SEASONAL ABUNDANCE, DAILY TRENDS AND PARITY STATUS OF STABLE FLIES (DIPTERA: MUSCIDAE) AT GLENLEA, MANITOBA

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Submitted to the Faculty

of

Graduate Studies

University of Manitoba

by

William Vezi Khumalo

In Partial Fulfilment of the

Requirements for the Degree

of

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ABSTRACT

Khumalo, William Vezi. M.Sc., The University of Manitoba, October, 1990. Seasonal Abundance, Daily Trends and Parity Status of the Stable Fly (Diptera: Muscidae) Populations at Glenlea, Manitoba. Major Professor: Terry D. Galloway.

Seasonal abundance of the stable flies, Stomoxys calcitrans (L.) was studied at Glenlea, Manitoba for two years (from June to mid-September, 1988 and 1989). Alsynite (TM) fibre glass sticky traps were used in which Tanglefoot (TM) was used as an adhesive. The efficiency of the Williams sticky trap system used was determined to be 36.2%.

Two study sites were established, one at the animal confinement facility and the other at the pasture. Traps were operated for nine hours per day once a week at each site. Trapped flies were removed from traps after a predetermined time interval of one or more hours. Trapped flies were counted, sexed and a subsample of 15-30 females was dissected to determine the parity status. A sweep net sample was also obtained on each sampling occasion and processed like the trap catches. The abundance of the stable flies was 7.5-fold larger at the animal confinement site than at the pasture in 1988 and about 2.1-fold larger at the animal confinement site than pasture in 1989. Peak abundance occurred from 16 June to 30 August at the animal confinement site when >50 flies per trap in nine hours of trapping were collected in 1988. The maximum number of flies collected from the animal confinement site was more than 1200 flies/trap on 28 June, 1988. Pasture stable fly peak abundance occurred from 17 June to 26 August when >15 flies per trap were collected in nine hours. The highest number of flies at the pasture was 160 flies/trap which was collected on 26 July, 1988. Diurnal activity of the stable flies yielded a peak abundance between 0700-1100 hrs when more than 60% of the daily catch was collected at the animal confinement site and 55-70% of the daily total at the pasture. In June and July, 1989 hourly temperatures were recorded during trapping and it was found that stable fly diurnal activity was influenced largely by temperature, rather than time of day. Maximum daily activity, as shown by mean bi-hourly trap catch, occurred at temperatures between 20°C and 31°C and very little flight activity took place outside this range.

Counts of stable flies were taken between 0900-1100 hrs on penned beef cattle on each sampling occasion in 1988. Fly numbers exceeded 15 flies/leg during peak fly abundance and exceeded five flies/leg from 21 June through 16 August. Bi-hourly stable fly counts were also taken on resting sites at the animal confinement site barn walls on each sampling day. There was a good seasonal correlation between the trap

catches and numbers of flies feeding on cattle and number of flies on the resting sites.

The newly emerged and nulliparous proportions predominated (>50%) in trap and sweep net samples throughout the season in both years except in sweep net samples at the beginning of the season in 1988. The newly emerged proportion was used as an index of seasonal changes in abundance and it fluctuated in a similar manner as the overall abundance on the sticky traps, e.g. on 28 June, 1988 the dissected trap samples from the animal confinement site comprised 100% newly emerged females, similarly, on 26 July, 1988, the trap sample was ca. 100% newly emerged females.

CHAPTER I

Introduction

The stable fly is a pernicious blood-sucking parasite of mammals including humans. It is usually the only biting, blood-feeding muscid that breeds in and around animal-enclosures. The stable fly is noted for its fondness of bright, sunlit objects where large numbers may be found during daylight hours in the summer and fall. This species is thought to have originated in the Old World and from there it spread to almost every habitable region of the world (Brues 1913).

Cattle are considered to be the primary hosts of the fly in North America and in the U.K., however, in some recreational areas the fly is a serious nuisance to humans. The stable fly attains high numbers from May through October in southern Manitoba where it feeds on livestock and bites people residing close to livestock facilities. High levels of biting activity associated with the fly may disrupt feeding or grazing patterns of livestock.

The stable fly problem has not been extensively researched in Canada. In the limited published data, stable flies are discussed rather generally, e.g. Hearle (1938) mentioned that the stable flies first appear in British

Columbia in April, and a month later in the Prairie Provinces; Teskey (1960) discussed the abundance of stable flies under the subheading "Other flies affecting pastured cattle", in which he reported that stable flies attained peak abundance in late July and early August in southern Ontario. The only recent published literature on the stable fly in Canada are laboratory studies on its physiology (Lee and Davies 1978; Venkatesh and Morrison 1980a, 1980b, 1980c). Extensive studies on biology and ecology of this species have been conducted in the U.S.A., e.g. seasonal abundance (Mullens and Meyer 1987), daily feeding patterns (Berry and Campbell 1985), and ovarian development (Moobola and Cupp 1978; Scholl 1980).

In an unpublished survey conducted prior to this research in southern Manitoba, it was evident that the stable fly is a notable livestock pest and that there is a definite need for research to provide some knowledge on this fly. A question that needs to be addressed is whether Manitoba populations of the stable flies behave in similar manners as the U.S. populations, given the higher latitude and short summer season in Manitoba.

Effective control or management programmes of a pest require some knowledge of the pest's biology and ecology. This study was conducted at the University of Manitoba's Glenlea Research Station following a preliminary survey in which there was evidence that stable flies occur in large numbers there in summer. The principal objectives of the study were:

1. to describe daily and seasonal activity patterns and abundance of the stable fly,
2. to evaluate the Williams sticky trap for estimating adult stable fly populations in Manitoba,
3. to compare estimates of relative abundance of the stable fly between the animal confinement facility and pasture,
4. to determine per cent parity of female stable flies caught on sticky traps and collected with the sweep net.

CHAPTER II

Review of the Pertinent Literature

Introduction

An extensive coverage of the literature on the stable flies has been published, and Morgan *et al*. (1983) listed more than 2,360 publications in an annotated bibliography on the stable fly in their Research Bulletin. Of the 18 described species in the genus *Stomoxys* (Diptera: Muscidae), the stable fly, *S. calcitrans*, is the most widely distributed and extensively studied. *Stomoxys calcitrans* is the only representative of the genus in North America. The stable fly was first reported in Ontario and other southern parts of Canada as early as the turn of the 18th Century (Brues 1913). The other 17 species are found chiefly in Africa and the Orient (Zumpt 1973). The stable fly reaches enormous numbers in temperate regions in summer and is generally more abundant in temperate than tropical regions (Brues 1913).

The stable fly is one of the most important pests of mammals throughout the world. Adults of both sexes are obligatory blood feeders (Harwood and James 1979). The stable fly is versatile and has adapted its feeding behaviour to accommodate an extensive host range (Bishopp 1913; Hafez and Gamal-Eddin 1959a). The mouthparts of the fly are highly modified with a hard, pointed and toothed-labellum which acts as a stabbing organ with which the host's skin is penetrated and engorgement occurs within 3-4 minutes if the fly is undisturbed (Harris et al. 1974; Harwood and James 1979). The stable fly is also characterized by an exceptionally strong flight ability. A parasite should not only locate nearby hosts, but should also demonstrate good dispersal ability in order to colonize new habitats and thus expand its potential host choice and range. These characteristics, among others, have undoubtedly assisted the fly in its cosmopolitan distribution from the Old World (Brues 1913; Greenberg 1973). It is estimated that the fly will cover a distance of up to three km in search of a blood meal (Bailey and Meifert 1973) and that it has a flight range of up to 225 km (Hogsette and Ruff 1985).

Life History

The stable fly is a synanthropic symbovine since it has adapted itself to coexist with humans and domestic animals, reaching high population densities in association with domestic animal-confinement facilities (Greenberg 1971). In many ways, the stable fly resembles the common house fly, *Musca domestica* (L.), but the stable fly takes a little longer to develop. Developmental times of the eggs, larvae and pupae are described by Kunz et al. 1977.

Eggs. The eggs are laid in batches of 25-80 per oviposition time (Killough and McKinstry 1965; Harwood and James 1979). There is considerable variation in the time required for eggs to hatch depending on temperature and the conditions under which observations were made. The incubation period of the eggs may range from 36 hours at 23.9°C to 22 hours at 35°C (Kunz et al. 1977; Abasa 1983). Humidity is also a crucial factor in egg viability. Contact with water or humid conditions within the first day after oviposition determines the success of egg-hatch (Abasa 1983).

Larvae. The newly hatched larvae submerge themselves at once in their developmental medium to avoid desiccation (Greenberg 1971; Harwood and James 1979; Skidmore 1985). Longevity of this stage is also dependent on environmental conditions including the quantity and quality of nutrients. Under controlled conditions of 33.3°C and 90% relative humidity it took about 10 days for the larvae to pupate (Parr 1959). Overcrowding and undernourishment significantly slow down growth rates of larvae giving rise to small-bodied adults (Parr 1959; personal observation). Larvae feed on fermenting vegetative matter. Larvae usually aggregate in the core portions of their developmental medium, which may attain higher temperatures (15-30°C) and remain moist as a result of this aggregation of larvae. The optimum developmental temperature range for larvae is 19.5-33.2°C (Sutherland 1980a).

Pupae. The final instar larvae crawl into the drier portions of the larval medium and most pupate at the medium-soil interface. In the laboratory the third instar larvae pupate within 2.5 cm from the surface of the larval medium (Parr 1959; personal observation).

Adults. The adult stable fly is on the wing from May through mid-November in the southern U.S. and from late May through mid-October in southern Canada (Greenberg 1971; personal observation). When an adult stable fly first emerges, the proboscis is normally soft and directed posteriorly. Skidmore (1985) reported that it takes six hours for the proboscis to become hard enough for the fly to be capable of taking its first blood meal. However, the stable fly generally does not feed on blood for the first twelve hours of its adult life (Lee and Davies 1979).

Females begin to mate at about two days of age and most are usually mated by the fifth day (Harris et al. 1966; Greenberg 1971). One male is capable of mating with at least nine females while a female mates once and will not re-mate if sperm are successfully transferred on the first encounter (Harris et al. 1966). The male is more active in mating; it engages the female in aerial interaction and the actual insemination takes place on a perch or on the ground. Thirty minutes may elapse before copulation takes place (Greenberg 1971). Copulation may last nearly six minutes (Anderson 1978). Killough and McKinstry (1965) reported that the female may not lay eggs before the 8th day of the adult life and most females began laying eggs after the 10th day. The females usually produce four or five batches of eggs (Harwood and James 1979), however, as many as 20 have been reported (Mitzmain 1913).

Blood feeding is obligatory for metabolism and reproduction in the stable fly (Meola _et_ _al_. 1977; Moobola and Cupp 1978; Venkatesh and Morrison 1980c). The male requires a blood meal for the maturation of the accessory gland, and consequently successful sperm transfer and not for spermatogenesis (Anderson 1978). A female usually requires 3-7 blood meals before it can start laying eggs and the number of blood meals between egg layings is not constant as it is in mosquitoes (Anderson and Tempelis 1970). Stable flies are strictly anautogenous (Venkatesh and Morrison 1980a). Continued blood-feeding is a necessity for egg laying and the female requires at least two blood meals between egg laying (Skidmore 1985).

The stable fly readily feeds on sucrose solution and water (Hopkins 1964; Lee and Davies 1979; Venkatesh and

Morrison 1980b). Sugar is a good source of energy and it is usually provided to laboratory-reared stable flies. Sugar-water increases the lifespan in the laboratory (Davies 1953) and the stable fly may depend on carbohydrates and water for survival in the field when hosts are unavailable (Venkatesh and Morrison 1980a; Hogsette and Ruff 1985). Adult flies live, on average, 20 days in the laboratory, (Harwood and James 1979).

Breeding habits. The stable fly prefers to lay eggs in fermenting organic matter. Breeding sites consist of vegetative matter, including silage, bedding mixed with urine, faeces, rotting hay, fermenting feed, piles of grass clippings, fermenting peanut litter or marine grasses (Bishopp 1913; Simmons and Dove 1941; Kunz and Monty 1976; Fye et al. 1980; Williams et al. 1980; Mullens and Meyer 1987). Hall et al. (1982) found stable flies breeding in large round hay bales that were stored outside, and noted that heavy rainfall may facilitate this phenomenon. There is a great diversity of breeding sites which result mainly from poor sanitation and management practices. Among the most productive breeding sites are ditches, fencelines and below feed bunkers where spilled hay, corn and oats may accumulate (Meyer and Petersen 1983).

Preferred breeding sites are also those that are well-aerated so that a good supply of oxygen for the developing larvae is available (Sutherland 1978). In warmer climates, loose porous materials having a high moisture content and lying in shady places are good breeding sites (Hafez and Gamal-Eddin 1959b). Breeding sites in beach areas have been associated with fresh-water bay grasses and weeds, as well as bodies of dead mayflies (Hexagenia bilineata (Say)) (Simmons and Dove 1941; Pickard 1968). However, most of the potential stable fly breeding areas are in agricultural areas where dairy, beef, horse, swine and poultry farms are found (Fye et al. 1980). Boire et al. (1988) showed that under controlled conditions, the production of stable flies from pure cattle manure (66%) and horse manure (68%) was not statistically different from each other nor from the control medium, containing sugar cane bagasse, meat and bone meal, whole wheat flour and water (68%). They also found that in swine dung (42%) and chicken dung (36%), significantly fewer stable flies were produced. These authors suggested that differences in their results from Sutherland's (1978) in South Africa, who reported that the larval mortality was lowest in faeces of swine, horses and cattle, may reflect geographical and cultural variations in diets of the animal species and consequently the nutritional value of the manure for larval development.

Ovarian Development and Parity Status

The ovaries consist of 80-100 meroistic , polytrophic ovarioles (Sutherland 1980b) in which nurse cells and oocytes are present. Nurse cells are enclosed in the same follicle with the oocyte (Bonhag 1958).

Follicular development starts within 24 hours after the first blood meal and fully developed eggs are present after at least seven blood meals (Kunz 1982). Newly-emerged females have a single follicle and the number of follicles per ovariole increases to four or five (Sutherland 1980b). At the time of oviposition the ovariole has five follicles (Scholl 1980). Immediately after eggs pass into the lateral oviducts, the follicular remnants remain as large sac-like structures and eventually shrink to form button-like structures called follicular relics or yellow bodies (Scholl 1980; Sutherland 1980b). Numerous follicular relics may be present and provide an indication of the number of times an individual may have oviposited (Scholl 1980). Nulliparous females can be distinguished from parous ones by the presence or absence of yellow bodies (Anderson 1964).

Dissections of ovaries have been used by various authors in order to describe the physiological age structure of stable fly populations (Detinova 1962; Anderson 1964; Moobola and Cupp 1978; Scholl 1980; Sutherland 1980b). Female flies are dissected and categorized into stages of follicular development, as follows:

Newly-emerged - the oldest or primary follicle has not differentiated or separated from the germarium and the whole ovary may still be covered by tracheal skeins.

Nulliparous - the older follicles are anywhere from completely separated from the germarium to mature eggs, without follicular relics in the ovaries.

Uniparous - the terminal pedicel in each ovariole contains a single follicular relic.

Biparous/ biparous+ or pauciparous - the distal pedicel contains a single follicular relic and one or more follicular relics are present in the lateral oviducts. The scheme described here is adapted from Moobola and Cupp (1978), Scholl (1980), and Sutherland (1980b). There is a difficulty in assigning a female which has mature eggs (gravid) either as a nulliparous or parous individual because the ovary is fragile and eggs evacuate easily from the membrane during dissection. This difficulty was reported by Anderson (1964) who suggested that relics are too dispersed within the ovariole sheath to be distinguishable. Scholl (1980) also pointed out that yellow bodies in uniparous females may only be seen after the ovary has been stained.

Interactions Between Environmental Factors and Stable Fly Host-seeking Activity.

The stable fly depends mainly on visual and olfactory perceptions in locating its hosts. For orientation to a host, the stable fly depends on detecting movements and/or form against the background and not the host's colour (Popsil and Zdarek 1965; Hocking 1971). Interactions of various sensory stimuli emanating from the host's body surface and exhaled air, all play an important role in host location (Lewis 1971). Thermal stimuli play a very small role in host-finding. Stable flies do not respond to infrared at energy levels and wavelengths typically emitted by cattle (Berry and Kunze 1970). Olfactory stimuli are well-known in their role of inducing probing action by many animal parasites. Carbon dioxide (CO_2) is the most common stimulus in this respect and its effect has been extensively investigated with inconsistent results in stable flies. Gatehouse (1970) reported that CO_2 did not effect a response in stable flies when tested in isolation or simultaneously with increase in ambient temperature. On the other hand Hoy (1970) showed that when CO_2 was used as a bait in Malaise traps, it significantly increased stable fly catches over unbaited traps or in carbon monoxide-baited traps. In a more recent study, Warnes and Finlayson (1986) also found that CO_2 was an important olfactory stimulus. Flies reacted positively to odours from cattle, cattle faeces, expired human breath, acetone and 1-octen-3-ol (Warnes and Finlayson 1986).

The effects of climatic factors on host seeking and feeding patterns of stable flies have been studied by many researchers. Temperature is the most important limiting factor; no feeding occurs below 14°C (Bailey and Meifert 1973; Zumpt 1973; Kunz and Monty 1976). Stable fly biting activity reaches its maximum level at temperatures between 24°C and 33.2°C (Berry and Campbell 1985; Berry et al. 1986; Mullens and Meyer 1987). Berry and Campbell (1985), however, reported that the effects of weather could only be identified after the function of feeding rate versus time had been established, thus suggesting that time also played a major role in as far as it determined when maximum temperature was attained.

Other weather factors, solar radiation, barometric pressure, wind and relative humidity may affect host-seeking in stable flies. Increasing solar radiation caused some decrease in the number of stable flies feeding or resting on cattle (Berry et al. 1986). Fly activity is also directly correlated with barometric pressure and was reported to be greater when barometric pressure was high (Voegtline et al. 1965). On the other hand, lower humidity may be associated with a higher stable fly biting activity (Voegtline et al. 1965; Spencer et al. 1976). Wind direction, rather than velocity was associated with increased biting activity on Lake Superior (Voegtline _et_ _al_. 1965) and in Point Pelee National Park, Ontario (Dewald and Michano 1982). Generally, one would expect a combination of all these factors, for example, high temperature, high solar radiation, high wind speeds and low humidity to cause a greater loss of moisture from the flies, and thus low feeding rates.

Monitoring Stable Fly Populations

Changes in daily activity and relative abundance of stable fly populations have received considerable attention. Various techniques have been used by different workers, e.g. emergence and box traps (Hansens 1951; Morgan _et_ _al_. 1970), electrocutor grid traps (Pickens 1989), stanchioned-calf or animal-baited traps (Williams _et_ _al_. 1977b; Thomas _et_ _al_. 1989), resting site counts (Buschman and Patterson 1981), sweep nets (Hafez and Gamal-Eddin 1959a), shingles or plywood panels coated with adhesives (Hansens 1951; Bailey _et_ _al_. 1973). The two most popular techniques are visual counts of flies on cattle legs (Campbell and Hermanussen 1971; LaBrecque _et_ _al_. 1975; Campbell and McNeal 1979; Buschman and Patterson 1981; Berry and Campbell 1985; Campbell _et_ _al_. 1987) and the Williams sticky traps (Williams 1973; Meifert _et_ _al_. 1978; Patterson _et_ _al_. 1981; Agee and Patterson 1983; Hall _et_ _al_. 1983; Scholl _et_ _al_.

1985; Tseng *et al*. 1986; Broce 1988; Thomas *et al*. 1989).

Daily and Seasonal Trends in Stable Fly Activity and Abundance.

Adult stable flies reach maximum activity and abundance in the months of May through October in southern Canada and May through November in the southern U.S. As daylength and weather conditions vary in this time period, the activity patterns and abundance of the fly also vary. The diel activities such as feeding and flight are not uniform throughout the daylight hours. These activities may be at a maximum once (unimodal peak) as reported in Nebraska (Berry and Campbell 1985) or twice (bimodal peak), for example in Mauritius (Kunz and Monty 1976). Hafez and Gamal-Eddin (1959a) observed that two feeding peaks occurred during the hot summer months and only one peak occurred during the cooler months in Egypt. High mid-day and afternoon temperatures may cause a decrease in number of flies that feed, separating activity into two peaks (Berry and Campbell 1985).

Stable flies spend most of the time basking in the sunshine and Greenberg (1971) has defined them as heliophilous and thermophilus because of their attraction for sunshine and warmth. The majority of flies found on the perching sites are engorged with fresh blood. Male flies may establish leks on the sunlit surfaces as lookout points from which intruding females or males are attacked for mating (Parker 1978).

Abundance of stable flies changes as the season progresses. Populations reached maximum levels from June to late July in Nebraska, depending on the spring and summer weather pattern (Scholl _et_ _al_. 1985). Abundance may also be influenced by densities and movements of potential hosts (Gersabeck and Merritt 1983) as well as by availability of oviposition sites, in the pasture or animal enclosure (Hall _et_ _al_. 1983). Like daily activities, seasonal abundance may be unimodal in some regions (e.g. Uganda, Harley 1965) or bimodal (e.g. central Missouri, Hall _et_ _al_. 1983; Iowa, Black and Krafsur 1985; Nebraska, Scholl _et_ _al_. 1985; Scholl 1986). Sex ratios may vary within a population and may be a reflection of either the sampling technique or differences in sexual behavioural activities. For instance, in Mackinac Islands, Michigan, consistently more females than males were captured on traps (Gersabeck and Merritt 1983). Similarly in northwestern Florida beaches, 75% of the stable flies collected were females (Hogsette and Ruff 1985). Females spend most of the time seeking oviposition sites and thus are more likely to be captured on traps located where breeding sites are very scanty e.g. in a beach. On locations close to cattle feedlots and dairy facilities males consistently outnumber females (Buschman and Patterson

1981). This may be explained as a sexual behaviour in that females that are not receptive to males shun prominent resting sites to avoid harassment by males (Parker 1978; Buschman and Patterson 1981).

Economic Impact of the Stable Fly

The stable fly is considered primarily as a livestock pest throughout the world even though this fly does not restrict its feeding to any particular host. It is also an important pest of man, though usually for brief periods of time, in recreational areas of the world.

Impact on Livestock Production. Studies on the losses due to stable flies have been conducted in the U.S. where economic losses were estimated at $142 million (Anonymous 1965; Steelman 1976), and more recently at $398.9 million (Drummond et al. 1981).

Different methods may be implemented to estimate economic impact of the stable fly on cattle. Campbell et al. (1987) considered weight gains, feed efficiency and cost of chemical control. Schwinghammer et al. (1982) focused on physiological and nutritional responses of cattle exposed to stable fly feeding. It was concluded that an infestation of 50 flies per head increased heart rates and reduced nitrogen retention.

Reduction in milk production as a response to stable fly infestation has also been documented. Granett and

Hansens (1956) found that cows treated with insecticides produced more milk than untreated cows. Both groups were almost equally susceptible to biting fly attack and provided similar milk production prior to the experiment. The economic threshold has been estimated as 25 flies per animal per day in dairy cows (Drummond et al. 1981). At the end of a three-year study, Bruce and Decker (1958) concluded that a loss of 0.7% per stable fly per cow occurred in milk production.

The stable fly is noted for its vicious and persistent attacks on animals and its abundance around livestock facilities. The fly inflicts a painful bite on its host which causes excessive irritation and annoyance (Bishopp 1913; Berry et al. 1983). When cattle are exposed to high fly pressures, the cattle may pass most of the daylight hours dislodging flies by head swings, tail flicks and foot stomps (Ralley 1986; Warnes and Finlayson 1987). Cattle may also lie down for most of the time or stand in mud puddles or pond water to shield their legs from fly bites (Bishopp 1913). Undoubtedly, the irritation, annoyance, and loss of potential grazing time endured by the animals can result in demonstration of lower weight gains and production of less milk (Bishopp 1913; Campbell et al. 1977). Even though blood loss is not the main concern, considerable amounts of blood are lost under extreme biting activity by the stable fly. Stable fly males take about three blood meals per day and females take two per day (Harris _et_ _al_. 1974), and an average blood meal is 25.8 mg (Greenberg 1971).

Transmission of disease-causing organisms by the stable fly is reported to occur mainly in horses. The stable fly may mechanically transmit equine infectious anaemia virus (Hyslop 1966; Foil _et_ _al_. 1983). Additional costs are imposed on screening procedures that must be performed when sales take place across state borders (Lancaster and Meisch 1986). In other disease transmission studies, the stable fly has been incriminated in transmitting hog cholera virus from infected to susceptible pigs (Morgan and Miller 1976). Zumpt (1973) listed some other possible transmission, e.g. Surra (_Trypanosoma_ _evansi_ Steel) is thought to be transmitted mechanically to horses, camels, water buffalo and cattle; Nagana (_Trypanosoma_ _brucei_ Plimmer and Bradford), _T_. _congolense_ Broden and _T_. _vivax_ Ziemann in Africa south of the Sahara may also be mechanically transmitted by the stable fly.

The fly tends to feed on the lower part of the animal's body and as a result, bunching or huddling of the animals in a herd is usually observed (Bishopp 1913). This behavioural response can reduce the rate of heat loss from the animal's body. The animal may respond by lessening its feed intake in order to reduce the rate of heat production which may result in lower performance. It is estimated that at high temperatures, flies may be responsible for a significantly high weight loss as they add to the thermal stress suffered by the animal (Feddes and DeShazer 1986).

Impact on Human Recreational Centres. The stable fly is widely recognized as an important pest of man but there are very few published studies. Among the few published accounts for recreation centres are those from northwest Florida (Simmons and Dove 1941; Simmons 1944; Hogsette and Ruff 1985; Jones et al. 1987). Most severe problems with the stable fly occur along the Gulf Coast from the Florida-Alabama border, approximately 640 km east to Aldon Keys, Florida (Newson 1977). The fly invades this area mainly from mid-August through mid-November at which time the beach areas are rendered untenable (Newson 1977; Hogsette and Ruff 1985). The problems are not only reported on the beaches, but the fly causes problems for offshore fishermen, 19 km from land (Hogsette and Ruff 1985). Even though accurate estimates of economic losses caused by the fly on the coast are not available, Newson (1977) gave an estimate of US$ 1 million per day in lost tourist revenues.

Problems associated with the stable fly are also reported in New Jersey where the fly is known as the beach fly (Hansens 1951). Hansens (1951) reported that a few hundred flies were enough to make bathers vacate beach resorts and often to cut their stay short.

The fly is also reported to cause problems for campers and fishermen in some areas of Kentucky and Pickwik Reservoirs on the Tennessee River Valley (Pickard 1968). When stable fly numbers are high, groups of people abandon camping and recreational facilities (Pickard 1968). Elsewhere, serious problems are experienced by swimmers, campers and fishermen along the shores of Lake Superior (Voegtline _et al_. 1965; Waldbillig 1965; Yu-Hwa and Gill 1970).

In environments where potential hosts of the stable fly are plentiful, for example in a zoo or park, the fly may attain such high numbers that the number of visitors to the facility may decline markedly. In the Taronga Zoo, Sidney, Australia, the stable fly is found throughout the year but peak numbers and biting activity of the fly occur in summer (Rugg 1982). The author reported that the fly becomes an ardent problem in summer, when it attacks both animals and people visiting in the zoo. Similarly, the fly is a great nuisance to visitors at Point Pelee National Park, Ontario, Canada in late July through August (Dewald and Michano 1982; Reaume and Michano 1983).

Control Strategies. Management techniques of the stable fly include cultural, biological, and chemical control, as well as combinations of all three techniques.

a) Cultural methods of stable fly control involve manipulation of abiotic factors of the environment to suppress fly numbers. This may be done by identifying breeding sites of the flies and attempting to modify them in such a way that large numbers of larvae can no longer complete development. Most breeding sites for stable flies are associated with spilled feed, animal excrement and bedding (Meyer and Petersen 1983; Meyer and Shultz 1990). Proper management of spilled feed under fencelines, feed bunkers and in drainage ditches as well as haylage piles is imperative. Manure and contaminated bedding must be hauled away and scattered over wider areas to ensure drying before larvae can pupate (Zumpt 1973). Manure and rotting straw must be kept at minimal levels within animal confinement facilities (Lazarus _et_ _al_. 1989).

Moisture content of breeding substrate is one of the most crucial factors in larval development, and therefore silage and hay bales, where they are used, must be properly covered to avoid fermentation (Scholl _et_ _al_. 1981). Waterers and feed bunkers must be situated on raised grounds so that spilled water may flow away or alternatively, properly sloped concrete floors may be used. Concrete aprons around feed bunkers also facilitate run-off of urine and/or water - unless run-off is mixed with bedding, manure and feed elsewhere, this may limit fly breeding sites.

b) Biological control methods consist of enhancing and preserving naturally occurring predator and parasite populations. The three most important steps include:

1. proper use and restriction of chemical treatment of manure,

2. alteration of rows in clean-out procedures in animal houses to ensure a widely distributed population of natural enemies and to give natural enemies time to multiply in the facilities, and

3. redistribution or release of parasites among farms in order to augment the naturally occurring parasite populations.

A diverse heterogeneous fauna of arthropods develops in association with the stable fly breeding grounds. Parasites, that are commonly associated with filth flies include mites, beetles (e.g. Philonthus theventi Horn (Campbell and Hermanussen 1974)), as well as parasitoid wasps (Smith et al. 1987).

In addition to parasite and predator release, the sterile male release technique has been used by many workers (e.g. LaBrecque et al. 1972; Williams et al. 1977a, Patterson et al. 1980, 1981). Even though some success has been achieved using this technique, because both sexes of the stable fly feed on blood, releasing males may seem initially to worsen the problem.

c) A considerable reduction in stable fly numbers is achieved by controlling the amount of breeding sites. It is only after a maximum effort has been made in applying cultural and biological methods that chemical treatment should be considered. Insecticides may be used as both larvicides (for spraying and fumigating breeding sites) and as adulticides (surface sprays and misting) and repellents.

Muma (1946) pointed out that stable flies spend very little time on the host. This habit of the flies makes insecticide application on the host almost useless. Another behavioural characteristic of stable flies is that they are inclined to feed on the lower parts of the host's body. These body parts are subject to a lot of abrasion as well as soiling with wet manure in barns. In pastured cattle, the lower body parts may be washed by dew on tall grass. Therefore chemicals applied to the host may not be practical. Nevertheless, some control has been achieved by spraying cattle with Tabutrex (di-n-butyl succinate) as a repellent (Bruce and Decker 1957), with pyrethroids (Schmidt and Matter 1978) and using insecticide-impregnated ear tags (Hogsette and Ruff 1986). Butyl methylcinchoninate has been used under controlled conditions for livestock (Yeoman and Warren 1970). Its potential use under field condition is unknown.

Resting site treatment with residual chemicals, may be an effective method of chemical control against the stable fly. Dimethoate and diazinon have been used successfully against stable flies when applied on barn walls, fences and other objects used by the flies as resting sites (Dahm and Raun 1955; Cheng *et al*. 1961; Morgan *et al*. 1973).

Repellents are also used for temporary protection and relief in cases where flies pose a serious nuisance to humans. Resmethrin has been commonly used for human beings' relief (Schreck *et al*. 1977). DEET formulations are usually used as insect repellents for human protection against many insects, however, DEET has been found unsatisfactory as a stable fly repellent (Petersen and Greene 1989).

CHAPTER III

Materials and Methods

3.1 Description of the Study Area

This research was conducted in the University of Manitoba's Glenlea Research Station (49° 38'N, 97° 08'W), which was *ca*. 20 km south of Winnipeg on Highway 75 (Fig.1). The station is situated on the Red River Plain in Ritchot Municipality. The topography is gentle undulating land. The drainage is dominantly imperfect as a result of the fine textured Osborne clay soils and levels of topography (Economic Atlas of Manitoba 1960; Barto and Vogel 1978). This area receives an average of 510 mm of rainfall annually and its vegetation is predominantly grassland with scattered groves of various tree types, for example, willow, aspen, elm, ash, maple.

Two study sites were established within the research station: the animal confinement facility and the pasture sites (Fig. 2). The animal confinement site consisted of barns housing 133 dairy cattle, 10-20 beef cattle, five horses, 686 pigs, and 30-60 sheep. The pasture covered *ca*. 310 ha and was divided into 12 paddocks each covering 19-72 ha. A total of 184 beef cattle (cows and calves) were held

Figure 1. Map of Manitoba with the location of the University of Manitoba Glenlea Research Station.

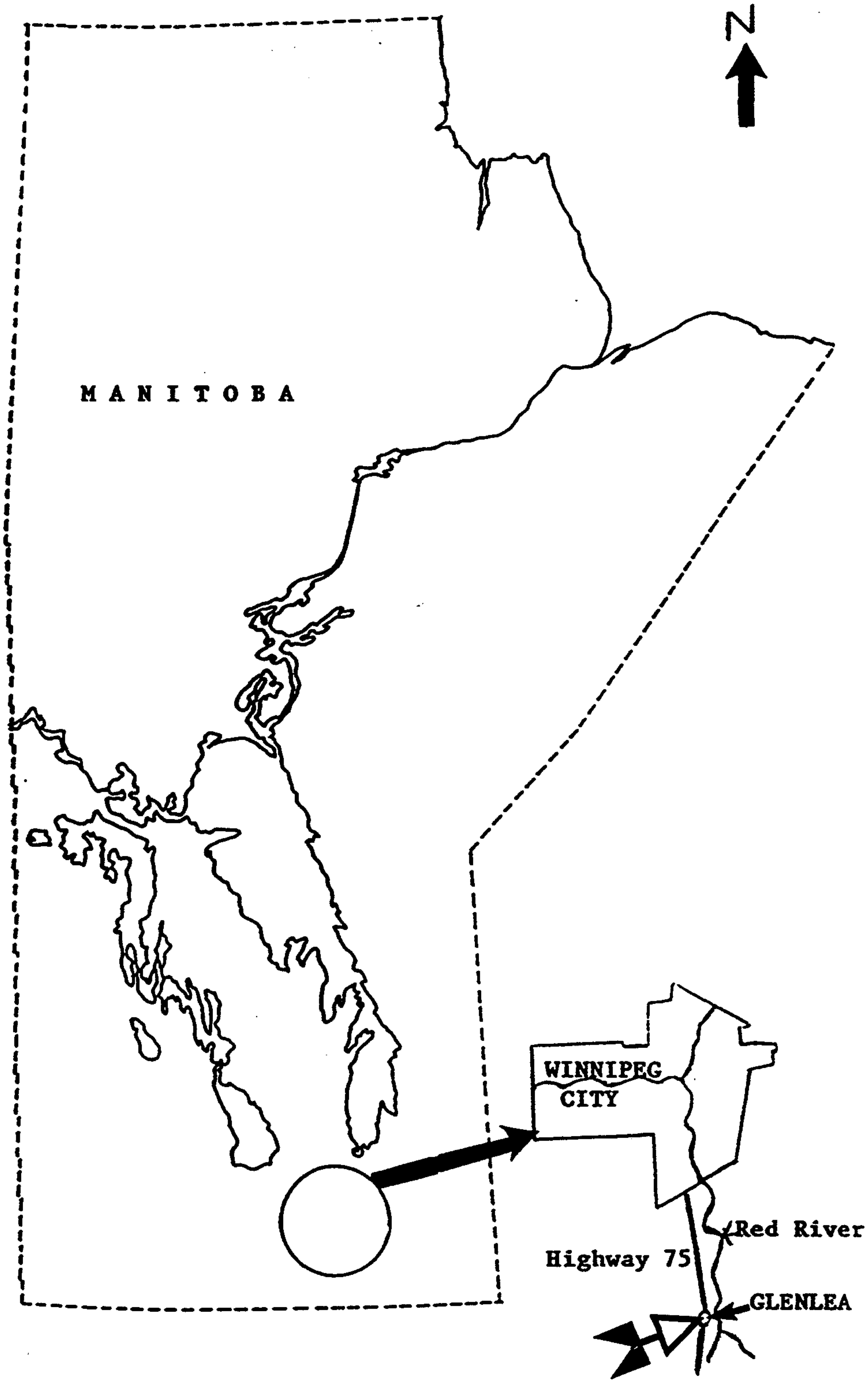
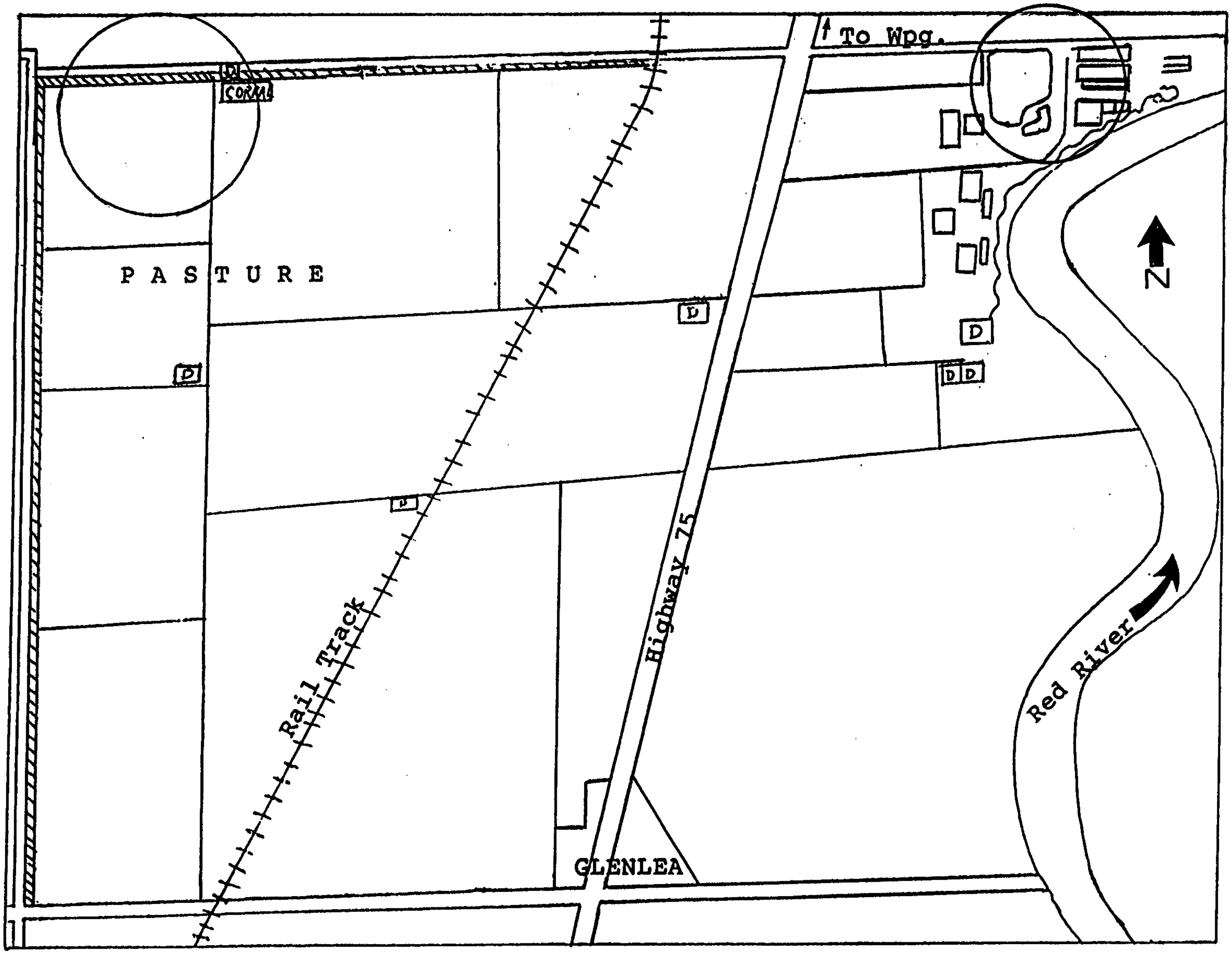

N
MANITOBA
WINNIPEG
CITY
Red River
Highway 75
GLENLEA

Figure 2. Diagramatic representation of the collection sites of stable flies. Williams traps (circles); Green ash tree windbreak (hatched bar); dugout (D).


To Wpg.
CORRAL
D
PASTURE
D
D
D
D
D D
Rail Track
Highway 75
GLENLEA
Red River
N

in at least three paddocks throughout the study. Cattle were held in the paddock where traps were placed (Fig. 2) from May to 8 July in 1988 and from May until the termination of the study on 15 September, 1989. The pasture is on an open site with a green ash tree windbreak bordering its west and north sides.

3.2 Trapping Regime

Sampling was conducted from 17 May to 16 September, 1988 and from 29 May to 15 September 1989. Modified Williams Sticky Traps (Williams 1973) were used to sample adult stable flies in both study sites. Each trap consisted of four Alsynite (TM) fibre glass panels-each panel measuring 34X30 cm. The four panels were held on a 4X4 cm wooden stake with screws and washers (to make them more rigid against the wind). The lower edges of the panels were *ca*. 50 cm above the ground.

Tanglefoot Paste (TM) was used as an adhesive. The adhesive was pre-thinned with 95% ethyl alcohol (4 parts Tanglefoot Paste to 1 part alcohol). Tanglefoot adhesive was then applied directly on each face of the panel using a paint brush.

At the end of each trapping day, the panels were brought down from the wooden stakes for cleaning in the laboratory using 95% ethyl alcohol before being re-used on the following sampling week. Grass was trimmed as needed around the traps. Six traps were placed in the animal confinement site and operated on Tuesdays and Thursdays in May and June, 1988 then on Tuesdays only until the end of sampling in 1988. They were operated on Fridays only in the 1989 sampling period. The other six traps were used in the pasture site on Mondays and Fridays in May and June 1988, and then on Fridays only until the end of sampling in 1988, while they were operated on Wednesdays only throughout the 1989 sampling period. Traps were left in place for ca. nine hours (0700h-1600h) on each sampling occasion.

Trap placement in the barn area was according to the classes of animals housed; three traps were placed close to the three beef cattle barns, the fourth trap was placed close to the dairy cattle barn, the fifth trap was placed close to the horse stable and the sixth trap was placed close to the hog barn. In the pasture all six traps were placed on two sides of one of the paddocks (Fig. 2): three were placed in an east-west line parallel and close to the windbreak and the other three were placed parallel to the fence in a north-south line. Traps were placed 120 m apart. Trap locations were permanent in each site in both years.

Trapped stable flies and other insects were removed from the traps with a pair of forceps at the end of a predetermined exposure time interval of one hour or more. Stable flies were put into 35 cm^3 plastic vials that were labelled with site, trap, date and time interval. The vials containing flies were stored on ice in a cooler and taken back to the laboratory for storage at $-15^{\circ}\mathrm{C}^{+}1^{\circ}\mathrm{C}$ for later processing.

3.2.1 *Efficiency of the Williams Sticky Trap*. Freshly prepared Tanglefoot paste (as described in 3.2) was applied on one face of an Alsynite fibre glass panel measuring 34X30 cm^2. The panel was held against a wooden stake *ca*. 50 cm above the ground. The number of stable flies that came into contact, but stuck or escaped was recorded by an observer during a predetermined time interval of 30-60 minutes. Temperature was also recorded at the end of the time interval. Observations were repeated on different days and time periods on the same site.

The efficiency of the Williams trap was expressed as a percentage, using the following formula:

$$T = \frac{C}{C + E} \mathrm{X}\ 100,$$

where, C = number of flies caught,

E = number of flies which escaped,

T = trapping efficiency.

3.3 Sweep Net Collection

On each trapping occasion, stable flies were collected live, and brought back to the laboratory. Flies were collected using a sweep net from the walls and vegetation near the animals in each site. The sweep net-collected flies were transferred into a plastic cage for transit to the laboratory. Stable flies were subsequently aspirated from the cage and transferred to moistened (to prevent freeze-drying) 20 cm^3 glass vials which were then sealed with rubber stoppers and marked with date and site of collection. The flies were killed by being subjected to a temperature of -15°C in the freezer, and were kept for later processing.

3.4 Weather Data

In 1988, the maximum and minimum temperatures, and precipitation were obtained from the Glenlea Research Station. In 1989, in addition to the parameters for 1988, hourly temperatures were taken using a chart recording thermometer (Wexler (TM) Type 06MIC5B) placed on the ground under shade provided by some shrubs in the confinement area. The prevailing wind directions during the 1988 and 1989 sampling periods were obtained from the Winnipeg International Airport. In 1989, hourly temperatures were recorded for June, July and August, however, because the numbers of stable flies caught on traps in August were very low, the temperatures used in analysis are those for June and July only. Hourly recorded temperatures were compared with hourly mean stable fly trap captures. Wind directions were used mainly to investigate the variations in trap catches in the pasture site. The precipitation data were used to assess the overall availability and suitability of breeding sites since moisture content of the oviposition substrates is crucial for larval survival.

3.5 Processing Sticky Trap- and Sweep Net-collected Stable Flies

Stable flies that had been collected were examined under the dissecting microscope, sexed, counted and a random subsample of 15-30 females from the day's collection was set aside for dissection and the remainder were discarded. Flies were dissected under the microscope where the abdomen was opened along the pleural membrane exposing the fatbodies, ovaries and the crop of the fly.

Finally, parity status of the dissected individual was assigned based on ovarian development. One ovary was removed from the abdominal cavity with a pair of forceps and placed on a glass slide in a drop of distilled water with a small amount of liquid soap added. Ovarioles were separated by teasing the ovary with dissecting needles. The individual ovarioles were then examined under a phase-contrast Nikkon dissecting microscope. Parity status was based on stages recognized by Scholl (1980) and Sutherland (1980b) (See Ch.2). Since uniparous and biparous+ individuals could not be distinguished, only three categories were used - nulliparous, parous and gravid (since I could not distinguish between gravid-nulliparous and gravid-parous individuals).

3.6 Instantaneous Population Estimates

In addition to trapping, stable fly population changes were monitored by counting flies on the front legs of beef cattle in pens in 1988. This was done once a week on the sampling day between 1000-1100hrs. The observer would stand on the side close to an animal and count the number of flies seen at the time on both front legs below the chest of the animal, with the naked eye or aided with binoculars. Since only one half of each front leg could be seen from the observer's position, the number of flies counted on both legs were summed and the total recorded as the number of flies per front leg for that animal. The mean number of flies for 5-10 animals was recorded as the mean feeding rate of the flies for that day.

Counts of resting stable flies on resting or perching sites were also taken to obtain a second instantaneous estimate of the population. In a preliminary investigation, stable flies were observed to assemble in large numbers on sunlit building walls in the confinement area. Areas on four walls were marked out with masking tape. Each area marked was 7-19 m^2. Resting site counts of stable flies were taken bi-hourly during each trapping occasion, once a week in 1988 and in 1989.

3.7 Statistical Analyses

Most of the statistical analyses were done with The System for Statistics (Wilkinson, Leland. SYSTAT: The System for Statistics. Evanston, IL: SYSTAT INC. 1988). The seasonal abundance data were subjected to a Chi square to determine if there were any differences in attractancy to the traps based on sex of the flies. The parity data was subjected to a paired t-test to determine if there were any differences in age-groups due to sampling technique, particularly the nulliparous portion. A Pearson Chi square was employed to test monthly sex ratios between trap-collected and sweep net-collected stable flies.

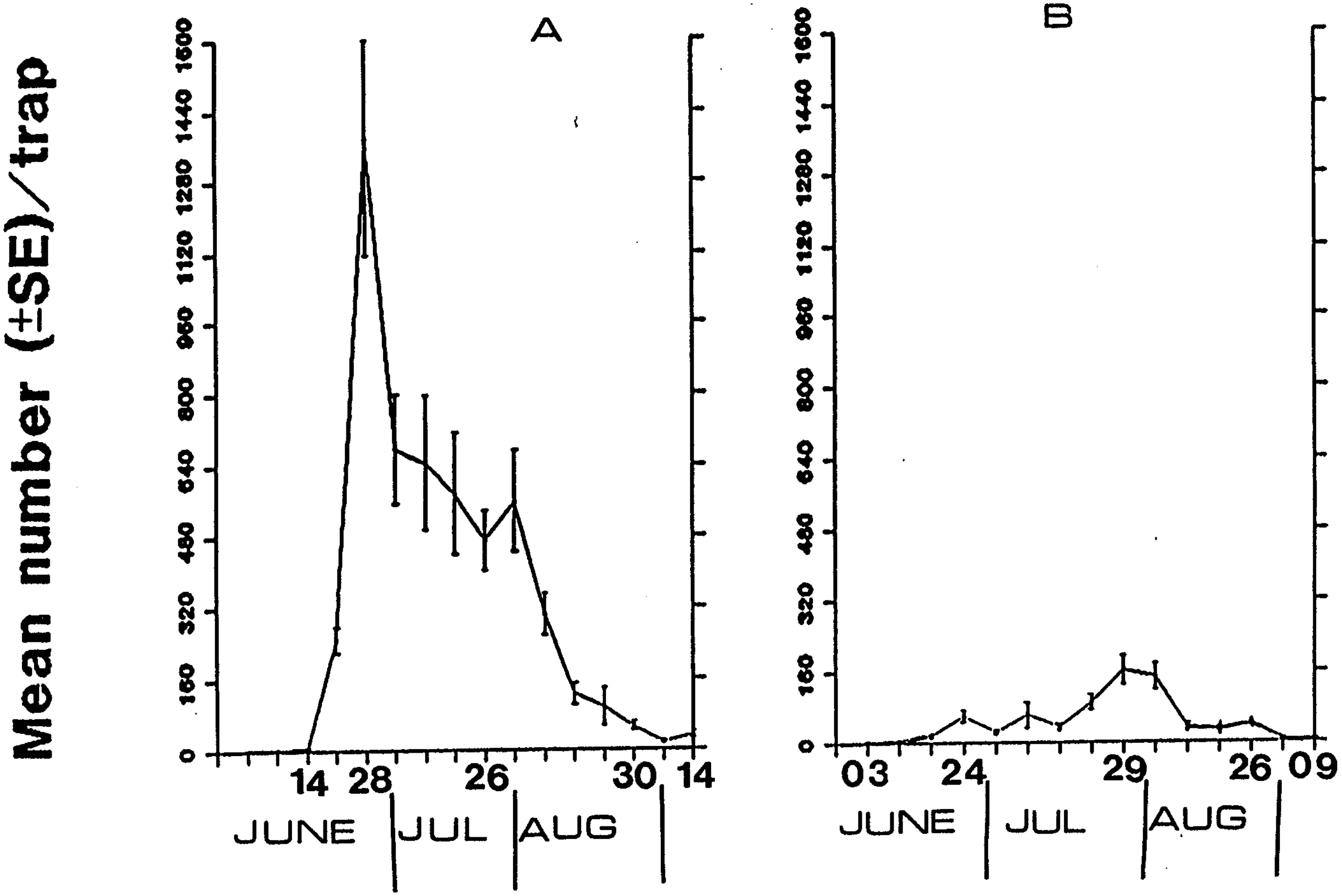
CHAPTER IV

Results

4.1 1988

4.1.1 Seasonal Abundance. Adult stable fly populations, as determined by Williams sticky traps, were markedly larger in the animal confinement site compared to the pasture (Fig. 3). A total of 38,146 adult stable flies were collected during 1988. The first flies were collected during the week ending on 4 June and the last were collected on 14 September. The experiments were terminated on 16 September when no flies were captured on the traps located at the pasture. The traps had been in place two weeks (from 17 May) prior to the collection of the first flies. A total of 33,672 (>88%) and 4,474 (<12%) stable flies were collected at the animal confinement site and at the pasture, respectively. Even though the animal confinement area and pasture were within two km of each other, the stable fly populations did not only differ in abundance but also in duration of relative peak numbers. Peak captures occurred from 16 June through 30 August at the animal confinement site when daily mean number of flies per trap exceeded 50. The highest number of flies, 138 flies/trap/h, were

Figure 3. Seasonal abundance of the stable flies caught in six Williams traps : A- Animal confinement, B- Pasture site, Glenlea, Manitoba, 1988. Error bars = standard errors of the mean.


A
B
Mean number (±SE)/trap
0
160
320
480
640
800
960
1120
1280
1440
1600
14
28
26
30
14
JUNE
JUL
AUG
03
24
29
26
09
JUNE
JUL
AUG

collected on 28 June at the animal confinement site. Peak numbers of flies were collected from 17 June through 26 August at the pasture when the daily mean capture per trap was more than 15 flies. On 28 July, 18 flies/trap/h were collected from the pasture. Both animal confinement and pasture populations exhibited unimodal fluctuations in 1988.

Monthly total stable fly catches for all six traps at each site are presented in Tables 1 and 2. On average, the months of June, July and August yielded more than 99% of the total collection from the animal confinement and July was the most prolific month with fly numbers averaging over 395 flies/h. A similar trend was observed in pasture collections; July accounted for >51% of the seasonal total, though weekly collections were more irregular than in the animal confinement site.

4.1.2 Efficiency of the Williams Traps. Williams traps, as used in this study, were 36.2% efficient, i.e. out of 100 flies that landed on the trap less than 40 could not escape (Table 3). Temperature did not appear to affect the trapping efficiency of the system during the period when the test was done.

4.1.3 Instantaneous Population Estimates. Stable flies feeding and/or resting on beef cattle were counted in the 1988 season only (Table 4). The leg counts varied from week

TABLE 1. Monthly totals of stable flies collected from six Williams traps at the animal confinement site and hours of trap operation in 1988 and 1989, Glenlea, Manitoba.

Period	Number of hours of trap operation	Total no. of flies	No. of flies/h[1]
May/1988	9	1	0.1
June/1988	61	12272	201.2
July/1988	36	14239	395.5
August/1988	44	6859	155.89
September/1988	18	301	16.7
OVERALL TOTALS	168	33672	
June/1989	38	423	11.1
July/1989	35.5	19014	535.6
August/1989	33	5360	162.4
September/1989	23.5	1767	75.2
OVERALL TOTALS	130	26564	

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[1] Total monthly catch divided by total no. of hours of trap operation.

TABLE 2. Monthly totals of stable flies collected from six Williams traps at the pasture and hours of trap operation in 1988 and 1989, Glenlea, Manitoba.

Period	Number of hours of trap operation	Total no. of flies	No. of flies/h[1]
June/1988	53	548	10.34
July/1988	51	2312	45.33
August/1988	36	1554	43.17
September/1988	26	60	2.31
OVERALL TOTALS	166	4474	
June/1989	36	783	21.75
July/1989	35	7987	228.2
August/1989	42	2795	66.55
September/1989	16	943	58.94
OVERALL TOTALS	129	12508	

---

[1] Total monthly catch divided by total no. of hours of trap operation.

TABLE 3. Estimation of the trapping efficiency of the Williams sticky traps coated with Tanglefoot (TM) as the adhesive.

Date	Time interval	No. of flies caught	No. of flies escaped	Temp. (°C)	Efficiency (%)[1]
07 July	1200 - 1300	12	28	16.5	30.0
14 July	1230 - 1300	2	10	19.0	16.7
28 July	1000 - 1100	151	83	19.0	64.5
28 July	1200 - 1300	81	109	21.0	42.6
28 July	1400 - 1500	77	206	21.6	27.2

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[1] Efficiency = [No. of flies caught/ Sum (No. of flies caught and escaped)] x 100

TABLE 4. Estimates of mean number of stable flies (restings site counts) on barn walls in 1988 and 1989, at the animal confinement site, Glenlea, Manitoba.

Date	No. of flies/m^2	Date	No. of flies/m^2
07/06/88	1.33	09/06/89	-[1]
14/06/88	0.33	16/06/89	<0.11
21/06/88	20.67	23/06/89	0.78
28/06/88	23.44	30/06/89	0.33
05/07/88	13.44	07/07/89	2.0
12/07/88	6.78	14/07/89	2.56
19/07/88	12.33	21/07/89	1.33
26/07/88	12.67	28/07/89	1.0
02/08/88	10.11	04/08/89	0.11
09/08/88	6.77	11/08/89	0.56
16/08/88	22.56	18/08/89	0.67
23/08/88	0.89	26/08/89	0.22
30/08/88	0.22	01/09/89	0
06/09/88	0.11	08/09/89	<0.11
14/09/88	<0.11	15/09/89	<0.11

---

[1] No count was taken.

to week and the trend was generally similar to numbers in the trap catches. The highest feeding rate was observed on 28 June and the number of flies counted during the following seven weeks was always >10 flies/leg. On a rainy day (23 August), no flies were seen on cattle legs. Resting site counts of stable flies also varied from week to week and showed increases generally similar to leg counts and trap catches, the highest numbers of flies were 21/m^2 on 21 June, 23/m^2 on 28 June and 16 August (Table 5).

4.1.4 Sex Ratios. The proportions of males from both collection sites were higher than those of females. The average male/female ratio of trap-collected flies was 2.6:1 at the animal confinement site and 1.3:1 for the pasture. In sweep net-collected samples from the animal confinement and pasture sites, the male/female ratios were 1.6:1 and 0.9:1, respectively. The male/female ratios increased slowly (from 1.9:1 in June) with the season and was at its highest (3.8:1) in September for confinement site traps. This trend was also observed in sweep net-collections where the male/female ratio increased from 0.9:1 in June to 3.1 in September at the animal confinement site. Pasture-collected flies exhibited lower male/female ratios for both trap and sweep net collections. The rate of increase in male/female ratio was not as consistent as in animal confinement data. In June and September, 1988, there were more females than

TABLE 5. Estimates of mean number of stable flies (restings site counts) on barn walls in 1988 and 1989, at the animal confinement site, Glenlea, Manitoba.

Date	No. of flies/m^2	Date	No. of flies/m^2
07/06/88	1.33	09/06/89	–[1]
14/06/88	0.33	16/06/89	<0.11
21/06/88	20.67	23/06/89	0.78
28/06/88	23.44	30/06/89	0.33
05/07/88	13.44	07/07/89	2.0
12/07/88	6.78	14/07/89	2.56
19/07/88	12.33	21/07/89	1.33
26/07/88	12.67	28/07/89	1.0
02/08/88	10.11	04/08/89	0.11
09/08/88	6.77	11/08/89	0.56
16/08/88	22.56	18/08/89	0.67
23/08/88	0.89	26/08/89	0.22
30/08/88	0.22	01/09/89	0
06/09/88	0.11	08/09/89	<0.11
14/09/88	<0.11	15/09/89	<0.11

---

[1] No count was taken.

males in the collections (0.8:1 and 0.9:1, respectively). Similarly, sweep net-collected flies at the pasture consisted of more females than males in June, July and August (0.5:1, 0.7, and 0.7, respectively).

A Chi square test was employed to test whether the sex ratios differed significantly from 50:50 (Table 6). The two sampling methods sampled different proportions of males and females, but in September 1988 the proportions were not significantly different ($P<0.05$).

4.1.5 Ovarian Development and Parity Rates. Two per cent (219 out of 10669) of the total female stable flies captured in the sticky traps and 31% (141 out of 449) of the sweep net collections from the animal confinement site were dissected in 1988. A total of 185 females (10% of 1819) captured in the traps located at the pasture and 138 (26% of 536) collected by the sweep net from the pasture were also dissected. The results for the dissections are given in Figs. 4 and 5. The proportions of newly emerged and nulliparous females were assumed to be indicative of young cohorts of flies in the populations. Significantly more young flies were captured on the sticky traps (97% overall) (Fig. 4), while the net collected samples had a higher parous proportion (20%) (Fig. 5).

The proportion of newly emerged females captured on the Williams traps at the animal confinement site increased from

TABLE 6. Observed monthly sex ratios (male/female) for trap-collected and sweep net-collected *S. calcitrans* at the animal confinement area and pasture, Glenlea, Manitoba, 1988 and 1989.

Month	Animal confinement site			Pasture		
	Traps Net	(M:F) (M:F)	Chi-sq[1]	Traps Net	(M:F) (M:F)	Chi-sq
June/1988	8052:4216	(1.9:1)*[2]	54.8 *	244:304	(0.8:1)*	10.3*
	218:230	(0.9:1)		153:291	(0.5:1)*	
July/1988	9879:4270	(2.3:1)*	21.8*	1388:924	(1.5:1)*	21.8*
	85:76	(1.1:1)		68:96	(0.7:1)*	
Aug/1988	4740:2119	(2.2:1)*	12.0*	995:559	(1.8:1)*	50.3*
	152:106	(1.4:1)*		93:141	(0.7:1)*	
Sept/1988	238:63	(3.8:1)*	0.8	28:32	(0.9:1)	1.9
	94:31	(3.1:1)*		14:8	(1.75:1)*	
June/1989	250:256	(1:1)	34.6*	429:456	(0.9:1)	14.4*
	81:208	(0.1:1)*		110:61	(1.8:1)*	
July/1989	13183:5831	(2.3:1)*	45.2*	4985:3002	(1.7:1)*	44.0*
	228:194	(1.2:1)		321:87	(3.7:1)*	
Aug/1989	3522:1838	(1.9:1)*	16.5*	1644:1151	(1.4:1)*	1.9
	168:141	(1.2:1)		338:207	(1.6:1)*	
Sept/1989	1216:551	(2.2:1)*	0.1	602:341	(1.8:1)*	4.4*
	198:93	(2.1:1)*		47:14	(1.3:1)*	
OVERALL AVE		(2.1:1)* (1.1:1)			(1.5:1)* (1.3:1)*	

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[1] Pearson Chi square-values for comparison of sex ratios of traps and net catches.

[2] * Sex ratios are significantly different from 50:50, ($X^2_{1,\ 0.05} = 3.84$)

Figure 4. Proportions (%) of Newly emerged (solid bars), Nulliparous (finely hatched bars) and Parous (hatched bars) female stable flies caught in six Williams traps: A- Animal confinement site, B- Pasture Glenlea, Manitoba, 1988. Each sample consisted of 15 randomly selected females.

Per cent parity/sample

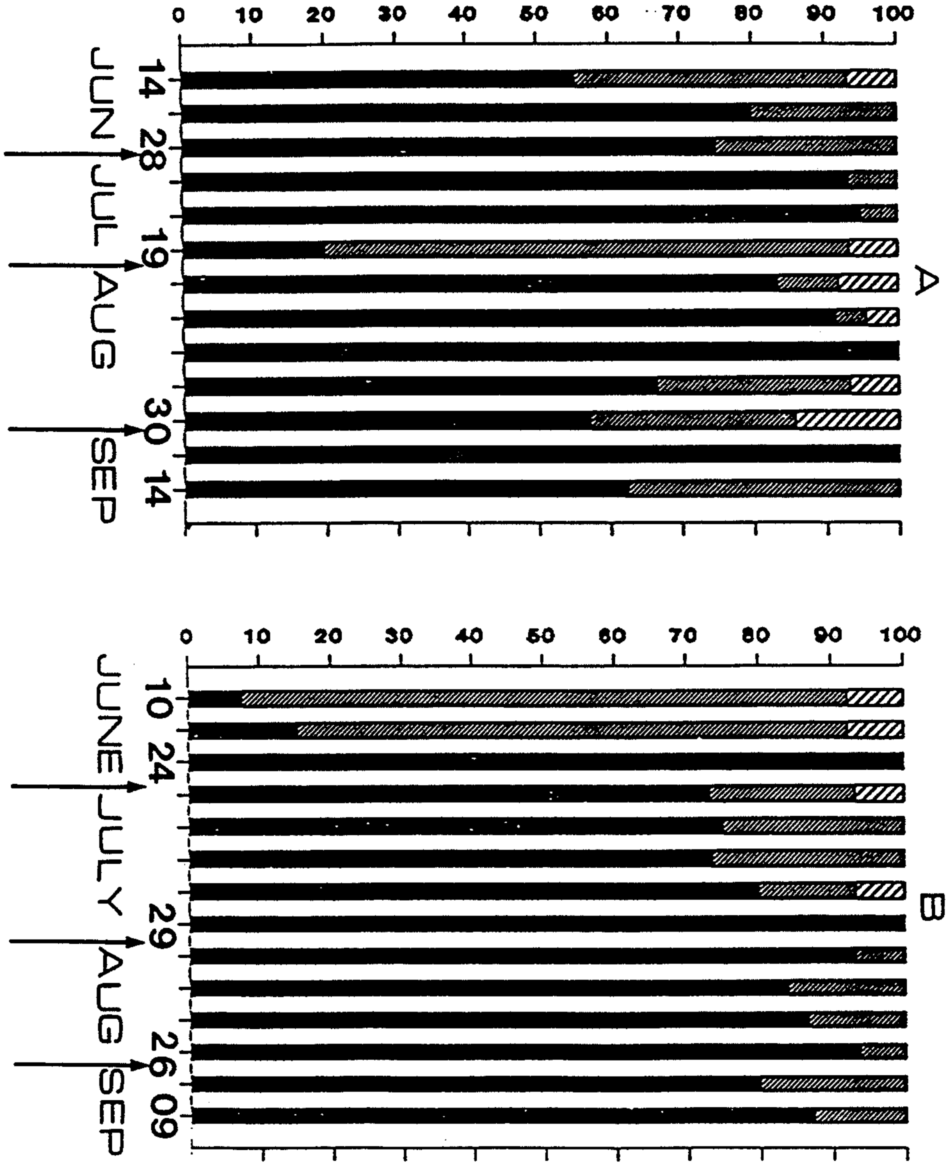
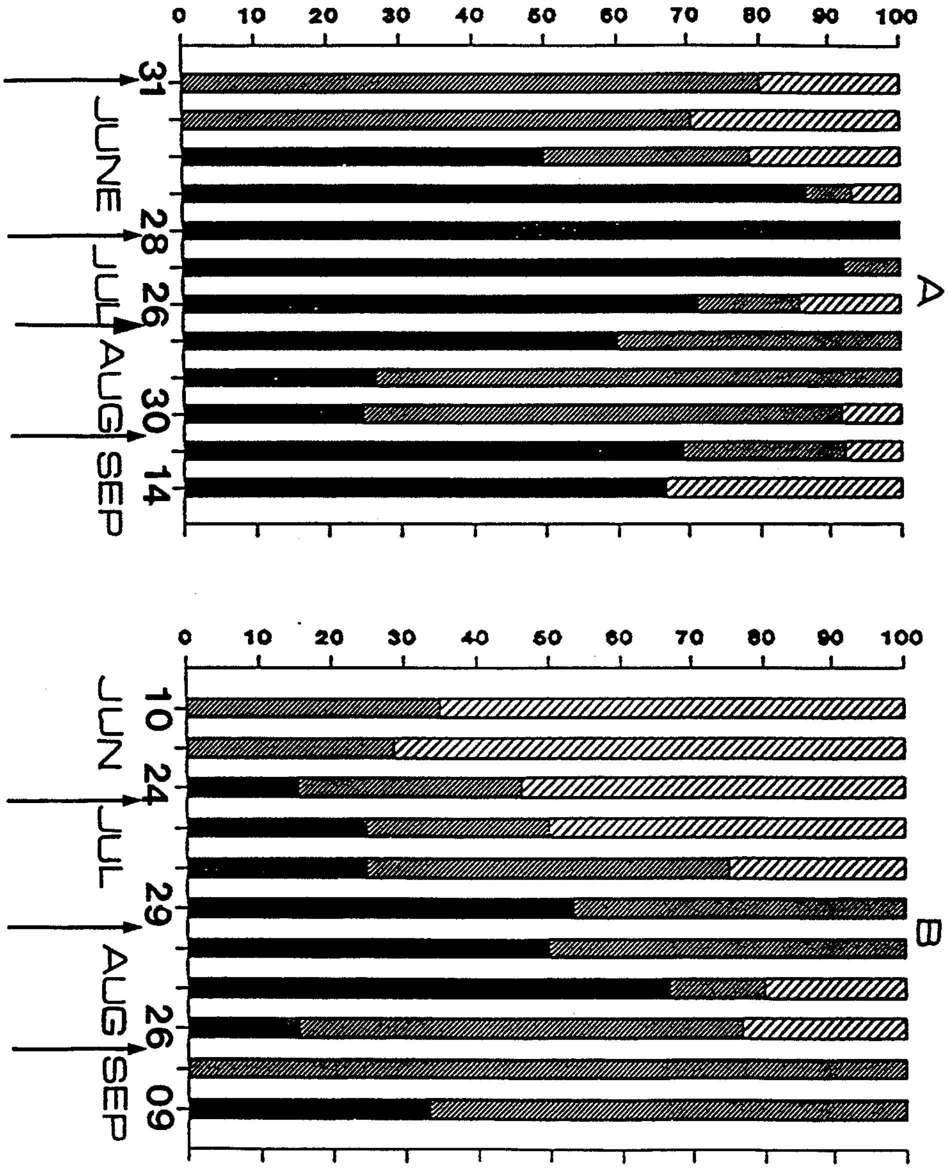


Figure 5. Proportions (%) of Newly emerged (solid bars), Nulliparous (finely hatched bars) and Parous (hatched bars) female stable flies collected by Sweep net from resting sites: A- Animal confinement site, B- Pasture, Glenlea, Manitoba, 1988. Each sample consisted of 15 randomly selected females.

Per cent parity/sample



56% on 7 June to _ca_. 94% on 28 June, the percentage remained at that level until 16 August and then declined to _ca_. 60% for the remainder of the sampling period (Fig. 4A). Similarly, the newly emerged proportion was _ca_. 9% on 10 June and then increased to _ca_. 72% until 29 July when a further rise to _ca_. 80% occurred and remained at that level until the end of sampling. Seasonal trends were more regular in sweep net-collected flies in 1988 (Fig. 5). There were no newly emerged females in samples collected from the animal confinement site and pasture during the first two sampling dates. The parous proportion in animal confinement collection was 20% on the first collection date and increased to 30% on the second. The dissected females comprised 50% newly emerged individuals on the third sampling date, and the proportion increased rapidly, reaching 100% newly emerged on 28 June. The newly emerged and nulliparous proportions remained almost 90% until 30 August.

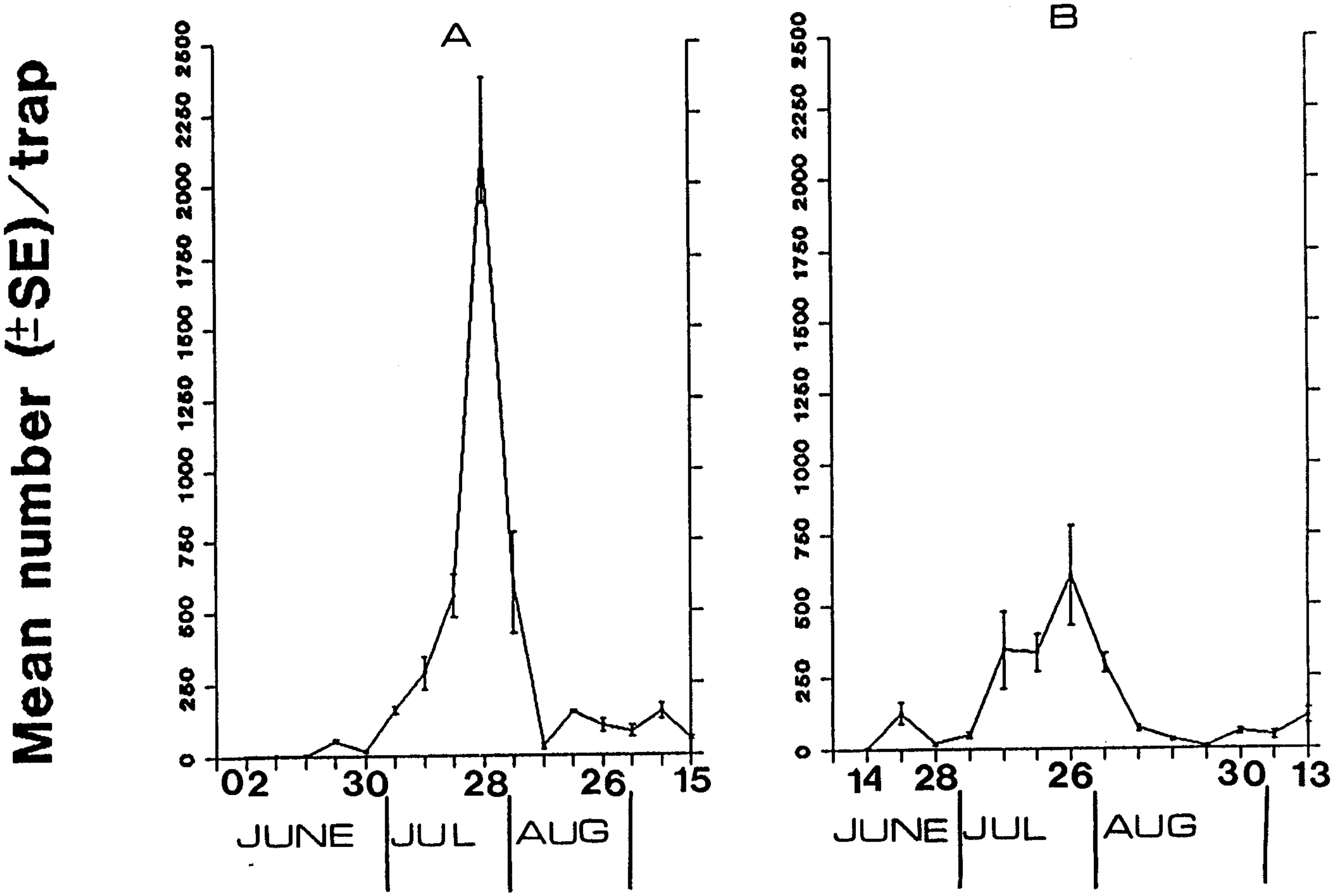
The pasture samples of sweep net-collected flies consisted of a high proportion of parous flies (>40%) for the first two sampling dates. During the next four sampling dates the newly emerged and nulliparous proportions increased, though the rate of increase was not as high as at the animal confinement site. On 29 July, the dissected individuals consisted of 50:50 newly emerged:nulliparous individuals and no parous ones. Newly emerged and nulliparous flies were >78% of the total for the remainder of the sampling period.

4.1.6 Diurnal Activity Patterns. Daily stable fly catches for selected dates are presented in Appendices A and B. Number of flies collected hourly on the dates excluded in the tables were too low to be of use in showing daily activity patterns (selection was based on a minimum of 20 flies collected during three or more time-intervals per sampling occasion). Peak activity at the animal confinement site (Appendix A) occurred >81% of the time in the morning, between 0700-1100 hrs. There were no distinct activity patterns in pasture-collected flies (Appendix B). Daily activity patterns were usually single-peaked, however, two peaks of activity occurred on 8, 15, 23 and 29 July in the pasture.

1989

4.2.1 Seasonal Abundance. Seasonal distribution patterns of the stable flies at the animal confinement site for the 1989 season were different from those of the 1988 season in terms of duration and occurrence of peak abundance (Fig. 6). The traps were set in place on 29 May and the first adult flies were collected on 2 June. Trap catches were comparable to the 1988 season except that the highest

Figure 6. Seasonal abundance of the stable flies caught in six six Williams traps : A- Animal confinement, B- Pasture site, Glenlea, Manitoba, 1989. Error bars = standard errors of the mean.


Mean number (±SE)/trap
A
B
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
02
30
28
26
15
14
28
26
30
13
JUNE
JUL
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capture rate was observed a month later (28 July) than in 1988. Daily catches were low until the end of June and then a considerable increase occurred from 7 July attaining the highest level on 28 July. Daily trap catches averaged >50 flies per trap from 23 June through 15 September. The total number of flies that was collected from the animal confinement was 26,567 (68% of seasonal total). A total of 12,466 stable flies (32% of seasonal total) was caught at the pasture site in 1989, more than 3.5-fold the 1988 total catch at the pasture when one takes into consideration the total number of hours of sampling for both years. The seasonal abundance pattern at the pasture was similar for both years. Peak numbers of stable flies were obtained during the last week of July as in 1988. However, 76 flies/trap/h were obtained in 1989 compared to 18 in 1988.

Monthly total trap catches of stable flies for the 1989 season are presented in Tables 1 and 2. Unlike in 1988, >98% of the total stable flies were captured during July, August and September. The highest number of flies that were collected per hour at the animal confinement site was during July (536), similar the previous year (Table 1). Similarly, at the pasture, >93% of the total number of flies was collected during the last three months of sampling. The highest number of flies collected per hour was 228, in July, and this rate was more than 5-fold the rate of flies collected in 1988 during July.

4.2.2 Instantaneous Population Estimates. In the 1989 season, no beef cattle were held in the barn, and therefore leg counts were not taken. Resting site counts were the only instantaneous population estimates made in 1989. The numbers were generally low throughout the sampling period in contrast to the previous year. The number of flies did not exceed 1 fly/m^2 in June, and a peak was observed on 12 July, 1989 (2.56 flies/m^2). Otherwise the numbers generally remained below 1 fly/m^2 in August and September (Table 5).

4.2.3 Sex Ratios. The observed sex ratios of stable flies in 1989 are presented in Table 6. The average proportion of males for traps at the animal confinement was 1.9, and 1.5 at the pasture. Similarly, the sex ratio for net-collected flies at the animal confinement was 1.2, and 2.1 in pasture collections.

4.2.4 Ovarian Development and Parity Rates. One thousand, two hundred and ninety three female stable flies collected during the 1989 season were dissected. The parity rates are shown on Figs. 7 and 8. The proportion of newly emerged stable flies was about 3% on 16 June at the animal confinement site, and increased in the following weeks' dissections to 100% on 14 July. Newly emerged flies exceeded 80% of the dissected samples until 19 August. The

Figure 7. Proportions (%) of Newly emerged (solid bars), Nulliparous (finely hatched bars) and Parous (hatched bars) female stable flies caught in six Williams traps: A- Animal confinement site, B- Pasture, Glenlea, Manitoba, 1989. Each sample consisted of 30 randomly selected females.

Per cent parity/sample

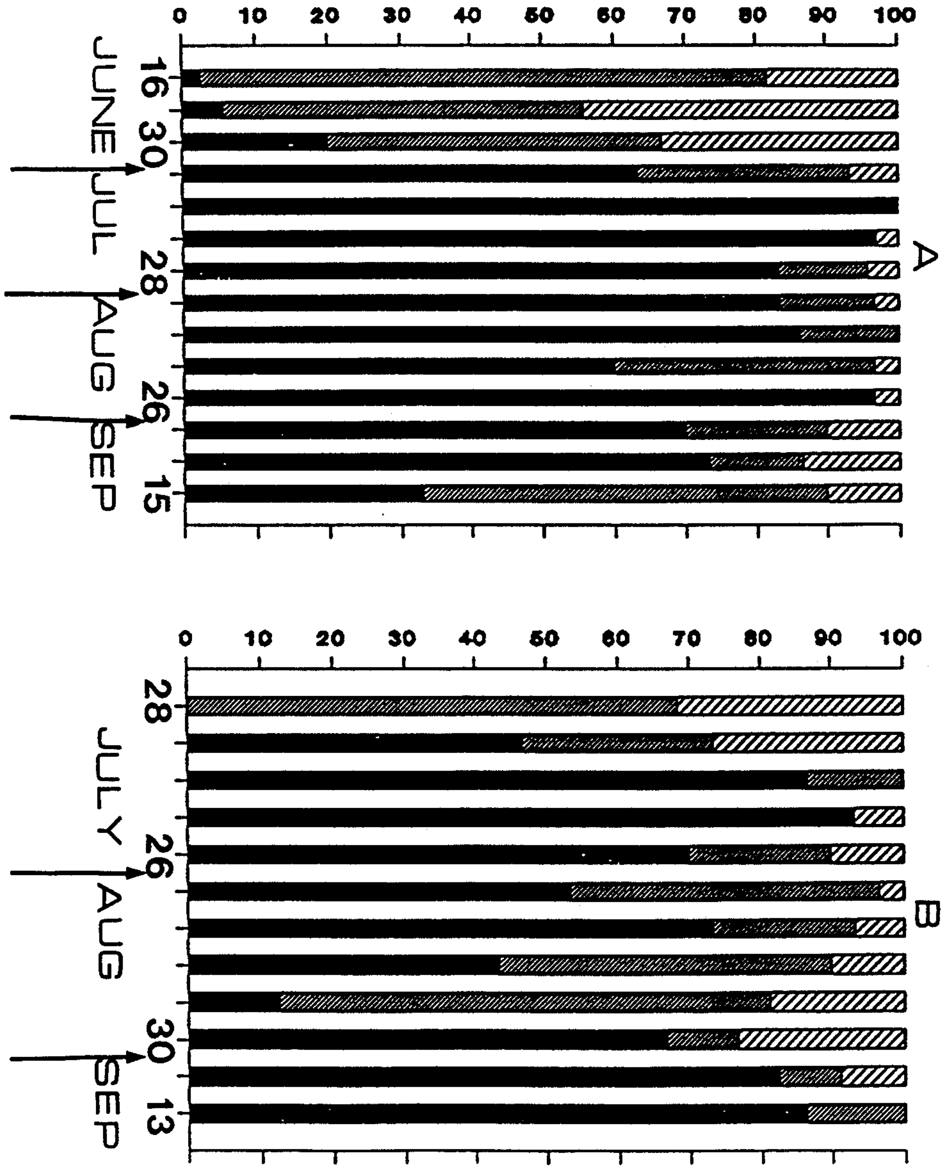
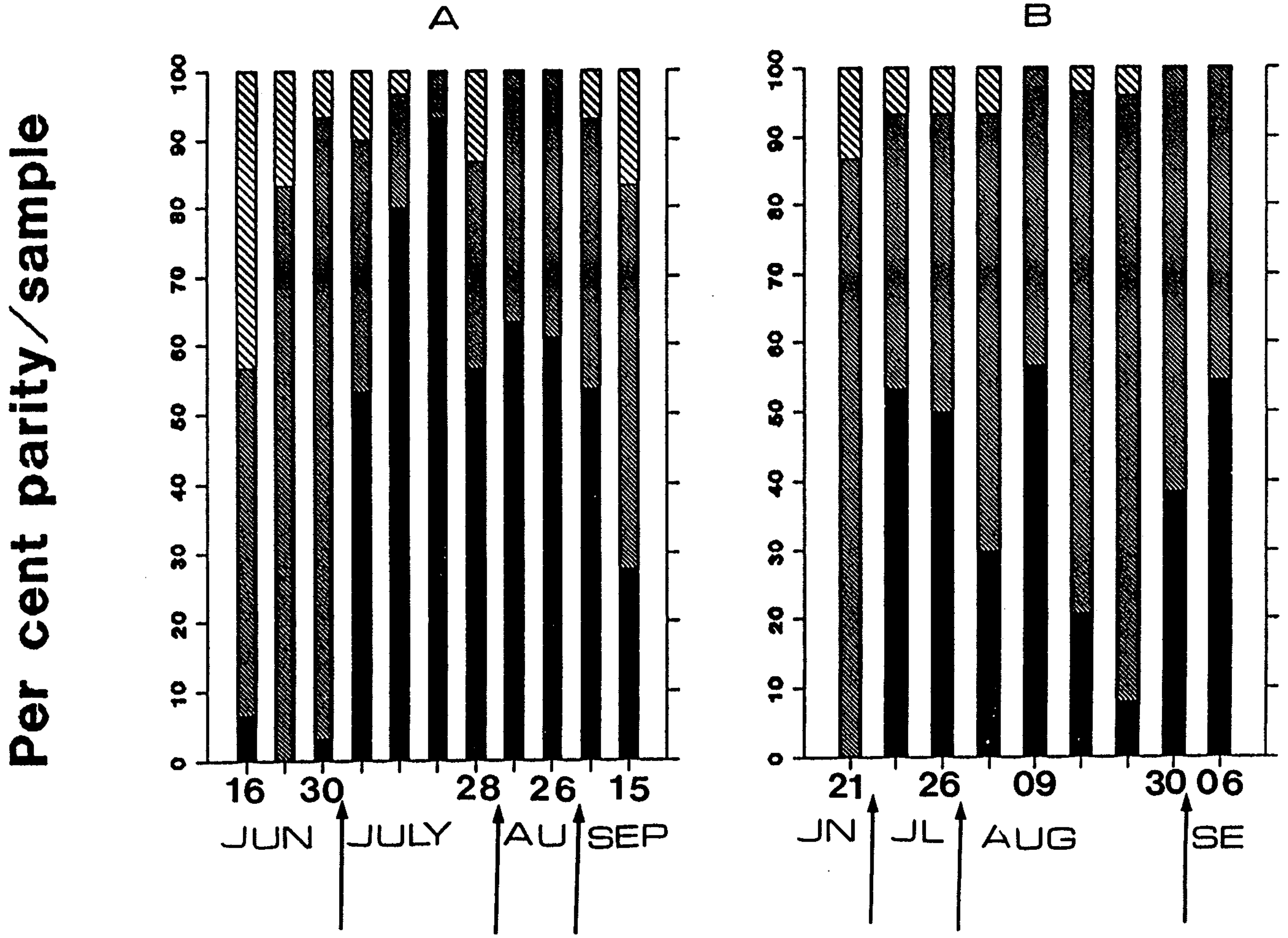


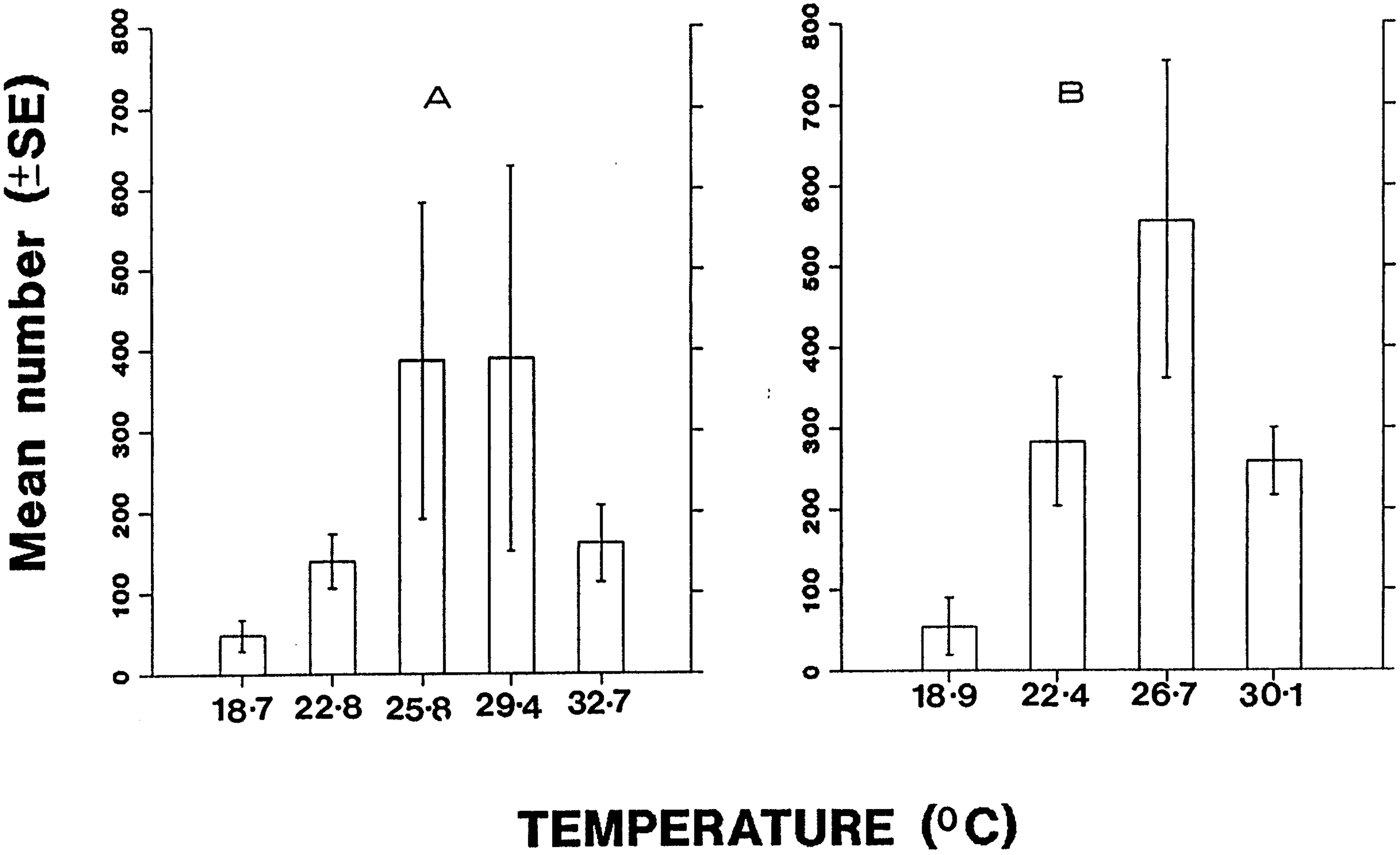
Figure 8. Proportions (%) of Newly emerged (solid bars), Nulliparous (finely hatched bars) and Parous (hatched bars) female stable flies collected by Sweep net from resting sites: A- Animal confinement site, B- Pasture, Glenlea, Manitoba, 1989. Each sample consisted of 30 randomly selected females.


Per cent parity/sample
A
B
0
10
20
30
40
50
60
70
80
90
100
16
30
28
26
15
JUN
JULY
AU
SEP
21
26
09
30
06
JN
JL
AUG
SE

rapid increase in the proportion of newly emerged flies during the first seven weeks of sampling corresponded with the increase in population as indexed by trap capture. There was an increase in the proportion of newly emerged flies in collections at the pasture site, to ca. 90% on 19 July. Proportions of parous flies were generally higher for both sites in 1989 compared to 1988. In terms of newly emerged fly proportions, sweep net-collected samples exhibited irregular patterns. However, the highest proportion of newly emerged flies coincided with peak abundance in trap catches at the animal confinement site. Coincidence of highest newly emerged females and peak abundance was not observed in pasture collections.

4.2.5 Diurnal Activity Patterns. Daily stable fly catches are given in Appendices C and D for selected dates in 1989. Selection was based on a minimum of 20 flies collected during three or more time-intervals per sampling effort. In Fig. 9 bi-hourly mean catches of the stable flies are plotted against bi-hourly mean temperatures. The two bar charts (Fig. 9) are based on data collected from 14 June to 26 July, 1989. The maximum activity as shown by bi-hourly catches appears to be affected mainly by temperature. Peak activity occurred at temperatures between 20°C and 31°C (Fig. 9). Time of day was not a major factor per se in determining peak activity, but was important in that time is

Figure 9. Profile of mean bi-hourly stable fly catches in six Williams traps (Error bars = standard errors of the mean) against bi-hourly mean temperatures for selected dates in 1989: A- Animal confinement site, B- Pasture, Glenlea, Manitoba.

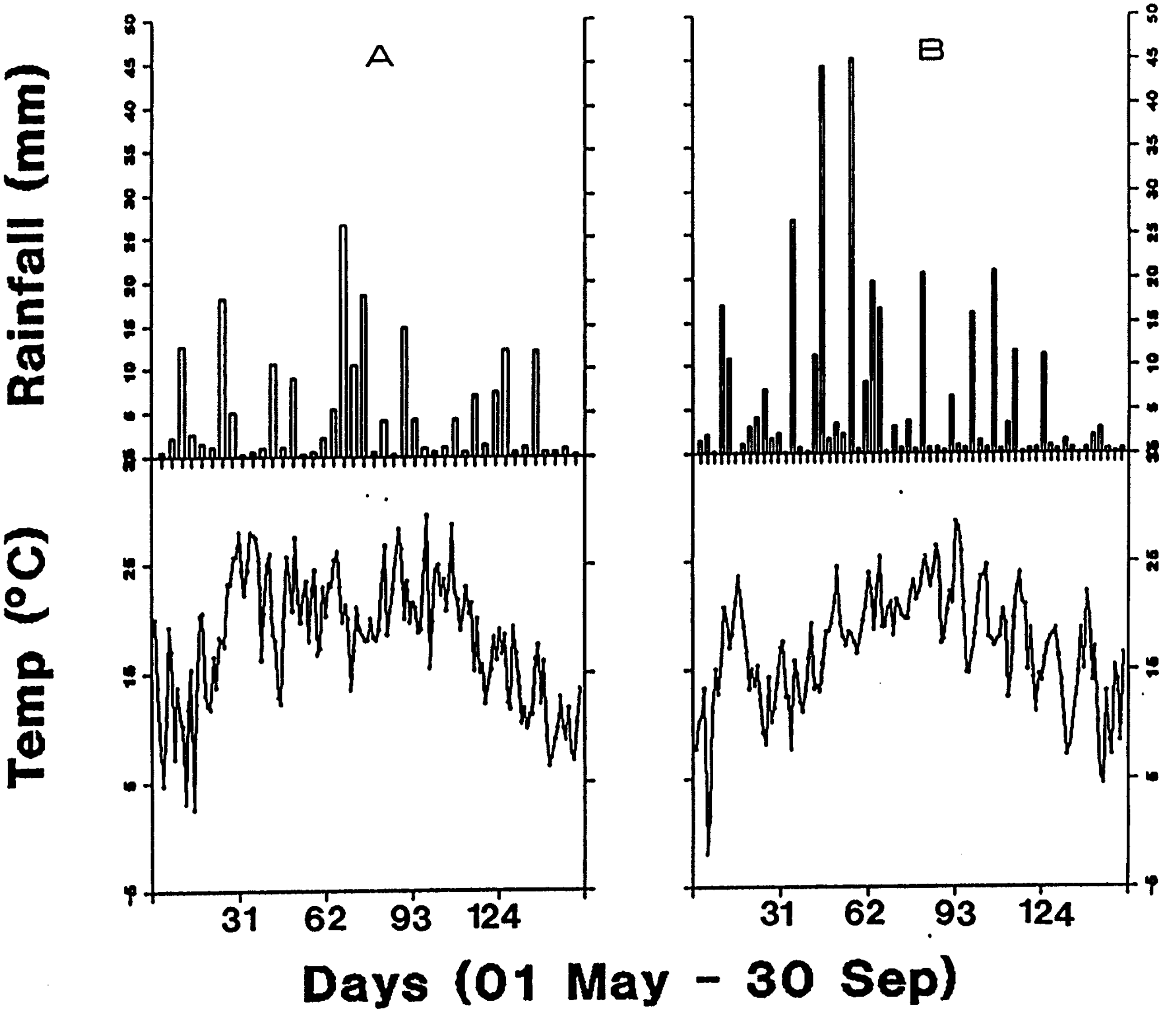

A
B
Mean number (±SE)
0
100
200
300
400
500
600
700
800
18·7
22·8
25·8
29·4
32·7
18·9
22·4
26·7
30·1
TEMPERATURE (°C)

highly correlated with temperature (Berry _et al_. 1986).

4.2.6 _Weather Parameters_. The lateness of the first appearance of the flies in traps was attributed to the low May 1989 temperatures (Fig. 10). While mean temperatures in May 1988 were generally above the freezing point, mean temperatures in the first week of May 1989 were between 0°C and -3°C, however a rapid increase in temperature occurred following this reaching 24°C by late May. An intense heat wave occurred in May 1988 causing well-above average temperatures for this month while May 1989 was only 2.4 degrees warmer than average, according to Environment Canada weather data. The mean temperature was 21.9°C for June 1988 and was 16.5°C for June 1989. June 1988 had very little precipitation (24.6 mm); 184 mm of rainfall was received in June 1989 versus the average of 80.1 mm for June. Temperatures for July were near the average for both years (21.6°C) while rainfall was slightly above average in 1988 (85 mm) and well-below average in 1989 (37.7 mm). Temperatures were generally above average in August for both years while precipitation was only 15 mm in 1988 and 67.8 mm in 1989 (the average amount is 75.2 mm for August). Finally, in September 1988 temperatures were near the average and above average in 1989, while 34.9 mm of precipitation was received in 1988 and only 8.6 mm in 1989.

The normal prevailing wind direction for the period in

Figure 10. Precipitation and mean temperatures (from maximum and minimum for 24 hours) recorded for the time period 1 May to 30 September, A- 1988, B- 1989 at Glenlea. (<u>SOURCE</u>: Glenlea Research Station).

A
B
Rainfall (mm)
Temp (°C)
0
5
10
15
20
25
30
35
40
45
50
-5
5
15
25
31
62
93
124
Days (01 May - 30 Sep)

which the study was carried out was southerly. Using the information on daily prevailing wind directions obtained from the Winnipeg International Airport (Appendix E), one could explain the abundance of stable flies at the pasture. Flies dispersed from the animal confinement site to procure blood meals from the beef cattle kept at the pasture; this is supported by the prevailing wind direction which was ESE on 22 June and was SE on 23 June, resulting in a total catch of 367 flies on the six traps at the pasture on 24 June. The winds were predominantly south-easterly during most of the following week. However on 30 June, the winds were southerly and would not have helped to attract stable flies to the pasture. This probably contributed to the low number of flies captured (144) on 1 July. During the two days preceding peak abundance at the pasture, the winds were predominantly easterly (E on 27 July and SE on 28 July). Wind directions were predominantly westerly during the week following 21 June, 1989 and mean temperatures were also low (Fig. 10). This may have caused the numbers of flies collected from the pasture to decrease (from 765 on 21 June to 125 on 28 June).

CHAPTER V

Discussion

Seasonal abundance. Stomoxys calcitrans infestations occurred from May to October in southern Manitoba. The seasonal abundance observed in this study is similar to the stable fly population trends that occur in South America and the western part of the U.S. in that the populations attained seasonal peak abundance in summer (Petersen and Greene 1989). The duration of the stable fly season in southern Manitoba is slightly shorter than in the U.S., probably due to the shorter summer season here. For example, in eastern Nebraska, the fly season lasts from late March to late November (Scholl et al. 1986). There was a single peak abundance in June and July, depending on the spring weather conditions, particularly temperature and precipitation (Figs. 3, 6 and 10). Peak stable fly populations in southern Manitoba were similar to those of central U.S. such as in Missouri (Hall et al. 1983), Nebraska (McNeal and Campbell 1981; Scholl 1986) and Iowa (Dahm and Raun 1955), except that a second peak abundance occurs in Nebraska in early September (Stage and Petersen 1981).

Thomas et al. (1989) reported a seasonal abundance pattern very similar to the one reported in this study in their study in southwest Nebraska. Peak abundance occurred during the last week in June to the second week in July. It is interesting that unlike in eastern Nebraska, no second peak abundance was observed in autumn in the southwest region of Nebraska (Thomas _et_ _al_. 1989). Even though a double-peak seasonal abundance occurs in some U.S. states, for example, California, east Nebraska, the autumn peak is inconsistent and is dependent on moisture availablity (Mullens and Meyer 1987). Even if the moisture conditions were favourable in Manitoba, temperatures would still be the major cause of the suppression in stable fly numbers in late summer.

Populations fluctuated throughout the sampling period (June-September). The numbers were particularly high in July as temperatures and moisture content of the breeding sites increased, providing almost ideal breeding conditions. Although the breeding conditions were not tested in this study, similar observations in September (late summer) were reported by Kunz and Monty (1976) in Mauritius. Scholl (1986) found large numbers of flies in Nebraska during mid-summer. It was assumed that the rate of immigration was equal to emigration and any increase in numbers represented a real increase in the population.

The stable fly numbers decreased substantially in

August 1988, even though temperatures remained high, probably because of the lack of moisture in the breeding grounds. Temperatures declined sharply in September 1988 and the stable fly numbers became even lower, especially at the pasture. Since the pasture was on an open site the flies were exposed more to wind and cold conditions which resulted in a sharp decline in numbers of flies compared to the animal confinement site which was surrounded by a dense bush and trees as well as buildings.

The population fluctuations between the animal confinement site and pasture were not identical in the two years of this study. In the 1988 season, the populations at the animal confinement were 7.5-fold greater than pasture populations and in 1989 the animal confinement populations were 2.1-fold greater than the pasture populations. The higher populations in 1989 at the pasture were attributed partly to the amount of precipitation received compared to the previous year. They were also attributed to changes in animal management. The cattle were fed silage in addition to pasture grass, and hence they spent most of the time closer to the traps, resulting in higher numbers of flies captured on average than in 1988. In 1989, no beef cattle were kept in the barn and all beef cattle were held at the pasture. This also contributed in increasing relative numbers of stable flies. It has been established that stable fly abundance at a location reflects host activity and abundance, and availability of oviposition sites (Gersabeck and Merritt 1983).

The differences in abundance between the two sites supported the hypothesis that pasture populations comprised mainly dispersers from the animal confinement area and/or the nearby dairy farm. Flies dispersed to the pasture, probably to procure blood meals from the cattle kept in the pasture, as populations increased. Such "spill-over" populations are not expected to be equal to the animal confinement site populations which are assumed to be source populations. Hall _et_ _al_. (1983), observed that in a year with above-average rainfall, pasture populations of flies were higher than during a dry year. Stable fly breeding sites were also found in large round hay bales (Hall _et_ _al_. 1982). Unlike in the studies referred to here, no breeding sites were found at the pasture, even in 1989 in this study. On the other hand, several breeding sites were located in both years at the animal confinement site, particularly along fences, below waterers and feed bunkers - typical to sites reported as preferred oviposition sites of the flies (Williams _et_ _al_. 1980; Scholl _et_ _al_. 1981).

The wind direction data from the Winnipeg International Airport also supported the dispersal hypothesis (Appendix E) in that the prevailing wind directions were easterly on most days when large numbers of flies were collected at the pasture. It was observed that the wind speeds were greater than the air speed of the flies (5-8 km/h) (Petersen and Greene 1989). The flies may have been carried by wind towards the pasture in an easterly direction. Air movement patterns may also be important since air is assumed to contain odours to which flies may respond (Lewis 1971). Provided the wind speed does not exceed the air speed of the flies, the flies will be attracted to potential hosts by the hosts' odours. In this case the flies would be attracted to the pastured cattle when the winds were westerly.

A similar observation was made by Gersabeck and Merrit (1985) in Mackinac Island in which gross wind directions were assumed to be related to air movement patterns at the microhabitat scale. Activity patterns of the flies were determined by host density and movement.

The observation that peak densities in the two sites did not coincide in both years lends further support to the dispersal hypothesis. It was interesting that peak abundance in the pasture occurred during the same week in both years (29 July in 1988 and 26 July in 1989). Even though there was a shift in the occurrence of the highest numbers of flies that were collected per day at the animal confinement site (28 June in 1988 and 28 July in 1989), the overall seasonal peak abundances in both sites were similar in both years. There was an apparent suppression in stable fly numbers during June 1989, probably as a result of low mean temperatures and heavy rainfall. Heavy rainfall may have flooded breeding grounds, thus increasing the mortality rate of immature flies. Kunz and Monty (1976) observed that during the summer in Mauritius, when breeding grounds were flooded with water, S. calcitrans development was suppressed, and increased only when the sites became drier. One may also postulate that low temperatures in the spring of 1989 might have delayed the onset of reproduction of stable flies in the spring, resulting in low fly numbers in June 1989. This is evident in the low numbers of newly emerged females in the initial weeks of sampling (Figs. 5-8).

Effectiveness of the Williams traps in Manitoba. Williams sticky traps were used to assess adult stable fly activity patterns in Glenlea. The traps have been used by other workers to study stable fly populations in various location, e.g. Gersabeck and Merritt (1983) used the traps in Michigan. One advantage of the Williams sticky traps is that they provide a standardized technique which can be applied in different geographical regions and the results may be compared. The traps also take advantage of the thermoregulation behaviour of the flies. Sunspotting on sunlit leks, common in calypterate Diptera, has been observed in the stable fly and is associated with both mating and basking (Downes 1969; Parker 1978; Buschman and Patterson 1981). The Williams traps yielded reasonably good data in the two years of sampling to enable the study of seasonal and daily activity patterns of the stable flies at Glenlea, southern Manitoba. The working principle of the trap was that Alsynite fibre glass reflects light of wavelength 360-421 nm, which correlates with the sensitivities of the compound eyes of the stable fly (Agee and Patterson 1983). Williams (1973) reported that the traps were more than seven times as effective as box traps in capturing stable flies. Many researchers have used modified Williams sticky traps. For example the panels may be covered with plastic sleeves on which the adhesive is applied, or the size of the panels may be increased or decreased. Different adhesives may also be used to catch flies that land on the panels. Plastic-covered panels were less efficient than a direct application of Tanglefoot on the panels, and as a result Tanglefoot was applied directly on the panels.

In spite of the popularity of the Williams traps in stable fly studies, no one has reported how efficient the traps are in catching flies that land on the panels. The system used in this study was less than 40% efficient. This may be attributed to the weakness of the resin used in

Tanglefoot. In a preliminary laboratory investigation it was found that three parts Tanglefoot to one part ethanol by weight was the optimum thinning level of Tanglefoot that would catch flies that land on a panel.

The Williams traps also required high-level maintenance such as cleaning because the attractiveness of the traps decreased as flies and other insects, dust and debris accumulated on the panels (Agee and Patterson 1983; Tseng *et al*. 1986). Another drawback was that the adhesive had to be applied on all eight faces and hence the traps were cumbersome (Broce 1988). Using screws and washers made the panels more rigid against the wind so that the problems with wind were minimal. Like in the study by Scholl *et al*. (1985), directional preferences by stable flies in landing on the panels were not detected. Williams (1973), however, reported that 68% of the flies were captured on the leeward side, and Broce (1988), observed that most of the flies were collected from the sides protected from wind.

Instantaneous fly counts. There was a single peak in front leg counts of stable flies on beef cattle, and the greatest average stable fly count per week coincided with peak trap catches in 1988. The number of animals on which stable fly counts were taken was inconsistent throughout the sampling period, since some of the cattle were taken out to the pasture following 28 June. This may have affected the number of flies since there were fewer hosts in the barn. It has been reported that the number of flies per animal is usually higher when the animal is in isolation than the average number of flies per animal in a herd (Mullens and Meyer 1987). For this reason, it appeared that the number of flies feeding on the cattle remained unduly high following removal of most cattle from the barn, since flies aggregated on the few cattle that remained. This claim is further supported by the finding made by Thomas et al. (1989), who observed that a stanchioned calf had >4-fold the number of stable flies than the herd average count on 20 cattle. Stable flies exceeded the control threshold level (Petersen and Greene 1989) of five flies/leg from 21 June through 16 August. Assuming that the same threshold of five flies per leg warrants application of chemical control in Manitoba, the months of June, July and the first half of August in a year with similar conditions to 1988, would require application of control measures against stable flies. No stable fly counts were taken on beef cattle at the pasture. However, stable flies were seen in large numbers on cattle legs, and there were obvious signs of irritation such as tail flicks, foot stamping, scratching against the fence and wallowing in mud.

Resting site counts of stable flies were also used to provide an index of fly abundance. Relative numbers of flies at resting sites were similar to those in sticky traps in 1988. The highest number of flies per square metre was observed on the same day as peak abundance in trap collections. However, in 1989 these two methods of sampling were not highly correlated. Correlation analysis was used to compare the three methods of sampling. The correlation coefficient, r, of resting site counts versus leg counts was 0.6. Trap catches versus leg counts had a higher correlation of r=0.7. The correlation coefficient of trap catches versus resting site counts (r=0.7 in 1988) and was 0.2 in 1989. The reason why the correlation coefficient between trap catches and resting site counts was low in 1989 was attributed to the generally low mean air temperatures compared to 1988. The numbers of flies encountered on the walls were generally low throughout the 1989 season (Table 2). Two of the marked areas on which resting sites counts of stable flies were taken were on east-facing walls, which were shaded during the afternoon. No flies were observed on these walls in afternoon hours in 1989 while flies were observed in 1988, when high air temperatures forced flies to stay in the shade.

The advantages of resting site and visual counts of flies on cattle legs were that they were quick and easy to do; cattle leg counts provided a direct indication of annoyance caused by the stable flies on cattle. Cattle leg counts of flies are also more convenient than whole body counts. It has been established that the ratio of stable flies per animal to stable flies per front leg is 2.81 (Berry et al. 1983). The usefulness of these techniques might be in making treatment decisions. When more than the threshold level of flies per leg are found on cattle legs, then treatment would be needed. The drawbacks of leg counts are that when the animals stand in mud, or in manure in the barn, it is not easy to see the flies on the legs. Unruly cattle do not keep still, and the similarity of stable flies and house flies, particularly when observation is done with an unaided eye, are also a problem. Among drawbacks associated with resting site counts is that these counts may be greatly influenced by proximity to animal hosts and decreased by lack of shade on hot days and conversely, the availability of shade on a cool day (Kunz and Monty 1976; Buschman and Patterson 1981; Petersen and Greene 1989).

Sex ratios. Males appeared to predominate in traps and sweep net samples in the animal confinement site. This observation was consistent with previous observations made in the U.S. by Buschman and Patterson (1981). Females apparently shun prominent spots such as light coloured-walls or traps, and also, males use such sites as waiting stations for mating and basking. Gravid females may spend most of the time searching for oviposition sites. The male/female ratio increased with the season with a slight lag following density increases in trap collections (Table 5). Once the females are inseminated, they avoid male harassment on traps and other prominent objects, and thus more males will be encountered in those sites (Harris _et_ _al_. 1966; Buschman and Patterson 1981). The male/female ratios were slightly lower in pasture trap samples compared to animal confinement samples and there was no clear increase as the season progressed. Pasture populations may have consisted of dispersing flies. As in other migrant insect populations, dispersers are usually predominantly females (Johnson 1966; Hogsette and Ruff 1985). The observed overall average sex ratios (Table 5) were close to ratios observed by other workers; for example, 60:40 (M:F) sex ratio was reported on traps by Buschman and Patterson (1981). Scholl _et_ _al_. (1985) reported a sex ratio of 50:45 (M:F).

Sex ratios were also dependent on the sampling technique (Table 5). The randomness with which traps sampled the flies might have been better than that of the sweep net, because traps were located on the same site throughout sampling. Sweep netting sites were determined by the presence or absence of flies on the perching sites. If this is true, one may assume that traps provided a true picture of how Williams traps are biased in favour of males. The male/female sex ratio of sweep net-collected samples was close to 50:50 most of the time. It is speculated that males probably flew away fast enough that they were not caught as readily in the net as females and the males were not well-represented in net collections. There is need to verify this speculation as there are no published data to support it.

Parity rates of female stable flies. The age structure of some insect populations can be described by physiological age-grouping of its female component. Although newly emerged flies are an indication of recruitment of a new cohort to the population, in this study, the proportion of newly emerged female stable flies was assumed to indicate changes in population density (Scholl 1986). This approach was chosen in view of the generation overlap in the stable fly populations. At any time during sampling, it was observed that the flies consisted of females in all developmental stages. Stable flies start to oviposit at the age of 7-10 days under summer conditions and the adult lives for 2-3 weeks (Killough and McKinstry 1965). The length of time required for immature stable flies to develop to the adult stage is also shortened as temperatures are higher in summer. This results in shorter generation times. The newly emerged and nulliparous proportions in trap collections on the whole were over 50% throughout the sampling period. There may have been a general bias in favour of younger flies as discussed above. That females that were ovipositing were generally not available on the traps is shown by the small number of gravid flies that were collected in traps. Less than 10% of trapped fies in both years of sampling were gravid. Scholl _et_ _al_. (1985) reported that only _ca_. 11% of 434 females collected from sticky traps had partially or fully developed ova.

Biases may be due to the sampling techniques. A paired t-test was carried out to compare trap-collected and sweep net-collected samples with respect to both newly emerged and nulliparous proportions. The two methods were not significantly different at the 5% level of significance. It was assumed that the two methods sampled similar proportions of nulliparous females and that this was representative of the whole population.

It was difficult to distinguish between uniparous and biparous flies, so the only categories that were used were newly emerged, nulliparous and parous. This problem was also encoutered by other workers. For example, Sutherland (1980b) reported that as a result of the accumulation of follicular relics in the calyces, it was impossible to identify individual relics and hence to distinguish between a uniparous and biparous individual. Follicular relics in ovarioles of a uniparous fly may not be identified easily. Scholl (1980) applied a dye which was absorbed by the follicular relics. Another difficulty was in assigning gravid individuals to any of the categories because the ovaries of gravid flies usually break up when the abdomen is dissected (Anderson 1964). All gravid females were discarded in this study.

The sample size of dissected flies was increased from 15 to 30 in 1989. However, no difference in the results which could be attributed to the larger sample size could be detected. Apparently, the generation overlap factor was dominant both years. In view of the results, it would be recommended to keep the sample size at 15 females per sample. There were no newly emerged females at the beginning of sampling, but this increased to 100% per sample as the season progressed. The samples of flies that were collected from the pasture yielded a rather high parous proportion which may be indicative of a higher survival rate or that the flies collected from the pasture disperse from somewhere else and thus are older compared to animal confinement samples (Scholl 1986). However, the age differences may not be detectable since a fly oviposits once in two days (Skidmore 1985). There seemed to be irregular trends in the parity status of the pasture samples compared to animal confinement collections. This would appear to be a further indication that the flies may not have been breeding in the pasture but dispersed from somewhere else.

Daily activity patterns. Strong diurnal variations were observed in both years and sites of trapping. Daily activity was usually unimodal. Catches at the animal confinement peaked in the morning between 0700-1100 hrs during the first weeks of trapping. A distinct shift of peak activity to the afternoon after July occurred, when temperatures increased to 20°C and above only in the afternoon. This pattern was not so clear in the pasture mainly because the numbers of flies were very low, probably due to movement of animals on pasture and proximity to traps in 1988. However, in 1989, peak activity was reached between 0700-1500 hrs and was irregular. This may reflect the differences due to the location of the pasture and the animal confinement site. While the animal confinement was surrounded by trees and a buildings, the pasture was on an open site. Temperature on a microclimatic scale would rise more slowly at the pasture compared to the animal confinement. In the 1989 season, when hourly temperatures were recorded concurrently with trapping, temperature appeared to be a major factor affecting daily activity patterns of the flies. Berry and Campbell (1985) noted that temperature played a dominant role in affecting daily feeding patterns of stable flies in eastern Nebraska. In this study, the maximum activity as indicated in trap catches in 1989, occurred at temperatures between 20°C and

31°C. This was in the range reported by other workers. For example, Gersabeck and Merritt (1983) reported that fly activity was at its the peak level at temperatures between 21 and 32°C. It is often difficult to correlate insect activities with environmental factors, particularly when the factors are studied in isolation from the others. Berry et al. (1986) reported that temperature and relative humidity affected the flies' feeding on animals and attraction to Williams traps. Solar radiation also increased trap collections by 23% in Nebraska (Berry et al. 1986). Although peak activity appeared to shift with season, the main cause for the shift appeared to be air temperature, since mean air temperatures rose from spring through summer. A comparison between Appendices A-D and Fig. 9 supports this contention. Sampling was discontinued after 16 September, 1988 because temperatures were very low and no stable flies were caught in the traps on that day, while in the same week in 1989 temperatures were still higher than 18°C and about 200 flies were collected from pasture traps.

CHAPTER VI

Conclusions

1) There was some strong indication that stable fly populations in southern Manitoba exhibited single seasonal abundance peaks during June and/or July, depending on the temperature and rainfall patterns during the spring.

2) There was circumstantial evidence that occurrence of extreme weather conditions, including high or low temperatures, too much or lack of rainfall were perhaps responsible for low stable fly numbers in June 1989 and August and September 1989.

3) Williams traps, in this study, were less than 40% effective in capturing stable flies that landed on the panels.

4) Instantaneous stable fly counts on cattle legs and resting sites do not necessarily correlate with sticky trap catches. However, these methods may be applied to supplement trap data. The number of stable flies counted on cattle legs during 1988 exceeded the published economic threshold of five flies per leg in June, July and the first half of August, 1988. In a year with similar conditions to 1988, application of control measures would be recommended in southern Manitoba.

5) Temporal variations were observed throughout this study where males outnumbered females in trap catches but peak catches of both sexes coincided. These sexual differences are not of any significance in as far as the pest problem of stable flies is concerned. However, in an ecological study, temporal variations may be very important.

6) Changes in the parity status of female flies and the seasonal abundance variations, and the use of newly emerged proportions provided a good indication of influxes of new cohorts of flies in the populations.

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APPENDIX A. Daily activity of stable flies (per six Williams traps) at the animal confinement site, Glenlea, Manitoba, for selected dates in 1988. Figures are expressed as percentages of daily totals (No. of flies in parentheses).

Date	0700-0900	0900-1100	1100-1300	1300-1500	1500-1600[1]	Total catch
14 June	10.0 (3)	23.3 (7)	16.7 (5)	33.3 (10)	16.7 (5)	30
21 June	82.0 (1225)	8.8 (131)	3.0 (45)	3.9 (58)	2.3 (34)	1493
28 June	36.6 (3024)	29.4 (2430)	7.9 (649)	12.7 (1049)	13.4 (1111)	8263
30 June	4.0 (83)	29.0 (601)	42.4 (879)	24.7 (512)	-[2]	2075
05 July	29.1 (1184)	51.6 (2100)	4.4 (177)	10.4 (423)	4.5 (182)	4066
12 July	21.5 (832)	43.1 (1671)	20.9 (808)	9.0 (349)	5.5 (213)	3873
19 July	35.7 (1237)	35.7 (1236)	26.0 (901)	2.6 (89)	0.1 (3)	3466
26 July	78.5 (2226)	13.9 (394)	4.6 (131)	1.9 (55)	1.0 (28)	2834
02 August	33.4 (1123)	36.2 (1215)	13.7 (459)	8.6 (290)	8.1 (273)	3360
09 August	43.7 (796)	29.7 (540)	14.9 (272)	6.0 (110)	5.6 (102)	1820
16 August	22.0 (163)	37.3 (277)	21.3 (158)	12.7 (94)	6.7 (50)	742
Overall %[3]	31.1	33.1	14.0	9.5	6.2	32022

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[1] Trapping interval of one hour.

[2] No trapping was carried out.

[3] Refers to contribution of each time interval to seasonal total.

APPENDIX B. Daily activity of stable flies (per six Williams traps) at the pasture, Glenlea, Manitoba, for selected dates in 1988. Figures are expressed as percentages of dasily totals (No. of flies in parentheses).

Date	0700-0900	0900-1100	1100-1300	1300-1500	1500-1600[1]	Total catch
17 June	4.4 (4)	15.4 (14)	15.4 (14)	40.7 (37)	24.2 (22)	91
24 June	21.2 (78)	24.5 (90)	25.6 (94)	20.2 (74)	8.4 (31)	367
01 July	27.1 (39)	36.8 (53)	19.4 (28)	9.0 (13)	7.6 (11)	144
08 July	22.5 (85)	14.1 (53)	12.7 (48)	25.2 (95)	25.5 (96)	377
15 July	26.0 (56)	6.5 (14)	8.4 (18)	32.6 (70)	26.5 (57)	215
23 July	53.1 (295)	20.7 (115)	10.4 (58)	9.7 (54)	6.1 (34)	556
29 July	9.7 (95)	26.9 (265)	14.7 (145)	26.8 (264)	21.8 (215)	984
05 August	36.1 (323)	22.1 (198)	11.1 (99)	17.4 (156)	13.2 (118)	894
13 August	20.5 (43)	28.6 (60)	17.1 (36)	17.6 (37)	16.2 (34)	210
Overall %[2]	26.5	22.5	14.1	20.8	16.1	

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[1] Trapping interval of one hour.

[2] Refers to contribution of each time interval to seasonal total.

APPENDIX C. Daily activity of stable flies (per six Williams traps) at the animal confinement site, Glenlea, Manitoba, for selected dates in 1989. Figures are expressed as percentages of daily totals (No. of flies in parenthses).

Date	0700-0900	0900-1100	1100-1300	1300-1500	1500-1600[1]	Total catch
16 June	20.0 (4)	10.0 (2)	10.0 (2)	30.0 (6)	30.0 (6)	20
23 June	-[2]	1.6 (5)	16.6 (52)	52.2 (164)	29.6 (93)	314
30 June	43.0 (37)	29.1 (25)	20.9 (18)	7.0 (6)	-	86
07 July	9.2 (89)	19.1 (185)	24.5 (238)	26.2 (254)	21.0 (204)	970
14 July	9.5 (165)	32.9 (569)	21.7 (376)	19.6 (339)	16.3 (283)	1732
21 July	55.6 (1861)	24.8 (830)	10.0 (334)	6.2 (208)	3.4 (113)	3346
04 August	31.2 (1128)	23.9 (866)	14.6 (527)	14.4 (521)	16.0 (579)	3621
11 August	59.4 (114)	17.2 (33)	10.9 (21)	6.3 (12)	6.3 (12)	192
Overall %[3]	33.0	24.5	15.3	14.7	12.5	

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[1] Trapping interval of one hour.

[2] No trapping was carried out.

[3] Refers to contribution of each time interval to the seasonal total.

APPENDIX D. Daily activity of stable flies (per six Williams traps) at the pasture, Glenlea, Manitoba, for selected dates in 1989. Figures are expressed as percentages of daily totals (No. of flies in parentheses).

Date	0700-0900	0900-1100	1100-1300	1300-1500	1500-1600[1]	Total catch
21 June	4.7 (36)	12.8 (98)	23.8 (182)	37.4 (286)	21.3 (163)	765
28 June	6.4 (8)	60.0 (75)	8.8 (11)	16.8 (21)	8.0 (10)	125
08 July	4.8 (14)	20.4 (60)	32.7 (96)	23.1 (68)	19.0 (56)	294
12 July	7.8 (160)	26.1 (539)	30.6 (632)	10.0 (207)	25.4 (525)	2063
19 July	42.9 (859)	18.3 (366)	11.9 (239)	16.9 (339)	9.9 (198)	2001
26 July	33.1 (1198)	35.1 (1270)	18.8 (679)	8.5 (309)	4.5 (163)	3619
02 August	45.8 (814)	9.8 (175)	17.4 (309)	15.2 (270)	11.8 (210)	1778
09 August	15.2 (65)	31.1 (133)	24.1 (103)	20.8 (89)	8.7 (37)	427
Overall %[2]	28.5	24.5	20.3	14.4	12.3	11072

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[1] Trapping interval of one hour.

[2] Refers to contribution of each time interval to seasonal total.

APPENDIX E. Prevailing wind directions for the months of June, July, August and September, 1988 and 1989. (<u>SOURCE</u>: Winnipeg International Airport).

Day	June		July		August		September	
	1988	1989	1988	1989	1988	1989	1988	1989
1	S	WSW	SSW	S	E	S	W	NNW
2	NW	N	SW	WNW	ESE	S	N	SE
3	NW	WSW	SSW	W	W	W	NNW	S
4	S	S	NE	CALM	W	N	N	WNW
5	S	N	SE	NE	S	W	NNW	SW
6	S	E	ESE	NNW	S	NNW	S	S
7	S	NE	W	S	W	NW	S	SW
8	E	N	WSW	S	W	WNW	W	W
9	S	CALM	NNW	NNW	S	SSW	W	NW
10	S	S	N	N	S	S	E	NNE
11	S	SE	ESE	E	N	S	NE	ENE
12	N	ENE	SSE	N	NE	S	NW	W
13	NNE	NE	W	N	NE	N	NW	SSW
14	N	NNE	S	NW	WNW	N	SSW	S
15	NNE	S	WNW	WNW	S	CALM	SSE	SSW
16	S	S	SSW	SSW	E	SSE	SE	NNW
17	S	S	W	SSW	NNE	SSE	S	S
18	S	WSW	WNW	N	E	S	N	S
19	NW	S	W	WNW	SSE	NNW	N	NNW
20	S	SSE	NNW	SW	ESE	NNW	N	S

APPENDIX E (CONT).

Day	June		July		August		September	
	1988	1989	1988	1989	1988	1989	1988	1989
21	N	N	SSE	S	SE	S	SSE	N
22	ENE	NW	S	S	WSW	SSE	W	NNW
23	SE	CALM	S	S	WNW	SSE	WSW	S
24	WNW	S	NW	S	W	SSE	wSE	S
25	NNW	CALM	S	S	WNW	S	WNW	NNW
26	CALM	W	WNW	N	W	W	NNW	S
27	SSE	W	E	NNW	NW	WSW	E	S
28	ESE	ESE	SE	SSE	NW	SE	SE	W
29	SE	E	NW	SSE	WNW	NW	SSW	SSE
30	S	WNW	S	NW	SSE	SSE	S	S
31			NW	S	SSE	NNE		
Mean	S	S	S	S	W	S	N	S
Normal	S	S	S	S	S	S	S	S