 1. | Dististyle with one terminal tooth . . . . . | *dacotensis* |
| | Dististyle with two terminal teeth . . . . . | *mutata* |

### Pupae

| | | |
|---|---|---|
| 1. | Respiratory filaments 12. . . . . . . . . . | *mutata* |
| | Respiratory filaments 30-40 (usually 34) . . . | *dacotensis* |

### Larvae

| | | |
|---|---|---|
| 1. | Subgenal cleft an inverted V-shape; antennae much longer than stalk of cephalic fan . . . . | *mutata* |
| | Subgenal cleft U-shaped with flattened apex; antennae shorter than stalk of cephalic fan . . | *dacotensis* |

## Key to the Species of *Simulium*

### Females

| | | |
|---|---|---|
| 1. | Vein R with hairs dorsally . . . . . . . . . | 2 |
| | Vein R without hairs dorsally . . . . . . . . | 10 |
| 2. | Claws simple. . . . . . . . . . . . . . | *furculatum* |
| | Claws with a large lobed basal projection . . . | 3 |
| 3. | Basal two-thirds of tibiae yellow, contrasting with the distal black portion; postscutellum with two patches of gold hair . . . . . . . . . . . | *aureum* |
| | Tibiae not yellow, may be brown, gray or black; postscutellum bare. . . . . . . . . . . . | 4 |
| 4. | Pedisulcus long and shallow, the depth less than one-third the width of the segment; sensory | |

vesicle of third palpal segment small, about one-fourth the length of the segment; second antennal segment longer and wider than third . . *excisum*

Pedisulcus short and deep, the depth at least one-half the width of the segment; sensory vesicle of third palpal segment large, one-half the length of the segment (except in *S. gouldingi*, which has a large patch of hair on the katepisternum); second antennal segment shorter than third . . . . . . . . . . . . . . 5

5. Katepisternum with a patch of hair along dorsal margin. . . . . . . . . . . . . . . 6

Katepisternum bare. . . . . . . . . . . . 7

6. Sensory vesicle of third palpal segment at least one-half the length of the segment; patch of hair on katepisternum small, centrally located; abdomen densely covered with silvery hair. . . . . . *croxtoni*

Sensory vesicle of third palpal segment at most one-third the length of the segment; patch of hair on katepisternum extensive, anteriorly placed; abdomen sparsely covered with golden hair . . . . . . . . . . . . . . . . *gouldingi*

7. Precoxal bridge incomplete, with a narrow interruption near proepisternum; silvery or white hair of abdomen dense laterally, but absent on the black, dorsolateral areas of segments three and four . . . . . . . . . . . . . . . . *euryadminiculum*

Precoxal bridge complete, narrow, strongly sclerotized; hair of abdomen yellow, sparse, dorsolateral areas of segments three and four not contrastingly black and bare . . . . . . . . 8

8. Posterolateral areas of terminal plates of genital fork, at points of attachment to ninth tergite, widened dorsoventrally to form strongly sclerotized, paddle-shaped structures which are most conspicuous in terminal or lateral view; scutum with pale brassy hair . . . . . . . . *quebecense*

Posterolateral areas of terminal plates not noticeably widened, not paddle-shaped; hair on scutum variable. . . . . . . . . . . . . 9

9. Genital fork arms diverging from stem near mid-point of the total length of the genital fork;

| | | |
|---|---|---|
| | tubercle on each internal dorsal arm of metasternum small, shallow, with a broad base; hair of scutum pale yellow, uniform. . . | *pugetense* |
| | Genital fork arms diverging from stem near a point two-thirds of the total length of the genital fork from the anterior end of the stem; tubercle on each internal dorsal arm of metasternum prominent; hair on central region of scutum golden, contrasting with pale hair on anterior and lateral margins . . . . . . | *latipes* |
| 10. | Claws each with a large lobed basal projection; fore coxa yellow . . . . . . . . . . . | *rugglesi* |
| | Claws simple, or with a small, distinct, subbasal tooth; fore coxa variable . . . . . . . . | 11 |
| 11. | Claws each with a small, distinct, subbasal tooth | *corbis* |
| | Claws simple . . . . . . . . . . . . . | 12 |
| 12. | Gray species with conspicuous vittae on dorsum of scutum; fore coxa dark; abdomen pale gray or with distinct black and light gray pattern . . | *vittatum* |
| | Brownish or blackish species without conspicuous vittae on dorsum of scutum; fore coxa variable; if abdomen pale or with indication of thoracic stripes the abdomen never pale gray and without distinct black and light gray pattern . . . . | 13 |
| 13. | Frons and terminal abdominal tergites distinctly pollinose; anal lobe large, subquadrate, narrow dorsally, broad ventrally, anteroventral margin rounded, with a short, posteroventral projection under cercus . . . . . . . . . . . . | *decorum* |
| | Frons and terminal abdominal tergites shining brown or black; anal lobe not as above. . . . | 14 |
| 14. | Fore tibia with a narrow grayish-white streak on anterior surface covering at most one-third the width of the tibia . . . . . . . . . . | *tuberosum* |
| | Fore tibia with a conspicuous, bright, yellowish-white patch on anterior surface covering at least one-half the width of the tibia . . . . | 15 |
| 15. | Inner margin of flaps of ovipositor straight and slightly diverging distally; anterior anal lobe | |

margin not noticeably more sclerotized than rest of lobe . . . . . . . . . . . . *venustum*

Inner margin of flaps of ovipositor concave, with an oval space between them; anterior anal lobe margin noticeably more sclerotized than rest of lobe . . . . . . . . . . . . *verecundum*

### Males

1. Vein R with hairs dorsally . . . . . . . . 2

   Vein R without hairs dorsally . . . . . . . 10

2. Ventral plate laterally compressed, twice as long as broad, basal arms extending laterally; postscutellum with two patches of golden hair . *aureum*

   Ventral plate dorsoventrally flattened, as broad as long, basal arms subparallel extending anteriorly; postscutellum bare . . . . . . 3

3. Dististyle tapering to a pointed apex, with a small apical spine . . . . . . . . . . 4

   Dististyle not pointed apically, but with a flattened, triangular flange medially, the small, apical spine directed anteromedially. . 6

4. Dististyle with a flattened, flange-like structure along the lateral edge, near the midpoint . . . . . . . . . . . . . *furculatum*

   Dististyle tapering uniformly, flange-like structure along lateral edge absent . . . . 5

5. Body of ventral plate rectangular in shape, widest portion distal to the point of attachment of the basal arms. . . . . . . . . *euryadminiculum*

   Body of ventral plate triangular to trapezoidal in shape, widest region at point of attachment of the basal arms, narrowing distally to the prominent, ventrally recurved lip . . . . . *excisum*

6. Katepisternum with a patch of golden hair along dorsal edge . . . . . . . . . . . *gouldingi*

   Katepisternum bare . . . . . . . . . . . 7

7. Body of ventral plate narrowing distally, in ventral view the small, central, hirsute lip extending like a tubercle beyond the posterior edge . . . . . . . . . . . *croxtoni*

Body of ventral plate truncate or emarginate distally, in ventral view the hirsute lip directed ventrally, not extending beyond the posterior edge . . . . . . . . . . . 8

8. Ventral plate distal margin, in ventral view, nearly truncate, shallow and broad, the lip about one-half the width of the body of the ventral plate . . . . . . . . . . . *latipes*

Ventral plate distal margin, in ventral view, nearly concave, the small lip occasionally projecting into this concavity but not beyond; lip at most one-third the width of the body of the ventral plate . . . . . . . . . 9

9. Lip of ventral plate, in terminal view, deeper than wide, appearing enlarged . . . . . . *quebecense*

Lip of ventral plate, in terminal view, smaller, wider than deep, without noticeable enlargement . . . . . . . . . . . . *pugetense*

10. Dististyle short and stout, apicolateral margin a continuous curve with at least three stout, somewhat separated, apical spines . . *vittatum*

Dististyle long, and/or with one or two apical spines or absent; apicolateral margin variable 11

11. Dististyle with a distinct lobe or tubercle near base internally . . . . . . . . . . 12

Dististyle without a distinct lobe or tubercle near base internally . . . . . . 13

12. Internal lobe of dististyle basal, with short, stout, spines . . . . . . . . . . *tuberosum*

Internal lobe of dististyle subbasal, or basal, with hairs only. . . . . . . . . . . . *rugglesi*

13. Ventral plate broad, tooth-shaped, dentate lateral margins flaring outward, ventral plate appearing trilobed when viewed on end . *venustum*

Ventral plate narrow, inverted Y-shape, with a ventral process, often not prominent, dentate lateral margins somewhat compressed laterally, not flaring outward . . . . . . . . . . 14

14. Ventral keel of ventral plate strongly compressed laterally, deep, square in profile and forming an angle before apex of median portion, with at most a short, bare, ventroapical projection beyond dentate portion . . . *decorum*

Ventral keel of ventral plate less strongly compressed laterally, shallow, not square in profile, the angle being at the apex and forming a conspicuous, bare, ventroapical projection beyond dentate portion . . . . . 15

15. Dentate lateral margins of ventral plate somewhat separated but turned inward toward each other; ventral keel, in profile, triangular in shape, inner margin straight; parameral hooks all about equal in length, not distinctly formed . . . . . . . . . . . . . . *verecundum*

Dentate lateral margins of ventral plate compressed laterally, not turned inward toward each other; ventral keel, in profile, oval, the inner margin slightly concave; parameral hooks gradually lengthening toward center, distinctly formed . . . . . . . . . *corbis*

Pupae

1. Anterodorsal margin of cocoon with a long, median projection; cocoon slipper-shaped so that the ventral part of the anterior opening is touching or nearly touching the substrate surface . . . 2

Anterodorsal margin of cocoon without a long median projection, but a short convex protrusion may be present; cocoon slipper-shaped, or boot-shaped so that the anterior opening is raised from the substrate, the anteroventral portion of the cocoon being woven into a collar standing at an angle from the surface of attachment . . . 5

2. Respiratory filaments 4. . . . . . . . . . *latipes*

Respiratory filaments 6 or more . . . . . . . 3

3. Respiratory filaments 6. . . . . . . . . . 4

Respiratory filaments 8. . . . . . . . . . *croxtoni*

4\. Anterodorsal projection of cocoon long, slender, tightly woven . . . . . . . . . . . . . *excisum*

Anterodorsal projection of cocoon short, broad, loosely woven . . . . . . . . . . . . . *gouldingi*

5\. Cocoon boot-shaped; respiratory filaments 10; sides of anterior opening with long, cross-woven loops. . . . . . . . . . . . . . . . *corbis*

Cocoon slipper-shaped; respiratory filaments variable; sides of anterior opening without long, cross-woven loops. . . . . . . . . . 6

6\. Respiratory filaments 4. . . . . . . . . . . 7

Respiratory filaments 6 or more . . . . . . . 10

7\. Dorsal respiratory filament strongly divergent at base from the other three; dorsal pair of filaments on a short petiole, the ventral pair with almost no petiole . . . . . . . . . . *aureum*

Dorsal respiratory filament not strongly divergent at base from the other three; filaments in two petiolate pairs. . . . . . 8

8\. Annuli along basal portion of respiratory filaments, just beyond petiole, numerous and narrow, giving a gray, roughened appearance; ventral filaments with 5-6 annuli per diameter of filament. . . . . . . . . . . . . . 9

Annuli along basal portion of respiratory filaments, just beyond petiole, less numerous and wider, giving a shiny appearance; ventral filaments with 2-3 annuli per diameter of filament. . . . . . . . . . . . . . . . *euryadminiculum*

9\. Respiratory filaments diverging dorsoventrally, petiole of dorsal pair at most one and one-half times as thick as petiole of ventral pair; tubercles on head and thorax small, regularly spaced, not strongly grouped . . . . . . . *quebecense*

Respiratory filaments not diverging, subparallel, petiole of dorsal pair twice as thick as petiole of ventral pair; tubercles on head and thorax large, irregularly grouped. . . . . . . . *pugetense*

10\. Respiratory filaments 6. . . . . . . . . . 14

Respiratory filaments 8 or more . . . . . . . 11

11. Respiratory filaments 8. . . . . . . . . . 12

Respiratory filaments 16 . . . . . . . . . *vittatum*

12. Cocoon tightly woven, with thickened anterior rim, or a slight mid-dorsal protrusion on anterior rim; respiratory filaments arising from 3 main trunks, branching 2 dorsal, 3 medial, 3 ventral . . . . . . . . . . . . . . *furculatum*

Cocoon loosely woven; without thickened anterior rim or mid-dorsal protrusion; respiratory filaments branching pattern not 2, 3, 3. . . . 13

13. Respiratory filaments thick, in three, short, petiolate pairs, plus two singles . . . . . *decorum*

Respiratory filaments thin, in four petiolate pairs. . . . . . . . . . . . . . . . *rugglesi*

14. Dorsal portion of cocoon about 2.5 mm in length. *tuberosum*

Dorsal portion of cocoon at least 3.0 mm in length . . . . . . . . . . . . . . . 15

15. Length of petioles .5, .5, .75 mm (dorsal, medial, ventral). . . . . . . . . . . . . . . *venustum*

Length of petioles .9, 1.25, 1.25 mm (dorsal, medial, ventral) . . . . . . . . . . . . *verecundum*

## Larvae

1. Abdominal segment 8 with two large ventral tubercles, one-third to one-half the depth of the abdomen below their points of attachment; antenna usually noticeably longer than stalk of cephalic fan; postgenal cleft short, or long and bulbous, not pointed apically; suboesophageal ganglion and epidermis in postgenal cleft not distinctly blackish . . . 2

Abdominal segment 8 without ventral tubercles, or these inconspicuous and reduced to less than one-sixth the depth of the abdomen below their points of attachment; antenna length variable; postgenal cleft pointed apically, or subquadrate, or long and bulbous; suboesophageal ganglion and/or epidermis in postgenal cleft often distinctly blackish . . . . . . . . 10

2. Second antennal segment subdivided into five annuli . . . . . . . . . . . . . . *euryadminiculum*

   Second antennal segment not subdivided into annuli . . . . . . . . . . . . . . 3

3. Postgenal cleft small, usually square, with a straight anterior border, its length (from anterior margin of cleft to posterior tentorial pit) one-fifth or less the length of the head between posterior tentorial pit and hypostomial teeth . . . . . . . . . . . . . . 4

   Postgenal cleft large, one-third or more the length of the head between posterior tentorial pit and hypostomial teeth, with rounded apex, usually broadest at about the mid-point of its length . . . . . . . . . . . . . . 5

4. Median hypostomial tooth equal to the longest lateral teeth; body pigment reddish brown . . *excisum*

   Median hypostomial tooth longer than lateral teeth; body pigment sand-brown . . . . . . *aureum*

5. Postgenal cleft long and bulbous, extending to, or nearly to base of hypostomium . . . . . *rugglesi*

   Postgenal cleft shorter, rounded apically, not bulbous, extending less than one-half the distance to the hypostomium . . . . . . . 6

6. Large pigmented area antero-ventral to eye . . 7

   Small pigmented area antero-ventral to eye, or absent . . . . . . . . . . . . . 8

7. Length, postgenal cleft at least one-third the distance from posterior tentorial pit to hypostomial teeth; dorsal background pigment of head extended anteriorly beyond bases of antennae as a dark median stripe . . . . . *croxtoni*

   Length of postgenal cleft at most one-quarter the distance from the posterior tentorial pit to hypostomial teeth, dorsal background pigment not extended beyond antero-median spot . . *latipes*

8. First abdominal segment with two dorsal and two ventral spots of darker, denser greenish pigment contrasting with paler pigment on

adjacent segments; head capsule pale on anterior half, dark brown basally . . . . . *quebecense*

Pigment of first-abdominal segment not contrastingly darker than that of adjacent segments . . . . . . . . . . . . . . 9

9. Toothed area of hypostome narrow, the teeth nearly uniform in size; postgenal cleft tapering apically, widest posteriorly. . . . *pugetense*

Toothed area of hypostome wider, the median tooth relatively long, the two flanking pairs of teeth relatively short, the remaining lateral teeth raised; postgenal cleft widest near mid-point of its length. . . . . . . . . . . . *gouldingi*

10. Postgenal cleft subquadrate, apical margin rounded; anal gill with simple lobes . . . . *vittatum*

Postgenal cleft long and bulbous, or sharply pointed apically; anal gill with digitately compound lobes . . . . . . . . . . . . 11

11. Antenna long, nearly entire two distal segments extending beyond apex of stalk of cephalic fan; suboesophageal ganglion or epidermis in postgenal cleft distinctly blackened; abdomen dark green . . . . . . . . . . . . . . . 12

Antenna short, extending at most, only slightly beyond apex of stalk of cephalic fan; suboesophageal ganglion and epidermis in postgenal cleft not blackened; abdomen not darkly pigmented. . . . . . . . . . . . 13

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

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

13. Spots of cephalic apotome dark, with, at most, a pale narrow fulvous area . . . . . . . . *furculatum*

Spots of cephalic apotome pale, with a dark, wide, fulvous area. . . . . . . . . . . 14

14. Infuscation around head spots narrow, not extending beyond inner edge of anterolateral spots; antenna not longer than stalk of cephalic fan; arms of anal sclerite narrowly fused medially . . . . . . . . . . . . . . *decorum*

Infuscation around head spots wider, extending beyond outer edge of anterolateral spots; antenna slightly longer than stalk of cephalic fan; arms of anal sclerite broadly fused medially 15

15. Lateral plate of proleg lightly sclerotized, faintly visible; cephalic fan with at least 52 rays; anal ring with about 66 rows of hooks; postgenal cleft not bordered by a fulvous band; head spots indistinct . . . . . . . . *verecundum*

Lateral plate of proleg heavily sclerotized, conspicuous; cephalic fan with at most 48 rays; anal ring with over 70 rows of hooks; postgenal cleft bordered by a narrow fulvous band; head spots distinct . . . . . . . *venustum*

*Prosimulium (Distosimulium) pleurale* Malloch

*P. pleurale* appears to be a fairly common species in the western half of the Island, collected from 15 streams, all west of Gander. Peterson (1970) recorded it from Shoal Harbour River, near Clarenville, and this is the only record east of Gander. It has not been collected nor recorded on the Avalon Peninsula.

The exact time of egg hatching is unknown, but larvae and pupae were collected in late May in water temperatures of 2 to 7°C.

This species was found in large rivers, with widths up to 50 m. It has been found only once in a stream which was less than 4.0 m in width. The usual substratum was rocks, and larvae and pupae have been collected at depths of 15 to 30 cm. The feeding habits are unknown in Newfoundland.

Peterson (1970) reported that its distribution includes Alaska, British Columbia, Alberta, Yukon Territory, Quebec, Labrador, and Newfoundland. He is of the opinion that, based on unpublished cytological investigations of Rothfels, the eastern form of *P. pleurale* is probably distinct from the western form, and points out that further collections are necessary before this can be morphologically verified.

Sommerman *et al.* (1955) indicated that hatching of this univoltine species begins in mid-August and continues until early October in Alaska. Larvae required eight to nine months for development and overwintered; larvae and pupae were collected in June. They also found that the maximum stream temperature ranged from 7.8 to 9.4°C during development, and that larvae preferred submerged or trailing branches.

Hearle (1932) reported that it was uncommon in British Columbia and he knew nothing about the early stages. Jenkins (1948) found *P. pleurale* in Alaska in fast, clear, mountain and bog drainage type streams with bottoms composed of rocks and boulders. Peterson (1970) collected specimens from a similar type stream in Quebec. Sommerman *et al.* (1955) found *P. pleurale* in streams ranging from 0.9 to 66 m wide, 5 to 45.7 cm deep, with current velocities 0.8 to 2.3 mps. Wolfe and Peterson (1959) collected two adult males in Quebec, but knew very little else about this species. Jenkins (1948) reported that females are attracted to humans but did not observe the biting habits. Shewell (1957) indicated *P. pleurale* was an occasional or localized pest of man and livestock. Peterson (1970) believed this species is probably ornithophilic.

While the biology of *P. pleurale* is far from complete, the Newfoundland form of this species appears to behave in a similar fashion to other forms in eastern and western Canada and Alaska.

Following is a summary of the aquatic stages of the life cycle of *P. pleurale* in Newfoundland during 1972:

| Stages collected | Date first collected | Date last collected |
|---|---|---|
| 1st instars | - | - |
| Immature larvae | 25-V-72 | 27-V-72 |
| Mature larvae | 25-V-72 | 26-V-72 |
| Pupae | 25-V-72 | 26-V-72 |

Newfoundland Distribution: Streams 44, 45, 64, 66, 68, 72, 73, 77, 87, 89, 90, 94; streams 38, 80, 85 (Ebsary, 1972); Peterson (1970).

### *Prosimulium (Prosimulium) fuscum* Syme and Davies, and *Prosimulium (Prosimulium) mixtum* Syme and Davies

Both *P. fuscum* and *P. mixtum* occur in Newfoundland and they will be discussed together since the biology and morphology of these two species is similar.

*P. fuscum* and *P. mixtum* are univoltine and overwinter in the larval stage. Egg hatching commences when the water temperature is about 7°C. In 1971 eggs began hatching in late October, and in 1972 in late September, presumably because the water temperature had dropped to the egg-hatching temperature earlier than in 1971 (Fig. 5A). Although most of the eggs hatch at this time, hatching occurs at least until March, since first instars were collected in small numbers throughout this period.

First instar larvae were recognized by the presence of an egg-burster on the dorsal region of the head capsule and by the absence of the cephalic fans, agreeing with the description of first instar *Prosimulium* from the Ottawa region (L. Davies, 1960). Larvae develop slowly throughout the winter in streams which may have a water temperature of 0°C for as long as three months. During this time, larvae were collected under as much as 30 cm of ice and 15 cm of snow. Larvae have been collected in water temperatures of 0 to 18.5°C, but are usually absent once the stream temperature reaches about 15°C. Immatures of *P. fuscum* and *P. mixtum* have been collected in a variety of streams, ranging from temporary roadside trickles to permanent rivers up to 50 m in width. Larvae were abundant on all available substrata and were collected at depths of 0.5 to 25.0 cm and in current velocities of 0.6 to 4.4 mps. The larval population was largest during the third week of March, 1972, when there was an average of 109 larvae per 100 cm sq in Pickavance Creek. Larval development required up to 7 months in Newfoundland. Mature larvae first appeared about mid-April and pupation commenced about the first week of May and continued for 3 to 5 weeks. During late May, 1972, larvae had pupated and adults had emerged on the east coast, whereas the bulk of the specimens collected on the west coast were immature larvae, a difference probably due to the colder streams on the western part of the Island.

Pupal development required 8 to 14 days, depending upon stream temperature. Pupae have been collected in water at temperatures of 2.5 to 18.5°C, depths of 0.5 to 14.0 cm, and current velocities of 1.2 to 4.4 mps.

Adult emergence begins in the first half of May and is completed in 3 to 5 weeks. Emergence is about 3 to 4 weeks later than emergence of these species in Ontario, but earlier than in Alaska and Labrador. Upon emergence, females of *P. fuscum* contain immature eggs, but have large fat bodies and are autogenous for the first gonotrophic cycle (author's data; Pickavance *et al.*, 1970). Females of *P. mixtum* may also be largely autogenous for the first gonotrophic cycle.

*P. mixtum* is the first pest species to emerge in Newfoundland. *P. fuscum* emerges about the same time, but is probably not as abundant as P. *mixtum*. It is difficult to estimate the ratio of P. *mixtum* and P. *fuscum* in any population. This is partly due to the close similarity between the two species in larval and pupal stages, and partly to the variation in P. *mixtum*. Therefore, the distribution of P. *fuscum* and P. *mixtum* will be presented together.

P. *fuscum* and P. *mixtum* are found in all areas of the Island; 153 of the 212 streams sampled contained these. It is assumed that the remaining 59 streams also contained P. *fuscum* and/or P. *mixtum*, but these streams were sampled late in the summer and the immature stages were not found.

P. *fuscum* and P. *mixtum* are two species which were once grouped together with at least one other species (P. *fontanum* Syme and Davies) under what was known as P. *hirtipes* in North America. Rothfels (1956), working with salivary gland chromosomes, discovered that in North America, P. *hirtipes* was a complex of species, none of which were identical with the European P. *hirtipes*, and L. Davies (1957a) found morphological differences also. Syme and Davies (1958) described and compared the three species, and Davies and Syme (1958) presented ecological differences. L. Davies (1961) also considered ecological differences between P. *fuscum* and P. *mixtum*.

P. *fuscum* and P. *mixtum* are univoltine and overwinter in the larval stage in Ontario (Davies, 1950; Davies and Peterson, 1956; Davies *et al.*, 1962; Davies and Syme, 1958), Quebec (Wolfe and Peterson, 1959), Labrador (Hocking and Richards, 1952), New York (DeFoliart, 1951a; Jamnback, 1969; Stone and Jamnback, 1955), New Hampshire (O'Kane, 1926), Illinois (Forbes, 1912), Tennessee (Snow *et al.*, 1958), Alaska

(Sommerman *et al.*, 1955), Alabama (Stone and Snoddy, 1969), Wisconsin (Anderson and Dicke, 1960), and in larger geographical regions of North America (Jamnback *et al.*, 1971; Johannsen, 1934; Peterson and Wolfe, 1958; Twinn, 1936a). Gill and West (1955) collected pupae during August in Michigan and thought this may have been a second generation.

Egg hatching may occur as early as mid-October in Ontario (L. Davies, 1961; Peterson, 1970), and may last for more than five months (L. Davies, 1961). Sommerman *et al.* (1955) found that eggs usually hatch during late August in Alaska. Davies and Syme (1958), L. Davies (1961), and Peterson (1970) reported that larvae develop slowly throughout the winter. Peterson and Wolfe (1958) found that the optimum temperature range for development was 12.8 to 18.3°C and indicated that temperatures over 21.1°C were generally unfavourable in Quebec. Sommerman *et al.* (1955) found that the stream temperatures reached a maximum of 13.9°C during the period of occupancy by *P. hirtipes*.

*P. fuscum* and *P. mixtum* have been reported from a wide variety of streams in Wisconsin (Anderson and Dicke, 1960), Ontario (Davies and Syme, 1958; Peterson, 1970), Illinois (Forbes, 1912), Michigan (Gill and West, 1955), Labrador (Hocking and Richards, 1952), New York (Jamnback, 1956), New Hampshire (O'Kane, 1926), Alaska (Sommerman *et al.*, 1955), Alabama (Stone and Snoddy, 1969), and eastern Canada (Twinn, 1936a; Wolfe and Peterson, 1959). Davies *et al.* (1962) and Peterson (1970), in Ontario, and Stone (1964) in Connecticut, reported that *P. mixtum* was usually found in smaller, slower streams than *P. fuscum*. Larvae have been collected in Wisconsin and Alaska in current velocities of 0.66 to 2.5 mps (Anderson and Dicke, 1960; Sommerman *et al.*, 1955), and a pH of 2.0 to 7.2 (Anderson and Dicke, 1960; Jenkins, 1948). Anderson and Dicke (1960), Jenkins (1948), and Sommerman *et al.* (1955) reported that the deflecting surfaces of stones (including the under surfaces of loose stones) were the preferred larval habitat.

Larval development requires as many as nine months in Alaska (Sommerman *et al.*, 1955). Anderson and Dicke (1960) indicated that the long developmental period was probably related to low water temperatures and scarcity of food.

Hocking and Richards (1952) and Sommerman *et al.* (1955) found larvae maturing during June in Labrador and Alaska. L. Davies (1961) suggested that the thermal threshold for pupation is higher than that for larval growth which results in an accumulation of last stage larvae and an ultimate synchronization of emergence. Hocking and Richards (1952) found that pupation commences when the water temperature is about 10°C, whereas Peterson and Wolfe (1958) indicated that pupation occurs at temperatures as low as 1.7°C. Sommerman *et al.* (1955) reported that pupal development required two to three weeks in Alaska, and Anderson and Dicke (1960) found the pupal stage to exist for six to nine days at water temperatures of 4.4 to 10.0°C in Wisconsin. Davies *et al.* (1962) and Peterson (1970) found that pupae of *P. mixtum* are less strongly grouped and are covered with less silk than those of *P. fuscum*.

Adult emergence begins in April in Ontario (Davies *et al.*, 1962); they found that when *P. fuscum* and *P. mixtum* occurred together in the same stream, *P. fuscum* usually emerged a few days earlier than *P. mixtum*.

Upon emergence, females of *P. fuscum* contain immature eggs, but have large fat bodies and are autogenous for the first gonotrophic cycle in Ontario (Davies *et al.*, 1962; L. Davies, 1961; Peterson, 1970), and New York (Jamnback, 1969). L. Davies (1961) found that the dispersal rate of this species is slow, and Peterson (1970) indicated that females biting and seeking a blood meal are almost entirely parous and that only about 10 percent of them survive to lay a second batch of eggs. For these reasons, L. Davies (1961) and Downes *et al.* (1962) suggested that *P. fuscum* is unimportant as a potential parasite vector.

Females of *P. mixtum* are largely anautogenous, feeding on the blood of mammals and possibly birds to provide blood for the first gonotrophic cycle in Ontario (Davies *et al.*, 1962; L. Davies, 1961; Peterson, 1970). Peterson (1970) reported that they disperse quickly after emergence and about 20 percent of the parous flies survive a second ovarian cycle. L. Davies (1961) considered *P. mixtum* to be an important potential vector of parasites.

*P. fuscum* and *P. mixtum* form mating swarms in Ontario (Davies *et al.*, 1962; Peterson, 1970). Oviposition has been observed by Anderson and Dicke (1960) in Wisconsin, Davies *et al.* (1962), Davies and Peterson (1956), and Peterson (1970) in Ontario, Stone and Jamnback (1955) in New York, and Wolfe and Peterson (1959) in Quebec. L. Davies (1961) found that the peak oviposition of *P. fuscum* occurs about six to seven days after peak emergence. Usually, females of both species freely deposit their eggs into the water by tapping the tips of their abdomens to the water surface while in flight. Davies and Peterson (1956) counted an average of 259 eggs per female of *P. hirtipes*.

*P. mixtum* is anautogenous and for this reason is a more troublesome biter than *P. fuscum*. Throughout their range, females of *P. fuscum* and *P. mixtum*, and in part, *P. hirtipes*, have been found feeding on man, livestock and other animals and birds by Anderson and DeFoliart (1961), Davies *et al.* (1962), Davies and Syme (1958), DeFoliart (1951a), Dimond and Hart (1953), Downe and Morrison (1957), Dyar and Shannon (1927), Fallis (1964), Frost (1949), Gill and West (1955), Hearle (1932), Hocking and Richards (1952), Jamnback (1952, 1969), Jamnback *et al.* (1971), Jenkins (1948), Johannsen (1934), Malloch (1914), McComb and Bickley (1959), Pickavance *et al.* (1970), Peterson (1970), Peterson and Wolfe (1958), Sailer (1953), Shewell (1957), Sommerman *et al.* (1955), Stone (1964), Stone and Jamnback (1955), Stone and Snoddy (1969), Twinn (1936a), and Wolfe and Peterson (1959).

*P. fuscum* and *P. mixtum* in Newfoundland are very similar morphologically and biologically to these species elsewhere. The main difference, and obviously an important one, is that *P. mixtum* appears to be autogenous in Newfoundland and thus is an important pest species after its first gonotrophic cycle. Egg hatching occurs about one to two months later in Newfoundland than in Alaska, and adult emergence in Ontario usually occurs about three to four weeks before emergence of these species in Newfoundland. The delay in adult emergence in

Newfoundland compared to Ontario can be attributed to a slower warming of the streams, while the delay in egg hatching compared to Alaska can be ascribed to the shorter summer and more rapid cooling of streams in the latter region.

Following is a summary of the aquatic stages of *P. fuscum/ mixtum* in Newfoundland during late 1971 and the first half of 1972:

| Stages collected | Date first collected | Date last collected |
|---|---|---|
| 1st instars | 30-X-71 | 17-III-72 |
| Immature larvae | 30-X-71 | 7-VI-72 |
| Mature larvae | 14-IV-72 | 7-VI-72 |
| Pupae | 2-V-72 | 7-VI-72 |

Newfoundland Distribution: Streams 1, 2, 4, 6-14, 16-24, 26-28, 31-41, 43-47, 49-98, 106-110, 113-122, 124-126, 129-131, 133-138, 140-143, 145-156, 159, 160, 162-167, 181-183, 185, 200, 206-212; streams 5, 42, Mount Carmel, St. Phillips, Healy's Pond runout, Power's Pond runout (Ebsary, 1972); Bradbury (1972); Dyar and Shannon (1927); Frost (1970); Frost and Manier (1971); Frost and Nolan (1972); Malloch (1914); Peterson (1970); Pickavance *et al.* (1970); Shewell (1957).

### *Cnephia (Cnephia) dacotensis* (Dyar and Shannon)

Very little is known about the biology of this species in Newfoundland. It is a univoltine species and the eggs are thought to hatch in the spring. Larvae have been collected in temporary and permanent streams. The four streams which had immatures of

*C. dacotensis* were about 3.0 m in width. The developmental period of larvae and pupae, ovarian development, oviposition, and adult feeding habits are unknown.

*C. dacotensis* appears to be uncommon in Newfoundland. It has been found in two streams on the Bonavista Peninsula, and two streams in the central Newfoundland region near Gander. Extensive sampling of 95 streams on the Avalon Peninsula has failed to demonstrate specimens of this species.

*C. dacotensis* is univoltine in Alberta (Abdelnur, 1968), Ontario (Davies, 1950; Davies *et al.*, 1962), Wisconsin (Anderson and Dicke, 1960), New York (Jamnback, 1969), Connecticut (Stone, 1969), and in eastern Canada (Peterson and Wolfe, 1958). It has a summer and a winter egg diapause throughout its range and the eggs usually hatch in the spring (Abdelnur, 1968; Anderson and Dicke, 1960; Davies, 1950; Davies and Peterson, 1956; Davies *et al.*, 1962; Nicholson and Mickel, 1950; Stone, 1964; Stone and Jamnback, 1955; Twinn, 1936a; and Wolfe and Peterson, 1959). Anderson and Dicke (1960) found that first instars of *C. dacotensis* appeared during April when the water temperature had risen to 5.0°C. Abdelnur (1968) reported that larvae appeared in early May and that pupae and adults were collected by the end of that month. Larvae of *C. dacotensis* were collected in temporary and permanent streams by Anderson and Dicke (1960) in Wisconsin. Hocking and Richards (1952) collected immatures from drainage streams which were not more than 0.33 m wide and 0.66 m deep. Davies *et al.* (1962) reported that larvae develop rapidly and are found usually at lake outlets in streams over 0.33 m in width. Jamnback (1969), Stone (1964), and Stone and

Jamnback (1955) also reported this species to be a lake-outlet inhabiting species. Wolfe and Peterson (1959) found immatures in young streams.

Anderson and Dicke (1960) found that the larval stages lasted 4 to 5 weeks at a temperature range of 4.4 to 18.3°C, and the pupal stage for 5 to 7 days in Wisconsin. Nicholson and Mickel (1950) reported that, in Minnesota, the pupal stage required less than 8 days in nature. Stone (1964) reported the presence of well-developed eggs in the pupa.

Davies (1950) found that "synchronized" emergence usually occurred during late May or early June, and Nicholson and Mickel (1950) reported emergence in May. Davies and Peterson (1956) and Nicholson and Mickel (1950) observed emergence and mating on the ground with little or no flight activity. At emergence, females contain mature eggs (Abdelnur, 1968; Davies and Peterson, 1956; Peterson and Wolfe, 1958; Stone, 1964; Wolfe and Peterson, 1959). Males outnumber the females about three to one (Davies, 1950) and mating takes place on objects near the stream immediately after emergence (Abdelnur, 1968; Davies and Peterson, 1956; Davies *et al.*, 1962; Stone, 1964).

Females have reduced mouthparts and *C. dacotensis* is therefore not a blood-sucking species (Anderson and Dicke, 1960; Davies and Peterson, 1956; Jamnback, 1969; Krafchick, 1942; Nicholson, 1945; Peterson and Wolfe, 1960; Shewell, 1957; Stone, 1964; and Wolfe and Peterson, 1959). Oviposition occurs a few hours after emergence and mating. Abdelnur (1968) and Davies *et al.* (1962) reported that oviposition occurs while the females are flying low over the water, tapping their abdomens to the water surface. According to Fredeen (1959a), females deposit their eggs in masses on objects at the water surface. Davies and Peterson (1956) indicated that it has one gonotrophic cycle, with an average of 287 eggs per female while Abdelnur (1968) found 276-288 eggs.

Davies (1950) and Davies and Peterson (1956) believed that the small size of the compound eyes of the males and the lack of a strong phototaxis as demonstrated by Twinn (1936a), are probably related to the absence of a mating swarm.

While knowledge is lacking about the biology of *C. dacotensis* in Newfoundland, it is probably not different from the mainland form of this species.

The known life cycle of *C. dacotensis* during 1971 is summarized by the following:

| Stages collected | Date first collected | Date last collected |
|---|---|---|
| 1st instars | - | - |
| Immature larvae | 10-IV-71 | 10-IV-71 |
| Mature larvae | 12-IV-71 | 12-IV-71 |
| Pupae | - | - |

Newfoundland Distribution: Streams 24, 27, 126, 128; Stone *et al.* (1965); Stone (1964).

### *Cnephia (Stegopterna) mutata*

*C. mutata* is univoltine and overwinters in the egg stage. The eggs are thought to be laid during June and undergo a summer diapause. Most of the eggs hatch during late fall or early winter, usually after the *Prosimulium* eggs have hatched, when the water cools to 0 to 3°C; in 1972 eggs hatched from the fourth week of November to the third week of December. Some eggs continue to hatch throughout the winter since the occasional first instar was collected until the first week of April. First instar larvae are characterized by the dorsal egg-burster on the head capsule, and unlike the *Prosimulium*, first instar larvae of *C. mutata* have cephalic fans. It appears that development is gradual throughout the winter. Larvae have up to a five month development period in water temperatures from 0 to 13°C. During development of the larvae, the water temperature is 0°C for at least three months, and the larvae are under as much as 10 cm of snow and 20 cm of ice. Larvae have been collected from rocks, vegetation, and tiles, and occur in all streams of the Pickavance Creek complex.

In Pickavance Creek, larvae were collected at depths of 2.5 to 25 cm, and in B, C, D, E, F, and G creeks at depths of 1 to 10 cm. In other streams on the Island, larvae have been collected at depths of 6.0 to 25.0 cm in streams ranging from 0.5 to 7.0 m in width. *C. mutata* apparently prefers smaller streams, since in larger streams (e.g. Pickavance Creek, Fig. 7), it comprises a maximum of 25 percent of the total population and usually much less, while in small creeks (e.g. D creek, Fig. 10), it may comprise upwards of 85 percent of the total population. The larvae of *C. mutata* have been collected in current velocities of 0.6 to 4.4 mps.

Mature larvae appear during mid-April and pupation occurs near the end of April or early May. The length of the pupal stage has not been determined, since only eight pupae were collected during the course of this study. The pupal respiratory filaments match those of the triploid form as presented by Basrur and Rothfels (1959). These pupae were all females and this suggests that at least the parthenogenetic form is found in Newfoundland. Pupae developed in water temperatures of 4 to 15°C.

Adult emergence is usually completed by mid-May and the adults are fully autogenous for the first gonotrophic cycle. Oviposition habits of *C. mutata* in Newfoundland are not known. Pickavance *et al.* (1970) captured a single female from duck bait at Pickavance Creek. They suggested that the general paucity of wild and domestic animals in this area may have forced this species onto unexpected hosts.

*C. mutata* has been collected from 52 streams distributed across the Island. Many streams were sampled after emergence of *C. mutata* and in others the populations may have been small and a random road-side sample may not have contained specimens.

Basrur and Rothfels (1959) found that populations of *C. mutata* in southern Ontario contained bisexual diploid forms and parthenogenetic forms which consisted of females only. They discovered that both forms may occur in the same stream and indicated that larvae collected in February were almost entirely diploid, while those collected after mid-April were almost entirely triploid. Davies (1950), Davies and Peterson (1956), and Davies *et al.* (1962) found that 90 to

100 percent of the individuals collected in Ontario were parthenogenetic females. Davies (1950) suggested that the sexes may be more nearly equal in numbers in a colder habitat. Abdelnur (1968) indicated that both diploid and triploid forms were found in Alberta. Stone (1964) also suggested that *C. mutata* may be parthenogenetic to a considerable extent, and Chutter (1970) thought that only the triploid form was encountered in his study of factors influencing the number of oocytes. Abdelnur (1968), Anderson and Dicke (1960), Davies (1950), Stone (1964), Stone and Jamnback (1955), Stone and Snoddy (1969), and Wolfe and Peterson (1959) reported that *C. mutata* is univoltine. Basrur and Rothfels (1959) indicated that this might be true for the diploid population but possibly not for the triploid one, since mature larvae could be obtained throughout the spring and summer. Davies (1950) reported that *C. mutata* was bivoltine on one occasion in Ontario.

Davies (1950), Mackay (1969), Snow *et al.* (1958), and Stone and Jamnback (1955) reported that *C. mutata* overwintered in the larval stage in Ontario, Quebec, Tennessee, and New York. Anderson and Dicke (1960) reported that overwintering occurred in the egg stage in southern Wisconsin and in the larval stage in northern Wisconsin. Stone (1964) found it overwintering in both the egg and larval stages in Connecticut. Abdelnur (1968) could find no overwintering larvae in Alberta. In Ontario, Davies *et al.* (1962) found that eggs are laid in summer and were in diapause until the end of summer or later.

Anderson and Dicke (1960) reported that *C. mutata* usually comprised two to five percent of the total population of streams in

Wisconsin. Davies and Peterson (1956) found larvae on the undersides of submerged rocks and trailing vegetation and pupae in crevices and under objects on the stream bottom. Stone and Snoddy (1969) found cocoons also on the undersides of stones and foliage. Abdelnur (1968) found immatures in a creek 3.3 m wide flowing in part in the shade of the forest. Immatures of this species are found in temporary and permanent forest streams throughout much of its range (Anderson and Dicke, 1960; Hocking and Pickering, 1954; Stone, 1964; Stone and Jamnback, 1955; Stone and Snoddy, 1969; Twinn, 1936a; Wolfe and Peterson, 1959).

Pupation occurs during March in New York (Stone and Jamnback, 1955), during late May and June in Quebec (Wolfe and Peterson, 1959), and during July in Labrador (Hocking and Richards, 1952).

Adults have been collected in May in Alberta (Abdelnur, 1968), Alabama (Stone and Snoddy, 1969), and Ontario (Davies, 1950), in June in Quebec (Wolfe and Peterson, 1959) and Manitoba (Hocking and Pickering, 1954), and from April to July in Connecticut (Stone, 1964).

Chutter (1970), Davies and Peterson (1956), and Davies (1962) reported that upon emergence females contain much stored nutrient. These authors and Abdelnur (1968) agreed that the eggs were approximately half mature. Davies and Peterson (1956) found the average number of eggs to be 192 and the maximum at maturity was 231, while Abdelnur (1968) found the maximum at emergence to be 337 and at maturity a maximum of 203 oocytes. Obviously, *C. mutata* is autogenous in Alberta and Ontario. Davies and Peterson (1956) reported that oviposition occurs in spring and is achieved by tapping the abdomen to the water surface while in flight.

Davies (1950), Frohne and Sleeper (1951), Hocking and Richards (1952), and Stone and Snoddy (1969) reported that *C. mutata* is rarely annoying to man. Rees and Peterson (1953) found it feeding on humans only above 2310 meters in Utah. Hearle (1932) indicated it was rare in British Columbia and took one specimen from a horse. Davies and Peterson (1956) found adults feeding on deer in Algonquin Park and also on the blueberry *Vaccinium myrtilloides* Michx.

Frohne and Sleeper (1951) collected adults in June and July from sea level to altitudes of 990 meters. They reported that next to *S. venustum, C. mutata* appears to be the most widespread and common blackfly in southeast Alaska. Jamnback (1969) reported that it is a common early species in New York and stated that it usually feeds on large mammals, rarely bites man but is occasionally a pest because of crawling on the neck and ears. Stone (1964) reported that it feeds on cattle and horses and probably deer, and it will swarm around and alight on man although it rarely feeds. Stone and Jamnback (1955) reported that *C. mutata* adults do not usually attack man in the Adirondacks.

The habits of *C. mutata* in Newfoundland and in other regions of North America appear to be similar, but stages of the life cycle are asynchronous in Newfoundland. Pupation occurs during late April or early May in Newfoundland, during March in New York, during late May and June in Quebec, and during July in Labrador.

Following is a summary of the aquatic stages of the life cycle of *C. mutata* in Newfoundland during late 1971 and the first half of 1972:

| Stages collected | Date first collected | Date last collected |
|---|---|---|
| 1st instars | 25-XI-71 | 7-IV-72 |
| Immature larvae | 25-XI-71 | 29-V-72 |
| Mature larvae | 14-IV-72 | 29-V-72 |
| Pupae | - | - |

Newfoundland Distribution: Streams 4, 6, 8, 19, 24, 26, 27, 39, 40, 86, 88, 95, 96, 109, 110, 113-118, 120, 121, 124, 126-129, 134, 137, 139, 143, 145-148, 150, 154, 155, 166, 167, 181-183, 201, 206-212; streams 9, 56, St. Phillips (Ebsary, 1972); Bradbury (1972); Frost (1971); Frost and Nolan (1972); Pickavance *et al.* (1970); Shewell (1957).

### *Simulium (Byssodon) rugglesi* Nicholson and Mickel

The immatures of this species have not been found in Newfoundland. Pickavance *et al.* (1970) collected seven females which had fed on elevated duck bait at Pickavance Creek but the immatures of this species do not occur in Pickavance Creek.

Davies *et al.* (1962) reported that overwintering eggs of *S. rugglesi* hatch in the spring. They collected immatures from submerged logs and trailing grass in the North Madawaska River. In Wisconsin, Anderson and Dicke (1960) reported that immatures were always found on the upper surfaces of aquatic vegetation 2.5 to 10 cm beneath the water surface. The current velocity was 0.3 to 0.8 mps and the water temperature ranged from 13.9 to 18.9°C. They also reported that the egg probably overwinters. Stone (1964) indicated that *S. rugglesi* appears to prefer young rivers and larger streams in Connecticut. Pupation occurs in late May in Ontario (Davies *et al.*, 1962) to mid-July in Wisconsin (Anderson and Dicke, 1960). Fredeen (1958) found immatures of *S. rugglesi* in only a few small rivers in the Canadian prairies and reported that emergence occurred during the first half of June. Wolfe and Peterson (1959) reported that *S. rugglesi* is probably univoltine in Quebec. Davies and Peterson (1956) counted an average of 256 eggs per female. This species was first taken from geese and identified by Nicholson and Mickel (1950). Shewell (1955) reported that this is the species that Walker (1927) recorded as *S. bracteatum* Coquillett. Bennett (1960) observed that *S. rugglesi* feeds earlier in the evening than other ornithophilic species.

Fallis *et al.* (1956) showed that *S. rugglesi* was an important vector of *Leucocytozoon* of birds and it has been found feeding mainly at ground level on lakeside ducks (Bennett, 1960; Davies and Peterson, 1956). Barrow *et al.* (1968), Downe and Morrison (1957), Fredeen (1958), Shewell (1957), and Stone (1964) also reported ornithophilic feeding by *S. rugglesi*. Barrow *et al.* (1968) studied the transmission of *Leucocytozoon* by *S. rugglesi* and expanded the host list for this species and indicated that the lack of host specificity would make it a likely vector of blood parasites among species of birds, although Bennett (1960) showed that in Algonquin Park, it was restricted to feeding on the Anseriformes.

Since the immature stages have not been found, no comparison with other regions is possible, but the adult feeding habits indicate that it is similar to that recorded for this species in other areas.

Newfoundland Distribution: Pickavance *et al.* (1970).

### *Simulium (Eusimulium) aureum* Fries

*S. aureum* is univoltine in the Pickavance Creek area where it was found in streams B, C, D, F, and G. It is possible that it is an immigrant into the Pickavance Creek area, since larvae appear usually in mid-August and this would then correspond to a second generation of a bivoltine form of *S. aureum*. This may be further substantiated by the fact that in 1971 it was present in streams B, C, D, F, and G, whereas in 1972 it was present only in streams B and C. Stream F had dried up, although streams D and G were flowing and appeared suitable for it. The nearest stream to Pickavance Creek in which immatures of *S. aureum* were found is Manuels River (Stream 155), which is 2.3 km west of the Pickavance Creek. *S. aureum* has been taken from the upper portion of Manuels River, which ceases to flow in July.

If *S. aureum* oviposits in streams B, C, D, F, and G, they overwinter. The eggs hatch in mid-August; larval development required 2 to 3 weeks and pupal development required 3 to 5 days. Larvae and pupae developed in water temperatures of 10 to 20°C and in depths of 1 to 3 cm. Larvae were collected in current velocities of approximately 1.1 to 4.4 mps and pupae in approximately 1.8 to 4.3 mps. These current measurements may not be accurate since the water depth at the time of measurement was about 3 cm. Larvae were more frequently collected on tiles than on rocks, and more frequently on rocks than on aquatic vegetation. Pupae were more commonly collected on tiles than on rocks, but none were found on vegetation.

Upon emergence, adult females have undeveloped eggs and little stored nutrient. Mating and oviposition habits of *S. aureum* in Newfoundland are unknown.

Blood-fed females of *S. aureum* have been collected from elevated birds at Pickavance Creek (Coombs, 1972), indicating that it is ornithophilic, but the low population precludes it being a pest species. It was collected only on the Avalon Peninsula; it probably occurs elsewhere, but failure to record it is due to lack of collecting at the right time and place.

Dunbar (1958, 1959) reported seven cytological forms of *S. aureum* from larvae. Five of these are North American and three of these are from Ontario. *S. aureum* forms "A", "B", and "D" are found in Ontario and forms "C" and "D" are found in northern Manitoba (Dunbar, 1958, 1959). Stone (1965) reported that more study is needed to determine whether any of the component sibling species are Holarctic.

Sommerman *et al.* (1955) reported one to two generations annually in Alaska, and Davies (1950) reported form "A" was bivoltine in Ontario. It is apparently bivoltine in Illinois (Forbes, 1912), New York (Stone and Jamnback, 1955), Connecticut (Stone, 1964), Quebec (Wolfe and Peterson, 1959), and Ontario (Davies *et al.*, 1962). Abdelnur (1968) and Anderson and Dicke (1960) reported three generations annually in Alberta and Wisconsin, and Twinn (1936a) indicated there were also probably three in eastern Canada; Peterson (1956) reported three to four generations annually in Utah and Jobbins-Pomeroy (1916) reported five to six generations in North Carolina; and Jamnback (1969) simply reported *S. aureum* to be multivoltine in New York.

Abdelnur (1968), Anderson and Dicke (1960), Davies (1950), Dunbar (1958), Forbes (1912), Jobbins-Pomeroy (1916), Peterson (1956), Sommerman *et al.* (1955), Stone (1964), Stone and Jamnback (1955), Twinn (1936a), and Wolfe and Peterson (1959) reported that eggs are the overwintering stage of *S. aureum*. Abdelnur (1968) indicated that eggs hatch late in May or early in June in Alberta. Sommerman *et al.* (1955) found that hatching of the first generation occurred during mid-May in Alaska, and hatching of the second generation began early in July. They also found that larvae required 2 to 4 weeks for development and pupae about 1 week. Peterson (1959a) reported that larval development required 2 to 5 weeks in Utah. Sommerman *et al.* (1955) found that the temperature of streams inhabited by this species ranged from 11.7 to 21.7°C in Alaska.

Peterson (1959a) reported that vegetation was the preferred substratum in Utah, and that sticks, stones and rocks were inhabited much less frequently. Immatures of *S. aureum* have been collected usually in small, shallow, warm, temporary or permanent streams including bog drainage streams, drainage and supply ditches, lake outlets and outlets of beaver dams (Davies *et al.*, 1962; Dunbar, 1958; Anderson and Dicke, 1960; Fredeen and Shemanchuk, 1960; Gill and West, 1955; Hearle, 1932; Jamnback, 1956; Jenkins, 1948; Jobbins-Pomeroy, 1916; Mackay, 1969; Peterson, 1959a; Sommerman *et al.*, 1955; Stone, 1964; Stone and Jamnback, 1955; Sutherland and Darsie, 1960; Twinn, 1936a; Wolfe and Peterson, 1959).

Anderson and Dicke (1960) found that larvae first appeared when the water temperature reached 11.1°C and development continued in water temperatures up to 21.1°C. Larvae may be collected from May to October in Ontario (Dunbar, 1958), June to August in New York (Jamnback, 1956), and July to early August in Alaska (Jenkins, 1948).

Immatures have been collected in current velocities of almost stagnant to 1.3 mps in Wisconsin, Utah and Alaska (Anderson and Dicke, 1960; Peterson, 1959a; Sommerman *et al.*, 1955). In Alaska, Jenkins (1948) collected immatures in streams with an average pH of 7.3 and Sommerman *et al.* (1955) usually collected immatures at depths of less than 15 cm.

Abdelnur (1968) found pupation occurring during mid-June, mid-July and early to mid-August in Alberta. Peterson (1959a) found that the maximum water temperature for pupal development was 21.1°C in Utah.

Abdelnur (1968) reported that newly emerged females have undeveloped eggs and little stored nutrient. He observed oviposition in streams with only patchy vegetation and thought this might explain the low amount of nutrients in adults and the slow development of larvae in Alberta. Davies and Peterson (1956) reported that females of form "A" may oviposit while in flight, but indicated that oviposition on grass or trailing vegetation is preferred. They netted females with mature eggs over the spillway of a dam. DeFoliart (1951a), and Peterson (1959a) reported that eggs are deposited on trailing grass or leaves and in a compact mass, one layer deep, all standing on end and covered by a thick, gelatinous material. Fredeen (1959b) also found that *S. aureum* deposits her eggs in masses on objects on the water surface.

Abdelnur (1968) reported that *S. aureum* is not attracted to humans in Alberta and that a blood meal is required for each gonotrophic cycle. Hearle (1932) reported that it does not appear to be a blood-sucker in British Columbia. Females do not bite man in Utah (Peterson, 1959a), and were only rarely attracted to man in Labrador (Hocking and Richards, 1952). Shemanchuk and Depner (1971) reported that it was attracted to and fed on chickens. Stone and Jamnback (1955) reported that this is not a pest species in New York. Bennett (1960) and Davies *et al.* (1962) found that form "A" feeds on birds and indicated that most feeding occurred in trees about 6.6 m above ground. Bennett and Fallis (1960) found oocysts and sporozoites of *Leucocytozoon* in dissections of *S. aureum* that had fed on infected crows, robins and an owl, and showed it to be a vector of *L. sakharoffi* Sambon, *L. dubreuli* Mathis and Leger, and *L. ziemanni* (Laveran). Anderson and DeFoliart (1961), Fallis and Bennett (1958, 1962), Jamnback (1969), and Stone (1964) reported *S. aureum* to be ornithophilic, and a vector of *Leucocytozoon* and *Trypanosoma* of birds.

If *S. aureum* is bivoltine in Newfoundland, then the single population in the Pickavance Creek area could account for the second generation. Eggs hatch at mid-August, whereas in Alaska, the eggs of the second generation hatch in July. Most of the habits of this species in Newfoundland are in general agreement with those elsewhere in North America.

The aquatic stages of the life cycle of *S. aureum* during 1972 are summarized by the following:

| Stages collected | Date first collected | Date last collected |
|---|---|---|
| 1st instars | - | - |
| Immature larvae | 31-VIII-72 | 15-X-72 |
| Mature larvae | 15-X-72 | 15-X-72 |
| Pupae | 15-X-72 | 30-X-72 |

Newfoundland Distribution: Streams 155, 190, 207-209, 211, 212; stream 6 (Ebsary, 1972); Shewell (1957).

### *Simulium (Eusimulium) croxtoni* Nicholson and Mickel

This is the first record of this species from Newfoundland. The author has not collected any stages but mature and maturing larvae have been collected during late May in streams about 2.0 m in width from rocks at a depth of about 12 cm (Ebsary, 1972). Little is known about its biology in Newfoundland, where it appears to be restricted to the Avalon Peninsula. The apparently limited distribution is probably due to sampling streams before and/or after occupation by this species.

*S. croxtoni* is thought to be univoltine in Wisconsin (Anderson and Dicke, 1960), Connecticut (Stone, 1964), and central

Ontario (Davies *et al.*, 1962), however, Davies *et al.* (1962) believed that there may be a second generation in southern Ontario. Davies *et al.* (1962) reported that this species overwinters in the egg stage and that larvae hatch in the spring and develop in both temporary and permanent streams from 0.66 to 4.95 m in width. Anderson and Dicke (1960) found immature stages in temporary drainage creeks and in young streams flowing through wooded areas in Wisconsin. They were attached to small rocks, and the undersides of grassblades. The current velocity ranged from 0.17 to 0.22 mps. Hocking and Richards (1952) collected immatures from a series of bog streams in Labrador which were not more than 0.33 m wide and 0.66 m deep.

Pupae were collected by Davies *et al.* (1962) during late May and early July. These authors indicated that females have well-developed mouthparts and bifid claws. *S. croxtoni* has been reported as an ornithophilic species by Bennett (1960), Davies and Peterson (1956), Fallis and Bennett (1962), and Shewell (1957). In Ontario, Davies *et al.* (1962) reported that upon emergence, adult females have immature eggs and much stored nutrient.

Davies and Peterson (1956) reported that adults were rarely collected more than a few meters from water, and they are of the opinion that this species feeds on shore or water birds. However, Bennett (1960) showed *S. croxtoni* to be a sylvatic species, feeding on a variety of Passeriformes and other birds at heights of 1.65 to 8.25 m in Ontario. He showed it to be the vector of a variety of *Leucocytozoon* species as well as *Trypanosoma avium* Danilewsky. Jamnback (1969) confirmed the vector potential of this species in

New York but reported it to be rare.

The lack of knowledge of this species in Newfoundland makes a comparison with other regions of North America impossible. The pupal and adult stages have not been collected in Newfoundland.

Newfoundland Distribution: Streams 8, 155 (Ebsary, 1972).

### *Simulium (Eusimulium) euryadminiculum* Davies

The author has not collected any stages of this species, although larvae have been taken in late May from a stream about 60 m in width and at a depth of 15.0 cm on a rock substratum (Ebsary, 1972). The only other aspect of the biology of *S. euryadminiculum* which is known in Newfoundland is that it is capable of being parasitized by *Harpella melusinae* Leger and Duboscq (Frost and Manier, 1971). It is probably univoltine and ornithophilic, and is not a pest species. Its biology elsewhere will be summarized, since like most species, it is probably not different from the form found in other North American regions.

*S. euryadminiculum* is univoltine in Ontario (Davies, 1950; Davies and Peterson, 1956), in eastern Canada (Peterson and Wolfe, 1958; Wolfe and Peterson, 1959), and in Connecticut (Stone, 1964). Larvae overwinter in Quebec (Wolfe and Peterson, 1959) and may overwinter in Ontario (Davies *et al.*, 1962). Pupation occurs during late April to early June when the water temperatures are 7.2 to 15.6°C in Ontario and Quebec (Davies, 1950; Davies *et al.*, 1962; Wolfe and Peterson, 1959). Peterson and Wolfe (1958) usually found larvae in adolescent streams. In Ontario, newly emerged females have undeveloped eggs and much stored nutrient; they have well-developed mouthparts and their bifid claws are adapted to feed on birds (Davies *et al.*, 1962). *S. euryadminiculum* is ornithophilic and appears host specific to the common loon, *Gavia immer* Brunnich (Anderson, 1956; Bennett *et al.*, 1972; Davies and Peterson, 1956; Davies *et al.*, 1962; Fallis and Smith, 1964, 1965; Jamnback, 1969; Lowther and Wood, 1964; Stone, 1964; Tarshis, 1972). Davies and Peterson (1956) counted an average of 394 eggs per females. Jamnback (1969) and Tarshis (1972) reported that *S. euryadminiculum* is a vector of *Leucocytozoon*.

Newfoundland Distribution: Stream 36 (Ebsary, 1972); Frost and Manier (1971).

### *Simulium (Eusimulium) excisum* Davies, Peterson and Wood

This is a new record for this species in Newfoundland. It has been collected from only one stream, and this is probably not indicative of its true distribution. Larvae were collected 25-V-72 on rocks and trailing vegetation at a depth of 15 cm in a stream 8.0 m in width.

Davies (1950) and Davies *et al.* (1962) reported that *S. excisum* was probably univoltine in Ontario, where it probably overwintered in the egg stage. Larvae hatched in mid-April when the water temperature was about 7.2°C (Davies *et al.*, 1962) and adult emergence occurred from late May to early June, when the water temperature was 10.0 to 12.8°C, depending on the location (Davies, 1950; Davies *et al.*, 1962). Upon emergence, females have eggs which may be partially developed with moderate to large amounts of stored nutrient, and they may be autogenous for the first gonotrophic cycle (Davies *et al.*, 1962). Females have well-developed mouthparts and bifid claws and Bennett (1960) indicated that this species (as *S. subexcisum*) was ornithophilic.

Newfoundland Distribution: Stream 51.

### *Simulium (Eusimulium) furculatum* (Shewell)

*S. furculatum* has been found only in one stream; the restricted distribution reported herein is undoubtedly due to lack of collecting during habitation of streams by this species. It does not appear to be a common species. Immatures have been collected from a rock substratum in that portion of Manuels River (Stream 155) which usually dries out by the end of June. Nothing more is known about this species in Newfoundland.

Twinn *et al.* (1948) collected immatures of *S. furculatum* (=*Eusimulium* species B) in the Goose River, which was 1.3 to 1.7 m deep and flowing 1.0 to 1.3 mps. Davies *et al.* (1962) collected larvae and pupae from a fast chute at the dam on the Crow River in Ontario. Stone (1964) indicated that larvae were usually found in rivers rather than small streams in Connecticut, and Hocking and Pickering (1954) reported that this species is the most abundant in the forest streams of northern Manitoba. In Ontario, Davies *et al.* (1962) collected pupae in late May; in Manitoba, Hocking and Pickering (1954) collected pupae from early June to early August, and Twinn *et al.* (1948) found that adult emergence had been completed by mid-July. Apparently, very little is known about the biology of this species but Stone (1964) indicated that it is univoltine in Connecticut.

Newfoundland Distribution: Stream 155; Stone (1964); Stone *et al.* (1965).

### *Simulium (Eusimulium) gouldingi* Stone

This is the first record of this species from Newfoundland. The descriptions of the larvae and the pupae and adults are adequately given by Wood *et al.* (1963) and Davies *et al.* (1962) for Ontario specimens. It is univoltine and overwinters in the egg stage.

Hatching usually occurs in the last week of May or the first week of June and larvae may be found until late June or early July. They require about 3 weeks for development from the egg to pupation. Mature larvae and pupae appear in the third week of June. First egg hatching and the last adult emergence usually occurs well within 4 weeks. This species was taken annually in streams C, D, F, and G during 1970 to 1972, but not in F in 1972 when it dried up completely rather early in the summer. *S. gouldingi* was found in creek E in 1971 but not in 1972. In creek C the temperature at which larval development occurred was 11.5 to 20.5°C. In creeks D, F, and G larval development occurred in a temperature range of 8.5 to 18°C, and pupae developed in a temperature of 11 to 18°C. Immature stages have been collected in current velocities of 0.36 to 1.04 mps. These values are probably higher than the actual current velocity since the water was often quite shallow in these creeks during the time this species was present, and accurate current velocity readings could not be obtained. In the six streams in which this species was found the larvae and pupae were found at depths of 1 to 5 cm, and were common on the tiles, rocks, and vegetation.

Dissection of newly emerged females indicated that they have undeveloped eggs and very little stored nutrient. Mating and oviposition have not been observed in Newfoundland. Females have well-developed mouthparts and bifid claws, and specimens have been collected from elevated birds at Pickavance Creek (Coombs, 1972).

*S. gouldingi* is univoltine and overwinters in the egg stage in Ontario (Davies *et al.*, 1962), Connecticut (Stone, 1964), and New York (Jamnback, 1956, 1969; Stone and Jamnback, 1955).

Anderson and Dicke (1960) collected mature larvae and pupae during the first week of May in Wisconsin at a temperature of 10 to 15°C, Davies *et al.* (1962) found that pupation occurred about mid-May in Ontario at a water temperature of 10 to 15.6°C, and Jamnback (1956) collected mature larvae in the last week of May and pupae during the first week of June in New York. Anderson and Dicke (1960) found larvae in a current velocity of less than 0.9 mps in Wisconsin and indicated that rocks were the preferred substratum.

*S. gouldingi* is found throughout much of its range in small, temporary or permanent streams, often flowing through wooded areas (Anderson and Dicke, 1960; Davies *et al.*, 1962; Jamnback, 1956; Stone, 1964; Stone and Jamnback, 1955).

Newly emerged females have undeveloped eggs and very little stored nutrient in Ontario (Davies and Peterson, 1956; Davies *et al.*, 1962). Davies *et al.* (1962), Stone (1964), and Stone and Jamnback

(1955) indicated that adult feeding and oviposition habits of this species are not well known. Females have well-developed mouthparts and bifid claws, and in Ontario and New York they are presumably ornithophilic (Davies *et al.*, 1962; Jamnback, 1969).

The habits of *S. gouldingi* in Newfoundland are similar to populations of *S. gouldingi* elsewhere in North America. The entire life cycle is a little later in Newfoundland, since pupation occurs in early May in Wisconsin, early June in New York, and late June in Newfoundland.

Following is a summary of the life cycle of the aquatic stages of this species in Newfoundland during 1972:

| Stages collected | Date first collected | Date last collected |
|---|---|---|
| 1st instars | - | - |
| Immature larvae | 13-VI-72 | 12-VII-72 |
| Mature larvae | 28-VI-72 | 12-VII-72 |
| Pupae | 28-VI-72 | 12-VII-72 |

Newfoundland Distribution: Streams 180, 208-212; Davies (1971).

### *Simulium (Eusimulium) latipes* (Meigen)

*S. latipes* overwintered in the egg stage and was usually bivoltine. Eggs of the first generation normally hatched during the first two weeks of May, when the water temperature was from 1 to

11.5°C, and the second generation eggs normally hatched in early July at water temperatures of 11 to 18°C.

There was only one generation in streams E and F in 1972 due to the early drought in these streams. A second generation in stream E during 1971 was not completed for the same reason.

Larval development required 3 to 4 weeks for the first generation and 2 to 3 weeks for the second.

Larvae have been collected at depths of 0.5 to 12.0 cm in the Pickavance Creek area in current velocities of 0.2 to 1.0 mps. In other streams and rivers, *S. latipes* immatures have been collected at depths of 8.0 to 15.0 cm and stream widths of 0.5 to 12.0 m. Larvae usually comprise a larger percentage of the total population of larval simuliids in smaller streams (e.g. creek G, Fig. 13). Development of larvae continued at water temperatures of 1 to 20.5°C. Both larvae and pupae have been collected on rocks, tiles, and trailing vegetation.

Pupation normally occurred during late June and late July. Pupae developed in temperatures of 10.5 to 18°C, at depths of 1 to 8 cm, and in current velocities of 0.33 to 1.20 mps. The duration of the pupal stage is 6 to 8 days for the first generation, and 3 to 5 days for the second.

The present distribution of *S. latipes* in Newfoundland is limited to eastern Newfoundland in 45 streams. It is probable that it is distributed all over the Island. On emergence, females have undeveloped eggs and very little stored nutrient. They have bifid claws and are the most abundant species of the *Eusimulium* group in

Newfoundland. They have been shown to be ornithophilic in Newfoundland by Pickavance *et al.* (1970). Coombs (1972) indicated that blood-fed specimens were collected from elevated birds at Pickavance Creek and at other locations on the Avalon Peninsula.

Stone (1965) reported that *S. latipes* is a species complex and pointed out that more study is necessary to determine if any of the component sibling species are Holarctic.

Wolfe and Peterson (1959) reported the larva was the overwintering stage in Quebec, but the egg has been shown to be the overwintering stage in Alberta (Abdelnur, 1968), Wisconsin (Anderson and Dicke, 1960), Ontario (Davies *et al.*, 1962), Utah (Peterson, 1959a), Alaska (Sommerman *et al.*, 1955), Connecticut (Stone, 1964,) and New York (Stone and Jamnback, 1955).

*S. latipes* has been shown to be univoltine in Wisconsin (Anderson and Dicke, 1960), Utah (Peterson, 1959a), Connecticut (Stone, 1964), New York (Stone and Jamnback, 1955), and in northern Manitoba (Twinn *et al.*, 1948), but it has been reported to be bivoltine in Alberta (Abdelnur, 1968), and eastern Canada (Peterson and Wolfe, 1958; Wolfe and Peterson, 1959). Sommerman *et al.* (1955) usually found one generation in Alaska, but indicated that a second may occur under certain conditions.

Abdelnur (1968) reported that in Alberta eggs hatched in May and mature larvae and pupae appeared during the last two weeks of June and the last two weeks of August. In Ontario, Davies *et al.* (1962) reported egg hatching of the first generation in mid-April at a water temperature of $15.6^{\circ}C$, and in Alaska, Sommerman *et al.* (1955)

reported egg hatching of the first generation during late May and the second generation in late July. In Alaska, larval development took 2 to 4 weeks and 2 to 3 weeks for the two generations (Sommerman *et al.*, 1955), in Wisconsin it took 4 weeks (Anderson and Dicke, 1960). Sommerman *et al.* (1955) reported that submerged and trailing vegetation was the preferred substrate; Peterson (1959a) agreed with this, but also indicated that in Utah the immatures were collected from the undersurface of rocks in slow, shallow streams.

Anderson and Dicke (1960) and Sommerman *et al.* (1955) found about one week was required for pupal development in Wisconsin and Alaska. Hocking and Richards (1952), Hocking and Pickering (1954), and Stone and Jamnback (1955) found that pupation occurred in June in Labrador, Manitoba, and New York, and Twinn *et al.* (1948) reported that in northern Manitoba pupation occurred in early July and adult emergence began about 4 days later. Davies *et al.* (1962) and Shewell (1958) found that pupation usually occurred under leaves, wood, pebbles and stones, usually sheltered from the current.

Immatures are usually found in small, shallow, slow-flowing, semi-permanent streams throughout much of its range (Anderson and Dicke, 1960; Davies *et al.*, 1962; Hocking and Richards, 1952; Hocking and Pickering, 1954; Jenkins, 1948; Peterson, 1959a; Sommerman *et al.*, 1955; Stone, 1964; Stone and Jamnback, 1955; Twinn, 1936a; Twinn *et al.*, 1948; Wolfe and Peterson, 1959).

Immatures have been collected in current velocities of 0.33 to 1.15 mps (Anderson and Dicke, 1960; Peterson, 1959a; Sommerman *et al.*, 1955). Larvae and pupae developed in water temperatures of

6.7 to 16.1°C in Wisconsin (Anderson and Dicke, 1960), and 8.3 to 18.3°C in Utah (Peterson, 1959a). Jenkins (1948) collected immatures in streams with an average temperature of 11.1°C and an average pH of 7.5 in Alaska.

In Ontario, adult females have bifid claws and mouthparts well adapted for sucking blood (Davies *et al.*, 1962). On emergence, they were found to contain undeveloped eggs and variable amounts of stored nutrients (Abdelnur, 1968; Davies and Peterson, 1956; Davies *et al.*, 1962). Abdelnur (1968) counted from 222 to 312 eggs per female. Bennett and Fallis (1960) reported that oocysts and sporozoites of *Leucocytozoon* were found in dissections of females that had fed on infected crows, robins, and a white throated sparrow. Abdelnur (1968), Anderson (1956), Bennett (1960), Davies and Peterson (1956), Davies *et al.* (1962), Fallis and Bennett (1958, 1962), and Jamnback (1969) also indicated that it feeds on birds and demonstrated its vector potential.

Downes *et al.* (1962) reported that the feeding habits of adults are probably rarely rigid. He indicated that although *S. latipes* usually feeds on birds, it will attack several mammals, including man. Wolfe and Peterson (1959) reported that it made no attempt to feed on man in Quebec.

The biology of *S. latipes* in Newfoundland is similar to its biology in other regions of North America. The time of egg hatching is the same as in Alberta (early May), but in Ontario and Alaska egg hatching occurs in mid-April and late May, respectively.

The occurrence of the aquatic stage of *S. latipes* during

1972 can be summarized by the following:

| Stages collected | 1st generation<br>Date first collected | <br>Date last collected | 2nd generation<br>Date first collected | <br>Date last collected |
|---|---|---|---|---|
| 1st instars | - | - | - | - |
| Immature larvae | 2-V-72 | 2-VI-72 | 18-VII-72 | 7-VIII-72 |
| Mature larvae | 2-VI-72 | 7-VI-72 | 2-VIII-72 | 7-VIII-72 |
| Pupae | 7-VI-72 | 28-VI-72 | 2-VIII-72 | 7-VIII-72 |

Newfoundland Distribution: Streams 1, 4, 6, 8-10, 12, 14, 19, 24, 99, 106, 107, 109, 111, 123, 124, 126, 134, 136, 141, 143, 155-158, 160, 163, 167, 171, 178, 180, 185, 186, 188, 198, 199, 205-212; streams 87, 101, Bay Bulls (Ebsary, 1972); Davies (1971); Pickavance *et al.* (1970); Shewell (1957).

*Simulium (Eusimulium) pugetense* Dyar and Shannon

*S. pugetense* is another species which is neither well known nor abundant in Newfoundland, but its distribution is probably wider than the one stream in eastern central Newfoundland where it has been found. Larvae were collected on rocks, at a depth of 15.0 cm in a stream which is 5.0 m in width.

The eggs undergo a summer diapause in Ontario and a winter diapause in Connecticut since Davies *et al.* (1962) reported that larvae overwinter and Stone (1964) reported that eggs overwinter. Davies *et al.* (1962) and Stone (1964) indicated that this species is univoltine, but was bivoltine in Ontario (Davies, 1950) and eastern Canada (Peterson and Wolfe, 1958; Wolfe and Peterson, 1959), and multivoltine in New York (Jamnback, 1969). Immatures were found in cold, mountain or forest streams, swamp drainages, lake outlets, and spring-fed streams throughout its range (Anderson and Dicke, 1960; Davies *et al.*, 1962; Jamnback, 1969; Jenkins, 1948; Stone, 1964). Aquatic vegetation was the usual substratum (Anderson and Dicke, 1960; Stone, 1964). Pupation occurred from late March to early May in Ontario and Wisconsin (Davies *et al.*, 1962; Anderson and Dicke, 1960). Newly emerged females contained immature eggs and some stored nutrient (Davies *et al.*, 1962). Females were rarely attracted to man in Labrador (Hocking and Richards, 1952) and are probably ornithophilic in New York (Jamnback, 1969).

Newfoundland Distribution: Stream 22; Shewell (1957).

### *Simulium (Eusimulium) quebecense* Twinn

*S. quebecense* has been recorded in only three streams, in the eastern, central, and western regions of the Island, giving a possible indication of its true distribution. Immatures were collected during late May from rocks and trailing vegetation at depths of 15.0 cm in streams with a width of 1.5 to 3.0 m. Pickavance *et al.* (1970) obtained a single female from ground level duck bait at Pickavance Creek, indicating that it is probably ornithophilic.

*S. quebecense* is apparently univoltine in Ontario, the overwintering eggs hatching in May (Davies *et al.*, 1962). Immatures were found attached to stones in streams over 4.9 m wide in eastern Canada

(Twinn, 1936a) or submerged logs, sticks and shrubs in Ontario (Davies *et al.*, 1962). Davies *et al.* (1962) also found *S. quebecense* in a shallow, cool, spring-fed stream about 1.2 m wide. Pupation usually occurred during late May or early June (Davies *et al.*, 1962; Twinn, 1936a). Immatures were usually collected when the water temperature reached 11.1 to 17.8°C. Newly emerged females have undeveloped eggs and little stored nutrient, and their bifid claws and well-developed mouthparts enable them to feed on avian blood (Davies *et al.*, 1962). Bennett (1960), Davies and Peterson (1956), and Fallis and Bennett (1962) also indicated that *S. quebecense* is ornithophilic. Davies and Peterson (1956) indicated that oviposition was accomplished while in flight.

*S. quebecense* is not an abundant species in Newfoundland and, since its biology is unknown, a comparison with this species in other regions of North America is impossible.

Newfoundland Distribution: Streams 48, 108; stream 96 (Ebsary, 1972); Pickavance *et al.* (1970).

### *Simulium (Gnus) corbis* Twinn

*S. corbis* is a univoltine species and overwinters in the egg stage. The eggs normally hatch during late April. It appears to be fairly common in Newfoundland, usually occurring in permanent streams, often in the coastal regions. Immatures were commonly collected at depths of 10 to 25 cm in streams and rivers 1 to 12 m in width. Rocks were the usual substratum.

Pupation commences at mid-May, and by the end of that month emergence has been completed. Because pupation and emergence are completed within 2 weeks, it is easy to miss the pupal stage. The pupal cocoons are more firmly attached to the substrate than any other species and extra care is required in collecting pupae.

Newly emerged females have undeveloped ovaries, with moderate to large fat bodies, and possess well-developed blood sucking mouthparts. Oviposition, mating, and feeding habits are unknown in Newfoundland.

*S. corbis* is univoltine in Wisconsin (Anderson and Dicke, 1960), New York (Jamnback, 1969), and eastern Canada (Peterson and Wolfe, 1958; Wolfe and Peterson, 1959). It is not known whether this species is multivoltine in Ontario (Davies *et al.*, 1962). Sommerman *et al.* (1955) indicated that there may be two generations annually in Alaska, and Stone (1964) reported there may be more than one generation over much of its range.

Anderson and Dicke (1960) and Stone (1964) reported that *S. corbis* overwinters in the egg stage in Wisconsin and Connecticut, and Davies *et al.* (1962) and Sommerman *et al.* (1955) also indicated that the egg probably overwinters in Ontario and Alaska.

This species is rare in Ontario (Davies *et al.*, 1962) and New York State (Stone and Jamnback, 1955), and is restricted to the forested regions of northern Wisconsin (Anderson and Dicke, 1960). Larvae and pupae have been collected in June and early July by Davies *et al.* (1962), mostly in rivers over 6.6 m in width. They found that pupal cocoons were unusually firmly attached to rocks and sticks. In Wisconsin, Anderson and Dicke (1960) collected larvae which were usually attached to rocks in small, cold streams flowing through swampy forest areas. These were 0.9 to 1.7 m wide, 15.2 to 45.7 cm deep and had a water temperature of 5.6 to 10.0°C. Jamnback (1969) reported that *S. corbis* is moderately abundant in larger streams in New York. Jenkins (1948) reported it as rare but widespread in Alaska. The immatures were found in bog and marsh drainage streams with water temperatures from 7.5 to 11.4°C and pH 7.5. Hocking and Richards (1952) collected immatures in Labrador from Traverspine River, which flows through heavily wooded country. Nicholson and Mickel (1950) found immatures in small, cold streams in Minnesota. In eastern Canada Peterson and Wolfe (1958) found it quite abundant in adolescent streams (Dalmat's (1955) stream classification). Stone (1964) indicated that immatures were usually found attached to submerged wood or rocks in small, swiftly flowing streams or rivers in Connecticut. Wolfe and Peterson (1959) found larvae attached to rock faces and stones in and below cascades and waterfalls in which the temperature was 13.3 to 15.0°C. Pupae were more concentrated in backwaters beneath the falls. Twinn (1936a) found pupae in late May on submerged stems of dogwood in the rapids a short distance below a waterfall in Quebec, at a temperature of 11.7°C. Hocking and Richards (1952) collected pupae in mid-June in Labrador in water at 10°C.

Sommerman *et al.* (1955) reported 3 to 5 weeks for larval development and about 10 days for pupal development in Alaskan streams at 10.0 to 15.6°C. Anderson and Dicke (1960) showed a 5 to 6 week larval period and about 8 days for pupal development in Wisconsin.

Davies *et al.* (1962) stated that newly emerged females have undeveloped ovaries, moderate to large sized fat bodies, and possess well-developed, blood-sucking mouthparts.

According to Wolfe and Peterson (1959), females deposit their eggs singly while in flight over rapids.

Downe and Morrison (1957) found that *S. corbis* had fed on horses and cows in Quebec. Hocking and Richards (1952) found that it is attracted to, and probably bites, man in Labrador. Jamnback (1969) indicated *S. corbis* is probably mammalophilic in New York, and Sailer (1953) reported it biting man in Alaska. Shewell (1957) reported *S. corbis* as being an occasional or local pest of man and livestock throughout its range in Canada. Stone (1964) reported there are no positive biting records from Connecticut.

Populations of *S. corbis* in Newfoundland are basically like populations of this species in other regions of North America. Pupation in Newfoundland and Quebec occurs during mid-May, whereas in Ontario, pupae were collected during June and early July.

In 1971, larvae appeared as early as 6-V-71, and pupae 13-V-71. Following is a summary of the occurrence of the aquatic stages of *S. corbis* in Newfoundland during 1972:

| Stages collected | Date first collected | Date last collected |
|---|---|---|
| 1st instars | 24-V-72 | 24-V-72 |
| Immature larvae | 23-V-72 | 8-VI-72 |
| Mature larvae | 8-VI-72 | 8-VI-72 |
| Pupae | 8-VI-72 | 8-VI-72 |

Newfoundland Distribution: Streams 16, 17, 22, 23, 25, 26, 28-30, 35, 36, 38, 42, 64, 68, 81-83, 99, 141, 144, 155, 161, 164, 168; streams 10, 19, 69, 98, 103, 104, Mitchells Brook, Cape Broyle, Ferryland (Ebsary, 1972); Stone (1964); Stone *et al.* (1965).

### *Simulium (Neosimulium) vittatum* Zetterstedt

*S. vittatum* is multivoltine, and has 2 to 3 generations per year. The eggs overwinter and probably hatch early in the spring, since collections in February did not contain specimens while collections in March did in streams where it was known to occur.

Immatures have been collected from 18 streams, all in eastern Newfoundland; 6 on the Bonavista Peninsula and 12 on the Avalon Peninsula. They were usually found on a rocky substratum at depths of up to 15 cm and usually in permanent streams up to 5.0 m in width.

Newly emerged females in Newfoundland are autogenous for the first generation (author's data; Bradbury, 1972). *S. vittatum* is one of the more important pests of man in Newfoundland (author's data; Pickavance *et al.*, 1970), however, it is not as important or abundant as *P. fuscum, P. mixtum* or *S. venustum.*

*S. vittatum* is multivoltine; it has 2 to 7 generations per year throughout its range (Abdelnur, 1968; Anderson and Dicke, 1960; Chutter, 1970; Davies, 1950; Davies *et al.*, 1962; DeFoliart, 1951a; Forbes, 1912; Fredeen, 1958; Jenkins, 1948; Jobbins-Pomeroy, 1916; Peterson and Wolfe, 1958; Stone, 1964; Stone and Jamnback, 1955; Stone and Snoddy, 1969; Twinn, 1936b; Wolfe and Peterson, 1959). Larvae are the overwintering stage in most areas (Abdelnur, 1968; Chutter, 1970; Fredeen, 1958; Fredeen and Shemanchuk, 1960; Hocking and Pickering, 1954; Stone and Jamnback, 1955; Twinn, 1936b; Twinn *et al.*, 1948). Stone (1964) and Wolfe and Peterson (1959) also found it overwintering in the egg stage in Connecticut and eastern Canada.

Larvae and pupae are found in a wide variety of streams but tend to be uncommon in the larger rivers (Davies *et al.*, 1962; Depner, 1971; Fredeen, 1958; Gill and West, 1955; Hearle, 1932; Jenkins, 1948; Peterson and Wolfe, 1958; Snow *et al.*, 1958; Sutherland and Darsie, 1960; Twinn, 1936b).

DeFoliart (1951a) reported that the duration of the larval stages is influenced by the amount of food available.

Immatures have been collected in current velocities of 0.2 to 2.0 mps in the Canadian prairies (Depner, 1971; Fredeen and Shemanchuk, 1960), Utah (Peterson, 1956; Rees and Peterson, 1953), Alabama (Stone and Snoddy, 1969), and Michigan (Wu, 1930). Larvae and pupae have been found in water temperatures of 0 to 33°C in Ontario (Davies *et al.*, 1962), Saskatchewan and Alberta (Fredeen and Shemanchuk, 1960), Alaska (Jenkins, 1948), and Alabama (Stone and Snoddy, 1969). The pH ranged from 8.2 to 9.6 in streams with *S. vittatum* (Fredeen and Shemanchuk, 1960; Jenkins, 1948). Wu (1930) found the pupal stage lasted about 4 days. Emergence occurred during early May in Algonquin Park (Davies, 1950), but in mid-April in extreme southern Ontario (Davies *et al.*, 1962).

Peterson (1956) indicated that emerging adults crawl out of the water onto rocks, sticks, or grass blades to expand and dry their wings before taking flight.

Newly emerged females of the first generation are autogenous; their eggs are almost mature in Ontario (Davies and Peterson, 1956) and Michigan (Wu, 1930). Chutter (1970), however, also in Ontario, reported that the oocytes were small and yolkless at emergence, although he did indicate that females with abundant nutrient reserves were autogenous. Peterson (1962b) observed mating swarms of this species and saw males and females in copula in flight. Females deposit their eggs on almost anything at or near the water surface (Davies and Peterson, 1956; Fredeen, 1959b; Stone and Snoddy, 1969). Davies and Peterson (1956) also reported that *S. vittatum* may freely oviposit while in flight, but noted that this was not the preferred procedure in Ontario. Stone and Jamnback (1955) indicated that the eggs are laid in characteristic strings joined by a gelatinous substance.

*S. vittatum* is a mammalophilic species. It appears to vary in feeding habits throughout its range, but man, horses, and domestic animals appear to be the preferred sources of blood (Anderson and DeFoliart, 1961; Anderson and Voskuil, 1963; Davies *et al.*, 1962; Downe and Morrison, 1957; Fredeen, 1958; Gill and West, 1955; Hocking and Pickering, 1954; Hocking and Richards, 1952; Jamnback, 1969; Peterson, 1956; Rees and Peterson, 1953; Shewell, 1957; Stone, 1964; Stone and Jamnback, 1955; Stone and Snoddy, 1969; Twinn, 1936b; Wu, 1930). Peterson (1956) found a female *S. vittatum* with its mouthparts inserted into the abdomen of a black ant, *Formica fusca subaenescens* Emery. The fly's abdomen was distended from sucking body fluids of the ant.

The biology of *S. vittatum* in Newfoundland is somewhat incomplete, but what is known appears similar to this species in other regions of North America.

The occurrence of the aquatic stages of *S. vittatum* in 1971 may be summarized by the following:

| Stages collected | 1st generation<br>Date first collected | <br>Date last collected | Successive generations<br>Date first collected | <br>Date last collected |
|---|---|---|---|---|
| 1st instars | - | - | - | - |
| Immature larvae | 6-III-71 | 7-VI-71 | 23-VI-71 | 6-IX-71 |
| Mature larvae | 17-V-71 | 3-VI-71 | - | - |
| Pupae | 12-IV-71 | 2-VI-71 | 23-VI-71 | 3-IX-71 |

Newfoundland Distribution: Streams 9, 15, 105, 122, 128, 132, 155-158, 166, 177, 179, 184, 190, 193, 195, 202; stream 8 (Ebsary, 1972); Bradbury (1972); Davies (1971); Frost (1970); Frost and Manier (1971); Pickavance *et al.* (1970); Shewell (1957).

### *Simulium (Simulium) decorum* Walker

Immatures of *S. decorum* have been collected from a rocky substratum in only two streams, both on the Avalon Peninsula. At least one of these streams is in the vicinity of a dam. It is thought to be multivoltine, since larvae and pupae were collected in late May and early September. Collections on the Avalon Peninsula, at least, indicate that it is neither common nor a pest species.

*S. decorum* is multivoltine throughout its range (Abdelnur, 1968; Anderson and Dicke, 1960; Davies, 1950; Davies *et al.*, 1962; Jamnback, 1969; Jenkins, 1948; Jones and Richey, 1956; Stone, 1964; Stone and Snoddy, 1969; Wolfe and Peterson, 1959). The egg is the overwintering stage (Abdelnur, 1968; Anderson and Dicke, 1960; Davies *et al.*, 1962; Stone, 1964; Wolfe and Peterson, 1959). Stone and Snoddy (1969) noted that overwintering of *S. decorum* in Alabama may occur in the egg, larval, or pupal stage, or combinations of these stages. Davies *et al.* (1962) reported that eggs usually hatch during late April in southern Ontario.

Larvae and pupae are found almost always in outflows from naturally or artificially impounded waters and may entirely cover the face of a dam or sticks of a beaver dam (Abdelnur, 1968; Anderson and Dicke, 1960; Fredeen and Shemanchuk, 1960; Jones and Richey, 1956; Stone, 1964; Stone and Jamnback, 1955; Stone and Snoddy, 1969; Sutherland and Darsie, 1969). Larvae and pupae are also collected in other small streams, including lake outlets and bog drainage streams (Davies *et al.*, 1962; Depner, 1971; Hocking and Richards, 1952; Jamnback, 1969; Jenkins, 1948; Peterson and Wolfe, 1958; Sutherland and Darsie, 1960; Wolfe and Peterson, 1959).

Larvae and pupae have been found in current velocities of 0.1 to 2.0 mps in Wisconsin (Anderson and Dicke, 1960), Alabama (Stone and Snoddy, 1969), and eastern Canada (Peterson and Wolfe, 1958), and in streams with temperatures of 0 to $33^{\circ}C$ in Wisconsin, Alaska, and Alabama (Anderson and Dicke, 1960; Jenkins, 1948; Stone and Snoddy, 1969). Jenkins (1948) found larvae in streams with pH of 7.5.

DeFoliart (1951a) found that larval development required 12 to 16 days during warm weather in New York, and Anderson and Dicke (1960) noted that larval development required about 4 weeks for the first generation and about 3 weeks for the second generation in Wisconsin. Pupation commenced about mid-May in Ontario (Davies *et al.*, 1962). The pupal stage required 3 to 5 days for development in Wisconsin and New York (Anderson and Dicke, 1960; DeFoliart, 1951a). Newly emerged females of the first generation contained well-developed eggs and much stored nutrient in Alberta, Ontario, and Quebec (Abdelnur, 1968; Davies *et al.*, 1962; Wolfe and Peterson, 1959). Wolfe and Peterson (1959) showed that females of this generation did not require a blood meal for the first gonotrophic cycle. Females of the succeeding generations contained immature eggs with decreasing amounts of stored nutrient (Abdelnur, 1968; Chutter, 1970; Davies *et al.*, 1962). Chutter (1970) found 514 to 582 oocytes per female in newly emerged adults in Ontario. Females laid their eggs in mats on any suitable substratum at lake outlets or natural or artificial impoundments (Abdelnur, 1968; Davies *et al.*, 1962; Fredeen, 1959b; Stone and Jamnback, 1955; Stone and Snoddy, 1969; Wolfe and Peterson, 1959). Adults fed on man, cattle, horses, deer, and birds (Abdelnur, 1968; Davies *et al.*, 1962; Downe and Morrison, 1957; Jamnback, 1969; Shewell, 1957; Stone, 1964; Stone and Snoddy, 1969). Jamnback (1969) noted that adults have been found with developing trypanosomal stages, thus indicating its vector potential. Stone (1965) indicated that he would adopt the species name *argyreatum* for the species which is known as *decorum* in America.

At present, the biology of *S. decorum* in Newfoundland is incomplete and, unfortunately, a comparison with this species in other North American regions is impossible.

Newfoundland Distribution: Streams 157, 191; Shewell (1957); Stone (1964); Stone and Snoddy (1969).

### *Simulium (Simulium) tuberosum* Lundstrom

*S. tuberosum* populations in Newfoundland are either univoltine or bivoltine, or there are two ecologically different forms. It is bivoltine in Pickavance Creek and univoltine in creeks C, D, F, and G. Creek B had one generation in 1972 but a small second generation occurred in 1971. It was not found at all in creek E.

Eggs overwinter and hatching of the first generation occurs during the second or third week of May, and the second generation hatches about two months later. Mature larvae and pupae of the first generation are found about the second and third weeks of June and the second generation about the third and fourth weeks of July. The duration of the larval stage of the first generation is about 3 to 4 weeks, and the pupal stage about 4 to 6 days. The second generation is usually smaller than the first and the aquatic phase of the life cycle is completed within 3 weeks. Larvae have completed development at temperatures of 6.0 to $18.5^{\circ}C$ and pupae in 10 to $18^{\circ}C$.

Both larvae and pupae have been collected from rocks, tiles, and trailing vegetation. There does not appear to be any substrate preference, but immatures are commonly found on rocks, probably because rocks are the main component of the substrate. They have been collected in 47 streams in eastern and central Newfoundland. Its absence in western Newfoundland is probably due to sampling of streams prior to egg hatching. The streams sampled were temporary and permanent up to 5.0 m in width. Larvae have been collected at depths of 0.5 to 20.0 cm and pupae at 1.0 to 14.0 cm. Larvae were commonly found in current velocities of 0.27 to 1.34 mps. Pupae were collected in a current velocity of 0.45 mps.

Creek C is the only part of the Pickavance Creek complex in which *S. tuberosum* formed a significant part of the larval population. In the second week of June it formed 40 percent of the larval population. In creek B, 1972, it was collected only in the first week of June. *S. tuberosum* pupae are generally smaller than those of *S. venustum* and *S. verecundum*. Females require a blood meal for the first gonotrophic cycle.

In Newfoundland it is presumably a mammalophilic species, but because of its low density, it is not usually an important pest of man. Pickavance *et al.* (1970) collected adults at Pickavance Creek and three other areas but they knew nothing of the feeding habits.

Landau (1962), in a detailed study of the salivary gland chromosomes of *S. tuberosum* in Southern Ontario, revealed four well-defined breeding units and a likely fifth, all of which were sympatric and with no evidence of hybridization. Davies *et al.* (1962) suggested the presence of two or more undescribed forms in Ontario. They considered these forms all different from the Palaearctic form and therefore the biology of that species will not be considered here. Jamnback (1969) indicated that *S. tuberosum* in New York is a complex of species, and Stone and Snoddy (1969) found two ecologically different forms in Alabama. Davies (1950) reported there were two generations in Ontario. Sommerman *et al.* (1955) indicated there were one to two generations a year in Alaska depending on the type of stream. They indicated there may be a third in some of the warmer streams. *S. tuberosum* is trivoltine in Ontario (Davies *et al.*, 1962), Alberta (Abdelnur, 1968), and Maryland (McComb and Bickley, 1959). It has three to four generations in the Adirondacks (Stone and Jamnback, 1955), four in Connecticut (Stone, 1964) and Quebec (Wolfe and Peterson, 1959), five in Alabama (Stone and Snoddy, 1969), and five to six in South Carolina (Jobbins-Pomeroy, 1916). Jamnback (1969) reported it to be multivoltine in New York, and Jamnback *et al.* (1971) indicated it was multivoltine throughout its range in North America.

Eggs overwinter in Alberta (Abdelnur, 1968), Ontario (Davies *et al.*, 1962), Alaska (Sommerman *et al.*, 1955), and New York (Jamnback, 1952; Stone, 1964; Stone and Jamnback, 1955). Eggs of the first generation hatch in May, usually after the hatching of the eggs of *S. venustum* in Ontario (Davies *et al.*, 1962) and New York (Stone and Jamnback, 1955). Sommerman *et al.* (1955) showed that hatching in Alaska occurred in May at a water temperature of 9.4°C and mature larvae appeared by the third week of May and pupae in the last week, and also indicated that 15.6 to 20.3°C were the maximum temperatures at which immatures of *S. tuberosum* developed. Fredeen and Shemanchuk (1960) found *S. tuberosum* living in temperatures of 12.8 to 21.7°C in Alberta and Saskatchewan. Sommerman *et al.* (1955) indicated that the second generation hatched in mid-July and mature larvae and pupae were collected in late July and early August at temperatures of 12.2 to 18.3°C.

Fredeen and Shemanchuk (1960) collected pupae from June 6 to September 4 in Saskatchewan and Alberta. Hocking and Richards (1952) collected pupae as early as June 13 in Labrador. Abdelnur (1968) collected maturing larvae and pupae on June 14-17, July 19-24, and August 20-24 in Alberta. Davies *et al.* (1962) showed that adult emergence in Ontario begins in late May or early June and continues in some streams throughout the summer. They reared adults from pupae collected as late as October 9. Davies (1950), in another study, collected the first adults on May 20. Wolfe and Peterson (1959), in Quebec, found adults of the four generations on June 10, early July, August 5, and September.

Sommerman *et al.* (1955) found that immatures of *S. tuberosum* preferred a stony substratum in Alaska. *S. tuberosum* has been collected from almost every available substrate in a wide variety of streams, usually permanent, which ranged from 0.66 m to about 1742 m in width (Abdelnur, 1968; Davies *et al.*, 1962; Depner, 1971; Fredeen and Shemanchuk, 1960; Hocking and Richards, 1952; McComb and Bickley, 1959; Mackay, 1969; Sommerman *et al.*, 1955; Stone and Snoddy, 1969; Sutherland and Darsie, 1960).

In Alberta, Abdelnur (1968) found that *S. tuberosum* larvae have a water depth preference of 7.5 to 20.5 cm. Fredeen and Shemanchuk (1960) collected *S. tuberosum* in a pH range of 7.9 to 9.1; salinity range of 120 to 1820 ppm; suspended solids range of 2 to 270 ppm; dissolved carbon dioxide range of 0 to 1 ppm; and dissolved oxygen range of 6.8 to 9.6 ml/liter with 106 to 143 saturation percentage in Saskatchewan and Alberta.

Davies *et al.* (1962) found that newly emerged females contained a moderate amount of stored nutrient and undeveloped eggs in Ontario. Abdelnur (1968), in Alberta, found that females also require a blood meal for the first gonotrophic cycle. Davies and Peterson (1956) found an average of 202 eggs in each *S. tuberosum* female examined.

Abdelnur (1968) indicated that in Alberta oviposition was probably on the surface of the water, when the females were observed to descend and settle on the water. Davies and Peterson (1956) indicated that in Ontario *S. tuberosum* probably lays eggs into the water while flying. Wolfe and Peterson (1959) observed oviposition in Quebec in the calm water on the shore of a lake among the stones just above the lake outlet. The females alighted on the water surface and each extruded a stream of 10 to 20 eggs, which sank slowly to lake bed among the rocks. The flies arose and repeated this process in a new location. Females were not observed to oviposit while in flight.

Downe and Morrison (1957), using positive precipitin tests, found *S. tuberosum* had fed on horses and cows in Quebec. Hocking and Richards (1952) found *S. tuberosum* attracted to man in Labrador and stated that they probably bite. Peterson (1956) and Rees and Peterson (1953) stated that this species rarely feeds on man at altitudes lower than 2310 m, but does so readily above that altitude in Utah. Stone and Snoddy (1969) indicated that *S. tuberosum* is probably the most persistent pest of man and livestock in Alabama. Feeding occurred in the ears or beneath the abdomen, udder and genitalia of cattle. Sommerman *et al.* (1955) showed that it is attracted to humans and may be annoying in Alaska. Stone (1964) and Stone and Jamnback (1955) reported that only the first generation is anthropophilic in New York. Snow *et al.* (1958) found it feeding in the ears of horses and mules in Tennessee. Wolfe and Peterson (1959) stated that it does not usually attack man in Quebec, but was attracted to him and could cause annoyance.

The habits of *S. tuberosum* in Newfoundland are in all aspects similar to those in other locations. The life cycle appears to be synchronous, as hatching of the first generation occurs during May in Alaska, Ontario, New York, and Newfoundland.

Following is a summary of the occurrence of the aquatic stages of *S. tuberosum* during 1972:

| | 1st generation | | 2nd generation | |
|---|---|---|---|---|
| Stages collected | Date first collected | Date last collected | Date first collected | Date last collected |
| 1st instars | 27-IV-72 | 27-IV-72 | - | - |
| Immature larvae | 14-V-72 | 20-VI-72 | 12-VII-72 | 7-VIII-72 |
| Mature larvae | 7-VI-72 | 20-VI-72 | - | - |
| Pupae | 8-VI-72 | 20-VI-72 | - | - |

Newfoundland Distribution: Streams 3-5, 7-10, 12, 14, 15, 19, 23, 29, 30, 99, 100, 102, 103, 105, 122, 126, 129, 134, 136, 141, 153, 155, 157, 168, 170, 174, 176, 179, 180, 186-188, 193, 194, 196, 197, 206-209, 211, 212; stream 64, Salmonier Line, Mitchells Brook, St. Catherines, Bay Bulls, Cape Broyle, Ferryland (Ebsary, 1972); Bradbury (1972); Davies (1971); Pickavance *et al.* (1970).

## *Simulium (Simulium) venustum* Say

*S. venustum* is multivoltine in Newfoundland and has 3 to 4 generations per year. Hatching of the first generation usually occurs during late April or early May. Eggs which hatch later in the summer may have been laid by first, second, or third generation females.

Larvae have been collected from rocks, tiles and vegetation at depths from 0.5 to 14 cm, and in current velocities of 0.6 to 4.85 mps. Pupae have also been collected from rocks, tiles and vegetation at depths of 0.5 to 14 cm, and in current velocities of 0.9 to 4.85 mps.

It is island-wide in distribution and has been collected from 85 streams ranging from temporary roadside trickles to large, swiftly flowing permanent rivers. This species probably inhabits all blackfly breeding streams in Newfoundland and is usually the most abundant species (Figs. 7-10, 13, 14). During 1972 larvae were not collected until the third week of May. Pupation began during the first week of June and this accounted for a decrease in larval numbers. Pupae of the second generation appeared during the second week of July and the larval population continued to decrease and disappeared by the second week of August.

*S. venustum* had at least two generations also in creeks B, C, D, and G. The first generation was by far the larger in Pickavance Creek and creeks C, D, and G, but the second generation was the larger in creek B. There was an almost complete separation between the two populations in creek D. *S. venustum* did not complete the first generation in creeks E and F due to the streams drying out.

In Newfoundland, the length of larval development varies with temperature, but in nature it takes 2 to 6 weeks at temperatures of 1 to 20°C. Larvae of the second generation usually require 2 to 4 weeks since the stream at this time is usually warmer. Pupae of the first generation require about 6 days for development while the later generations require about 4 days.

Adult emergence commences about mid-June and continues in some streams until the end of August. In some areas, pupae may be collected in small numbers late in September. Newly emerged females of all generations contain undeveloped eggs, small amounts of stored nutrient, and require a blood meal for each gonotrophic cycle.

Oviposition of several females was observed on trailing grass blades at Site 2 in Pickavance Creek, but it was not determined whether this was the first or a later gonotrophic cycle. Eggs laid by the first and second generations normally hatch in 3 to 5 days.

*S. venustum* is the most important mammalophilic blackfly pest in Newfoundland (author's data; Pickavance *et al.*, 1970). Pickavance *et al.* (1970) collected adult females from rabbit and elevated duck baits at Pickavance Creek but did not determine whether feeding had occurred on the duck.

Stone (1965) reported that typical *S. venustum* is found on both sides of the Atlantic but, Jamnback *et al.* (1971), are of the opinion that *S. venustum* is a complex of species, some of which are not pests.

*S. venustum* is univoltine in Maryland (McComb and Bickley, 1959), and in the colder streams of Alaska (Sommerman *et al.*, 1955) and New York (Jamnback, 1969). It is bivoltine in Ontario (Davies, 1950) and northern Canada (Twinn, 1950), and in the warmer streams of Alaska (Sommerman *et al.*, 1955) and New York (Jamnback, 1969). It has two to three generations in Alaska (Jenkins, 1948) and Manitoba (Twinn *et al.*, 1948), and three to four generations in Illinois (Jobbins-Pomeroy, 1916) and eastern Canada (Peterson and Wolfe, 1958; Twinn 1936b; Wolfe and Peterson, 1959). It has four generations in Alabama (Stone and Snoddy, 1969) and five to six in North Carolina (Jobbins-Pomeroy, 1916). Davies *et al.* (1962) indicated that generations continued as long as the season permitted in Ontario. It has been recorded as multivoltine throughout North America (Jamnback *et al.*, 1971), New York (Stone and Jamnback, 1955), and the Canadian prairies (Fredeen, 1958, 1959a; Fredeen and Shemanchuk, 1960).

The egg has been shown to be the overwintering stage in Alberta (Abdelnur, 1968), Ontario (Davies, 1950), the Canadian prairies (Fredeen 1958, 1959a), northern Canada (Twinn *et al.*, 1948), New York (Jamnback, 1969), Alaska (Sommerman *et al.*, 1955) and, generally, throughout North America (Jamnback *et al.*, 1971), but Twinn (1936b) reported that *S. venustum* overwintered in the larval stage in eastern Canada. In Ontario and New York, the eggs hatch in the spring (April or May) when the water has warmed up to 4.4 to 7.2°C (Davies *et al.*, 1962; Jamnback, 1969; Jamnback *et al.*, 1971).

Throughout its range, larvae have been found to attach themselves firmly to any available substratum in a wide variety of streams, including small and large temporary and permanent streams and rivers, bog drainage streams and lake outlets (Abdelnur, 1968; Davies *et al.*, 1962; Depner, 1971; Fredeen, 1958; Gill and West, 1955; Hearle, 1932; Hocking and Pickering, 1954; Hocking and Richards, 1952; Jenkins, 1948; McComb and Bickley, 1959; O'Kane, 1926; Peterson and Wolfe, 1958; Snow *et al.*, 1958; Sommerman *et al.*, 1955; Stone, 1964; Stone and Snoddy, 1969; Sutherland and Darsie, 1960; Twinn, 1936b; Twinn *et al.*, 1948; Wolfe and Peterson, 1959). Immatures have been collected in current velocities of almost stagnant to 2.3 mps (Abdelnur, 1968; Depner, 1971; Sommerman *et al.*, 1955). Abdelnur (1968) found that larvae appeared when the water temperature rose to 4.4°C in Alberta. Gill and West (1955) collected larvae and pupae in temperatures of 23.3 to 28.9°C in Michigan. Jenkins (1948) collected larvae and pupae in Alaska in streams which had an average temperature of 15.0°C, average pH of 7.6, dissolved oxygen range of 7.0 to 9.0 ppm, and an alkalinity range of 100 to 120 ppm. Twinn *et al.* (1948) collected pupae of the first generation early in July in northern Canada, and Sommerman *et al.* (1955) first collected mature larvae and pupae during late May and early June in Alaska.

The duration of the larval stage is dependent upon temperature and may range from 8 days to several weeks throughout North America (Jamnback *et al.*, 1971). Peterson and Wolfe (1958) indicated that larvae required 15 to 18 days for development in eastern Canada. Sommerman *et al.* (1955) reported 2 to 3 weeks for larval development in Alaska, and as long as 5 weeks in colder streams. Generally, pupation begins in mid-May to early June in many regions of North America (Jamnback *et al.*, 1971). Pupae of the first generation were usually collected during the first half of June in northern Manitoba (Hocking and Pickering, 1954). Jamnback (1969) reported that *S. venustum* requires 8 to 12 days to reach the pupal stage in warm streams in New York. The pupal stage lasts from 4 to 9 days across North America (Jamnback *et al.*, 1971). The pupal stage requires 82 hours in South Carolina to a maximum of 9 days in Illinois (Jobbins-Pomeroy, 1916); 5 to 8 days at water temperatures of 12.8 to 15.6°C in eastern Canada (Peterson and Wolfe, 1958), and 4 to 7 days in Alaska (Sommerman *et al.*, 1955).

In Ontario adult emergence begins in late May or early June (Davies, 1950; Davies and Peterson, 1956; Davies *et al.*, 1962) or in mid-May (L. Davies, 1963; Shewell, 1955). Newly emerged adults of all generations have undeveloped eggs, little stored nutrient, and require a blood meal for each gonotrophic cycle in Alberta (Abdelnur, 1968) and Ontario (Davies *et al.*, 1962). Davies and Peterson (1956) found an average of 455 eggs per female and Hocking and Pickering (1954) an average of 594 eggs per female.

Abdelnur (1968) reported that females dove under water or settled on the water surface, vegetation, rocks, stones, or logs and usually shared oviposition sites. Oviposition does not occur until 2 to 3 weeks after emergence (Davies, 1950). Davies and Peterson (1956) indicated that females lay their eggs in mats, often several layers deep, almost exclusively on vegetation at or below the water surface. They also reported that often 10 to 20 females oviposited together on trailing vegetation. Fredeen (1959b) indicated that *S. venustum* females deposit their eggs in masses on objects at the water surface. Oviposition apparently occurs on the evenings of warm days, particularly after inclement weather (Hocking and Pickering, 1954). They found the average number of eggs per ovipositing female to be 594. Jamnback *et al.* (1971) indicated that eggs are usually oviposited on trailing vegetation in the stream. Females oviposit on trailing vegetation, stones, or logs, depending on the season in Quebec (Wolfe and Peterson, 1959). Wolfe and Peterson (1960) observed oviposition immediately after sunset and continuing until dark in Quebec.

It appears that *S. venustum* is a major pest species throughout much of its range (Davies *et al.*, 1962; Fredeen, 1959a; Gill and West, 1955; Jenkins, 1948; Twinn, 1936b, 1950; Twinn *et al.*, 1948; Wolfe and Peterson, 1959). Abdelnur (1968) reported that females showed a definite preference for man over cows, and for cows over horses in Alberta. Feeding females were collected from a dog, sparrows, and pigs. Davies and Peterson (1956) reported females feeding on a variety of birds and mammals but indicated they were most frequently observed on the northern white-tailed deer in Ontario. It fed on cows and horses in Quebec (Downe and Morrison, 1957). Fredeen (1958) reported that outbreaks in the Canadian prairies were severe enough to reduce milk production in cattle by 50 percent and to prevent weight gains in beef animals. Gill and West (1955) collected females from cattle in Michigan. Hearle (1932) indicated that in British Columbia females do not appear to have marked host preferences but will attack most animals. It is reported as a serious pest of man and livestock throughout Canada (Shewell, 1957) and of horses, in particular, in Connecticut (Stone, 1964). Stone (1964) indicated that females will feed on man, cattle, sheep, deer, and occasionally, birds. Stone and

Jamnback (1955) reported that *S. venustum* adults are troublesome only between late May and early July in New York State, and they also believed that either it is anthropophilic only for the first generation or two separate species are involved. In Alabama, the adults appear in large numbers in late winter and early spring, but the population declines as warm weather approaches. Adults were found to readily bite man and livestock in Alabama (Stone and Snoddy, 1969). Twinn (1936b) also found *S. venustum* to be a troublesome pest of animals and man in eastern Canada.

*S. venustum* appears to be a pest species throughout its range, including Newfoundland. The eggs hatch during late April or early May in Ontario, New York, and Newfoundland. The length of the larval and pupal stages fluctuates from area to area, but this is related to stream temperature, which, in turn, is related to topography.

The occurrence of the aquatic stages of this species in Newfoundland during 1972 is summarized by the following:

| Stages collected | Date first collected | Date last collected |
|---|---|---|
| 1st instars | 2-V-72 | 8-V-72 |
| Immature larvae | 29-V-72 | 7-VIII-72 |
| Mature larvae | 7-VI-72 | 7-VIII-72 |
| Pupae | 13-VI-72 | 7-VIII-72 |

The three to four generations could not be separated due to the overlapping of the generations. The dates of the latest collection of stages of *S. venustum* may not be accurate due to the presence of *S. verecundum* which is morphologically similar. Fig. 7 indicates that there are at least three generations in Pickavance Creek.

Newfoundland Distribution: Streams 3-7, 9, 10, 12, 14, 15, 19, 30, 45, 55, 65, 69, 96, 99, 100-105, 108-110, 112, 116, 122, 123, 126, 128, 129, 131-133, 137, 138, 141, 144, 145, 154-158, 160, 163-180, 182, 185-188, 196-199, 202-204, 206-212; Salmonier Line, St. Catherines, Mount Carmel, Bay Bulls, La Manche, Cape Broyle, Ferryland, Healy's Pond runout, Power's Pond runout (Ebsary, 1972); Bradbury (1972); Davies (1971); Davis (1971); Frost (1970); Pickavance *et al.* (1970); Shewell (1957).

## *Simulium (Simulium) verecundum* Stone and Jamnback

There are probably three or four generations of *S. verecundum* in Newfoundland and the eggs overwinter. The eggs of the first generation hatch about mid-June. Eggs continued to hatch during late August but it is difficult to determine whether these were laid by the first, second, or third generation females.

Larval development requires about 3 weeks. Larvae have been collected at depths of 0.5 to 10 cm and in water temperatures of 9.0 to 18.0°C. Immatures have been collected from tiles, rocks, and vegetation but apparently prefer vegetation, particularly later in the summer. Pupae require 4 to 7 days for development and have been collected in depths of 0.5 to 10 cm and temperatures of 13.0 to 17.0°C.

*S. verecundum* is found in all creeks of the Pickavance Creek study area, except creek E, but was absent from creek F during 1972.

It is probably found in as many streams as *S. venustum*. The distribution does not indicate this because most of the streams were sampled early in the summer before eggs of *S. verecundum* hatched. It is not an important pest species here because it usually occurs in smaller numbers than *S. venustum*, and also because it is found in many small streams which dry out in the middle of larval development.

*S. verecundum* is multivoltine in Alabama (Stone and Snoddy, 1969); it has 2 to 3 generations in New York (Stone and Jamnback, 1955); probably 2 in Wisconsin (Anderson and Dicke, 1960); and probably 3 in Alberta (Abdelnur, 1968).

The eggs overwinter in Ontario and hatch in late April or early May (Davies *et al.*, 1962). Abdelnur (1968) indicated that larvae appeared when the water temperature was about 4.4°C in Alberta.

Abdelnur (1968) found immatures in current velocities of only a trickle in 2.5 cm of water to about 1.7 mps in more than 1.0 m of water in Alberta. Immatures have been collected in a variety of streams. Davies *et al.* (1962) found that it was apparently restricted to streams over 3.3 m in width in Ontario, while Sutherland and Darsie (1960) collected immatures in Delaware in streams from 0.7 to 3.3 m wide. Abdelnur (1968) also collected it in streams rather than rivers in Alberta. Anderson and Dicke (1960) regarded *S. verecundum* as part of the *Simulium venustum* complex and found immatures of this complex in small, permanent streams, semi-permanent streams, and more frequently in large streams and rivers in Wisconsin. Stone and Snoddy (1969) collected immatures on spillways of dams in Alabama and indicated that it is apparently more tolerant of high temperatures than *S. venustum*, and is likely to be found in larger streams and emerge a little later. Stone and Jamnback (1955) indicated that in New York its biology is very similar to that of *S. venustum* but that it appears somewhat later. Wolfe and Peterson (1959) knew little about this species, but also reported that it appeared to be a late summer species in Quebec.

It is morphologically similar to *S. venustum*. Wolfe and Peterson (1959) reported that the immature stages of *S. verecundum* are not distinguishable from those of *S. venustum*. According to Anderson and Dicke (1960), Stone and Jamnback (1955), and Stone and Snoddy (1969), live larvae of *S. verecundum* are entirely white in contrast to the distinct reddish tinge of *S. venustum*. This distinction is of little value in Newfoundland because both are pale green. Almost the only time *S. venustum* larvae have a 'distinct' reddish tinge is when they are parasitized by mermithid nematodes. Stone and Jamnback (1955) indicated that pupae of *S. venustum* and *S. verecundum* are indistinguishable, but Stone and Snoddy (1969) reported that the pupal respiratory filaments of *S. verecundum* are usually somewhat longer. Stone and Jamnback (1955), Stone and Snoddy (1969), and Wolfe and Peterson (1959) indicated that adult females of *S. verecundum* are indistinguishable from females of *S. venustum*, but point out that the ventral plate of the male terminalia are different. Females can now be differentiated by the characters presented in the key to the Ontario species by Davies *et al.* (1962).

Stone (1964) suggested that *S. verecundum* is so close to other members of the *S. venustum* complex that data on adult habits, in particular, are not readily obtained. Abdelnur (1968) found it difficult to study it separately in Alberta. Adults were not attracted to him but were captured feeding on cattle. *S. verecundum* does not appear to be annoying to man in New York State (Jamnback, 1969; Stone and Jamnback, 1955). Stone (1964) reported that *S. verecundum* is probably not as annoying to man as *S. venustum* and, apparently, emerges later in Connecticut. *S. verecundum* is uncommon in Alabama and the adults do not appear to harm man (Stone and Snoddy, 1969).

It appears that *S. verecundum* in Newfoundland is basically similar to this species in other regions of North America, but it hatches one and one half to two months later than the Ontario species.

Following is a summary of the occurrence of the aquatic stages of *S. verecundum* in Newfoundland in 1972:

| Stages collected | Date first collected | Date last collected |
|---|---|---|
| 1st instars | 7-VI-72 | 7-IX-72 |
| Immature larvae | 7-VI-72 | 30-IX-72 |
| Mature larvae | 28-VI-72 | 30-IX-72 |
| Pupae | 28-VI-72 | 30-IX-72 |

The several generations of this species could not be separated due to overlapping, but Figs. 7-10 indicate that there are a minimum of two generations in creeks A, B, C, and D.

Newfoundland Distribution: Streams 126, 128, 129, 141, 155, 156, 158, 169-180, 186, 188-198, 202, 203, 206-209, 211, 212; Bradbury (1972); Davies (1971); Pickavance *et al.* (1970).

### *Simulium hematophilum* Laboulbène

This species was described by Laboulbène (1882) from notes and unpublished sketches made in the field in eastern Newfoundland by Treille (1882). Treille reported it as a very troublesome blood-sucker and Bequaert (1945) indicated that it was clearly a simuliid and thought that it should be easily recognized by the description. Stone (1964) indicated that the description does not fit any *Simulium* satisfactorily and was doubtful that it would ever be recognized.

It appears to the author that *S. hematophilum* is probably what is now known as *P. fuscum/mixtum*. There are two reasons for this. The first is the description: while it does not fit *P. fuscum/mixtum* accurately, it must be realized that Laboulbène described the fly from notes and sketches. The fact that he did not see the specimen itself leaves room for error.

The second reason for believing that *S. hematophilum* is synomymous with *P. fuscum/mixtum* is the time at which the flies were troublesome. Treille (1882) indicated that they were rare towards the end of May, but by the first part of June they were "en quantités innombrables". Adults of *P. fuscum/mixtum* are the first pest species to occur each year in Newfoundland and peak emergence is usually around the end of May or early June. *S. vittatum* appears shortly afterwards but is not as common as *P. fuscum/mixtum* or *S. venustum*, which emerges sometime later.

## POPULATION DYNAMICS

### Sampling

According to Williams *et al.* (1961b) an animal community in a stream can only be assessed by repeated sampling which will indicate seasonal variations, irregular distribution, and possible habitat selection, and relate the findings to the part of the stream examined.

A single collection can be very misleading as to the species and their numbers present in any one area, since some species can only be taken during the summer and others during the winter. Even two well-spaced collections will help correct this distorted picture.

The methods used to sample immature populations of blackflies are numerous and varied. Some traps or artificial substrates have been used only to facilitate collecting, while others have been designed to estimate population density. Basically, there are two techniques, the first uses the natural substrata and the second, artificial ones.

Abdelnur (1968) used two such methods. The first method was direct counting in one square foot of stream bottom. A wooden frame was placed on the stream bottom, at a selected place with suitable substrate. This method has been used in ecological studies and assessments of control. Arnason *et al.* (1949), Anderson and Dicke (1960), Fredeen *et al.* (1953), Jamnback and Eabry (1962), Metcalf (1932), Sommerman *et al.* (1955), and Wolfe and Peterson (1959) made a five minute stone count in selected areas.

Obeng (1967) initially used metal cones and then polythene tapes but both of these were abandoned. She then investigated natural substrates and found that vegetation gave the most reliable indication of blackfly abundance. At another stream 21 stones were marked with white paint and specimens which settled on them were removed at each visit. Obeng also sampled stones using another method. She chose ten stones, and these were washed clean in a pie-dish so that even the first instars were obtained.

Zahar (1951) sampled vegetation and stones to estimate population density. A standard sample of the vegetation covering one square foot was taken and this was sufficient to fill a 16 oz jar. A standard sample of ten water-washed stones was taken at random and the larval population was estimated according to the degree of uniformity of larval distribution on individual stones and more precisely the number of larvae present per square inch.

Maitland (1964) and Maitland and Penney (1967) sampled gravel or small boulders with a shovel sampler, and Chutter (1968) sampled individual stones.

Holbrook (1967) used a circular wire frame of a 300 sq. cm area, which was placed on the stream bottom and the sample collected from the substrate enclosed.

The author sampled natural substrata but relied on an artificial substratum for quantitative samples. Sampling of natural substrata is advantageous only because artificial substrata are not required for collection of specimens, but while sampling natural substrata should give quantitative as well as qualitative results, the selection of the sample is usually subjective.

Ladle *et al.* (1972) placed a rubber-covered metal plate underneath stems of *Ranunculus* and a bottomless square metal box (0.05 sq. m) was positioned on top. The *Ranunculus* plants enclosed in the box were removed by hand to a polythene bag and the water, together with *Simulium* larvae and any plant fragments, was pumped out by means of a plastic bilge pump through a sieve of 0.125 mm aperture. All material retained by the sieve was added to the sample. This large quantitative sample was collected in an attempt to overcome the variable distribution of animals within *Ranunculus* plants.

Disney (1972) suspended a length of cord from a bridge. The portion of the cord in the water had loops tied in it at 50 cm intervals and to each loop was attached a freshly-picked mango leaf. Leaves of approximately the same size were used in any one experiment. The whole string of leaves could be rapidly lifted from the water at the time of sampling and the leaves quickly detached by cutting the petioles. The leaves were then placed in jars of alcohol.

Wolfe and Peterson (1958) developed the hollow metal cone concept. These had a base diameter of 10 cm, a height of 20 cm, and an apex angle of $30^{\circ}$. They were painted white and attached by wire to logs, stones, or vegetation and suspended in the streams. Peterson and Wolfe (1958) found that these cones were preferred to stones and trailing vegetation. They found that the cones were useful for several purposes: determining the density at a particular locality; estimating the growth rate of larvae; determining periods of migration of small larvae through water courses from oviposition areas; determining periods of peak abundance of larvae and pupae; indicating streams suitable for larval growth; and assessing larval control methods.

Zahar (1951) placed white glazed tiles 6 in. square in a stream at places where the effect of different currents and other conditions on *Simulium* populations could be investigated.

Williams and Obeng (1962) employed metal cones, like those of Wolfe and Peterson (1958) and also polythene tapes. These tapes were cut from a medium gauge polythene sheet and attached to a 6 in. length of wood; a strip 45 cm long and 2.5 cm wide was exposed to the current. Doby *et al.* (1967) also used polythene tapes.

Johnson and Pengelly (1966) used a galvanized sheet-metal cone covered by a removable paper cone of the type used at soda fountains. The metal cone was attached to a short length of steel fence post by means of a short carriage bolt, with the apex of the cone pointing upstream. Sampling was accomplished quickly by removing the paper cones with attached larvae. This technique was devised to simplify sampling. Phillipson (1956) used plastic cones.

Abdelnur (1968) also used a method which involved the use of artificial attachment sites. These were hollow cones which were suspended by wire through the apices to wooden spikes fixed in the collection area. Depth could be adjusted by using cork or lead weights. Phelps and DeFoliart (1964) and West *et al.* (1960) used a similar method. Abdelnur found that the cone was approximately one-ninth of a square foot, however, the number of larvae on a trailing cone was subequal to the number of larvae in a square foot of stream bottom. He indicated that this might be due to the attraction of larvae to bright objects or perhaps to the nature of shape or movement of the surfaces. This was supported by the fact that white cones always had more larvae than cones painted yellow, brown, red, green, or blue.

Other methods which have not been as popular or as widely used as those discussed include wooden boards (Carlsson, 1962); white hardboard strips (Curtis, 1968); and nets, wooden floats, and sealed tins (Wanson and Henrard, 1945). For convenience, Disney (1970) and Tarshis (1965, 1968a) used palm fronds and lengths of fabric respectively for collecting large numbers of larvae and pupae. Disney (1972) reported that a satisfactory technique has not been devised for sampling phoretic species of blackflies.

Holbrook (1967) used a plasterer's lath for collection of larvae. The lath was 1.75 in. in width, 0.75 in. thick, and 14.25 in. in length. Two strips of lead flashing were attached to the bottom surface of wood strips to ensure they would sink.

The author used tiles 10 cm x 10 cm for sampling because they had a uniform surface, convenient measurements for density studies, were easily cleared of larvae, and except for extreme flood conditions, were heavy enough to remain on the stream bottom for indefinite lengths of time.

Zahar (1951) used similar tiles. He found that the white glazed tiles were liable to become silted over and coated with algae which apparently rendered their surfaces unsuitable for larval attachment. He also found that in spates the tiles may be washed away, and in periods of low water they may be left high and dry. Algae were not a serious problem at Pickavance Creek and, if the tiles were sampled regularly, it is doubtful whether there would be time enough for them to be silted over or overgrown with algae.

Johnson and Pengelly (1966) used a paper cone on top of a metal cone, therefore the entire paper cone would be pickled in alcohol for later examination. The other cones, however, all required removal of larvae in the field, and the author suggests that larvae are easier to scrape off the flat side of a tile rather than the curved surface of a cone. Another disadvantage of cones is that they require fairly deep water, whereas a tile needs only 1 to 2 cm.

Polythene tapes used by Obeng (1967) and Williams and Obeng (1962) are probably the simplest method of collecting larvae. Rapid drops in the water level however can result in the tapes becoming entangled in rocks and other debris. Holbrook (1967) found that the plasterer's lath could be washed away by the current. Tapes are more useful in shallow streams than are cone traps. Sampling of vegetation (Zahar, 1951) and stones (Abdelnur, 1968; Zahar, 1951) per square foot of stream bottom is somewhat tedious and the actual randomness employed in this way may not always be valid. Obeng's (1967) method for sampling rocks and the technique of Ladle *et al.* (1972) for vegetation are also tedious. Five minute stone counts are somewhat impractical. Disney's (1972) technique with mango leaves, presumably applicable to other leaf species, involves a certain amount of expertise and it is doubtful whether the area of the leaves is uniform or easily derived for quantitative studies.

In many ways the tile appears to be the better method of collecting larvae, at least in Newfoundland streams. Tiles facilitate collecting of immatures and are more easily placed in the stream. They are of uniform surface and, when sampled regularly (e.g. weekly), there is usually not sufficient time for silt or algal accumulation and, since they are relatively heavy, they will be washed out of place only during spates.

## Seasonal Succession and Abundance

At the beginning of the blackfly season the larval and pupal populations are clearly defined, but as the season advances there is considerable overlapping of generations due to late development of some species and egg hatching of other species. The seasonal succession and abundance of blackflies presented here is based entirely on the immature stages. Fig. 6 indicates the seasonal succession of the nine species of blackflies found in each of the seven creeks of the Pickavance Creek area during January, 1971 to October, 1972. Figs. 7 to 13 show the succession again for creeks A to G respectively, but present a detailed examination of the abundance of each species present in each stream during 1972. The abundance is based on the average number of larvae collected per tile per stream per collection. Fig. 14 compares the total number of larvae per tile per stream with special emphasis on *S. venustum*.

There are normally two peaks of abundance of blackflies in Newfoundland. The first consists mainly of *P. fuscum* and *P. mixtum* which overwinter as larvae and the second consists mainly of *S. venustum* which overwinters as eggs.

The spring peak depends upon the abundance of the overwintering larvae and eggs, and the effects of winter on both these stages. The high water of the spring "run-off" is advantageous to larvae as it invades new areas and thus increases the area of substrate available for attachment, and also increases the amount of food material (Anderson and Dicke, 1960; Carlsson, 1962; Fredeen and Shemanchuk, 1960; Peterson and Wolfe, 1959; Phillipson, 1956, 1957). High water may also have adverse effects as some of the larvae may be washed downstream and silt and sand may be deposited on the substrate.

The summer peak results from the combined presence of the first generation larvae of several species with higher temperature requirements.

*C. mutata, P. fuscum,* and *P. mixtum* all overwinter as larvae and gradually develop through the winter in water at 0°C. During this time they may find themselves in darkness for up to three months since thick layers of ice and snow over the streams are not uncommon. *P. fuscum* and *P. mixtum* are more abundant in larger streams (e.g. Pickavance Creek, Fig. 7) whereas *C. mutata* is more abundant in smaller creeks (e.g. creek D, Fig. 10). Theoretically, these three species should increase in numbers until late April or early May when pupation begins. However, parasites, predators, natural mortality, and drift probably account for the fluctuations in larval population during this time (Figs. 7-13). During pupation of *P. fuscum, P. mixtum,* and *C. mutata,* the eggs of several other species begin to hatch. *S. venustum, S. tuberosum,* and *S. latipes* usually hatch in May, and this may fluctuate two to three weeks from year to year depending on environmental conditions (Fig. 6). *S. venustum* is normally found throughout the summer until at least August. It is at least bivoltine and there may be a third or fourth generation (Figs. 7-10, 13). *S. tuberosum* and *S. latipes* normally go through their first generation at the same time as *S. venustum*, but with these two species there is often one to two weeks between the end of the first generation and the appearance of the second (Figs. 7-10, 13). This separation of successive generations is not normally observed in *S. venustum*, but a separation between the first and second generations came close to reality in creek B (Fig. 8) and creek D (Fig. 10). *S. venustum* is the most abundant species in almost all of the creeks studied (Figs. 7-10, 13). It is difficult to estimate the abundance of *S. venustum* in creeks E and F (Figs. 11, 12) as these creeks had dried out early in *S. venustum* development. *S. tuberosum* was most abundant in creek G (Fig. 13) but it has been observed to be an important part of the population in larger streams in other regions of the Island. *S. latipes* was most abundant in the smaller streams (e.g. creeks E and G, Figs. 11, 13), whereas in Pickavance Creek itself it did not occur in large numbers. One to two weeks after the eggs of the first generation of *S. venustum*, *S. tuberosum*, and *S. latipes* hatched, eggs of *S. gouldingi* hatched. *S. gouldingi* has only one generation and at the time of its pupation *S. tuberosum* and *S. latipes* usually begin their second generation. During this time larvae and pupae of *S. venustum* are also living in the streams. The second generations of *S. tuberosum*, *S. latipes*, and *S. venustum* are usually much less numerous than the first generation. *S. verecundum* usually hatches during the first half of June, normally about two to three weeks after egg hatching of *S. venustum*. It may be found until late October and there may be three or four generations, but with considerable overlapping. Near the end of August, the final species in the Pickavance Creek area, *S. aureum*, makes its appearance. During development of this species, larvae and pupae of *S. verecundum* are common and scattered specimens of *S. venustum* may also be found. *S. aureum* and *S. gouldingi* both prefer the smaller streams since neither was observed in Pickavance Creek. *P. fuscum*, *P. mixtum* and *C. mutata* hatch in September or October and the succession begins again. In some streams (e.g. Pickavance Creek, Fig. 7) larvae may be present in the stream all year round. In other streams immatures may be absent for several months (e.g. creek E, Fig. 11). Such absence may result from drought or species completing development early due to a variety of factors such as higher temperatures or more nutrients in streams.

It was observed that small larvae and large larvae often occurred on any given substrate. This is similar to Obeng's (1967) observations. She found that succeeding generations of *S. variegatum* Meigen and *S. reptans* Linnaeus were out of phase, so that small larvae of one species were found with large larvae of the other species. Hynes (1970a) thought that this probably reduces the competition between the two species and allows them to occur together. This conclusion is challenged in this study since mature and maturing larvae of *S. venustum*, *S. tuberosum*, *S. latipes*, and *S. vittatum* have been collected at the same time on the same substrate in several streams. Each of these species had a high population in each stream and small larvae of all species were absent. However, that is not to say that, were these species out of phase, the populations would not be larger.

## Factors Affecting Simuliid Distribution in Streams

### Rate of Flow (Current Velocity)

Current velocity is a parameter which affects the nature of the substrate and, in turn, the substrate and the depth and width of a stream determine the current velocity; the relationship between current velocity and substratum is reciprocal. The substrate does not consist of bare rocks in sluggish water, and a substrate of mud does not exist under swiftly-flowing water.

In natural water courses, current velocity is subject to considerable seasonal variation. This is particularly true in Pickavance Creek where an overnight rainfall may increase the depth as much as four times and significantly increase the current velocity. Investigations of the importance of these changes for blackfly larvae have shown that any variation, either decrease or increase, induces the larvae to migrate (Carlsson, 1967).

The possibility that current velocity might have some influence on the species inhabiting the various creeks of the Pickavance Creek system was investigated. Current is a factor affecting distribution in Pickavance Creek insofar as it affects the substrate. Where the current is fast, the substrate consists of rocks and larvae are abundant, but four species, *S. aureum*, *S. gouldingi*, *S. tuberosum*, and *S. verecundum*, did not occur in all streams (Table II) and some other factor, as yet unknown, influenced this distribution.

Fig. 4 indicates the minimum, maximum, and average current velocity at which the nine species were collected; all species occurred

Table II

Species occurrence in the Pickavance Creek area

| Species | Creek | | | | | | |
|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G |
| *P. fuscum/mixtum* | x | x | x | x | x | x | x |
| *C. mutata* | x | x | x | x | x | x | x |
| *S. aureum* | | x | x | x | | x | x |
| *S. gouldingi* | | | x | x | x | x | x |
| *S. latipes* | x | x | x | x | x | x | x |
| *S. tuberosum* | x | x | x | x | | x | x |
| *S. venustum* | x | x | x | x | x | x | x |
| *S. verecundum* | x | x | x | x | | x | x |

in a velocity range of 0.33 to 0.92 mps. On the basis of these tolerances, there does not appear to be any current velocity preference and all nine species would be expected to occur in all seven streams.

Larvae have been found distributed over the entire surface of tiles, but on rocks, logs, boulders, and other large debris on the substrate they were commonly collected from the upstream part of the upper surface. When the flow was laminar, larvae were normally found on the more exposed areas of rocks. Pupae, on the other hand, have been observed to inhabit the opposite end of the rock or boulder, and the closed end of the pupal case is normally orientated towards the current.

Pennak (1971) reported that the mean current velocity should be measured during the ten driest months of the year. He thought that the spring runoff should not be included since this could give a distorted picture of normal lotic conditions. He also indicated that current velocity should be measured at midstream 0.6 of the way down from the surface, but realized that this is often difficult under field conditions. Blackfly larvae have an inherent need for current (Wu, 1930), possibly for feeding and/or respiratory requirements. Some species can survive in quite low oxygen concentrations, but none can tolerate still water for long periods.

Hynes (1970b) reported that many workers have found that particular species of benthic fauna are restricted to specific current velocity ranges as measured in the field. Hynes also indicated that many of these results are obtained at one specific time of the year and, since current is extremely variable, no absolute values of current requirements or tolerances are obtainable from field studies.

Maitland and Penney (1967) reported that the absence of larvae from the lower reaches of the River Endrick in Scotland was probably due to the reduced current velocities as the river entered its flood plain. However, a secondary feature of this reduction of current speed was the transition from a stable substrate in the upper portion of the river to an unstable one in the lower portion, which was unsuitable for blackfly larvae.

Grenier (1949), Phillipson (1956, 1957) and Zahar (1951) indicated that *Simulium* larvae respond to current speed, and found that certain species have different velocity preferences.

Blackfly larvae are generally filter feeders, depending upon the current to carry food particles to their straining cephalic fans. Therefore the current velocity and the amount of food in the water undoubtedly affect the survival and rate of growth of the larvae.

Fredeen and Shemanchuk (1960) found that where the water was rich in plankton, dense colonies of *S. vittatum* were found in current velocities as low as 0.2 mps, and smaller numbers of these larvae in water that was scarcely flowing at 0.03 mps.

Harrod (1965) found that the cephalic fans are held open by the current into which the cephalic fans are thrust from the larval shelter in the boundary layer. Harrod reported that strong musculature allowed larvae to open and close their cephalic fans at will, and also noticed that in slow moving and still water the fans remained open for only very short periods of time. She considered it likely that a current of water of a certain velocity was necessary to hold the fans open for long periods of time to enable the larva to feed. This imposes a lower limit of rate of flow in which the larvae can feed. She found that it was about 0.2 mps for *S. ornatum* Meigen. Larvae apparently feed unselectively, straining any and all organic particles suspended in the water, and are capable of completing their life cycles on suspensions of bacteria (Fredeen, 1964b).

Chutter (1968) found that slow current velocities probably play a part in the appearance of an abundance of epiphytic growths. He observed that the increase in several types of animals was in nearly every case related to the epiphyte increase.

Wolfe and Peterson (1959) indicated that two entities must be considered when relating current properties to attachment. The first is the macrocurrent which delimits the section of a stream that is suitable for attachment, and second the microcurrent which determines the suitability of a particular surface on an individual rock, log, or grassblade. Therefore, the larval environment should be classified by measurements of the microcurrent rather than the rate of flow of the stream.

Larvae have been usually found on the upstream part of the upper surface of rocks and boulders (Grenier, 1949; Maitland and Penney, 1967). Larvae were normally found on the more exposed areas of rocks when the flow was laminar (Hocking and Pickering, 1954; Obeng, 1967; Wolfe and Peterson, 1959). Zahar (1951) observed that larvae do not occupy sites where the water beats directly upon the substrate but select those areas where there is a steady flow of water. The current provides the mechanical force that moves the larvae to sites favorable for attachment (Hocking and Pickering, 1954) and visual and tactile stimuli presumably complete the process (Wolfe and Peterson, 1959).

The position of larvae at the upstream dorsal end of boulders (with relation to the current) is probably connected with the feeding habits, as here they can more easily filter the water (Maitland and Penney, 1967). Pupae have been observed at the other end of a rock or boulder suggesting that active migration must occur. The water flow at the downstream part of a rock or boulder is highly turbulent and thus permits a slower current speed. Pupae do not feed and therefore do not have the same current requirements as the larvae. Furthermore, if a pupa is dislodged from the substrate, it cannot re-attach.

Wu (1930) found that the angle of the body of the larva to the substrate decreases as the current increases. In a moderate current the larvae are almost erect, whereas in a torrent they lie almost horizontal. When pupae are found in laminar flow, the pupal cases are orientated with the closed end of the case towards the current. This agrees with observations of Grenier (1949) and Maitland and Penney (1967). Obeng (1967) also found pupae in sheltered regions. On the back surfaces of rocks and boulders the pupae are more varied in their position, and this is sometimes due to crowding.

Current velocity is extremely important in stream ecology. Its mode of action is quite variable in time and over short distances, and as Hynes (1970b) indicates, it is virtually impossible to qualify except in general terms.

Generally, blackfly larvae appear to behave in a similar manner in all types of streams with respect to location on the substratum and orientation towards the current. Simuliid larvae in Newfoundland have not been shown to have current velocity preferences as have been demonstrated in species studied by Grenier (1949), Phillipson (1956, 1957), and Zahar (1951).

Harrod (1965) found that 0.2 mps was the lower limit of rate of flow in which the larvae of *S. ornatum* can feed. It is suggested that this low limit of flow rate is less for some Newfoundland species of simuliids, since *P. fuscum, P. mixtum, C. mutata, S. aureum,* and *S. venustum* were all collected, apparently feeding, on at least one occasion in a current velocity below 0.2 mps (Fig. 4). It is interesting to note as well that sites A-2 and A-9 had 0.2 mps as their minimum current velocity, and creeks C and E had below 0.2 mps for their minimum current velocity (Fig. 4). These are macrocurrent measurements and it is suggested that the results of many of the studies related to distribution of larvae are somewhat obscured by the lack of microcurrent measurements.

### Temperature

Stream temperature is related to altitude, latitude, season, and to the distance from the source. Warm streams can easily be distinguished from cold streams and, as Hynes (1970b) indicated, spring-fed and shaded streams which are cool in the summer are warmer in the winter than the summer-warm streams. As topographic features affect temperature, so temperature affects the rate of development, time of emergence and blackfly species to be found in any given stream.

Blackfly field studies have shown that there is a clear relationship between altitude and occurrence of certain species. Altitude has no effect on species distribution at Pickavance Creek because there is insufficient change in altitude from the creek's source to its termination to warrant altitudinal temperature changes, and this is also related to the fact that the stream is only about 1200 m in length. The source is approximately 183.0 m and the termination of the creek at Paddy's Pond is about 137.25 m, for a drop of about 45.75 m in altitude.

Stream temperature may influence the presence of some species in certain streams in Newfoundland, but it does not appear to be the factor responsible for the absence of *S. aureum*, *S. gouldingi*, *S. tuberosum*, and *S. verecundum* from streams in the Pickavance Creek area (Table II). The 1971-72 yearly temperatures of streams A to G (Fig. 5) are not sufficiently different to explain the absence of these four species. Pickavance Creek and its six tributaries warm up at about the same speed since Pickavance Creek is large and warm, whereas the tributaries are cold, small, and shallow, and warm up quickly after leaving the source.

The temperatures of the creeks in Pickavance Creek area are not only subject to seasonal fluctuations but also daily ones. The temperature of Pickavance Creek was 13°C at 0800 hours and 19.5°C at 1300 hours. Creek D had warmed up to 19°C from 14°C during the same time period. These measurements were taken during the second week of July, 1970. This rapid increase in temperature is due to the fact that the streams are small and shallow and, in the case of Pickavance Creek, the source is also shallow and thus warms up more quickly than a larger stream and lake. Fig. 15 shows the temperatures at which larvae and pupae were collected at the Pickavance Creek area. Development appeared normal within these temperature ranges but low and high temperatures probably decreased and increased the rate of development respectively.

According to Carlsson (1967), each species also has a certain optimal temperature for pupal development but the range of possible temperatures is usually very broad. When the pupa has turned a dark color it can endure desiccation due to decreasing water levels below the point of attachment. Pupae, in dry areas exposed to the sun, usually hatch earlier than those in water exposed to sunlight. However, Carlsson indicates this occurs only if the air temperature does not exceed certain values.

In southeastern Scotland, Zahar (1951) found *S. latipes* and *S. monticola* Friederichs only above 200 m, while *S. reptans* and *S. variegatum* were found below this altitude. At the same time, he found *S. ornatum* at all altitudes.

Grenier (1949) found *S. aureum* and *S. ornatum* to have wide altitudinal distribution in France. However, both of these species are now considered species complexes and further taxonomy may show that these altitudinal tolerances may be much narrower. Hynes (1970b) indicated that if a species appears to have a wide altitudinal tolerance it may indicate that its taxonomy would perhaps bear further study. Davies and Smith (1958) found in Northern England that *P. hirtipes* was invariably present below altitudes of 450 m and rather sparse or absent altogether above this elevation. Repeated sampling showed that within the range of 180 to 450 m, the proportion of larvae tended to decrease as the upper limit was approached.

Carlsson (1967) reported that each species of *Simulium* has a certain optimal temperature for the larval and the pupal stage. For the larvae, he considered 4°C optimum for some *Prosimulium* species, 5 to 10°C optimum for some *Cnephia* species, and above 12°C for most other species. Since many workers report the absence of larvae and pupae from warm waters, it is interesting to note that Brues (1932) found large numbers of larvae attached to stones in an overflow of a hot spring in Lassen National Park at 30.6°C. He was doubtful of the species, although at first he thought it was *S. vittatum*.

Davies and Smith (1958) found that development of *P. hirtipes* larvae in England was completed before relatively high temperatures occurred with the beginning of spring. They showed that *P. hirtipes* larvae were rapidly killed by water temperatures of 16 to 18°C, and a temperature of 15°C would probably retard development, even if not proving fatal. They also suggested that the absence of *P. hirtipes* from some streams was due to the rapid warm-up of these streams and the resulting high temperatures would be unfavourable for larval development. Sommerman *et al.* (1955) also reported the absence of a species from a particular stream location during the entire season can usually be attributed to stream temperature not reaching the species requirements. They attributed spotty absences to other physical factors such as depth, current, or substratum.

Ice formation is intimately associated with temperature. Anchor ice has not been found at Pickavance Creek. Surface ice is abundant and may be present for about three months. During most of this time the whole stream is completely frozen over with as much as 30 cm of ice. Due to the small waterfall at site A-5, ice accumulation by late March built up to 0.6 m in depth, and water was found flowing beneath the ice in all areas. The ice-covering rarely leads to deoxygenation and protects the water from further cooling. In the area of A-11, the water depth was 7.5 cm and the ice was about 10 cm thick, and there were 50 cm between the upper water surface and the lower ice surface. Unlike anchor ice, surface ice does not usually come into contact with invertebrates, but Brown *et al.* (1953) found that when they freeze in it they die. No invertebrates of any kind were found in the ice at Pickavance Creek. It is quite possible that ice formation over the entire stream may have protected the larvae from environmental fluctuations such as spates and biotic factors such as predators (e.g. fish).

According to Hynes (1970b) several workers have found that anchor ice damages invertebrates. They become caught in it, and when it drifts, drift with it, but Logan (1963) found that the presence of ice does not always increase the numbers of drifting animals. Anchor ice, unlike surface ice, does not become very cold since it is immersed in water at $0^{\circ}$C. Benson (1955) found that all the specimens of a considerable number of species frozen in anchor ice collected in Michigan were alive. Gaufin (1959) found that the severe winter of 1948-49 in Utah apparently completely wiped out thousands of organisms in the

Provo River, and he attributed this to anchor ice. Hynes (1970b) indicated that damage is probably due to the scouring of the stream bottom as the ice forms and becomes detached.

The effect of surface and anchor ice on the fauna of a stream needs more investigation, but it appears that it may not be as severe as is often believed.

## Substrate

Substrate was examined for two reasons: first, to determine whether the species present in the Pickavance Creek area demonstrated a substrate preference and, second, to determine if substrate influenced the absence of *S. aureum, S. gouldingi, S. tuberosum,* and *S. verecundum* from certain streams in the same area (Table II).

Substrate is a factor which markedly influences the distribution of larvae. Larvae were collected on rocks, twigs, trailing vegetation and tiles which were introduced into the stream. Larvae were not found in the pools of the stream, possibly because the substrate in these areas consists of mud and sand. The surface of this type of substratum is too soft and unstable for larvae to attach themselves. Therefore, substrate distribution of larvae is influenced by the effects of current velocity as already indicated.

In the Pickavance Creek area, all species have been collected from tiles, vegetation, twigs, rocks, and other assorted introduced debris. Where vegetation is growing, it is inhabited by the species occurring there, and, wherever rocks and stones are found, the same species occupy this substrate. Immatures of all species may be collected more commonly on rocks, probably and logically because most of the available attachment sites are on rocks. Rocks are more stable and probably easier to attach to than vegetation.

Several tile samples were compared with rock samples to determine if in fact one substratum was preferred to another. Since tiles were introduced factors into a stream, a study was made to determine whether the tiles were selected by the larvae randomly and whether they would give an accurate estimation of density and species present. Rocks were selected in the vicinity of tiles which were estimated to have the same surface area as the tile. Monthly comparisons throughout the year were made and in all cases rocks bore the same species and approximately the same ratio as the tile populations, but the tile populations were usually greater (Table III). Tiles were apparently a better substrate.

Tiles facilitated collecting, since the entire population could be scraped off in two minutes or less with a plastic ruler without damaging any of the larvae. In addition, stoneflies and mayflies were frequently observed crawling on the tiles, caddisflies often built cases on them, and when tiles protruded slightly out of the water, caddisflies also laid eggs on the exposed portion.

To determine whether or not color influenced substrate choice by the larvae, two series of colored tiles were placed in Pickavance Creek. In the first experiment ten tiles of different colors (Table IV) were placed in a linear series on apparently uniform stream bed at intervals of 15 cm. The experiment was replicated seven

Table III

A comparison of rock and tile simuliid populations

| Date (1972) | Species | Number of larvae | |
|---|---|---|---|
| | | Tile | Rock |
| January 5 | *P. fuscum/mixtum* | 11 | 8 |
| | *C. mutata* | 1 | 0 |
| February 11 | *P. fuscum/mixtum* | 55 | 48 |
| | *C. mutata* | 15 | 12 |
| March 10 | *P. fuscum/mixtum* | 11 | 9 |
| | *C. mutata* | 1 | 2 |
| April 7 | *P. fuscum/mixtum* | 42 | 40 |
| | *C. mutata* | 1 | 0 |
| May 2 | *P. fuscum/mixtum* | 43 | 37 |
| | *C. mutata* | 1 | 0 |
| June 7 | *P. fuscum/mixtum* | 2 | 1 |
| | *S. tuberosum* | 5 | 3 |
| | *S. venustum* | 73 | 75 |
| July 12 | *S. venustum* | 4 | 3 |
| | *S. verecundum* | 2 | 2 |
| August 2 | *S. venustum* | 59 | 56 |
| | *S. verecundum* | 55 | 50 |
| | *S. latipes* | 4 | 4 |
| September 7 | *S. verecundum* | 12 | 13 |
| October 14 | *P. fuscum/mixtum* | 11 | 10 |

Table IV

Larval attachment to colored tiles placed in a linear arrangement in Pickavance Creek

| | Number of larvae | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|
| Color | Test Number* | | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| Yellow | 3 | 32 | 50 | 20 | 10 | 16 | 9 | 140 |
| Speckled yellow | 1 | 1 | 5 | 0 | 2 | 12 | 2 | 23 |
| Dark brown | 5 | 32 | 11 | 14 | 2 | 10 | 9 | 83 |
| Champagne beige | 2 | 6 | 5 | 29 | 7 | 7 | 4 | 60 |
| Rust | 19 | 62 | 42 | 4 | 3 | 5 | 72 | 207 |
| Brown | 11 | 55 | 53 | 9 | 3 | 5 | 2 | 128 |
| Dark green | 10 | 15 | 36 | 10 | 3 | 6 | 27 | 107 |
| Foam green | 10 | 3 | 13 | 0 | 0 | 0 | 53 | 79 |
| White | 17 | 25 | 52 | 17 | 24 | 7 | 12 | 154 |
| Blue | 16 | 11 | 33 | 17 | 9 | 11 | 94 | 191 |

*1-6 24 hour experiments;
7 48 hour experiment

times, the sequence of tiles randomized in each experiment according to a Table of Random Numbers. In the second experiment, sixteen colored tiles were placed randomly to form a 4 x 4 grid in a ½ inch hardware cloth tray. All tiles were in contact with each other at the edges. The results (Table V) show the order of preference: purple, black, metallic blue, dark green, white, moonglow yellow, brown, aluminum, red, gold, light green, indian red, orange, wood, and pink. Unfortunately, this experiment was carried out only once.

The results (Table IV, V) indicated that larvae were abundant on some light colors (e.g. yellow and white in Table IV, and white in Table V). They were not abundant on speckled yellow, champagne beige, and foam green in Table IV or on orange, wood, light green, or pink (Table V). In neither table is white the preferred color. One would expect light-colored tiles to be heavily populated if there is a light color preference, and expect the dark colored tiles to be heavily populated because they blend with the stream bottom. In Table V it appears that larvae either prefer dark colors (black and purple) or they colonize the first suitable substrate following active or passive drift. Nevertheless, there does not appear to be any clear cut color preference by simuliid larvae in the Pickavance Creek area.

Abdelnur (1968) found the vast majority of larvae on white plastic cones rather than yellow, brown, red, green, or blue. Several other workers who devised traps for larvae painted them white, because they found larvae to be attracted to light colors. Wolfe and Peterson (1959) found a larval preference for light colored rocks and submerged white birch logs.

Table V

Larval attachment to colored tiles placed in a 4 x 4 grid in Pickavance Creek

Colors

| | | | |
|---|---|---|---|
| Gray | Black | Purple | Metallic Blue |
| Orange | Wood | Indian Red | Pink |
| Brown | Red | Light Green | Dark Green |
| Aluminum | Moonglow Yellow | Gold | White |

Number of larvae

| | | | |
|---|---|---|---|
| 2 | 23 | 34 | 21 |
| 2 | 2 | 3 | 2 |
| 10 | 7 | 4 | 16 |
| 9 | 12 | 6 | 15 |

In any stream which has pools situated in or near it, any increase in water level leads to an increase in current velocity which stirs up the muddy substratum and deposits silt and sand downstream. This has been frequently observed during flood conditions during the course of this study in Pickavance Creek. The deposition of silt and sand may be the stimulus for larvae to migrate under flood conditions rather than just an increase in water depth and current velocity.

Filamentous algae also influence distribution of the larvae. Very few larvae and pupae were collected in Stream 116 when portions of it became almost green with algae. At the same time immatures were abundant in other parts of the stream.

Although it may seem strange to consider the close proximity of suitable habitats as a factor controlling the occurrence of aquatic invertebrates, it does nevertheless often lead to unexpected occurrences in unusual places. Moreover, quite large numbers of individuals may be involved and give the impression that the species is well established.

Hynes (1941) and Sprules (1947) have noted this proximity effect on the detailed distribution of stream insects, and it should always be considered as a possibility when a population is found which appears to be in a habitat unusual for the species.

Fredeen and Shemanchuk (1960) found that *Simulium* larval distribution was limited in some irrigation canals in the Prairies because of a lack of attachment sites.

Vegetation may be an important factor in determining the distribution and habitat of *Simulium* larvae and pupae. Vegetation is of two types: dominant streamside vegetation, and rooted aquatics. The biology of wide rivers is probably unaffected by marginal vegetation, but the fauna of streams and brooks is modified by shoreline growth in several ways, especially by provision of oviposition substrates for adult blackflies and other aquatic insects, and by providing allochthonous food material. If the stream banks have arching growths of trees or tall shrubs, the maximum water temperature during the summer is reduced by one to several degrees (Gray and Edington, 1969). The lack of streamside vegetation usually encourages erosion and turbidity. The annual leaf fall of deciduous trees and shrubs is now known to significantly affect the trophic structure and also the dissolved nutrients in small streams. According to Pennak (1971) a stream with a thick growth of submerged rooted plants will have a standing crop of invertebrate biomass which is usually in the magnitude of three to ten times that supported in a similar stream lacking rooted aquatics, because of the additional spatial and food niches provided. Some species of blackflies have been shown to prefer a substratum of vegetation and other species (e.g. *S. venustum*) usually oviposit on trailing vegetation. Obviously, plants would offer a suitable substratum and also increase the blackfly population in the area covered by the plants.

Wu (1930) carried out some field experiments with blackfly larvae. Sticks and vegetation with attached larvae were moved about in streams and it was found that larvae move away from parts of the substrate on which silt is deposited, even though current speed and other factors might be suitable for them. She observed that larvae would move to the underside of sticks and leaves as sediment accumulated on them. Blackfly larvae do not tolerate silty surfaces although they apparently are not adversely affected by silty water. While silt and sand may not affect the fauna itself, it leads to increased instability of the substrate which does affect the fauna (Cordone and Kelley, 1961; Chutter, 1969).

Simuliid larvae apparently have no substrate preference in Newfoundland, provided that the substrate is stable and suitable for attachment. It appears that larvae have no color preference but inhabit colored substrata at random. Silt and sand, and vegetation might influence the distribution of larvae but for different reasons. Silt and sand will exclude larvae from certain areas, whereas vegetation increases the number of sites suitable for attachment.

### Depth

The influence of depth on the dynamics of simuliid populations was studied for the Pickavance Creek area. Fig. 16 shows the minimum and maximum water depths at which larvae and pupae were collected.

Depth may influence distribution of immature blackflies in some areas but this has not been observed at Pickavance Creek, except in flood conditions. Prior to flood conditions certain areas of Pickavance Creek had blackfly larval populations of about 300 larvae per 100 sq. cm. At this time the water depth was 20 cm; 24 hours later, after a heavy rainfall, the depth in the same location (upstream from A-8) was 80 cm, and it was extremely difficult at this time to obtain 10 larvae per 100 sq. cm. At first it was thought that regulation of water levels might be worthy of consideration as a control method. However, three to four days after the heavy rainfall the water level returned to normal, and the simuliid population was again observed to be about 300 larvae per 100 sq. cm.

Experiments were conducted using a clamp apparatus to determine the possibility of depth preference. Four tiles were placed on a clamp stand; one near the stream bottom, one at the top of the clamp stand, and the other two equidistant between the top and the bottom. The tiles were placed so that each was either over and/or under another and were numbered 1 to 4 from top to bottom. Obviously, if larvae did not migrate, then this clamp apparatus would be experimentally useless. Figure 17a shows the results of 24 hour recruitment. The apparatus was set up on 28-V-70 and larvae were collected from the tiles 24 hours later on 29-V-70. More larvae were collected from the top tile than from the other three combined. Figure 17b demonstrates a five-day recruitment (29-V-70 to 3-VI-70) and although the population had decreased, the top tile was still preferred. Unfortunately, whether this is actually depth preference is open to question, since the water currents near these four tiles were also different (Fig. 18). There were usually more larvae on the top tile and this would also indicate the possibility of light preference, since light intensity would be greater nearer the surface than at greater depths. However, it is also interesting to note that there were more larvae on the bottom of the top two tiles than on the top of the same two tiles (Fig. 17a). Figure 17c shows that there are the same number on the top and on the bottom of the lower two tiles. This would suggest that light may not be an important factor affecting depth distribution of simuliid larvae. Therefore, this may be an indication of current preference, or possibly a combination of depth and current. An eight day recruitment showed similar results (Fig. 17c). The apparatus was set up on 29-V-72 and cleared on 7-VI-72. During this experiment the population was moderately heavy, and again the top tile had a heavier population than the other three combined.

No species preference was observed during any of these experimental studies. The nine species studied at Pickavance Creek have been collected at various depths, but this is due to seasonal fluctuation of the stream depth. During February, March, and April the Pickavance Creek system was completely frozen over for much of the time. *Prosimulium fuscum/mixtum* and *C. mutata* were frequently collected in depths of 20 cm of water under as much as 30 cm of ice and 50 cm of snow.

It is rather difficult to interpret these results. Either larvae will select the faster current at a suitable depth or will select a lower depth at a feasible current velocity. The clamp apparatus was used in the summer of 1970 as a depth indicator. The surface of the top tile was 32 cm above the stream bottom and measurements were made above and below this point. Figure 19 illustrates the water depth at this area (near Site A-3) for the summer.

All of the streams of the Pickavance Creek complex are subject to flooding, both in "spring thaws" and also in heavy rainfalls. However, only creeks E and F are normally subject to drought. These creeks are usually completely dry during July and August.

Dry periods, whether they are a normal or an exceptional occurrence, exert a considerable influence on the fauna. The fact that certain streams dry up does not mean that they are short of inhabitants. Drought often affects only part of a stream, of which the head waters continue to flow and later, when the water returns, the formerly dry portion is often recolonized from areas which remained wet. One must also recognize the significance of downstream drift and upstream movement. More interesting from an ecological view point is the fact that often, after a disaster such as an unusual drought, species which were not found there before appear in the affected area. *S. ornatum* is one opportunist species which can move rapidly into a disaster area, pass through one generation and disappear again (Hynes, 1970b). Pupae of blackflies are often found dried, attached to stones after the creeks have dried out, but larvae presumably respond to low levels of water by drifting out of low streams. When these streams flow again, usually in early September, no larvae are found until the hatching of *Prosimulium fuscum/mixtum* and *C. mutata* late in September or October.

After hatching the larvae usually migrate in various ways in search of optimum conditions, which they do not always find (Carlsson, 1967). Carlsson also reported that depth is important in the sense that most species have an optimum level near the surface, and the maximum depth range appears to be from 1 m to a few meters below the water surface. Therefore, small variations in the water level, which usually change the current speed, disturb the larvae and cause them to migrate. Blackfly larvae attached to drying substrata have been observed to loosen themselves and join the organic drift (Carlsson, 1967); pupae cannot do this.

It has often been observed that periods of high water reduce the invertebrate fauna of streams. Moffatt (1936) working in several localities in Utah, found that South Willow Creek suffered from a cloudburst on 7 August, 1934, which produced the first major flood in 50 years and completely altered the stream bed. On 20 August Moffatt could find no animals at all, but by late September, 17 specimens of *Simulium* were collected, and by 11 November, 690 specimens were collected per sq. ft. Hynes (1970b) records several examples of spates wiping out stream fauna. This reduction may not be and probably is not uniform. Allen (1951, 1959) showed how the effects of spates vary from place to place in the Horokiwi River in New Zealand. The effect may be different in different reaches and may actually lead to some increases. Minckley (1963) found that a severe flood, emanating mostly from the large spring at the head of Doe Run in Kentucky, reduced the fauna near the spring but increased it in areas further downstream, presumably by the simple process of washing animals out of their original habitat and depositing them lower downstream. Hynes (1970b) indicates that the two most important factors in spates are abrasion and fluctuation, and that a high rate of flow itself is not of great importance; temporary shelter can always be found.

Wolfe and Peterson (1959) found that during floods, larvae were washed away, except those attached at the extreme tips of grasses that rested parallel to the current direction. They also found that floods altered the distribution of larvae, and larvae were found in sections of the stream which earlier were unoccupied by blackflies.

During high water levels, larvae and pupae obviously detach from their substrate, but as Lewis (1958) observed, they probably tend to concentrate in places inaccessible to entomologists. This must be the case, otherwise the population density would not return to normal.

### Drift

Heavy rainfall, which increases the water depth and current velocity, was observed to cause simuliid larvae to migrate in Pickavance Creek. Under normal water conditions, larvae were observed to migrate mainly by night and the number of migrating larvae varied from site to site and day to day (Table VI). The fact that 599 larvae were found on one tile within 24 hours of placement indicates that the numbers of migrating larvae may be quite high.

Peterson and Wolfe (1958) found that after hatching from the egg, the first instar larva floats in the water and is carried by the current to swifter waters. A silk thread is secreted and this serves as initial attachment to the substrate. Firm attachment is accomplished by the anal hooks. The larva may then migrate to a position where the character of the current is optimal. Changing characters of the stream or other disturbances may cause the larva to release the anal hooks and the larva is then carried by the current, held only by the thread of silk by which it can migrate back to its original position. Sometimes, or frequently, they will release themselves from the thread and

Table VI

Tile recruitment indicating drift density

| Day | Number of larvae | | | | |
|---|---|---|---|---|---|
| | Site | | | | |
| | 1 | 3 | 5 | 7 | 9 |
| 1* | - | - | - | - | - |
| 2 | - | 385 | 37 | 47 | 18 |
| 9 | 4 | 599 | 91 | 124 | 106 |
| 17 | 2 | 80 | 206 | 119 | - |

*Tiles placed Day 1

reattach at a new site. Jobbins-Pomeroy (1916) found that a heavy rain causing an increase in current velocity would often entirely change the distribution of the larvae. This has been observed by Carlsson (1967) and Lewis (1958).

Yakuba (1959) found that migration results from disturbances in normal conditions of existence, such as increased turbidity and current speed which are obviously due to changes in the water level. He also found that the numbers of migrating larvae depend on the rapidity of the rise in level: the more rapid and noticeable the rise, the more larvae migrate. The greatest numbers of migrating larvae are observed at the very beginning of a rapid rise in water level. Larvae of all species present at any one time migrate and the migrational ability of larvae increases with size. Jobbins-Pomeroy (1916) believed this was of considerable economic importance since it may account for the sudden appearance of *Simulium* in localities where *Simulium* is usually not found. Migration of blackfly larvae occurs mainly by night (Elliott, 1965, 1971; Peterson and Wolfe, 1958), and Anderson (1966) found that moonlight has a depressant effect on the rate of drift. He found that there was a significantly greater drift rate on a dark night than on a moonlit night. Clifford (1972), on the other hand, found that the drift of *Simulium* larvae in an intermittent stream in Alberta occurred mainly during the day. He indicated that it was possible that the significantly larger number of simuliid larvae in the daytime drift was possibly due to the sampling procedure. Carlsson (1967) reported that the number of drifting *Simulium* larvae varies considerably from stream to stream and, in the same stream, larval drift may vary from day to day, hour to hour, and site to site.

Carlsson (1967) reported that larvae tagged with radiophosphorus were found 475 m downstream from the point of release.

Patrick (1959) found that *S. vittatum* was the first macroscopic animal to occur in a new stream. Most of the rocks in the riffle bore a few specimens. These were small larvae and probably were the result of recent hatching in the parent stream.

Investigations of downstream drift have indicated that drift is continuous; it fluctuates but never ceases. In theory, then, the upper portion of the stream must steadily become depleted but this does not occur. Müller (1954) believed that this downstream drift is half of a colonization cycle, the other half being the imagines migrating upstream to oviposit. This ensures a balance and a continuation and completion of the population. However, this does not explain why univoltine overwintering species may be found in the upper portion of a stream at any time when they normally occur in the stream. Therefore, to maintain a population in the upper portion of any stream two things are possible: the first is that not all larvae migrate and this is undoubtedly true since the drift rate has been shown to be quite variable from stream to stream, site to site, and hour to hour (Carlsson, 1967). The second is that there is active upstream migration which has not been investigated thoroughly. Elliott (1971) has shown that blackfly larvae do move upstream but more study is necessary before its ecological importance can be assessed.

## Shade and Light

Although no thorough study was made to determine whether light intensity affected the distribution of simuliid larvae, sites which were shaded (Table I) were chosen for the collection of larvae. At Pickavance Creek larvae were found in those portions of the stream that were shaded by overgrowing shrubs and trees, and also throughout the length of the culvert at Site A-9. In the middle of this culvert the author collected rocks and tiles and had to carry them out of the culvert to see whether or not larvae and pupae were present. This would indicate that larvae do not move towards light or it would indicate that they occupy this habitat as a result of downstream drift and are content to rest there for at least a short time. Consideration must also be given as to how *P. fuscum/mixtum* and *C. mutata* move towards light during the winter months when they are in darkness, under snow and ice, for as much as three months.

A few investigators have indicated that there is a definite correlation between shade and the occurrence or abundance of certain species along the lengths of variously shaded streams. Bequaert (1934), Carlsson (1967), and Smart (1944) indicated that *Simulium* larvae are positively phototropic. Grenier (1949) reported that blackfly larvae move towards light but that this tendency is subservient to their response to current. Zahar (1951) in Scotland found that larvae tend to be scarce in heavily wooded streams, except in open places. This may be due either to the larvae moving towards light or to the failure of gravid females to oviposit in shaded reaches.

## Water Chemistry

Natural waters contain a wide range of dissolved materials and their direct effects on the biota are poorly known. Generally, water accumulates progressively larger quantities of dissolved materials as it passes downstream. Ammonia, calcium, carbon dioxide, chlorides, oxygen, hardness, magnesium, nitrate, pH, phosphate, silica, and sulfide were examined in the Pickavance Creek area. The results are to be found in Table VII. There is not a sufficient difference from stream to stream to account for the presence or absence of certain species, neither is there any correlation of water chemistry with any other physical or biotic factors.

It is interesting to note that Phillipson (1956) showed that the larvae of *S. ornatum* are not affected by low oxygen concentration and that they do not show a preference for highly oxygenated streams.

## Parasites and Predators

In any community of living organisms, the usual factors of predation, parasites, and disease operate. Parasites, which included microsporida, fungi, and nematodes, were not abundant in Pickavance Creek and it is assumed that they were not very important. The species of parasites, which were identified by Ebsary (1972), and the species of blackflies in which they were found, are presented in Table VIII. Predators may have been more successful but it is difficult to determine whether a significant proportion of the population was affected. Pickavance Creek supports a population of endemic trout *Salvelinus*

## Table VII

Water chemical analyses in the Pickavance Creek area

| Creek | Ammonia (ppm) | | Calcium (ppm) | | $CO_2$ (ppm) | | Chlorides (ppm) | | $O_2$ (ppm) | | Hardness (ppm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Range | Avg. | Range | Avg. | Range | Avg. | Range | Avg. | Range | Avg. | Range | Avg. |
| A | 0-2.0 | 1.2 | 10 | 10 | 5-7.5 | 5.8 | 25-50 | 33.3 | 7.8-8.0 | 7.9 | 10-30 | 15.0 |
| B | 0-2.0 | 1.1 | 10 | 10 | 5-6.3 | 5.4 | 25-50 | 40.8 | 7.0 | 7.0 | 20-30 | 21.7 |
| C | 1.0 | 1.0 | 10 | 10 | 2.5-5.0 | 4.3 | 20-25 | 23.3 | 6.0-8.0 | 7.0 | 10-25 | 14.2 |
| D | 0-2.0 | 1.2 | 10 | 10 | 4.0-7.5 | 6.6 | 20-25 | 24.2 | 6.4-6.8 | 6.6 | 10-20 | 13.5 |
| E | 0-1.0 | 0.5 | 10 | 10 | 6.0-15.0 | 10.7 | 20-25 | 23.0 | 2.8-10.0 | 6.4 | 10-20 | 12.0 |
| F | 0-2.0 | 1.2 | 10 | 10 | 4.0-7.5 | 6.6 | 20-25 | 24.2 | 6.4-6.8 | 6.6 | 10-20 | 13.5 |
| G | 0-2.0 | 1.2 | 10 | 10 | 4.0-7.5 | 6.6 | 20-25 | 24.2 | 6.4-6.8 | 6.6 | 10-20 | 13.5 |

| Creek | Magnesium (ppm) | | Nitrate (ppm) | | pH | | Phosphate (ppm) | | Silica (ppm) | | Sulfide (ppm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Range | Avg. | Range | Avg. | Range | Avg. | Range | Avg. | Range | Avg. | Range | Avg. |
| A | 0-20 | 5.0 | 0-2 | 1 | 5.5-6.0 | 5.9 | 0-1 | 0.5 | 1-3 | 2.6 | 0-0.2 | 0.1 |
| B | 10-20 | 11.7 | 0-2 | 1 | 5.5-6.0 | 5.9 | 0-1 | 0.5 | 2-4 | 3.5 | 0-0.2 | 0.1 |
| C | 0-15 | 4.2 | 0-2 | 1 | 6.0 | 6.0 | 0-1 | 0.5 | 3-4 | 3.6 | 0-0.2 | 0.1 |
| D | 0-10 | 3.5 | 0-2 | 1 | 6.0 | 6.0 | 0-1 | 0.5 | 1-2.5 | 2.0 | 0-0.2 | 0.1 |
| E | 0-10 | 2.0 | 0-2 | 1 | 5.5-6.0 | 5.8 | 0-1 | 0.5 | 2-3 | 2.2 | 0-0.2 | 0.1 |
| F | 0-10 | 3.5 | 0-2 | 1 | 6.0 | 6.0 | 0-1 | 0.5 | 1-2.5 | 2.0 | 0-0.2 | 0.1 |
| G | 0-10 | 3.5 | 0-2 | 1 | 6.0 | 6.0 | 0-1 | 0.5 | 1-2.5 | 2.0 | 0-0.2 | 0.1 |

Table VIII

Parasites of simuliid larvae in the Pickavance Creek area

| Blackfly Species | Parasite Species |
|---|---|
| *P. fuscum/mixtum* | *Neomesomermis flumenalis* (Welch) |
| *S. latipes* | *Neomesomermis flumenalis* (Welch) |
| | *Thelohania fibrata* Strickland |
| *S. tuberosum* | *Plistophora simulii* Lutz and Splendore |
| *S. venustum* | *Neomesomermis flumenalis* (Welch) |
| | *Plistophora simulii* Lutz and Splendore |
| | *Thelohania bracteata* Strickland |
| | *Thelohania fibrata* Strickland |
| | *Thelohania* sp. |
| | *Coelomycidium simulii* Debaisieux |

*fontinalis* (Mitchell) and possibly the introduced species *Salmo trutta* L. (Bradbury, 1972). These probably feed heavily on blackfly larvae since the other fauna, namely caddisflies, chironomids, mayflies, and stoneflies do not normally occur in large numbers.

# SUMMARY DISCUSSION

Twenty-one species of simuliids are recorded from insular Newfoundland, of which eleven are thought to be ornithophilic, eight mammalophilic, one which probably does not feed in the adult stage *(C. dacotensis)*, and one which has parthenogenetic populations and may be mammalophilic *(C. mutata)*.

It is not surprising that a greater number of species recorded from Newfoundland are bird-feeders, since larger wild and domestic animals are not abundant in most regions of the island. However, only two of the eleven bird-feeders are abundant. *S. latipes* is widespread, while *P. pleurale* is apparently abundant only in western Newfoundland. The other nine species appear to be restricted to localized areas. This patchy distribution is partly due to sampling of streams prior to egg hatching and after adult emergence, but this explanation does not hold for species such as *S. gouldingi*. This species has been found only in six streams on the Avalon Peninsula, and most of the ninety-five streams on the Avalon which have been examined have been sampled several times during the period when *S. gouldingi* would normally occur in streams. This species, then, appears to be restricted to certain streams.

The mammalophilic species, except for *S. decorum* are widespread and abundant. The paucity of *S. decorum* may be due to the lack of natural and artificial water impoundments where it normally breeds. There are virtually no studies on adult simuliid feeding habits in Newfoundland, but the main source of blood is probably man, moose, and caribou. In agricultural areas, livestock may be preferred but this has not been investigated in Newfoundland.

The Newfoundland species of simuliids are morphologically similar to their counterparts on the mainland of North America. The main problem is with specimens of the *P. fuscum/mixtum* complex. The characters of these two species are apparently highly variable and more work is necessary to clearly sort out these species in Newfoundland. Smith (1972) indicated that the *Prosimulium* are in a rapid state of evolution, and it is suggested here that hybridization may occur between members of the *P. mixtum* group in Newfoundland. Rothfels (1972), on the basis of cytological rather than morphological studies, indicated that a species of *P. mixtum* affinity and compatible with the description of either *P. approximatum* Peterson or *P. saltus* Stone and Jamnback has been found in eastern Newfoundland.

The simuliid species in Newfoundland are biologically similar to these species in other North American regions. Ovarian studies of Newfoundland simuliids agree almost completely with the same species on the mainland of Canada. The one exception to this, and it may eventually be shown that it is not an exception, is *P. mixtum* which may be autogenous for the first gonotrophic cycle. Unfortunately, this is not definitely known, but if it is, it could raise problems since in the past many studies on blackflies have assumed that *P. fuscum* is autogenous and *P. mixtum* anautogenous for the first gonotrophic cycle.

Newfoundland is usually regarded as having a severe winter, and while it is often lengthy in duration, it is actually much milder than that in most of central and northern Canada. Therefore, streams and rivers do not freeze over as quickly or to as great a depth as they might in these colder regions. This would explain why the eggs of *P. fuscum/mixtum* hatch about one to two months later in Newfoundland than Alaska. On the other hand, due to the extended winter, the streams probably warm up more slowly in the spring in Newfoundland than they do in other regions. This would then explain the adult emergence occurring about a month later in Newfoundland than in Ontario. Streams in Newfoundland are not likely to freeze completely, thus the immature simuliids are not affected by this occurrence.

The slower warming of streams in Newfoundland also explains the late egg hatching of the *Simulium* species, in comparison with these species in areas such as New York and northern Ontario. Another effect of the slow warming of the streams is the asynchronous emergence of first generation adults of many species. In many regions of North America the adults of several species, for example *S. venustum*, *S. tuberosum*, *S. latipes* emerge about the same time, but in Newfoundland this may not occur. The short summer in Newfoundland also reduces the number of generations of the multivoltine species such as *S. venustum*, *S. verecundum*, *S. tuberosum*, and *S. vittatum*. These are at least bivoltine in Newfoundland, but in regions such as Ontario, they are at least trivoltine.

The common species in Newfoundland are also common in other North American regions. The notable exception to this is *S. corbis*, which is widespread and abundant in Newfoundland, but apparently rare in Ontario (Davies *et al.*, 1962) and New York State (Stone and

Jamnback, 1955).

Seasonal succession closely follows the general pattern across the continent, but the various species occur a little later in the year in Newfoundland, as already considered, and this will delay the total succession on a seasonal basis. The abundance of biting simuliids in late May and early June is influenced by the amount of freezing of the streams and the effects of the spring run-off on the overwintering larvae maturing and pupating. The spring run-off also affects the summer species since eggs and early hatching larvae may be displaced from the stream proper and when the water level recedes, these stages can be destroyed. Flooding during the summer will affect simuliid immatures in the same manner, while drought also influences the abundance of blackflies in a different way. Parasites and predators are probably acting through the year and probably are subject to the same environmental fluctuations as are simuliids. In the Pickavance Creek area, parasites were few and their effects upon the larval population were apparently negligible.

Sampling of the immature stages of simuliids was accomplished using 10 x 10 x 0.8 cm ceramic tiles. These were inexpensive, had a uniform surface, easily placed on the stream bottom, heavy enough to remain there except in extreme flood conditions, and were apparently preferred as a substratum over rocks by larvae. Tiles are capable of withstanding environmental fluctuations, such as water level, more so than other artificial substrata such as cone traps.

All species of simuliids in the Pickavance Creek area were shown to have wide tolerances of current velocity, temperature, and depth. Current affects the distribution of larvae, probably because of its action upon the substratum rather than the slow current flow. Immatures were not found in low current velocities because in these areas the substrate usually consisted of sand, silt, and mud, which are unstable for larval attachment. Overwintering larvae had low temperature requirements, while overwintering eggs had high temperature requirements for the larval stage. Ice was not shown to adversely affect the abundance of simuliid larvae.

Experiments with the clamp apparatus indicated that larvae either prefer shallow water with a rapid rate of flow or a rapid rate of flow in shallow water. Light, shade, water chemistry, and other physical parameters already mentioned, were apparently not responsible for the absence of *S. aureum, S. gouldingi, S. tuberosum,* and *S. verecundum* from streams in the Pickavance Creek area. *S. aureum* was absent from creek E because this creek was dry during the normal developmental period for that species, but Pickavance Creek was flowing and this species did not occur in it. *S. gouldingi* was absent from creek B and also Pickavance Creek; both streams are permanent. *S. tuberosum* and *S. verecundum* were absent from creek E, again probably due to drought of this stream when these species would normally inhabit it. Therefore, an explanation for the absence of *S. aureum* from Pickavance Creek, and the asbence of *S. gouldingi* from Pickavance Creek and creek B is lacking. These species may prefer small shallow streams which would exclude them from Pickavance Creek, but it does not explain the absence of *S. gouldingi* from creek B. Therefore some factor, as yet unknown, influences this puzzling species occurrence in the

Pickavance Creek area, and it is suggested that it may be due to oviposition behaviour and instinct of gravid females.

In conclusion, the simuliids of Newfoundland are generally similar to the same species of simuliids in other regions of North America. The fact that Newfoundland is an island does not grossly affect the life cycles, habits, or abundance of blackflies.

## REFERENCES CITED

Abdelnur, O. M. 1968. The biology of some black flies (Diptera: Simuliidae) of Alberta. Quaest. Entomol., 4: 113-174.

Aigner-Abafi, L. V. 1903. Die Kolumbácser Fliege. Allgm. Zeitschr. Entom., 8: 93-96. (Reference from Puri, 1925a).

Allen, K. R. 1951. The Horokiwi Stream. A study of a trout population. Fish. Bull. N.Z., 10: 231 pp.

Allen, K. R. 1959. The distribution of stream bottom faunas. Proc. N.Z. Ecol. Soc., 6: 5-8

Anderson, J. R. and G. R. DeFoliart. 1961. Feeding behaviour and host preferences of some black flies (Diptera: Simuliidae) in Wisconsin. Ann. Entomol. Soc. Amer., 54: 716-729.

Anderson, J. R. and R. J. Dicke. 1960. Ecology of the immature stages of some Wisconsin blackflies (Simuliidae: Diptera). Ann. Entomol. Soc. Amer., 53: 386-404.

Anderson, J. R. and G. H. Voskuil. 1963. A reduction in milk production caused by the feeding of blackflies (Diptera: Simuliidae) on dairy cattle in California, with notes on the feeding activity on other animals. Mosq. News, 23: 126-131.

Anderson, N. H. 1966. Depressant effect of moonlight on activity of aquatic insects. Nature, 209: 319-320.

Anderson, R. C. 1956. The life cycle and seasonal transmission of *Ornithofilaria fallisensis* Anderson, a parasite of domestic and wild ducks. Can. J. Zool., 34: 485-525.

Arnason, A. P., A. W. A. Brown, F. J. H. Fredeen, W. W. Hopewell and J. G. Rempel. 1949. Experiments in the control of *Simulium arcticum* Malloch by means of DDT in the Saskatchewan River. Sci. Agric., 29: 527-537.

Baker, J. R. 1970. Transmission of *Leucocytozoon sakharoffi* in England by *Simulium angustitarse*. Parasitology, 60: 417-423.

Barnley, G. R. 1952. The Mbwa fly and problems of its control. Uganda J., 16: 113-120.

Barreto, P., H. Trapido and V. H. Lee. 1970. Onchocerciasis in Colombia. Entomologic findings in the first observed focus. Amer. J. Trop. Med. Hyg., 19: 837-841.

Barrow, J. H. Jr., N. Kelker and H. Miller. 1968. The transmission of *Leucocytozoon simondi* to birds by *Simulium rugglesi* in northern Michigan. Amer. Midl. Nat., 79: 197-204.

Basrur, P. K. 1962. The salivary gland chromosomes of seven species of *Prosimulium* (Diptera: Simuliidae) from Alaska and British Columbia. Can. J. Zool., 40: 1019-1033.

Basrur, V. R. and K. H. Rothfels. 1959. Triploidy in natural populations of the black fly *Cnephia mutata* (Malloch). Can. J. Zool., 37: 571-589.

Bengston, S.-A. and S. Ulfstrand. 1971. Food resources and breeding frequency of the harlequin duck *Histrionicus histrionicus* in Iceland. Oikos, 22: 235-239.

Bennett, G. F. 1960. On some ornithophilic blood-sucking Diptera in Algonquin Park, Ontario, Canada. Can. J. Zool., 38: 377-389.

Bennett, G. F. 1970. Development of trypanosomes of the *T. avium* complex in the invertebrate host. Can. J. Zool., 48: 945-957.

Bennett, G. F. and A. M. Fallis. 1960. Blood parasites of birds in Algonquin Park, Canada, and a discussion of their transmission. Can. J. Zool., 38: 261-273.

Bennett, G. F., A. M. Fallis and A. G. Campbell. 1972. The response of *Simulium (Eusimulium) euryadminiculum* Davies (Diptera: Simuliidae) to some olfactory and visual stimuli. Can. J. Zool., 50: 793-800.

Benson, N. G. 1955. Observations on anchor ice in a Michigan trout stream. Ecology, 36: 529-530.

Bequaert, J. C. 1934. Notes on the black flies of Simuliidae with special reference to those of the *Onchocerca* region of Guatemala. In Onchocerciasis with special reference to the Central American form of the disease. Harvard Univ. Dept. Trop. Med. Contrib., 6: 187-194.

Bequaert, J. C. 1945. Dr. Luis Vargas on American black-flies - a review, with critical notes (Diptera). Bull. Brooklyn Entomol. Soc., 40: 111-115.

Berner, L. 1954. Phoretic association between a species of *Simulium* and a mayfly nymph, with a description of the nymph. Ann. Mag. Nat. Hist., 7: 116-121.

Bradbury, W. C. 1972. Experiments and observations on the near-host orientation and landing behavior of Simuliidae (Diptera). M.Sc. Thesis. Memorial University of Newfoundland.

Bradley, G. H. 1935. Notes on the southern buffalo gnat, *Eusimulium pecuarum* (Riley) (Diptera: Simuliidae). Proc. Entomol. Soc. Wash., 37: 60-64.

Bradt, S. 1932. Notes on Puerto Rican black flies. Puerto Rico J. Publ. Hlth. Trop. Med., 8: 69-81.

Britten, H. 1915. A note on the oviposition of *Simulium maculatum* Mg. Entomol. Mon. Mag., 51: 170-171.

Brown, A. W. A., R. P. Thompson, C. R. Twinn and L. K. Cutkomp. 1951. Control of adult mosquitoes and black flies by DDT sprays applied from aircraft. Mosq. News, 11: 75-84.

Brown, C. J. D., W. D. Clothier, and W. Alvord. 1953. Observations on ice conditions and bottom organisms in the West Gallatin River, Montana. Proc. Mont. Acad. Sci., 13: 21-27.

Brues, C. T. 1932. Further studies on the fauna of North American hot springs. Proc. Amer. Acad. Arts Sci., 67: 185-303.

Burton, G. J. 1966. Observations on cocoon formation, the pupal stage, and emergence of the adult of *Simulium damnosum* Theobald in Ghana. Ann. Trop. Med. Parasitol., 60: 48-56.

Burton, G. J. 1971a. Attachment of first instar *Simulium damnosum* (Diptera: Simuliidae) larvae to older larvae. Mosq. News, 31: 443.

Burton, G. J. 1971b. Cannibalism among *Simulium damnosum* (Simuliidae) larvae. Mosq. News, 31: 602-603.

Burton, G. J. and T. M. McRae. 1965. Dam-spillway breeding of *Simulium damnosum* Theobald in northern Ghana. Ann. Trop. Med. Parasitol., 59: 405-412.

Burton, G. J., G. K. Noamesi, V. H. Zeve, and T. M. McCrae. 1964. Quantitative studies on the mortality of *Simulium damnosum* larvae following dosing with DDT under field conditions. I. Mortality within the first three hours. Ghana Med. J., 3: 93-97.

Cameron, A. E. 1922. Morphology and biology of a Canadian cattle-infesting black-fly, *Simulium simile* Mall. (Diptera, Simuliidae). Can. Dept. Agric. Bull., 5 (N.S.): 1-20.

Carlsson, G. 1962. Studies on Scandinavian blackflies (fam. Simuliidae Latr.). Opusc. Entomol., Suppl., 21: 279 pp.

Carlsson, G. 1967. Environmental factors influencing blackfly populations. Bull. W.H.O., 37: 139-150.

Chance, M. M. 1970a. The functional morphology of the mouthparts of blackfly larvae (Diptera: Simuliidae). Quaest. Entomol., 6: 245-284.

Chance, M. M. 1970b. A review of chemical control methods for blackfly larvae (Diptera: Simuliidae). Quaest. Entomol., 6: 287-292.

Chutter, F. M. 1968. On the ecology of the fauna of stones in the current in a South African river supporting a very large *Simulium* (Diptera) population. J. Appl. Ecol., 5: 531-561.

Chutter, F. M. 1969. The effects of silt and sand on the invertebrate fauna of streams and rivers. Hydrobiologia, 34: 57-76.

Chutter, F. M. 1970. A preliminary study of factors influencing the number of oocytes present in newly emerged blackflies (Diptera: Simuliidae) in Ontario. Can. J. Zool., 48: 1389-1400.

Clifford, H. F. 1972. Drift of invertebrates in an intermittent stream draining marshy terrain of west-central Alberta. Can. J. Zool., 50: 985-991.

Conradi, A. F. 1905. Black-fly studies. U.S. Dept. Agric., Bur. Entomol. Bull., 52: 100-101.

Coombs, R. F. 1972. Personal communication.

Coquillett, D. W. 1898. The buffalo-gnats, or black-flies, of the United States. U.S. Dept. Agric., Div. Entomol. Bull., 10 (N.S.): 66-69.

Corbet, P. S. 1962. A new species of *Afronurus* (Ephemeroptera) from Tanganyika and records of *Simulium* associated with *Afronurus* larvae. Ann. Mag. Nat. Hist., 4: 573-576.

Cordone, A. J. and D. W. Kelley. 1961. The influence of inorganic sediment on the aquatic life of streams. Calif. Fish and Game, 47: 189-228.

Coscaron, S. and P. Wygodzinsky. 1972. Taxonomy and distribution of the blackfly subgenus *Simulium (Pternaspatha)* Enderlein (Simuliidae, Diptera, Insecta). Bull. Am. Mus. Nat. Hist., 147: 199-240.

Craig, D. A. 1969. The embryogenesis of the larval head of *Simulium venustum* Say (Diptera: Nematocera). Can. J. Zool., 47: 495-503.

Crisp, G. 1956. *Simulium* and onchocerciasis in the Northern Territories of the Gold Coast. H. K. Lewis. London. 171 pp.

Crosskey, R. W. 1960. A taxonomic study of the larvae of West African Simuliidae (Diptera: Nematocera) with comments on the morphology of the larval blackfly head. Bull. Br. Mus. (Nat. Hist.) Entomol., 10: 1-74.

Crosskey, R. W. 1965. The identification of African Simuliidae (Diptera) living in phoresis with nymphal Ephemeroptera, with special reference to *Simulium berneri* Freeman. Proc. R. Entomol. Soc. Lond. Ser. A Gen. Entomol., 40: 118-124.

Crosskey, R. W. 1967. A preliminary revision of the black-flies (Diptera: Simuliidae) of the Middle East. Trans. R. Entomol. Soc. Lond., 119: 1-45.

Curtis, L. C. 1968. A method for accurate counting of blackfly larvae (Diptera: Simuliidae). Mosq. News, 28: 238-239.

Dalmat, H. T. 1954. Ecology of simuliid vectors of onchocerciasis in Guatemala. Amer. Midl. Nat., 52: 175-196.

Dalmat, H. T. 1955. The black flies (Diptera, Simuliidae) of Guatemala and their role as vectors of onchocerciasis. Smithson. Misc. Collect., 125: 425 pp.

Davies, D. M. 1949. The ecology and life history of blackflies (Simuliidae, Diptera) in Ontario with a description of a new species. Ph.D. Thesis. University of Toronto.

Davies, D. M. 1950. A study of the black fly population of a stream in Algonquin Park, Ontario. Trans. R. Can. Inst., 28: 121-159.

Davies, D. M. 1951. Some observations of the number of black flies (Diptera: Simuliidae) landing on colored cloths. Can. J. Zool., 29: 65-70.

Davies, D. M. 1952. The population and activity of adult female black flies in the vicinity of a stream in Algonquin Park, Ontario. Can. J. Zool., 30: 287-321.

Davies, D. M. 1971. Personal communication.

Davies, D. M. and B. V. Peterson. 1956. Observations on the mating, feeding, ovarian development, and oviposition of adult black flies (Simuliidae, Diptera). Can. J. Zool., 34: 615-655.

Davies, D. M., B. V. Peterson and D. M. Wood. 1962. The black flies (Diptera: Simuliidae) of Ontario. Part I. Adult identification and distribution with descriptions of six new species. Proc. Entomol. Soc. Ont., 92: 70-154.

Davies, D. M. and P. D. Syme. 1958. Three new Ontario black flies of the genus *Prosimulium* (Diptera: Simuliidae) Part II. Ecological observations and experiments. Can. Entomol., 90: 744-759.

Davies, L. 1954. Observations on *Prosimulium ursinum* Edw. at Holandfjord, Norway. Oikos, 5: 94-98.

Davies, L. 1955. Behaviour of young and old females of the black-fly, *Simulium ornatum* Mg. Nature, 176: 979-980.

Davies, L. 1957a. A new *Prosimulium* from Britain, and a re-examination of *P. hirtipes* Fries from the Holarctic region (Diptera: Simuliidae). Proc. R. Entomol. Soc. Lond. Ser. B Taxon., 26: 1-10.

Davies, L. 1957b. A study of the blackfly, *Simulium ornatum* Mg. (Diptera) with particular reference to its activity on grazing cattle. Bull. Entomol. Res., 48: 407-424.

Davies, L. 1960. The first-instar larva of a species of *Prosimulium* (Diptera: Simuliidae). Can. Entomol., 92: 81-84.

Davies, L. 1961. Ecology of two *Prosimulium* species (Diptera) with reference to their ovarian cycles. Can. Entomol., 93: 1113-1140.

Davies, L. 1963. Seasonal and diurnal changes in the age-composition of adult *Simulium venustum* Say (Diptera) population near Ottawa. Can. Entomol., 95: 654-667.

Davies, L. 1966. The taxonomy of British black-flies (Diptera: Simuliidae). Trans. R. Entomol. Soc. Lond., 118: 413-511.

Davies, L. 1968. A key to the British species of Simuliidae (Diptera) in the larval, pupal and adult stages. Freshwater Biol. Assoc. Sci. Publ., 24: 126 pp.

Davies, L. and C. D. Smith. 1958. The distribution and growth of *Prosimulium* larvae (Diptera: Simuliidae) in hill streams in northern England. J. Anim. Ecol., 27: 335-348.

Davies, L. and C. B. Williams. 1962. Studies on blackflies (Diptera: Simuliidae) taken in a light trap in Scotland. I. Seasonal distribution, sex ratio and internal condition of catches. Trans. R. Entomol. Soc. Lond., 114: 1-20.

Davis, C. C. 1971. A study of the hatching process in aquatic invertebrates. XXV. Hatching in the blackfly, *Simulium* (probably *venustum*) (Diptera, Simuliidae). Can. J. Zool., 49: 333-336.

DeFoliart, G. R. 1951a. The life histories, identification and control of black-flies (Diptera: Simuliidae) in the Adirondack Mountains. Ph.D. Thesis. Cornell University.

DeFoliart, G. R. 1951b. A comparison of several repellants against blackflies. J. Econ. Entomol., 44: 265.

Depner, K. R. 1971. The distribution of black flies (Diptera: Simuliidae) of the mainstream of the Crowsnest-Oldman River system of southern Alberta. Can. Entomol., 103: 1147-1151.

Dimond, J.B. and W. G. Hart. 1953. Notes on the blackflies (Simuliidae) of Rhode Island. Mosq. News, 13: 238-242.

Disney, R. H. L. 1969a. Phoretic association between Simuliid blackflies and a prawn. Trans. R. Soc. Trop. Med. Hyg., 63: 292.

Disney, R. H. L. 1969b. The timing of adult eclosion in blackflies (Dipt., Simuliidae) in West Cameroon. Bull. Entomol. Res., 59: 485-503.

Disney, R. H. L. 1970. The timing of the first blood meal in *Simulium damnosum* Theobald. Ann. Trop. Med. Parasitol., 64: 123-128.

Disney, R. H. L. 1971a. *Simulium berneri* Freeman (Diptera: Simuliidae) and its mayfly host (Ephemeroptera: Oligoneuridae). J. Entomol. Ser. A Gen. Entomol., 46: 39-51.

Disney, R. H. L. 1971b. Two phoretic black-flies (Diptera: Simuliidae) and their associated mayfly host (Ephemeroptera: Heptageniidae) in Cameroon. J. Entomol. Ser. A Gen. Entomol., 46: 53-61.

Disney, R. H. L. 1971c. Associations between blackflies (Simuliidae) and prawns (Atyidae), with a discussion of the phoretic habit in Simuliids. J. Anim. Ecol., 40: 83-92.

Disney, R. H. L. 1971d. Notes on *Simulium ovazzae* Grenier and Mouchet (Diptera: Simuliidae) and river crabs (Malacostraca: Potamidae) and their association. J. Nat. Hist., 5: 677-689.

Disney, R. H. L. 1972. Observations on sampling pre-imaginal populations of blackflies (Dipt., Simuliidae) in West Cameroon. Bull. Entomol. Res., 61: 485-503.

Doby, J.-M., F. David, and B. Rault. 1959. L'élevage, en laboratoire, de l'oeuf a l'adulte, de *Simulium ornatum* Meigen, 1818, *S. aureum* Fries, 1824, *S. erythrocephalum* de Geer, 1776, *S. decorum* Walker, 1848, (Diptères Nématocères Simuliidés). Observations biologiques concernant ces espèces. Ann. Parasitol. Hum. Comp., 34: 676-693.

Doby, J.-M., B. Rault, and F. Beaucournu-Saguez. 1967. Utilisation de rubans de plastique pour la récolte des oeufs et des stades larvaires et nymphaux de Simulies (Diptères Paranématocères) et pour l'étude biologique de ceux-ci. Ann. Parasitol. Hum. Comp., 42: 651-657.

Dorier, A. 1945. Sur la capsule céphalique des larves de Simulies (Dipt., Nématocères). Bull. Soc. Entomol. Fr., 50: 108-109.

Downe, A. E. R. and P. E. Morrison. 1957. Identification of blood meals of blackflies (Diptera: Simuliidae) attacking farm animals. Mosq. News, 17: 37-40.

Downes, J. A. 1965. Adaptations of insects in the Arctic. Ann. Rev. Entomol., 10: 257-274.

Downes, J. A. 1969. The swarming and mating flight of Diptera. Ann. Rev. Entomol., 14: 271-298.

Downes, J. A. 1970. The ecology of blood-sucking Diptera: An evolutionary perspective. In Symposium on ecology and physiology of parasites. University of Toronto Press. Toronto. pp. 232-258.

Downes, J. A., A. E. R. Downe and L. Davies. 1962. Some aspects of the behaviour and physiology of biting flies that influence their role as vectors. Proc. XIth Int. Congr. Entomol., 3: 119-121.

Duke, B. O. L., P. J. Moore and J. Anderson. 1972. Studies on factors influencing the transmission of onchocerciasis. VII. A comparison of the *Onchocerca volvulus* transmission potentials of *Simulium damnosum* populations in four Cameroon rain-forest villages and the pattern of onchocerciasis associated therewith. Ann. Trop. Med. Parasitol., 66: 219-234.

Dunbar, R. W. 1958. The salivary gland chromosomes of two sibling species of black flies included in *Eusimulium aureum* Fries. Can. J. Zool., 36: 23-44.

Dunbar, R. W. 1959. The salivary gland chromosomes of seven forms of black flies included in *Eusimulium aureum* Fries. Can. J. Zool., 37: 495-525.

Dunbar, R. W. 1966a. Cytotaxonomic studies in black flies (Diptera: Simuliidae). In Proceedings of the first Oxford Chromosome Conference on chromosomes today, 28-31 July, 1964, Oxford, England. Plenum Press. New York. pp. 179-181.

Dunbar, R. W. 1966b. Four sibling species included in *Simulium damnosum* Theobald (Diptera: Simuliidae) from Uganda. Nature, 209: 597-599.

Dunbar, R. W. 1967. The salivary gland chromosomes of six closely related black flies near *Eusimulium congareenarum* (Diptera: Simuliidae). Can. J. Zool., 45: 377-396.

Dunbar, R. W. 1969. Nine ecological segregates in the *Simulium damnosum* complex (Diptera: Simuliidae). Bull. W.H.O., 40: 974-979.

Dyar, H. G. and R. C. Shannon. 1927. The North American two-winged flies of the family Simuliidae. Proc. U.S. Natl. Mus., 69: 1-54.

Ebsary, B. A. 1972. Personal communication.

Edwards, F. W. 1915. On the British species of *Simulium*. -I. The adults. Bull. Entomol. Res., 6: 23-42.

Edwards, F. W. 1920. On the British species of *Simulium*. -II. The early stages; with corrections and additions to Part I. Bull. Entomol. Res., 11: 211-246.

Edwards, F. W. 1928. *Simulium* larvae and pupae found on a crab. Entomologist, 61: 42.

Edwards, F. W. 1934. Deutsch Limnologische Sunda-Expedition. The Simuliidae (Diptera) of Java and Sumatra. Arch. Hydrobiol. Suppl., 13: 92-138.

Eichler, D. A. 1971. Studies on *Onchocerca gutturosa* (Neumann, 1910) and its development in *Simulium ornatum* (Meigen, 1818). II. Behaviour of *S. ornatum* in relation to the transmission of *O. gutturosa*. J. Helminthol., 45: 259-270.

Elliott, J. M. 1965. Invertebrate drift in a mountain stream in Norway. Nor. Entomol. Tidsskr., 13: 97-99.

Elliott, J. M. 1971. Upstream movements of benthic invertebrates in a lake district stream. J. Anim. Ecol., 40: 235-252.

Emery, W. T. 1913. Morphology and biology of *Simulium vittatum* and its distribution in Kansas. Kans. Univ. Sci. Bull., 8: 323-362.

Fallis, A. M. 1964. Feeding and related behavior of female Simuliidae (Diptera). Exp. Parasitol., 15: 439-470.

Fallis, A. M. and G. F. Bennett. 1958. Transmission of *Leucocytozoon bonasae* Clarke to ruffled grouse (*Bonasa umbellus* L.) by the blackflies *Simulium latipes* Mg. and *Simulium aureum* Fries. Can. J. Zool., 36: 533-539.

Fallis, A. M., R. C. Anderson and G. F. Bennett. 1956. Further observations on the transmission and development of *Leucocytozoon simondi*. Can. J. Zool., 34: 389-404.

Fallis, A. M. and G. F. Bennett. 1962. Observations on the sporogony of *Leucocytozoon mirandae, L. bonase,* and *L. fringillinarum* (Sporozoa: Leucocytozoidae). Can. J. Zool., 40: 395-400.

Fallis, A. M. and S. M. Smith. 1964. Ether extracts from birds and $CO_2$ as attractants for some ornithophilic simuliids. Can. J. Zoöl., 42: 723-730.

Fallis, A. M. and S. M. Smith. 1965. Attractions of some simuliids to ether extracts from birds and to carbon dioxide. Proc. XIIth Int. Congr. Entomol., p. 795.

Field, G. 1961. A possible explanation of the chemical control of Simuliid larvae. J. Econ. Entomol., 54: 607-608.

Field, G., R. J. Duplessis and A. P. Breton. 1967. Progress report on laboratory rearing of black flies (Diptera: Simuliidae). J. Med. Entomol., 4: 304-305.

Forbes, S. A. 1912. On black-flies and buffalo-gnats (*Simulium*) as possible carriers of pellagra in Illinois. 27th Rept. State Entomol. Ill., 21-55.

Fredeen, F. J. H. 1958. Black flies (Diptera: Simuliidae) of the agricultural areas of Manitoba, Saskatchewan, and Alberta. Proc. Xth Int. Congr. Entomol., 3: 819-823.

Fredeen, F. J. H. 1959a. Rearing black flies in the laboratory (Diptera: Simuliidae). Can. Entomol., 91: 73-83.

Fredeen, F. J. H. 1959b. Collection, extraction, sterilization and low-temperature storage of black-fly eggs (Diptera: Simuliidae). Can. Entomol., 91: 450-453.

Fredeen, F. J. H. 1960. Bacteria as a source of food for black-fly larvae. Nature, 187: 963.

Fredeen, F. J. H. 1961. A trap for studying the attacking behaviour of black flies, *Simulium arcticum* Mall. Can. Entomol., 93: 73-78.

Fredeen, F. J. H. 1964a. On the determination of the approximate age of a black fly (Diptera: Simuliidae) and its significance. Can. Entomol., 96: 109.

Fredeen, F. J. H. 1964b. Bacteria as food for blackfly larvae (Diptera: Simuliidae) in laboratory cultures and in natural streams. Can. J. Zool., 42: 527-548.

Fredeen, F. J. H., A. P. Arnason, and B. Berck. 1953. Adsorption of DDT on suspended solids in river water and its role in blackfly control. Nature, 171: 700.

Fredeen, F. J. H., J. G. Rempel, and A. P. Arnason. 1951. Egg-laying habits, overwintering stages, and life-cycle of *Simulium arcticum* Mall. (Diptera: Simuliidae). Can. Entomol., 83: 73-76.

Fredeen, F. J. H., and J. A. Shemanchuk. 1960. Black flies (Diptera: Simuliidae) of irrigation systems in Saskatchewan and Alberta. Can. J. Zool., 38: 723-735.

Freeman, P. 1950. The external genitalia of male Simuliidae. Ann. Trop. Med. Parasitol., 44: 146-152.

Freeman, P. 1954. A new African species of *Simulium* (Diptera, Simuliidae) in phoretic association with mayfly nymphs. Ann. Mag. Nat. Hist., Ser. 12, 7: 113-115.

Frohne, W. C. and D. A. Sleeper. 1951. Reconnaissance of mosquitoes, punkies, and blackflies in southeast Alaska. Mosq. News, 11: 209-213.

Frost, S. 1970. Microsporidia (Protozoa: Microsporidia) in Newfoundland blackfly larvae (Diptera: Simuliidae). Can. J. Zool., 48: 890-891.

Frost, S. and J.-F. Manier. 1971. Notes on Trichomycetes (Harpellales: Harpellaceae and Genistellaceae) in larval blackflies (Diptera: Simuliidae) from Newfoundland. Can. J. Zool., 49: 776-778.

Frost, S. and R. A. Nolan. 1972. The occurrence and morphology of *Caudospora* spp. (Protozoa: Microsporida) in Newfoundland and Labrador blackfly larvae (Diptera: Simuliidae). Can. J. Zool., 50: 1363-1366.

Frost, S. W. 1949. The Simuliidae of Pennsylvania (Dipt.). Entomol. News, 60: 129-131.

Gambrell, F. L. 1933. The embryology of the blackfly, *Simulium pictipes* Hagen. Ann. Entomol. Soc. Amer., 26: 641-659.

Gaufin, A. R. 1959. Production of bottom fauna in the Provo River, Utah. Iowa St. Coll. J. Sci., 33: 395-419.

Germain, M. and P. Grenier. 1967. Observations biologiques et écologiques sur l'association de *Simulium berneri kumboense* Grenier, Germain et Mouchet, 1965, avec *Elassoneuria* sp. (Ephemeroptera, Oligoneuridae). Cah. O.R.S.T.O.M. (Off. Rech. Sci. Tech. Outre-Mer) Sér. Entomol. Méd., 5: 71-92.

Germain, M., P. Grenier and J. Mouchet. 1966. Une simulie nouvelle du Cameroun occidental: *Simulium rickenbachi* n.sp. (Diptera, Simuliidae) associée a des larves d'éphémères (*Afronurus*). Bull. Soc. Pathol. Exot., 59: 133-144.

Gibbins, E. G. 1938. The mouthparts of the female in *Simulium damnosum* Theobald, with special reference to the transmission of *Onchocerca volvulus* Leuckart. Ann. Trop. Med. Parasitol., 32: 9-20.

Gill, G. D. and L. S. West. 1955. Notes on the ecology of certain species of Simuliidae in the upper peninsula of Michigan. Pap. Mich. Acad. Sci. Arts Lett., 40: 119-124.

Gray, J. R. A. and J. M. Edington. 1969. Effect of woodland clearance on stream temperature. J. Fish. Res. Board Can., 26: 399-403.

Grenier, P. 1949. Contribution à l'étude biologique des Simuliides de France. Physiol. Comp. Oecol., 1: 165-330.

Grenier, P. 1953. Simuliidae de France et d'Afrique de Nord. (Systematique, biologie, importance medicale). Encycl. Entomol. Sér. A, 29: 7-170.

Grenier, P. and L. Feraud. 1960. Étude biométrique et morphologique de la croissance larvaire chez *Simulium damnosum* Theobald. Bull. Soc. Pathol. Exot., 53: 563-581.

Grenier, P., M. Germain and J. Mouchet. 1965. Observations morphologiques et biologiques sur les stade pré-imaginaux d'une Simulie (*S. berneri kumboense* n.ssp.) associée aux larves d'*Elassoneuria* (Ephemeroptera: Oligoneuridae). Bull. Soc. Pathol. Exot., 58: 276-291.

Gross, H. P., W. F. Baldwin and A. S. West. 1972. Introductory studies on the use of radiation in the control of black flies (Diptera: Simuliidae). Can. Entomol., 104: 1217-1222.

Halgoš, J. and L. Jedlička. 1971. The blackflies (Diptera, Simuliidae) attacking horses in the environs of Bratislava. Biológia (Bratisl.), 26: 431-433.

Hall, R. E. and J. J. Harrod. 1963. A method of rearing *Simulium ornatum* var. *nitidifrons* (Diptera, Simuliidae) in the laboratory. Hydrobiologia, 22: 197-201.

Harrison, A. D. 1966. Recolonisation of a Rhodesian stream after drought. Arch. Hydrobiol., 62: 405-421.

Harrod, J. J. 1964. The instars of *Simulium ornatum* var. *nitidifrons* Edwards (Dipt., Simuliidae). Entomol. Mon. Mag., 25: 34-35.

Harrod, J. J. 1965. Effect of current speed on the cephalic fans of the larva of *Simulium ornatum* var. *nitidifrons* Edwards (Diptera: Simuliidae). Hydrobiologia, 26: 8-12.

Hartley, C. F. 1955. Rearing Simuliids in the laboratory from eggs to adults. Proc. Helminthol. Soc., 22: 93-95.

Hearle, E. 1932. The blackflies of British Columbia (Simuliidae, Diptera). Proc. Ent. Soc. Br. Columbia, 29: 5-19.

Hinton, H. E. 1958. The pupa of the fly *Simulium* feeds and spins its own cocoon. Entomol. Mon. Mag., 94: 14-16.

Hinton, H. E. 1959. The function of chromatocytes in the Simuliidae, with notes on their behaviour at the pupal-adult moult. Quart. J. Microsc. Sci., 100: 65-71.

Hinton, H. E. 1964. The respiratory efficiency of the spiracular gill of *Simulium*. J. Insect Physiol., 10: 73-80.

Hocking, B. and L. R. Pickering. 1954. Observations on the bionomics of some northern species of Simuliidae (Diptera). Can. J. Zool., 32: 99-119.

Hocking, B. and W. R. Richards. 1952. Biology and control of Labrador black flies (Diptera: Simuliidae). Bull. Entomol. Res., 43: 237-257.

Holbrook, F. R. 1967. The black flies (Diptera: Simuliidae) of western Massachusetts. Ph.D. Thesis. University of Massachusetts.

Hora, S. L. 1927. The mechanism of the so-called 'posterior sucker' of a *Simulium* larva. Nature, 119: 599-600.

Hora, S. L. 1928. Animal life in torrential streams. J. Bombay Nat. Hist. Soc., 32: 111-126.

Horvarth. 1884. (Reference from Meinert, 1886).

Hungerford, H. B. 1913. Anatomy of *Simulium vittatum*. Kans. Univ. Sci. Bull., 8: 365-382.

Hynes, H. B. N. 1941. The taxonomy and ecology of the nymphs of British Plecoptera, with notes on the adults and eggs. Trans. R. Entomol. Soc. Lond., 91: 459-557.

Hynes, H. B. N. 1970a. The ecology of stream insects. Ann. Rev. Entomol., 15: 25-42.

Hynes, H. B. N. 1970b. The ecology of running waters. University of Toronto Press. Toronto.

Jamnback, H. 1952. The importance of correct timing of larval treatments to control specific blackflies (Simuliidae). Mosq. News, 12: 77-78.

Jamnback, H. 1956. An illustrated key to the blackfly larvae commonly collected in New York State. N.Y. State Sci. Serv., Univ. State N.Y. (Rept. of Investigations). 10 pp.

Jamnback, H. 1969. Bloodsucking flies and other outdoor nuisance arthropods of New York State. N.Y. State Mus. Sci. Serv. Mem. 19: 90 pp.

Jamnback, H. 1970. *Caudospora* and *Weiseria*, two genera of Microsporidia parasitic in blackflies. J. Invertebr. Pathol., 16: 3-13.

Jamnback, H. and H. S. Eabry. 1962. Effects of DDT, as used in blackfly larval control, on stream arthropods. J. Econ. Entomol., 55: 636-639.

Jamnback, H., J. D. M. Marr, B. B. Waddy and L. Kartman. 1971. Blackflies in the Americas. WHO/VBC/71.283, 24 pp.

Jamnback, H. and R. Means. 1966. Length of exposure period as a factor influencing the effectiveness of larvicides for blackflies (Diptera: Simuliidae). Mosq. News, 26: 589-591.

Jamnback, H. and A. S. West. 1970. Decreased susceptibility of blackfly larvae to p, p'-DDT in New York State and eastern Canada. J. Econ. Entomol., 63: 218-221.

Jenkins, D. W. 1948. Ecological observations on the blackflies and punkies of central Alaska. Mosq. News, 8: 148-155.

Jenkins, D. W. 1964. Pathogens, parasites and predators of medically important arthropods. Annotated list and bibliography. Bull. W.H.O. Suppl., 30: 150 pp.

Jobbins-Pomeroy, A. W. 1916. Notes on five North American buffalo gnats of the genus *Simulium*. U.S. Dept. Agric. Bull., 329: 48 pp.

Johannsen, O. A. 1934. Aquatic Diptera. Part I. Nemocera, exclusive of Chironomidae and Ceratopogonidae. Cornell Univ. Agr. Exp. Sta. Mem., 164: 1-71.

Johnson, A. F. and D. H. Pengelly. 1966. A cone trap for immature blackflies (Diptera: Simuliidae). Proc. Entomol. Soc. Ont., 96: 120.

Johnson, A. F. and D. H. Pengelly. 1969. The larval instars of *Simulium rugglesi* Nicholson and Mickel (Diptera: Simuliidae). Proc. Entomol. Soc. Ont., 100: 182-187.

Jones, C. M. and D. J. Richey. 1956. Biology of the black flies in Jasper County, South Carolina, and some relationships to a *Leucocytozoon* disease of turkeys. J. Econ. Entomol., 49: 121-123.

Kellogg, V. L. 1899. The mouthparts of the Nematocerous Diptera, II. Psyche J. Entomol. (Camb. Mass.), 8: 327-330.

Kellogg, V. L. 1901. Food of larvae of *Simulium* and *Blepharocera*. Psyche J. Entomol. (Camb. Mass.), 9: 166-167.

Krafchick, B. 1942. The mouthparts of blackflies with special reference to *Eusimulium lascivum* Twinn. Ann. Entomol. Soc. Amer., 35: 426-434.

Kuzoe, F. A. S. 1969. Some observations on *Simulium damnosum* from southern Ghana. Ghana J. Sci., 9: 35-40.

Laboulbène, A. 1882. Note sur l'insecte Diptère nuisible de Terre-Neuve signalé par M. le Docteur Treille. Arch. Méd. Pharm. Nav., 38: 222-224.

Ladle, M., J. A. B. Bass and W. R. Jenkins. 1972. Studies on production and food consumption by the larval Simuliidae (Diptera) of a chalk stream. Hydrobiologia, 39: 429-448.

Laird, M. 1971. A bibliography on diseases and enemies of medically important Arthropods 1963-67 with some earlier titles omitted from Jenkins' 1964 list. In Microbial control of insects and mites (Ed: H. D. Burges and N. W. Hussey), Academic Press. London. pp. 751-790.

Landau, R. 1962. Four forms of *Simulium tuberosum* (Lundstr.) in southern Ontario: a salivary gland chromosome study. Can. J. Zool., 40: 921-939.

Lewis, D. J. 1958. Some aspects of the study of *Simulium dmanosum*. Proc. VIth Int. Congr. Trop. Med. Malaria, 2: 305-314.

Lewis, D. J. 1960. Observations on the *Simulium neavei* complex at Amani in Tanganyika. Bull. Entomol. Res., 51: 95-113.

Lewis, D. J. 1965. Sand-flies and black-flies (Dipt. Phlebotominae and Simuliidae). Proc. S. Lond. Entomol. Nat. Hist. Soc., pp. 14-17.

Lewis, D. J. and R. H. L. Disney. 1969. A new phoretic *Simulium* from West Cameroon (Diptera: Simuliidae). Proc. R. Entomol. Soc. Lond. Ser. B Taxon., 38: 117-120.

Lewis, D. J., R. H. L. Disney, and R. W. Crosskey. 1969. A new phoretic species of *Simulium* (Dipt., Simuliidae) from West Cameroon, with taxonomic notes on allied forms. Bull. Entomol. Res., 59: 229-239.

Lewis, D. J., E. T. Reid, R. W. Crosskey and J. B. Davies. 1960. Attachment of immature Simuliidae to other Arthropods. Nature, 187: 618-619.

Lichtwardt, R. W. 1967. Zygospores and spore appendages of *Harpella* (Trichomycetes) from the larvae of Simuliidae. Mycologia, 59: 482-491.

Liu, T. P. and D. M. Davies. 1971. Ultrastructural localization of glycogen in the flight muscle of the blackfly, *Simulium vittatum* Zett. Can. J. Zool., 49: 219-221.

Liu, T. P. and D. M. Davies. 1972a. Ultrastructure of protein and lipid inclusions in frozen-etched blackfly oocytes (Simuliidae, Diptera). Can. J. Zool., 50: 59-62.

Liu, T. P. and D. M. Davies. 1972b. Fine structure frozen-etched lipid granules in the fat body of an insect. J. Lipid Res., 13: 115-118.

Liu, T. P. and D. M. Davies. 1972c. Ultrastructure of the cytoplasm in fat-body cells of the blackfly, *Simulium vittatum*, with microsporidian infection; a freeze-etching study. J. Invertebr. Pathol., 19: 208-214.

Liu, T. P. and D. M. Davies. 1972d. Ultrastructure of the nuclear envelope from black-fly, fat-body cells with and without Microsporidan infection. J. Invertebr. Pathol., 20: 176-182.

Liu, T. P. and D. M. Davies. 1972e. Ultrastructural localization of glutamic oxaloacetic transaminase in mitochondria of the flight muscle of Simuliidae. J. Insect Physiol., 18: 1665-1671.

Logan, S. W. 1963. Winter observations on bottom organisms and trout in Badger Creek, Montana. Trans. Am. Fish. Soc., 92: 140-145.

Lowther, J. K. and D. M. Wood. 1964. Specificity of a black fly, *Simulium euryadminiculum* Davies, toward its host, the common loon. Can. Entomol., 96: 911-913.

McBride, S. J. 1870. The death-web of young trout. Amer. Entomol. Bot., 2: 227-228.

McComb, C. W. and W. E. Bickley. 1959. Observations on blackflies in two Maryland counties. J. Econ. Entomol., 52: 629-632.

Mackay, R. J. 1969. Aquatic insect communities of a small stream on Mont. St. Hilaire, Quebec. J. Fish. Res. Board Can., 26: 1157-1183.

Mackerras, I. M. and M. J. Mackerras. 1948. Revisional notes on Australasian Simuliidae (Diptera). Proc. Linn. Soc. N.S.W., 73: 372-405.

Mackerras, I. M. and M. J. Mackerras. 1952. Notes on Australasian Simuliidae (Diptera). III. Proc. Linn. Soc. N.S.W., 77: 104-113.

Mackerras, M. J. and I. M. Mackerras. 1950. Notes on Australasian Simuliidae (Diptera). II. Proc. Linn. Soc. N.S.W., 75: 167-187.

Mackerras, M. J. and I. M. Mackerras. 1955. Notes on Australasian Simuliidae (Diptera). IV. Proc. Linn. Soc. N.S.W., 80: 105-112.

McMahon, J. P. 1952. Phoretic association between Simuliidae and crabs. Nature, 169: 1018.

McMahon, J. P. 1967. A review of the control of *Simulium* vectors of onchocerciasis. Bull. W.H.O., 37: 415-430.

Maitland, P. S. 1964. Quantitative studies on the invertebrate fauna of sandy and stony substrates in the River Endrick, Scotland. Proc. R. Soc. Edin. Ser. B, 68: 277-301.

Maitland, P. S., and M. M. Penney. 1967. The ecology of the Simuliidae in a Scottish river. J. Anim. Ecol., 36: 179-206.

Malloch, J. R. 1914. American black flies or buffalo gnats. U.S. Dept. Agric. Bur. Entomol. Tech. Ser., 26: 82 pp.

Manier, J. F. and J. Maurand. 1966. Sporogonie de deux microsporidies de larves de *Simulium: Thelohania bracteata* (Strickland 1913) et *Plistophora simulii* (Lutz et Spuendore 1904). J. Protozool. (suppl.), 13: 39.

Mansingh, A., R. W. Steele and B. V. Helson. 1972. Hibernation in the blackfly *Prosimulium mysticum:* quiescence or oligopause? Can. J. Zool., 50: 31-34.

Marr, J. D. M. 1962. The use of an artificial breeding-site and cage in the study of *Simulium damnosum* Theobald. Bull. W.H.O., 27: 622-629.

Maurand, J. 1967. Relations Microsporidies-larves de *Simulium:* spécificité parasitaire d'hôte; spécificité parasitaire tissulaire. Ann. Parasitol. Hum. Comp., 42: 285-290.

Meinert, Fr. 1886. De eucephale Myggelarver. K. Dan. Viden. Selsk. Skr., 3: 373-493. (Reference from Puri, 1925a).

Metcalf, C. L. 1932. Black flies and other biting flies of the Adirondacks. N.Y. State Mus. Bull., 289: 5-58.

Metcalf, C. L. and W. E. Sanderson. 1932. Control of biting flies in the Adirondacks. N.Y. State Mus. Bull., 289: 59-75.

Minckley, W. L. 1963. The ecology of a spring stream, Doe Run, Meade County, Kentucky. Wildl. Monogr., 11: 1-124.

Moffett, J. W. 1936. A quantitative study of the bottom fauna in some Utah streams variously affected by erosion. Bull. Univ. Utah (Biol. Ser. 3), 26: 1-32.

Moss, S. T. 1970. Trichomycetes inhabiting the digestive tract of *Simulium equinum* larvae. Trans. Br. Mycol. Soc., 54: 1-13.

Müller, K. 1954. Investigations on the organic drift in north Swedish streams. Rep. Inst. Freshwater Res. Drottningholm, 35: 133-148.

Newstead, R., J. E. Dutton and J. L. Todd. 1907. Insects and other Arthropoda collected in the Congo Free State. Ann. Trop. Med. Parasitol., 1: 1-112.

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. Entomol. Soc. Amer., 38: 281-297.

Nicholson, H. P. and C. E. Mickel. 1950. The black flies of Minnesota (Simuliidae). Univ. Minn. Agr. Exp. Sta. Tech. Bull., 192: 64 pp.

Nielsen, A. 1950. The torrential invertebrate fauna. Oikos, 2: 176-196.

Noamesi, G. K. 1962. A preliminary study of the susceptibility of *Simulium* larvae to DDT, γ-BHC and Dieldrin. Bull. W.H.O., 27: 620-622.

Obeng, L. E. 1965. The identification of the aquatic stages of the British Simuliidae. Ann. Trop. Med. Parasitol., 59: 240-254.

Obeng, L. E. 1967. Life-history and population studies on the Simuliidae of North Wales. Ann. Trop. Med. Parasitol., 61: 472-487.

O'Kane, W. C. 1926. Blackflies in New Hampshire. N.H. Agric. Exp. Sta. Tech. Bull., 32: 1-23.

Ottonen, P. O. 1966. The salivary gland chromosomes of six species in the IIIS-1 group of *Prosimulium* Roub. (Diptera: Simuliidae). Can. J. Zool., 44: 677-701.

Ottonen, P. O. and R. Nambiar. 1969. The salivary gland chromosomes of *Prosimulium multidentatum* Twinn and three forms included in *Prosimulium magnum* (Dyar and Shannon) (Diptera: Simuliidae). Can. J. Zool., 47: 943-949.

Pasternak, J. 1964. Chromosome polymorphism in the blackfly *Simulium vittatum* (Zett.) Can. J. Zool., 42: 135-158.

Patrick, R. 1959. Aquatic life in a new stream. Water Sewage Works, Dec., pp. 531-535.

Pennak, R. W. 1971. Toward a classification of lotic habitats. Hydrobiologia, 38: 321-334.

Pentelow, F. T. K. 1935. Notes on the distribution of the larvae and pupae of *Simulium* spp. in the River Tees and its tributaries. Parasitology, 27: 543-546.

Perez, J. R. 1971. Distribucion geografica y revision taxonomica de los Simulidos (Diptera: Nematocera) de Venezuela con descripcion de diez especies nuevas. Acta Biol. Venez., 7: 271-372.

Peschken, D. and A. J. Thorsteinson. 1965. Visual orientation of black flies (Simuliidae: Diptera) to colour, shape and movement of targets. Entomol. Exp. Appl., 8: 282-288.

Peterson, B. V. 1956. Observations on the biology of Utah black flies (Diptera: Simuliidae). Can. Entomol., 88: 496-507.

Peterson, B. V. 1959a. Notes on the biology of some species of Utah blackflies (Diptera: Simuliidae). Mosq. News, 19: 86-90.

Peterson, B. V. 1959b. Observations on mating, feeding and oviposition of some Utah species of black flies (Diptera: Simuliidae). Can. Entomol., 91: 147-155.

Peterson, B. V. 1960. The Simuliidae (Diptera) of Utah, Part I. Keys, original citations, types and distribution. Great Basin Nat., 20: 81-104.

Peterson, B. V. 1962a. *Cnephia abdita*, a new black fly (Diptera: Simuliidae) from eastern North America. Can. Entomol., 94: 96-102.

Peterson, B. V. 1962b. Observations of mating swarms of *Simulium venustum* Say and *Simulium vittatum* Zetterstedt (Diptera: Simuliidae). Proc. Entomol. Soc. Ont., 92: 188-190.

Peterson, B. V. 1970. The *Prosimulium* of Canada and Alaska (Diptera: Simuliidae). Mem. Entomol. Soc. Can., 69: 216 pp.

Peterson, B. V. and D. M. Davies. 1960. Observations on some insect predators of black flies (Diptera: Simuliidae) of Algonquin Park, Ontario. Can. J. Zool., 38: 9-18.

Peterson, D. G. and L. S. Wolfe. 1958. The biology and control of black flies (Diptera: Simuliidae) in Canada. Proc. Xth Int. Congr. Entomol., 3: 551-564.

Phelps, R. J. and G. R. DeFoliart. 1964. Nematode parasitism of Simuliidae. Univ. Wisc. Res. Bull., 245: 78 pp.

Phillipson, J. 1956. A study of factors determining the distribution of the larvae of the black fly, *Simulium ornatum* Mg. Bull. Entomol. Res., 47: 227-238.

Phillipson, J. 1957. The effect of current speed on the distribution of the larvae of the blackflies, *Simulium variegatum* (Mg.) and *Simulium monticola* Fried. (Diptera). Bull. Entomol. Res., 48: 811-819.

Pickavance, J. R., G. F. Bennett, and J. Phipps. 1970. Some mosquitoes and blackflies from Newfoundland. Can. J. Zool., 48: 621-624.

Puri, I. M. 1925a. On the life-history and structure of the early stages of Simuliidae (Diptera, Nematocera). Part I. Parasitology, 17: 295-334.

Puri, I. M. 1925b. On the life-history and structure of the early stages of Simuliidae (Diptera, Nematocera). Part II. Parasitology, 17: 335-369.

Quelennec, G. 1962. Essais de portée de deux insecticides utilisés contre les larves de *Simulium damnosum*, dans le Nord Dahomey. Bull. W.H.O., 27: 615-619.

Quelennec, G. 1970. Essais sur le terrain de nouvelles formulations d'insecticides, OMS-187, OMS-786 et OMS-971, contre les larves de Simulies. Bull. W.H.O., 43: 313-316.

Quelennec, G. and M. Ovazza. 1968. La lutte contre les Simulies. Cah. O.R.S.T.O.M. (Off. Rech. Sci. Tech. Outre-Mer) Sér. Entomol. Méd., 6: 197-205.

Quelennec, G., B. Philippon, R. Cordellier and E. Simonkovich. 1970. Essais d'activité d'une poudre insecticide à base de sevin contre les larves de Simulies. Med. Trop., 30: 3-6.

Raybould, J. N. 1967. A method of rearing *Simulium damnosum* Theobald (Diptera: Simuliidae) under artificial conditions. Bull. W.H.O., 37: 447-453.

Rees, D. M. and B. V. Peterson. 1953. The black flies (Diptera: Simuliidae) in the canyons near Salt Lake City, Utah. Proc. Utah Acad. Sci. Arts Lett., 30: 57-59.

Reichle, R. E. and R. W. Lichtwardt. 1972. Fine structure of the Trichomycete, *Harpella melusinae*, from black-fly guts. Arch. Mikrobiol., 81: 103-125.

Rothfels, K. H. 1956. Black flies; siblings, sex, and species grouping. J. Hered., 47: 113-122.

Rothfels, K. H. 1972. Personal communication.

Rothfels, K. H. and P. K. Basrur. 1962. The inter-relations of *Prosimulium hirtipes* (Fries) and allied European and North American species (Diptera: Simuliidae) - a salivary gland chromosome study. Proc. XIth Int. Congr. Entomol., 1: 435.

Rothfels, K. H. and R. W. Dunbar. 1953. The salivary gland chromosomes of the blackfly *Simulium vittatum* Zett. Can. J. Zool., 31: 226-241.

Rubtsov, I. A. 1956. Fauna of USSR Insects (Diptera). Blackflies (family Simuliidae). (In Russian). Zool. Inst., Acad. Sci. USSR (N.S. 64), 6: 1-860.

Sacken, R. O. 1870. On the transformations of *Simulium*. Amer. Entomol. Bot., 2: 229-231.

Sailer, R. I. 1953. The blackfly problem in Alaska. Mosq. News, 13: 232-235.

Schönbauer, J. A. 1795. Geschichte der schädlichen Kolumbatczer Mücken im Bannat. Wien, 100 pp. (Reference from Puri, 1925a).

Schemanchuk, J. A. and K. R. Depner. 1971. Seasonal distribution and abundance of females of *Simulium aureum* Fries (Simuliidae: Diptera) in irrigated areas of Alberta. J. Med. Entomol., 8: 29-33.

Shewell, G. E. 1955. Identity of the black fly that attacks ducklings and goslings in Canada (Diptera: Simuliidae). Can. Entomol., 87: 345-349.

Shewell, G. E. 1957. Interim report on distributions of the black flies (Simuliidae) obtained in the Northern Insect Survey. Can. Dept. Nat. Def., Def. Res. Bd. Envir. Prot. Tech. Rep. 7.

Shewell, G. E. 1958. Classification and distribution of Arctic and Subarctic Simuliidae. Proc. Xth Int. Congr. Entomol., 1: 635-643.

Smart, J. 1934a. Notes on the biology of *Simulium pictipes* Hagen. Can. Entomol., 66: 62-66.

Smart, J. 1934b. On the biology of the black fly, *Simulium ornatum* Mg. (Diptera, Simuliidae). Proc. R. Phys. Soc., 22: 217-238.

Smart, J. 1935. The internal anatomy of the black-fly, *Simulium ornatum* Mg. Ann. Trop. Med. Parasitol., 29: 161-170.

Smart, J. 1944. The British Simuliidae with keys to the species in the adult, pupal and larval stages. Freshwater Biol. Assoc. Sci. Publ., 9: 57 pp.

Smart, J. 1945. The classification of the Simuliidae (Diptera). Trans. R. Entomol. Soc. Lond., 95: 463-532.

Smart, J. and E. A. Clifford. 1965. Simuliidae (Diptera) of the Territory of Papua and New Guinea. Pac. Insects, 7: 505-619.

Smart, J. and E. A. Clifford. 1968. Simuliidae (Diptera) of Sabah (British North Borneo). J. Linn. Soc. London Zool., 48: 9-47.

Smith, S. M. 1972. Personal communication.

Snoddy, E. L. 1967. The common grackle, *Quiscalus quiscula quiscula* L. (Aves: Icteridae) a predator of *Simulium pictipes* Hagen larvae (Diptera: Simuliidae). J. Ga. Entomol. Soc., 2: 45-46.

Snoddy, E. L. 1968. Simuliidae, Ceratopogonidae, and Chloropidae as prey of *Oxybelus emarginatum*. Ann. Entomol. Soc. Amer., 61: 1029-1030.

Snoddy, E. L. and J. R. Chipley. 1971. Bacteria from the intestinal tract of *Simulium underhilli* (Diptera: Simuliidae) as a possible index to water pollution. Ann. Entomol. Soc. Amer., 64: 1467-1468.

Snow, W. E., E. Pickard and J. B. Moore. 1958. Observations on blackflies (Simuliidae) in the Tennessee River Basin. J. Tenn. Acad. Sci., 33: 5-23.

Sommerman, K. M. 1953. Identification of Alaskan black fly larvae. (Diptera: Simuliidae). Proc. Entomol. Soc. Wash., 55: 258-273.

Sommerman, K. M., R. I. Sailer, and C. O. Esselbaugh. 1955. Biology of Alaskan black flies (Simuliidae, Diptera). Ecol. Mongr., 25: 345-385.

Sprules, W. M. 1947. An ecological investigation of stream insects in Algonquin Park, Ontario. Univ. Toronto Stud., Biol. Ser., 56: 1-81.

Stains, G. S. and G. F. Knowlton. 1943. A taxonomic and distributional study of Simuliidae of Western United States. Ann. Entomol. Soc. Amer., 36: 259-280.

Stone, A. 1952. The Simuliidae of Alaska (Diptera). Proc. Entomol. Soc. Wash., 54: 69-96.

Stone, A. 1964. Guide to the insects of Connecticut. Part VI. The Diptera or true flies of Connecticut. Ninth Fascicle. Simuliidae and Thaumaleidae. St. Geol. Nat. Hist. Survey Bull., 97: 126 pp.

Stone, A. 1965. The relationships of Nearctic and Palaearctic Simuliidae (Diptera). Proc. XIIth Int. Congr. Entomol., p. 762.

Stone, A. and H. A. Jamnback. 1955. The black flies of New York State (Diptera: Simuliidae). N.Y. State Mus. Bull., 349: 144 pp.

Stone, A., C. W. Sabrosky, W. W. Wirth, R. H. Foote and J. R. Coulson. 1965. A catalog of the Diptera of America north of Mexico. U.S. Dept. Agric., Agric. Res. Serv., Agric. Handb. 276: 1696 pp.

Stone, A. and E. L. Snoddy. 1969. The black flies of Alabama (Diptera: Simuliidae). Auburn Univ. Agric. Exp. Sta. Bull., 390: 93 pp.

Sutherland, D. W. S. and R. F. Darsie Jr. 1960. A report on the black flies (Simuliidae) of Delaware. Part II. Description and discussion of blackfly habitats. Bull. Brooklyn Entomol. Soc., 55: 53-61.

Syme, P. D. and D. M. Davies. 1958. Three new Ontario blackflies of the genus *Prosimulium* (Diptera: Simuliidae). Part I. Descriptions, morphological comparisons with related species, and distribution. Can. Entomol., 90: 697-719.

Tarshis, I. B. 1965. A simple method for the collection of black fly larvae. Bull. Wildl. Dis. Assoc., 1: 8.

Tarshis, I. B. 1968a. Use of fabrics in streams to collect black fly larvae. Ann. Entomol. Soc. Amer., 61: 960-961.

Tarshis, I. B. 1968b. Collecting and rearing black flies. Ann. Entomol. Soc. Amer., 61: 1072-1083.

Tarshis, I. B. 1971. Individual black fly rearing cylinders (Diptera: Simuliidae). Ann. Entomol. Soc. Amer., 64: 1192-1193.

Tarshis, I. B. 1972. The feeding of some ornithophilic black flies (Diptera: Simuliidae) in the laboratory and their role in the transmission of *Leucocytozoon simondi*. Ann. Entomol. Soc. Amer., 65: 842-848.

Taylor, T. H. 1902. On the tracheal system of *Simulium*. Trans. Entomol. Soc. Lond., 49: 701-716.

Terterjan, A. E. 1957. The determination of the number of instars in the larvae of black-flies (Diptera, Simuliidae). (In Russian). Entomol. Obozr., 36: 860-868.

Teshima, I. 1972. DNA-DNA hybridization in blackflies (Diptera: Simuliidae). Can. J. Zool., 50: 931-940.

Thomas, L. J. 1946. Black fly incubator-aerator cabinet. Science, 103: 21.

Tömösváry, D. E. 1892. Golubacka muha. Glasnik Hrvatskoga Naravosl. Druztva, 6: 187-203. (Reference from Puri, 1925a).

Tonnoir, A. 1923a. Comment les larves de *Simulium* filent leurs cocons. Bull. Soc. Entomol. Belg., 4: 85-90.

Tonnoir, A. 1923b. Notes sur la biologie des larves de *Simulium* (Diptera). Étude critique de certaines opinions courantes. Ann. Biol. Lac., 11: 163-172.

Tonnoir, A. 1925. Australasian Simuliidae. Bull. Entomol. Res., 15: 213-255.

Travis, B. V. 1966. The biology and control of black flies. Proc. 53rd Ann. Meet. N.J. Mosq. Exterm. Assoc., 194-197.

Travis, B. V. 1967. Biology and control of biting flies in New York State. N.Y. State Coll. Agric. Ext. Bull., 1186: 38 pp.

Travis, B. V. 1968. Some problems with simulated stream tests of black-fly larvicides. Proc. 55th Ann. Meet. N.J. Mosq. Exterm. Assoc., 129-134.

Travis, B. V., D. Guttman and R. R. Crafts. 1967. Tests (1966) with black fly larvicides. Proc. 54th Ann. Meet. N.J. Mosq. Exterm. Assoc., 49-53.

Travis, B. V., D. C. Kurtak and L. C. Rimando. 1970. Tests (1969) with black fly larvicides. Proc. 57th Ann. Meet. N.J. Mosq. Exterm. Assoc., 106-110.

Treille, E. 1882. Quelques considérations sur un insecte Diptère nuisible de Terre-Neuve. Arch. Méd. Pharm. Nav., 38: 216-221.

Twinn, C. R. 1936a. The blackflies of eastern Canada (Simuliidae, Diptera). Part I. Can. J. Res. D., 14: 97-130.

Twinn, C. R. 1936b. The blackflies of eastern Canada (Simuliidae, Diptera). Part II. Can. J. Res. D., 14: 131-150.

Twinn, C. R. 1950. Studies on the biology and control of biting flies in northern Canada. Arctic, 3: 14-26.

Twinn, C. R., B. Hocking, W. C. McDuffie and H. F. Cross. 1948. A preliminary account of the biting flies at Churchill, Manitoba. Can. J. Res. D., 26: 334-357.

Underhill, G. W. 1940. Some factors influencing feeding activity of Simuliidae in the field. J. Econ. Entomol., 33: 915-917.

Underhill, G. W. 1944. Blackflies found feeding on turkeys in Virginia, *(Simulium nigroparvum* Twinn and *Simulium slossonae* Dyar and Shannon). Va. Agric. Exp. Sta. Tech. Bull., 94: 32 pp.

Ussova, Z. V. and Z. P. Kulikova. 1958. The activity of black flies (Diptera, Simuliidae) in Karelia. Entomol. Rev., 37: 751-762.

Vargas, L. 1945. Simulidos del Nuevo Mundo. Inst. Salubr. Enferm. Trop. Mongr., 1: 241 pp.

Walker, G. P. 1927. A blackfly, *(Simulium bracteatum)*, fatal to goslings. Can. Entomol., 59: 123.

Wanson, M. and C. Henrard. 1945. Habitat et comportement larvaire du *Simulium damnosum* Theobald. Rec. Trav. Sci. Med. Congo Belge, 4: 113-121.

Waters, T. F. 1972. The drift of stream insects. Ann. Rev. Entomol., 17: 253-272.

Webster, F. M. 1889. *Simulium*, or buffalo gnats. 4th & 5th Ann. Repts. Bur. Anim. Ind. (1887-1888), pp. 456-465.

Weed, C. M. 1904a. An experiment with black flies. U.S. Dept. Agric. Bur. Entomol. Bull., 46: 108-109.

Weed, C. M. 1904b. Experiments in destroying black-flies. N.H. Coll. Exp. Sta. Bull., 112: 133-136.

Wenk, P. 1965. Über die biologie blutsaugender Simuliiden (Diptera) III. Kopulation, blautsaugen und eiablage von *Boophthora erythrocephala* de Geer im laboratorium. Tropenmed. Parasitol., 16: 207-226.

Wenk, P. and J. N. Raybould. 1972. Mating, blood-feeding and oviposition of the "Kibwezi" form of *Simulium damnosum* Theobald (Diptera: Simuliidae) in the laboratory. WHO/ONCHO/72.88, WHO/VBC/72.351, 13 pp.

West, A. S., A. W. A. Brown, and D. G. Peterson. 1960. Control of blackfly larvae (Diptera: Simuliidae) in the forests of eastern Canada by aircraft spraying. Can. Entomol., 92: 745-754.

Williams, M. C. and R. W. Lichtwardt. 1971. A new *Pennella* (Trichomycetes) from *Simulium* larvae. Mycologia, 63: 910-914.

Williams, T. R., R. Conolly, H. B. N. Hynes and W. E. Kershaw. 1961a. Size of particles ingested by *Simulium* larvae. Nature, 189: 78.

Williams, T. R., H. B. N. Hynes and W. E. Kershaw. 1961b. The fauna in a Welsh hillstream containing *Simulium*. Ann. Soc. Belge Med. Trop., 41: 293-297.

Williams, T. R. and L. Obeng. 1962. A comparison of two methods of estimating changes in *Simulium* larval populations, with a description of a new method. Ann. Trop. Med. Parasitol., 56: 359-361.

Wolfe, L. S. and D. G. Peterson. 1958. A new method to estimate levels of infestations of black-fly larvae (Diptera: Simuliidae). Can. J. Zool., 36: 863-867.

Wolfe, L. S. and D. G. Peterson. 1959. Black flies (Diptera: Simuliidae) of the forests of Quebec. Can. J. Zool., 37: 137-159.

Wolfe, L. S. and D. G. Peterson. 1960. Diurnal behavior and biting habits of black flies (Diptera: Simuliidae) in the forests of Quebec. Can. J. Zool., 38: 489-497.

Wood, D. M. and D. M. Davies. 1965. The rearing of Simuliids (Diptera). Proc. XIIth Int. Congr. Entomol., Sect. 12, pp. 821-823.

Wood, D. M. and D. M. Davies. 1966. Some methods of rearing and collecting black flies (Diptera: Simuliidae). Proc. Entomol. Soc. Ont., 96: 81-90.

Wood, D. M., B. V. Peterson, D. M. Davies and H. Gyorkos. 1963. The black flies (Diptera: Simuliidae) of Ontario. Part II. Larval identification, with descriptions and illustrations. Proc. Entomol. Soc. Ont., 93: 99-129.

Wright, F. N. 1957. Rearing of *Simulium damnosum* Theobald (Diptera, Simuliidae) in the laboratory. Nature, 180: 1059.

Wu, Y. F. 1930. A contribution to the biology of *Simulium* (Diptera). Pap. Mich. Acad. Sci. Arts Lett., 13: 543-599.

Wygodzinsky, P. and S. Coscaron. 1970. A new species-group of the blackfly genus *Simulium* from western South America (Simuliidae, Diptera, Insecta). Amer. Mus. Novit., 2433: 20 pp.

Yakuba, V. N. 1959. On the migrations of black fly larvae. Entomol. Rev., 38: 379-387.

Yang, Y. J. and D. M. Davies. 1968a. Amylase activity in black-flies and mosquitoes (Diptera). J. Med. Entomol., 5: 9-13.

Yang, Y. J. and D. M. Davies. 1968b. Digestion, emphasizing trypsin activity, in adult simuliids (Diptera) fed blood, blood-sucrose mixtures, and sucrose. J. Insect Physiol., 14: 205-222.

Yang, Y. J. and D. M. Davies. 1968c. Occurrence and nature of invertase activity in adult black flies (Simuliidae). J. Insect. Physiol., 14: 1221-1232.

Zahar, A. R. 1951. The ecology and distribution of blackflies (Simuliidae) in south-east Scotland. J. Anim. Ecol., 20: 33-62.

Figure 1

Aerial photograph of the Pickavance Creek area


COCHRANE POND
ST. JOHNS
MAGNETIC NORTH
PADDYS POND

Figure 2

Location of sampling sites in the Pickavance Creek area

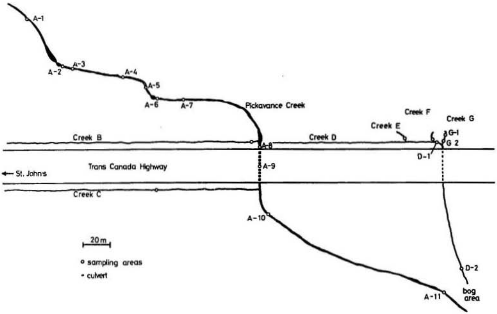

A-1
A-2
A-3
A-4
A-5
A-6
A-7
Pickavance Creek
Creek F
Creek G
Creek E
Creek B
A-8
Creek D
G-1
G 2
D-1
← St. John's
Trans Canada Highway
A-9
Creek C
A-10
20 m
o sampling areas
- culvert
D-2
A-11
bog area

Figure 3

Streams sampled 1970-1972

a. Newfoundland distribution

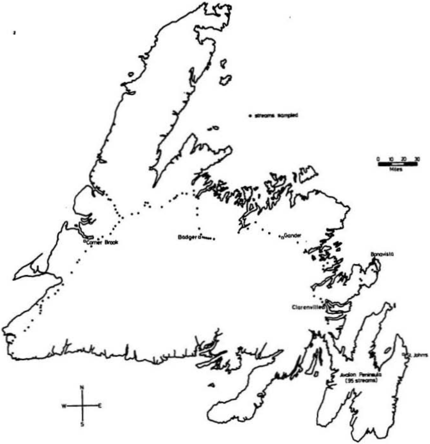

• streams sampled
0 10 20 30
Miles
Corner Brook
Badger
Gander
Bonavista
Clarenville
St. Johns
Avalon Peninsula
(95 streams)
N
W
E
S

Figure 3

Streams sampled 1970-1972

b. Avalon Peninsula distribution

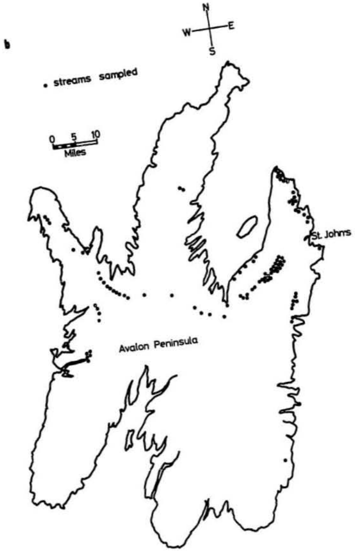

b
N
W
E
S
• streams sampled
0 5 10
Miles
St. John's
Avalon Peninsula

Figure 4

Current velocity ranges in the Pickavance Creek area

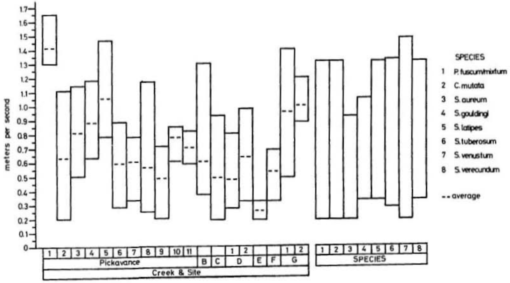

1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
meters per second
1
2
3
4
5
6
7
8
9
10
11
Pickavance
B
C
1
2
D
E
F
1
2
G
Creek & Site
1
2
3
4
5
6
7
8
SPECIES
SPECIES
1 P. fuscum/mixtum
2 C. mutata
3 S. aureum
4 S. gouldingi
5 S. latipes
6 S. tuberosum
7 S. venustum
8 S. verecundum
-- average

Figure 5

Creek temperatures 1971 (solid line) and 1972 (broken line)

a. Pickavance Creek

b. Creek B

c. Creek C

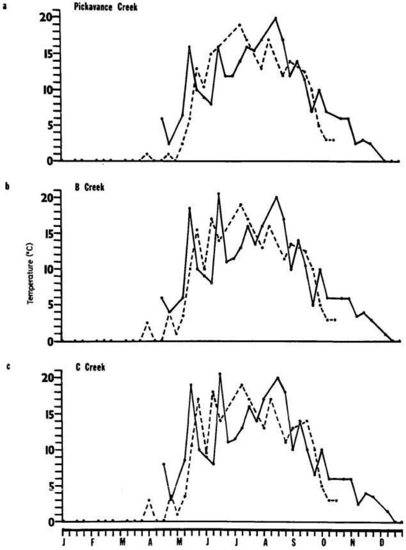

a
Pickavance Creek
20
15
10
5
0
b
B Creek
20
15
10
5
0
Temperature (°C)
c
C Creek
20
15
10
5
0
J
F
M
A
M
J
J
A
S
O
N
D

Figure 5

Creek temperatures 1971 (solid line) and 1972 (broken line)

d. Creeks D and G

e. Creek E

f. Creek F

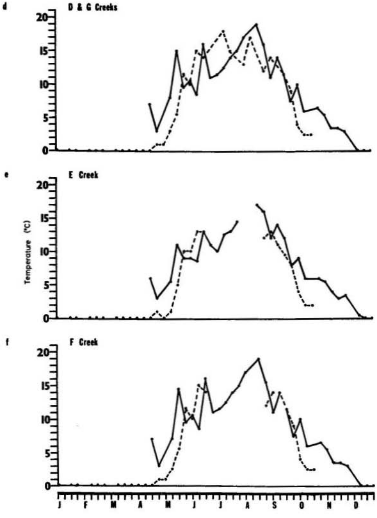
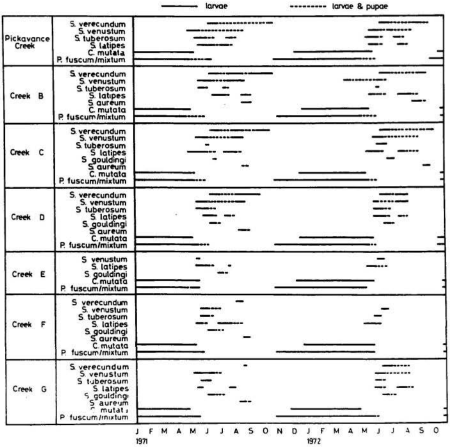

d
D & G Creeks
20
15
10
5
0
e
E Creek
Temperature (°C)
20
15
10
5
0
f
F Creek
20
15
10
5
0
J
F
M
A
M
J
J
A
S
O
N
D

Figure 6

Seasonal succession of simuliid larvae and pupae

in the Pickavance Creek area 1971-72



larvae
larvae & pupae
Pickavance Creek
S. verecundum
S. venustum
S. tuberosum
S. latipes
C. mutata
P. fuscum/mixtum
Creek B
S. verecundum
S. venustum
S. tuberosum
S. latipes
S. aureum
C. mutata
P. fuscum/mixtum
Creek C
S. verecundum
S. venustum
S. tuberosum
S. latipes
S. gouldingi
S. aureum
C. mutata
P. fuscum/mixtum
Creek D
S. verecundum
S. venustum
S. tuberosum
S. latipes
S. gouldingi
S. aureum
C. mutata
P. fuscum/mixtum
Creek E
S. venustum
S. latipes
S. gouldingi
C. mutata
P. fuscum/mixtum
Creek F
S. verecundum
S. venustum
S. tuberosum
S. latipes
S. gouldingi
S. aureum
C. mutata
P. fuscum/mixtum
Creek G
S. verecundum
S. venustum
S. tuberosum
S. latipes
S. gouldingi
S. aureum
C. mutata
P. fuscum/mixtum
J F M A M J J A S O N D J F M A M J J A S O
1971
1972

Figure 7

Seasonal succession and abundance in Pickavance Creek 1972

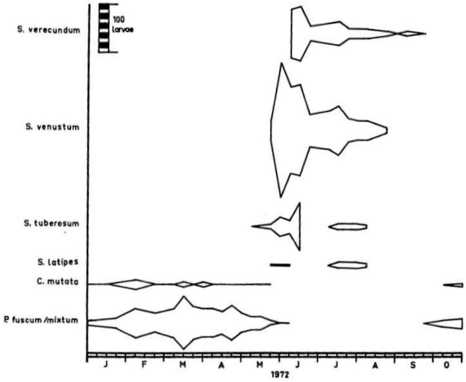

S. verecundum
S. venustum
S. tuberosum
S. latipes
C. mutata
P. fuscum /mixtum
100
larvae
J
F
M
A
M
J
J
A
S
O
1972

Figure 8

Seasonal succession and abundance in Creek B, 1972

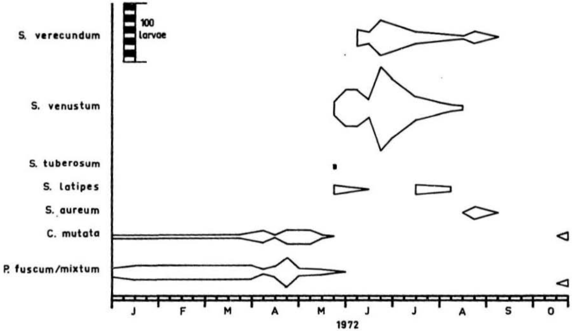

S. verecundum
S. venustum
S. tuberosum
S. latipes
S. aureum
C. mutata
P. fuscum/mixtum
100 larvae
J
F
M
A
M
J
J
A
S
O
1972

Figure 9

Seasonal succession and abundance in Creek C, 1972

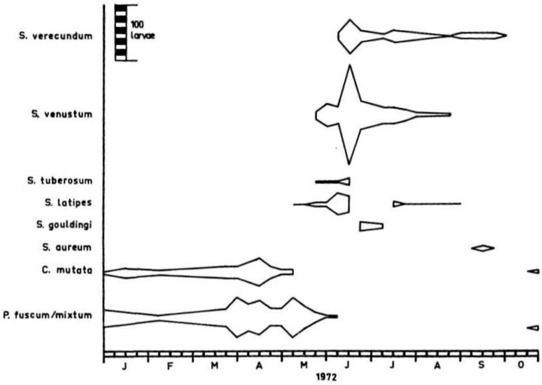

100
larvae
S. verecundum
S. venustum
S. tuberosum
S. latipes
S. gouldingi
S. aureum
C. mutata
P. fuscum/mixtum
J
F
M
A
M
J
J
A
S
O
1972

Figure 10

Seasonal succession and abundance in Creek D, 1972

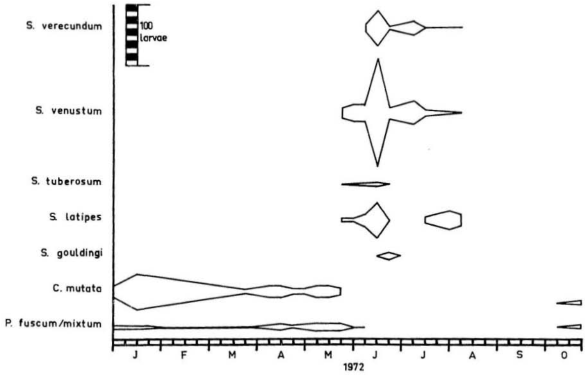

S. verecundum
100 larvae
S. venustum
S. tuberosum
S. latipes
S. gouldingi
C. mutata
P. fuscum/mixtum
J
F
M
A
M
J
J
A
S
O
1972

Figure 11

Seasonal succession and abundance in Creek E, 1972

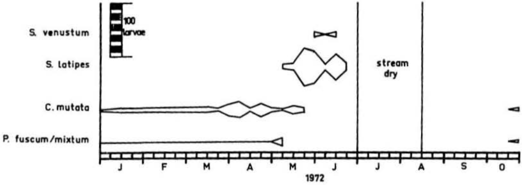

S. venustum
S. latipes
C. mutata
P. fuscum/mixtum
100 larvae
stream dry
J
F
M
A
M
J
J
A
S
O
1972

Figure 12

Seasonal succession and abundance in Creek F, 1972

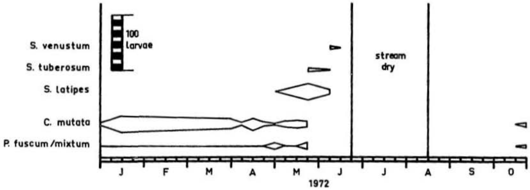
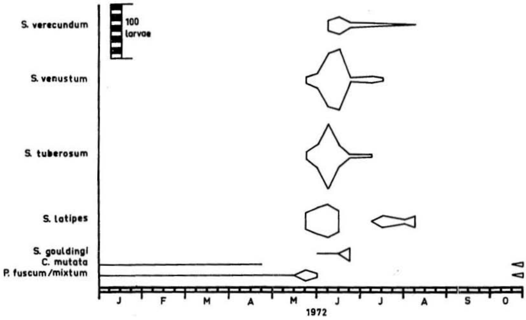

100
larvae
S. venustum
S. tuberosum
S. latipes
C. mutata
P. fuscum/mixtum
stream
dry
J
F
M
A
M
J
J
A
S
O
1972

Figure 13

Seasonal succession and abundance in Creek G, 1972



S. verecundum
S. venustum
S. tuberosum
S. latipes
S. gouldingi
C. mutata
P. fuscum/mixtum
100
larvae
J
F
M
A
M
J
J
A
S
O
1972

Figure 14

Comparison of the larval populations in the streams of the Pickavance Creek area, with emphasis on *S. venustum*

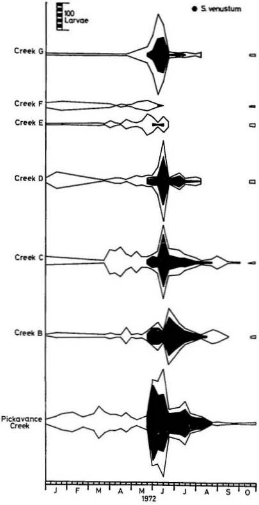

100
Larvae
● S. venustum
Creek G
Creek F
Creek E
Creek D
Creek C
Creek B
Pickavance Creek
J
F
M
A
M
J
J
A
S
O
1972

Figure 15

Species temperature range in the Pickavance Creek area

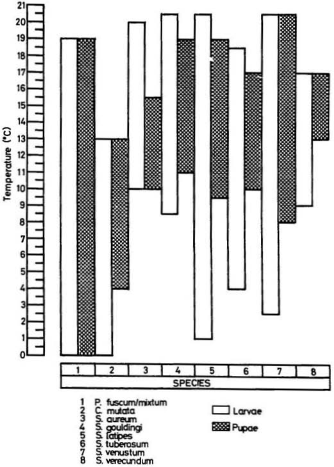

21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Temperature (°C)
1
2
3
4
5
6
7
8
SPECIES
1 P. fuscum/mixtum
2 C. mutata
3 S. aureum
4 S. gouldingi
5 S. latipes
6 S. tuberosum
7 S. venustum
8 S. verecundum
Larvae
Pupae

Figure 16

Species depth range in the Pickavance Creek area

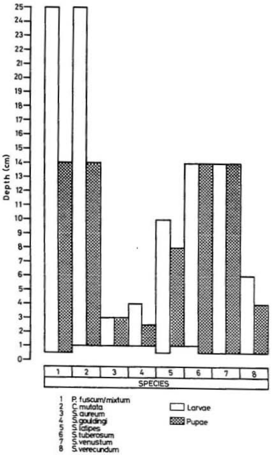

Depth (cm)
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
1
2
3
4
5
6
7
8
SPECIES
1 P. fuscum/mixtum
2 C. mutata
3 S. aureum
4 S. gouldingi
5 S. latipes
6 S. tuberosum
7 S. venustum
8 S. verecundum
Larvae
Pupae

Figure 17

Simuliid depth preference in the Pickavance Creek

a. Tiles placed 28-V-70; collected 29-V-70

b. Tiles placed 29-V-70; collected 3-VI-70

c. Tiles placed 29-V-72; collected 7-VI-72

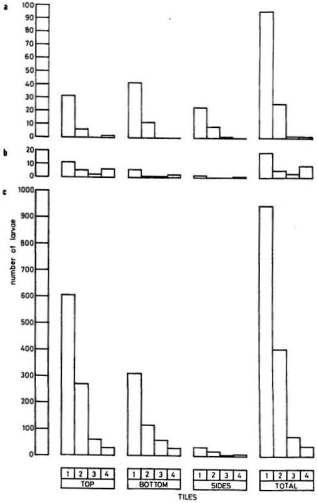

a
100
90
80
70
60
50
40
30
20
10
0
b
20
10
0
c
1000
900
800
700
600
500
400
300
200
100
0
number of larvae
1 2 3 4
TOP
1 2 3 4
BOTTOM
1 2 3 4
SIDES
1 2 3 4
TOTAL
TILES

Figure 18

Current velocity at the clamp apparatus

in Pickavance Creek 1970

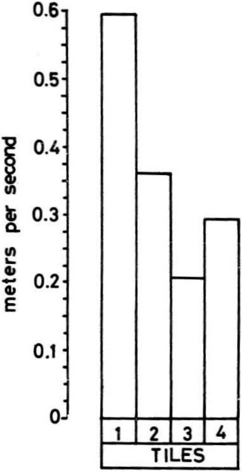
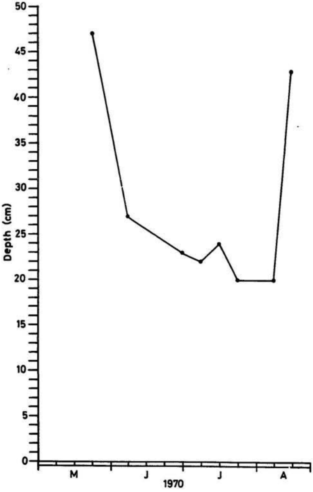

meters per second
0.6
0.5
0.4
0.3
0.2
0.1
0
1
2
3
4
TILES

Figure 19

Fluctuations in stream depth at Pickavance Creek 1970


50
45
40
35
30
25
20
15
10
5
0
Depth (cm)
M
J
J
A
1970

# APPENDIX A

## Description and simuliid fauna of streams sampled in insular Newfoundland during 1970-1972

Descriptions of the first 99 streams have the following format: stream number; map number; military grid reference; name of stream or location; T, I, or P, depending on whether the stream is temporary, intermittent or permanent (the temporary streams are not illustrated on the maps); depth (cm) at which immatures were collected; average width (m) of the stream; and species obtained from that stream. Streams 100 to 212 have all of this data except for the widths and depths. All map numbers and grid references are from the Canadian National Topographic Series 1:50,000.

| | | | |
|---|---|---|---|
| 1. | 1 N/5E | 051584 | 1.2 mi. west of Argentia access; T, 12, 1.5; *P. fuscum/mixtum*, *S. latipes* |
| 2. | 1 N/5E | 047586 | 1.5 mi. west of Argentia access; I, 12, 2.0; *P. fuscum/mixtum* |
| 3. | 1 N/5E | 039589 | 1.7 mi. west of Argentia access; P, 15, 4.0; *S. tuberosum*, *S. venustum* |
| 4. | 1 N/5E | 020599 | 3.0 mi. west of Argentia access; I, 8, 1.0; *P. fuscum/mixtum*, *C. mutata*, *S. latipes*, *S. tuberosum*, *S. venustum* |
| 5. | 1 N/5E | 006608 | 4.0 mi. west of Argentia access; P, 20, 4.0; *S. tuberosum*, *S. venustum* |
| 6. | 1 N/5E | 997612 | 4.7 mi. west of Argentia access; P, 8, 0.5; *P. fuscum/mixtum*, *C. mutata*, *S. latipes*, *S. venustum* |
| 7. | 1 N/12 | 971641 | 7.0 mi. west of Argentia access; P, 20, 4.0; *P. fuscum/mixtum*, *S. tuberosum*, *S. venustum* |

| | | | |
|---|---|---|---|
| 8. | 1 N/12 | 956660 | 1.2 mi. west of Chapel Arm-Long Harbour access; P, 12, 2.0; *P. fuscum/mixtum*, *C. mutata*, *S. latipes*, *S. tuberosum* |
| 9. | 1 N/12 | 940695 | 2.6 mi. west of Chapel Arm-Long Harbour access; P, 15, 5.0; *P. fuscum/mixtum*, *S. latipes*, *S. tuberosum* |
| 10. | 1 N/12 | 922713 | 4.3 mi. west of Chapel Arm-Long Harbour access; P, 10, 3.0; *P. fuscum/mixtum*, *S. latipes*, *S. tuberosum*, *S. venustum* |
| 11. | 1 N/12 | 802898 | 12.7 mi. west of Bellevue east access; P, 15, 3.0; *P. fuscum/mixtum* |
| 12. | 1 N/12 | 709907 | 13.3 mi. west of Bellevue east access; P, 12, 3.0; *P. fuscum/mixtum*, *S. latipes*, *S. tuberosum*, *S. venustum* |
| 13. | 1 N/13 | 784946 | 1.1 mi. west of Jacks Pond Provincial Park access; P, 12, 2.0; *P. fuscum/mixtum* |
| 14. | 1 N/13 | 797113 | Goobies east access; P, 15, 3.0; *P. fuscum/mixtum*, *S. latipes*, *S. tuberosum*, *S. venustum* |
| 15. | 1 N/13 | 796144 | 2.2 mi. west of Goobies east access; P, 10, 3.0; *S. tuberosum*, *S. venustum*, *S. vittatum* |
| 16. | 1 N/13 | 789165 | Come By Chance River; P, 12, 4.0; *P. fuscum/mixtum*, *S. corbis* |
| 17. | 2 C/4W | 805311 | Deep Bight River; P, 15, 4.0; *P. fuscum/mixtum*, *S. corbis* |
| 18. | 2 C/4W | 784369 | Lower Shoal Harbour River; P, 20, 5.0; *P. fuscum/mixtum* |
| 19. | 2 D/8 | 134500 | 6.5 mi. west of Shoal Harbour River crossing Trans Canada Highway; P, 15, 3.0; *P. fuscum/mixtum*, *C. mutata*, *S. latipes*, *S. tuberosum*, *S. venustum* |
| 20. | 2 D/8 | 095543 | 11.1 mi. west of Shoal Harbour River crossing Trans Canada Highway, P, 15, 7.0; *P. fuscum/mixtum* |
| 21. | 2 C/12W | 813847 | 2.0 mi. west of Terra Nova National Park Headquarters; P, 15, 4.0; *P. fuscum/mixtum* |

| | | | |
|---|---|---|---|
| 22. | 2 C/12W | 807884 | 4.1 mi. west of Terra Nova National Park Headquarters; P, 15, 5.0; *P. fuscum/mixtum, S. pugetense, S. corbis* |
| 23. | 2 D/9 | 125981 | 3.3 mi. west of Glovertown access; P, 15, 1.0; *P. fuscum/mixtum, S. tuberosum, S. corbis* |
| 24. | 2 D/9 | 116984 | 4.1 mi. west of Glovertown access; P, 10, 3.0; *P. fuscum/mixtum, C. dacotensis, C. mutata, S. latipes* |
| 25. | 2 D/16 | 797092 | Middle Brook; P, 10, 6.0; *S. corbis* |
| 26. | 2 D/16 | 862181 | 9.4 mi. west of Middle Brook; I, 12, 2.0; *P. fuscum/mixtum, S. corbis* |
| 27. | 2 D/15 | 585256 | 4.7 mi. west of Little Harbour access; P, 6, 2.0; *P. fuscum/mixtum, C. dacotensis, C. mutata* |
| 28. | 2 E/3 | 431389 | Neyles Brook; P, 25, 7.0; *P. fuscum/mixtum, C. mutata, S. corbis* |
| 29. | 2 E/3 | 398422 | Notre Dame Provincial Park; P, 15, 5.0; *S. tuberosum, S. corbis* |
| 30. | 2 E/3 | 317412 | Eel Brook; P, 15, 7.0; *S. tuberosum, S. venustum, S. corbis* |
| 31. | 2 E/3 | 169311 | Jumpers Brook; P, 20, 4.0; *P. fuscum/mixtum* |
| 32. | 2 D/13 | 857217 | Leech Brook; P, 20, 6.0; *P. fuscum/mixtum* |
| 33. | 2 D/13 | 796225 | Aspen Brook; P, 15, 7.0; *P. fuscum/mixtum* |
| 34. | 2 D/13 | 795225 | 200 ft. west of Aspen Brook; T, 8, 1.5; *P. fuscum/mixtum* |
| 35. | 12 A/16E | 720245 | 4.8 mi. west of Aspen Brook; P, 12, 4.0; *P. fuscum/mixtum, S. corbis* |
| 36. | 12 A/16E | 716248 | Junction Brook; P, 15, 6.0; *P. fuscum/mixtum, S. corbis* |
| 37. | 12 H/1E | 697278 | 1.9 mi. west of Badger west entry sign; I, 10, 4.0; *P. fuscum/mixtum* |
| 38. | 12 H/1E | 667335 | Catamaran Brook; P, 15, 6.0; *P. fuscum/mixtum, S. corbis* |
| 39. | 12 H/1E | 657471 | 10.4 mi. west of Catamaran Brook; P, 12, 3.0; *P. fuscum/mixtum, C. mutata* |

| | | | |
|---|---|---|---|
| 40. | 12 H/1E | 641552 | Gull Brook; P, 10, 2.0; *P. fuscum/mixtum*, *C. mutata* |
| 41. | 12 H/8E | 653674 | 3.5 mi. west of Gull Brook; I, 8, 1.0; *P. fuscum/mixtum* |
| 42. | 12 H/8E | 605780 | Burnt Berry Brook; P, 20, 10.0; *S. corbis* |
| 43. | 12 H/8W | 502784 | 4.6 mi. west of Indian River Provincial Park; P, 8, 1.0; *P. fuscum/mixtum* |
| 44. | 12 H/8W | 450793 | 8.6 mi. west of Indian River Provincial Park; P, 15, 4.0; *P. fuscum/mixtum*, *P. pleurale* |
| 45. | 12 H/8W | 388766 | 0.7 mi. west of Baie Verte access; P, 15, 5.0; *P. fuscum/mixtum*, *P. pleurale*, *S. venustum* |
| 46. | 12 H/7E | 359744 | 3.0 mi. west of Baie Verte access; I, 15, 3.0; *P. fuscum/mixtum* |
| 47. | 12 H/7E | 343732 | 4.0 mi. west of Baie Verte access; P, 20, 5.0; *P. fuscum/mixtum* |
| 48. | 12 H/7E | 291691 | 8.3 mi. west of Baie Verte access; T, 15, 3.0; *P. fuscum/mixtum*, *S. quebecense* |
| 49. | 12 H/7W | 179617 | 4.9 mi. west of river which joins Sheffield Lake with Birchy Lake; P, 15, 1.0; *P. fuscum/mixtum* |
| 50. | 12 H/7W | 048625 | 4.6 mi. west of Birchy Narrows; P, 15, 2.0; *P. fuscum/mixtum* |
| 51. | 12 H/7W | 011696 | White Spruce Brook; P, 15, 8.0; *P. fuscum/mixtum*, *S. excisum* |
| 52. | 12 H/6E | 988661 | Flights Brook; P, 20, 4.0; *P. fuscum/mixtum* |
| 53. | 12 H/6E | 987654 | McIsaacs Brook; P, 20, 6.0; *P. fuscum/mixtum* |
| 54. | 12 H/6E | 925569 | Boot Brook; P, 20, 5.0; *P. fuscum/mixtum* |
| 55. | 12 H/3E | 825517 | Crooked Feeder; P, 20, 6.0; *P. fuscum/mixtum*, *S. venustum* |
| 56. | 12 H/3W | 727501 | 3.5 mi. west of Junction Brook; T, 15, 2.0; *P. fuscum/mixtum* |
| 57. | 12 H/3W | 649425 | 4.0 mi. west of Bonne Bay access; P, 20, 5.0; *P. fuscum/mixtum* |

| | | | |
|---|---|---|---|
| 58. | 12 H/4E | 604370 | 8.3 mi. west of Bonne Bay access; P, 25, 5.0; *P. fuscum/mixtum* |
| 59. | 12 H/4E | 578322 | 11.6 mi. west of Bonne Bay access; I, 20, 4.0; *P. fuscum/mixtum* |
| 60. | 12 H/4E | 552288 | South Brook; P, 20, 4.0; *P. fuscum/mixtum* |
| 61. | 12 A/13E | 480268 | Matthews Brook; P, 25, 4.0; *P. fuscum/mixtum* |
| 62. | 12 A/13W | 397220 | Steady Brook; P, 25, 10.0; *P. fuscum/mixtum* |
| 63. | 12 A/13W | 319142 | Whale Back Brook; P, 20, 3.0; *P. fuscum/mixtum* |
| 64. | 12 B/16E | 219052 | Pinchgut Brook; P, 25, 10.0; *P. fuscum/mixtum*, *P. pleurale*, *S. corbis* |
| 65. | 12 B/9E | 154952 | 19.9 mi. west of Corner Brook west entry; P, 15, 3.0; *P. fuscum/mixtum*, *S. venustum* |
| 66. | 12 B/9E | 142929 | Grand Lake Brook; P, 25, 6.0; *P. fuscum/mixtum*, *P. pleurale* |
| 67. | 12 B/9W | 064762 | Wheeler Brook; P, 15, 3.0; *P. fuscum/mixtum* |
| 68. | 12 B/8W | 935360 | Dribble Brook; P, 20, 10.0; *P. fuscum/mixtum*, *P. pleurale*, *S. corbis* |
| 69. | 12 B/8W | 895566 | Journois Brook; P, 20, 5.0; *P. fuscum/mixtum*, *S. venustum* |
| 70. | 12 B/7E | 854520 | Barry Brook; P, 15, 4.0; *P. fuscum/mixtum* |
| 71. | 12 B/7E | 767479 | 2.5 mi. west of Fishels River; T, 15, 3.0; *P. fuscum/mixtum* |
| 72. | 12 B/2E | 709440 | Robinsons River; P, 30, 50.0; *P. fuscum/mixtum*, *P. pleurale* |
| 73. | 12 B/2W | 681389 | Crabbes Brook; P, 20, 15.0; *P. fuscum/mixtum*, *P. pleurale* |
| 74. | 12 B/2W | 680350 | 0.7 mi. west of Crabbes Brook; I, 20, 6.0; *P. fuscum/mixtum* |
| 75. | 12 B/2W | 673316 | 2.4 mi. west of Crabbes Brook; I, 20, 5.0; *P. fuscum/mixtum* |
| 76. | 12 B/2W | 649266 | 4.8 mi. west of Crabbes Brook; I, 15, 4.0; *P. fuscum/mixtum* |

| | | |
|---|---|---|
| 77. | 12 B/2W 559189 | North Branch; P, 25, 20.0; *P. fuscum/mixtum*, *P. pleurale* |
| 78. | 11 O/15W 509103 | Coal Brook; P, 20, 5.0; *P. fuscum/mixtum* |
| 79. | 11 O/14E 470069 | 1.1 mi. west of South Branch access; P, 20, 5.0; *P. fuscum/mixtum* |
| 80. | 11 O/14E 439062 | Mollychignic Brook; P, 25, 7.0; *P. fuscum/mixtum* |
| 81. | 11 O/14E 317937 | 1.8 mi. west of St. Andrews access; P , 25, 4.0; *P. fuscum/mixtum*, *S. corbis* |
| 82. | 11 O/14W 302924 | 3.2 mi. west of St. Andrews access; I, 25, 4.0; *P. fuscum/mixtum*, *S. corbis* |
| 83. | 11 O/11E 318797 | 0.9 mi. west of J. T. Cheeseman Provincial Park; P, 15, 4.0; *P. fuscum/mixtum*, *S. corbis* |
| 84. | 12 H/3W 666513 | Nichols Brook; I, 15, 2.0; *P. fuscum/mixtum* |
| 85. | 12 H/3W 643547 | 1.7 mi. north of the Cormack access; P, 20, 4.0; *P. fuscum/mixtum* |
| 86. | 12 H/5E 612603 | 4.8 mi. north of the Cormack access; P, 25, 2.0; *P. fuscum/mixtum*, *C. mutata* |
| 87. | 12 H/5E 615639 | White Hill Brook; P, 25, 8.0; *P. fuscum/mixtum*, *P. pleurale* |
| 88. | 12 H/5E 574695 | 14.0 mi. north of the Cormack access; I, 20, 3.0; *P. fuscum/mixtum*, *C. mutata* |
| 89. | 12 H/5E 554722 | East Branch River; P, 20, 15.0; *P. fuscum/mixtum*, *P. pleurale* |
| 90. | 12 H/5E 511786 | South East Brook; P, 20, 7.0; *P. fuscum/mixtum*, *P. pleurale* |
| 91. | 12 H/5E 482799 | Dicks Brook; P, 20, 5.0; *P. fuscum/mixtum* |
| 92. | 12 H/5W 431828 | 12.6 mi. north of Wilton Dale; P, 25, 3.0; *P. fuscum/mixtum* |
| 93. | 12 H/12W 309979 | 1.1 mi. north of Norris Point west access; P, 20, 3.0; *P. fuscum/mixtum* |
| 94. | 12 H/12W 309005 | Bakers Brook; P, 20, 9.0; *P. fuscum/mixtum*, *P. pleurale* |

| | | | |
|---|---|---|---|
| 95. | 12 H/12W | 329093 | Sally Cove; P, 20, 5.0; *P. fuscum/mixtum, C. mutata* |
| 96. | 12 H/13W | 432249 | 5.7 mi. north of Western Brook; P, 15, 1.5; *P. fuscum/mixtum, P. pleurale, C. mutata, S. venustum* |
| 97. | 12 I/4E | 539544 | 6.6 mi. north of Three Mile Rock access; P, 15, 2.5; *P. fuscum/mixtum* |
| 98. | 12 J/5E | 594678 | Bowing Brook; P, 15, 7.0; *P. fuscum/mixtum* |
| 99. | 2 D/1 | 209424 | Shoal Harbour River; P, 15, 12.0; *S. corbis, S. latipes, S. tuberosum, S. venustum* |
| 100. | 1 N/12 | 911750 | 1.4 mi. east of Bellevue east access; P; *S. tuberosum, S. venustum* |
| 101. | 1 N/6 | 203564 | Grand Pond runout; P; *S. venustum* |
| 102. | 1 N/6 | 280516 | Gushues Pond runout; P; *S. tuberosum, S. venustum* |
| 103. | 1 N/6 | 299485 | 2.4 mi. east of Gushues Pond runout; P; *S. tuberosum, S. venustum* |
| 104. | 1 N/6 | 351448 | North Arm River; P; *S. venustum* |
| 105. | 1 N/7 | 492534 | Soldiers Pond; I; *S. tuberosum, S. venustum, S. vittatum* |
| 106. | 1 N/6 | 455490 | Butterpot Provincial Park; P; *P. fuscum/mixtum, S. latipes* |
| 107. | 1 N/6 | 456490 | Butterpot Provincial Park; P; *P. fuscum/mixtum, S. latipes* |
| 108. | 1 N/6 | 474519 | Kellys Pond; P; *P. fuscum/mixtum, S. quebecense* |
| 109. | 1 N/7 | 508555 | Foxtrap access; T; *P. fuscum/mixtum, C. mutata, S. latipes, S. venustum* |
| 110. | 1 N/7 | 502546 | Foxtrap access; P; *P. fuscum/mixtum, C. mutata, S. venustum* |
| 111. | 1 N/7 | 524566 | Foxtrap access; T; *S. latipes* |
| 112. | 1 N/7 | 525566 | Foxtrap access; I; *S. venustum* |
| 113. | 1 N/7 | 587596 | Paddys Pond; T; *P. fuscum/mixtum, C. mutata* |

| | | | |
|---|---|---|---|
| 114. | 1 N/7 | 587595 | Paddys Pond; T; P. *fuscum/mixtum*, C. *mutata* |
| 115. | 1 N/7 | 588596 | Paddys Pond; T; P. *fuscum/mixtum*, C. *mutata* |
| 116. | 1 N/7 | 575587 | Paddys Pond; T; P. *fuscum/mixtum*, C. *mutata*, S. *venustum* |
| 117. | 1 N/7 | 647495 | Middle Pond; T; P. *fuscum/mixtum*, C. *mutata* |
| 118. | 1 N/7 | 636463 | Long Pond; T; P. *fuscum/mixtum*, C. *mutata* |
| 119. | 1 N/7 | 634455 | Long Pond; T; P. *fuscum/mixtum* |
| 120. | 1 N/7 | 633455 | Long Pond; T; P. *fuscum/mixtum*, C. *mutata* |
| 121. | 1 N/7 | 633454 | Long Pond; I; P. *fuscum/mixtum*, C. *mutata* |
| 122. | 1 N/7 | 627440 | Long Pond; P; P. *fuscum/mixtum*, S. *tuberosum*, S. *venustum*, S. *vittatum* |
| 123. | 1 N/7 | 596607 | Paddys Pond; I; S. *latipes*, S. *venustum* |
| 124. | 1 N/10E | 749756 | Logy Bay; P; P. *fuscum/mixtum*, C. *mutata*, S. *latipes* |
| 125. | 1 N/10E | 745757 | Logy Bay; P; P. *fuscum/mixtum* |
| 126. | 2 C/11 | 452859 | Bonavista; P; P. *fuscum/mixtum*, C. *dacotensis*, C. *mutata*, S. *latipes*, S. *tuberosum*, S. *venustum* |
| 127. | 2 C/11 | 456759 | Catalina; T; C. *mutata* |
| 128. | 2 C/11 | 475781 | Catalina; P; C. *dacotensis*, C. *mutata*, S. *venustum* |
| 129. | 2 C/11 | 473789 | Catalina; P; P. *fuscum/mixtum*, C. *mutata*, S. *tuberosum*, S. *venustum*, S. *vittatum* |
| 130. | 1 N/10E | 731768 | Outer Cove; P; P. *fuscum/mixtum* |
| 131. | 1 N/10E | 718791 | Middle Cove; P; P. *fuscum/mixtum*, S. *venustum* |
| 132. | 1 N/10E | 694889 | Shoe Cove; P; S. *venustum*, S. *vittatum* |
| 133. | 1 N/15 | 661959 | Cape St. Francis; P; P. *fuscum/mixtum*, S. *venustum* |
| 134. | 1 N/15 | 659953 | Cape St. Francis; P; P. *fuscum/mixtum*, C. *mutata*, S. *latipes*, S. *tuberosum* |

| | | | |
|---|---|---|---|
| 135. | 1 N/15 | 667942 | Cape St. Francis; P; *P. fuscum/mixtum* |
| 136. | 1 N/15 | 670936 | Cape St. Francis; P; *P. fuscum/mixtum, S. latipes, S. tuberosum* |
| 137. | 1 N/15 | 677925 | Cape St. Francis; P; *P. fuscum/mixtum, C. mutata, S. venustum* |
| 138. | 1 N/15 | 677912 | Pouch Cove; P; *P. fuscum/mixtum, S. venustum* |
| 139. | 2 D/15 | 551290 | Glenwood; T; *C. mutata* |
| 140. | 1 N/10E | 699874 | Half Moon Brook; P; *P. fuscum/mixtum* |
| 141. | 1 N/10E | 699830 | Piccos Brook; P; *P. fuscum/mixtum, S. corbis, S. latipes, S. tuberosum, S. venustum, S. verecundum* |
| 142. | 1 N/10E | 700831 | Near Piccos Brook; T; *P. fuscum/mixtum* |
| 143. | 1 N/10E | 699832 | Near Piccos Brook; T; *P. fuscum/mixtum, C. mutata, S. latipes* |
| 144. | 2 D/16 | 978092 | Near Middle Brook; T; *S. corbis, S. venustum* |
| 145. | 2 C/12W | 964922 | Eastport; T; *P. fuscum/mixtum, C. mutata, S. venustum* |
| 146. | 2 D/9 | 101981 | Near North West Brook; T; *P. fuscum/mixtum, C. mutata* |
| 147. | 2 D/9 | 090989 | Near North West Brook; T; *P. fuscum/mixtum, C. mutata* |
| 148. | 2 D/9 | 099989 | Near North West Brook; T; *P. fuscum/mixtum, C. mutata* |
| 149. | 2 C/12W | 807884 | Terra Nova National Park; P; *P. fuscum/mixtum* |
| 150. | 2 C/4W | 840360 | Random Island; T; *P. fuscum/mixtum, C. mutata* |
| 151. | 2 C/4W | 867375 | Random Island; P; *P. fuscum/mixtum* |
| 152. | 1 N/7 | 612392 | Bay Bulls; T; *P. fuscum/mixtum* |
| 153. | 1 N/7 | 612391 | Bay Bulls; P; *P. fuscum/mixtum, S. tuberosum* |
| 154. | 1 N/7 | 641476 | Middle Pond; T; *P. fuscum/mixtum, C. mutata, S. venustum* |

| | | | |
|---|---|---|---|
| 155. | 1 N/7 | 551584 | Manuels River; P; *P. fuscum/mixtum, C. mutata, S. aureum, S. furculatum, S. decorum, S. latipes, S. tuberosum, S. venustum, S. vittatum, S. corbis* |
| 156. | 1 N/7 | 552583 | Near Manuels River; T; *P. fuscum/mixtum, S. latipes, S. venustum, S. vittatum* |
| 157. | 1 N/7 | 552584 | Near Manuels River; P; *S. decorum, S. latipes, S. tuberosum, S. venustum, S. vittatum* |
| 158. | 1 N/7 | 553584 | Near Manuels River; T; *S. latipes, S. venustum, S. verecundum, S. vittatum* |
| 159. | 1 N/7 | 552586 | Near Manuels River; T; *P. fuscum/mixtum* |
| 160. | 1 N/10d | 524642 | Long Pond; P; *P. fuscum/mixtum, S. latipes, S. venustum* |
| 161. | 1 N/10d | 520641 | Long Pond; P; *S. corbis* |
| 162. | 1 N/6 | 478623 | Kelligrews; P; *P. fuscum/mixtum, S. corbis* |
| 163. | 1 N/6 | 458607 | Upper Gullies; P; *P. fuscum/mixtum, S. latipes, S. venustum* |
| 164. | 1 N/6 | 441575 | Seal Cove; P; *P. fuscum/mixtum, S. corbis, S. venustum* |
| 165. | 1 N/6 | 400508 | Holyrood; P; *P. fuscum/mixtum, S. venustum* |
| 166. | 2 C/11 | 350758 | Upper Amherst Cove; P; *P. fuscum/mixtum, C. mutata, S. venustum, S. vittatum* |
| 167. | 1 N/7 | 585598 | Paddys Pond; T; *P. fuscum/mixtum, C. mutata, S. latipes, S. venustum* |
| 168. | 1 N/10E | 699833 | Near Piccos Brook; T; *S. tuberosum, S. venustum, S. corbis* |
| 169. | 2 C/11 | 440894 | Bonavista; T; *S. venustum, S. verecundum* |
| 170. | 2 C/11 | 269786 | Stock Cove; P; *S. tuberosum, S. verecundum, S. venustum* |
| 171. | 2 C/11 | 424865 | Bonavista; P; *S. latipes, S. venustum, S. verecundum* |
| 172. | 1 N/10E | 716795 | North Pond Brook; P; *S. venustum* |
| 173. | 1 N/5W | 851393 | Dunville; T; *S. venustum* |

| | | | |
|---|---|---|---|
| 174. | 1 N/5W | 852394 | Dunville; T; *S. tuberosum, S. venustum* |
| 175. | 1 N/5W | 851392 | North East River; P; *S. venustum* |
| 176. | 1 N/5W | 853387 | Dunville; P; *S. tuberosum, S. venustum* |
| 177. | 2 C/4W | 794220 | Queen's Cove; T; *S. venustum, S. vittatum* |
| 178. | 2 D/16 | 004073 | Square Pond; T; *S. latipes, S. venustum* |
| 179. | 2 C/12 | 871918 | Traytown; T; *S. tuberosum, S. venustum S. vittatum* |
| 180. | 1 N/12 | 907774 | Bellevue; T; *S. gouldingi, S. latipes, S. tuberosum, S. venustum* |
| 181. | 12 H/8E | 606828 | Springdale; T; *P. fuscum/mixtum, C. mutata* |
| 182. | 12 H/1E | 678302 | Badger; P; *P. fuscum/mixtum, C. mutata, S. venustum* |
| 183. | 1 N/10E | 694866 | Near Half Moon Brook; T; *P. fuscum/mixtum, C. mutata* |
| 184. | 2 C/6W | 252673 | Lockston; P; *S. vittatum* |
| 185. | 1 N/10E | 771641 | Spear Bay Brook; P; *P. fuscum/mixtum, S. latipes, S. venustum* |
| 186. | 1 K/15W | 493898 | Cappahayden; P; *S. latipes, S. venustum, S. tuberosum* |
| 187. | 2 C/11 | 371790 | Catalina; P; *S. tuberosum, S. venustum* |
| 188. | 2 C/12W | 577943 | Sandy Cove; I; *S. latipes, S. tuberosum, S. venustum* |
| 189. | 1 N/5W | 922498 | Long Harbour; T; *S. verecundum* |
| 190. | 1 N/5W | 923534 | Long Harbour; I; *S. aureum, S. verecundum, S. vittatum* |
| 191. | 1 N/5W | 922543 | Long Harbour; I; *S. decorum, S. verecundum* |
| 192. | 1 N/5W | 912581 | Long Harbour; P; *S. verecundum* |
| 193. | 2 C/11 | 415842 | Birchy Cove; P; *S. tuberosum, S. verecundum, S. vittatum* |
| 194. | 1 N/12 | 866787 | Doe Hills; T; *S. tuberosum, S. verecundum* |

| | | | |
|---|---|---|---|
| 195. | 2 C/11 | 447866 | Bonavista; P; *S. verecundum*, *S. vittatum* |
| 196. | 1 N/6 | 446503 | Butterpot Provincial Park; P; *S. tuberosum*, *S. venustum* |
| 197. | 1 N/6 | 445504 | Butterpot Provincial Park; P; *S. tuberosum*, *S. venustum* |
| 198. | 2 C/6W | 250673 | Lockston Path Provincial Park; T; *S. latipes*, *S. venustum* |
| 199. | 2 C/5 | 040625 | Sweet Bay; T; *S. latipes*, *S. venustum* |
| 200. | 2 C/11 | 405854 | Birchy Cove; P; *P. fuscum/mixtum* |
| 201. | 1 N/5W | 854395 | Dunville; T; *C. mutata* |
| 202. | 1 N/14 | 297951 | Victoria; I; *S. venustum*, *S. vittatum* |
| 203. | 1 N/14 | 312939 | Victoria; I; *S. venustum* |
| 204. | 2 C/11 | 457758 | Lookout Pond outflow; P; *S. venustum* |
| 205. | 1 N/6 | 396445 | Near Four Mile Pond; T; *S. latipes* |
| 206. | 1 N/7 | 591604 | Pickavance Creek; P; *P. fuscum/mixtum*, *C. mutata*, *S. latipes*, *S. tuberosum*, *S. venustum*, *S. verecundum* |
| 207. | 1 N/7 | 592605 | B creek; P; *P. fuscum/mixtum*, *C. mutata*, *S. aureum*, *S. latipes*, *S. tuberosum*, *S. venustum*, *S. verecundum* |
| 208. | 1 N/7 | 591605 | C creek; P; *P. fuscum/mixtum*, *C. mutata*, *S. aureum*, *S. gouldingi*, *S. latipes*, *S. tuberosum*, *S. venustum*, *S. verecundum* |
| 209. | 1 N/7 | 590602 | D creek; T; *P. fuscum/mixtum*, *C. mutata*, *S. aureum*, *S. gouldingi*, *S. latipes*, *S. tuberosum*, *S. venustum*, *S. verecundum* |
| 210. | 1 N/7 | 591603 | E creek; T; *P. fuscum/mixtum*, *C. mutata*, *S. gouldingi*, *S. latipes*, *S. venustum* |
| 211. | 1 N/7 | 591602 | F creek; T; *P. fuscum/mixtum*, *C. mutata*, *S. aureum*, *S. gouldingi*, *S. latipes*, *S. tuberosum*, *S. venustum*, *S. verecundum* |
| 212. | 1 N/7 | 591601 | G creek; P; *P. fuscum/mixtum*, *C. mutata*, *S. aureum*, *S. gouldingi*, *S. latipes*, *S. tuberosum*, *S. venustum*, *S. verecundum* |

## APPENDIX B

Occurrence of dominant streamside vegetation in the Pickavance Creek area

| Vegetation | Creek and Site | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pickavance Creek | | | | | | | | | | | B | C | D | | E | F | G | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | | 1 | 2 | | | 1 | 2 |
| *Picea mariana* (Mill.) B.S.P. | x | | | | x | | | | | | | | | | | | | | |
| *Abies balsamea* (L.) Mill. | x | | | | x | | | | | | | | | | | | | | |
| *Rubus idaeus* L. | | | | | | | | x | | | | | | | | x | | | |
| *Picea glauca* (Moench) Voss | x | | | | x | | | | | | | | | | | | | | |
| *Solidago rugosa* Ait. | | x | x | x | x | x | x | x | | x | x | x | | x | | x | x | x | x |
| *Aster puniceus* L. | | x | x | x | x | x | x | x | | x | x | | x | x | | x | x | x | x |
| *Ranunculus acris* L. | | x | x | x | x | x | x | x | | x | x | | | | x | | | x | x |
| *Viburnum cassinoides* L. | | | | x | | | x | | | | | | | | | | | | |
| *Acer spicatum* Lam. | x | | | | x | | x | | | | | | | | | | | | |
| *Anaphalis margaritacea* (L.) Gray | | | | | | | | x | | | | | x | | | | | | |
| *Betula papyrifera* Marsh. | x | x | | x | x | x | x | | | | | | | | | x | | x | |
| *Alnus rugosa* (DuRoi) Spreng. | x | x | | | | x | x | x | | x | x | x | x | x | x | x | x | | x |
| *Myrica Gale* L. | | x | x | x | x | | x | | | x | x | x | x | x | x | x | x | x | x |
| *Prunus virginiana* L. | | | | | | | x | | | | | | | | | | | | |
| *Prunus pensylvanica* L.f. | | | | | | x | | | | | x | | x | | | x | | | |
| *Sorbus americana* (Marsh.) D.C. | | | | | | | x | | | | | | | | | | | | |
| *Viburnum edule* (Michx.) Raf. | | | | | | x | | | | | x | | | | | x | | | |
| *Juncus effusus* L. | | | | x | | x | | | | | x | x | x | x | x | x | x | x | x |
| *Salix candida* Flugge | | | | | | | | | | x | x | | | | | x | | | |
| *Athyrium filix-femina* (L.) Roth | | x | x | | x | x | | | | | x | | | x | | | | | x |
| *Onoclea sensibilis* L. | | x | x | | x | x | | | | | x | | | x | | | | | x |
| *Equisetum arvense* L. | | | | | | | | | | | | | | | | | x | x | x |
| *Polytrichum commune* Hedw. | x | x | x | x | x | x | x | | | | | x | x | | | | | | |
| *Sphagnum recurvum* P. Beauv. | x | x | x | x | x | x | x | | | | | x | x | | | | | | |
| *Aulacomnium palustre* (Hedw.) Schw. | x | x | x | x | x | x | x | | | | | x | x | | | | | | |
| *Larix laricina* (DuRoi) K. Koch | | | | | | | | | | | | | x | | | | | | |
| *Rosa nitida* Willd. | | | | | | | | | | | | | | | | | | | x |
| *Viola cucullata* Ait. | | | | x | | | | | | | | | | | | | | | |
| Grasses | | x | x | x | x | x | x | x | | x | x | x | x | x | x | x | x | x | x |