FLIGHT AND HOST SEEKING BEHAVIOUR OF ADULT BLACK FLIES IN THE SOURIS RIVER AREA, MANITOBA

BY

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A thesis submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

MASTER OF SCIENCE

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ABSTRACT

Van Deveire, Peter Joseph. M.Sc., The University of Manitoba, September, 1981.

Flight and Host Seeking Behaviour of Adult Black Flies in the Souris River Area, Manitoba. Major Professor; R. A. Brust.

Flight and host-seeking activity of adult black flies were studied in the Souris River area, Manitoba. Six species, *Simulium meridionale*, *Simulium luggeri*, *Simulium johannseni*, *Simulium venustum/verecundum* complex and *Simulium vittatum* were potential pest species. These black flies fed on cattle, humans, poultry and horses. *Simulium meridionale* and *Simulium luggeri* are potentially the most important black fly pests in this area because they are abundant, they attack a wide range of hosts and they are multivoltine in the Souris River.

Flight and feeding activity occurred between 0600 h and 2200 h, at air temperatures between 17.3^{0}C and 36.7^{0}C, at relative humidities between 7% and 81% at light intensities between 0.6 and 11,250 lux, at winds with gusts up to 15.7 km/h and on days with 0-100% cloud cover. Most host-seeking adults were active between 1900 h and 2100 h, at air temperatures between 25^{0}C and 30^{0}C and at light intensities between 60 and 1,620 lux.

Simulium meridionale, *Simulium luggeri*, *Simulium johannseni* *Simulium venustum/verecundum* complex are anautogenous while *Simulium vittatum* and *Cnephia dacotensis* are autogenous.

Cone samplers did not correctly estimate larval populations, and were of little value in predicting adult population size. Cone samplers gave the relative stage of development and the relative proportions of black fly species present.

CHAPTER I

Introduction

Severe black fly outbreaks were first reported in the Hartney-Cameron area of the province of Manitoba in 1949 (Michener unpub. rept. and Bird unpub. rept.). Cattle, horses, poultry and humans were all attacked by simuliids. Due to continuous outbreaks in the early 1950's, the river was treated with DDT to reduce simuliid populations.

More recent black fly outbreaks in the spring and early summer of 1974 and 1975, resulted in the death of numerous domestic chickens and wild birds. Several humans in the area were hospitalized and outdoor activities were curtailed during attacks. These outbreaks prompted the residents of the Hartney-Cameron area to request assistance from the Government of Manitoba. In 1976, high water levels and high black fly numbers led to the use of the larvicide, methoxychlor, to control black fly breeding in the Souris River. Since this treatment, Westwood (1979) studied the biology and ecology of immature simuliids in the Souris River. He found five species, *Simulium* (*Phosterodorus*) *luggeri* Nicholson and Mickel, *Simulium* (*Byssodon*) *meridionale* Riley, *Simulium* (*Simulium*) *venustum* Say, *Simulium* (*Simulium*) *verecundum* Stone and Jamnback and *Simulium* (*Eusimulium*) *johannseni* Hart to be potential pest species. These simuliids were observed feeding on cattle, horses, poultry and humans. Westwood (1979) found that *S. johannseni* and the

S. venustum/verecundum complex were the first simuliids to emerge in spring, followed 10 to 14 days later by S. luggeri and S. meridionale. He recommended that two larvicide treatments should be undertaken to control simuliid populations: the first aimed at S. johannseni and S. venustum/verecundum; the second at S. luggeri and S. meridionale.

The present study was undertaken during the summers of 1979 and 1980 to study adult flight activity and host-seeking behaviour of simuliids in the Souris-Hartney area. Females were given a choice of domestic fowl (turkeys and chickens) or a bovine host. Flies feeding on equines, humans and a small herd of cattle were sampled on an irregular basis (mainly, as time permitted), and identified to species.

CHAPTER II

Literature Review

Section A - Review of Capture Studies of North American Black Fly Adults Using Carbon Dioxide-Baited Traps and Animal-Baited Traps

Carbon Dioxide-Baited Traps. In the U.S.A., Snoddy and Hays (1966) were the first to report that more simuliids were attracted to humans when a stream of CO_2 was supplied through clothing than without. Using modified New Jersey light traps and CO_2, Snoddy and Hays were able to captured 11 species of simuliids, including *Simulium vittatum* Zetterstedt, *Simulium venustum* Say, *Simulium tuberosum* Lundström and *Simulium decorum* Walker. The average catch was 45 flies per h while traps without CO_2 collected few flies.

In Ontario, CO_2 was provided from cylinders along with the ether extracts of ducks and loons to study the behaviour of simuliids (Fallis and Smith, 1964). They found that *Simulium rugglesi* Nicholson and Mickel is attracted in greater numbers to a combination of CO_2 and an ether extract of the uropygial gland of ducks than to the ether extract alone. In Ontario, Canada, Baldwin *et al*. (1966) caught large numbers of *S. venustum* females with cylindrical, dark blue sticky traps baited with dry ice.

Upwind orientation to CO_2 by *S. venustum* was studied in Ontario

by Golini and Davies (1971) confirming the findings of Smith (1966) who first proposed the hypothesis of upwind orientation of simuliids to CO_2 during host seeking.

In Newfoundland, Bradbury and Bennett (1974) reported that the number of simuliids orientating to a CO_2 source decreased with the distance downwind from the source. In Algonquin Park, Ontario, simuliids were numerous in fan traps and on sticky flesh coloured cylinders and mannequins only when CO_2 was released nearby (Fallis *et al.*, 1967). Ninety to 99% of simuliid catches consisted of *S. venustum*, the remaining being mostly *S. decorum*. They found that the greater the discharge of CO_2 the higher the number of simuliids caught.

Animal-Baited Traps. Large and small cages or traps, containing animals, were used in the U.S.A. and Canada to study simuliid biting activity (Bennett, 1960; Anderson and Defoliart, 1961; Roberts, 1965; Wright and Defoliart, 1970; Service, 1977; Shemanchuk, 1978).

In Algonquin Park, Ontario, Bennett (1960) exposed birds in 400 or 900 cubic cm boxes having tops and sides made of chicken wire or heavy mesh netting, and bottoms made of 1.2 cm mesh hardware cloth. Cages were placed at heights varying from the ground to 7.6 m in the tree canopy. Flies were given 20-30 min. to feed and cages were then covered with nylon netting. Blood-fed *S. venustum* were captured, primarily along the lake shore and the ground, around ravens, ruffed grouse, domestic ducks, crows, grackles, robins and saw-whet owls. Blood-fed *S. decorum* were taken from crows and domestic ducks, at the lake shore and at ground level. Other simuliids, including *S. aureum* Fries and *S. latipes* (Meigen) were at greater heights in forest habitats

(Bennett, 1960).

In Wisconsin, Anderson and Defoliart (1961) confined a variety of wild and domestic birds and small mammals to wire mesh cages, 61 x 30.5 x 30.5 cm or 50 x 41 x 30.5 cm. After 30 minutes they were covered with a cardboard box. Flies were allowed to escape from windows cut into the sides of the box. Windows were fitted with sleeves of cheesecloth. A sheet of cheesecloth larger than the bottom of the box was attached to the lower edge of one side of the box. As the box was lifted from the cage, the sheet of cheesecloth was drawn over the open bottom to prevent black flies from escaping. Flies were then aspirated from the box. S. johannseni and S. meridionale fed on domestic turkeys (white and bronze varieties), white Leghorn chickens, ring-necked pheasants, domestic white Pekin ducks, ring-necked doves, and starlings. Blood-fed S. decorum were taken from horses, cattle, and white-tail deer; S. venustum from humans, horses, cattle, white-tail deer and sheep; S. tuberosum from humans, and S. vittatum from horses and cattle.

In Mississippi, Roberts (1965) used a steer-baited trap, 1.5 x 1.8 x 2.1 m having the top and sides covered with a fine mesh screen. An internal stanchion was constructed and extended the full length of the trap. A door was provided at one end of the trap to gain admittance. Flies entered the trap through a series of angled baffles constructed into the sides of the traps. Blood-fed S. vittatum were captured in this trap.

In Wisconsin, Wright and Defoliart (1970) used animal traps, 45 x 50 x 50 cm having a wooden frame, wooden top and bottom and sides covered with saran screen. A 10 cm angled baffle with a 2 cm opening was

positioned 10 cm from the top and along the entire length of each side. Plywood doors were attached to the frame at the front centre of the trap for removal and placement of the caged animal. In these traps, 2 of 41 flies of the S. venustum-tuberosum complex, attracted to racoon, were engorged and 1 fly attracted to a fawn deer was engorged. Although S. johannseni and S. meridionale were attracted to racoon and woodchuck they did not feed. S. meridionale engorged on chickens (1,283 of 1,501 flies attracted to chickens were engorged) and on humans during the summer of this study. On two occasions, it was confirmed that this fly feeds on humans either indoors or in a screened porch (Wright and Defoliart, 1970).

In Alberta, Shemanchuk (1978) used a steer-baited trap which differed from Roberts (1965) in that the sides of the trap were completely removed between collections. In this way flies which were present on the host as it entered the trap could not accidently become trapped in the cage. Several steers were trained to enter the stanchion of the trap, at which time the sides made of fine nylon mesh, were lowered as quickly as possible. The steer was covered for 10 min. to allow flies to complete feeding and settle on the walls and ceiling of the trap. A collector would then enter the trap and aspirate adults into 70% ethanol. Blood-fed and non blood-fed S. venustum, S. vittatum and S. decorum were successfully collected by this method.

Section B - Review of Host Specificity and Site of Attack of Some North American Simuliids

Simulium (Simulium) venustum Say. In Ontario, S. venustum feeds on birds and mammals but prefers mammals (Bennett, 1960). This simuliid

feeds at the back of the neck, behind the ears and on the forearms and ankles of humans (Wolfe and Peterson, 1960). S. venustum was also reported to feed on the eyes, ears and nose of beaver in Ontario (Davies and Peterson, 1956).

In Wisconsin, this simuliid feeds on horses in preference to cattle, humans, dogs, cats or birds (Anderson and Defoliart, 1961). Here, S. venustum feeds on the chest, neck, behind the jaw and on the inner margin of the legs of horses. In Virginia, Teskey (1960) reported that S. venustum fed over the general body surface of cattle. In Manitoba, blood-fed S. verecundum, a species closely related to S. venustum, has been taken from humans and horses (Westwood, 1979). Few other reports of hosts attacked by S. verecundum are available (Golini and Davies, 1975a).

Simulium (Phosterodorus) luggeri Nicholson and Mickel. In Saskatchewan and Manitoba, S. luggeri feeds on horses, cattle and humans (Fredeen, 1977). This fly swarms around the head of cattle and feeds aggressively about the eyes (Fredeen, 1977). This mode of attack makes this simuliid very alarming to cattle and attacks often result in the death or injury to animals through stampeding and trampling.

Simulium (Byssodon) meridionale Riley. In Wisconsin, S. meridionale feeds on a wide variety of bird hosts and is the most common simuliid feeding on turkeys and chickens (Anderson and Defoliart, 1961). Flies feed on the unfeathered head and comb and beneath the feathers of large turkeys. On young poults, this simuliid prefers to attack the feathered body over the head area.

Reports of this simuliid feeding on humans (Anderson and Defoliart,

1961; Defoliart and Rao, 1965; Wright and Defoliart, 1970 and Westwood, 1979) and on cattle (Westwood, 1979) suggest that this fly is not restricted to avian hosts.

S. meridionale is the principal vector of Leucocytozoon in turkeys in Wisconsin (Anderson and Defoliart, 1961) and strong evidence suggests that this simuliid may vector Leucocytozoon to turkeys in Manitoba as well (Fredeen, 1977). In Wisconsin, Eastern Equine Encephalitis has been isolated from this simuliid (Anderson and Defoliart, 1961).

Simulium (Eusimulium) johannseni Hart. In Wisconsin, S. johannseni feeds on a variety of avian hosts but prefers to feed on chickens rather than on pheasants, and on turkeys rather than chickens or pheasants. Reports by Anderson and Defoliart (1961), indicated that greater numbers of this simuliid were taken at the lower forest canopy than at ground height perhaps suggesting a preference for birds over mammals. However, in Manitoba, Westwood (1979) has took blood-fed S. johannseni from humans and cattle. Eastern Equine Encephalitis has been isolated from S. johannseni in Wisconsin (Anderson and Defoliart, 1961).

Simulium (Psilozia) vittatum Zetterstedt. In Utah, Knowlton and Maddock (1944), and in Virginia, Townsend et al. (1977), found that S. vittatum prefers to feed on the ears of horses. In California, Anderson and Voskuil (1963) and in Manitoba, Westwood (1979), took this simuliid from the ears of horses and cattle. However, in Ontario, Teskey (1960) observed this simuliid feeding on cattle only. In Utah, Knowlton and Maddock (1944) found S. vittatum to feed on the head, neck, shoulders, back, front legs, brisket and the underbelly of horses.

Section C - Behaviour of Some North American Simuliids During Various Meteorological Conditions

Host-seeking Activity. Host-seeking behaviour of simuliids during various meteorological conditions, indicate that flight occurs under a wide range of conditions (Underhill, 1940; Davies, 1950; Davies, 1952; Davies, 1953; Davies and Peterson, 1956; Wolfe and Peterson, 1960; Anderson and Defoliart, 1961; Alverson and Noblet, 1976).

Air temperatures below 7^0 to 9^0C and above 30^0C in Wisconsin inhibit simuliid flight and feeding activity (Anderson and Defoliart, 1961; Alverson and Noblet, 1976). In Ontario, Davies (1952) reported that the highest number of S. venustum adults landed on human skin at air temperatures between 13^0C and 18^0C. He found no correlation between landing rates and air temperature, but reported that landing rates dropped to ½ and biting rates to ¼ when human skin was exposed to direct sunlight. Davies suggested that some black flies seem very susceptible to dessication under hot, dry conditions. In Virginia, Underhill (1940) reported that maximum simuliid feeding occurred between relative humidities of 65% and 75% and between air temperatures 24^0C and 29^0C with few flies feeding below 21^0C. Simuliids remained active under a greater range of relative humidity than air temperature. Air temperature therefore was the more limiting factor. Unfortunately, Underhill does not indicate which simuliid species he worked with. In Quebec, Wolfe and Peterson (1960) found that S. venustum feeding activity was curtailed at relative humidity extremes below 25% and above 95% and at air temperatures below 7^0C and above 30^0C.

In Wisconsin, Anderson and Defoliart (1961) reported that hundreds

of S. venustum fed on horses under overcast skies and at an air temperature of 15^{0}C and a relative humidity of 79%. During the initial period of attack flies were present throughout the day but in following days biting activity was greatest in the evening.

Many simuliids have a diurnal feeding pattern with morning and evening peaks (Wolfe and Peterson, 1960; Anderson and Defoliart, 1961). In Quebec, the peak activity of S. venustum occurred 1 to 2 h after dawn and ½ to 1 h before sunset at light intensities of 215 lux and 54 lux respectively (Wolfe and Peterson, 1960). Wolfe and Peterson suggested that greater peak periods of activity in the evening may have been related to higher air temperatures before sunset than after dawn.

Anderson and Defoliart (1961) reported that simuliids, including S. johannseni, S. meridionale, S. decorum, S. luggeri, S. venustum and S. vittatum, fed continually throughout warm overcast or sunny days, with morning and evening peaks of activity. No feeding occurred after dark. They found that morning and evening peaks of activity were correlated with peaks in relative humidity. However, in British Columbia, Wellington (1974) found no such correlation.

In South Carolina, Alverson and Noblet (1976) reported that simuliids, including Simulium slossonae (Dyar and Shannon), were active at light intensities between 17 and 27,500 lux. Feeding activity was reduced between 1000 h and 1600 h or during the time of greatest light intensity. They concluded that simuliid feeding activity was correlated to light intensity, air temperature, relative humidity and time of day. They also reported that significant increases in activity occurred during the presence of cumuliform clouds. The presence of cumuliform clouds was regularly associated with small changes in barometric

pressure throughout this study. In British Columbia, Wellington (1974) correlated the approach of cumulus clouds to small fluctuations in barometric pressure. He reported that in the absence of an indigenous breeding population of simuliids, swarms suddenly appeared as cumulus clouds passed directly overhead, or plus or minus 20 degrees to either side of the zenith.

In Utah, Peterson (1956) reported that simuliids, including S. arcticum, S. tuberosum and S. vittatum, seldom fed on humans below 2,100 m but did so quite readily above this elevation. Peterson (1956) suggested that simuliid feeding activity increases at high elevations where barometric pressure is lower. One record of S. vittatum feeding on humans at 1,300 m may have been due to low barometric pressure. In Virginia, Underhill (1940) found that maximum feeding activity occurred at barometric pressures between 701 and 712 mm Hg at an elevation of 610 m. He also reported that a dropping barometric pressure, as occurs before thunderstorms, increased simuliid feeding activity. In Ontario, Baldwin and Gross (1972) reported that rainfall preceded increases in simuliid activity. However, in Quebec, Wolfe and Peterson (1960) found that black fly activity increased preceding thunderstorms and rain and attributed these increases to changes in light intensity.

Feeding activity of most simuliids is severely reduced at wind speeds greater than 8 km/h (Underhill, 1940; Wolfe and Peterson, 1960). However, Alverson and Noblet (1976) reported simuliid activity at wind speeds of 19 km/h. In Algonquin Park, Davies (1952) reported that the flight activity of S. venustum was reduced at wind speeds greater than 24 km/h.

Alverson and Noblet (1976) concluded that less than 25% of all

changes in simuliid activity could be attributed to changes in relative humidity, barometric pressure, percent cloud cover or hourly light intensity at individual trapping sites. However, light intensity is considered by many to be the singular most important meteorological factor governing black fly activity (Davies, 1952; Wolfe and Peterson, 1960; Anderson and Defoliart, 1961).

Oviposition Activity. Simuliids lay eggs in rivers, creeks and streams or on vegetation, dam faces, rocks or debris found in flowing water. Those simuliids which oviposit directly into the water do so by touching or dipping the abdomen into the water while in flight (Davies, 1950; Hocking and Pickering, 1954; Davies and Peterson, 1956) or land to oviposit on a suitable substrate (Golini and Davies, 1975b). Davies and Peterson (1956) reported that *S. decorum* and *S. vittatum* engage in both methods while *S. venustum* and *S. verecundum* oviposit on vegetation (Merrit *et al.*, 1978). *S. venustum* was observed to oviposit frequently on cattail, *Typha latifolia* Linnaeus and less frequently upon reed meadow grass, *Glycera grandis* Wats., bur reed, *Sparangium sp.*, eelgrass, *Vallisneria spiralis* Linnaeus, leaves of alder, *Alnus rugosa* Spreng. and meadow rue *Thalictrum polygamum* Muhl. (Davies and Peterson, 1956). In the absence of suitable oviposition substrates, *S. venustum* has been observed to lay eggs on filamentous green algae floating at the water surface (Davies and Peterson, 1956). Most eggs were laid on days during which thunderstorms occurred, between 1800 h and 2045 h, at light intensities between 0 and 1,145 lux and at air temperatures between 11^0C and 27^0C. *S. venustum* also oviposited on evenings with little or no wind, on overcast days and on warm sunny days (Davies and Peterson, 1956).

In Ontario and Quebec, Davies and Peterson (1956) and Corbet (1967) reported that oviposition peaks for S. vittatum occurred near sunset and less frequently shortly after sunrise.

CHAPTER III

Materials and Methods

Section A - Sampling and Rearing Methods for Eggs and Immatures

Eggs. Eggs of *Simulium vittatum* were collected during 1979 and 1980 from various substrates: vegetation, rocks, sticks, moist dam faces, sluice gates, algae, pieces of 1 cm dia. yellow nylon ropes (Fig. 15), expanded polystyrene floats (Fig. 14) and occasionally from a larval cone sampler. Forceps were used to scrape eggs from the substrate. Some eggs were preserved in 70% ethyl alcohol, and some were transported to the laboratory on wet paper towels. Time of day, air temperature, relative humidity, wind velocity and light intensity were recorded when freshly laid eggs were found.

Immatures.

Collection of Immatures. Immatures were collected in 1979 and 1980 from vegetation, sticks, rocks and artifical samplers. Artificial samplers consisted of white polystyrene cones 18.5 cm long x 10 cm maximum dia. (Fig. 2). A cone sampler set consisted of 3 cones, each 1.5 m apart, tied to a 6.3 mm nylon rope. About 5 kg of building bricks were attached to one end of the nylon rope to act as an anchor and a 900 cm^2 expanded polystyrene float, 4 cm in thickness, was tied to the other end of the rope. Cone samplers were placed into the river from bridges at sites 4 and 5, since the water was too deep to navigate at

these locations. Two sampler sets were placed in the river at each site and sampled weekly. The sampler sets were placed equidistant from each river bank. Immatures were removed from cones by forceps and placed in 95% ethyl alcohol. Cones were thoroughly cleaned each week, and returned to the river. Cones were the only artificial samplers used in 1979 and 1980. Immatures were also removed from natural substrates at or near the edge of the river. Occasionaly vegetation was removed with live immatures and placed into 95% ethyl alcohol.

Transport of Immatures and Rearing of Pupae. Live immatures were transported to the laboratory on wet paper towelling. Natural substrates were sampled along the river bank at a variety of depths and when possible at random locations all across the river. In the laboratory, pupae were removed from natural substrates by grasping the posterior tip of the cocoon with forceps and gently pulling upward. Pupae were then placed individually on wet paper towelling, and each pupa covered with a 2 cm x 1.5 cm cylindrical cage made from plastic tubing and fine mesh screening. After ecolsion, adults were placed in 95% ethyl alcohol for five seconds and then transferred immediately to Belar's modified physiological saline (Hayes, 1953) for dissection of ovaries. Pupae were reared at 22^0C and 5^0C and at light:dark photoperiod of 16:8.

Rearing of Larvae. In 1979, larvae were reared using three rearing methods: in all methods, 100 larvae, instars 5-7, were placed in a clear Perspex^R (plastic) container 26 cm in diameter and 9 cm deep. Three and one half litres of tap water were added to the container. In the first method, water was circulated by an air current which made contact with the water at an angle 20 degrees from horizontal and at a point corresponding to one half the radius of the rearing container.

Filtered, compressed, air was delivered via a glass tube fashioned to release a fan shaped current of air from its tip. A second glass tube was placed with tip at the centre of the container to provide aeration and to prevent clustering of larvae in this location. Both tubes were fastened to the top edge of the container. Screw clamps were placed on the hose, to regulate the flow of air and current speed. A coil was fashioned out of 6.3 mm black rubber hosing, and fixed to a 15 cm long x 15 cm wide piece of clear flat Perspex^{R}. This was placed in the bottom of the container. One free end of the hose was attached to a water tap and the other to the sink drain. Water temperature of the container was then regulated by passing water through the coil in a direction opposite to the current of water. Water temperature was maintained at 20^{0}C in this apparatus and larvae were reared at light:dark 16:8. Stones were placed in the bottom of the container for larval attachment. A mixture of 50% Fleischmann's active dry yeast and 50% TetraMin^{R} fish food was placed in a mortar with a small amount of tap water and ground to a fine paste. A dilute mixture was then poured into the rearing container until the water became milky. The mixture was fed every second day or when the water became clear. The medium was changed on alternate days by siphoning off the old medium and adding new. Water lost through evaporation was replenished.

In the second rearing procedure, a Corning PC-353 magnetic stirrer was used to create a water current. This method was used at 20^{0}C and 5^{0}C. The rearing container, 26 cm in dia. and 9 cm deep, held 3.5 l of water. A clear glass jar, 7.5 cm in dia. and 4.8 cm deep, was placed in the centre of the rearing container. A 1 cm x 4 cm magnetic stirring

bar was then placed into the jar. Four Perspex^R larval attachment plates were regularly spaced about the central glass jar and glued to the bottom of the container with epoxy glue. The air supply was filtered through a flask filled with glass wool, and then passed through an air stone. One hundred larvae, instars 5-7, were placed in the rearing container and fed a dilute diet of yeast. Yeast was fed every second day or when the water became clear. The medium was siphoned off on alternate days, and clean medium was added. Water lost by evaporation was replenished.

A cage, covered with fine mesh screening, was placed over the rearing tank to capture emerging adults. A small platform was provided around the base of the cage as a resting area for emerging flies. The emergence cage was used in rearing methods one and two. For longer storage, adults were moved to Perspex^R cages 18 cm to a side.

The third rearing apparatus consisted of an aquarium tank 51 cm x 53 cm x 22 cm. A clear plate of glass, 5 mm in thickness, 20 cm wide and 57 cm long was placed at an angle of 30 degrees, extending from the lower corner of the tank to the upper edge of the opposite side. The glass was held in place by 12.5 mm diameter rubber hose slit longitudinally and placed between the tank wall and the edge of the glass plate. Air was supplied to the bottom of the aquarium. A water current was created along one side of the tank, as bubbles rose from the tip of the air hose at the lower edge of the glass plate. River water was collected from the dam at site 4 and stored in the dark at 5^0C. The water was replaced periodically by siphoning off a portion of the old and adding fresh river water from a supply at 5^0C. No food source, other than that present in the river water, was added to the rearing tank in this method.

Several hundred larvae, instars 5-7, were placed in the tank and larval and pupal development and adult emergence observed.

Section B - Sampling Methods and Dissection of Adults

Collection of Emerging Adults. Pyramidal traps (Fig. 3) 60 cm in height with a 0.81 m^2 opening at the bottom were used to capture emerging adults at sites 1, 2, 4, 5 and 10 in 1979 and sites 2 and 5 in 1980. Fine mesh Nytex^R screening was used to cover the trap. Adults were captured in an inverted one litre clear glass jar which was screwed into the top of the trap. A 10 x 10 x 100 cm piece of expanded polystyrene was fastened to the base of the trap to act as a float. Traps were anchored with ropes attached to two separate 1.5 m galvinized steel poles embedded in the river bed. At sites 4 and 5, where the river was too deep to navigate, traps were attached to bridge railings. At these sites traps were pulled from the water with the aid of a grappling hook. In 1980, flies were collected from emergence traps on an hourly or a 24 h basis. Power or mouth aspirators were used to collect flies from traps. Flies were placed in 70% ethyl alcohol or frozen. In 1980, air temperature, relative humidity, light intensity, time of day, wind velocity, and cloud cover were recorded each time flies were collected.

Collection of Ovipositing Adults. In 1979 and 1980 ovipositing adults were collected from natural and man-made substrates and placed in 70% ethyl alcohol. When available, eggs were scraped from the substrate with forceps and placed in a vial with the adult. Substrate type and location were recorded at each collection site.

Two kinds of artificial substrates were used in 1979 and 1980 to collect ovipositing adults. In 1979, white plastic strips 5 cm wide and

100 cm long were covered with a thin layer of Vaseline[R] and attached to a wood float at site 4. In 1980, 8 m of 10 mm yellow nylon rope was attached to steel poles embedded in the river bed at site 2. At site 4, ropes were tied to the bridge railing.

Collection of Host Seeking Adults.

Collection of Adults from Attractant Traps in 1979 and 1980. In 1979, black fly adults were collected at site 2 from a modified New Jersey mosquito trap. The trap consisted of a tubular metal body, fan, screen and collecting bottle. The trap body was fixed in a horizontal position. The base and body of the trap was painted flat black and the completed trap stood 50 cm high. The trap was provided with CO_2 from a 9.1 kg tank equipped with a regulator and a length of hose. The CO_2 delivery was regulated by screw clamp and a tank regulator at a rate of 200-300 ml per min. The trap was located 8 m from the edge of the river in a well treed area.

In 1979, black flies were also collected at site 2 in a New Jersey mosquito trap fitted with an ultra violet light bulb. The trap was suspended from a tree branch 1.5 m above ground level (2 m above river water level) and 2 m from the edge of the river. The trap was operated continuously and emptied at 2100 h and at 0800 h.

In 1979, four New Jersey mosquito traps were placed along the river to observe black fly activity at site 5 (Fig. 11). The first trap (D_1) was suspended from a tripod 1.5 m above ground level, 5 m from the edge of the river and 5 m above the surface level of the water. The trap was equipped with a 100 watt incandescent light bulb and 200-300 ml of CO_2 per min. was delivered from a 9.1 kg tank. CO_2 was released via a delivery hose fixed below the canopy of the trap but above the electric

fan blades. A tank regulator and a screw clamp fastened to the hose controlled the release of CO_2. Trap two (D_2) was located 5 m from the river, 5 m above water level and 40 m downstream of trap D_1. Trap D_2 was the same as D_1, but without light. Trap three (D_3) was located 100 m downstream from D_2 and 40 m from the edge of the river at an elevation of 8 m above water level. D_3 was equipped with a 100 watt light bulb but lacked a CO_2 source. Trap four (D_4) was placed 8 m above water level and 5 m from the rivers edge with no light or CO_2 source. Traps D_3 and D_4 were suspended from tripods 1.5 m above ground level, while D_2 was suspended from a tree limb. All traps were equipped with fine mesh cheesecloth screening, one litre collecting bottles and were green in colour. Traps were emptied at the same time each day, and the black flies placed in 70% ethyl alcohol.

In 1980, black flies were collected with New Jersey mosquito traps at site 2. Trap one (C_1) was located 2 m above water level, 1.5 m above ground level and 2 m from the river's edge. C_1 was supplied with CO_2 as an attractant at a flow rate of 200-300 ml per min. and lacked a light source. Trap two (C_2), a control trap with no CO_2 or light source, was located 40 m upstream of C_1, 3.5 m above water level and 10 m from the edge of the river. Both were suspended from tree limbs and equipped with 1 litre collecting jars and fine mesh cheesecloth screening. Both traps were painted light green. Black flies were preserved in 70% ethyl alcohol.

Collection of Adults from Animal-baited Traps in 1980. In 1980, flies were collected from chicken and turkey-baited traps at site 2 (Figs. 4, 10). Traps were placed 3 m apart, in a linear formation along the river bank and 10 m from the edge of the water. Traps consisted of a base of

plywood, 65 x 75 x 2 cm. A cage with 6.5 cm^2 wire mesh, 50 cm wide, 60 cm long and 60 cm high was placed on the plywood base. Newspaper was placed beneath the wire cages for easy removal of feces. The cover, 60 x 70 x 65 cm was constructed of 1.3 cm plywood and 2 x 2 cm wood struts. The cover fitted tightly over the cage and rested squarely on the platform. A hole was cut into the top centre of the cover, and a collecting container was placed over the opening. The interior of the cover was painted flat black and the exterior was painted white. The collecting container was covered at one end with fine mesh screening. Flies were aspirated by mouth aspirator from the collecting container and placed directly into 70% ethyl alcohol. Bird density per cage consisted of two 8 wk old turkey broilers, or 3 one yr old leghorn layers. Food and water was supplied to birds on alternate days and cages were cleaned once to twice a week. Standard chicken and turkey rations were fed ad lib. Birds were uncovered and covered in a different (random) order each hour on the hour and exposed for a period of 15 min. After covering exposed birds, flies were removed from the Perspex^R collecting container until the next exposure period. Simuliids were also collected from a large animal-baited trap similar to that used by Shemanchuk (1978) (Figs. 5, 10). The trap, 120 x 240 x 180 cm contained a stanchion 45 x 165 x 135 cm. A 3 wk old calf was used as bait. The calf was exposed for 15 min. each h. The side curtain were then dropped and the trapped flies collected.

Hourly recordings of air temperature, time of day, relative humidity, light intensity, cloud cover and wind velocity were taken.

Collection of Adults by Sweep Net and Aspiration. In 1979, black fly adults flying around humans at site 5 were collected with a sweep net.

Flies were also netted from bridge railings at site 5 and around dairy cattle at site 4 and placed in 70% ethyl alcohol. No attempt at quantitative sweeping was made.

In 1980, black fly adults were sweep netted around 27 dairy calves contained in a small corral situated 1.5 km south of site 2. Flies were collected from the inner surface of the ear, the face and neck of calves at this site. Flies were also collected from horses 5.6 km and 2.4 km north from site 2. No attempt at quantitative sweeping was made.

Maintenance of Adults in the Laboratory. Adults reared in the laboratory were dissected after emergence or placed in Perspex^R cages. Adults were provided with water and sugar cubes, and maintained at 22^{0}C and 5^{0}C.

Dissection of Adults. Live adults were briefly wetted in 95% ethyl alcohol prior to dissection in a small amount of Belar's modified physiological saline. One ovary of each fly was randomly removed, teased apart with fine dissecting pins and viewed at high power under a phase contrast microscope. The stage of development of follicles was determined according to Watts and Smith (1978) in order to confirm the necessity of a blood meal for egg development. The number of follicles/ovary and the quantity of fat body on a scale of 1-5, 5 being the largest, was also determined when possible. Flies were dissected at intervals of 1-12, 12-24, 24-48 and 48-72 h after adult eclosion in the laboratory.

Flies from emergence cage collections in the field were frozen shortly after collection and stored until the ovaries could be examined. Flies were transported in a cooler with ice and refrozen upon arrival in Winnipeg.

Section C - Description of Sites*

Site 1. This site was located in Souris on Plum Creek at the entrance of Victoria Park, about 10 m downstream of a one lane bridge and 20 m downstream of small rapids (Fig. 1). The creek was approximately 10 m wide. One cone sampler set and one emergence trap were placed in the centre of the creek. The area along both creek banks was well treed and numerous cattails were growing in the creek throughout the summer.

Site 2. This site was located 0.75 km downstream from the bridge on Provincial Road #348 at Bunclody (Figs. 1, 8, 9). The site consisted of a rocky section of river which varied in width from 20 m to 100 m depending on river flow. Two emergence traps were positioned in the rapids at accessible locations. This site was well treed along both river banks. In 1980, algal masses covered large sections of the river along both banks, particularly where rocks protruded from the water. Water velocity was fastest at this site and many suitable attachment sites were available to larvae.

Site 4. This site was located 1.5 km west of Hartney at a wooden bridge (Fig. 1). Equipment was attached to the bridge. The river was 40 m wide and the area in general was well forested with intermittent sandy soil patches.

Site 5. This site was located about 12 km west of Hartney or about 10 km upstream from site 4 (Figs. 1, 6, 7). A wooden bridge was present at this site and provided an attachment site for sampling equipment. The river was 26 m wide at this site and both banks were well treed. The

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*The site numbers correspond with those of Westwood, 1979.

site was located at the margin of the Lauder Sandhills.

Site 10. This site was located 1.5 km north of Elgin in Elgin creek (Fig. 1). The creek was about 2 m wide in early spring and ceased flowing by July in 1979. This site was located 5 m downstream of a concrete bridge in a small ravine. Long grass and cattails were numerous and provided ample attachment sites for immature black flies.

Site 11. This site was located 1 km south and 5 km west of site 2. This site consisted of a small intermittent creek running through a 2 m dia. culvert. Long grass, cattails and rocks were available for larval and pupal attachment.

Section D - Collection of Meteorological Data

Air temperature and relative humidity were measured with a Taylor sling psychrometer and a Bendix Hygrothermograph recorder. Psychrometer readings were taken at chest height for a period of 3 min. The hygrothermograph was placed in a modified Stevenson screen 1.5 m above ground level and 12 m from the edge of the river.

Light intensity was measured by a Li-cor quantum/radiometer/photometer model Li-185. All recordings were taken in an open area, at the beginning of each hour and in the same location. The light probe was placed 45 cm above ground, pointing directly upward.

Wind velocity was taken at the CO_2 trap and bird traps at the beginning of each hour. A hand held cup anemometer was used to measure velocity in m/sec. Two readings were taken each hour at each location and an average value was calculated.

Section E - Identification of Black Flies

Keys to immatures and adults from Davies, Peterson and Wood (1962),

Wirth and Stone (1963), Stone (1964), Merrit, Ross and Peterson (1978), Westwood (1979) and Fredeen (1972, unpublished) were used to identify specimens.

Section F - Explanation of Figures 42-51

The percentages for the histograms in Figs. 42-47 were derived by summing adults taken at the same hour but on a number of different days. For instance, flies taken at 1000 h on one day were summed to flies taken at 1000 h on a second and third day and so on. This being done for each hour of the day, the percent of flies active each hour was then calculated by dividing the total number of flies taken at each hour by the total number of flies taken throughout all hours. The same method was used for calculation of percentages in Figs. 48-51 except all flies taken at a particular temperature were summed rather than hourly summed.

In histograms 46-51 "X" indicates that data was not being collected during those times or temperatures. "O" indicates that no flies were taken during times or temperatures when data was being collected.

Figure 1. Map of Souris River and adjacent Assiniboine River area: 1979-80.

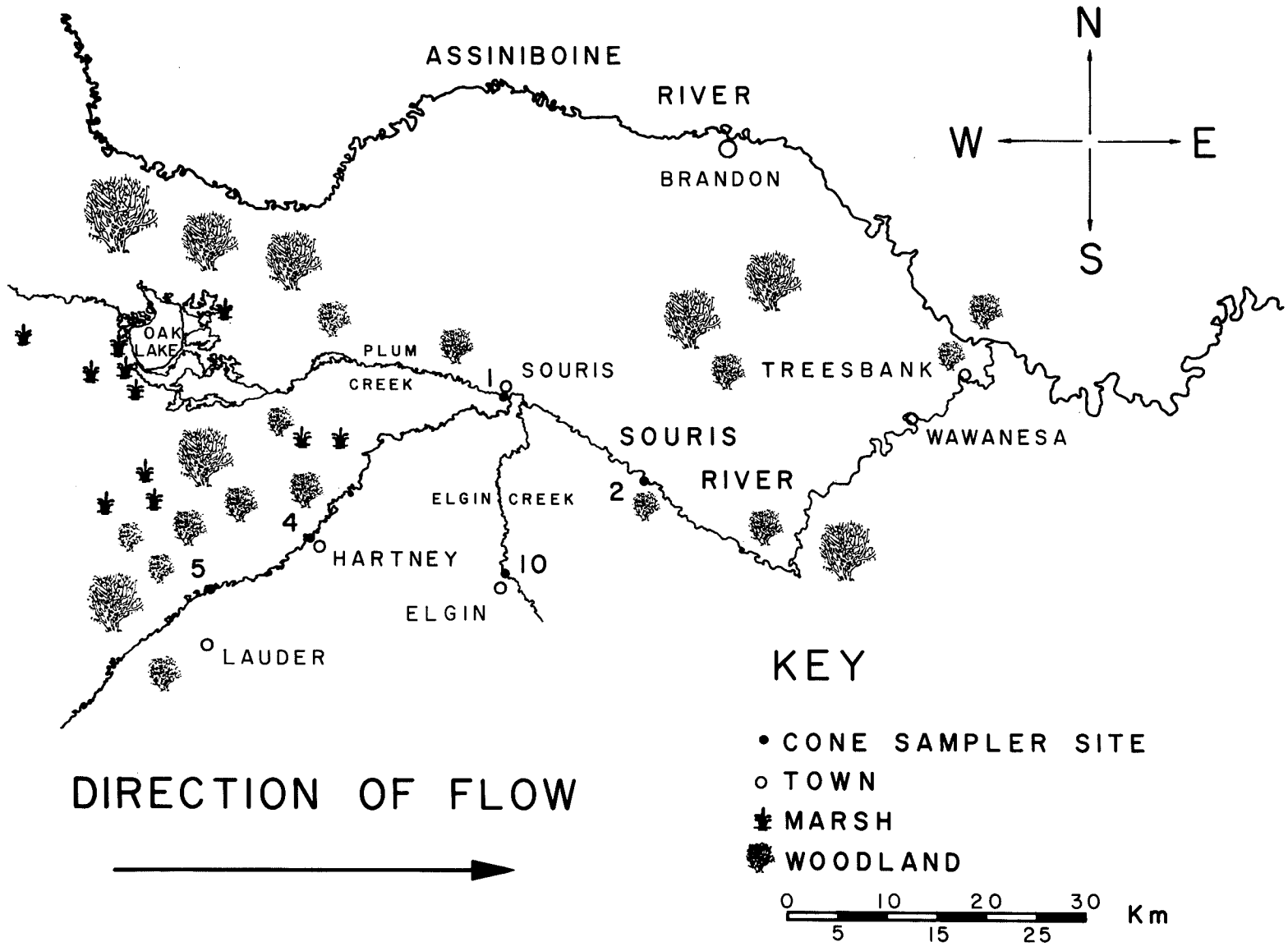
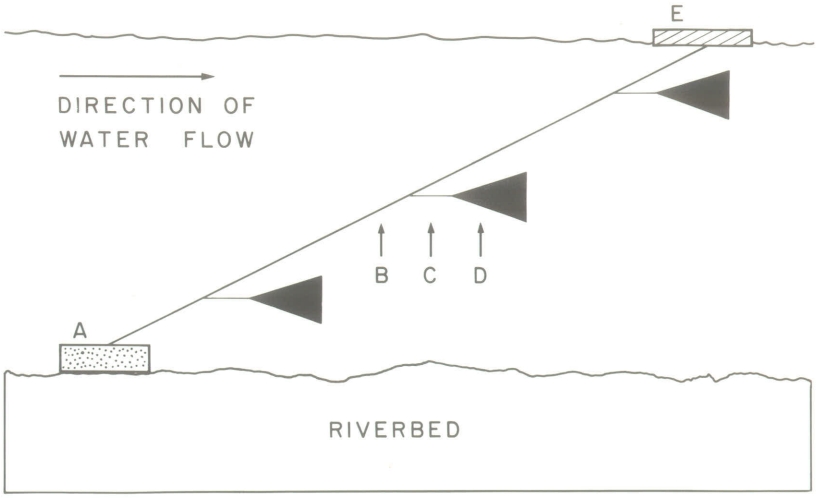

ASSINIBOINE
RIVER
BRANDON
N
W
E
S
OAK LAKE
PLUM
CREEK
1
SOURIS
TREESBANK
SOURIS
RIVER
WAWANESA
2
ELGIN CREEK
4
HARTNEY
5
10
ELGIN
LAUDER
DIRECTION OF FLOW
KEY
• CONE SAMPLER SITE
o TOWN
MARSH
WOODLAND
0 10 20 30 Km
5 15 25

Figure 2. Cone sampler. A-brick weight, B-6.3 mm nylon rope, C-nylon cord, D-white polystyrene cone, E-expanded polystyrene float

Figure 3. Floating emergence trap (taken from Westwood 1979).


E
DIRECTION OF
WATER FLOW
B C D
A
RIVERBED

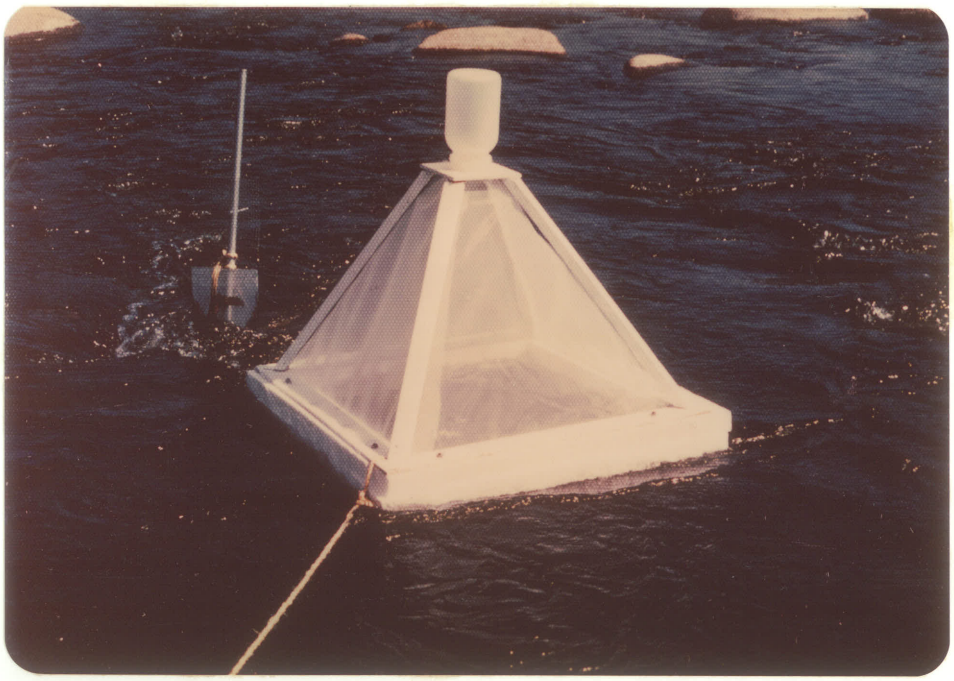
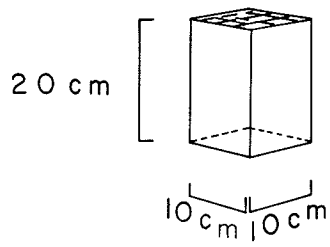
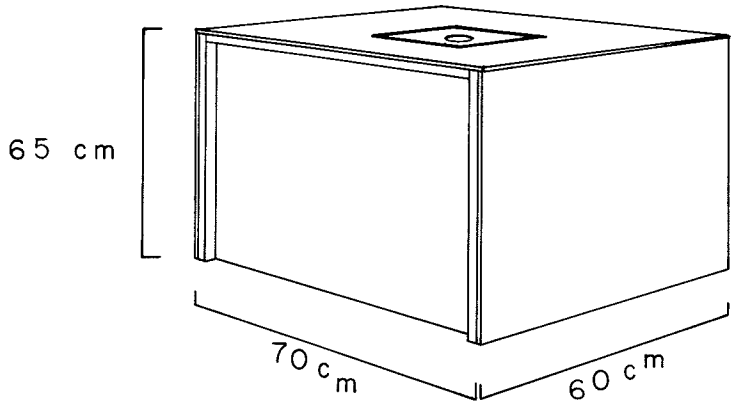


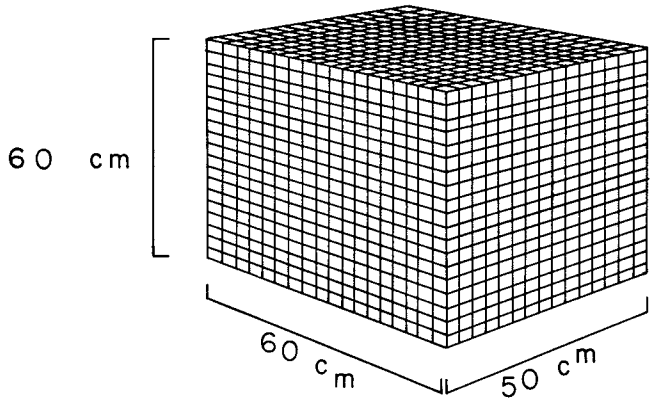
Figure 4. Bird-baited trap. A-platform, B-2.5 x 2.5 cm mesh wire cage, C-cover, D-collecting container



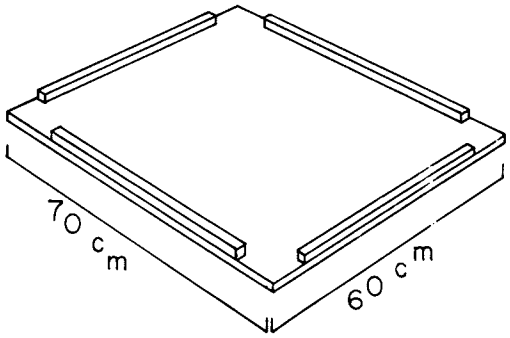
D



C



B



A

Figure 5. Calf-baited trap (modified from Shemanchuk 1978).

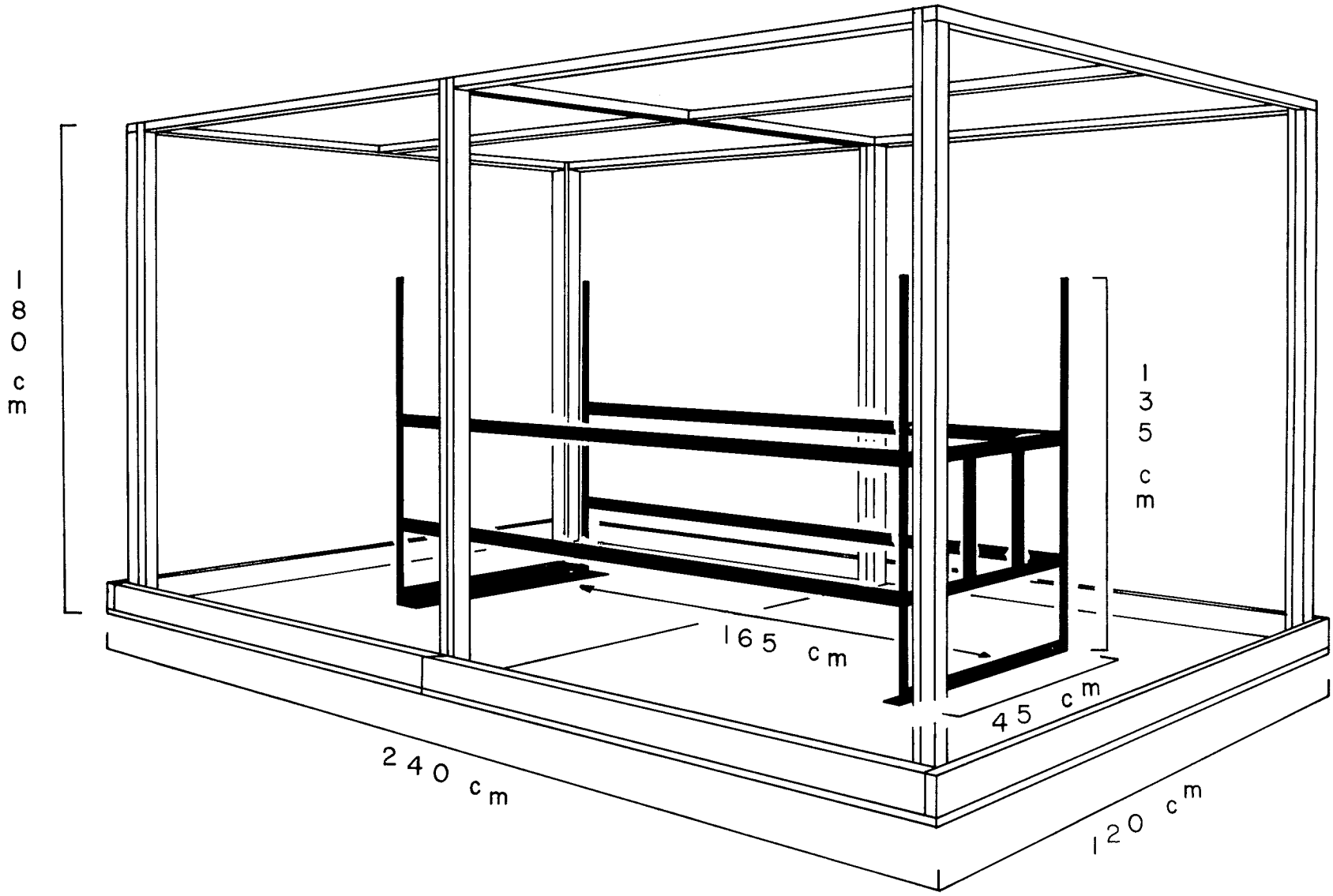

180 cm
135 cm
165 cm
45 cm
240 cm
120 cm

Figure 6. Site 5, Souris River, Lauder, Manitoba - 15 May, 1979.

Figure 7. Site 5, Souris River, Lauder, Manitoba - 19 June, 1980.

Figure 8. Site 2, Souris River, Bunclody, Manitoba - 15 May, 1979.

Figure 9. Site 2, Souris River, Bunclody, Manitoba - 19 June, 1980.

Figure 10. Adult black fly sampling equipment at site 2 (Bunclody), in 1980. Large animal-baited trap-middle left and bird-baited traps-centre to middle right.

Figure 11. Adult black fly sampling equipment at site 5 (Lauder), in 1979. CO_2-baited New Jersey light trap.

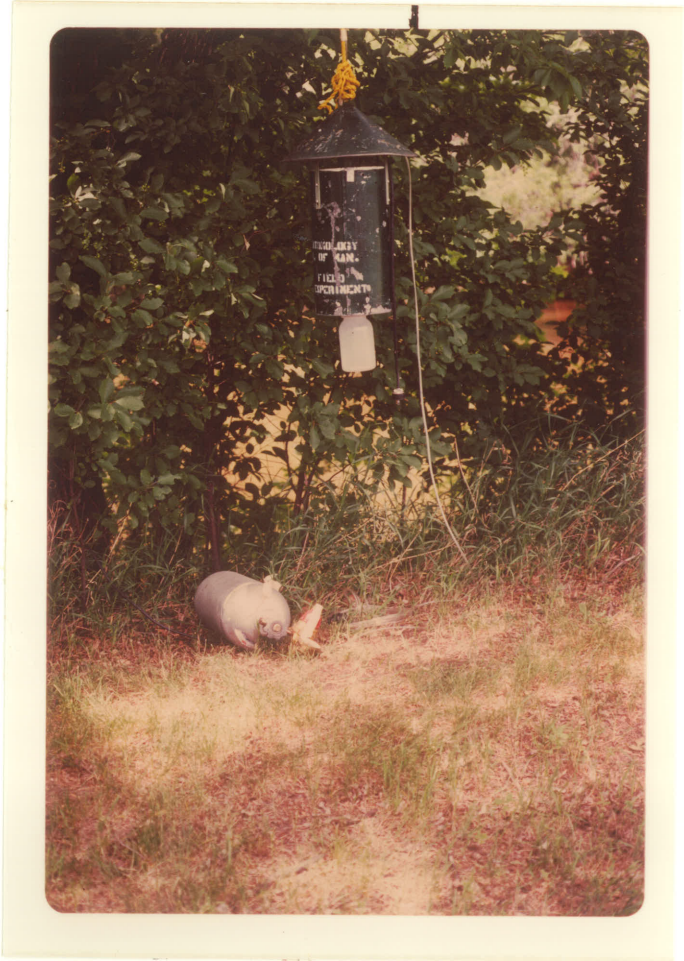
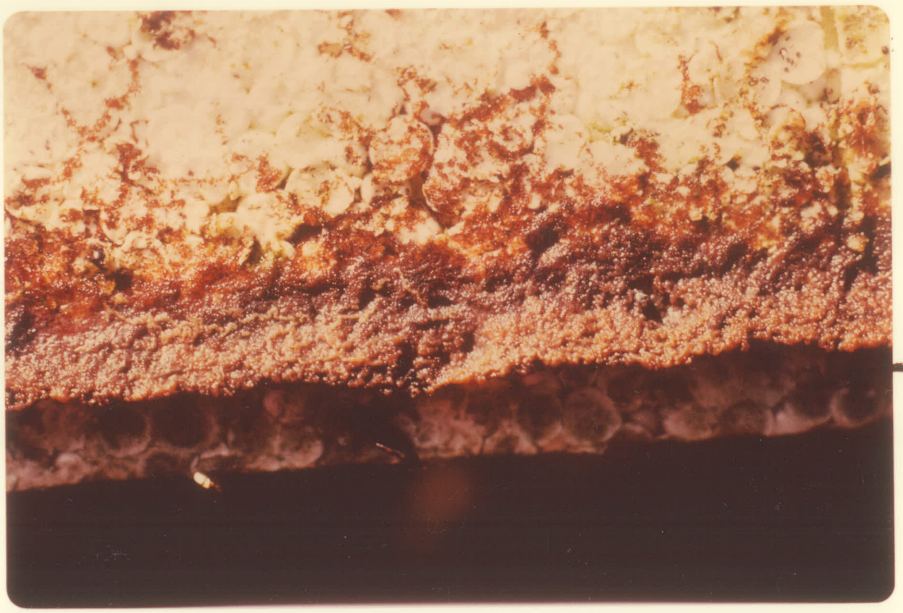

FIELD

Figure 12. Simulium meridionale adult engorging on human shoulder at site 2, Bunclody, Manitoba.

Figure 13. Simulium luggeri bite on human leg at site 2, Bunclody, Manitoba.

Figure 14. Simulium vittatum egg mass on expanded polystyrene float at site 2, Bunclody, Manitoba.

Figure 15. Simulium vittatum adults ovipositing on nylon rope at site 2, Bunclody, Manitoba.



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CHAPTER IV

Results and Discussion

Section A - Bionomics of Black Fly Adults Found in the Souris River

Simulium johannseni Hart

Collection Sites. *S. johannseni* immatures and adults were collected from sites 2, 4 and 5 in 1979 and 1980. No attempt was made to seperate *S. johannseni johannseni* Hart and *S. johannseni duplex* (Shewell and Fredeen) although both are known to occur in the Souris River system.

Seasonal Distribution. In 1979, sampling began on 19 May. *S. johannseni* larvae were collected between 19 May and 6 June, pupae between 28 May and 6 June, and adults between 6 and 25 June (App. 1). In 1980, sampling began on 15 April. Larvae were collected between 24 April and 15 May (Figs. 29, 32), pupae between 1 and 15 May and adults between 18 May and 9 June (Tables 9, 10, 11).

In 1980, the period of peak larval density occurred between 24 and 30 April (Figs. 29, 32). In 1979, the period of peak density could not be determined because sampling began too late. Although larvae were more abundant on cone samplers at sites 4 and 5 than at site 2 during 1979 and 1980, more adults were taken at site 2 in 1980. The warm dry fall of 1979 and the warm dry spring of 1980 resulted in low river flow, low water velocity and low *S. johannseni* adult populations at all sites. The relatively higher adult populations at site 2, in 1980, may have been

due to greater water velocity (note rapids, Fig. 9) and more larval attachment sites. The latter inconsistencies seem to indicate that cone samplers by themselves poorly estimate black fly populations.

Trap collections. Adults were collected by emergence trap, sweep net and CO_2-baited traps at sites 4 and 5 in 1979. Most adults (838) were taken in 2 CO_2-baited traps at site 5 (Table 1) and the remainder were collected by sweep netting around cattle (13) and from floating emergence traps at sites 4 and 5 (Tables 3,8). No adults were collected by emergence trap or CO_2-baited trap at site 2 in 1979 and adults were more abundant at sites 4 and 5 than at site 2 in 1979. In 1980, S. johannseni adults were not collected in emergence traps at site 5 and only 3 flies were captured in CO_2-baited traps at this site. The absence of males and low numbers of females (19) collected by emergence trap at site 2 in 1980 (Fig. 36), suggests that sampling began after the period of peak emergence.

At site 2, in 1980, S. johannseni (469) were collected by a CO_2-baited trap between 18 May and 9 June (Table 9), from 2 turkey-baited traps (108) between 18 May and 4 June (Table 10), from 2 chicken-baited traps (115) between 18 and 31 May (Table 10) and from a calf-baited trap (63)(Table 11). Seventy-seven (71.3%) and 76 (66.1%) S. johannseni taken from turkey and chicken-baited traps respectively were blood-fed (Table 10).

Host Selection and Site of Attack. In the Souris River area, S. johannseni fed on avian hosts, rather than mammals. Turkeys and chickens were equally attractive. Females of S. johannseni fed on the unfeathered head and wattles, and crawled beneath the body feathers, presumably to feed. Although attracted to mammals, including humans, only one took a blood meal from a calf. Previous work by Westwood (1979) showed that

this simuliid fed on humans and cattle in the Souris area, as well as bird hosts.

Ovarian Development. The mean follicle stage of flies collected by sweep netting around cattle, on 12 and 20 June in 1979, was stage IIIa to IIIb (Table 8). Small amounts of undigested blood were found in the midgut of these flies. Twenty flies collected from CO_2-baited traps had undeveloped ovarian follicles (stage Ia) and an absence of blood in their midguts (Table 8).

Flight Behaviour. Adults of *S. johannseni* were collected at air temperatures between 18.3^{0}C and 36.7^{0}C (Fig. 50), at relative humidities between 6% and 62%, at light intensities between 0.6 and 8,000 lux and during winds with gusts up to 7.9 km/h. Adults were collected on sunny, partly overcast and completely overcast days. Periods of peak activity occurred between 0700 h and 1100 h in the morning and 1700 and 2100 h in the evening (Figs. 43, 46). Air temperatures during these times ranged from 20.6^{0}C to 33.3^{0}C (Fig. 50), light intensities from 60 to 1,950 lux, relative humidities from 7 to 62% and gusting winds up to 7.8 km/h.

General Bionomics. *S. johannseni* overwinters in the egg stage in the Souris River and is one of the first species to hatch in early spring after the river ice breaks up. Larval development took 20 to 30 days, and pupal development 7 to 14 days.

Adults emerged with undeveloped ovarian follicles (stage Ia) and required one or more blood meals to develop eggs. In the Souris River, this fly has only one generation a year.

Simulium meridionale Riley

Collection Sites. *S. meridionale* immatures and adults were collected

from sites 2, 4 and 5 in 1979 and 1980.

Seasonal Distribution. In 1979, sampling began on 19 May. *S. meridionale* larvae were collected between 1 June and 21 August (Figs. 21, 22, 25), pupae between 27 June and 21 August and adults between 11 and 27 June, as well as 17 July and 1 and 14 August (Tables 1, 8). In 1980, sampling began on 15 April. Larvae were collected between 1 and 28 May (Figs. 21, 30, 33), pupae between 9 and 22 May and adults between 18 May and 9 June (Tables 9, 10, 11).

In 1979, periods of peak larval density occurred between 13 and 19 June and 6 and 18 July. In 1980, these occurred between 1 and 8 May (Figs. 21, 30, 33). Again larvae were more abundant on cone samplers at sites 4 and 5 than at site 2 during 1979 and 1980, and in 1980 more adults were taken at site 2. In 1979, more adults were taken at sites 4 and 5. The warm dry fall of 1979 and the warm dry spring of 1980 which resulted in low river flow and low water velocity subsequently lead to low adult populations at all sites. The relatively higher adult populations at site 2 in 1980 may have been due to greater water velocity and more larval attachment sites (note rapids at site 2, Figs. 8,9). Cone samplers alone gave a poor estimate of black fly populations.

Trap Collections. Adults were collected by emergence trap, sweep net and CO_2-baited traps at sites 2, 4 and 5 in 1979. *S. meridionale* adults (7,813) were taken in 2 CO_2-baited traps at site 5 (Table 1), by sweep netting (70) around humans at site 5 (Table 8), from a CO_2-baited trap (47) at site 2 (Table 2) and from floating emergence traps (34) at sites 2 and 4 (Tables 3, 4).

At site 2 in 1980, *S. meridionale* adults (1,258) were collected with a single CO_2-baited trap between 18 May and 9 June (Table 9), from

2 turkey-baited traps (106) between 20 May and 9 June (Table 10), from 2 chicken-baited traps (103) between 20 and 31 May (Table 10), from a calf-baited trap (38) (Table 11) and from human hosts (20). Eighty-three (81.1%) and 84 (81.5%) S. meridionale taken from turkey and chicken-baited traps respectively, were blood-fed, while 1 out of 38 taken from the calf-baited trap and 15 out of 20 taken from human hosts were blood-fed (Tables 10, 11).

Host Selection and Site of Attack. In the Souris River area, S. meridionale fed on birds and mammals. This fly usually attacks avian hosts, however, on a number of occasions, it fed upon human hosts. Like S. johannseni, it preferred the unfeathered avian head, wattle and comb and often crawled through the body feathers. Females fed on the human forearm, upper arm, elbow, shoulders, upperpart of the back, armpit and thighs (Fig. 12). On one occasion, a female fed on the human forearm in the cab of a truck at 2000 h and an air temperature of 24^{0}C. In Wisconsin, Wright and Defoliart (1970) also reported that S. meridionale fed on humans indoors or in a screened porch. In the Souris area, females became fully engorged on humans in 6 min. The somewhat painful bite bled freely, without subsequent swelling.

Ovarian Development. The mean follicle stage of flies collected by sweep netting around cattle, by emergence trap and by CO_2-baited traps in 1979, was stage Ia to Ib (Tables 4, 8). Many of the individuals dissected from CO_2-baited traps had a clear, sticky, highly viscous liquid in their midgut, presumably nectar. Simuliids are known to require nectar as an energy source during flight (Davies and Peterson, 1956). Ovarian development was not studied in 1980. From 1979 data, it appears that females are anautogenous.

Flight Behaviour. Adults of S. meridionale were collected at air temperatures between 18.3^{0}C and 36.7^{0}C (Fig. 51), at relative humidities between 6% and 62%, at light intensities between 0.6 and 7,200 lux and during winds with gust up to 7.9 km/h. Adults were collected on sunny, partly overcast and completely overcast days. Highest peaks of activity occurred from 1600 h to 2100 h (Figs. 44, 47) but high levels of flight activity occurred at other times of the day, making morning and evening peaks less distinguishable than for S. johannseni. During the study, S. meridionale seemed very active during most meteorological conditions.

General Bionomics. S. meridionale overwinters in the egg stage in the Souris River, and appears 1 to 2 weeks after S. johannseni in spring. This simuliid apparently requires warmer water temperatures for development than does S. johannseni. Larval development takes 20 to 30 days and pupal development 7 to 14 days. This fly is normally multivoltine in the Souris River, however, in 1980, only one generation was recorded due to unfavorable conditions. If a second egg hatch did occur, larval populations were too low to detect. Apparently the low water level and low water velocity prevented a second egg hatch. In 1979, larvae were found at water temperatures between 16.9^{0}C and 26.7^{0}C. Adults emerged with undeveloped ovarian follicles (stage Ia to Ib) and required one or more blood meals for egg development.

Simulium luggeri Nicholson and Mickel

Collection Sites. S. luggeri immatures and adults were collected at sites 2, 4 and 5 in 1979. In 1980, immatures were collected at sites 2, 4 and 5 while adults were collected at site 2, 1.6 km south of site 2 and 8 km north of site 2.

Seasonal Distribution. In 1979, sampling began on 19 May. *S. luggeri* larvae were collected between 5 June and 21 August (Figs. 20, 24, 26), pupae between 13 June and 21 August and adults between 19 June and 21 August (Tables 1, 2, 4). In 1980, sampling began on 15 April and larvae were collected between 1 May and 9 June (Fig. 20), pupae between 9 and 28 May and adults between 18 May and 9 June (Tables 9, 11).

In 1979, periods of peak larval density occurred between 13 and 19 June, 12 and 18 July and 1 and 8 August (Figs. 20, 24, 26). In 1980, a single period of peak larval density occurred between 23 and 28 May (Fig. 20). Low water levels and low water velocity prevented development at sites 4 and 5, and consequently few larvae and no adults were collected at these sites. Most larvae and adults were found at site 2, where water velocity was faster and where more larval attachment sites were available. In 1979, when Souris River water levels and water velocity were much greater, more larvae, but fewer adults, were found at sites 4 and 5 than at site 2. It appears that although larval densities were higher at sites 4 and 5, as measured by cone samplers, the total population of *S. luggeri* was lower at these sites. Another possible explanation, is that fewer attachment sites available to larvae at sites 4 and 5 resulted in greater larval drift and increased their densities on cone samplers. This is supported by the fact that high densities of *S. johannseni* and *S. meridionale* larvae were found on cone samplers in 1980 at these sites (Figs. 21, 29, 30, 32), but virtually no adults were caught (none in emergence traps). Fewer acceptable larval attachment sites also suggest increased mortality since the final larval instar requires a smooth, clean, surface to pupate.

A reduction in water levels and water velocity in the fall shortened

the season for black fly development. S. luggeri was not found after 8 August at sites 4 and 5 or after 21 August at site 2 in 1979. In 1980, no S. luggeri larvae were found after 22 May at sites 4 and 5 or after 9 June at site 2. It appears that S. luggeri prefers a habitat with fast flowing, turbulent water, with numerous acceptable attachment sites.

Trap Collections. Adults were collected by emergence trap at sites 2 and 4 and by CO_2-baited trap at sites 2 and 5 in 1979. Most adults (1,721) were taken in a CO_2-baited trap at site 2 (Table 2) and the remainder were collected by floating emergence traps (144) and CO_2-baited traps (143) at site 5 (Tables 1, 3).

At site 2, in 1980, S. luggeri (2,232) were collected in a CO_2-baited trap between 18 May and 9 June (Table 9), from a calf-baited trap (209) and other bovine hosts between 22 May and 9 June, from humans (3) on 20 May, from horses (2) on 9 June (Table 11) and from chicken-baited traps (2). Forty-five (21.5%), 3 (100%), 1 (50%) and 0 flies from bovine, human, equine and avian hosts respectively were blood fed. S. luggeri (1,259) were collected in emergence traps in 1980 (Fig. 38). The ratio of males to females (611:648) was close to 1:1.

Host Selection and Site of Attack. In the Souris River, S. luggeri fed readily on cattle, horses and humans. Most flies collected from bovine hosts were taken from the inner ear and around the eyes, but some flies were observed crawling around and feeding on the underbelly and inner thigh. Blood feeding by S. luggeri was also observed on the inner thigh of the back legs, on the underbelly of horses, and on the distal part of the legs on humans (Fig. 13). Bites on humans caused swelling and redness over an area of 7 cm^2.

Ovarian Development. The mean follicle stage of S. luggeri (25) collected by emergence trap on 17 July and 21 August, was stage Ib (Table 3). Fat body content (on a scale from 1 to 5, 5 being largest) was 3 (Table 4). S. luggeri is anautogenous in the Souris area, during midsummer and early fall generations. Several females from the spring generation collected from a CO_2-baited trap on 25 June had a mean ovarian follicle stage of Ib.

Flight Behaviour. Adults of S. luggeri were collected at air temperatures between 17^{0}C and 36.7^{0}C (Fig. 49), at relative humidities between 7% and 81%, at light intensities between 0.6 and 11,250 lux and during winds with gust up to 15.7 km/h. Adults were collected on sunny, partly overcast and completely overcast days and also before, during and after fairly heavy rains. A small but defined peak of activity occurred between 0700 h and 0800 h and a larger well defined peak between 1900 h and 2100 h (Fig. 45). During mid-day and afternoon hours, S. luggeri steadily increased in activity.

General Bionomics. S. luggeri overwinters in the egg stage in the Souris River and appears 1 to 3 weeks after S. johannseni. Larval development takes between 15 and 25 days, and pupal development 5 to 10 days. In 1979, larvae were collected at water temperatures between 16.9^{0}C and 26.7^{0}C. Development of this species probably begins at water temperature between 12^{0}C and 14^{0}C (Westwood, 1979). Hatching and development of this species appeared to be dependent on water temperatures following the spring run off during both 1979 and 1980.

Adults emerge with undeveloped ovarian follicles (Ia) and require a blood meal for egg development. Under average conditions, S. luggeri has 2 to 3 generations a year in the Souris River. In 1980, however,

when water levels and water velocity were severly reduced, only one generation was observed at sampling sites.

Simulium vittatum Zetterstedt

Collection Sites. Immatures were collected from sites 1, 2, 4, 5, 10 and 11, and adults were collected from sites 2, 4, 5 and 10 in 1979. In 1980, immatures and adults were collected at sites 2, 4 and 5. Adults were also collected at site 11 and 1.6 km south and 8 km north of site 2.

Seasonal Distribution. In 1979, sampling began on 19 May. S. vittatum larvae were collected between 19 May and 21 August and again on 4 November in the Souris River (Figs. 19, 23, 27). Pupae were collected between 14 May and 21 August and on 4 November while adults were collected between 28 May and 21 August (Tables 1, 2). In 1979, larvae were also collected at site 1 between 9 and 26 June (App. 2), at site 10 between 2 and 10 June (App. 3) and at site 11 between 3 and 19 June (App. 3). Adults were collected from site 10 on 12 June (App. 4).

In 1980, sampling began on 15 April and larvae were collected between 24 and 30 April at sites 4 and 5 and between 1 May and 9 June at site 2 (Fig. 19). Pupae were collected between 16 May and 9 June and adults between 18 May and 9 June at site 2 (Table 9).

In 1979, periods of peak larval density occurred between 13 and 19 June, 6 and 18 July and 15 and 21 August (Figs. 19, 23, 25). In 1980, S. vittatum had a single peak between 5 and 19 June at site 2 (Fig. 19). No peak was detected at sites 4 and 5 because larval numbers were too low. The larvae collected at sites 4 and 5 on 30 April were fifth instar, indicating that S. vittatum overwinters as larvae in the Souris river. Early instars (2-4) were present in abundance between

16 and 22 May at site 2, but were not detected at sites 4 or 5. Possibly too few larvae were able to survive the reduced water level and velocity at these sites.

Oviposition Activity. In 1979, S. vittatum was the only simuliid observed to oviposit on substrates (Figs. 14, 15). Females oviposited on yellow nylon ropes more readily than on 4 cm x 100 cm white plastic strips. Females also oviposited on a wide variety of natural substrates, including cattail, numerous other grasses, sticks, rocks, leaves, concrete and floating strands of filamentous green algae. Lacking these substrates, adults would oviposit on almost any substrate found on or near the water surface.

In 1980, oviposition by an aggregation of S. vittatum was observed at the Hartney Dam 2 km east of site 4. Large egg masses having hundreds of adults attached to them were located on the concrete uprights at the water surface. Fewer eggs were collected upstream of the dam on vegetation and below the dam on rocks on or near the bank. In 1979 and 1980, S. vittatum females oviposited freely on expanded polystyrene floats and floating white larval sampling cones.

Females of S. vittatum were collected while ovipositing between 8 and 28 May, at 0600 h and 2200 h and at light intensities between 1.1 and 5,600 lux. Most flies, however, oviposited in the evening between 1900 h and 2200 h during light intensities between 1.1 and 340 lux (Table 12).

Trap Collections. In 1979, adults were collected by emergence traps at sites 1, 2, 4, 5 and 10 (Tables 3, 5; App. 4) and by CO_2-baited traps at sites 2 and 5. Most adults (344) were taken in 2 CO_2-baited traps at site 5 (Table 1) and the remainder (209) were collected by floating

emergence traps at sites 2, 4, 5 and 10 (Tables 3, 4, 5; App. 4) and by a CO_2-baited trap (12) at site 2 (Table 2).

At site 2, in 1980, S. vittatum (113) were collected with a CO_2-baited trap between 18 May and 4 June (Table 9), from a calf-baited trap (168) and other bovine hosts between 27 May and 9 June and from horses (5) (Table 11). Forty-four (26.9%) and 2 (40%) S. vittatum from bovine and equine hosts respectively were blood fed. No S. vittatum fed upon or were attracted to avain or human hosts. S. vittatum (4,280) were collected in emergence traps in 1980 (Fig. 39). The ratio of males to females (2,220:2,060) was close to 1:1.

Host Selection and Site of Attack. In the Souris River, S. vittatum fed readily on cattle and horses. All flies collected from equine and bovine hosts were taken from the inner ear. Apparently this simuliid feeds more readily in areas devoid of hair than on hairy areas of the body. Once inside the ear, they are protected from wind, heat and rubbing by the host animal. Since no S. vittatum were taken from human or avian hosts, this fly may prefer to feed on larger mammals.

Ovarian Development. The mean follicle stages in S. vittatum (76) taken from floating emergence traps were stages IVb to V (Tables 3, 4, 5). On a scale of 1 to 5 (5 being largest) most had a fat body content of 4 (Table 4). All field collected S. vittatum larvae (instars 5-7) and pupae reared in the laboratory at water temperatures of 22^0C and 5^0C gave rise to adults with mean follicle stages of IIb and IIIa and a fat body content of 5 at emergence (Tables 6, 7). Individuals reared at 22^0C had a mean number of 157 developing follicles/ovary at emergence (Table 6). No follicle counts were made for individuals reared from larvae at 5^0C. Individuals (4) reared from pupae at 5^0C had a mean number of 158 developing

follicles/ovary, 2 to 3 days after emergence while 9 individuals dissected 6 days after emergence had a mean number of 103 developing follicles/ovary (Table 7). Follicles of 68 females collected as pupae on 26 June at site 1, ranged from stage IIb to V, at 12 to 48 h after emergence (Table 5). It took 3 to 5 days for females to complete autogenous egg development (Table 7). All females appeared to be capable of first cycle autogeny.

Rearing. Larvae of S. vittatum were collected on 4 November, 1979 and kept in the laboratory at 5^0C. Older larvae reached the adult stage after 2 months; young larvae after 3 to 4 months. In the field, under the ice, larvae may develop even slower, reaching the pupal stage shortly after spring breakup. As well, eggs may hatch during the winter giving rise to larvae which continue to develop slowly throughout the winter months. Females of laboratory-reared larvae contained a large fat body (scale 5), typical of autogenous black flies.

General Bionomics. S. vittatum overwinters as immatures in the Souris River. This is the first black fly to emerge in the spring, shortly after river breakup. Larval development of the spring generation takes between 20 to 30 days and pupal development between 7 and 14 days.

Adults undergo at least 2 gonotrophic cycles; the first one is autogenous, while the second and subsequent cycles are anautogenous. Since S. vittatum feeds vigorously on cattle and horses, it is a potential pest species in the Souris-Hartney area.

Simulium venustum Say and Simulium verecundum Stone and Jamnback

Collection Sites. The immatures and adults of S. venustum/verecundum complex were collected from sites 1, 2, 4, 5, 10 and 11 in 1979. In

1980, this complex was collected from sites 2, 4 and 5. No attempt was made during this study to separate immatures or adults of S. venustum from those of S. verecundum.

Seasonal Distribution. In 1979, sampling began on 19 May. S. venustum/verecundum larvae were collected between 19 May and 12 June, pupae between 28 May and 6 June and adults between 2 and 9 June from the Souris River (App. 5). At site 1, larvae were collected on 9 June. At site 10, larvae were collected between 2 and 10 June (App. 3), pupae between 2 and 6 June and adults between 9 and 12 June. Larvae and pupae were also collected from site 11 between 6 and 12 June in 1979 (App. 3).

In 1980, sampling began on 15 April. Larvae were collected between 24 April and 9 June (Figs. 28, 31, 31a), pupae between 1 and 28 May and adults between 14 and 27 May (Table 9; Fig. 41). In 1979, sampling began too late to determine a period of peak density.

In 1980, larvae were more abundant at site 2 than at sites 4 and 5. The warm dry fall of 1979 and the warm dry spring of 1980 resulted in low water levels and low water velocity at all sites. There was a much larger black fly population at site 2 in 1980. Again greater survival at this site suggests it is a better habitat at times of low river flow.

Trap Collections. Adults were collected by emergence trap, and CO_2-baited traps at sites 2 and 5 in 1979. Most adults (310) were taken in 2 CO_2-baited traps at site 5 (Table 1) and the remainder were collected from floating emergence traps (12) at site 2 and 5. No adults were collected by CO_2-baited traps at site 2 in 1979. S. venustum/verecundum adults (4 and 146) were also collected by emergence trap at sites 1 and 10 respectively (App. 4). At site 5, in 1980, S. venustum/verecundum adults (10) were collected in CO_2-baited traps and none in animal-baited

or emergence traps. These low numbers of adults were attributed to low water levels and water velocity.

At site 2, in 1980, S. venustum/verecundum adults (189) were collected with a CO_2-baited trap between 18 and 22 May (Table 9). No adults were taken in calf-baited or bird-baited traps and only 249 were taken in floating emergence traps (Fig. 41). This indicated that sampling probably began after the period of peak adult activity.

Host Selection. Since sampling was begun after the peak had passed, few S. venustum/verecundum adults were observed feeding on hosts. One adult of S. verecundum was collected while feeding on a human host. Bird (1949) reported that S. venustum feed on horses, cattle, humans and poultry. Later, half of the flies reported to be S. venustum were found to be S. verecundum. Westwood (1979) found S. verecundum fed on humans and horses, and that S. venustum was attracted to cattle, domestic chickens and domestic geese at site 2.

Ovarian Development. The mean follicle stage of flies collected by emergence trap at sites 1, 2 and 10 was stage Ib to IIa (Tables 3, 4, 5), indicating that the S. venustum/verecundum complex is anautogenous in the Souris River area.

General Bionomics. S. venustum/verecundum complex overwinters in the egg stage in the Souris River. It is one of the first species to hatch in early spring, together with S. johannseni. Larval development takes between 20 and 30 days and pupal development between 7 and 14 days. Adults emerge with ovarian follicles in stages Ib to IIa, and require a blood meal to develop eggs. In the Souris River, the complex appears to have one generation per year.

Simulium tuberosum Lundström

Collection Sites. S. tuberosum immatures and adults were collected from site 2 in 1980. No larvae or adults were collected from any other sites in 1979 and 1980.

Seasonal Distribution. In 1980, sampling began on 15 April. Larvae (61) were collected from cone samplers between 24 April and 22 May at site 2. Adults (10) were collected by floating emergence traps between 20 and 27 May (Fig. 37). Pupae were not collected during this study. The number of larvae was too low to determine a period of peak activity.

Trap Collections. No S. tuberosum were caught in CO_2-baited or animal-baited traps, probably because the number of adults was too low.

Cnephia dacotensis (Dyar and Shannon)

Collection Sites. C. dacotensis immatures and adults were collected from sites 1, 2, 4, 5, 10 and 11 in 1979.

Seasonal Distribution. In the Souris River, larvae were collected between 19 May and 12 June, pupae between 28 May and 6 June and adults between 9 and 12 June in 1979 (App. 6). At sites 1, 10 and 11, immatures were collected between 24 May and 6 June (App. 2, 3). Adults were not sampled at these locations. In 1980, only 2 larvae were found. These were taken at site 4.

Trap Collections. C. dacotensis was collected by emergence trap at site 5 (146) and site 10 (26) on 9 June, and at site 5 (4) on 12 June, 1979. C. dacotensis emerged synchronously from the Souris River and from a small creek. This suggests a uniform development in both river and creek and a possible tool to estimate larval development when the Souris River is inaccessible.

Ovarian Development. The mean follicle stage of 3 individuals collected by emergence trap was stage V (Table 5). *C. dacotensis* is known to be autogenous in other regions (Davies and Peterson, 1956), and appears to be autogenous in the Souris River as well.

General Bionomics. *C. dacotensis* overwinters in the Souris River in the egg stage, and hatches after the ice melts in the spring. Larval development takes between 20 and 30 days, and pupal development between 7 and 14 days. This species was univoltine in 1979 and 1980. Westwood (1979) reported *C. dacotensis* to be univoltine in the Souris River in 1978 and 1979.

Section B - Daily and Seasonal Occurrence of Black Flies in the Souris River and Sampler Efficiency

Immatures. In 1979, at site 2, larvae were present from early June when sampling began, to late August (Fig. 16). In 1980, immatures were present from the last week in April to the first week in July. Similarly, in 1979, at sites 4 and 5, larvae were present until 15 August but in 1980, populations were absent after the first week in June (Figs. 17, 18). The differences in the seasonal distribution of black fly immatures between 1979 and 1980 are attributed to water conditions. In 1979, spring water runoff was greater than usual, as were river water levels and velocity (Figs. 6, 8). Water flooded low areas adjacent to the river near Hartney, Manitoba (Fig. 6). This resulted in black fly levels higher than is generally considered acceptable to residents of this area. However, dry conditions throughout the area during the fall of 1979, and winter and spring of 1980, resulted in spring water levels slightly higher than those of the preceding fall (Figs. 7, 9). As the water levels

and water velocity continued to decrease in the spring of 1980, so did black fly populations.

Relative to 1979, higher cone sampler densities of S. johannseni and S. meridionale larvae (instars 2-5) were observed at sites 4 and 5 in 1980 (Figs. 21, 29, 30, 32). However, only a few adults were collected at these sites. Presumably only low numbers of adults emerged.

Larvae are more concentrated during low water levels, and larvae may be more prone to drift when fewer acceptable attachment sites are available to them. This could restrict the development of massive black fly populations during non-flood years. Without attachment sites, larval feeding and consequently development is reduced. Westwood (1979) stated "that serious black fly outbreaks occur in the Souris River when it undergoes moderate to heavy flooding in the spring" and "river flow prior to the beginning of black fly breeding often gives a good indication as to the potential of an outbreak". If correct, the latter statement suggests a practical method to predict potential outbreaks. It may in fact be more reliable than using artificial samplers for estimating black fly populations. Cone samplers monitored the relative proportions of different black fly species and the relative stages of development, but did not provide a good estimate of larval populations and were of little value in predicting the size of adult populations.

Adults. In 1979, black fly adults were collected in floating emergence traps from the first week of June to 31 August (Fig. 34). Periods of peak emergence occurred on 1 June and 21 August, 1979. In 1980, adults were collected in emergence traps between 15 May and 9 June. Peak emergence occurred during the last week of May. No further peaks were

observed in 1980 (Fig. 35).

In 1980, female black flies were attracted to CO_2-baited traps and to animal-baited traps between 18 May and 9 June (Tables 9, 10, 11). Blood feeding activity was greatest between 21 May and 4 June (Tables 10, 11). No flies were taken in New Jersey mosquito traps fitted with ultraviolet bulbs or 100 watt white incandescent bulbs not supplied with a source of CO_2.

Black fly adults remained active at wide ranges of temperature, relative humidity, light intensity and cloud cover in the Souris River area. Black flies are very versatile, and can remain active, often, under seemingly unsuitable conditions. In this study, black flies were active at relative humidities as low as 7% and air temperatures as high as 36.7^{0}C. Black flies were most active at air temperatures between 25^{0}C and 31^{0}C (Fig. 48, 49, 50, 51), at relative humidities between 10% and 58%, at light intensities between 60 and 1,620 lux and at diurnal periods between 1900 h and 2100 (Fig. 42). Black flies fed most actively during the morning from 0700 h to 1000 h and in the evening from 1800 h to 2200 h (Figs. 43, 44, 45, 46, 47). However, high levels of *S. johannseni* and *S. meridionale* also fed at mid-day (Figs. 46, 47).

Section C - Pest Species and Implication for Control

S. meridionale, *S. luggeri*, *S. johannseni*, *S. venustum/verecundum* and *S. vittatum* are potential pests of cattle, horses, humans and domestic fowl in the Souris River area. *S. meridionale* is considered to be the worst pest species in this area for a number of reasons. First, in 1979 and 1980, this species was the most plentiful in CO_2-baited traps and attacked the largest variety of hosts (birds, humans, cattle). Secondly,

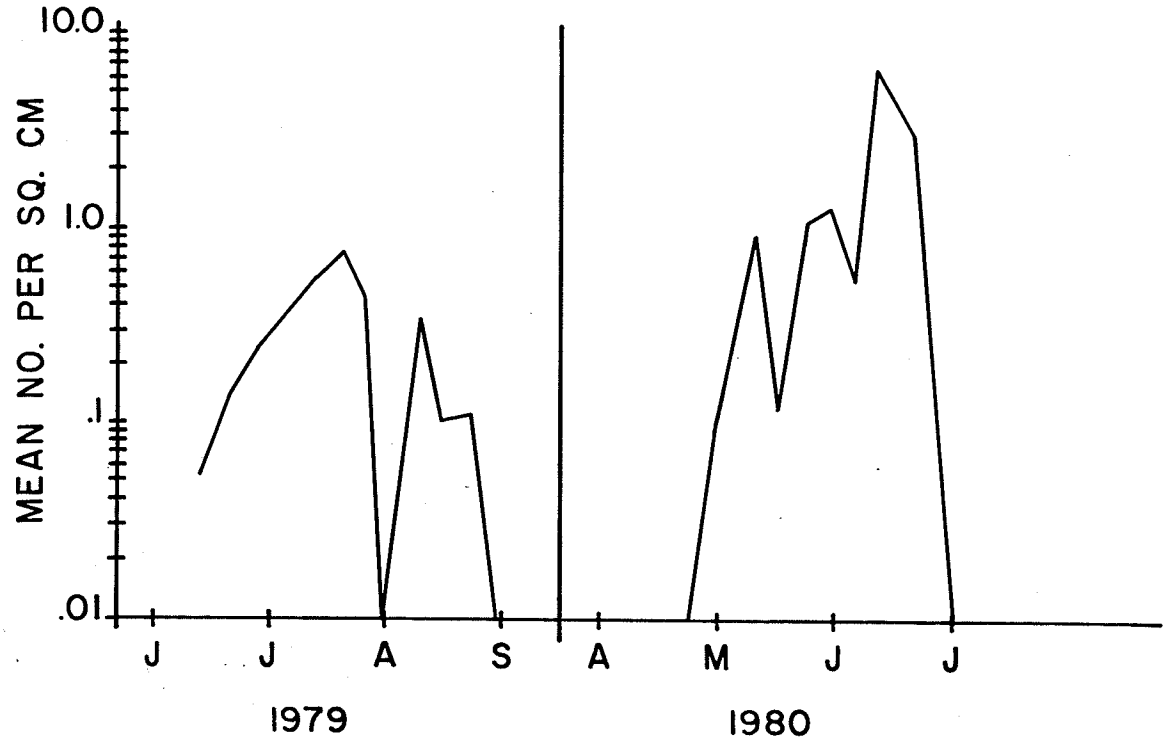
unlike S. johannseni or S. venustum/verecundum complex, which have one annual generation, S. meridionale has at least 2 generations in the Souris River. This black fly was probably responsible for most of the domestic and wild bird losses during 1974 and 1975. Second in importance was S. luggeri. It was captured in CO_2-baited traps, and it attacked cattle, humans and horses. It too is multivoltine, having 2-4 generations annually. Next in importance are two univoltine species, S. venustum/verecundum complex and S. johannseni. Of the former, S. johannseni is probably more important. Although both flies developed together in early spring, adults of S. johannseni took blood 2 to 3 weeks longer than the S. venustum/verecundum complex. This suggests that S. johannseni has greater longevity than the S. venustum/verecundum complex. The autogenous, multivoltine species, S. vittatum, is last in importance. This species requires no blood meal to produce the first cycle of eggs and apparently many adults die following oviposition. These become stuck to the egg mass during oviposition and die before they are able to obtain a blood meal for the second gonotrophic cycle. Those feeding following oviposition prefer to feed on the inner ear of cattle and horses and not on the underbelly. Although this species had the highest larval numbers (Figs. 19, 23, 27), the highest numbers of emerged adults (Fig. 39) and the most generations annually (3-4), only small numbers were attracted to CO_2-baited traps. This further supports the observation that many flies die shortly after oviposition.

The most feasible method for control of black flies in the Souris River is larviciding. Westwood (1979) proposed that the river be treated twice, once for the S. venustum/verecundum complex and S. johannseni peak and once 10-14 days later for the S. meridionale and S. luggeri peak.

If only one treatment is to be made, larvae of S. meridionale and S. luggeri should be controlled for reasons mentioned above. Treatment of late larval instars of these species will also control a third pest species, S. vittatum. In 1979, under flood conditions, development of the larvae of S. meridionale, S. luggeri and S. vittatum was very uniform, particularly at sites 4 and 5. If larviciding was to be carried out, the material should be released just upstream from these sites.

Figure 16. Mean number of black fly larvae (all species) collected on cone samplers at site 2 in 1979 and 1980.

Figure 17. Mean number of black fly larvae (all species) collected on cone samplers at site 4 in 1979 and 1980.


10.0
1.0
.1
.01
MEAN NO. PER SQ. CM
J
J
A
S
A
M
J
J
1979
1980

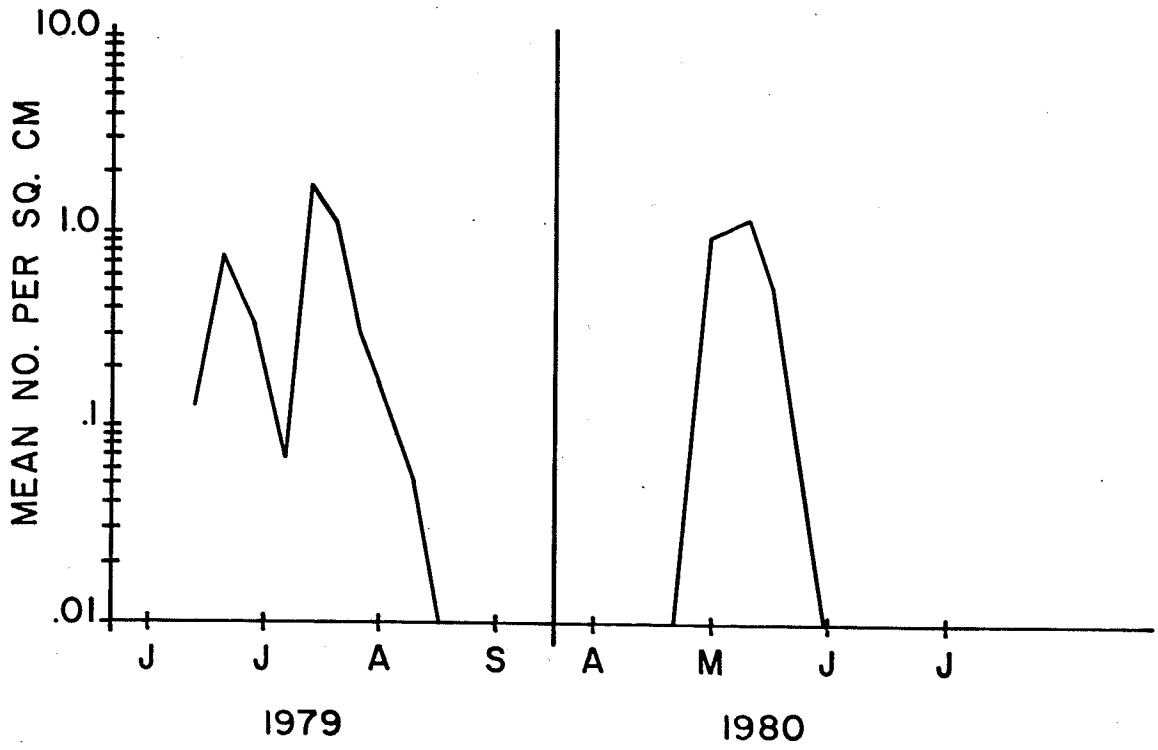
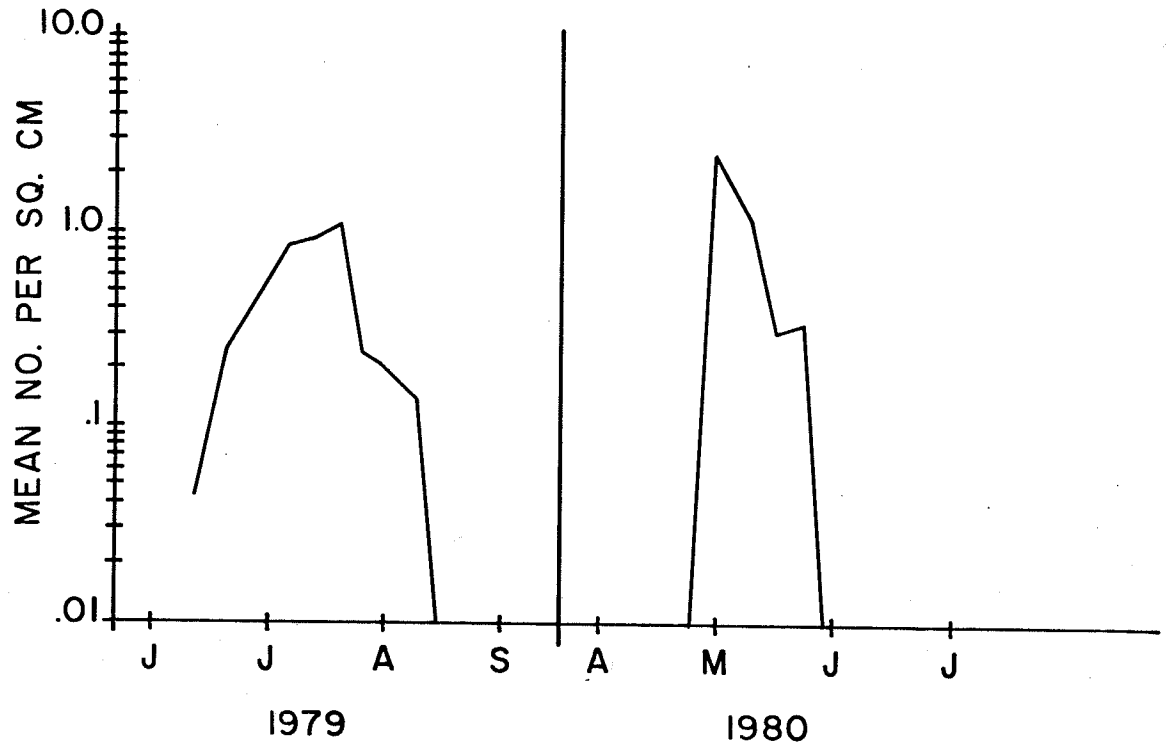

10.0
1.0
.1
.01
MEAN NO. PER SQ. CM
J
J
A
S
A
M
J
J
1979
1980

Figure 18. Mean number of black fly larvae (all species) collected on cone samplers at site 5 in 1979 and 1980.

Figure 19. Mean larval density of *Simulium vittatum* collected on cone samplers at site 2 in 1979 and 1980. Numbers at points along the curve indicate stages in larval development.


10.0
1.0
.1
.01
MEAN NO. PER SQ. CM
J
J
A
S
A
M
J
J
1979
1980

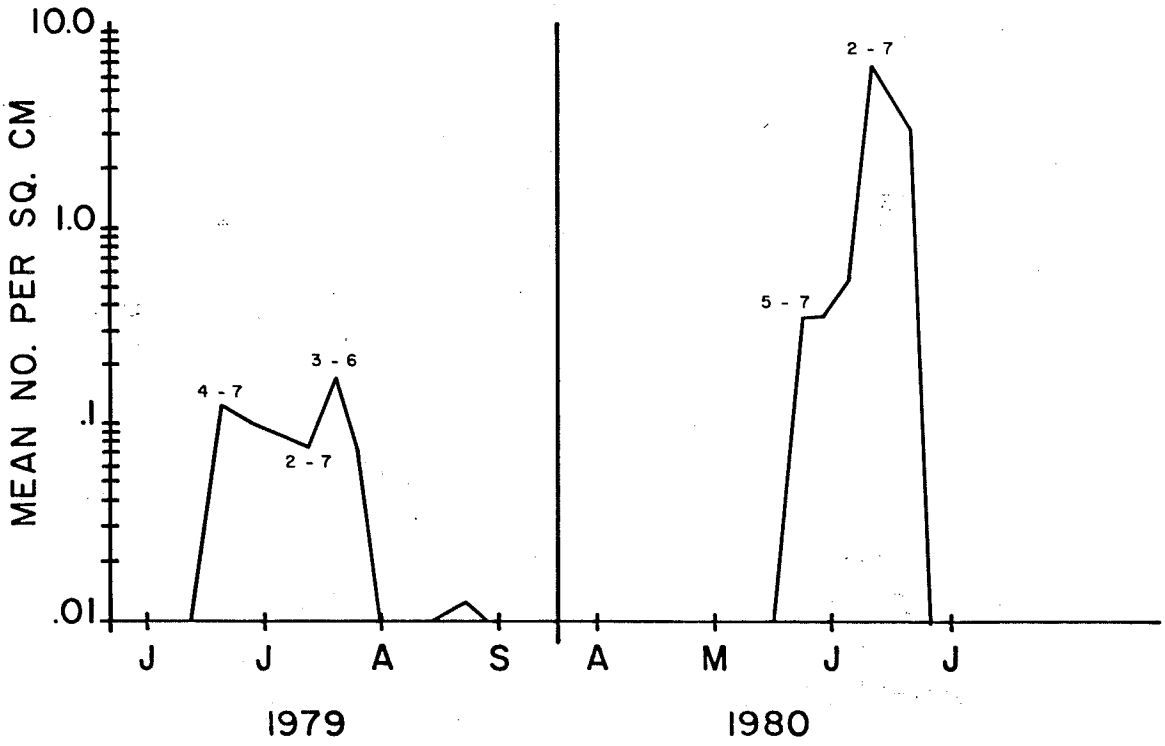
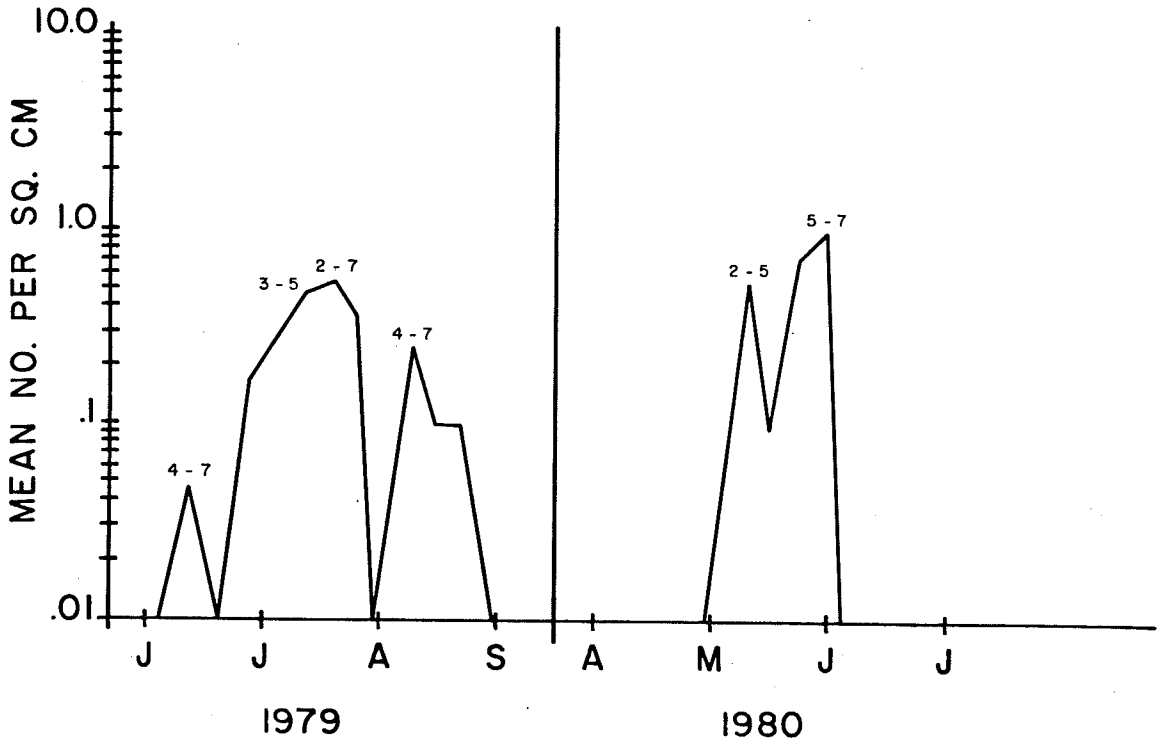

10.0
1.0
.1
.01
MEAN NO. PER SQ. CM
4 - 7
3 - 6
2 - 7
5 - 7
2 - 7
J
J
A
S
A
M
J
J
1979
1980

Figure 20. Mean larval density of *Simulium luggeri* collected on cone samplers at site 2 in 1979 and 1980.

Figure 21. Mean larval density of *Simulium meridionale* collected on cone samplers at site 5 in 1979 and 1980.


10.0
1.0
.1
.01
MEAN NO. PER SQ. CM
4 - 7
3 - 5
2 - 7
4 - 7
2 - 5
5 - 7
J
J
A
S
A
M
J
J
1979
1980

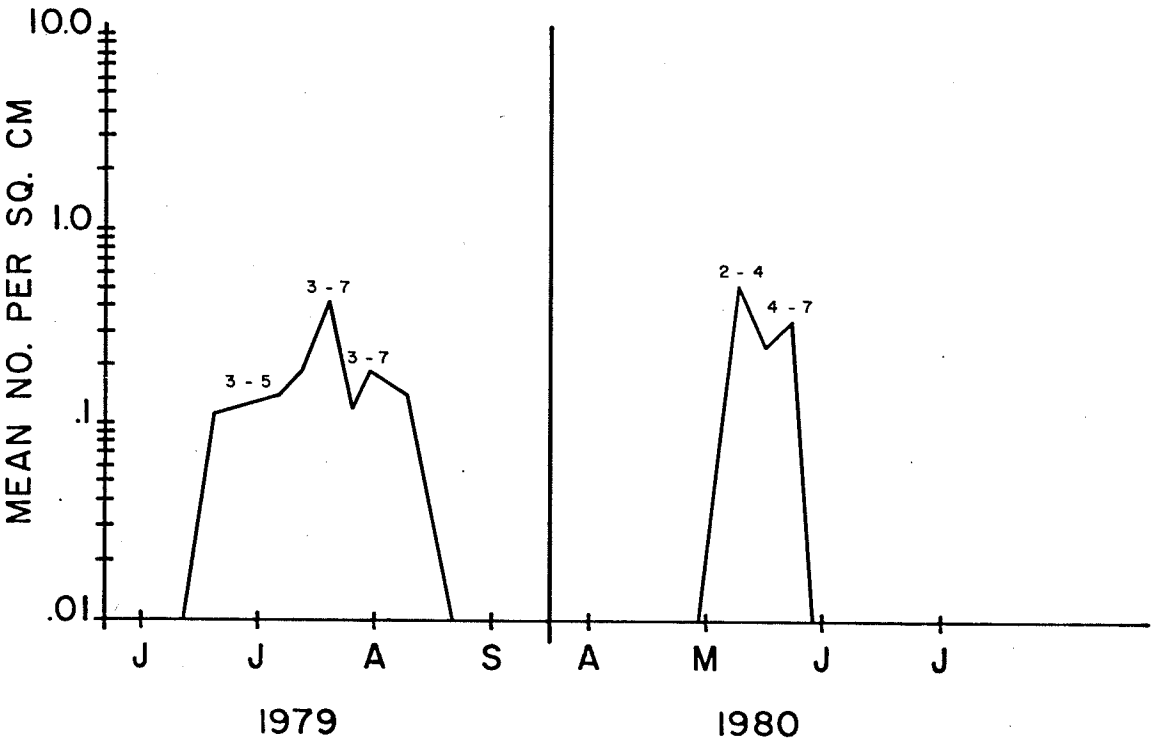
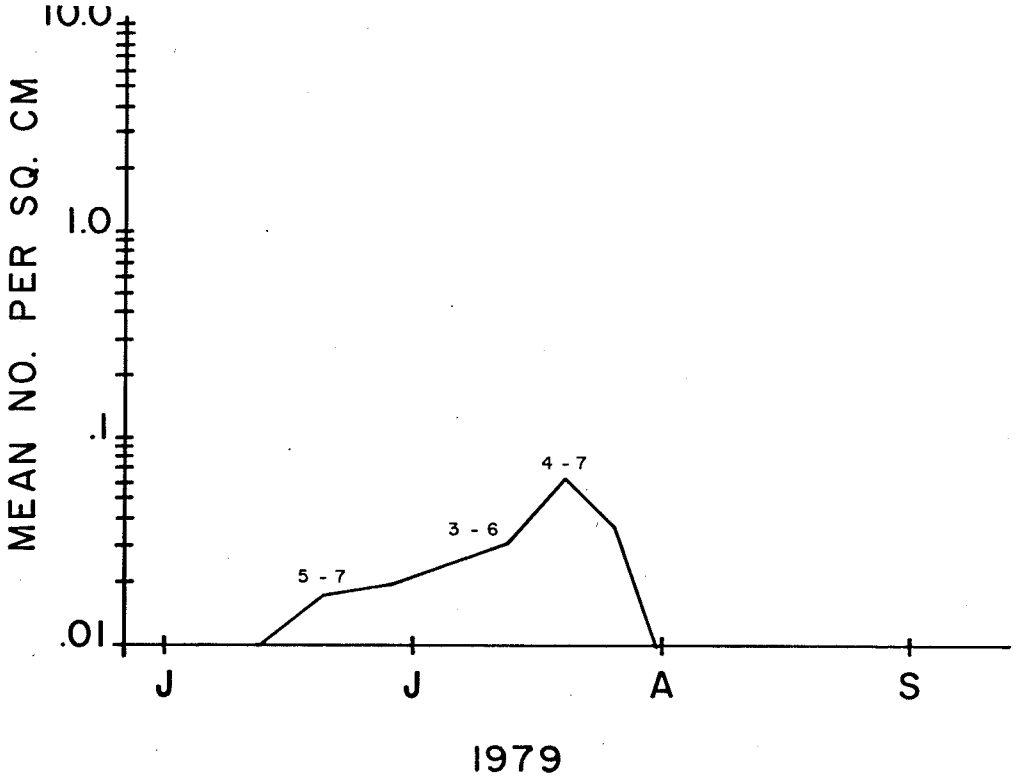

10.0
1.0
.1
.01
MEAN NO. PER SQ. CM
3 - 5
3 - 7
3 - 7
2 - 4
4 - 7
J
J
A
S
A
M
J
J
1979
1980

Figure 22. Mean larval density of Simulium meridionale collected on cone samplers at site 2 in 1979.

Figure 23. Mean larval density of Simulium vittatum collected on cone samplers at site 4 in 1979.


10.0
1.0
.1
.01
MEAN NO. PER SQ. CM
5 - 7
3 - 6
4 - 7
J
J
A
S
1979

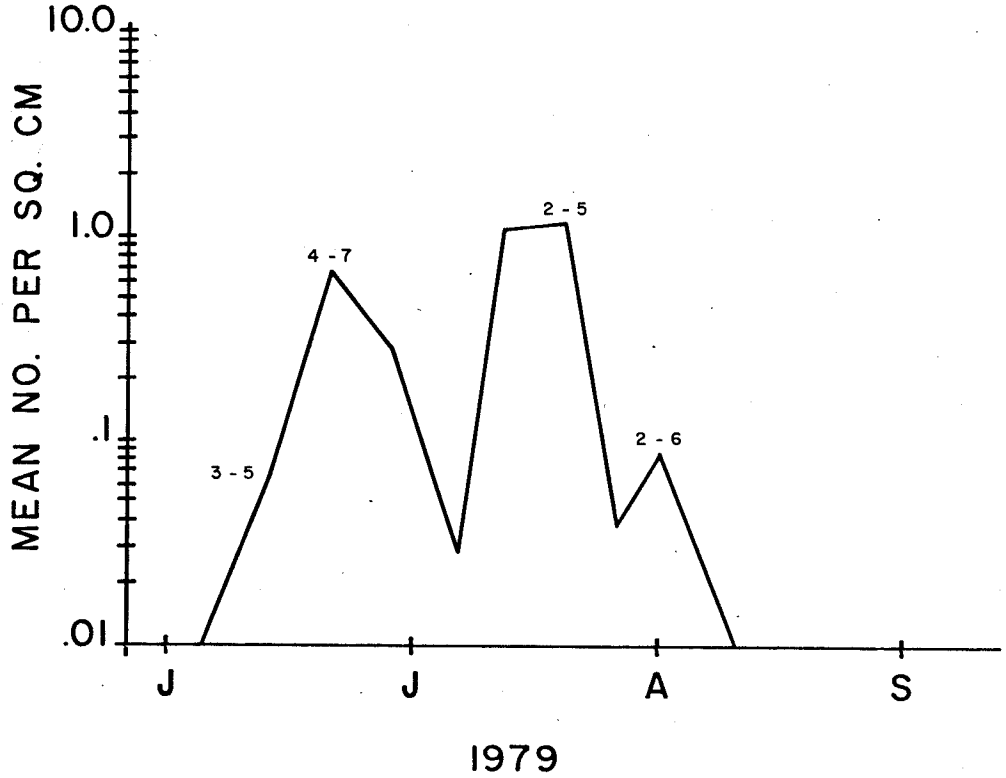
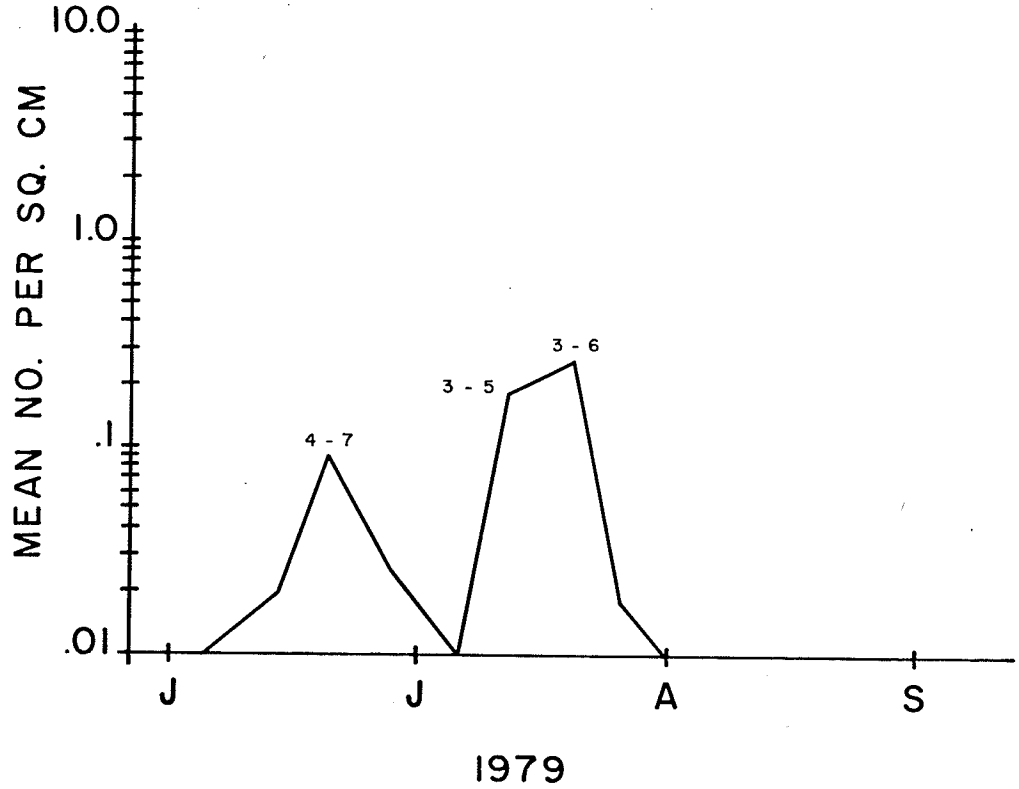

10.0
1.0
.1
.01
MEAN NO. PER SQ. CM
3 - 5
4 - 7
2 - 5
2 - 6
J
J
A
S
1979

Figure 24. Mean larval density of *Simulium luggeri* collected on cone samplers at site 4 in 1979.

Figure 25. Mean larval density of *Simulium meridionale* collected on cone samplers at site 4 in 1979.


10.0
1.0
.1
.01
MEAN NO. PER SQ. CM
4 - 7
3 - 5
3 - 6
J
J
A
S
1979

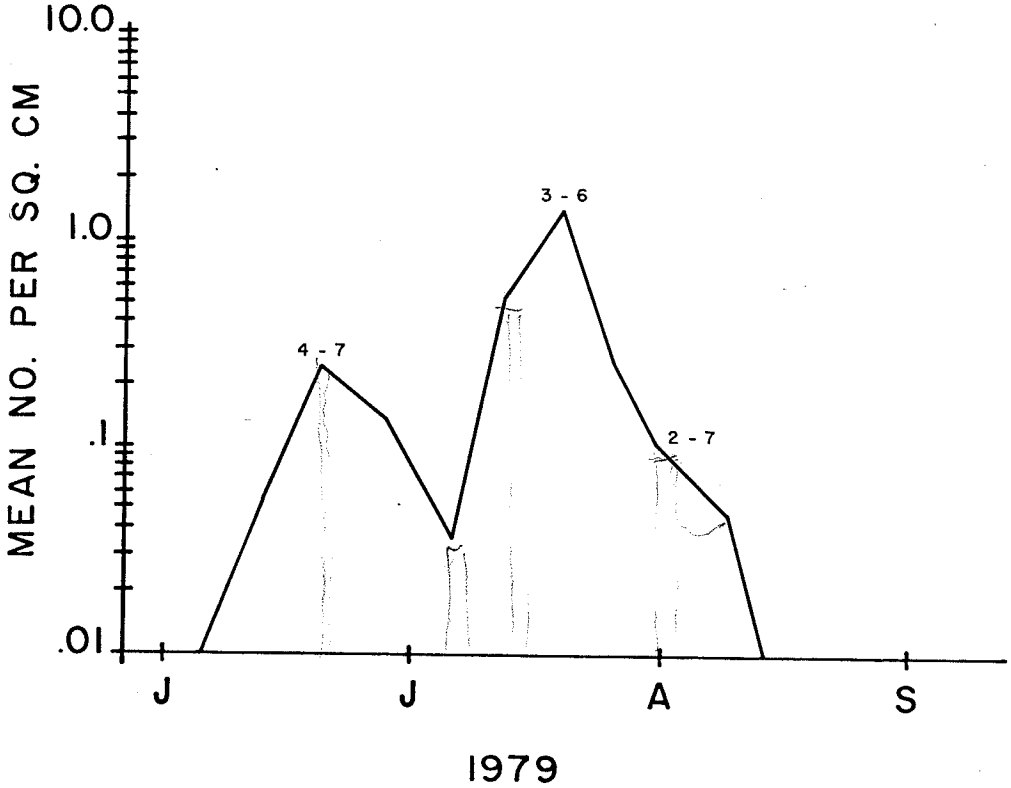
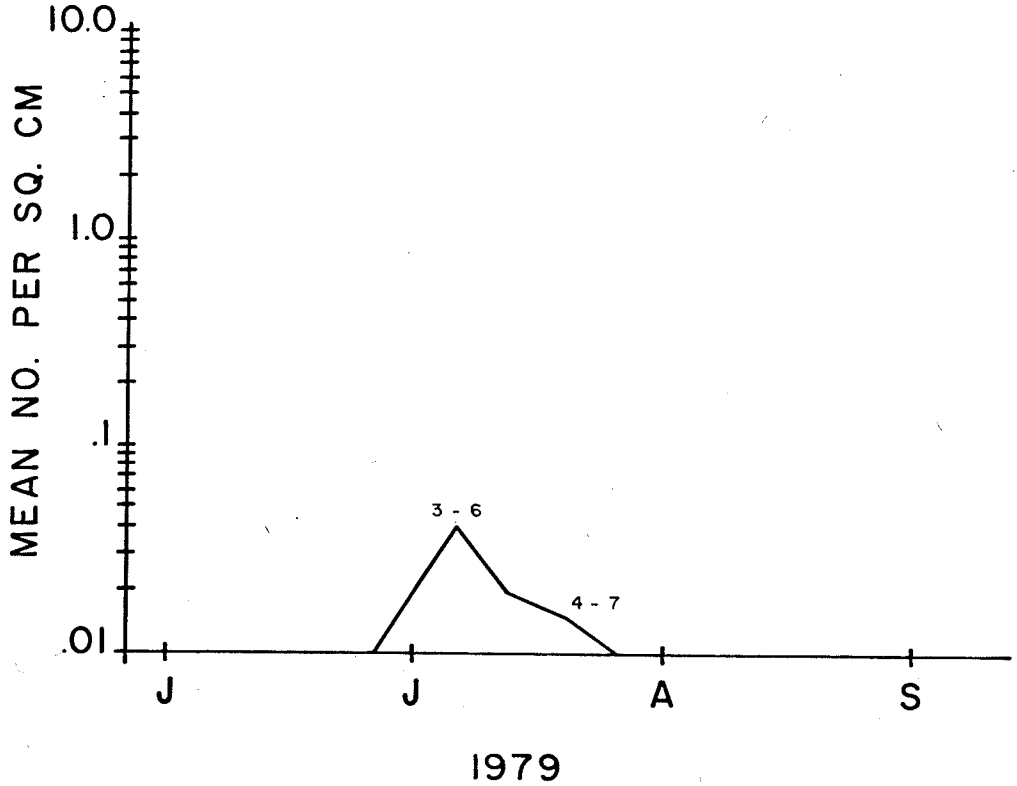

10.0
1.0
.1
.01
MEAN NO. PER SQ. CM
4 - 7
3 - 6
2 - 7
J
J
A
S
1979

Figure 26. Mean larval density of Simulium luggeri collected on cone samplers at site 5 in 1979.

Figure 27. Mean larval density of Simulium vittatum collected on cone samplers at site 5 in 1979.


10.0
1.0
.1
.01
MEAN NO. PER SQ. CM
3 - 6
4 - 7
J
J
A
S
1979

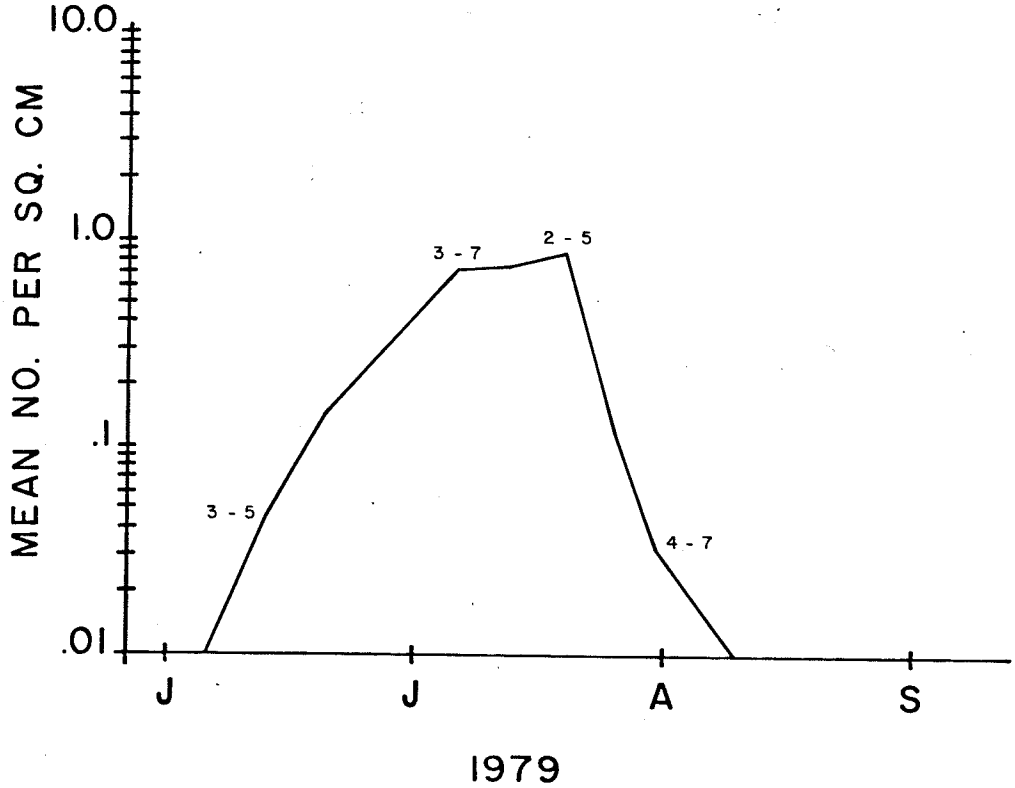
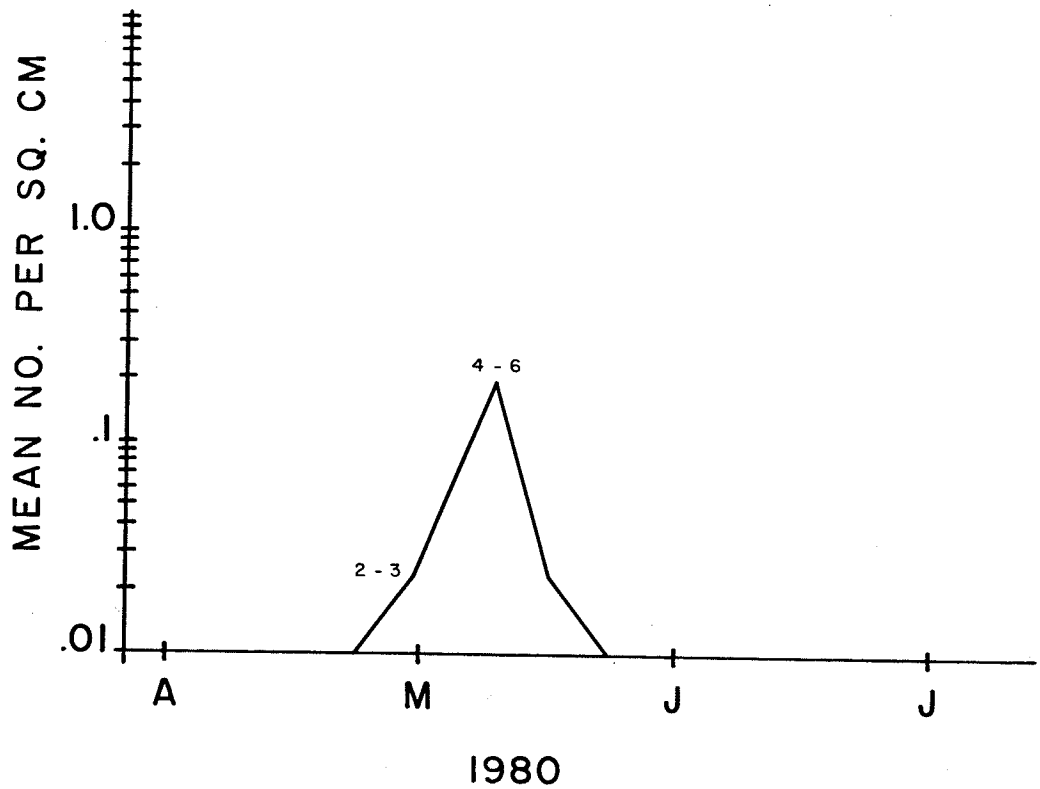

10.0
1.0
.1
.01
MEAN NO. PER SQ. CM
3 - 5
3 - 7
2 - 5
4 - 7
J
J
A
S
1979

Figure 28. Mean larval density of Simulium venustum/verecundum on cone samplers at site 4 in 1980.

Figure 29. Mean larval density of Simulium johannseni collected on cone samplers at site 4 in 1980.


MEAN NO. PER SQ. CM
1.0
.1
.01
4 - 6
2 - 3
A
M
J
J
1980

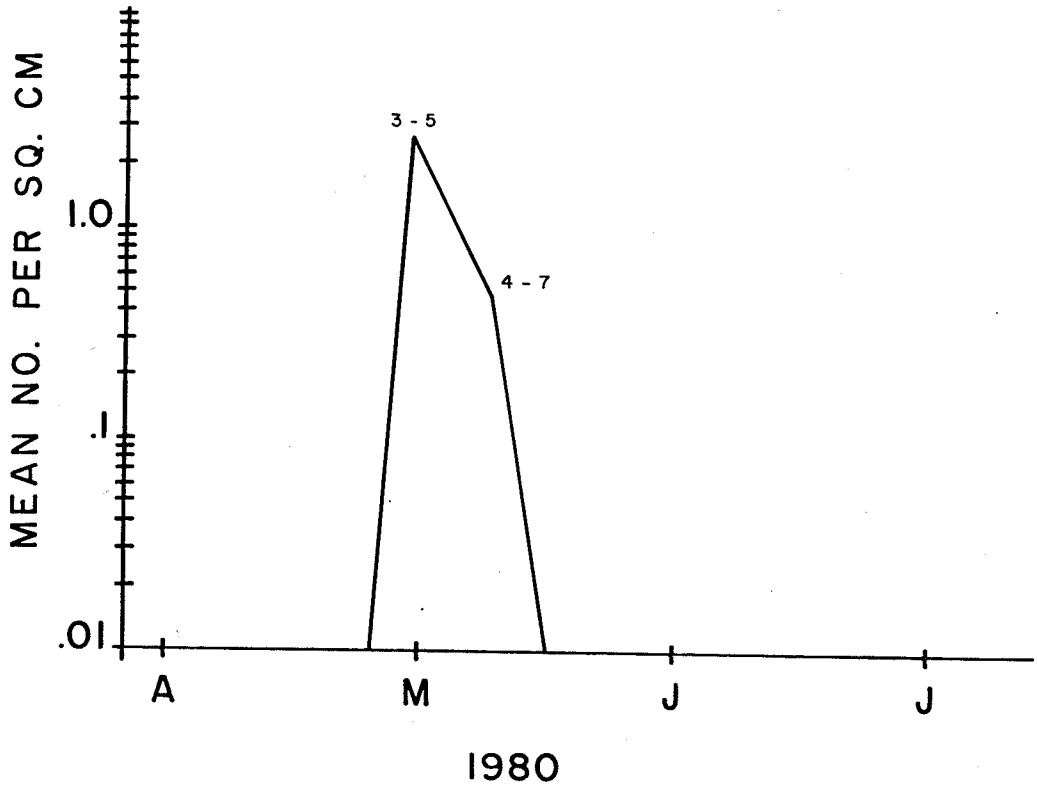
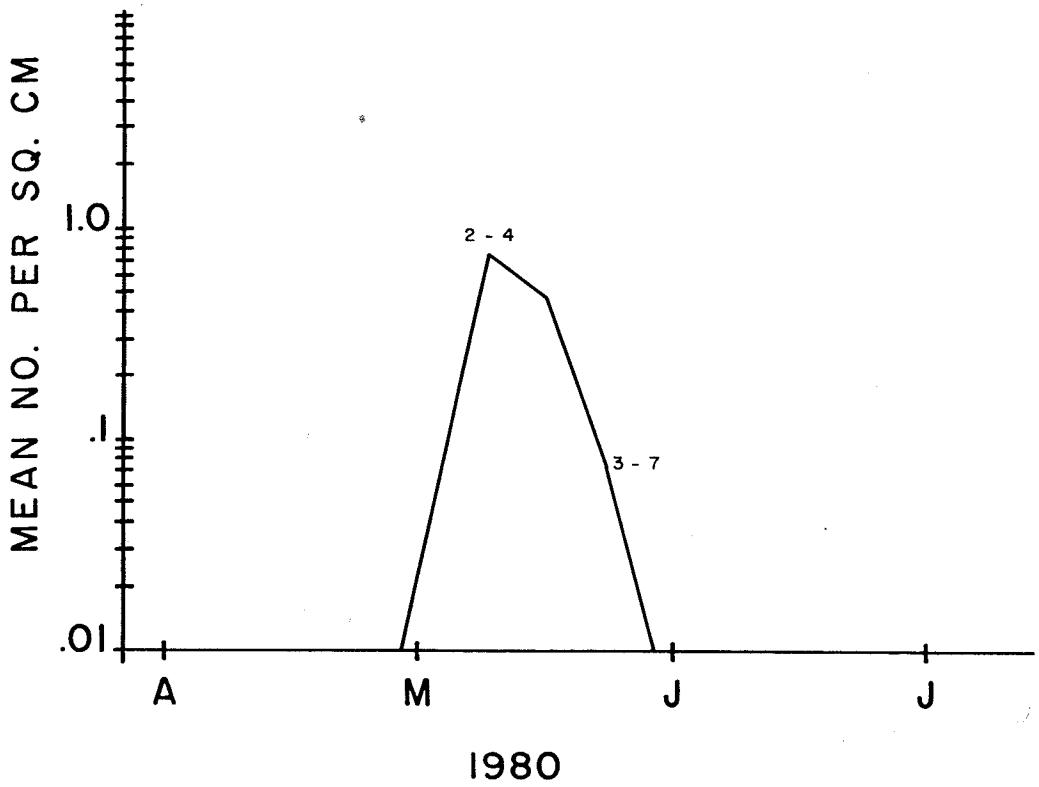

MEAN NO. PER SQ. CM
1.0
.1
.01
3 - 5
4 - 7
A
M
J
J
1980

Figure 30. Mean larval density of Simulium meridionale collected on cone samplers at site 4 in 1980.

Figure 31. Mean larval density of Simulium venustum/verecundum collected on cone samplers at site 5 in 1980.


MEAN NO. PER SQ. CM
1.0
.1
.01
2 - 4
3 - 7
A
M
J
J
1980

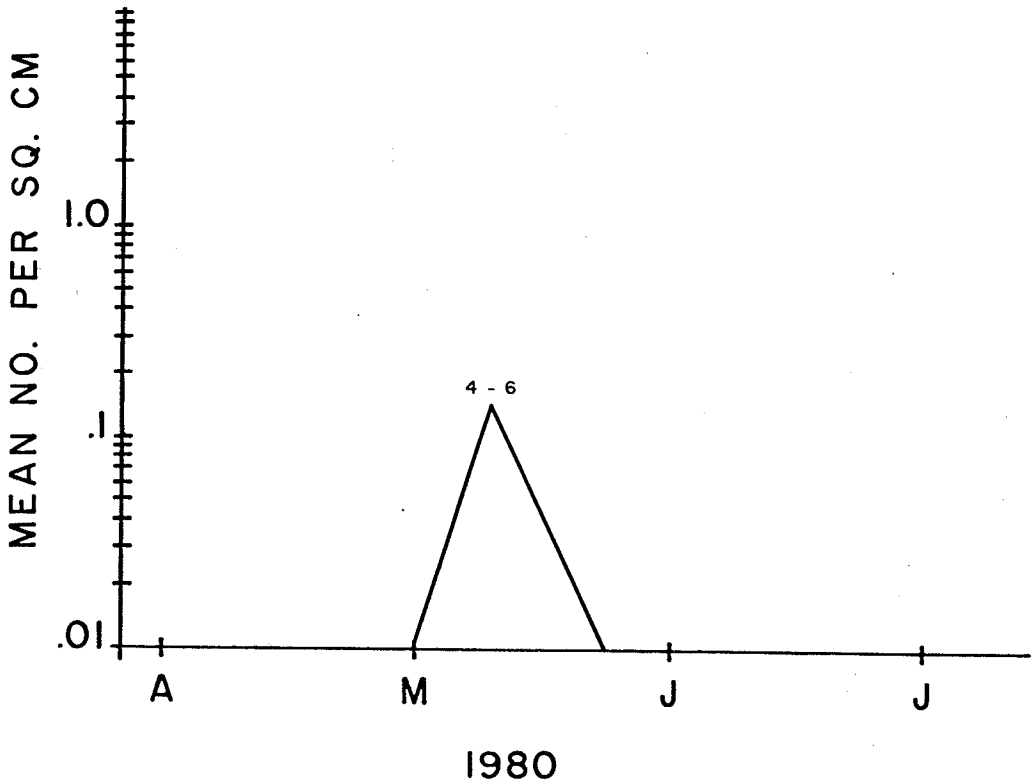

MEAN NO. PER SQ. CM
1.0
.1
.01
4 - 6
A
M
J
J
1980

Figure 31a. Mean larval density of *Simulium venustum/verecundum* collected on cone samplers at site 2 in 1980.

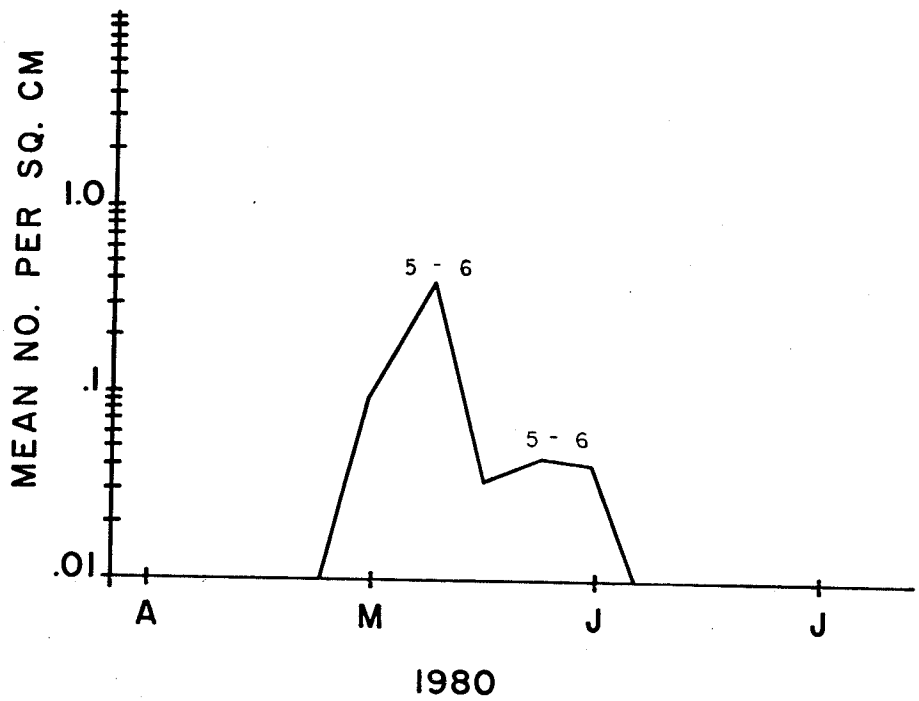
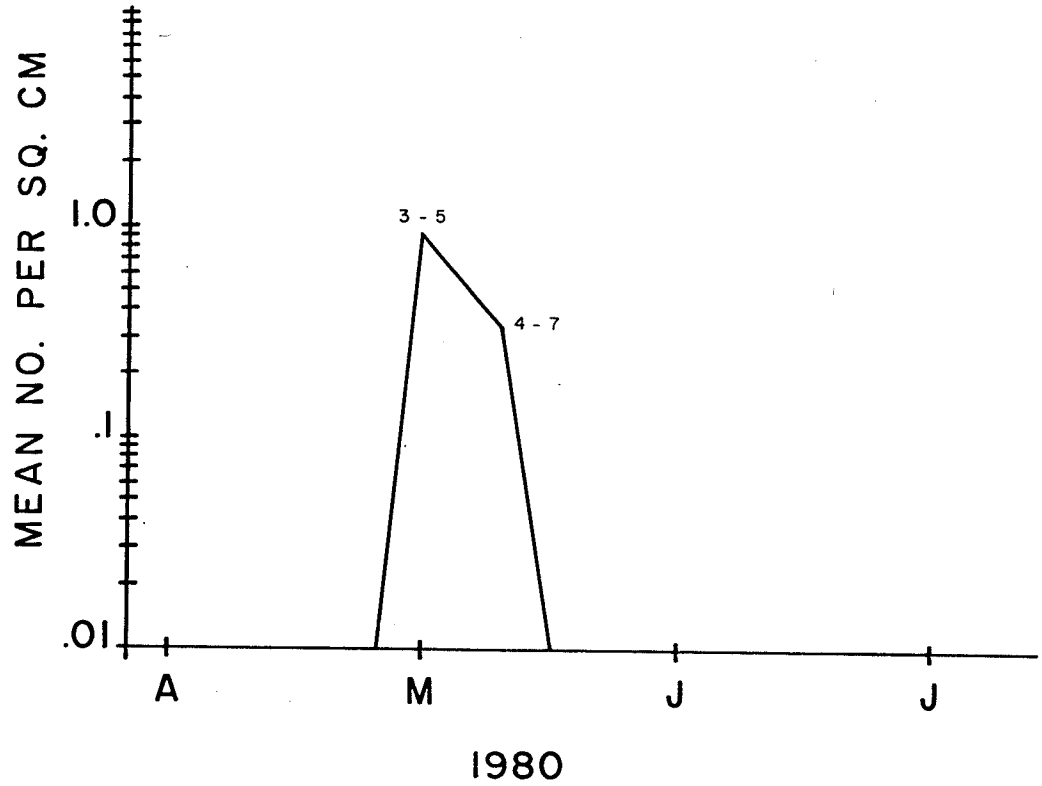

MEAN NO. PER SQ. CM
1.0
.1
.01
5 - 6
5 - 6
A
M
J
J
1980

Figure 32. Mean larval density of Simulium johannseni collected on cone samplers at site 5 in 1980.

Figure 33. Mean larval density of Simulium meridionale collected on cone samplers at site 2 in 1980.


MEAN NO. PER SQ. CM
1.0
.1
.01
3 - 5
4 - 7
A
M
J
J
1980

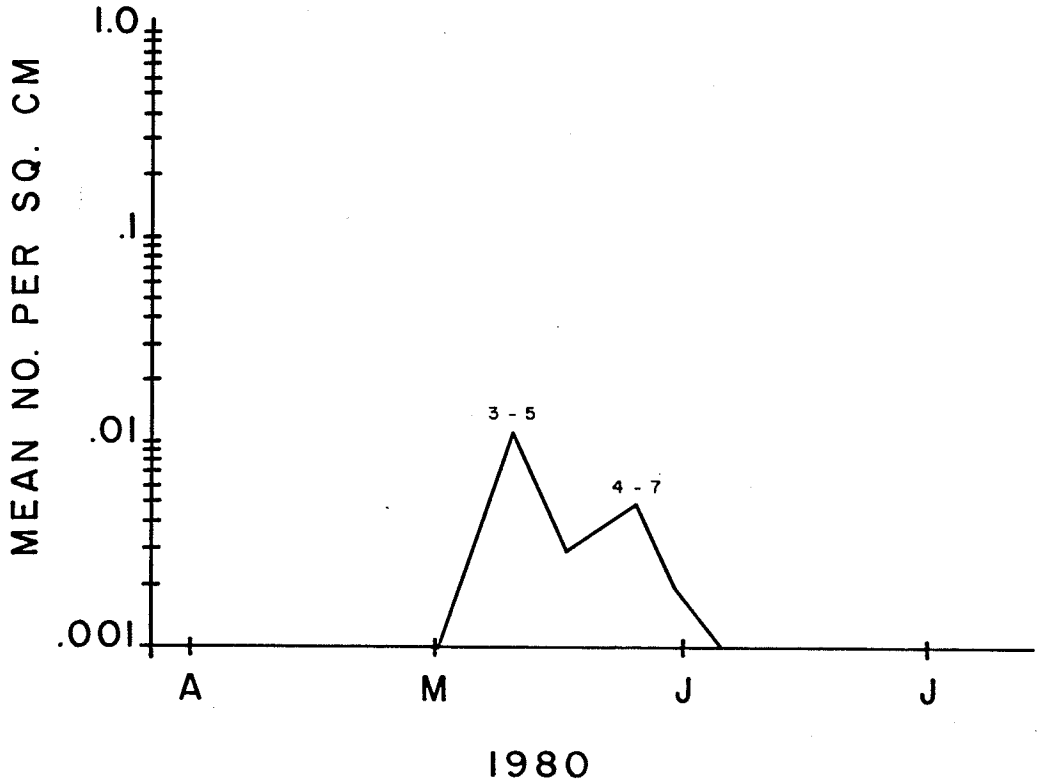
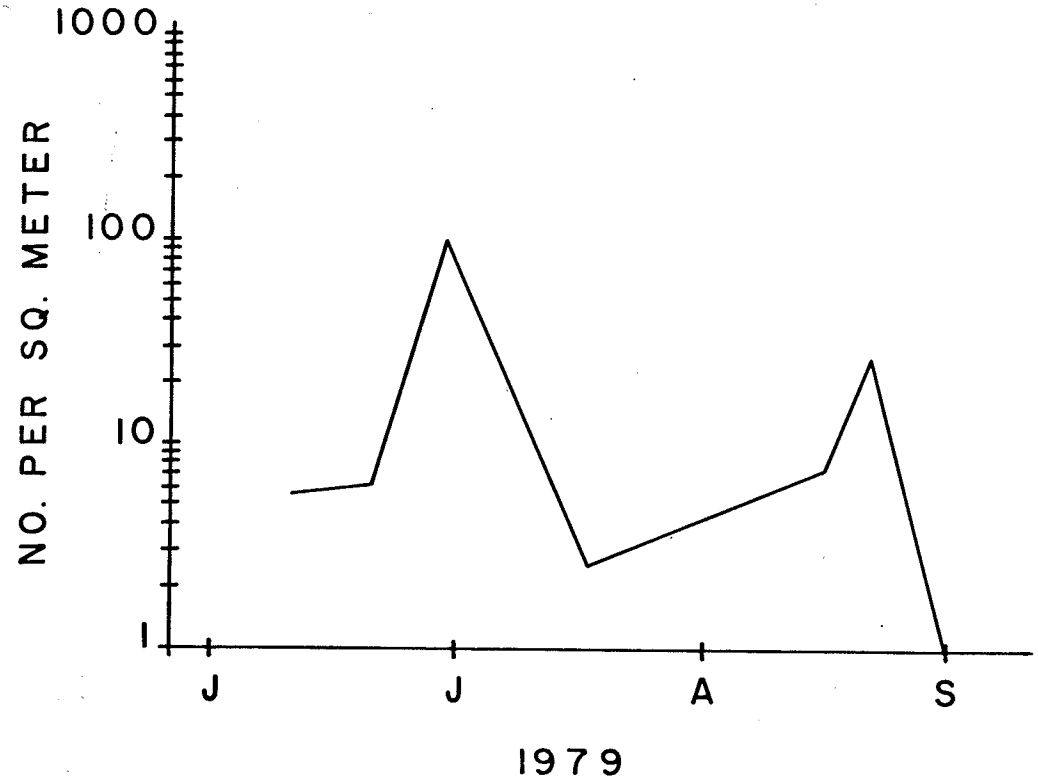

MEAN NO. PER SQ. CM
1.0
.1
.01
.001
3 - 5
4 - 7
A
M
J
J
1980

Figure 34. Mean number of adults (all species) collected in emergence traps at site 2 in 1979.

Figure 35. Mean number of adults (all species) collected in emergence traps at site 2 in 1980.


1000
100
10
1
NO. PER SQ. METER
J
J
A
S
1979

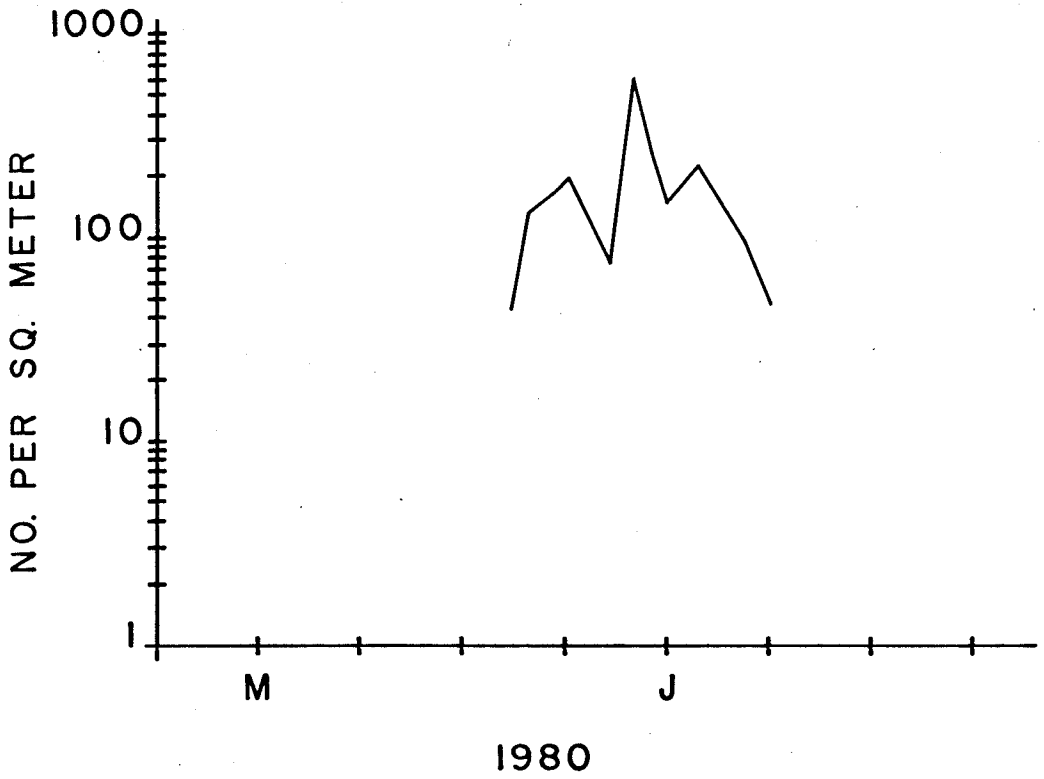
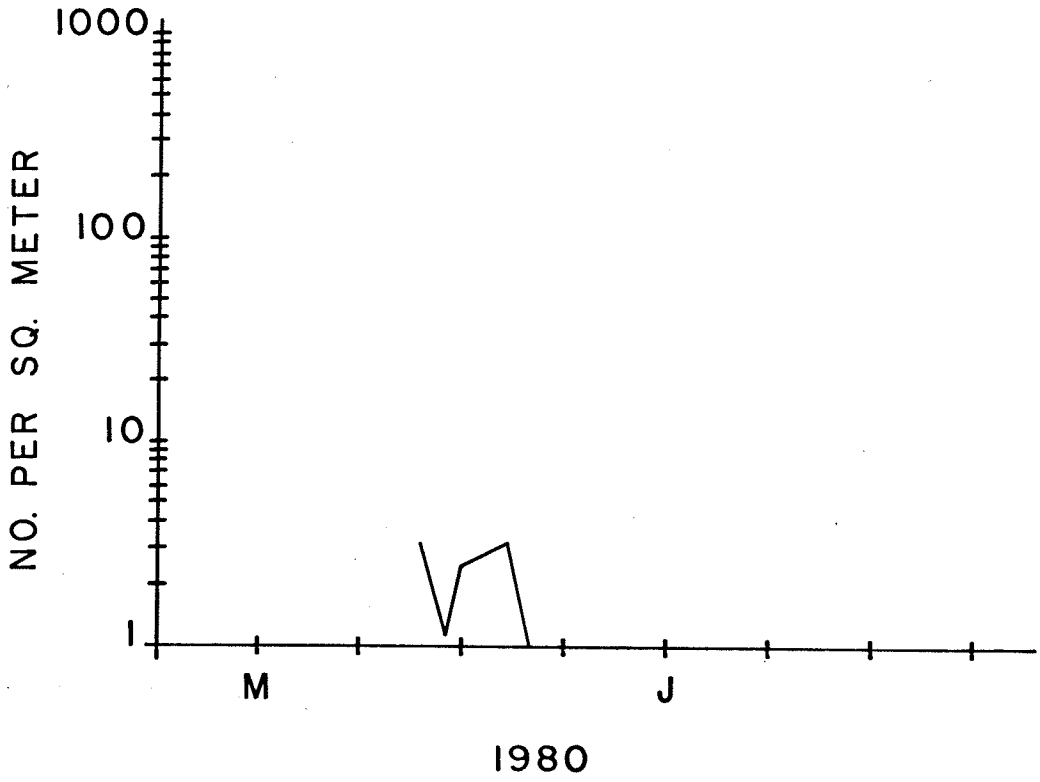

1000
100
10
1
NO. PER SQ. METER
M
J
1980

Figure 36. Mean number of Simulium johannseni females collected in emergence traps at site 2 in 1980.

Figure 37. Mean number of Simulium tuberosum adults collected in emergence traps at site 2 in 1980. ——— females, ----- males


1000
100
10
1
NO. PER SQ. METER
M
J
1980

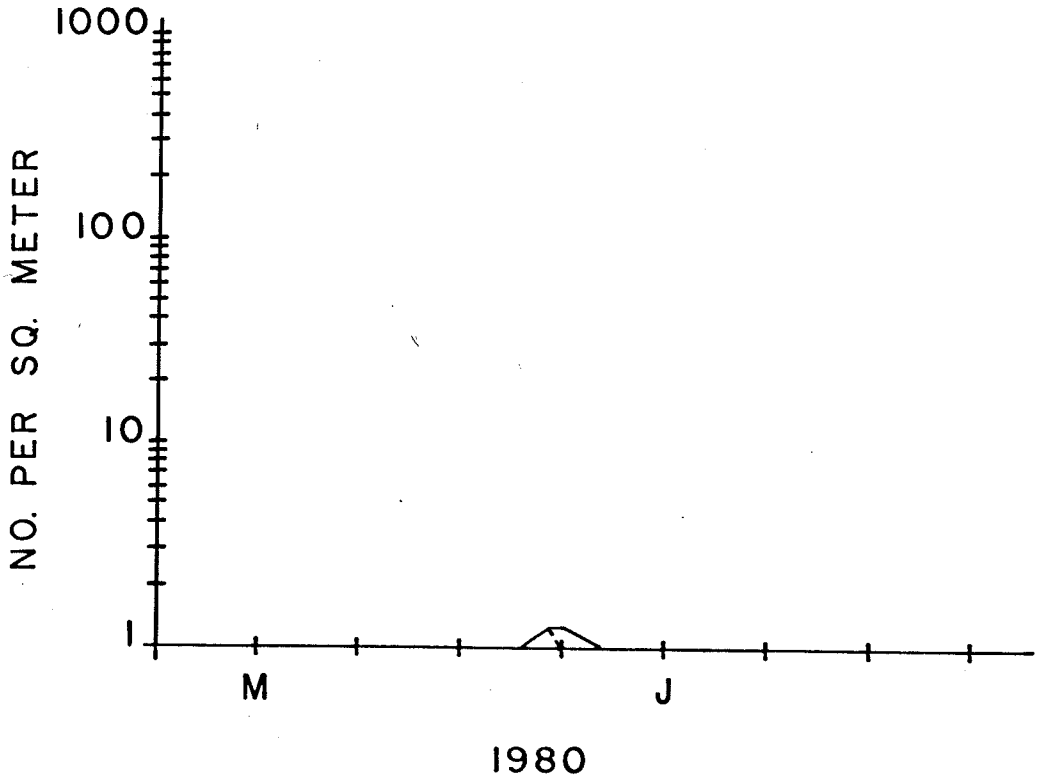
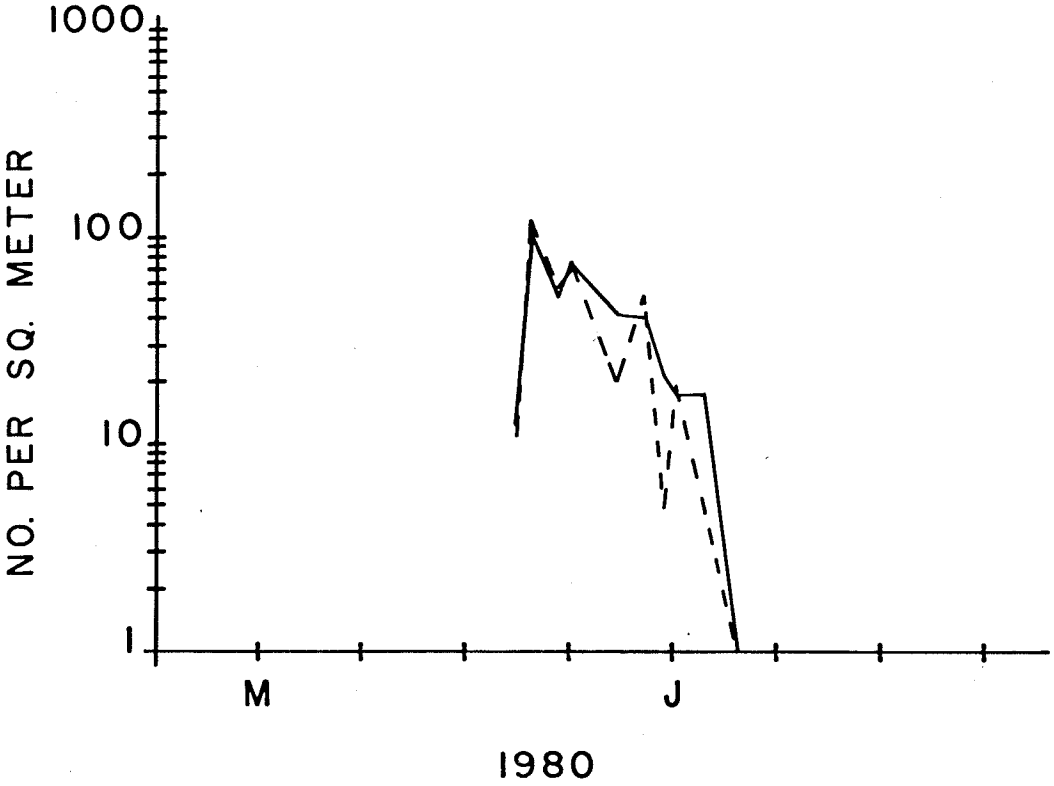

1000
100
10
1
NO. PER SQ. METER
M
J
1980

Figure 38. Mean number of Simulium luggeri adults collected in emergence traps at site 2 in 1980. ——— females, ----- males

Figure 39. Mean number of Simulium vittatum adults collected in emergence traps at site 2 in 1980. ——— females, ----- males


1000
100
10
1
NO. PER SQ. METER
M
J
1980

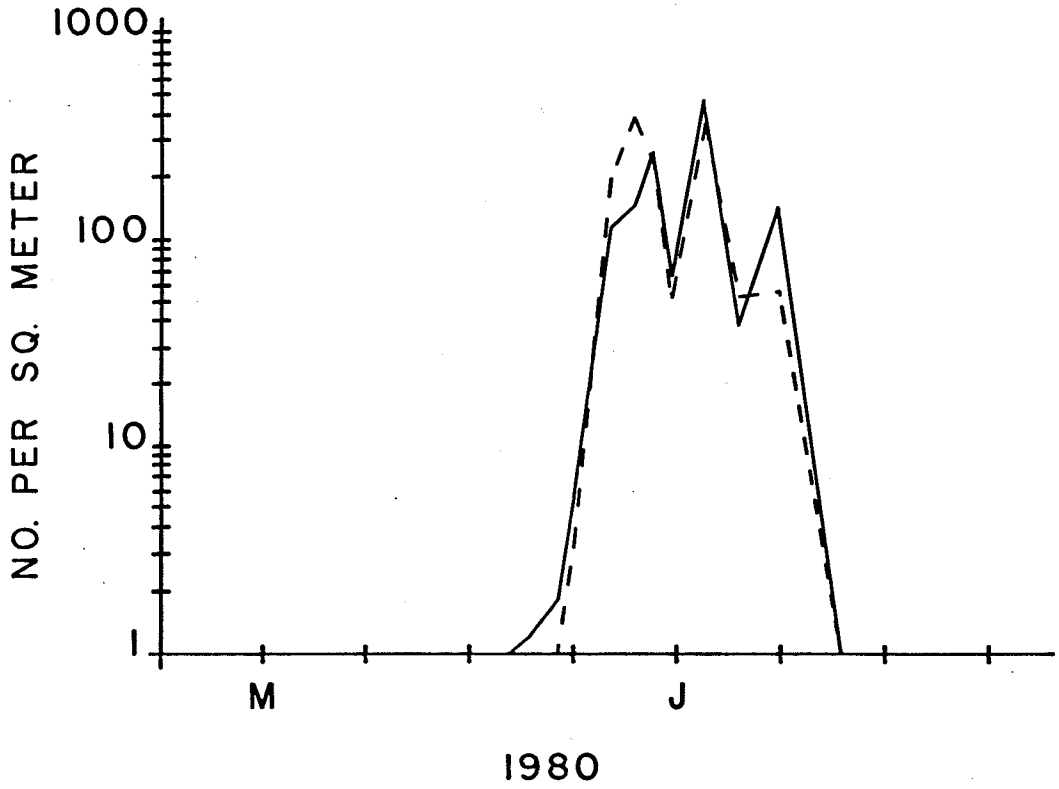
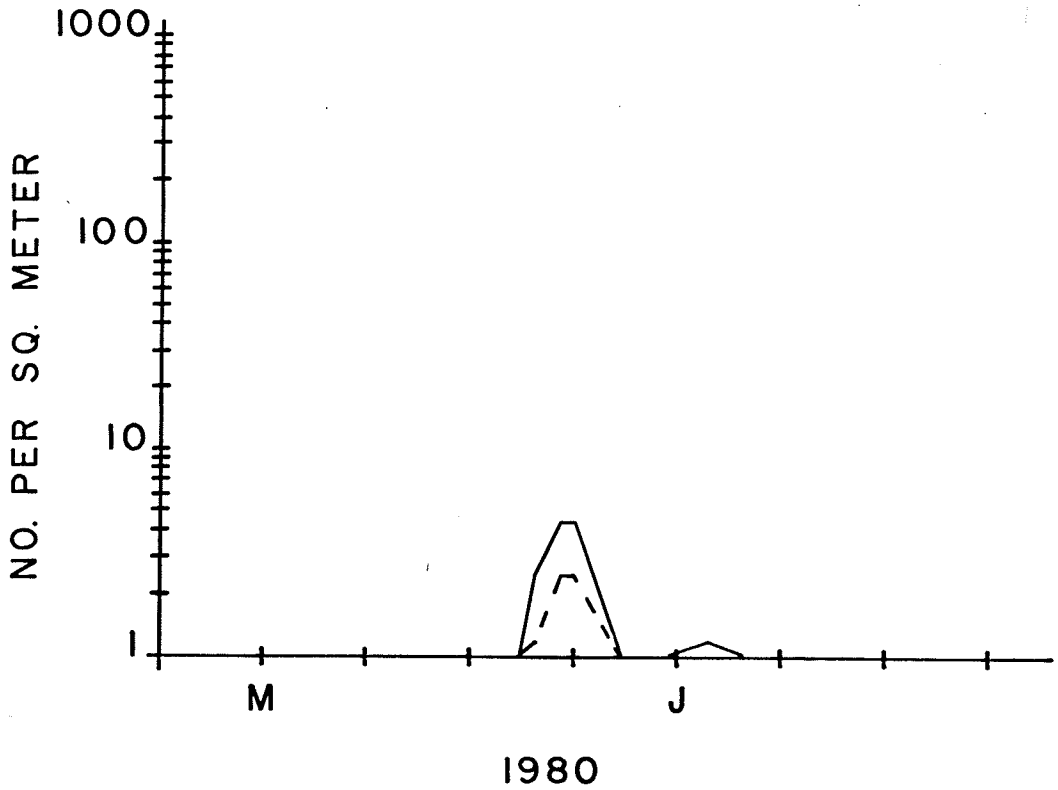

1000
100
10
1
NO. PER SQ. METER
M
J
1980

Figure 40. Mean number of Simulium meridionale adults collected in emergence traps at site 2 in 1980. ——— females, ----- males

Figure 41. Mean number of Simulium venustum/verecundum adults collected in emergence traps at site 2 in 1980. ——— females, ----- males


1000
100
10
1
NO. PER SQ. METER
M
J
1980

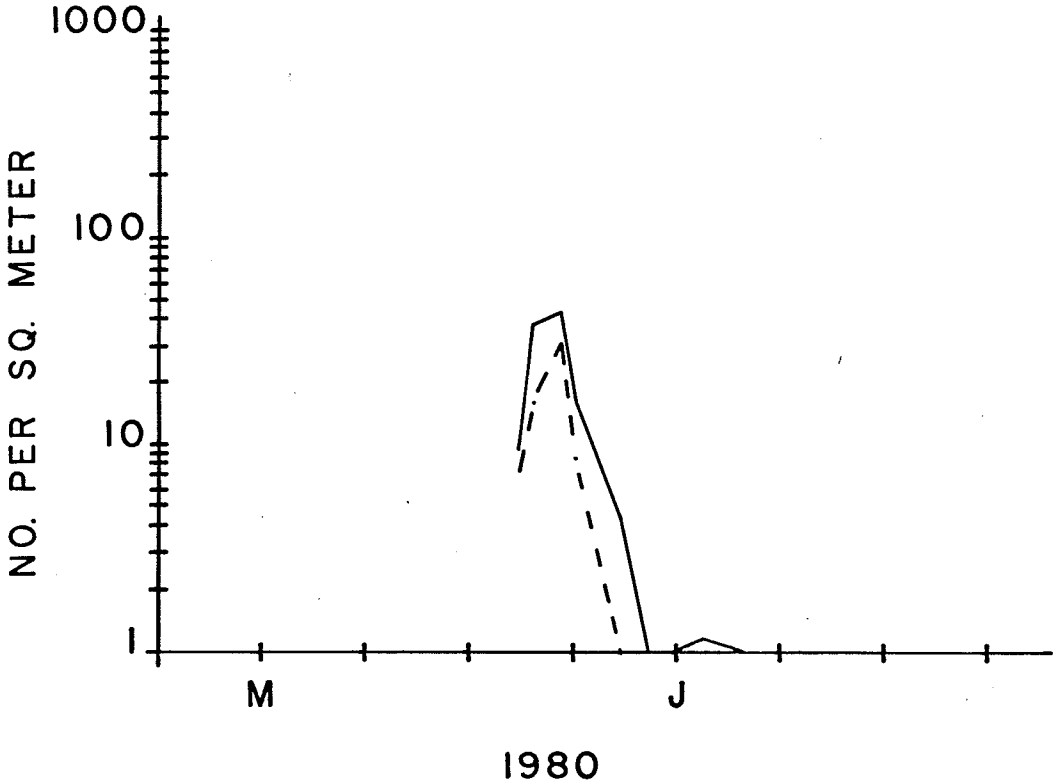
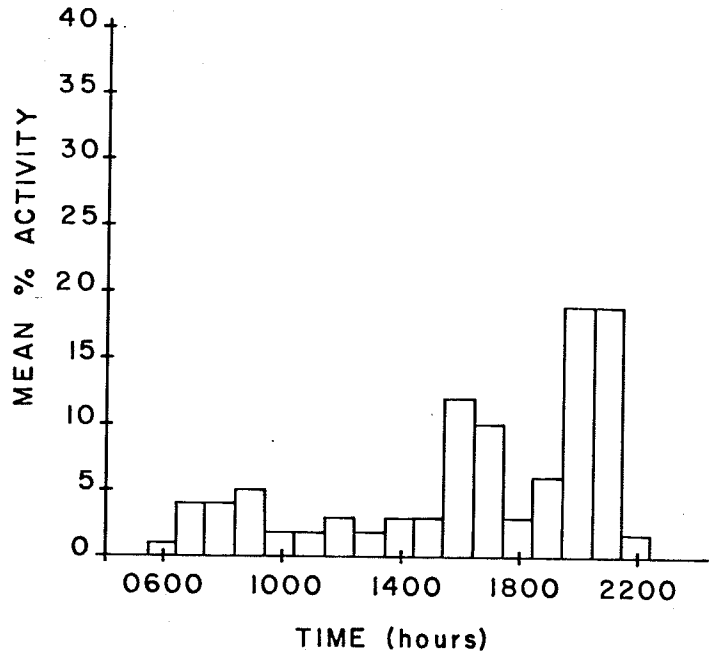

1000
100
10
1
NO. PER SQ. METER
M
J
1980

Figure 42. Mean hourly flight activity (all species) collected in a CO_2-baited trap at site 2 in 1980.

Figure 43. Mean hourly flight activity of *Simulium johannseni* collected in a CO_2-baited trap at site 2 in 1980.


MEAN % ACTIVITY
40
35
30
25
20
15
10
5
0
0600
1000
1400
1800
2200
TIME (hours)

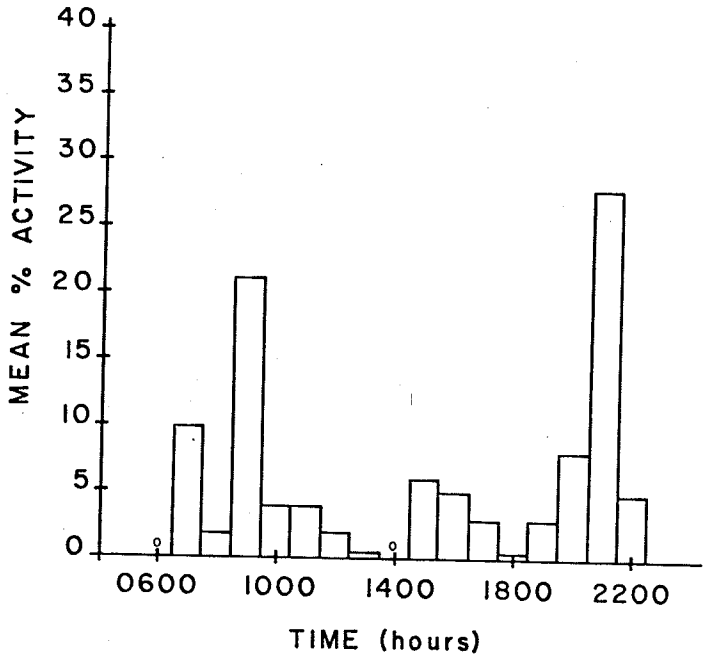
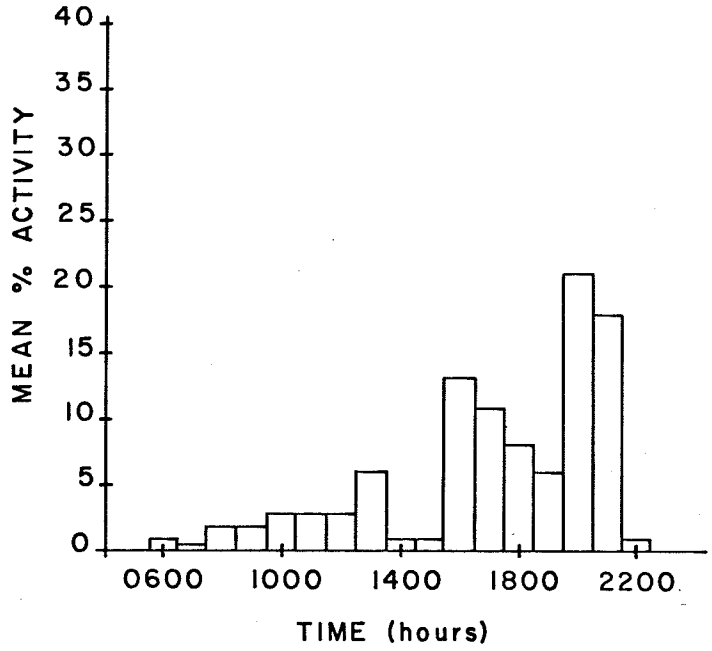

MEAN % ACTIVITY
40
35
30
25
20
15
10
5
0
0600
1000
1400
1800
2200
TIME (hours)

Figure 44. Mean hourly flight activity of Simulium meridionale collected in a CO_2-baited trap at site 2 in 1980.

Figure 45. Mean hourly flight activity of Simulium luggeri collected in a CO_2-baited trap at site 2 in 1980.


MEAN % ACTIVITY
40
35
30
25
20
15
10
5
0
0600
1000
1400
1800
2200
TIME (hours)

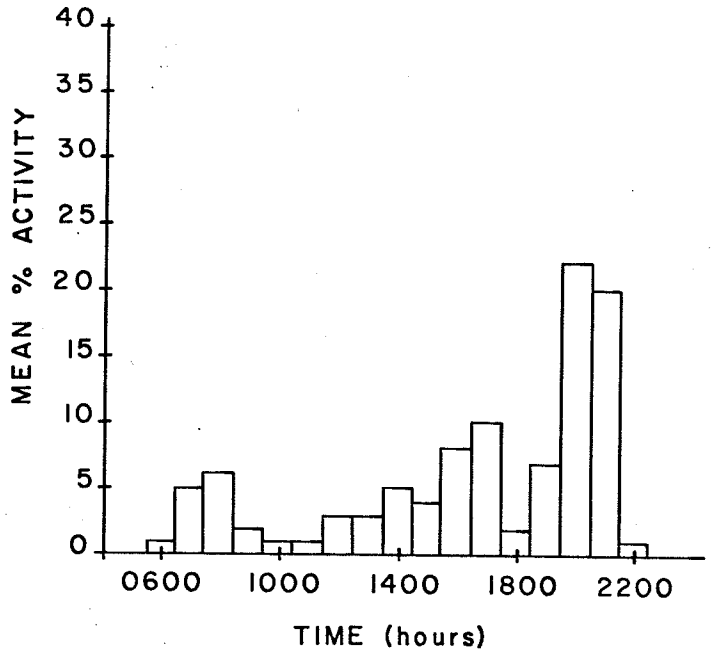
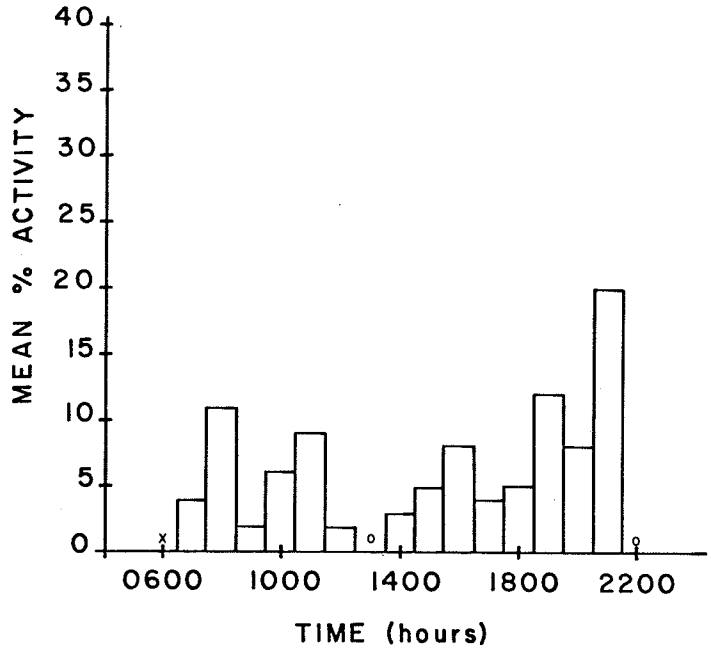

MEAN % ACTIVITY
40
35
30
25
20
15
10
5
0
0600
1000
1400
1800
2200
TIME (hours)

Figure 46. Mean hourly host-seeking activity of Simulium johannseni collected in live bird-baited traps at site 2 in 1980.

Figure 47. Mean hourly host-seeking activity of Simulium meridionale collected in live bird-baited traps at site 2 in 1980.


MEAN % ACTIVITY
40
35
30
25
20
15
10
5
0
0600
1000
1400
1800
2200
TIME (hours)

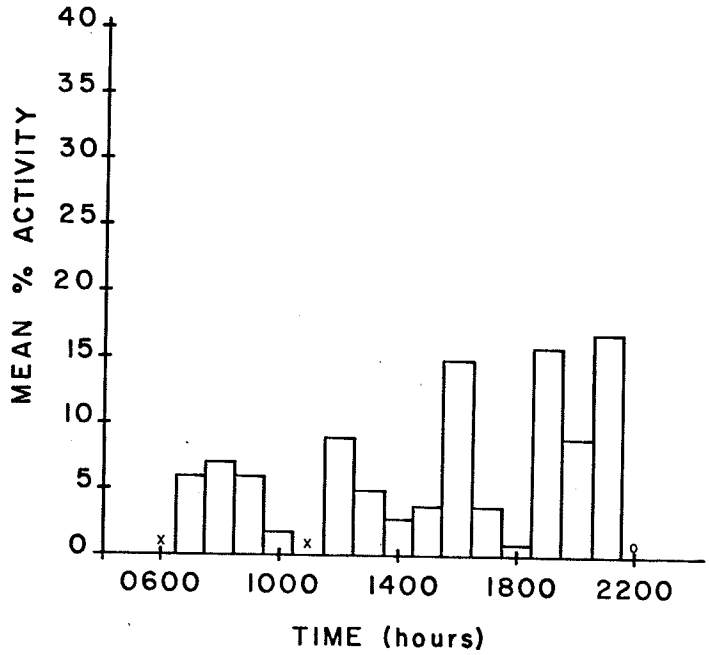
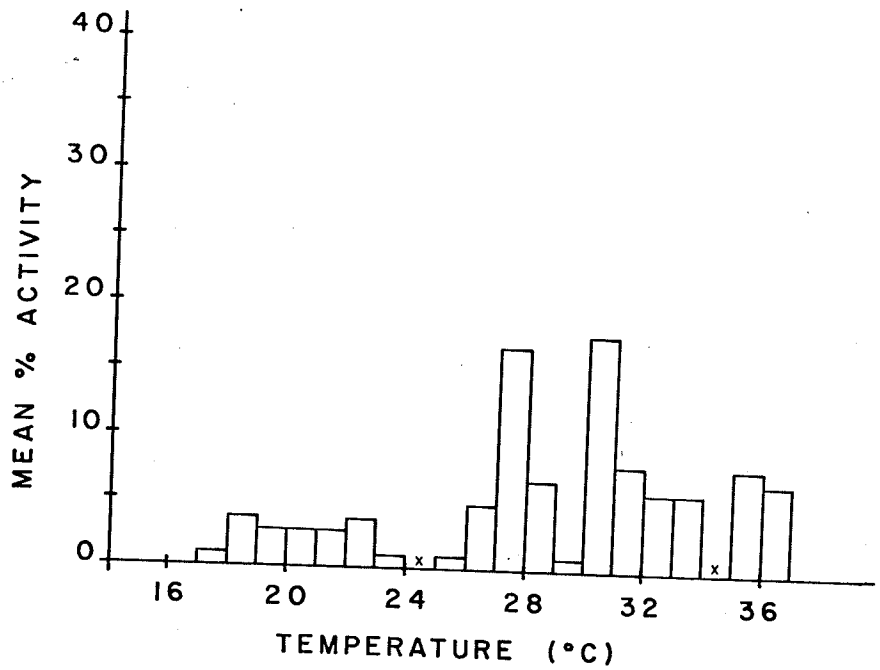

MEAN % ACTIVITY
40
35
30
25
20
15
10
5
0
0600
1000
1400
1800
2200
TIME (hours)

Figure 48. Mean hourly flight activity at different temperatures (all species). Adult flies were collected in a CO_2-baited trap at site 2 in 1980.

Figure 49. Mean hourly flight activity at different temperatures for *Simulium luggeri* collected in a CO_2-baited trap at site 2 in 1980.


40
30
20
10
0
MEAN % ACTIVITY
16
20
24
28
32
36
TEMPERATURE (°C)

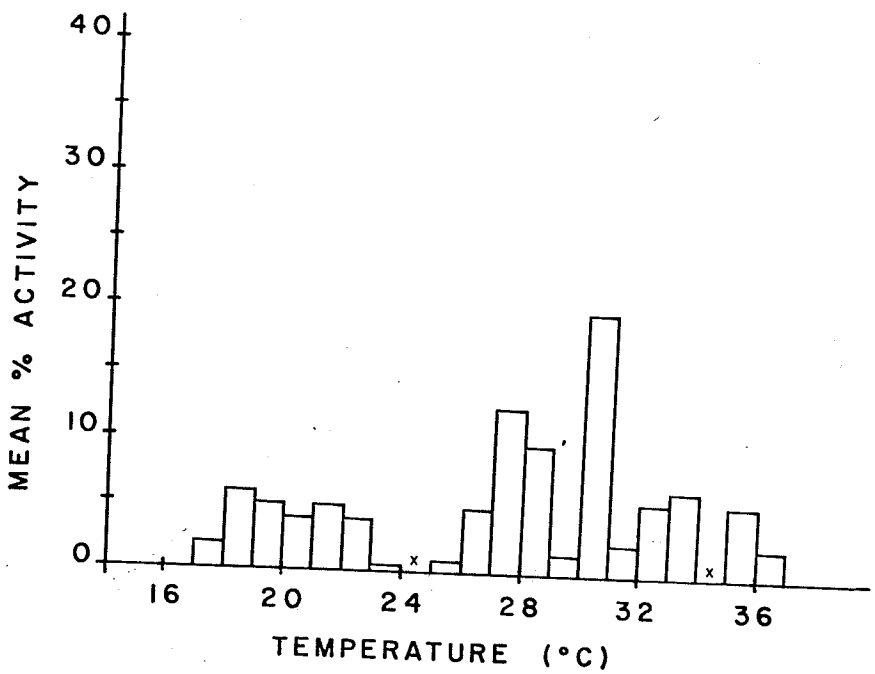
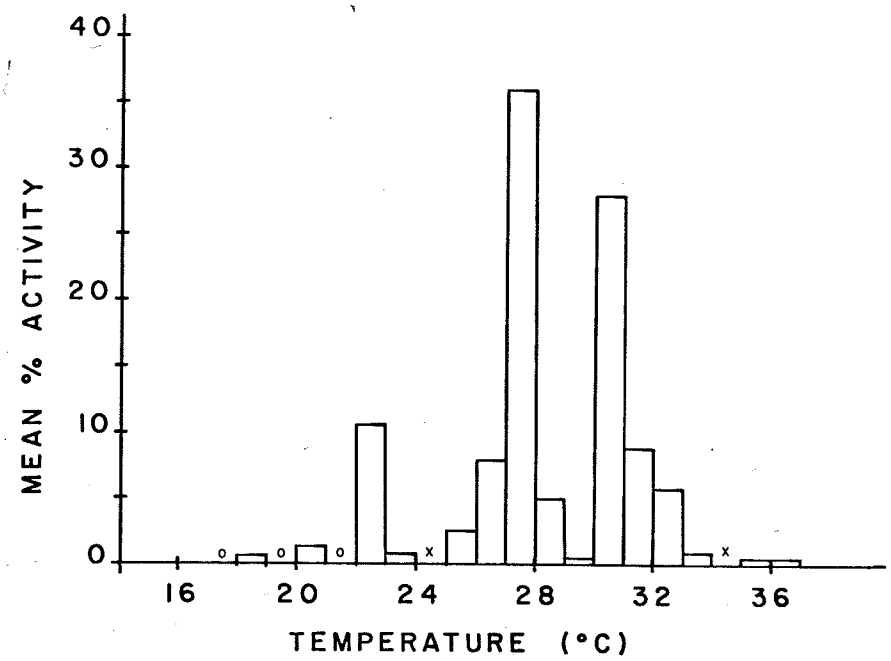

40
30
20
10
0
MEAN % ACTIVITY
16
20
24
28
32
36
TEMPERATURE (°C)

Figure 50. Mean hourly flight activity at different temperatures for *Simulium johannseni* collected in a CO_2-baited trap at site 2 in 1980.

Figure 51. Mean hourly flight activity at different temperatures for *Simulium meridionale* collected in a CO_2-baited trap at site 2 in 1980.


40
30
20
10
0
MEAN % ACTIVITY
16
20
24
28
32
36
TEMPERATURE (°C)

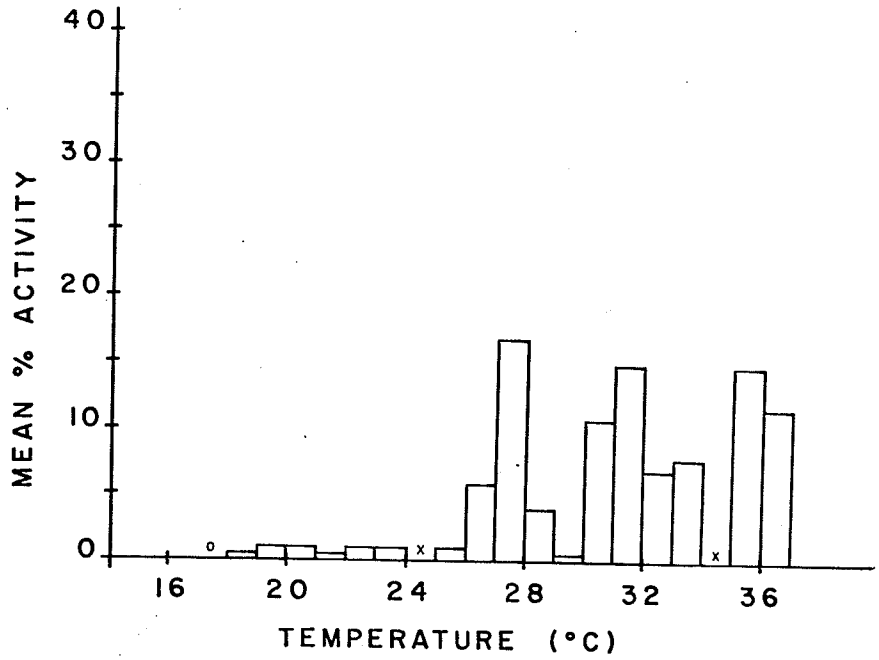

40
30
20
10
0
MEAN % ACTIVITY
16
20
24
28
32
36
TEMPERATURE (°C)

TABLE 1. Number of adult black flies collected in attractant traps at site 5 in 1979.

Date	Trap No.	Females	Males	Species
June 20	D_1	410	0	*S. meridionale*
		17	0	*S. johannseni*
		16	0	*S. venustum*/*verecundum*
		8	0	*S. luggeri*
		2	0	*S. vittatum*
	D_2	63	1	*S. meridionale*
		59	0	*S. johannseni*
		4	0	*S. luggeri*
		3	0	*S. vittatum*
	D_3	0	0	———
	D_4	0	0	———
June 25*	D_1	0	0	———
	D_2	5350	1	*S. meridionale*

TABLE 1. Continued.

Date	Trap No.	Females	Males	Species
June 25	D_2	762	0	*S. johannseni*
		158	130	*S. venustum/verecundum*
		130	0	*S. luggeri*
		337	0	*S. vittatum*
	D_3	0	0	———
	D_4	0	0	———
June 26	D_1	1924	2	*S. meridionale*
		4	0	*S. venustum/verecundum*
		1	0	*S. vittatum*
		1	0	*S. aureum*
	D_2	0	0	———
	D_3	0	0	———
	D_4	0	0	———

TABLE 1. Concluded.

Date	Trap No.	Females	Males	Species
June 27	D_1	0	0	———
	D_2	66	1	*S. meridionale*
		1	0	*S. luggeri*
		2	0	*S. venustum/verecundum*
		1	0	*S. vittatum*
	D_3	0	0	———
	D_4	0	0	———

D_1 - New Jersey trap with a carbon dioxide flow of 200-300 ml per minute.
D_2 - New Jersey trap with a carbon dioxide flow of 200-300 ml per minute and a 100 watt incandescent light.
D_3 - New Jersey trap with a 100 watt incandescent light bulb but no carbon dioxide source.
D_4 - New Jersey trap with no carbon dioxide source or light.
* - June 25th data represents a 72 hour collection period (24 to 26 June). Ten subsamples of 100 flies each were identified and the relative percentage of each species and sex determined.

TABLE 2. Number of adult black flies collected in an attractant trap at site 2 in 1979.

Date	Trap No.	Females	Males	Species
June 12	B_1	4	0	*S. meridionale*
June 16	B_1	2	0	*S. luggeri*
June 27	B_1	360	0	*S. luggeri*
		32	0	*S. meridionale*
July 17	B_1	383	0	*S. luggeri*
		5	0	*S. meridionale*
		5	0	*S. vittatum*
July 18	B_1	37	0	*S. luggeri*
August 1	B_1	4	0	*S. luggeri*
		4	0	*S. meridionale*
August 14*	B_1	935	0	*S. luggeri*
		2	0	*S. meridionale*

TABLE 2. Concluded.

Date	Trap No.	Females	Males	Species
August 14	B_1	7	0	*S. vittatum*

B_1 - The attractant trap is a modified New Jersey fan trap. See materials and methods for a description.

* - Four subsamples of 100 flies each were identified from August 14th data and the relative percentage of each species and sex was determined.

TABLE 3. Follicle development and number of follicles per ovary in adult black flies prior to blood feeding. Flies were collected from site 4 in 1979 by emergence traps.

Date	Follicle Stage Range*	Mean Follicle Stage	Mean No. Follicle/Ovary	Number Females	Species
June 19	Ia-V	IIIb	—	4	*S. vittatum*
	Ia	Ia	—	4	*S. meridionale*
	Ia	Ia	—	1	*S. venustum/verecundum*
	Ia	Ia	—	2	*S. johannseni*
	Ia-Ib	Ia-Ib	—	2	*S. luggeri*
June 23	Ia-V	IVb-V	84(19)	25	*S. vittatum*
	Ia-IIb	IIa	120(4)	7	*S. luggeri*
	IIa-IIb	IIa-IIb	90(1)	17	*S. meridionale*
	IIb	IIb	—	1	*S. johannseni*

* Watts and Smith (1978).
( ) Numbers in parentheses indicate the number of individuals dissected.

TABLE 4. Follicle development and fat body content after emergence and prior to blood feeding. Flies were collected from site 2 in 1979 by emergence trap.

Date	Follicle Stage Range	Mean Follicle Stage	Fat Body*	Number Females	Species
June 9	Ia-Ib	Ia-Ib	2	5	*S. venustum/verecundum*
June 19	Ib-IIa	Ib	1	1	*S. meridionale*
June 27	Ia-IIa	Ib	1	12	*S. meridionale*
	IIb-V	IVb-V	4	25	*S. vittatum*
July 17	IIIb-IVa	IIIb-IVa	3	1	*S. vittatum*
	Ia-IIa	Ib	3	5	*S. luggeri*
August 21	IIIa-Va	IVb-V	4	7	*S. vittatum*
	Ia-IIa	Ib	3	19	*S. luggeri*

* On a scale of 1-5, 5 is the largest.

TABLE 5. Ovary development 12 to 72 h after emergence and prior to blood feeding at site 1, 5, and 10 in 1979. Flies collected from emergence traps.

Date	Follicle Stage Range	Mean Follicle Stage	Site	Number Females	Species
June 9	Ia	Ia	1	1	*S. venustum/verecundum*
	V	V	5	3	*Cnephia dacotensis*
	Ia-Ib	Ia-Ib	10	25	*S. venustum/verecundum*
June 12	Ib-IIb	IIa	10	10	*S. venustum/verecundum*
June 23	IIa-V	IVb	5	4	*S. vittatum*
June 26*	IIb-V	—	1	68	*S. vittatum*

* Collected as pupae from vegetation.

TABLE 6. Ovary and fat body development in *S. vittatum*. Instars 5-7 were collected at site 4, November 4, 1979.

Temperature	Date Emerged	Mean Follicle Stage	Fat Body*	Mean No. Follicles/ Ovary	Number Females
22°C	Nov. 8	IIb	5	148(1)	1
	Nov. 9	IIb-IIIa	5	147(2)	2
	Nov. 13	IIa-IIIb	5	159(18)	31
5°C	Nov. 25	IIa-IIIa	5	—	3
	Nov. 27	IIb	5	—	8
	Nov. 30	IIb-IIIa	5	—	5
	Dec. 15	IIa-IIb	5	—	14

* On a scale from 1-5, 5 is the largest.
( ) Numbers in parentheses indicate number of individuals dissected.

TABLE 7. Ovary development in *S. vittatum*. Pupae were collected at site 4, November 4, 1979.

Temperature	Date Emerged	Mean Follicle Stage	Mean No. Follicles/ Ovary	Number Females	Age (h)
22°C	Nov. 5	IIIa	—	2	12-24
	Nov. 6	IIb-IIIa	—	21	1-12
	Nov. 7	IIb-IIIa	—	16	1-12
	Nov. 8	IIIa	—	1	1-12
	Nov. 11	IIb	—	6	1-12
	Nov. 12	IIb	—	3	1-12
		IVa	121(3)	5	12-24
		IVb-V	110(6)	7	48-72
5°C	Nov. 12	IIa-IIb	158(4)	4	48-72
	Nov. 17	IIIb	103(9)	9	144

( ) Numbers in parentheses indicate the number of individuals dissected.

TABLE 8. Ovary development in black flies collected by sweep net around humans and from a carbon dioxide-baited trap at site 5 in 1979.

Date	Mean Follicle Stage	Number Females	Species
June 12	Ib-IIa	12*(42)	*S. meridionale*
	IIb-IIIa	8*	*S. johannseni*
June 20	IIIb-IVa	5∞	*S. johannseni*
	Ia-Ib	8*	*S. meridionale*
June 26†	Ia	20*	*S. johannseni*

( ) Numbers in parentheses indicate number of individuals collected.
* Non blood-fed.
∞ Blood-fed.
† Flies collected from carbon dioxide-baited traps.

TABLE 9. Black fly adults collected from attractant traps at site 2 in 1980.

Dates	Trap No.	Females	Males	Species
May 18-May 22	C_1	187	2	*S. venustum/verecundum*
	C_2	0	0	———
May 18-June 9	C_1	469	0	*S. johannseni*
	C_2	0	0	———
May 18-June 9	C_1	1,258	0	*S. meridionale*
	C_2	0	0	———
May 18-June 9	C_1	2,232	0	*S. luggeri*
	C_2	0	0	———
May 18-June 4	C_1	113	0	*S. vittatum*
	C_2	0	0	———

C_1 - New Jersey trap with a carbon dioxide flow of 200-300 ml per minute.
C_2 - New Jersey trap with no carbon dioxide source or light.

TABLE 10. Adult female black flies collected while feeding on and flying about caged domestic chickens and turkeys at site 2 in 1980.

Date	Chickens		Turkeys		Species
	Blood Fed	Non Blood Fed	Blood Fed	Non Blood Fed	
May 18	30	19	25	10	*S. johannseni*
May 20	20	8	23	5	*S. johannseni*
	23	6	22	1	*S. meridionale*
May 21	11	2	15	4	*S. johannseni*
	27	3	31	8	*S. meridionale*
May 22	7	4	8	9	*S. johannseni*
	9	3	6	5	*S. meridionale*
	0	0	0	1	*S. luggeri*
May 27	7	3	5	2	*S. johannseni*
	16	4	14	2	*S. meridionale*
	0	1	0	0	*S. luggeri*
May 28	1	2	1	0	*S. johannseni*

TABLE 10. Concluded.

Date	Chickens		Turkeys		Species
	Blood Fed	Non Blood Fed	Blood Fed	Non Blood Fed	
May 28	7	1	3	4	*S. meridionale*
	0	1	0	0	*S. luggeri*
May 31	0	1	0	0	*S. johannseni*
	2	2	5	2	*S. meridionale*
June 4	0	0	0	1	*S. johannseni*
	0	0	1	1	*S. meridionale*
June 9	0	0	1	0	*S. meridionale*

TABLE 11. Adult female black flies collected while feeding on and flying about hosts at site 2 in 1980.

Date	Host	Blood Fed	Non Blood Fed	Species
May 18	human	1	0	*S. venustum/verecundum*
May 20	human	3	0	*S. luggeri*
		0	1	*S. meridionale*
May 21	human	8	3	*S. meridionale*
May 22	bovine*	0	2	*S. johannseni*
		1	11	*S. meridionale*
		0	2	*S. luggeri*
May 27	bovine*	1	51	*S. johannseni*
		0	11	*S. meridionale*
		0	52	*S. luggeri*
		4	62	*S. vittatum*
May 27	human	5	1	*S. meridionale*
May 28	bovine*	0	8	*S. johannseni*

TABLE 11. Continued.

Date	Host	Blood Fed	Non Blood Fed	Species
May 28	bovine*	0	9	*S. meridionale*
		2	56	*S. luggeri*
		6	51	*S. vittatum*
May 28	human	1	0	*S. meridionale*
May 31	bovine*	0	6	*S. meridionale*
		3	16	*S. luggeri*
		0	3	*S. vittatum*
June 4	equine	1	2	*S. vittatum*
June 4	bovine∞	26	36	*S. luggeri*
		30	7	*S. vittatum*
June 4	human	1	0	*S. meridionale*
June 5	bovine∞	6	1	*S. luggeri*
		3	0	*S. vittatum*

TABLE 11. Concluded.

Date	Host	Blood Fed	Non Blood Fed	Species
June 9	bovine[∞]	8	1	*S. luggeri*
		1	1	*S. vittatum*
June 9	equine	1	1	*S. luggeri*

* - 1 Hereford calf.
∞ - 27 Dairy calves.

TABLE 12. Time of day, light intensity and type of substrate from which *Simulium vittatum* adults and eggs were recovered at sites 2 and 5 in 1980.

Date	Hour	Substrate	Light Intensity (Lux)
May 8	1800	rope sampler	——
May 13	1800	"	5,600
May 14	2000	"	1,500
	2100	"	——
May 18	1400	"	3,600
	1900	"	450
	2000	"	450
	2145	"	——
May 21	0900	"	1,155
	2140	"	1.1
May 22	0700	"	340
May 27	1900	"	370
	2000	"	350
	2100	"	60
	2200	"	5.1
May 28	0630	"	42
	0900	"	300
	1600	"	690

CHAPTER V

Conclusions

As a result of the study described herein, the following conclusions were made concerning black fly biology, adult behaviour during host-seeking and pest status.

1. Eight species were collected during this study: *Simulium johannseni*, *Simulium johannseni duplex*, *Simulium venustum/verecundum* complex, *Simulium meridionale*, *Simulium luggeri*, *Simulium vittatum*, *Simulium tuberosum* and *Cnephia dacotensis*.

2. Six species, *Simulium johannseni*, *Simulium meridionale*, *Simulium luggeri*, *Simulium vittatum* and *Simulium venustum/verecundum* complex are potential pest species.

3. *Simulium johannseni* fed on turkeys, chickens and cattle; *Simulium meridionale* on turkeys, chickens, humans and cattle; *Simulium vittatum* on cattle and horses and *Simulium venustum/verecundum* on humans.

4. Adults were active between 0600 h and 2200 h, at air temperatures between 17.3^{0}C and 36.7^{0}C, at relative humidities between 7% and 81%, at light intensities between 0.6 and 11,250 lux, at winds with gusts up to 15.7 km/h and on days with 0 to 100% cloud cover.

5. Most adults were actively seeking hosts between 1900 h and 2100 h, at air temperatures between 25^{0}C and 30^{0}C and at light intensities between 60 and 1,620 lux.

6. Simulium johannseni, Simulium meridionale, Simulium luggeri and Simulium venustum/verecundum complex were anautogenous and emerged with undeveloped ovarian follicles while Simulium vittatum and Cnephia dacotensis were autogenous and emerged with partly or fully developed follicles.

7. Simulium vittatum completed egg development in 3-5 days in the laboratory without an adult food source. On a scale of 1-5, fat body content was 5 (large) at emergence.

8. Cone samplers did not give a reliable estimate of the overall larval populations in the Souris River, and of little value in predicting the magnitude of adult populations. Cone samplers did, however, sample the relative developmental stage and the relative proportions of black fly species present.

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APPENDIX 1. *Simulium johannseni* immatures and adults collected from the Souris River in 1979.

Stage	Dates	Substrates	Trapping Methods	Sites	No.
larvae	May 19- June 6	vegetations cones sticks	———	2,4,5, Souris Dam	413
pupae	May 28- June 6	vegetations cones sticks	———	4,5	104
adults	June 6- June 25	———	truck cab sweep net fan trap	4,5	901

APPENDIX 2. Black fly larvae collected at site 1 in 1979.

Date	Number	Substrate Type	Species
May 20	7	cone sampler*	*S. venustum/ verecundum*
May 24	54	"	*S. venustum/ verecundum*
	6	"	*S. luggeri*
	6	"	*Cnephia dacotensis*
	2	"	*S. meridionale*
May 28	129	vegetation	*S. venustum/ verecundum*
June 1	3	cone sampler	*S. venustum/ verecundum*
June 2	198	vegetation	*S. venustum/ verecundum*
	1	"	*Cnephia dacotensis*
June 9	18	cone sampler	*S. venustum/ verecundum*
	2	"	*S. vittatum*
June 13	76	"	*S. venustum/ verecundum*
June 19	190	vegetation	*S. vittatum*
	64	cone sampler	*S. vittatum*
	5	"	*S. venustum/ verecundum*
June 26	3	"	*S. vittatum*

* Cone samplers manufactored by Spence-Lemare Industries, Edmonton, Alberta.

APPENDIX 3. Black fly larvae collected from creeks and streams in vicinity of the Souris River in 1979.

Date	Number	Substrate	Site	Species
June 2	42	vegetation	10	*S. venustum/verecundum*
	3	"	10	*S. vittatum*
	9	"	10	*Cnephia dacotensis*
June 3	5	vegetation and rocks	11	*Cenphia dacotensis*
	53	"	11	*S. vittatum*
June 6	20	vegetation	10	*S. vittatum*
	2	"	10	*S. venustum/verecundum*
	41	vegetation and rocks	11	*Cnephia dacotensis*
	17	"	11	*S. vittatum*
	65	"	11	*S. venustum/verecundum*
June 10	34	vegetation	10	*S. vittatum*
	9	"	10	*S. venustum/verecundum*

APPENDIX 3. Concluded.

Date	Number	Substrate	Site	Species
June 10	2	vegetation and rocks	11	*S. venustum/verecundum*
	16	"	11	*S. vittatum*
June 12	167	"	11	*S. vittatum*
	19	"	11	*S. venustum/verecundum*
June 14	80	"	11	*S. vittatum*
June 19	81	"	11	*S. vittatum*

APPENDIX 4. Black fly adults collected in emergence traps at sites 1 and 10 in 1979.

Date	Females	Males	Site	Species
June 9	116	13	10	*S. venustum/ verecundum*
	0	26	10	*Cnephia dacotensis*
	1	3	1	*S. venustum/ verecundum*
June 12	12	5	10	*S. venustum/ verecundum*
	1	0	10	*S. meridionale*
	0	75	10	*S. vittatum*

APPENDIX 5. *Simulium venustum/verecundum* complex collected from the Souris River in 1979.

Date	Site	Stage	Sample Type	Number
May 19–June 12	2,4,5,	larvae	cone sampler vegetation	329
May 28–June 6	2,4,5,	pupae	"	154
June 2–June 9	2,4,5	adults	CO_2-baited trap emergence trap	322

APPENDIX 6. *Cnephia dacotensis* collected from the Souris River in 1979.

Date	Site	Stage	Sample Type	Number
May 19- June 12	2,4,5,	larvae	cone samplers vegetation	158
May 28- June 6	2,4,5	pupae	vegetation	6
June 1- June 12	2,4,5	adults	emergence trap sweep net	158