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SEASONAL ABUNDANCE, PHYSIOLOGICAL AGE, AND DAILY ACTIVITY OF HOST-SEEKING HORSE FLIES (DIPTERA: TABANIDAE) AT SEVEN SISTERS, MANITOBA, WITH AN EVALUATION OF PERMETHRIN SPRAY TREATMENTS AS A MEANS OF INCREASING THE PERFORMANCE OF GROWING BEEF HEIFERS SUBJECT TO HORSE FLY ATTACK.

by

Paul Edward Kaye McElligott, B.Sc.

A thesis
presented to the
University of Manitoba
in partial fulfillment of the
requirements for the degree of
Master of Science

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ABSTRACT

Effects of biweekly permethrin treatments on the weight gain performance of growing beef heifers subject to attack by large numbers of blood-feeding tabanids was evaluated. In 1987 and 1988 respectively, groups of 55 and 72 heifers (of similar age and weight) were divided into two herds. Animals in one herd received biweekly whole-body sprays of permethrin (aqueous emulsion, 0.5% permethrin, applied at 1 L/animal), while the other herd was left untreated. Animals in both herds were weighed biweekly and those in one herd were treated concomitantly from early June through mid July. Permethrin spray treatments did not effectively reduce the impact of horse flies on the animals' weight gains. No consistent trend was apparent in differences between the average daily weight gains of animals in untreated and treated herds, and animals in both herds gained, on average, from 35.38 to 44.82 kg over the 6-week experimental period in both years.

Tabanids were trapped from dawn until dusk using four Manitoba Horse Fly Traps (MHFT's) at Seven Sisters, from mid May until mid July in 1987, and from mid May until mid August in 1988, to determine the seasonal activity patterns of the various species present. Thirty one tabanid species in four genera (<u>Hybomitra</u> (15 spp.), <u>Tabanus</u> (4 spp.),

Chrysops (11 spp.), Haematopota (1 sp.)), of which ten Hybomitra spp. were abundant, were present in MHFT catches. Hybomitra lurida (Fallen), and H. nitidifrons nuda (McDunnough) peaked in abundance in late May to early June; H. illota (Osten Sacken) and H. lasiophthalma (Macquart) in early June; H. affinis (Kirby), H. arpadi (Szilady), and H. zonalis (Kirby) in mid June; and H. epistates (O.S.) and H. pechumani Teskey & Thomas in late June to early August. Hybomitra trepida (McD.) peaked in abundance twice, in late June and early August. Tabanid density and diversity was greatest during June, and few flies were present at the site after mid July.

Subsamples (10-30 flies) of daily trap catches were dissected to determine seasonal changes in the per cent parity of ten abundant Hybomitra species. At the beginning of the flight season, 80 to 100% of flies dissected were nulliparous. As the flight season progressed, however, an increasing proportion of flies captured were parous. After approximately one month of flight activity, parity in all but three species reached levels approaching 100%, and remained high thereafter. Hybomitra lurida and H. nitidifrons nuda were 100% parous within two weeks of their first appearance in trap catches, and parity of H. trepida increased to 100% after four weeks, declined to 40% two weeks later, and rose again to 100% after a further 2 weeks.

Hourly trapping was carried out between 0530 hr and 2230 hr for four days weekly throughout the summers of 1987 and 1988, to determine the patterns of daily activity of nine tabanid species at Seven Sisters. One MHFT was used in 1987; four traps in 1988. Temperature and light intensity were recorded at hourly intervals in 1988 only. Hybomitra epistates and H. pechumani were most active during late morning or midday; H. arpadi and H. zonalis in early afternoon; H. affinis, H. illota, and H. lasiophthalma in late afternoon; and H. nitidifrons nuda and H. lurida in early evening. The morning onset of tabanid flight activity was usually temperature related, while the cessation of flight activity in the evening was either temperature or light related, depending on whether temperature or light intensity was first to fall below threshold levels. Tabanid flight activity was generally low at temperatures below 20° C, although H. lasiophthalma and H. affinis were caught at temperatures as low as 12° C. Little flight activity occurred at light intensity levels below 1000 lux. At Churchill, Manitoba, where hourly trapping was carried out in 1988, tabanid (H. affinis and H. frontalis (Walker)) activity was low below 14° C, although limited activity occurred down to 6° C.

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FOREWARD

This thesis is written in manuscript format. As a result, some of the material presented in the Literature Review at the beginning of the thesis is repeated in the Introduction and Discussion sections of later chapters. The repeated description of the study area in each chapter may also seem redundant. If you, the reader, are interested in a broad overview of the literature related to this thesis, you will find it in the Literature Review. If your interest lies more in the specific research area discussed in one or more of the chapters, you are advised to skip over the Literature Review section and proceed directly to the chapter(s).

GENERAL INTRODUCTION

In the southeastern (s.e.) region of Manitoba, the boreal forest of northern Canada extends southward to the U.S. border and beyond. The part of this forest which lies adjacent to aspen parkland could, if cleared, provide excellent livestock pasture. In those areas which have been cleared for this purpose, however, large numbers of horse flies relentlessly harass pastured livestock throughout the summer months. These insects represent a serious deterrent to livestock production in s.e. Manitoba, since there are no methods currently recommended here for tabanid control (Manitoba Insect Control Guide, 1989).

Since 1979, Dr. Terry Galloway and his students in the Department of Entomology at the University of Manitoba have been studying the tabanid problem in s.e. Manitoba. Much of this work has been carried out at the Seven Sisters, Eastern Grassland Society Project, a Manitoba Agriculture pasture demonstration area which is plagued by very large numbers of horse flies annually from June until August. In particular, experiments have been conducted evaluating the application of contact insecticides to cattle as a means of tabanid control (Ralley 1986, Galloway, unpubl.) and examining the impact of horse flies on livestock behaviour (Ralley 1986). This present work represents the most recent step in procuring an overall picture of the biology, impact, and potential for control of horse flies at Seven Sisters.

My research on tabanids comprised three distinct areas of study:

1) an evaluation of spray applications of permethrin (a synthetic pyrethroid insecticide) as a means of improving the weight gains of cattle under intense tabanid attack,

2) an examination of patterns of seasonal abundance of those horse fly species common at the Grassland Project, and a description of seasonal changes in the physiological age structure of the populations of different species, and finally,

3) an examination of the daily activity patterns of the common tabanid species, and the effects of temperature and light intensity on the onset and cessation of each species' daily host-seeking activity. As a supplement to this last study, trapping was also conducted at Churchill, in northern Manitoba, to compare the activity of flies at Seven Sisters with conspecifics in the northern part of their range.

LITERATURE REVIEW

Forty eight species of horse and deer flies (Diptera: Tabanidae) are known to occur in Manitoba (Teskey, unpubl.). Females of all of these species feed upon the blood of warm-blooded animals at some point during their adult lives (Pechuman 1981, Pechuman et al. 1961, 1983), and the importance of horse and deer flies as pests stems from this blood-feeding habit. Biting tabanids can cause considerable nuisance to humans (Miller 1951, Hocking 1952, Hansens 1980a), and severely harass wild and domestic animals (Morgan 1987, Clark et al. 1976, Steelman 1976). In addition, tabanids vector a number of different pathogens among animals (Krinsky 1976, Foil 1989).

Impact of Tabanids on Livestock Production:

There are no published estimates of the impact of tabanids on livestock production in Manitoba, although enormous numbers of these flies can be observed circling and biting cattle here during early summer. Elsewhere in North America and in Europe, the impact of tabanid attack on livestock production has been estimated by several different techniques.

One method has been to estimate the amount of blood lost per animal per day to feeding tabanids (Clark et al.

1976, Hollander and Wright 1980, Miller 1951, Tashiro and Schwardt 1949, 1953). By this method, it has been estimated that individual cattle may lose up to 352 cc of blood per day to horse flies (Tashiro and Schwardt 1953), although estimates vary considerably among studies and tabanid species considered (Hansens 1980a). Blood-loss estimates consider only the direct effects of biting tabanids on cattle, however, and do not take into account the effects of annoyance caused by flies attempting to feed. Tabanids are telmophages, meaning that to obtain blood a fly pierces her host's skin with large, blade-like mouthparts. This lacerates the underlying tissues until a pool of blood forms, and from this pool the fly sponges her meal (Lall 1970, Miller 1951). Tabanid bites are extremely painful and consequentially, hosts are usually energetic in their attempts to dislodge feeding flies (Ralley 1986, Hughes et al. 1981). A dislodged fly may bite repeatedly in order to complete its meal, each bite causing the host considerable pain. The pain caused by tabanids repeatedly biting may have far greater adverse effects on host animals than simple blood-loss alone (Chvala et al. 1972, Anderson 1973, Anthony 1962, Krinsky 1976).

An alternative to blood-loss estimates has been to estimate the effect of tabanids on livestock performance. Performance in cattle is generally measured in terms of the weight gain of beef animals, or milk production by dairy cattle (Ensminger 1971, 1976). By comparing the performance of cattle during periods of tabanid attack with that of the same or similar animals in the absence of tabanids, an estimate of the total impact of tabanids upon livestock production (which takes into account both blood loss and annoyance effects) is obtained. Heavy tabanid attack is accompanied by reduced weight gains in beef cattle (Roberts and Pund 1974, Perich et al. 1986), reduced milk production (Bruce and Decker 1951, Christensen 1982, Minar et al. 1979, Grannett and Hansens 1956) and lowered milk quality (Bruce and Decker 1951) in dairy cattle.

Some hosts are less affected than others by attacking tabanids. Reactions of host animals to tabanids vary depending on factors such as the species(s) of flies involved, condition of host animal, and intensity of attack. Several authors have observed that cattle are irritated to different degrees by tabanids of different species, and it has been suggested that some species may bite more painfully than others (Blickle 1955, Hollander and Wright 1980, Issel and Foil 1984, Clark et al. 1976, Magnarelli and Anderson 1980). Different tabanid species preferentially feed on different regions of the host's body (Blickle 1955, Hollander and Wright 1980, Mullens and Gerhardt 1979) and this, too, may influence the irritation which they cause.

In general vigorous, healthy animals are better able to deal with attacking tabanids than unhealthy ones, as they are more energetic and more apt to dislodge feeding flies (Tashiro and Schwardt 1953, Morgan 1987). As well, sickly animals are more likely to find themselves separated from the herd, thereby losing the protection provided by adjacent herd members against tabanid attack. The immobilization of a tail or leg used in dislodging flies may also render an animal more susceptible to attack by biting tabanids (Morgan 1987, T.D. Galloway, pers. comm.).

As numbers of attacking tabanids increase, so does the amount of fleeing and dislodgement activity undertaken by the host animal, with a concurrent increase in the animal's energy expenditures (Hollander and Wright 1980, Clark et al. 1976). In cases of extreme attack, animals may become so stressed that they collapse from exhaustion (Ralley 1986). The number of horse flies attacking an animal is affected both by local tabanid population levels and the activity of the population at a given time. The animals is also affected by its degree of isolation from conspecifics and its physical position in a herd; attack rates are generally highest on isolated animals and those at the periphery of herds. Cattle (Ralley 1986) and horses (Duncan and Vigne 1979, Hughes et al. 1981) often aggregate into tight herds to minimize individual body exposure under conditions of intense tabanid attack.

The annoyance caused by biting tabanids forces cattle to occupy the daylight hours with avoidance and dislodgement activities at a time of the year (i.e. the summer months) when the most productive grazing should occur (Howell et al. 1949, Bruce and Decker 1951). Besides causing cattle to lose grazing time, tabanids also increase the susceptibility of animals to heat stress. Tabanid flight and host-seeking activity is most intense on hot, sunny days (Burnett and Hayes 1974, Alverson and Noblet 1977, Joyce and Hansens 1968, Hollander and Wright 1980), when cattle are already prone to heat stress (Finch et al. 1982, Schleger and Turner 1965).

The overall effect of tabanid attack is that cattle suffer through losses of blood, energy, and grazing time. As well, fly-stressed animals display reduced vitality and increased susceptibility to other stresses and disease. Because of these negative effects, and the fact that tabanids are present in pest numbers in many cattle-producing areas, tabanids have a profound impact on livestock production. Losses to the cattle industry in North America alone are estimated to exceed 30 million dollars annually (Perich et al. 1986).

Control Measures:

Methods employed in attempts to control horse and deer flies fall into three broad categories:

1. eradication or reduction of adult populations;
2. eradication or reduction of larval populations;
3. repelling or killing those adults attempting to blood feed, and those beginning to blood-feed.

1. Aerial applications of DDT, lindane, and dieldrin (Brown and Morrison 1955) and DDT, methoxychlor, and chlordane (Howell et al. 1949) have been employed to control adult tabanids in wooded areas. These control attempts, however, had little or no measurable effect on local horse and deer fly populations, either because the flies were inaccessible to the insecticides, or because flies were immigrating into the treated areas from elsewhere (Brown and Morrison 1955). Ground-based applications of resmethrin (Hansens 1980b) and/or permethrin (Hansens 1981) to control adult salt-marsh tabanids have also met with very limited success, presumably for the same reasons (Hansens 1981). In general, adulticiding programs aimed at tabanids are of little use. They are expensive, minimally effective, and potentially damaging to the environment by their indiscriminate destruction of non-target organisms.

2. Control of tabanid larvae has been attempted using chemical larvicides, or by physical manipulation of the larval habitat. Although the larval habitats of many tabanid species are poorly known or otherwise inaccessible to control measures (Teskey 1969, Roberts and Dicke 1964), a few tabanid species undergo larval development in discrete, well-defined areas, and larviciding can be a feasable method of controlling these species. This is the case for salt-marsh species, where local reductions of larval populations up to 100 per cent have been possible through a larvicide application (Hansens 1956, Jamnback and Wall 1957, Gerry 1949). Despite successful larval control, there are serious problems with larviciding techniques. As with adulticiding, reductions of local adult populations through destruction of larvae are often offset by immigration of adults into treated areas, making the technique only applicable to isolated marshes (Jamnback and Wall 1957). As well, levels of pesticides (such as DDT and dieldrin) which are sufficient to kill tabanid larvae have devastating effects on non-target organisms. (Hansens 1956).

Habitat alteration as a means of larval tabanid control is an alternative to chemical larviciding, but this technique is subject to a number of the same limitations as larviciding, such as limited applicability (e.g. suitable to only a few tabanid species in a few locales), immigration of adults into altered areas, and negative affects on non-target organisms. Nonetheless, Anderson and Kneen (1969) were able to eradicate a population of immature *Chrysops fuliginosus* Wied. by temporarily impounding salt-marsh waters following a perigee (spring) tide, thereby drowning larvae and pupae.

Inland (non-salt marsh) tabanid species have been controlled using other types of habitat manipulations to reduce larval populations. Emergent vegetation has been removed from seepage areas and small ponds, eliminating tabanid oviposition sites. Emergent vegetation can be removed either manually (Pechuman 1981) or by allowing cattle to graze pond margins (Easton 1982). In either case, this can significantly reduce tabanid populations locally. However, this method cannot be applied to large or inaccessible water bodies or swamps (Pechuman 1981). Tabanid species which breed away from water margins are not affected, and non-target organisms may be adversely affected.

3. A number of control strategies have been directed specifically at host-seeking flies. Host-simulating traps may be used to intercept tabanids before they reach livestock. Wilson (1968) successfully used a perimeter of

carbon dioxide-baited sticky traps to prevent tabanids from attacking cattle confined on a small pasture area. Numbers of flies on the animals were significantly reduced while the traps were in operation. Wall and Doane (1980), however, were unsuccessful in reducing numbers of biting *Tabanus nigrovittatus* Macq. using box traps. In general, trapping as a means of tabanid control is impractical, since most cattle pastures are too large to be surrounded cost-effectively by a perimeter of traps. As well, even if thousands of tabanids are trapped, trapping has little effect if the population of attacking tabanids numbers in the hundreds of thousands or millions (see Cooksey and Wright 1989).

Repellents are the most frequently used means to prevent tabanids from biting humans, and the most effective compounds, such as DEET and HECC, can repel deer flies for up to 4 1/2 hours (Schreck *et al*. 1976). Even so, such repellents are far less effective against tabanids than against other types of biting flies (e.g. mosquitoes), which may be repelled for 8 or more hours by a single DEET application (Davis 1985). As a means of protecting livestock from tabanid attack, repellents such as DEET are of little use, since they are expensive, must be re-applied every 1-4 hours in order to be effective, and may, with continued use, cause severe skin irritations in animals (Blume *et al*.

1971). Other repellents, which are more persistent and better-tolerated by animals, do not appear to repel tabanids, though they are effective against other types of biting flies (Shemanchuk 1981).

As an alternative to chemical repellents is the treatment of the external surfaces of livestock with a contact insecticide to kill tabanids which land and attempt to feed. Insecticides used in this fashion include methoxychlor (Grannett and Hansens 1956, 1957), methoxychlor in combination with pyrethrins and piperonyl butoxide (Roberts and Pund 1974), pyrethrin (Bruce and Decker 1951), and synthetic pyrethroids such as permethrin (Lang et al. 1981, Bay et al. 1976), fenvalerate (Galloway unpubl.) and cypermethrin (Ralley 1986). Reports vary as to the effectiveness (measured in terms of increased performance of sprayed animals) of contact insecticides in controlling tabanids. Bruce and Decker (1951) found that daily pyrethrin treatments dramatically increased butterfat production in dairy cattle under tabanid attack, and similarly, Grannett and Hansens (1956, 1957) reported increased milk production in dairy cattle for 1-2 days following weekly methoxychlor treatments. Studies in which no differences in performance between treated and untreated cattle were reported include those of Ralley (1986), in which animals received bi-weekly cypermethrin treatments, and Roberts and Pund (1974), in which animals received weekly treatments of methoxychlor. It is difficult, however, to make comparisons amongst these studies since the studies differ in tabanid attack level, species of flies involved, pasture quality, and condition and type of animals used in each study.

It is notable that in all contact insecticide trials, very high mortality was observed among tabanids contacting insecticide-treated animals from 1 to 14 days post-treatment (depending upon the type of insecticide used). Even those studies which reported no performance differences between treated and untreated animals report that flies contacting the treated animals were killed. Permethrin was toxic to tabanids for up to two weeks post-treatment on horses (Harris and Oehler 1976, Lang et al. 1981). The main problem with contact insecticides appears to be that they do not kill tabanids immediately. Even though all attacking flies may be killed, they still have the opportunity to bite and harass a treated animal before the insecticide takes effect. As well, insecticide application (e.g. spraying and handling animals) can be very labour-intensive unless a forced-use self-treatment technique is employed.

Climatic Factors and Tabanid Host-Seeking Activity:

It is well documented that host-seeking activity by female tabanids is affected by climatic factors. Temperature is considered most important, and many authors agree that a temperature threshold exists, below which host-seeking ceases. The value of this threshold varies among studies and among species, but is generally considered to be around 20° C for most North American tabanids (e.g. Anderson et al. 1974, Blickle 1959, Dale and Axtell 1975, Baribeau and Maire 1983, Miller 1951). One species, Apatolestes actites Philip and Steffan, is apparently more cold-tolerant, with a threshold of 11° C (Lane et al. 1983). At the other end of the temperature scale, host-seeking activity is suppressed above 35° C (Anderson et al. 1974, Dale and Axtell 1975, Tashiro and Schwardt 1949). Within low and high temperature limits, host-seeking activity is highly variable but generally increases with increasing temperature (Miller 1951), and is lowest at temperatures near the lower threshold (Brown and Morrison 1955).

There is a strong correlation between daily fluctuations in temperature and light intensity (Auroi 1988), although temperature affects tabanid flight activity independently of light intensity. Light intensity, also affects tabanid flight activity. Tabanids are less active on cloudy days than on sunny ones, and tabanid flight activity declines dramatically when clouds obscure the sun (e.g. Burnett and Hays 1974, Leprince *et al*. 1983). That light intensity rather than temperature affects flight activity in these instances, since a sudden blocking of the sun by clouds is not usually accompanied by a drastic drop in temperature. Temperatures often remain above threshold levels on summer evenings long after tabanid flight activity has ceased with the onset of darkness (Hollander 1977, Anderson 1971, Roberts 1974).

Wind speed is another climatic variable which apparently affects tabanid flight activity, particularly in maritime areas or mountaintops where frequent strong prevailing winds occur. Catts and Olkowski (1972), Joyce and Hansens (1968), and Lane *et al*. (1983) reported depressed flight activity in sea-shore tabanids during periods of high winds. Similar observations were reported by Leprince *et al*. (1983) for tabanids observed on a mountain-top in Quebec. In more sheltered areas, wind apparently has minimal effect on flight activity at the low wind velocities encountered (Alverson and Noblet 1977, Strickman and Hagan 1986). Wind speeds above 30 km/hr were required before flight was suppressed in coastal species.

Tabanid flight activity levels have been correlated with changes in barometric pressure (Alverson and Noblet 1977, Burnett and Hays 1974), and horse flies are particularly active during periods of low pressure preceding storm fronts (Tashiro and Schwardt 1949, Pechuman et al. 1961). Relative humidity has also been correlated with tabanid flight activity (Burnett and Hays 1974, Dale and Axtell 1975, Alverson and Noblet 1977, Kniepert 1982, Auroi and Graf-Jaccottet 1983).

There is considerable disagreement concerning the relative importance of different climatic factors in determining tabanid activity, despite general agreement that temperature is important (see Auroi and Graf-Jaccottet 1983). Any attempt to compare different studies is difficult because of differences in species of flies considered, climatic regimes under which studies took place, differences in types of traps and climatic recorders employed and climatic factors considered, and different degrees of sampling effort. In order to ascertain the effect of one climatic variable on tabanid flight activity with any certainty, one must somehow control for simultaneously occurring variables which are often mutually correlated. One approach which has been applied to this problem is the use of multivariate analyses (e.g. Auroi and Graf-Jaccottet 1983, 1985, Schulze et al. 1975, Strickman and Hagan 1986), although models generated by these studies are very limited (i.e. local) in predictive ability.

Host-seeking activity of female tabanids varies in a diel fashion which may, in turn, vary interspecifically (Hollander and Wright 1980, Roberts 1974, Schulze et al. 1975, Burnett and Hays 1977, Harley 1965). Although climatic factors affect the absolute level of tabanid activity at any particular time, there is some evidence of an underlying rhythm of daily flight activity which is intrinsically controlled. Kaufman and Sorokina (1986) found that female Hybomitra spp. varied during the diel period in their responsiveness to light independently of their external environment, and that the unimodal pattern of this photopreferendum (sic) completely coincided with their rhythm of daily flight activity in nature.

Seasonal Trends in Horse Fly Populations:

Adult horse flies are present only during the warm months of the year in temperate North America. Since summer length varies latitudinally, so does the length of the tabanid flight season. Flight seasons vary from 8 months (March-October) in the southern U.S. (Tidwell 1973, Roberts 1971) to under 2 months (July-August) in northern Canada (Miller 1951, Maire 1984). Regionally, interspecific differences exist in regard to when certain species begin their flight activity. The activity of different species may be highest in the early, mid, or late part of the summer season (Hollander 1979, Smith et al. 1970). The result is a succession of tabanid species over the summer months. The length of the flight season also varies among species, and the annoyance caused by tabanids may be more or less concentrated temporally. In Mississippi, for example, *Hybomitra lasiophthalma* (Macq.) is an annoying pest of livestock for up to 3 months (Roberts 1971), whereas in Manitoba, this species is abundant for about 6 weeks (Hanec and Bracken 1964, Pechuman *et al*. 1961).

CHAPTER I

The Effect of Permethrin Treatments on the Weight Gains of Beef Heifers Subject to Stress Caused by Biting Horse Flies (Diptera: Tabanidae).

INTRODUCTION

Horse flies and deer flies are notorious pests of humans and livestock because of their aggressive attack and blood-feeding behaviour. In many areas of North America, these insects are of considerable economic importance as pests of pastured beef and dairy cattle (Perich et al. 1986, Roberts and Pund 1974). In Manitoba, tabanid populations can reach very high levels during the summer months, even though the tabanid flight season is relatively short (8-10 weeks). Unfortunately for cattle producers, peak tabanid populations occur during the summer pasture season, when peak performance (either in milk production or beef weight gains) is expected from the animals.

There are no recommendations for horse fly control on cattle in Manitoba (Manitoba Insect Control Guide, 1989). Large-scale larvicide programs which are effective against black flies, mosquitoes, and salt-marsh tabanids are ineffective against tabanids in Manitoba because the larval habitats are too diffuse to be treated adequately (Teskey 1969). Even if areas could be successfully larvicided, adult tabanids can quickly re-colonize treated areas (Jamnback and Wall 1957). In addition, the cost of large-scale control programs is beyond the reach of the small isolated cattle producers whose animals suffer most from tabanids. Other control measures, such as adulticiding and destruction of larval habitat are not practical for the same reasons.

Horse fly traps have met with moderate success in reducing numbers of flies attacking cattle (Wilson 1968), but trapping is not applicable to large areas, and, like larviciding, is very costly and labour-intensive. There are repellents which can prevent tabanids from biting cattle, but these, too, are impractical in pasture situations due to cost, frequency of application required, and the allergic reactions of animals to repellent chemicals after continued use (Blume et al. 1971).

Direct application of methoxychlor (Grannett and Hansens 1956, 1957) and synergized pyrethrins (Cheng 1958) to cattle are apparently of limited use in reducing the impact of attacking Tabanidae, although these insecticides are effective against biting Muscidae. Surface applications of synthetic pyrethroid insecticides, on the other hand, have considerable promise for tabanid control. These chemicals are well-tolerated by livestock, and are very persistent and effective in killing those horse flies which contact treated animals (Harris and Oehler 1976, Bay et al. 1976, Ralley 1986). Whether these chemicals can actually reduce the impact of tabanids on cattle has not been determined. It was the purpose of this study to determine whether biweekly permethrin spray treatments could reduce numbers of tabanids attacking (and thereby increase the weight gains of) beef heifers on pasture in s.e. Manitoba.

MATERIALS AND METHODS:

Study Area:

The Seven Sisters Grassland Project is located in southeastern Manitoba, approximately 10 km southwest of the town of Seven Sisters (50°7'N 96°2'W). The site consists of 74.5 ha of pasture, divided into 6 paddocks varying in size from 9 to 18 ha. (Fig. 1). The area was cleared from the surrounding spruce/fir/aspen forest in 1979, and the soil at the site is of a relatively well-drained fine sandy loam type. The area surrounding the site is mainly peat soil which is poorly drained, with numerous bogs and ditches which provide an abundance of tabanid breeding habitat. Very high tabanid populations are known to occur at the pasture site (Ralley 1986, Dr. T.D. Galloway, pers. comm.).

Tabanid Populations:

In both 1987 and 1988, horse flies were the only abundant biting insects at the Seven Sisters site. Tabanid populations were monitored using four Manitoba Horse Fly Traps (MHFT's) (Thorsteinson *et al*. 1964) located adjacent to the pasture area (Fig.1). Manitoba-type traps provide a good index of tabanid biting pressure on cattle (Hollander and Wright 1980). In 1987 traps were operated for a total of 25 days, 15 May to 15 July. Trapping was carried out between 0600-0800 hr and 1900-2200 hr daily, 1 to 5 days per week. In 1988 traps were operated for a total of 64 days, 22 May to 19 August, for 5 or 6 days per week, 0600 to 2200 hr. In both 1987 and 1988, traps were emptied several times daily. The sum of the 4 daily trap catches for each day was recorded as the day's tabanid catch. Daily catches provided an index of seasonal variation in tabanid abundance at the site.

Study Animals

Beef heifers (various breeds) were provided by local producers. In 1987, 55 animals were supplied by 13 producers, each producer supplying 2 to 5 animals (Appendix A). The animals arrived at the site on or before 16 December, 1986 and were maintained in a feedlot on ammoniated alfalfa silage until spring. They were released onto pasture in late May, 1987. Prior to the onset of the experiment, all heifers were heat-synchronized using Lutalase® and bred by artificial insemination (A.I.). A yearling bull was pastured with each herd of heifers to ensure the insemination of animals which were not successfully bred artificially.

On 1 June, 1987, the heifers were divided into two herds, each having similar breed and producer representation. The initial weight distribution of the animals was comparable in both herds. At the beginning of the experiment, heifers were 11 - 16 months of age and mean weight (range) of 369 kg (300 - 442 kg). In the one herd, designated the treated herd, each animal received a 1 L, full-body spray of 0.5% permethrin (Ectiban 5^{R}) biweekly, applied to confined animals using a hand-held spray gun (Bean Sprayer Co. Model 57) powered by a gasoline-powered pump (Bean Sprayer Co. Trojan Model 2020). Animals in the other (check) herd received no insecticide treatment. Heifers in both herds were weighed biweekly, and spraying was coincident with the weighing process for the treated herd. Intervals between weighings and/or sprayings were termed spray periods.

Herds were maintained separately on two pastures, 7.2 and 8.8 ha in size (Fig. 1), and herds were alternated between paddocks weekly to reduce pasture bias. Pasture vegetation was primarily orchard grass (Dactylus glomerata L.), with some timothy grass (Phleum pratens L.). The experiment was carried out in 1987 for 6 weeks, 3 June to July 15.

In 1988, 72 animals were provided by 16 producers, 1 to 6 animals per producer (Appendix B). Heifers arrived at the study area between late December 1987 and mid May 1988. Those arriving in winter or early spring were maintained in a feedlot until spring (similar to 1987 animals), whereas heifers arriving in late spring were released directly onto pasture. As in 1987, heifers were heat-synchronized and bred by A.I. prior to the onset of the experimental period. The animals were divided into 2 herds on similar criteria as in the 1987 experiment, and treated as in 1987. Heifers used in the 1988 experiment were (for those animals for which date of birth was known) 11 - 14 months of age, and weighed on average 399 kg (333 - 533 kg) at the onset of the experiment. The first weighing/spraying occurred on 3 June, 1988, and the experiment was terminated on 14 July, 1988.

In 1988, control and treated herds were maintained separately on two pastures (14.6 and 12.7 ha in size), each of which was subdivided into 2 smaller paddocks (Fig. 1). Herds were rotated weekly between paddocks. In 1988, as in 1987, pasture vegetation consisted of orchard and timothy grasses.

Statistical comparisons of average daily weight gains (ADG's) between herds for each spray period, and comparisons of total weight gained/animal between herds for each year's total (6-week) experimental period were carried out using a

2-way ANOVA procedure, in which treatment (sprayed vs. unsprayed) and producer of origin were main effects.

RESULTS

Tabanid Populations

Twenty horse fly and 11 deer fly species were trapped at the Seven Sisters site. Of these, 10 species of horse flies (Hybomitra spp.) were abundant in the pasture area (Table 1), and together comprised over 99 % of tabanids captured. Females of all 10 common species were observed feeding from cattle. If the assumption is made that all tabanid species at the site are similar in the degree to which they annoy cattle, then the sum of the catches of all horse fly species present on a given day is considered as an index of the fly pressure or level of tabanid biting activity for that day. Fly pressure in both 1987 and 1988 varied considerably among days and among spray periods at the site, reaching peak levels in mid to late June (Fig. 2). In 1987, tabanid pressure, as recorded in 4 MHFT catches, was most intense between 6 June and 28 June, averaging over 1000 flies/4 MHFT/day during that time, and on one occasion (20 June) exceeding 3000 flies/4MHFT/day. The peak tabanid activity period encompassed the latter half of spray interval 1 and most of interval 2. Before 6 June and after

28 June, fly pressure was generally quite low (< 1000 flies/4MHFT/day). In 1988, overall tabanid pressure was much greater than in 1987, and catches of > 2000 flies/4MHFT/day were frequent from the beginning of the experiment until 4 July, during spray periods 1, 2, and the first half of period 3. Catches exceeded 5000 flies/4MHFT/day on 10 and 17 June. Numbers of tabanids trapped dropped considerably after 5 July.

Weight Gains

In 1987, the performance of animals in treated and control herds, as indicated by mean average daily gains (ADG's) and overall weight gains, was similar during the first spray period (Table 2). In the second spray period treated animals exhibited significantly higher ADG's than heifers in the control herd. In the final period the opposite was true, with control animals performing significantly better than treated animals. Despite weight gain differences between the herds in the last 2 spray periods, heifers in the sprayed and unsprayed herds exhibited similar total weight gains over the entire 6-week experimental period (total gain = 42.81 and 44.82 kg/animal in control and treated herds respectively).

In 1988, the performance of animals in the sprayed and treated herds was quite different over the experimental period than was observed in 1987. During the first spray period, ADG's of heifers in the control herd were considerably greater than those of animals in the treated herd, yet in the second and third periods the performance of animals in the two herds was similar (Table 2). Because of the great difference in the performances of the two herds during the first period, the total gains of the control animals were significantly higher than the overall gains of the treated animals (total gain = 41.47 and 35.38 kg/animal in control and treated herds respectively). Pasture quality in 1988 declined steadily due to very dry weather, and this is reflected in the decreasing weight gains of animals in successive experimental periods.

DISCUSSION

Biweekly, whole-body permethrin spray treatments did not effectively reduce the impact of horse flies on the weight gains of pastured beef heifers at Seven Sisters, Manitoba. Treated cattle gained significantly more than untreated animals in only one two-week period (15-19 June, 1987) during the entire 12 weeks that the study was conducted, whereas untreated animals gained significantly more than treated heifers during 2 of the spray intervals (29 June-13 July, 1987 and 3 June-13, July 1988).

Permethrin is highly toxic to tabanids. Harris and Oehler (1976) reported 100 % kill of tabanids that contacted permethrin-treated horses (1.0 % water emulsion spray, 50 ml/animal) for up to 2 weeks post-treatment. Similarly, Bay et al. (1976) found that permethrin applications to horses and cattle (0.05 and 1.0 % water emulsion spray, 1 L/animal) killed 100 % of tabanids contacting treated animals for 9-14 days post-treatment. The assumption can therefore be made that all (or at least a very high percentage of) tabanids contacting the permethrin-treated cattle during the present study were killed by the insecticide. Even so, those aspects of tabanid attack which reduce the weight gains of pastured animals were not significantly affected.

Several aspects of tabanid attack have the potential to adversely influence a host's (e.g. a heifer's) weight-gain performance. Cattle can lose considerable amounts of blood to feeding horse flies (Clark et al. 1976, Hollander and Wright 1980), and the annoyance caused by biting tabanids can cause cattle to interrupt grazing (Chvala et al. 1972, Anderson 1973). Cattle expend considerable energy, which might otherwise contribute to weight gains, in the process of fleeing from and attempting to dislodge feeding tabanids (Ralley 1986, Hughes et al. 1981). Finally, tabanid attack can potentially reduce performance by increasing the susceptibility of cattle to heat stress. On hot, sunny days cattle are prone to heat stress (Finch et al. 1982), and tabanid pressure is often greatest on such days (Alverson and Noblet 1977, Burnett and Hayes 1974). Cattle frequently aggregate in response to tabanid attack (Ralley 1986), and convective heat loss from individual cattle is reduced in the resultant tightly-bunched herds. Heat-stressed animals do not perform as well as those which are not stressed.

Much of the way in which tabanids adversely affect their hosts stems from annoyance caused by painful bites and from the physical presence of large numbers of persistent, noisily-buzzing insects around the host animal. Even if all of those flies which land on and feed from a permethrin-treated animal subsequently die, they do so after they have caused annoyance to the treated animal. The sheer numbers of tabanids present at the Seven Sisters site ensured that those flies killed were quickly replaced, and thus the insecticide did not likely affect the level of tabanid attack on individual animals.

The assumption has been made throughout this study that tabanid attack negatively affects weight gain performance. The flies, when common, certainly appeared to cause the cattle distress, and are known to interrupt the grazing behaviour of cattle at the Seven Sisters site (Ralley 1986). The question arises, however, whether cattle can compensate in some way for blood, energy, and stress-related losses arising from horse fly attack. Tabanids (of the species present in Manitoba) seek hosts only during daylight hours. The possibility therefore exists that cattle were able to compensate, through nocturnal grazing, for losses occurring during periods of intense tabanid attack. Mosquitoes were not sufficiently abundant to be important cattle pests at Seven Sisters in 1987 and 1988, so late evenings and nights were essentially pest-free. Ralley (1986) did not observe nocturnal grazing in growing dairy heifers at Seven Sisters, but during the present study, beef heifers were observed grazing at dawn and dusk, undisturbed by tabanids. This crepuscular grazing may have been more than sufficient to meet the animal's needs, since in 1987 and 1988 cattle gained, on average, between 35.4 and 44.8 kg. It is unknown, however, whether or not the animals' weight gains would have been even greater in the absence of tabanids.

Table 1: Tabanidae collected at the Seven Sisters, Manitoba, pasture site in 1987 and/or 1988.

Hybomitra affinis (Kirby)*
H. astuta (Osten Sacken)
H. arpadi (Szilady)*
H. brennani (Stone)
H. criddlei (Brooks)
H. epistates (Osten Sacken)*
H. frontalis (Walker)
H. illota (Osten Sacken)*
H. lasiophthalma (Macquart)*
H. lurida (Fallen)*
H. microcephala (Osten Sacken)
H. nitidifrons nuda (McDunnough)*
H. pechumani Teskey and Thomas*
H. trepida (McDunnough)*
H. zonalis (Kirby)*

Tabanus marginalis Fabricius
T. similis Macquart
T. reinwardtii Wiedemann
T. vivax Osten Sacken

Haematopota americana Frost

Chrysops aestuans Wulp
C. ater Macquart
C. dawsoni Philip
C. excitans Walker
C. frigidus Osten Sacken
C. furcatus Walker
C. indus Osten Sacken
C. mitis Osten Sacken
C. montanus Osten Sacken
C. sackeni Hine
C. venus Philip

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* abundant species

Table 2: Mean average daily weight gain per animal (ADG), and mean weight gain per animal for beef heifers in treated and control herds for each of 3 spray periods in 1987 and 1988 at Seven Sisters, Manitoba.

	$\bar{x}$ ADG (kg/day)			$\bar{x}$ GAIN (kg)		
	control		treated	control		treated
1987	n = 25		n = 27	n = 25		n = 27
01June-15June	1.61 ± 0.09	ns	1.38 ± 0.09	22.00 ± 1.36		19.37 ± 1.21
15June-29June	0.48 ± 0.12	*	0.86 ± 0.09	6.82 ± 1.66		12.00 ± 1.27
29June-13July	1.25 ± 0.12	**	0.82 ± 0.07	17.52 ± 1.75		11.44 ± 0.92
Total:				44.82 ± 1.84	ns	42.81 ± 1.60
1988	n = 37		n = 34	n = 37		n = 34
03June-17June	1.68 ± 0.15	**	1.14 ± 0.11	25.22 ± 1.45		15.97 ± 1.53
17June-30June	0.96 ± 0.09	ns	0.99 ± 0.08	12.46 ± 1.14		12.94 ± 1.05
30June-14July	0.40 ± 0.07	ns	0.46 ± 0.07	6.13 ± 0.85		6.47 ± 1.01
Total:				41.47 ± 2.38	*	35.38 ± 1.61

* significantly different ($p \leq 0.05$)
** significantly different ($p \leq 0.01$)
ns not significantly different ($p > 0.05$)

Figure 1: Map of the study area at Seven Sisters, Manitoba.

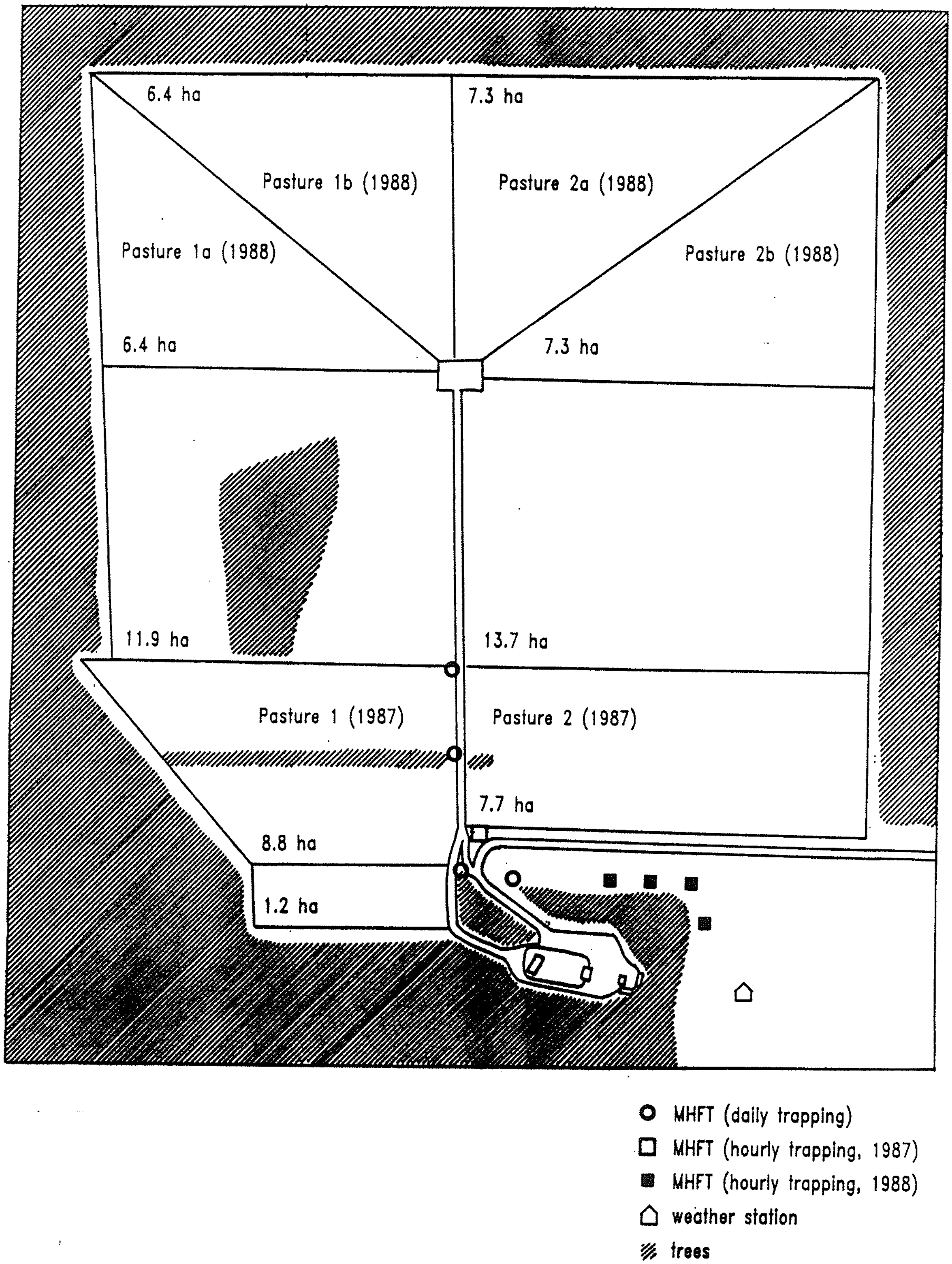
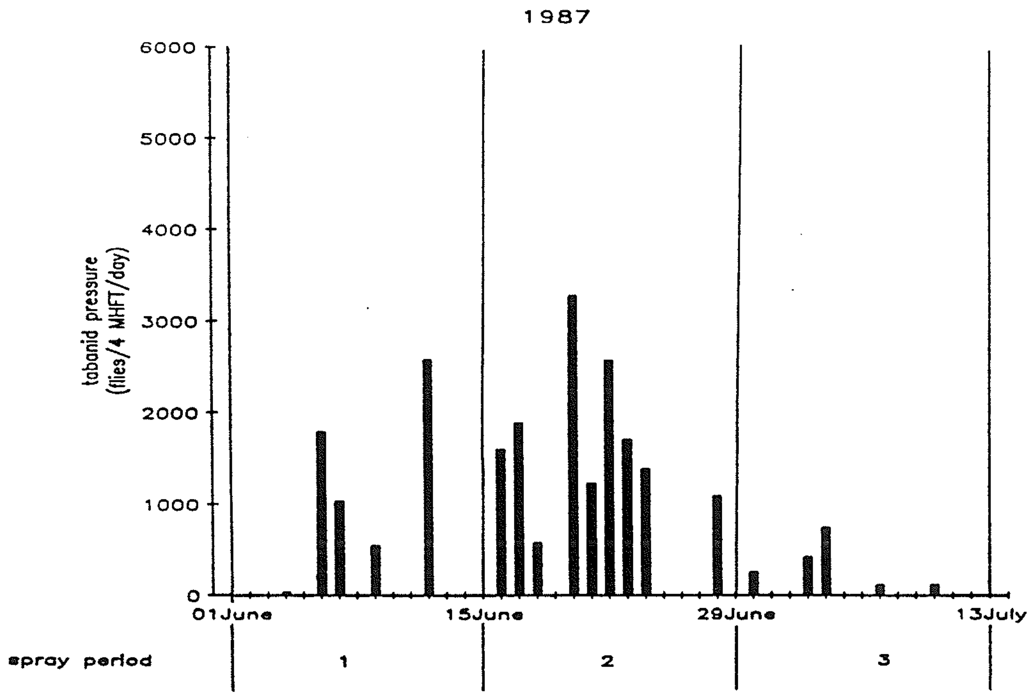
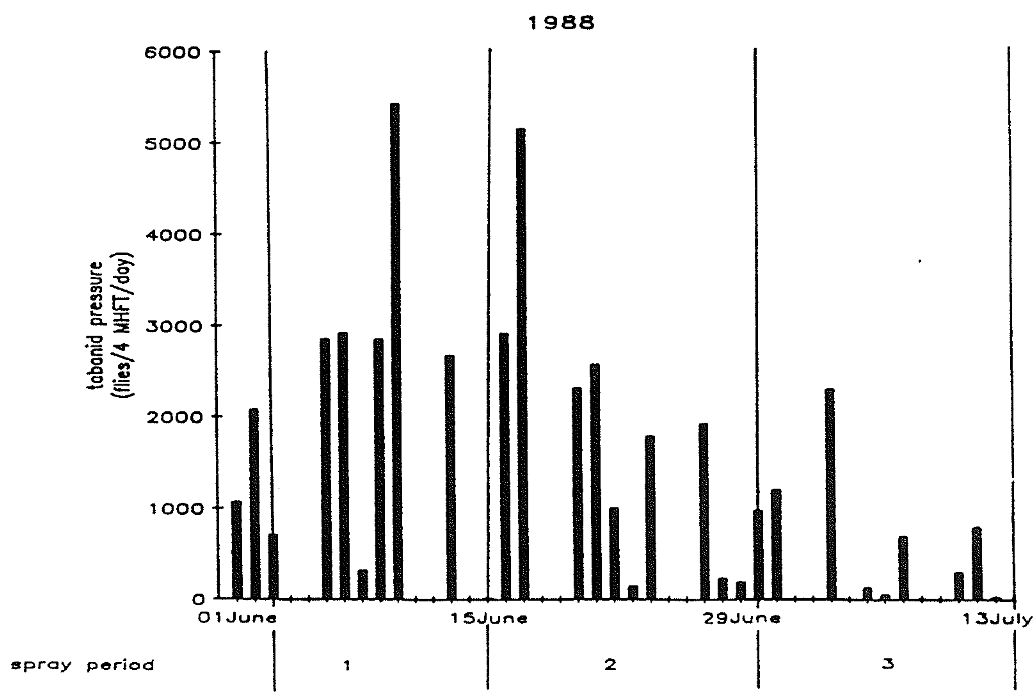

6.4 ha
7.3 ha
Pasture 1b (1988)
Pasture 2a (1988)
Pasture 1a (1988)
Pasture 2b (1988)
6.4 ha
7.3 ha
11.9 ha
13.7 ha
Pasture 1 (1987)
Pasture 2 (1987)
7.7 ha
8.8 ha
1.2 ha
MHFT (daily trapping)
MHFT (hourly trapping, 1987)
MHFT (hourly trapping, 1988)
weather station
trees

Figure 2: Tabanid activity (as indexed by no. of flies caught daily in 4 MHFT) during each of 3 spray periods at Seven Sisters, Manitoba in 1987 and 1988.


1987
tabanid pressure (flies/4 MHFT/day)
0
1000
2000
3000
4000
5000
6000
01June
15June
29June
13July
spray period
1
2
3


1988
tabanid pressure (flies/4 MHFT/day)
0
1000
2000
3000
4000
5000
6000
01June
15June
29June
13July
spray period
1
2
3

CHAPTER II

Seasonal Distribution and Physiological Age of Host-Seeking Horse Flies (Diptera: Tabanidae: *Hybomitra* spp.) at Seven Sisters, Manitoba.

INTRODUCTION

In temperate North America, adult horse flies are active only during the warm months of the year from late spring until early autumn. Throughout this period, the blood feeding activities of female horse flies cause considerable annoyance to man (Miller 1951, Hocking 1952) and to other large mammals (Hollander and Wright 1980, Morgan 1987). Cattle on pasture are particularly affected when large numbers of tabanids are present, since the flies interrupt the normal grazing patterns of animals (Tashiro and Schwardt 1953, Ralley 1986) and take large quantities of blood (Perich et al. 1986, Clark et al. 1976). Female tabanids can also vector a variety of animal pathogens (Anthony 1962, Krinsky 1976, Foil 1989).

Information concerning seasonal population dynamics of tabanids in a given locale is important for several reasons. Considerable variation may exist among a region's tabanid species in their potential for causing annoyance and vectoring disease, due to interspecific differences in host preference (Smith et al. 1970) and feeding site preference (Mullens and Gerhardt 1979). A knowledge of the seasonal abundance patterns of various local tabanid species, combined with a knowledge of the annoyance or vector potential of each species, allows identification and anticipation of the periods when these insects present the greatest nuisance or health risk, and when to take steps to minimize their impact.

The seasonal abundance of most Manitoba tabanid species is poorly known, although several authors (Miller 1951, Pechuman et al 1961, Hanec and Bracken 1964, Ralley 1986) have briefly described activity for several species. It was one objective of this study to provide a detailed account of the patterns of seasonal abundance for commonly occurring tabanids at a site near Seven Sisters, Manitoba, where the flies are important pests of cattle.

Of considerable importance, in terms of potential disease transmission, is a knowledge of the physiological (i.e. reproductive) age structure of a biting fly population. Physiological age, in this sense, is the number of gonotrophic cycles completed by a haematophagous female fly (i.e. number of egg batches laid), where generally speaking, one blood meal is required for each gonotrophic cycle. The vector potential of a biting fly species, at any point in its flight season, can be determined by the physiological age structure of the population, since a biologically-transmitted pathogen can only be passed on if more than one blood meal is taken. Seasonal changes in the physiological age structure of a tabanid population can also provide insights into the dynamics of the population. The second objective of this study was to document seasonal changes in the physiological age composition of tabanid populations for the common species at the Seven Sisters, Manitoba, site.

MATERIALS AND METHODS

Study Area

Tabanids were trapped at the Seven Sisters Grassland Project, which is located approximately 10 km southwest of the town of Seven Sisters (50°7'N 96°2'W) in s.e. Manitoba, Canada. The study site consisted of 74.5 ha of open pasture, which was cleared from the surrounding spruce/fir/aspen forest in 1979. The area surrounding the grassland project is underlain by poorly drained peat soil, and is dotted with numerous bogs and ditches.

Collection Techniques

In 1987 and 1988, 4 Manitoba Horse Fly Traps (MHFT's) (Thorsteinson *et al*. 1964) were used to sample tabanid populations at the study site. Two of these traps were located adjacent to the wooded margin of the pasture area, while two others were located away from the margin on the open pasture (Chapt. I, Fig. 1). Sampling was carried out in 1987 for a total of 24 days between 15 May and 15 July, for 1 to 5 days per week. Traps were operated between 0600-

0800 hr and 1900-2200 hr on each sampling day. In 1988, sampling was conducted for a total of 64 days between 22 May and 19 August, for 4 to 6 (usually 5) days per week. Daily sampling was conducted between 0600 hr and 2100 hr in 1988. Traps were emptied several times daily using a modified portable vacuum. Tabanids removed from the traps were killed in a closed box containing a piece of dichlorvos-impregnated resin. Flies killed in this manner succumbed quickly with minimal damage. Pooled daily catches in the four MHFT's provided a daily index of the activity of each tabanid species.

Physiological Age Grading

When the pooled daily catch of females of a tabanid species met or exceeded 10, a sample of 10-30 flies was frozen and retained for later dissection and ovarian age-grading in the laboratory. Reproductive age was determined in 10-30 flies/day by ovarian examination. Ovaries were exposed by removing the two terminal abdominal segments and opening the abdomen along the right pleural membrane. This technique allowed easy removal of complete ovaries and, as well, permitted examination of the abdominal cavity for the presence of fat body and parasites, and detection of nectar in the crop. Ovaries were removed from the abdomen using #5 watchmaker's forceps, placed on a slide in a drop of distilled water, teased apart, and the individual ovarioles examined using a dissecting microscope (40 X). Female horse flies were recorded as being nulliparous (never having laid eggs), or parous (having laid at least one egg batch) based on to the state of ovarian development. Reproductive age-grading criteria used in this study were similar to those used by Thomas (1972), although no attempt was made in the present study to separate biparous from uniparous flies.

RESULTS

Seasonal Abundance

Between 15 May and 15 July in 1987, and between 22 May and 19 August in 1988, 31 tabanid species in 4 genera were caught in MHFT's at the Seven Sisters site (Chapt. 1, Table 1). Only data concerning horse flies (subfamily Tabaninae: *Hybomitra*, *Tabanus*, and *Haematopota* spp.) are included in the present study, primarily because very few deer flies (*Chrysops* spp.) were observed at the site, and also because MHFT-type traps are generally ineffective for trapping Chrysopinae (Pechuman and Burton 1969, Thompson 1970). Twenty-one horse fly species were collected at Seven Sisters (Table 3).

A total of 80,333 horse flies were captured over the course of the summers of 1987 and 1988. Of the species present, *Hybomitra astuta* (O.S.), *H. criddlei* (Brooks), *H.*

brennani (Stone), H. microcephala (O.S.), Tabanus reinwardtii Weidemann, T. vivax O.S., and Haematopota americana Frost were rarely trapped, and each accounted for less than 0.1 % of the total tabanine catch (Table 4). Slightly more abundant were H. frontalis (Walker), T. marginalis Fabr., and T. similis Macq. which, though uncommon, were caught relatively consistently during their observed flight seasons.

Ten Hybomitra spp. were abundant at the Seven Sisters site (H. affinis (Kirby), H. arpadi (Szilady), H. epistates (O.S.), H. illota (O.S.), H. lasiophthalma (Macq.), H. lurida (Fallen), H. nitidifrons nuda (MacD.), H. pechumani Teskey and Thomas, H. trepida MacD., and H. zonalis (Kirby)), and together these species accounted for more than 99 % of the total horse flies captured in 1987 and 1988 (Table 4). Combined total daily catches of these 10 species in both years are shown in Figure 3.

Hybomitra lurida and H. nitidifrons nuda were the first species captured at the site in both 1987 and 1988, appearing in the traps in mid-late May (Fig. 4). In 1987, H. lurida was likely present before the onset of trapping, and this may account for this species' very low abundance in trap catches in that year. Peak catches of H. lurida in 1988 were made at the end of May, several days after the first individuals were trapped at the site. This species had practically disappeared by early June in both 1987 and 1988, although in 1988 a few individuals persisted until late June.

As with H. lurida, some H. nitidifrons nuda may also have been active before trapping began in 1987. Peak populations of H. nitidifrons nuda in 1987 and 1988 occurred in late May to early June. Catches declined steadily thereafter, but a few individuals persisted until late May or early June. Both H. lurida and H. nitidifrons nuda contributed relatively little to the overall tabanid population at Seven Sisters (Table 4), but caused considerable annoyance to cattle at the site when they were present.

Hybomitra illota was not present in large numbers at any point during its observed flight season, but was present in traps over most of the trapping period in both 1987 and 1988 (Fig. 4). Activity of this species was highest during the first 3 weeks of June in both years, but even on peak days never exceeded 150 flies/4 MHFT.

Hybomitra lasiophthalma constituted over 42 % of all horse flies collected at Seven Sisters (Table 4), and was the most abundant species present each year. In both 1987 and 1988 this species appeared in trap catches by late May, and generally peaked in early to mid June (Fig. 4). In 1988, peak trap catches were 2.6 times those in 1987. In

1987, *H. lasiophthalma* activity had virtually ceased by mid July, but in 1988 this species persisted in trap catches until mid August. Both in terms of numbers and voracity of attack, *H. lasiophthalma* was the most serious livestock pest at Seven Sisters.

Hybomitra affinis comprised almost 12 % of the total catch of horse flies over the two years of study, although the relative abundance of *H. affinis* in trap catches in 1987 was nearly double that in 1988 (Table 4). The first *H. affinis* were trapped in late May in both years. Trap catches of this species peaked in early to mid June in 1987, and about one week later in 1988 (Fig. 4). In 1987 and 1988, *H. affinis* was present at the site until mid July.

Hybomitra arpadi was also considerably more common in trap catches in 1988 than in 1987 (Fig. 4). This species appeared at the site in late May in both years and persisted until early July. In 1987, catches peaked in early June, whereas in 1988 peak numbers were trapped in mid June. The seasonal abundance pattern of *H. zonalis* was similar to that of *H. arpadi* in both years, except that *H. zonalis* persisted for a week longer than *H. arpadi* in 1988 (Fig. 4).

Hybomitra epistates represented almost 15 % of the total horse fly catch at the site over the 2 years of study, although the relative abundance of this species in trap catches was approximately twice as great in 1987 as in 1988.

In both years peak populations broadly occurred between mid June and early July. Hybomitra epistates was a major biting pest of cattle in both 1987 and 1988. In 1988, the flight season of this species apparently continued for 4 weeks longer than in 1987.

Numbers of Hybomitra pechumani in trap catches at Seven Sisters peaked between late June and early July in both 1987 and 1988, several days after populations of H. epistates had peaked. Like H. epistates, H. pechumani in 1988 was present for almost a month after the point where activity appeared to cease in 1987. Hybomitra pechumani comprised nearly 17 % of the total horse fly catch at the site, and was a voracious biter of cattle.

Hybomitra trepida was never very common in daily catches (i.e. daily catch in 4 MHFT never exceeded 55 flies) but this species was consistently present at the site for much of the fly season in both 1987 and 1988. In 1987 only one population peak, (in late June) was recorded, whereas in 1988 2 peaks were observed (one in late June and another in early August). Trapping in 1987 was discontinued in mid July, and the second peak may have been missed.

Daily trapping was discontinued in 1987 over a month earlier than in 1988. By mid July of 1987 very few tabanids were caught at the site, and on the last trapping day (which was warm, sunny, and apparently conducive to tabanid host-seeking activity) only 24 horse flies were captured. At the time I felt that the tabanid flight season at the site was nearly over. In 1988, however, similar circumstances did not occur until mid August. Whether or not some species (e.g. H. trepida, H. epistates H. pechumani) continued their flight seasons in 1987 for longer than was recorded is unknown.

Seasonal Changes in Physiological (Reproductive) Age

A total of 7394 of the 10 Hybomitra spp. most common at the site in 1987 and 1988 were dissected. To facilitate comparisons of changes in parous rates among species and between years, daily per cent parity for each species was considered according to days after a species first appeared in trap catches at the site, rather than according to calendar date (Figs. 5-15).

The relative proportion of females in each reproductive age class varied seasonally in all of those species for which dissections were conducted. For most species (i.e. H. lasiophthalma, H. affinis, H. arpadi, H. zonalis, H. epistates, H. pechumani) per cent parity gradually increased over the course of the flight season, from 0 - 10 % at the onset of activity to levels at or approaching 100 % at the conclusion of the season (Figs. 5-10). A similar trend was apparent for *H. illota*, although the seasonal rise in per cent parity for this species was more erratic (Fig. 11). Per cent parity in *H. lurida* and *H. nitidifrons nuda* (in 1988 only) also increased over the course of the flight season, but the rate of increase was considerably higher than in other species. Per cent parity reached 100 % within 2 weeks of the first appearance of *H. lurida* and *H. nitidifrons nuda* (Figs. 12,13), whereas 3-4 weeks were required for parity to reach 100 % in most other species. A substantial proportion of the first *H. lurida* in both 1987 and 1988 were parous.

Per cent parity in *H. trepida* in 1988 increased gradually until it reached 100% by the 50th day of the observed flight season. Between days 50 and 62, per cent parity in the population declined steadily until it reached 40 %. After day 62, per cent parity again increased until, by day 70, per cent parity was again 100 % (Fig. 14). For both *H. trepida* and *H. nitidifrons nuda* in 1987, no consistent seasonal trend was apparent in per cent parity.

DISCUSSION

Seasonal Succession of Species

Horse flies were generally common at Seven Sisters (i.e. catch/4 MHFT/day exceeded 100 flies) from early June until mid July in 1987 and 1988. There was a marked seasonal succession of abundance peaks among the 10 *Hybomitra* spp. most common in MHFT catches, and the species composition of the local tabanid fauna changed dramatically over the course of the summer. The greatest density and diversity of tabanid species at the site was recorded in mid June, at which time the heaviest attacks on cattle occurred. Early springs in 1987 and 1988 may, however, have resulted in seasonal abundance patterns of tabanids at the site occurring unusually early in the summer. Ralley (1986) described seasonal tabanid species successions in 1983 and 1984 at Seven Sisters, which parallel the findings of the present study except that first appearances and peak abundances of species were, on average, 2 weeks later than were found in 1987 and 1988. Ralley (1986) and Dr. T.D. Galloway (pers. comm.) note that July is usually the month of greatest tabanid abundance at Seven Sisters. The seasonal phenologies described by Ralley are supported by the limited accounts of Pechuman *et al.*(1961) of seasonal tabanid abundance in the nearby Whiteshell Provincial Park.

In northern Manitoba, tabanid seasonal abundances similar to those described in the present study have been found, except that these too occur considerably later than those found during the present study. In the northern regions of the province, spring occurs much later than in the south. At The Pas (Hanec and Bracken 1964) and at

Churchill (Miller 1951), tabanid species appeared and peaked in numbers considerably later than at Seven Sisters. Local and annual variation in the arrival of spring, and co-incident variation in seasonal abundance patterns, should be considered when anticipating seasonal patterns of tabanid activity, although once the first flies appear, there is a predictable succession of species.

Seasonal Changes in Per Cent Parity

Considerable fluctuation was apparent in the observed seasonal increases in per cent parity in tabanids at Seven Sisters. Some of this fluctuation is attributable to experimental error, as a result of the assumption that a subsample of 10 - 30 flies was representative of a day's trap-catch, which may have numbered in the thousands. Day-to-day variation in numbers of flies emerging also likely occurred (e.g. suppression of emergence on days when climatic conditions are poor). Despite fluctuations, there is considerable similarity between 1987 and 1988 data in the overall trend of per cent parity increase for most tabanid species at Seven Sisters (e.g. _H_. _lasiophthalma_, _H_. _affinis_, _H_. _epistates_, and _H_. _pechumani_), although the seasonal increase in per cent parity observed in _H_. _zonalis_ in 1988 occurred approximately 5 days later than that seen in 1987 (Fig. 8). Very few published accounts document seasonal changes in the parity of tabanid populations. Fewer still concern tabanid species dissected in the present study, and these accounts are based upon very limited data. In some cases (e.g. Magnarelli 1976, Troubridge and Davies 1975), estimates of per cent parity in tabanid populations for a given day or week are based upon 1 fly. The seasonal changes in parity reported in the present study are, however, largely supported by previously published accounts. Similar increases in per cent parity over the flight season have been reported for H. lasiophthalma in Texas (Thompson et al. 1979) and in Wisconsin (Morris and Defoliart 1971); for H. lasiophthalma, H. nitidifrons nuda, H. lurida, H. arpadi, H. affinis, and H. pechumani in Alberta (Thomas 1972); H. lasiophthalma, H. illota, and H. epistates in s.w. Ontario (Troubridge and Davies 1975); for H. lasiophthalma, H. nitidifrons nuda, H. illota, and H.epistates in New York (Magnarelli 1976). Anautogeny has been proven or is suspected in all of these species (Thomas 1972, Thompson et al. 1979, Magnarelli 1976).

In terms of host-seeking, there appear to be two distinct components to a population of adult tabanids at any instant. There are those flies which host-seek, or have the potential to do so, and there are also those flies which cannot host-seek. This latter component includes male tabanids, which do not blood-feed at all, and females which are physiologically incapable of feeding at a given time. For the most part, by virtue of its design, the MHFT only captures the host-seeking component. Within this component are two sub-components: those nulliparous flies host-seeking for the first time and (assuming anautogeny) those flies which are parous and seeking their second or third blood meal.

At the beginning of the flight season (for most species) relatively few host-seeking female tabanids were trapped, and most of these were nulliparous. Most early-season host-seeking flies therefore appear to be recently-emerged individuals in search of their first blood meal. If the assumption is made that a host-seeking individual has a high probability of obtaining a blood meal, then it can also be assumed that most of those flies host-seeking on a given day will engorge successfully and subsequently leave the host-seeking population to develop eggs and oviposit. Roberts (1980) observed that oogenesis in H. lasiophthalma required 6 to 12 days, depending on temperature, and similar developmental periods have been reported for other tabanine species (Magnarelli 1985, Lane and Anderson 1982). Flies which successfully feed are therefore absent from the host-seeking population for at least 1 week afterwards. A relatively small proportion of these flies is thought to survive oviposition (McClain et al. 1975) and subsequently return to the host-seeking population as parous individuals.

As the flight season progresses, the host-seeking tabanid population increases, peaks, declines, and eventually disappears. Coincidentally, changes occur in the relative proportions of nulliparous and parous sub-components of the host-seeking population. In general, as long as the influx of nullipars exceeds the number of returning pars, the adult population remains in a state of growth, and is primarily nulliparous (Fig. 15). Some proportion of the nullipars present in the host-seeking population at one time will, however, return to the population several days later as parous individuals. There is, therefore, an ongoing process of conversion of nullipars to pars, in which numbers of parous flies in a host-seeking population reflect numbers of nulliparous flies several days previously. Once emergence has peaked and the influx of nullipars is in decline, pars begin to outnumber nullipars in the population (Fig. 14). Fewer nullipars present one day mean proportionately fewer pars present later on, and thus the overall host-seeking population declines. After emergence has declined to almost nil, the few flies remaining in the population are primarily parous, with a few late emerging nullipars. In some species, limited emergence appears to occur until the end of the flight season (e.g. *H. epistates*, Fig. 8), since nulliparous individuals are always present, and per cent parity never attains the 100% level. An alternate explanation is that late season nullipars are "losers", e.g. flies which emerged earlier, but for some reason were unable to obtain a blood meal. If it is true that very few flies survive the rigors of oviposition, then very few of the small number of late-occurring nullipars return to the population, and thus none are seen at the end of the season as parous individuals.

Per cent parity in several tabanid species did not progressively increase over the flight season. A high proportion (i.e. 43 - 80 %) of H. lurida was parous at the beginning of its observed flight season. Despite the fact that the first H. lurida may have been missed in 1987 and 1988, this species' very rapid rise to 100 % parity, coincident with (not following) its population peak, leads me to speculate that a component of the population of this species at Seven Sisters is autogenous (see criteria of Troubridge and Davies 1975). The pattern of seasonal abundance and per cent parity observed in Hybomitra nitidifrons nuda in 1988 was similar to that of H. lurida, although the first H. nitidifrons nuda trapped were nulliparous. This species reached 100 % parity within 17 days of first appearance.

Considerable day to day variation in numbers was apparent over the flight season of H. illota in both 1987 and 1988 (Fig 11). Coincidentally, wide fluctuation was encountered in per cent parity, although the general trend was that of increasing parity over the flight season. It is likely that large influxes of nullipars (e.g. at day 29 in 1988) periodically reduced the per cent parity of the population.

In 1988 early and late season population peaks were recorded for _H. trepida_. Following the initial peak, per cent parity increased gradually, reaching 100 % only when populations had declined, not unlike most species with unimodal seasonal abundance patterns. Immediately after per cent parity peaked, populations of _H. trepida_ again increased and per cent parity declined. Per cent parity had again increased to 100 % by the conclusion of the flight season. A large influx of nullipars into the population apparently occurred between days 60 and 70 of the flight season. It is unknown whether this influx represented the emergence of second _H. trepida_ cohort at Seven Sisters, or whether another (late-season) species, perhaps a sibling species, is involved.

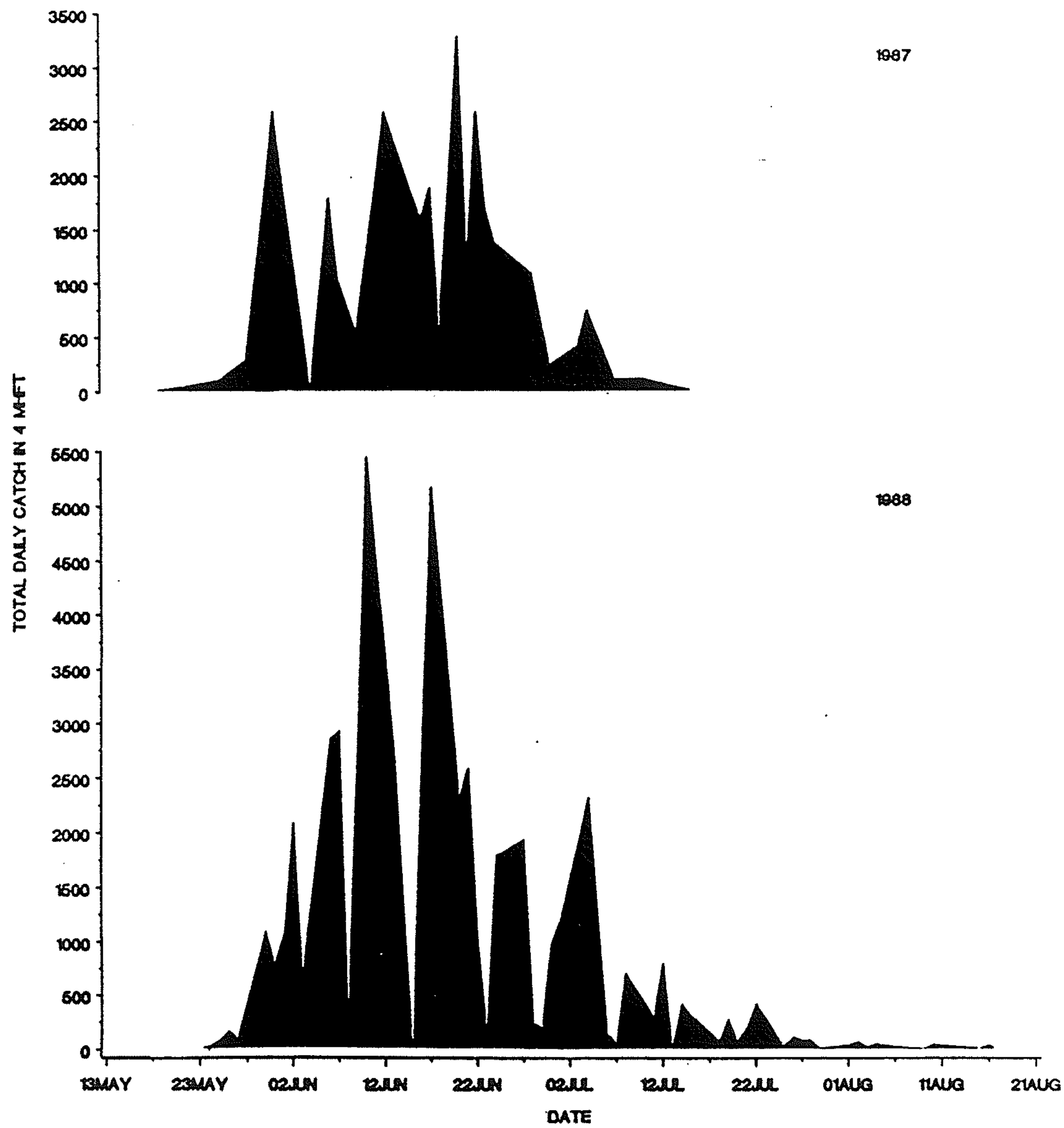
Table 3: Dates of observed activity of selected tabanid species at Seven Sisters Manitoba, in 1987 and 1988.

SPECIES	1987	1988
Hybomitra affinis (Kirby)	25 May - 15 Jul	30 May - 22 Jul
H. astuta (Osten Sacken)	-	22 Jul - 19 Aug
H. arpadi (Szilady)	28 May - 04 Jul	30 May - 14 Jul
H. brennani (Stone)	-	20 Jun - 01 Jul
H. criddlei (Brooks)	21 Jun - 28 Jun	10 Jun - 20 Jun
H. epistates (Osten Sacken)	31 May - 15 Jul	30 May - 19 Aug
H. frontalis (Walker)	31 May - 10 Jul	10 Jun - 15 Aug
H. illota (Osten Sacken)	25 May - 10 Jul	26 May - 16 Aug
H. lasiophthalma (Macquart)	25 May - 10 Jul	26 May - 16 Aug
H. lurida (Fallen)	25 May - 12 Jun	22 May - 27 Jun
H. microcephala (Osten Sacken)	04 Jul - 07 Jul	20 Jun - 22 Jul
H. nitidifrons nuda (McDunnough)	15 May - 28 Jun	22 May - 04 Jul
H. pechumani Teskey and Thomas	06 Jun - 15 Jul	10 Jun - 19 Aug
H. trepida (McDunnough)	31 May - 15 Jul	31 May - 19 Aug
H. zonalis (Kirby)	31 May - 04 Jul	31 May - 28 Jul
Tabanus marginalis Fabricius	16 Jun - 10 Jul	13 Jun - 17 Aug
T. similis Macquart	12 Jun - 10 Jul	06 Jun - 16 Aug
T. reinwardtii Wiedemann	20 Jun - 04 Jul	08 Jun - 20 Jul
T. vivax Osten Sacken	-	22 Jul
Haematopota americana Frost	31 May - 07 Jul	22 Jun - 14 Jul
Period sampled:	15 May - 15 Jul	22 May - 19 Aug
Total number of days sampling occurred:	24	64

Table 4: Per cent species composition of horse flies caught in MHFT at Seven Sisters, Manitoba, in 1987 and 1988, with total catches given in parentheses.

SPECIES	1987	1988	OVERALL
Hybomitra affinis (Kirby)	18.0 (4951)	8.7 (4581)	11.9 (9532)
H. astuta (Osten Sacken)	0.0 (0)	<0.1 (35)	<0.1 (35)
H. arpadi (Szilady)	1.4 (398)	2.2 (1182)	2.0 (1580)
H. brennani (Stone)	0.0 (0)	<0.1 (24)	<0.1 (24)
H. criddlei (Brooks)	<0.1 (4)	<0.1 (6)	<0.1 (10)
H. epistates (Osten Sacken)	23.7 (6494)	9.7 (5159)	14.5 (11653)
H. frontalis (Walker)	0.2 (69)	0.2 (106)	0.2 (175)
H. illota (Osten Sacken)	3.0 (830)	1.9 (1007)	2.3 (1837)
H. lasiophthalma (Macquart)	28.8 (7892)	49.0 (25970)	42.1 (33862)
H. lurida (Fallen)	0.3 (96)	2.2 (1156)	1.6 (1252)
H. microcephala (Osten Sacken)	<0.1 (5)	<0.1 (13)	<0.1 (18)
H. nitidifrons nuda (McDunnough)	3.7 (1023)	6.2 (3273)	5.3 (4296)
H. pechumani Teskey and Thomas	16.6 (4559)	16.5 (8742)	16.6 (13301)
H. trepida (McDunnough)	1.8 (487)	1.1 (573)	1.3 (1060)
H. zonalis (Kirby)	1.6 (439)	1.6 (836)	1.6 (1275)
Tabanus marginalis Fabricius	0.2 (48)	0.1 (77)	0.1 (125)
T. similis Macquart	0.5 (131)	0.2 (125)	0.3 (256)
T. reinwardtii Wiedemann	<0.1 (4)	<0.1 (23)	<0.1 (27)
T. vivax Osten Sacken	0.0 (0)	<0.1 (1)	<0.1 (1)
Haematopota americana Frost	<0.1 (4)	<0.1 (10)	<0.1 (14)
Total Tabaninae:	27434	52899	80333
Number of sampling days:	24	64	88

Figure 3: Seasonal abundance of horse flies at Seven Sisters, Manitoba in 1987 and 1988 (as determined by daily catches in 4 MHFT's).



3500
3000
2500
2000
1500
1000
500
0
1987
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1988
TOTAL DAILY CATCH IN 4 M-FT
13MAY
23MAY
02JUN
12JUN
22JUN
02JUL
12JUL
22JUL
01AUG
11AUG
21AUG
DATE

Figure 4: Seasonal abundance of the ten most abundant *Hybomitra* spp. at Seven Sisters, Manitoba in 1987 and 1988 (as determined by daily catches in 4 MHFT's).

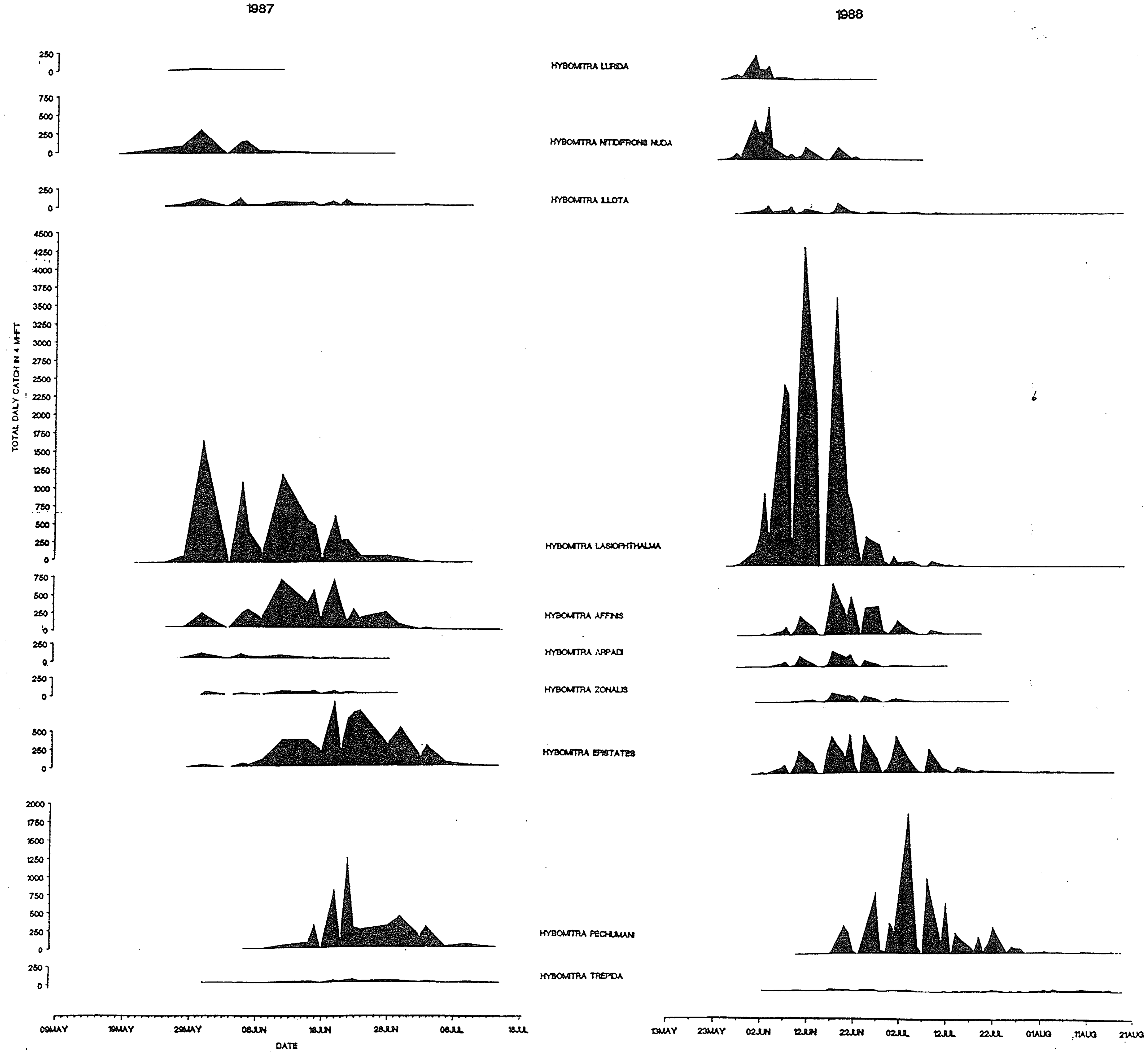

1987
1988
TOTAL DAILY CATCH IN 4 MHFT
HYBOMITRA LURIDA
HYBOMITRA NITIDIFRONS NUDA
HYBOMITRA ILLOTA
HYBOMITRA LASIOPHTHALMA
HYBOMITRA AFFINIS
HYBOMITRA ARPADI
HYBOMITRA ZONALIS
HYBOMITRA EPISTATES
HYBOMITRA PECHUMANI
HYBOMITRA TREPIDA
09MAY 19MAY 29MAY 08JUN 18JUN 28JUN 08JUL 18JUL
DATE
13MAY 23MAY 02JUN 12JUN 22JUN 02JUL 12JUL 22JUL 01AUG 11AUG 21AUG

Figure 5: Seasonal abundance and per cent parity of _Hybomitra lasiophthalma_ at Seven Sisters, Manitoba, in 1987 (——) and 1988 (---), plotted against days after first appearance in MHFT catches.

Note: Dates of first capture were - 25 May 1987
- 26 May 1988

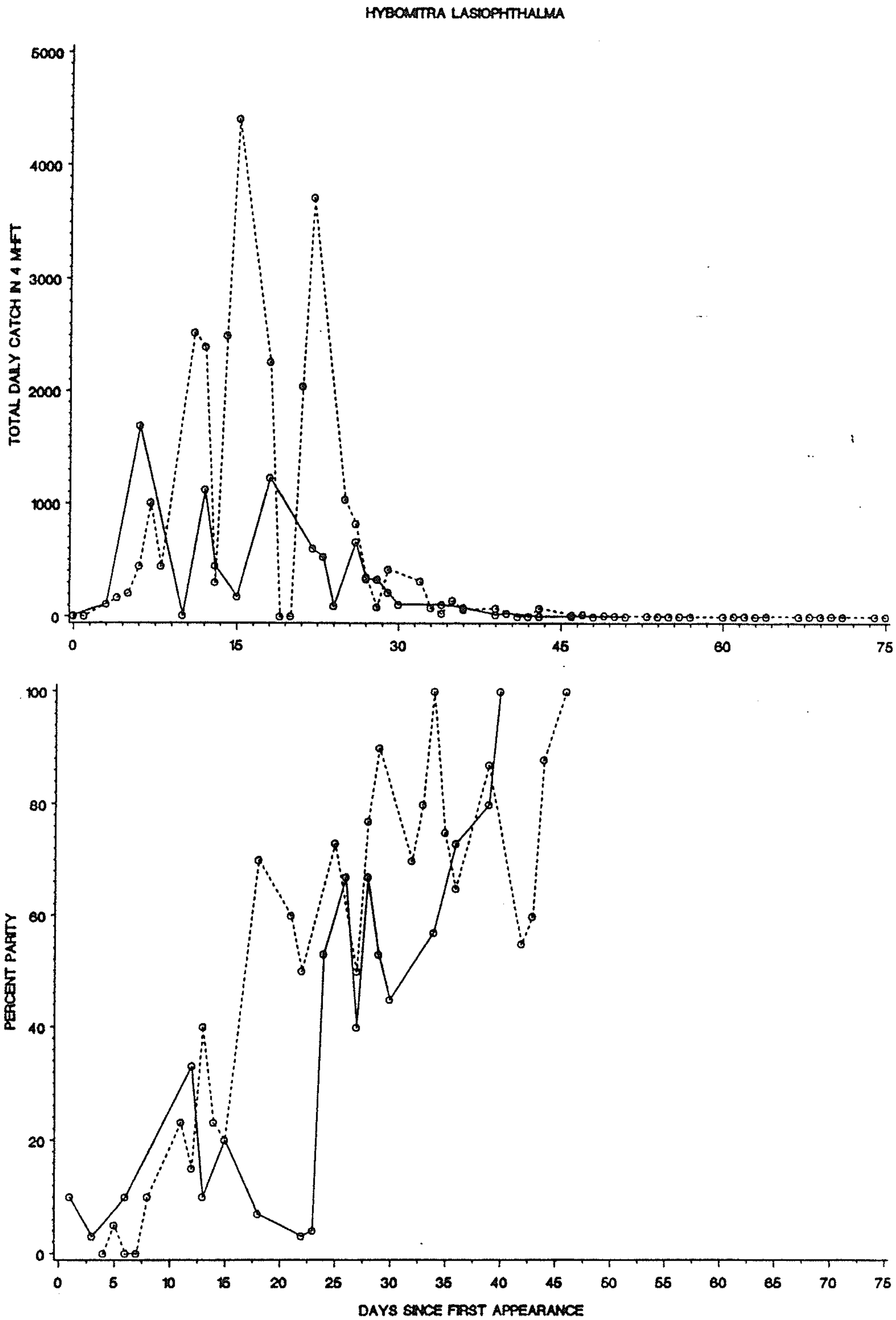

HYBOMITRA LASIOPHTHALMA
TOTAL DAILY CATCH IN 4 MHFT
5000
4000
3000
2000
1000
0
0
15
30
45
60
75
PERCENT PARITY
100
80
60
40
20
0
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
DAYS SINCE FIRST APPEARANCE

Figure 6: Seasonal abundance and per cent parity of <u>Hybomitra</u> <u>affinis</u> at Seven Sisters, Manitoba, in 1987 (——) and 1988 (---), plotted against days after first appearance in MHFT catches.

Note: Dates of first capture were - 25 May 1987
- 30 May 1988

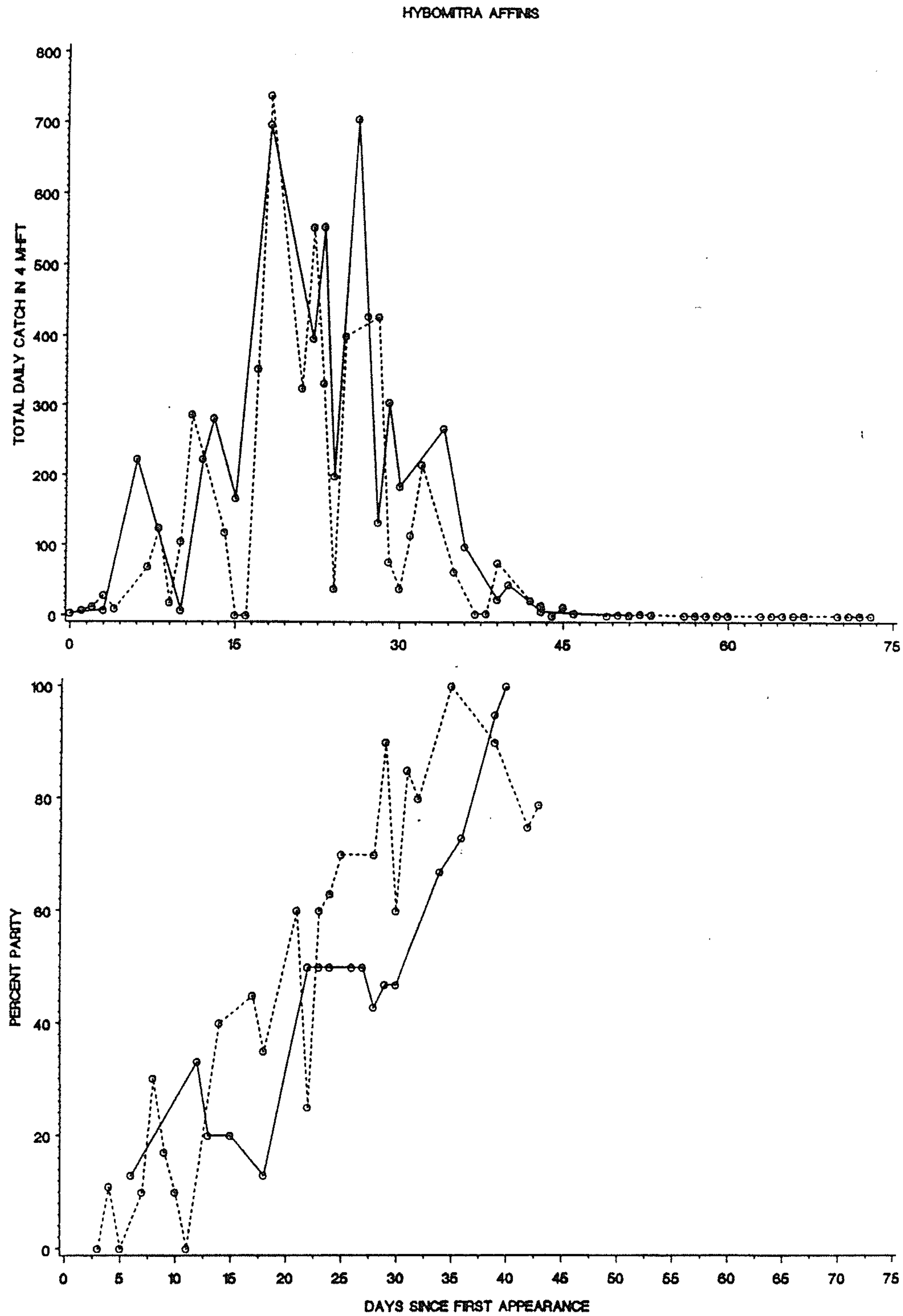
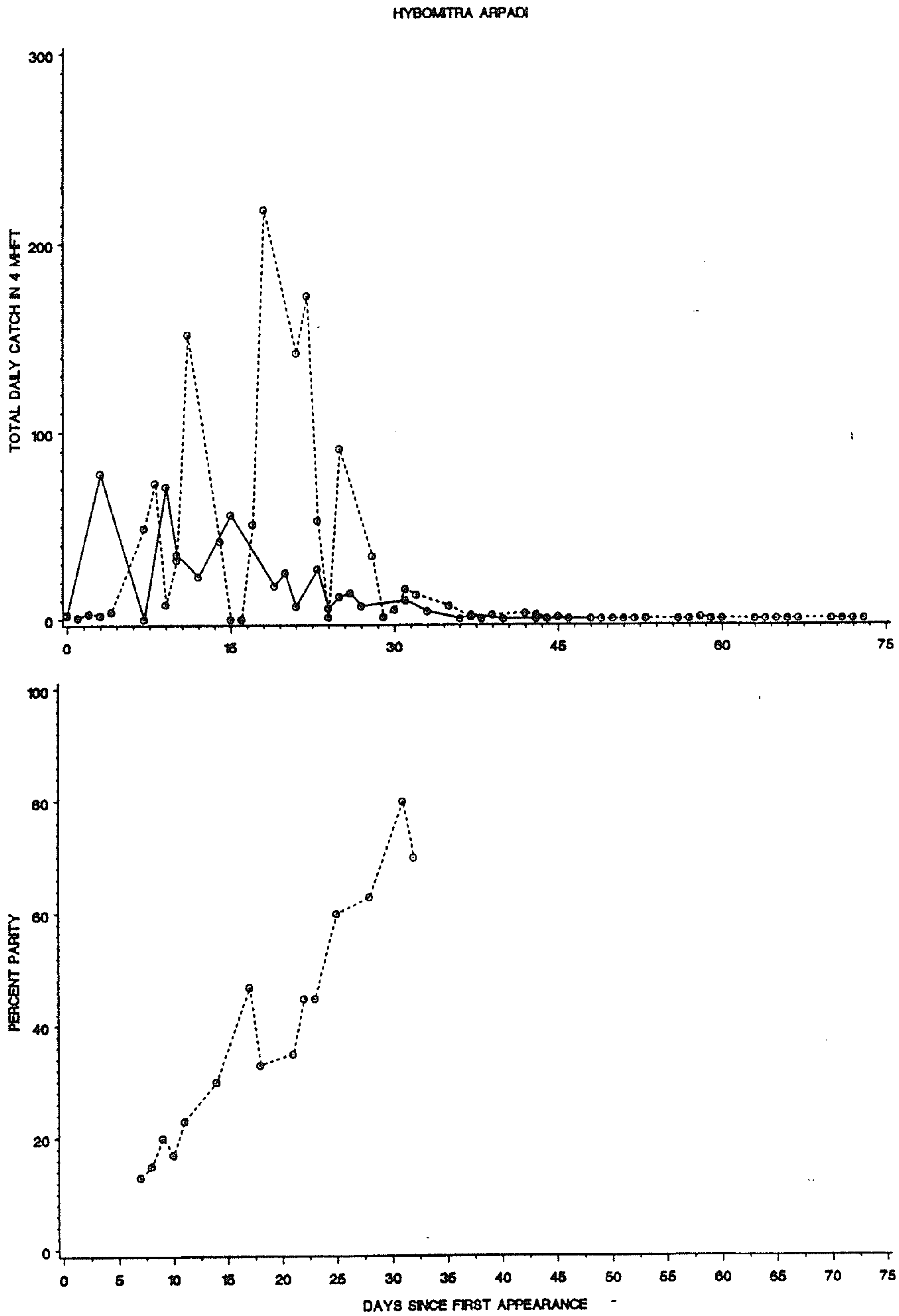

HYBOMITRA AFFINIS
TOTAL DAILY CATCH IN 4 MHFT
800
700
600
500
400
300
200
100
0
0
15
30
45
60
75
PERCENT PARITY
100
80
60
40
20
0
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
DAYS SINCE FIRST APPEARANCE

Figure 7: Seasonal abundance and per cent parity of <u>Hybomitra</u> <u>arpadi</u> at Seven Sisters, Manitoba, in 1987 (——) and 1988 (---), plotted against days after first appearance in MHFT catches.

Note: Dates of first capture were - 28 May 1987
- 30 May 1988

(No dissections were carried out in 1987)



HYBOMITRA ARPADI
TOTAL DAILY CATCH IN 4 MHFT
300
200
100
0
0
15
30
45
60
75
PERCENT PARITY
100
80
60
40
20
0
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
DAYS SINCE FIRST APPEARANCE

Figure 8: Seasonal abundance and per cent parity of <u>Hybomitra zonalis</u> at Seven Sisters, Manitoba, in 1987 (——) and 1988 (---), plotted against days after first appearance in MHFT catches.

Note: Dates of first capture were - 31 May 1987
- 31 May 1988

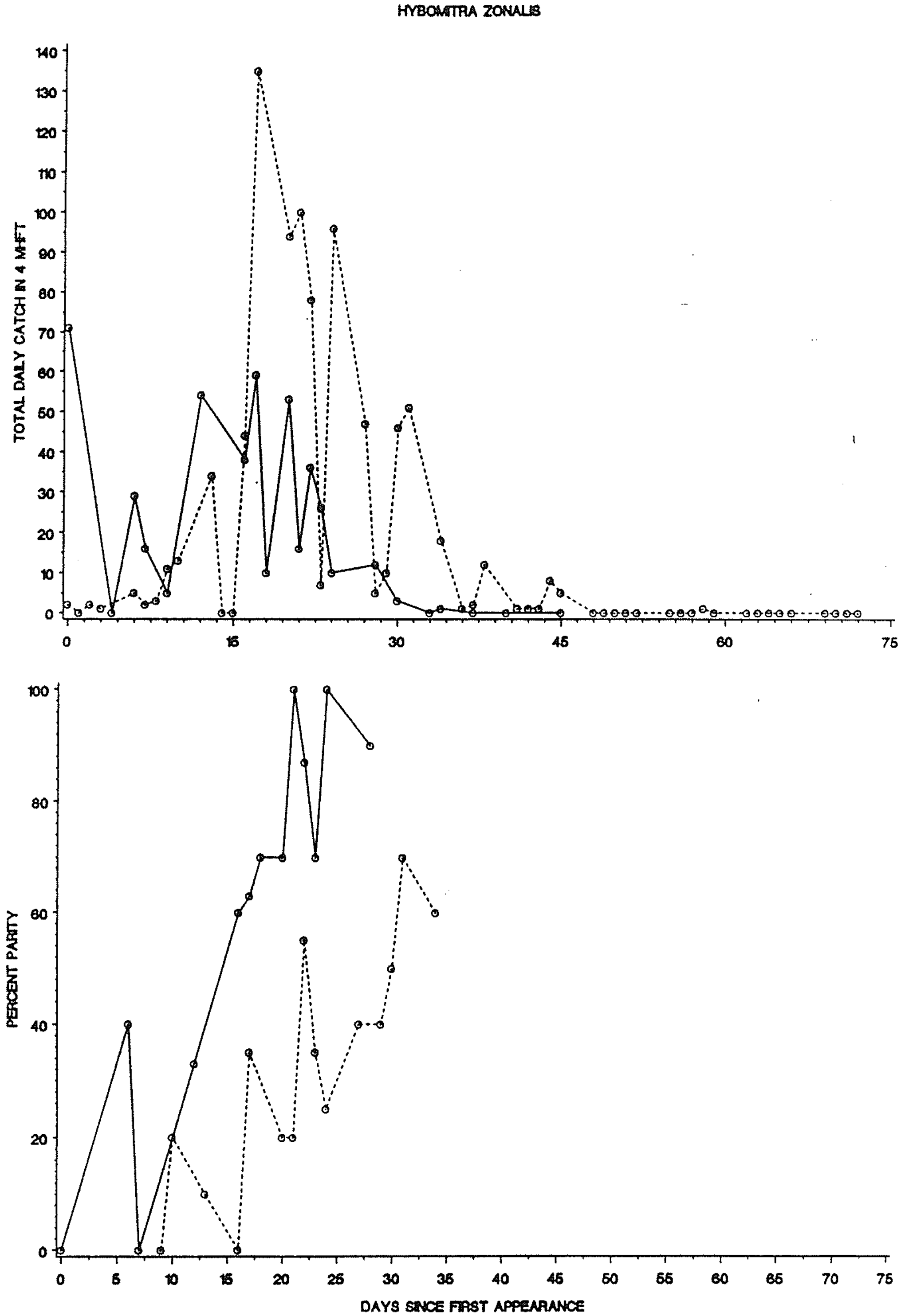

HYBOMITRA ZONALIS
TOTAL DAILY CATCH IN 4 MHFT
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
0
15
30
45
60
75
PERCENT PARITY
0
20
40
60
80
100
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
DAYS SINCE FIRST APPEARANCE

Figure 9: Seasonal abundance and per cent parity of <u>Hybomitra</u> <u>epistates</u> at Seven Sisters, Manitoba, in 1987 (——) and 1988 (---), plotted against days after first appearance in MHFT catches.

Note: Dates of first capture were - 31 May 1987
- 30 May 1988

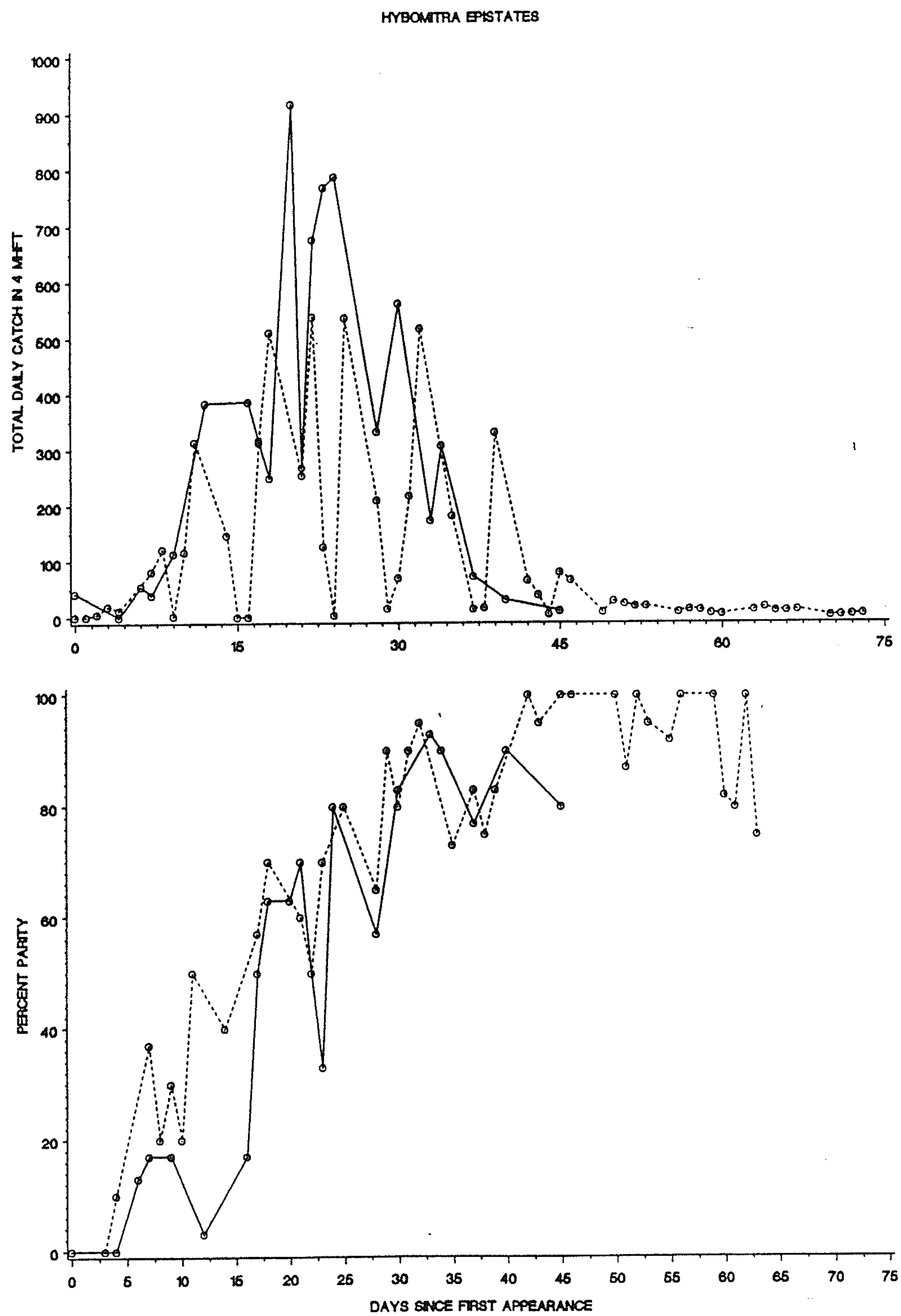
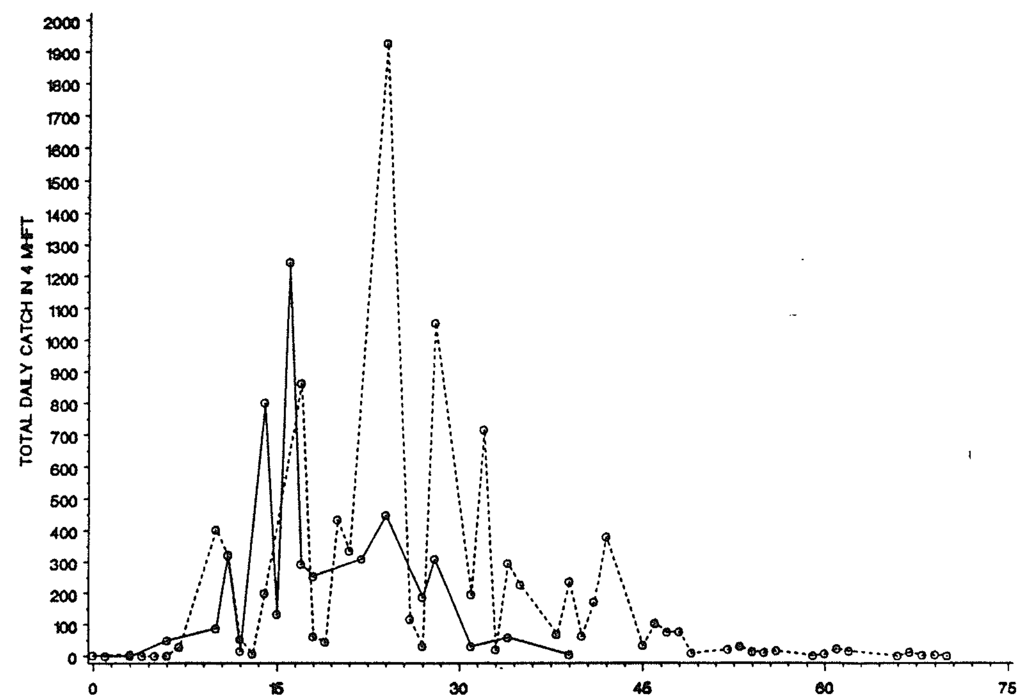

HYBOMITRA EPISTATES
TOTAL DAILY CATCH IN 4 MHFT
0
100
200
300
400
500
600
700
800
900
1000
0
15
30
45
60
75
PERCENT PARITY
0
20
40
60
80
100
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
DAYS SINCE FIRST APPEARANCE

Figure 10: Seasonal abundance and per cent parity of <u>Hybomitra</u> <u>pechumani</u> at Seven Sisters, Manitoba, in 1987 (——) and 1988 (---), plotted against days after first appearance in MHFT catches.

Note: Dates of first capture were - 6 June 1987
- 10 June 1988

HYBOMITRA PECHUMANI



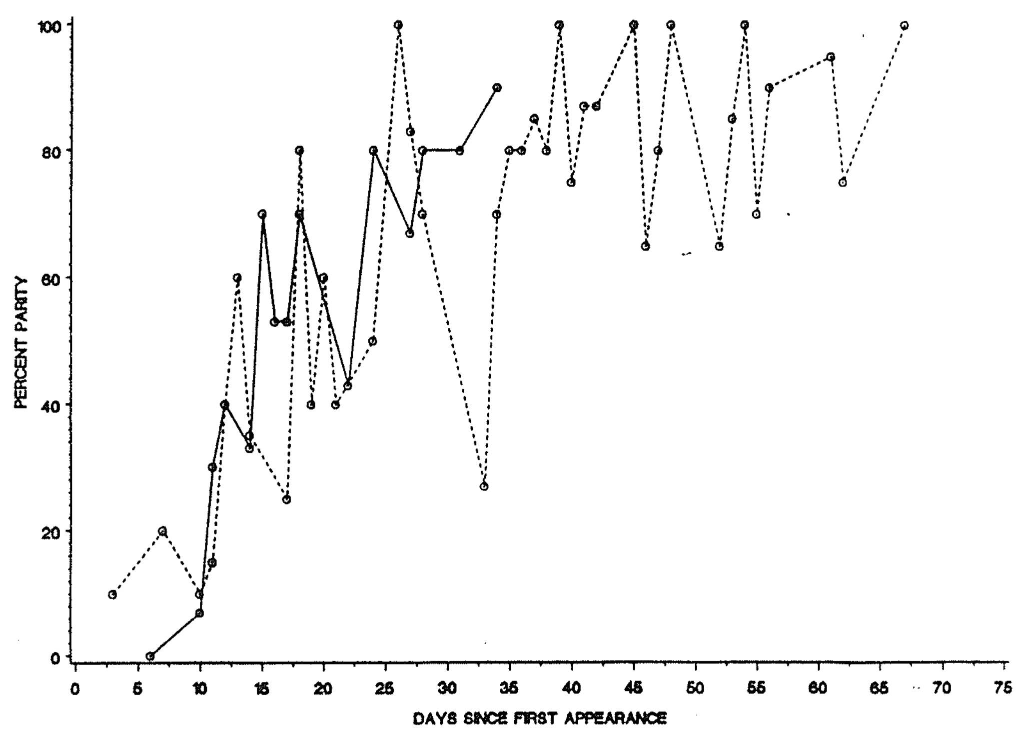


Figure 11: Seasonal abundance and per cent parity of Hybomitra illota at Seven Sisters, Manitoba, in 1987 (——) and 1988 (---), plotted against days after first appearance in MHFT catches.

Note: Dates of first capture were - 25 May 1987
- 26 May 1988

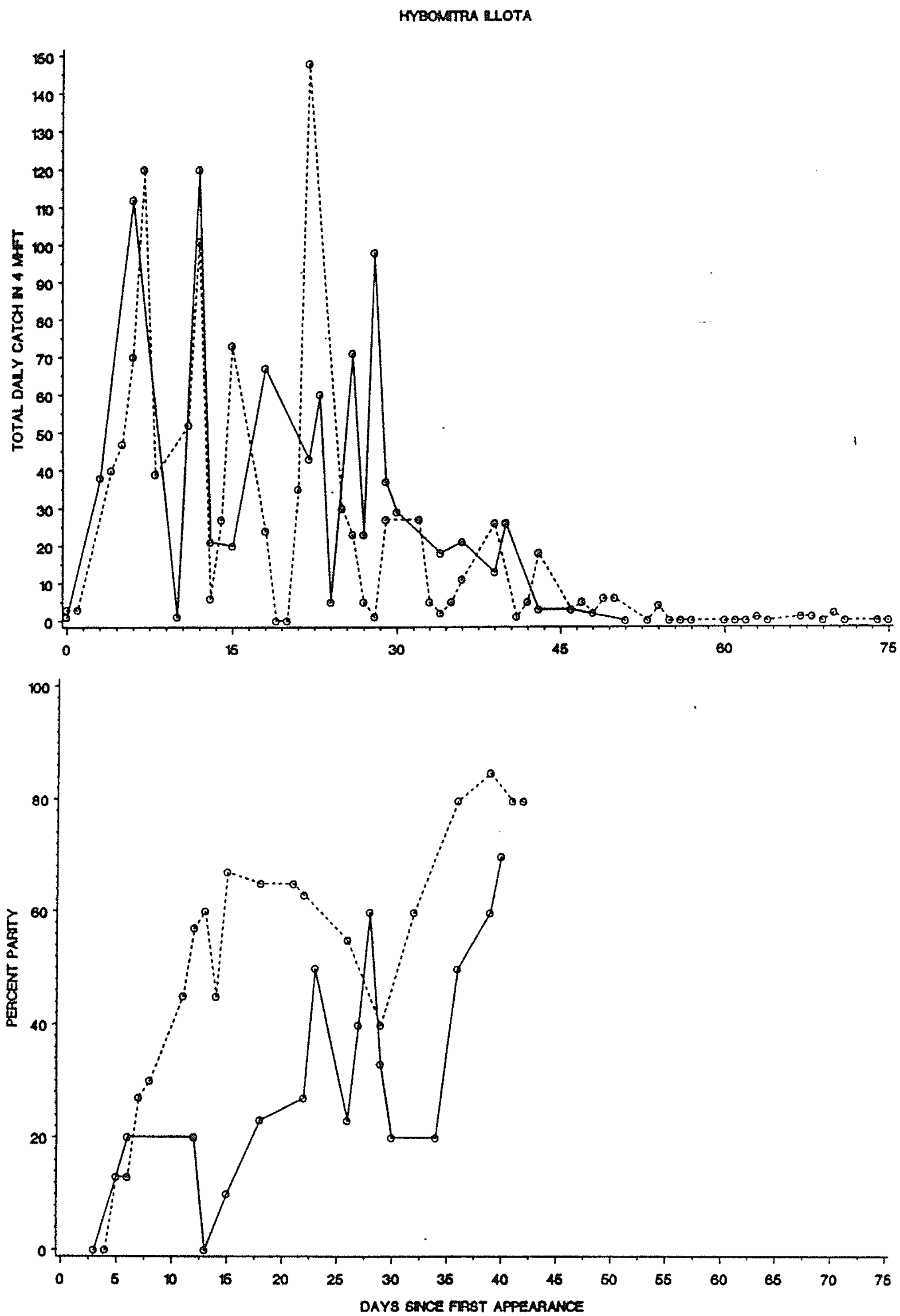

HYBOMITRA ILLOTA
TOTAL DAILY CATCH IN 4 MHFT
PERCENT PARITY
DAYS SINCE FIRST APPEARANCE

Figure 12: Seasonal abundance and per cent parity of Hybomitra lurida at Seven Sisters, Manitoba, in 1987 (——) and 1988 (---), plotted against days after first appearance in MHFT catches.

Note: Dates of first capture were - 25 May 1987
- 22 May 1988

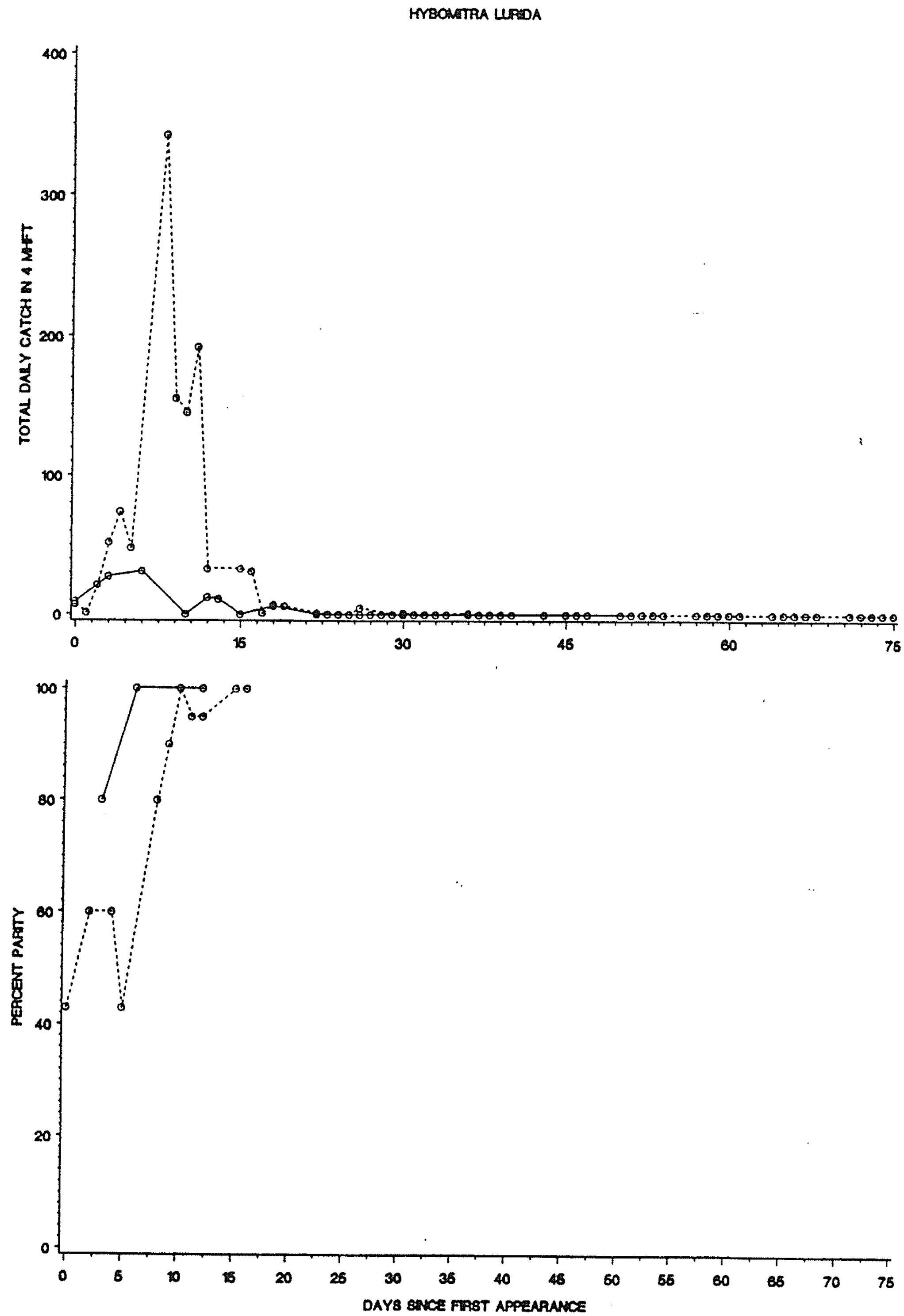

HYBOMITRA LURIDA
TOTAL DAILY CATCH IN 4 MHFT
PERCENT PARITY
DAYS SINCE FIRST APPEARANCE

Figure 13: Seasonal abundance and per cent parity of <u>Hybomitra</u> <u>nitidifrons</u> <u>nuda</u> at Seven Sisters, Manitoba, in 1987 (——) and 1988 (---), plotted against days after first appearance in MHFT catches.

Note: Dates of first capture were - 15 May 1987
- 22 May 1988

HYBOMITRA NITIDIFRONS NUDA

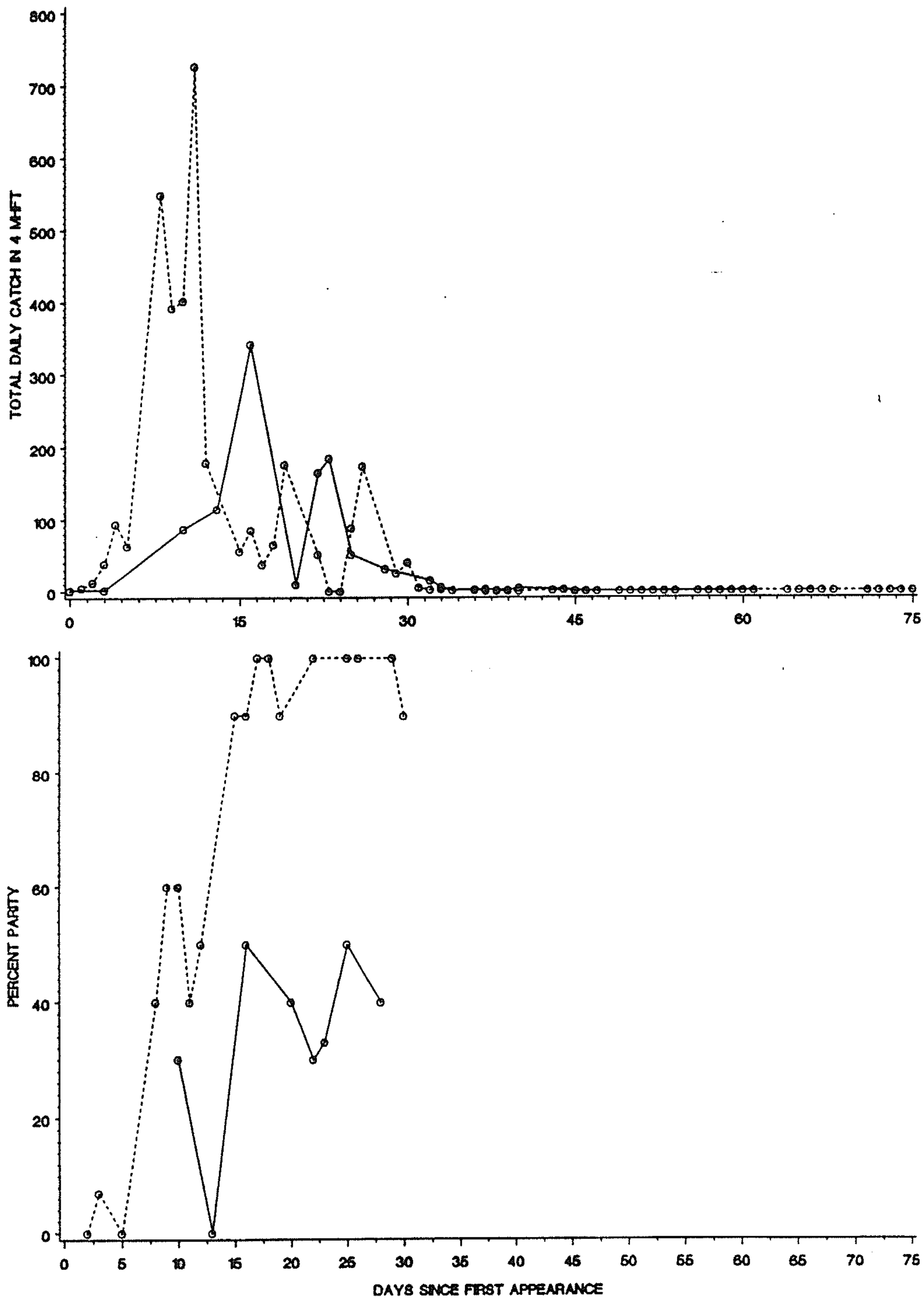


Figure 14: Seasonal abundance and per cent parity of _Hybomitra trepida_ at Seven Sisters, Manitoba, in 1987 (——) and 1988 (---), plotted against days after first appearance in trap catches.

Note: Dates of first capture were - 31 May 1987
- 31 May 1988

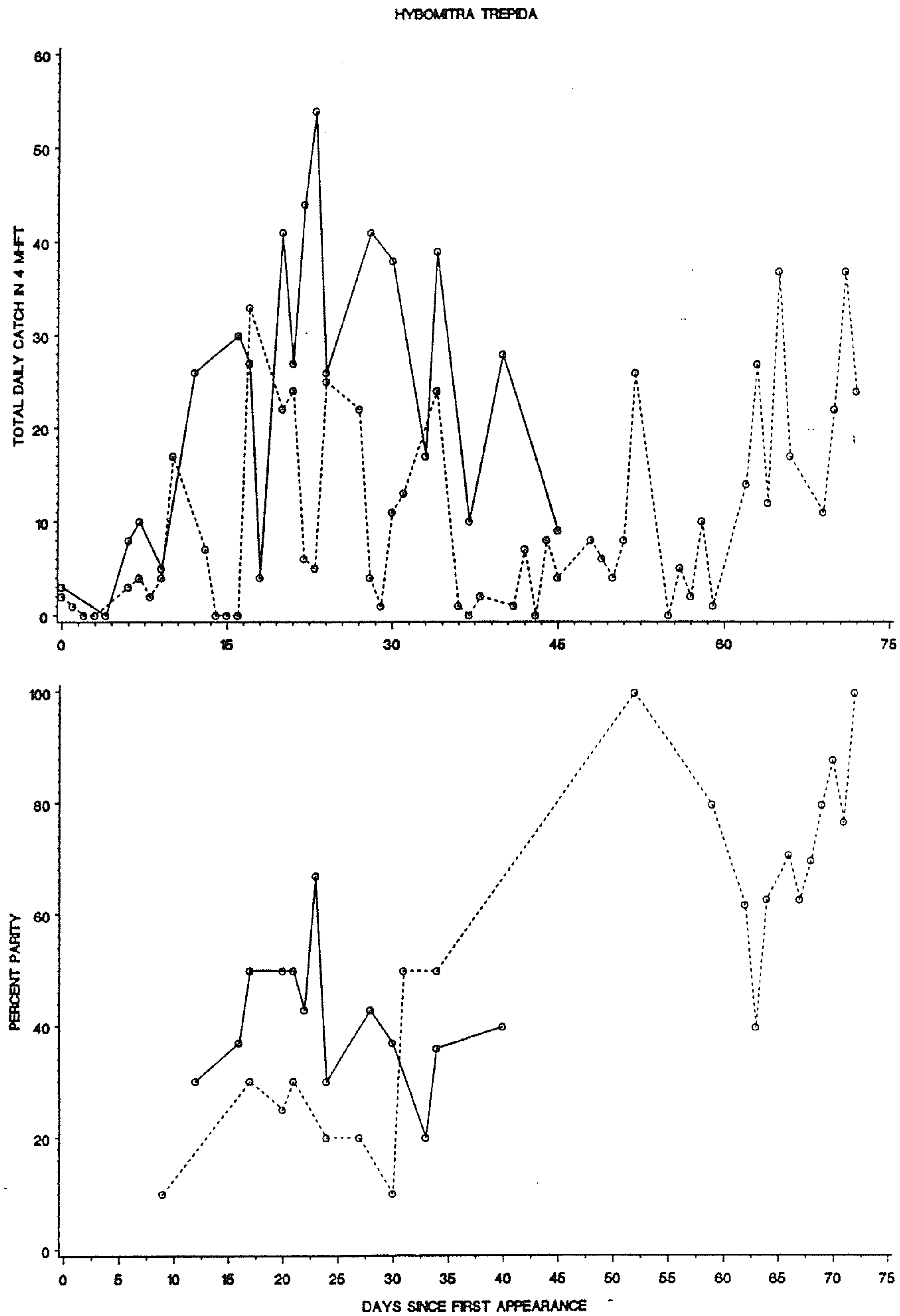
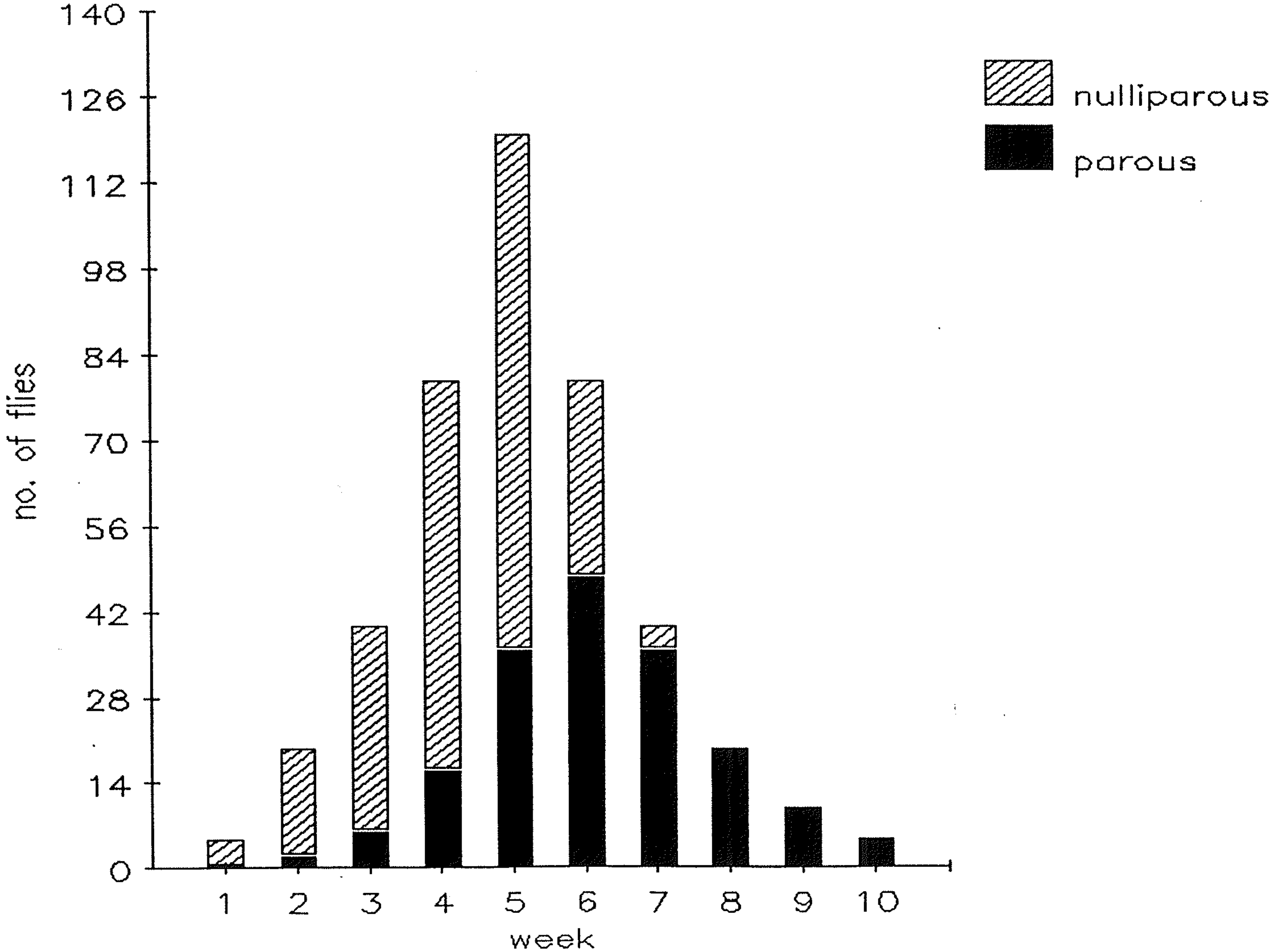

HYBOMITRA TREPIDA
TOTAL DAILY CATCH IN 4 MHFT
PERCENT PARITY
DAYS SINCE FIRST APPEARANCE

Figure 15: Seasonal variation in numbers of parous and nulliparous anautogenous individuals in a hypothetical tabanid species, based upon trends observed in species at Seven Sisters, Manitoba in 1987 and 1988.


140
126
112
98
84
70
56
42
28
14
0
no. of flies
1
2
3
4
5
6
7
8
9
10
week
nulliparous
parous

CHAPTER III

Daily Activity of several horse fly species (Diptera: Tabanidae: *Hybomitra* spp.) in Manitoba

INTRODUCTION

Females of most Nearctic tabanid species actively host-seek only during the daylight hours, unlike mosquitoes (Culicidae) and no-see-ums (Ceratopogonidae), which are primarily crepuscular or nocturnal. Only a very few North American tabanid species are active during hours of twilight or darkness (Pechuman 1981, Hollander and Wright 1980). Throughout the daylight hours, the host-seeking activity of female tabanids can vary considerably, with not all tabanid species being equally active at all times of the day. Hollander and Wright (1980) described differences among the daily activity cycles of eight Oklahoma species, and comparable variation in activity patterns was noted among salt-marsh tabanids in North Carolina (Dale and Axtell 1975).

Activity patterns are affected by climatic factors. Flight activity of tabanids may be suppressed if ambient conditions are unfavourable: temperature, light intensity, and wind speed appear to be the most important climatic variables in this regard (Appendix C). Tabanid host-seeking activity does not occur when temperature falls below certain levels (Dale and Axtell 1975, Baribeau and Maire 1983). Most authors report little or no flight activity below 20° C (Anderson et al. 1974, Blickle 1959), although actual thresholds vary. For some tabanid species flight activity may occur at temperatures as low as 11 or 12° C (Twinn et al. 1948, Lane et al. 1983). Horse fly activity does not generally occur in darkness (Roberts 1974, Anderson 1971), therefore some threshold level of light intensity must also exist, although there are no published estimates of this level.

Tabanids are strong fliers, and in several studies wind speed did not affect tabanid flight activity significantly (e.g. Alverson and Noblet 1977). Only in windy areas, such as seashores (Joyce and Hansens 1968, Catts and Olkowski 1972, Lane et al. 1983) and mountain tops (Leprince et al. 1983), have high winds (e.g. >30 km/hr) been reported to suppress tabanid activity. In addition to temperature, light intensity, and wind speed, other climatic factors such as relative humidity, barometric pressure, cloud cover, and precipitation have been correlated with tabanid flight activity (Appendix C), although these factors are not known to suppress activity completely.

It is difficult to distinguish correlation from causation when considering the effects of the various factors on tabanid activity, since changes in many climatic variables are interrelated (e.g. increasing sunlight often is accompanied by a coincident temperature increase). Some authors (Appendix C) have proposed models whereby diurnal variation in tabanid activity can be accounted for by coincident changes in climatic factors. In this context, interspecific variation in activity patterns is the result of differences among species in responses to climatic variables. There is evidence, however, that daily activity patterns of tabanids are to a large degree independent of extrinsic (e.g. climatic) factors, and are governed instead by an internal diel rhythm (Kaufman and Sorokina 1986). If this is the case, then climatic variables affect activity only if they are unfavourable, by reducing activity within the context of the daily cycle.

It was the main purpose of this study to document the patterns of daily activity, based upon trap captures, for host-seeking females of the abundant tabanid species at a location in s.e. Manitoba, where these insects are of particular importance as livestock pests. An additional objective was to measure the minimum levels of temperature and light intensity at which activity occurred, by recording these variables at the onset and cessation of daily activity of the different species present. Lastly, a comparison was made between the daily activity patterns and temperature threshold estimates for horse flies at the s.e. Manitoba site and conspecifics some 900 km north in Churchill, Manitoba, to determine whether northern flies respond differently to climatic factors (particularly temperature) than their southern counterparts.

MATERIALS AND METHODS

Study Areas and Data Collection

Seven Sisters (50° 7'N 96° 2'W):

Tabanids were trapped in 1987 and 1988 at the Seven Sisters Grassland Project, approximately 10 km southwest of the town of Seven Sisters (Fig. 16) in s.e. Manitoba, Canada. The grassland project consists of 74.5 ha of open pasture, which is surrounded almost entirely by spruce/ fir/aspen forest. Much of the area around the site is underlain by peat soil, which is poorly drained and supports numerous bogs and ditches suitable for tabanid breeding habitat.

Tabanid catches in canopy-type traps are known to provide a good index of coincident numbers of tabanids attacking cattle (Hollander 1980), and for this reason, Manitoba Horse Fly Traps (MHFT's) (Thorsteinson et al. 1964) were used to index hourly levels of tabanid host-seeking activity. In 1987, one MHFT with a removable wire-mesh catch box was used to catch Tabanidae. This trap was located at the southern edge of the pasture area (Chapter I,

Fig. 1) and was emptied each hour on the half-hour from 0530-0830 hr CDT to 1730-2230 hr CDT. Trapping was carried out for a total of 17 days between 30 May to 8 July, 1987. Flies in each hourly sample were killed by freezing and identified to species.

In 1988, four MHFT's were used in hourly tabanid trapping and these were located south of the pasture area, adjacent to a woodlot (Chapter I, Fig. 1). Traps were set an average of four days per week, from 31 May to 7 July, from 0530 hr CDT until 2230 hr. In 1988, temperature and light intensity data were recorded at the beginning of each hourly trapping interval in a field adjacent to the study area. Temperature was recorded using a Stevenson screen-enclosed recording thermometer (Wexler^R Type 06MIC5B), with the temperature probe positioned close to ground level. Light intensity was recorded using a portable light meter (Li-Cor^R Model LI-185). The photoconductive cell of the light meter was positioned pointing upwards perpendicular to the ground.

Churchill (58° 46'N 96° 11'W):

Tabanids were collected in 1988 on the grounds of the Churchill Northern Studies Centre, approximately 20 km east of the town of Churchill (Fig. 16) in Northern Manitoba. Traps were placed in a dry tundra-spruce forest transition area. One trap was located in a treed area, while the other three were placed on open tundra adjacent to the forest (Fig. 17). The terrain for several kilometers around the study area was largely wet tundra.

Hourly trapping was conducted at the Churchill site from 0530 CDT until 2230 CDT, 27 July to 5 August, 1988. Apart from the locale and trap placement, the methodology and equipment employed at Churchill were similar to that at Seven Sisters in 1988.

Daily Activity Patterns

Because of the seasonal succession of tabanid species at the Seven Sisters site (see Chapter II), all species were not equally abundant in trap catches over the entire trapping period. For this reason, only sampling days falling within a species' peak interval (i.e. an interval about the date of peak capture for each species, during which 2/3 of all flies of that species were caught) were considered in the analysis (Table 5). Outside each species' peak interval, flies may have been absent from hourly trap catches due to low numbers, rather than due to low activity levels. On sampling days within the peak interval, on which the sum of the hourly catches in a given trap exceeded 20 flies (Table 5), hourly catches were expressed as percentages of the total day's catch in that trap. The mean percentage of daily flight activity which occurred during each hour was then calculated and plotted to obtain the mean daily activity pattern for each species. For the same hourly intervals, mean temperature and light intensity values were also calculated and plotted.

Estimation of Thresholds

In 1988, the time, temperature and light intensity at the beginning of the hour in which flies were first trapped, and at the end of the hour wherein the last flies were caught, were determined for each trap-day (in each trap on each day) for each tabanid species during the species' periods of peak abundance. The mean of these values was then calculated, in order to obtain the average time, temperature, and light at the beginning and end of each species' daily activity period.

Frequency distributions

The number of trap-hours (within each species' peak interval) at which each value of temperature and light intensity were recorded were summed for all intervals trapped, whether or not tabanid activity occurred. These values were compared with numbers of trap-hours at each temperature and light intensity when tabanids were present in trap catches. The range of temperature and light values where tabanids of each species were active, relative to the overall range of values encountered, were thus determined. It was then possible to determine the relative degree of tabanid activity which occurred at each temperature and light intensity level encountered.

RESULTS

Daily Patterns of Tabanid Activity, Temperature, and Light Intensity

At Seven Sisters, nine horse fly species were caught in numbers sufficient to determine patterns of daily activity (Table 5). In 1988, trapping effort was much greater and more consistent throughout the summer than in 1987, and temperature and light intensity data, coincident with sampling intervals, were recorded. For these reasons only 1988 daily activity patterns will be considered. The 1987 patterns are presented in Appendix D.

Daily temperature and light intensity profiles were similar among the sampling periods for the different tabanid species. Generally, temperatures were coolest in early morning, highest in mid afternoon, and dropped again in the evening. Light intensity also varied over the course of the day, and was lowest at dawn and dusk.

Peak numbers of H. epistates were trapped relatively early in the day, at 1030 hr, and generally this species was active between 0630 and 1830 hr (Fig. 18). Peak catches of H. pechumani occurred somewhat later than H. epistates, at 1230 hr. Very few H. pechumani were observed before 1030 hr (Fig. 19), but as with H. epistates, activity of H. pechumani usually ceased in the evening around 1830 hr.

Peak catches of other species at the site occurred during the afternoon, as follows: H. zonalis (peak at 1430 hr, Fig. 20), H. arpadi (peak at 1530 hr, Fig. 21), H. lasiophthalma and H. illota (peak at 1630 hr, Figs. 22,23), and H. affinis (peak at 1730 hr, Fig. 24). For all of these species, catches increased gradually throughout the day until the peak, after which they declined fairly rapidly. Very few H. arpadi or H. zonalis were caught after 1830 hr, whereas H. lasiophthalma and H. affinis were active until after 2130 hr on several occasions.

For H. lurida and H. nitidifrons nuda, peak activity did not occur until very late in the afternoon, at 1830 hr (Figs. 25, 26). These species generally first appeared in trap catches in early morning, with numbers steadily increasing throughout the day until the peak. Following the peak, trap catches declined very rapidly until 2130, after which no flies were caught.

At Churchill, only two tabanid species, H. affinis and H. frontalis, were common enough for daily activity patterns to be determined. Temperatures during the study period at Churchill were generally much cooler than at Seven Sisters, although daily patterns of light intensity were similar at the two sites. As at Seven Sisters, peak catches of H. affinis at Churchill occurred in late afternoon (1630 hr, Fig. 27). Peak numbers of H. frontalis at Churchill were generally trapped at 1230 hr (Fig. 28), much earlier than peak catches of H. affinis.

Estimation of Thresholds

Onset of daily activity (as determined by trap catches) almost always occurred in the morning hours, whereas cessation usually occurred in the late afternoon or early evening. The average time of first capture, however, varied somewhat among species (Table 6). At Seven Sisters, on average, H. lurida was the earliest species active, at 0730 hr, followed by H. lasiophthalma and H. nitidifrons nuda at 0830 hr, H. affinis and H. arpadi at 0930 hr, H. epistates, H. illota and H. pechumani at 1030 hr, and lastly H. zonalis at 1130 hr. At Churchill, H. frontalis were usually first trapped at 0930 hr, and H. affinis at 1030 hr.

In late afternoon, the time after which no captures were made also appeared to vary among species (Table 6), although at Seven Sisters, activity for all species usually ceased between 1830 and 2030 hr. At Churchill, _H_. _frontalis_ was generally not active after 1730, whereas _H_. _affinis_ was usually active until 1830.

At Seven Sisters, average temperatures at the onset of activity ranged from 19° C for _H_. _affinis_, to 24° C for _H_. _illota_ (Table 6). At Churchill, temperatures at the onset of activity were considerably lower. First daily catches of _H_. _affinis_, on average, occurred at 15° C, and catches of _H_. _frontalis_ were usually first made at 14° C.

In the late afternoon or early evening, temperatures below which flies were no longer caught were, on average, similar to morning threshold temperatures below which no activity occurred (Table 6). Average light intensities at the onset of tabanid activity were usually much higher in the morning than those recorded at the cessation of activity in the evening (30000-70000 lux _vs_ 3000-30000 lux) (Table 6).

Frequency Distributions

Temperatures encountered at Seven Sisters during hours sampled ranged between 0 and 34° C. Within the sampling period of each individual species, a subset of this overall range was realized. Flies were only trapped when temperature exceeded a certain value, which varied interspecifically (Figs. 29-31). In most cases, flies were trapped in very few trap-hours sampled at temperatures immediately above this minimum value, but as temperature increased, tabanids were caught in an increasing proportion of trap-hours sampled. At the highest temperatures, tabanids were trapped during virtually all trap-hours sampled.

Hybomitra arpadi was trapped during one trap-hour at 18° C, but flies were caught in the majority (i.e. >50%) of trap-hours sampled where temperature was at or above 24° C (Fig. 15a). For *H. pechumani* and *H. epistates* respectively, activity occurred at 15 and 16° C, but flies were not caught in the majority of trap-hours sampled until temperatures reached 23 and 25° C (Figs. 15b, 16c). *Hybomitra lasiophthalma* and *H. nitidifrons nuda* were both present in catches at 12° C, but were present during most trap-hours sampled only when temperature met or exceeded 20° C (Figs. 15d, 16b). Only limited data were available for *H. lurida* (only 3 days of data were analyzed), however this species was not caught at temperatures below 16° C, and was active in the majority of trap-hours sampled when temperatures reached 19° C (Fig. 16a).

Catches of *H. zonalis* and *H. illota*, respectively, were only made when temperatures reached 16 and 17° C (Figs. 15c,16d). *Hybomitra zonalis* and *H. illota* were not present consistently in hourly trap-catches, and these species were only caught during the majority of trap-hours sampled when temperatures were very high (> 28 and 27° C, respectively). The absence of these species in trap-catches at lower temperatures may have been the result of low numbers of flies at the site (even during peak season; see Chapter II), or because flies present were not responding to traps, rather than to a lack of flight activity.

At Seven Sisters, H. affinis was trapped only at temperatures at or above 12° C, and was caught in most trap-hours where temperatures met or exceeded 20° C. At Churchill, this species was caught when temperatures reached 9° C, and was present in the majority of trap-hours sampled where temperatures were at or above 19° C (Fig 17). Hybomitra frontalis at Churchill was caught during trap-hours when temperatures met or exceeded 6° C. When temperatures reached 19° C, flies were caught in the majority of trap-hours sampled. At Seven Sisters, H. frontalis was uncommon, and thus the probability of capture in any trap-hour was low. Hybomitra frontalis was captured only when temperatures reached 21° C. Activity may have occurred below this temperature, but was not recorded because of the rarity of the flies and their consequent low probability of capture, even under optimal conditions.

A wide range of light intensity values (between 0 and 120000 lux) was recorded, but relatively small numbers of trap-hours (4-32) occurred a each level of light intensity. Tabanids at Seven Sisters were not trapped at light intensity levels below 290 - 6600 lux. At Churchill, *H. affinis* was not trapped at light intensities below 3500 lux, and *H. frontalis* was not trapped at light intensities below 11700 lux.

DISCUSSION

Daily Activity Patterns

Host-seeking female tabanids at Seven Sisters and Churchill exhibited considerable interspecific variation in the time of day at which peak activity occurred. Species which were important pests early in the day were only of secondary importance later on, and vice versa. Comparable interspecific variation in daily activity patterns have been reported among other tabanid species, in Oklahoma (Hollander and Wright 1980), Mississippi (Roberts 1974) and North Carolina (Dale and Axtell 1975).

Although the literature is limited, the daily activity patterns described in the present study are very similar to those described for the same species in previous studies.

Hybomitra lasiophthalma at Seven Sisters displayed a flight activity pattern which was comparable to that described for this species in Oklahoma (Hollander and Wright 1980). At Churchill, my findings for H. affinis and H. frontalis parallel very closely those of Miller (1951). Apart from these 2 studies there are no other published accounts concerning the flight activity patterns of any of the 11 tabanid species studied at Seven Sisters and Churchill. Mid-day and late afternoon peaks are not unique to the Hybomitra spp. examined in this study, however. Such activity patterns have also been described for various Tabanus and Chrysops spp. in North America (Dale and Axtell 1975, Hollander and Wright 1980) and Africa (Harley 1965).

Estimates of Thresholds

It is very difficult in a field situation to estimate those levels of light and temperature below which tabanids are inactive, since flight activity levels are low at this time. Numbers of host-seeking flies fluctuate considerably during those times when flight activity is possible.

Many factors suppress or enhance flight activity. Climatic variables not measured in the present study (e.g. barometric pressure and relative humidity) may have affected flight activity. Wind may have hindered flight activity while still permitting some host-seeking to occur, or may have reduced trap efficiency.

Interspecific variation in daily activity patterns means that the probability of capturing flies varied according to species, regardless of climatic factors. Tabanid species which were uncommon were less likely to have been captured than abundant species.

Perhaps the greatest difficulty in estimating temperature or light intensity thresholds lies in separating the effects of one factor from the other. Temperature and light intensity are closely correlated with one another, and on some occasions it is impossible to determine which factor brought about the onset or cessation of activity.

Temperature

Tabanids are physiologically incapable of flight activity below certain temperatures. The precise time when this temperature is exceeded for a particular fly on a given day is a function of the nature of the microhabitat where the fly is resting, as well as ambient conditions. Flies resting in areas more exposed to sunlight have the potential to gain heat and begin activity earlier than flies in more shaded locations. Conversely, the temperature of flies in shaded locations may remain below the threshold value for considerably longer periods than for flies in sunny areas.

A thermometer reading taken at a given place and time may therefore over- or under-estimate the temperature in the microhabitat where tabanids are resting. Combined with this bias is the fact that tabanid flight activity changes with temperature. At temperatures barely above threshold levels, activity appears to be limited, and thus trap catches are low. As temperature increases and conditions become more favourable for flight, however, flies appear to host-seek further and faster, and the probability of catching them increases coincidentally. The reduction of apparent activity at low temperatures (i.e. immediately above threshold levels) may therefore reflect tabanid abundance in the vicinity of the trap, rather than the absolute presence or absence of flight activity. If, at low temperatures, few or no flies are close enough to the trap to be caught, no activity appears to occur, based upon trap-catches. On the other hand, at higher temperatures flies appear to be very active and can easily approach a trap from greater distances.

In spite of the difficulty in estimating temperature thresholds, it is apparent that there are temperatures below which tabanids are inactive, and above which most activity occurs. At Seven Sisters, tabanids were not caught below 12° C although, for most species, considerable sampling effort occurred at temperatures below this level. Some species were not caught until temperatures reached slightly higher levels (i.e. 15 - 16°). With minor interspecific variation, tabanids at Seven Sisters generally began host-seeking when temperatures reached around 20°, and ceased host-seeking activity when temperatures declined below this level in the evening (Table 4). Optimal temperatures for activity were generally above 20 - 25°, depending upon the species. Above these temperatures, flies were caught consistently during most trap-hours sampled, except for those species which were not consistently present in trap catches, even under optimal conditions, either due to rarity, or due to trap bias (i.e. H. illota, H. zonalis).

At Churchill, tabanids were active at temperatures considerably lower than the estimated threshold levels at Seven Sisters. This has likely been selected for by the generally lower daily temperatures at Churchill, since temperatures there did not often exceed 20° C. The lower temperature thresholds of the northern flies enable them to host-seek during most of the day at Churchill, whereas if these flies had temperature thresholds comparable to those of conspecifics in the south, they would be very limited in their flight activity, and thus in their ability to mate, acquire blood, and lay eggs.

While most tabanid species examined in the present and previous studies exhibit a unimodal daily activity pattern with peak activity usually occurring in the afternoon, some species, such as Tabanus abdominalis Fabr. (Roberts 1974), and T. nigrovittatus Macq. (Dale and Axtell 1975), have bimodal daily activity patterns, with early morning and late afternoon peaks. At Seven Sisters and Churchill, H. affinis on several occasions displayed such a pattern (i.e. on 4 and 1 trap-days respectively), but on most days this species had only one late afternoon activity peak. It is possible that for this, and possibly other species with late afternoon peaks, cool early morning temperatures suppress the morning activity peak.

Light Intensity

On days sampled, light intensity in the mornings was sufficient to permit tabanid activity before temperatures exceeded threshold levels. Only on two occasions, when temperatures remained high throughout the night, did the onset of activity in the morning appear to be a function of light. In the evenings, however, temperatures remained high (>20° C) even after sunset on approximately 36% of days when trapping was conducted, and on these days light was important in determining when activity stopped. This likely accounts for the great difference between the average light intensities at which activity began and ended. Tabanid activity was generally low below 5000 lux, although activity in _H_. _affinis_ was recorded at 78 lux. On over 50% of sampling days, flight activity ceased in the evening at much higher light intensities, because of temperature.

Hybomitra _frontalis_ at Churchill was active at very low temperatures and because of this, temperatures recorded in most of the trap-hours sampled exceeded the 6° C minimum threshold value. For this species, light may have been the most important factor determining onset and cessation of activity.

Threshold levels of temperature and light intensity appear to determine whether or not tabanids will be active, but in order to test the field estimates of the present study, laboratory studies must be conducted wherein the effect of only one variable on activity can be studied with all other variables held constant. As well, monitoring of temperature at the microhabitat level is necessary, to obtain a more accurate picture of the temperatures at which tabanids fly.

Temperature thresholds differ between northern and southern flies of the same species. In view of the much lower temperatures at the northern site, differences in temperature thresholds are not surprising, and lead me to wonder whether similar differences exist amongst populations of other tabanid species with broad latitudinal ranges.

Table 5: Periods of peak activity[1], numbers of trap-days[2], numbers of trap-hours, and numbers of days on which total of hourly catches exceeded 20 flies for common tabanid species at Seven Sisters, Manitoba in 1987 and 1988, and at Churchill, Manitoba in 1988.

Species	Peak Period	Trap-days Sampled	Trap-hrs Sampled	Trap-days when total catch was > 20 flies
1987 (Seven Sisters)				
H. affinis	07Jun-28Jun	11	161	11
H. arpadi	31May-20Jun	9	125	2
H. epistates	12Jun-30Jun	10	149	10
H. illota	31May-20Jun	10	140	6
H. lasiophthalma	31May-20Jun	9	125	9
H. lurida	28May-07Jun	3	39	0
H. nitidifrons nuda	25May-07Jun	3	39	3
H. pechumani	16Jun-04Jul	10	153	10
H. zonalis	31May-22Jun	10	140	7
1988 (Seven Sisters)				
H. affinis	09Jun-01Jul	48	804	23
H. arpadi	10Jun-24Jun	32	532	11
H. epistates	10Jun-01Jul	44	736	22
H. illota	30May-17Jun	52	868	8
H. lasiophthalma	02Jun-21Jun	44	732	36
H. lurida	25May-02Jun	12	204	12
H. nitidifrons nuda	30May-17Jun	44	732	28
H. pechumani	20Jun-12Jul	39	618	19
H. zonalis	13Jun-01Jul	48	804	7
1988 (Churchill)				
H. affinis	27Jul-15Aug	36	607	16
H. frontalis	27Jul-15Aug	36	607	7

[1] period of peak activity:

a) at Seven Sisters = period of days, centered on the day of peak activity, in which 2/3 of all activity occurred;

b) at Churchill = all days on which sampling was carried out, assuming the seasonal activity pattern of tabanids at Churchill was similar in 1988 to the pattern described by Miller (1951).

[2] Hourly samples were taken with one trap in 1987, whereas four traps were used in 1988. Thus, in 1988, 4 trap-hours occurred each hour, but only one trap hour per hour occurred in 1987. The same is true for trap-days.

Table 6: Average time, temperature, and light intensity (L.I.), and range of times, temperatures and light intensity values encountered at onset and cessation of activity for selected tabanid species at Seven Sisters, Manitoba, and Churchill, Manitoba in 1988.

Species	Average at onset of activity						Average at cessation of activity					
	TIME (hr)	range	TEMP (°C)	range	L.I. (lux)	range	TIME (hr)	range	TEMP (°C)	range	L.I. (lux)	range
Seven Sisters												
H. affinis	9:30	5:30-16:30	19	12-25	54927	810-105000	19:30	16:30-21:30	18	9-24	13358	72-92000
H. arpadi	9:30	6:30-15:30	22	18-24	67057	5200-120000	18:30	15:30-21:30	20	17-27	33288	72-91000
H. epistates	10:30	6:30-15:30	22	18-24	67057	5200-120000	18:30	14:30-20:30	21	17-27	36232	2300-99000
H. illota	10:30	5:30-16:30	24	17-34	67436	810-120000	19:30	15:30-21:30	22	12-31	26203	150-98000
H. lasiophthalma	8:30	5:30-12:30	20	14-28	43332	810-102000	20:30	18:30-21:20	17	9-24	8544	72-45000
H. lurida	7:30	6:30-10:30	20	16-25	34617	1080- 81000	20:30	19:30-21:30	23	19-25	3560	150- 9000
H. nitidifrons nuda	8:30	6:30-15:30	20	14-26	46383	6900-120000	19:30	15:30-21:30	19	9-25	1630	150-92000
H. pechumani	10:30	6:30-17:30	22	15-26	61670	2300-120000	18:30	14:30-21:30	22	19-27	32024	390-98000
H. zonalis	11:30	5:30-17:30	23	16-30	66088	810-114000	18:30	15:30-21:30	22	6-29	33199	150-93000
Churchill												
H. affinis	10:30	7:30-13:30	15	9-23	50693	5400-105000	18:30	11:30-21:30	17	12-21	22784	225-83000
H. frontalis	9:30	7:30-13:30	14	6-23	43602	11700-105000	17:30	13:30-21:30	17	13-21	24400	1620-52000

Figure 16: Locations of study areas in Manitoba, Canada.

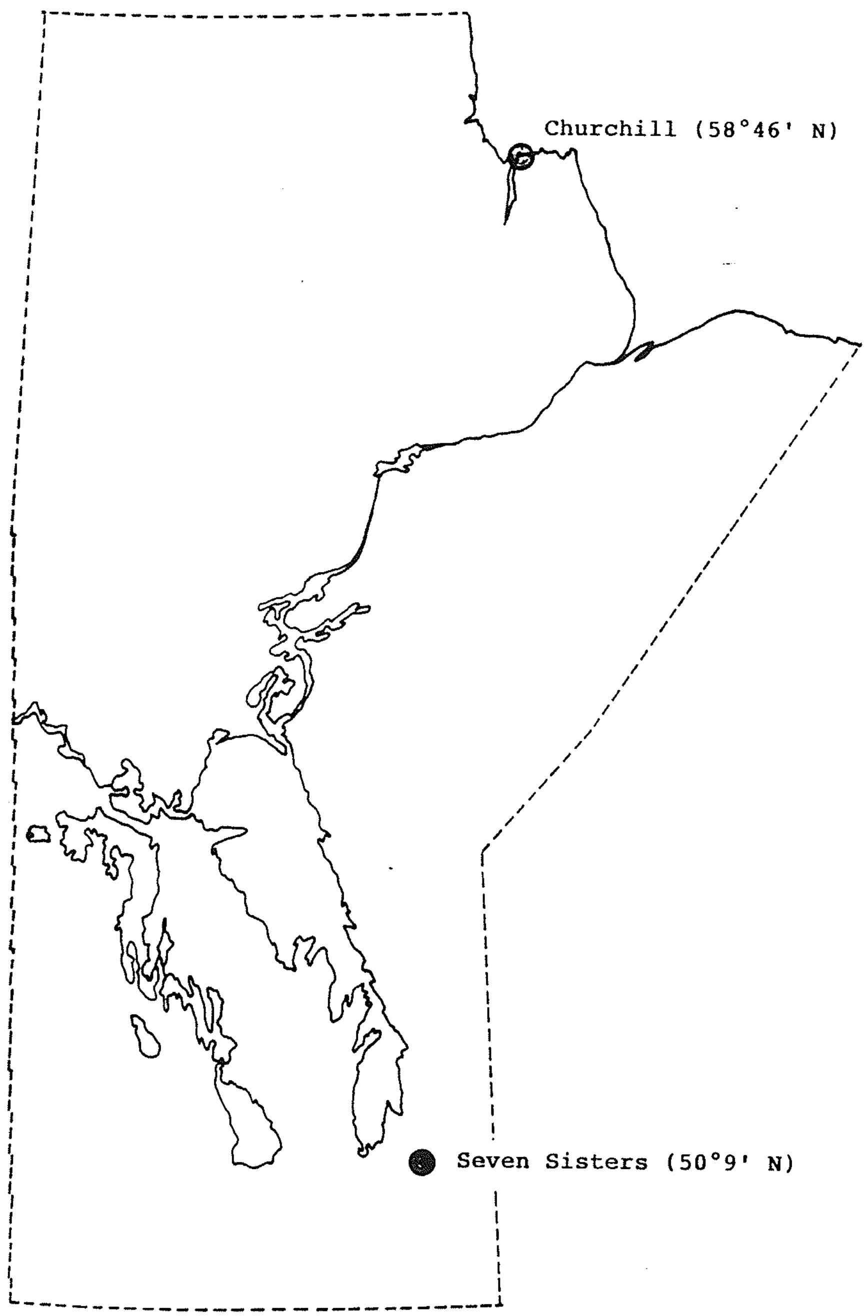

Churchill (58°46' N)
Seven Sisters (50°9' N)

Figure 17: Map of study area at Churchill, Manitoba.

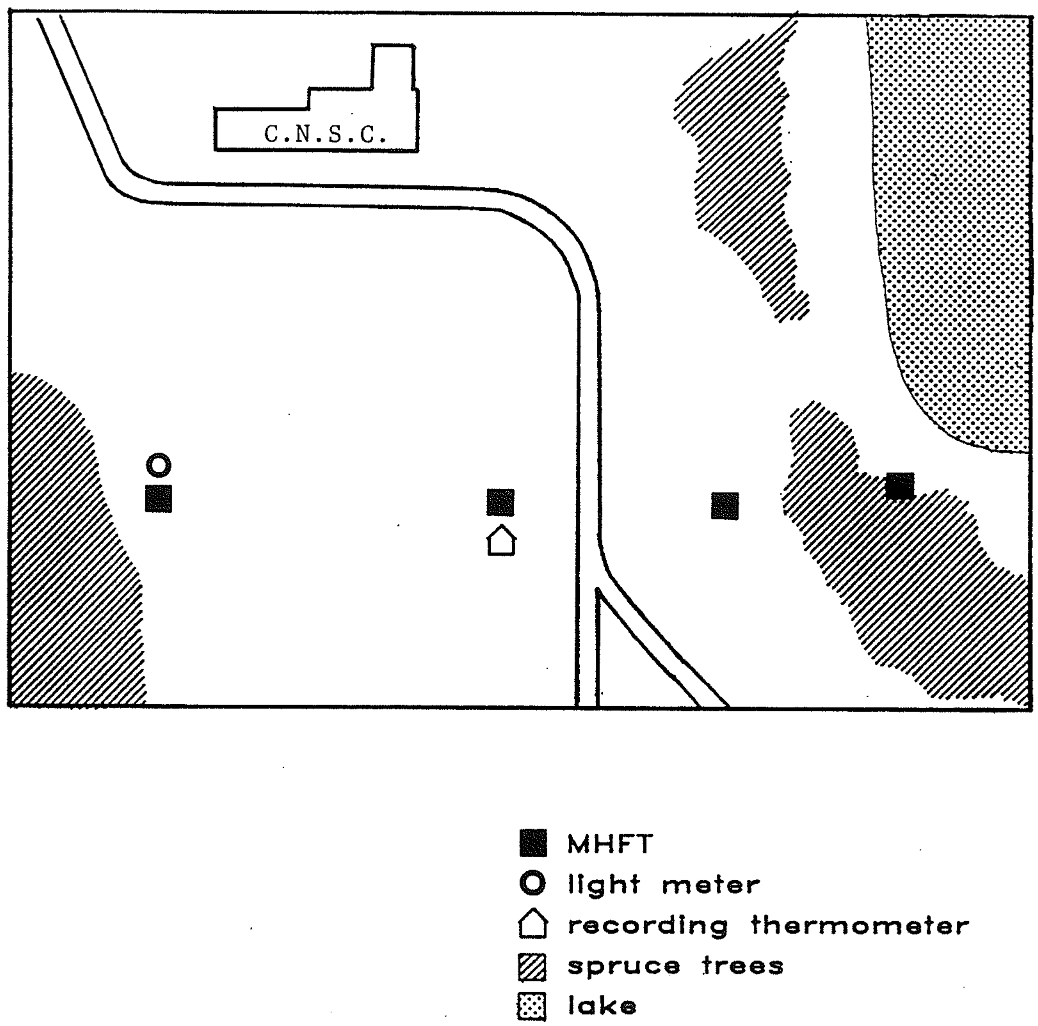

C.N.S.C.
MHFT
light meter
recording thermometer
spruce trees
lake

Figure 18: Mean (± standard error) profile of hourly percentages of total daily catch of Hybomitra epistates, and coincident mean (± standard error) hourly temperature and light intensity profiles at Seven Sisters, Manitoba, in 1988.

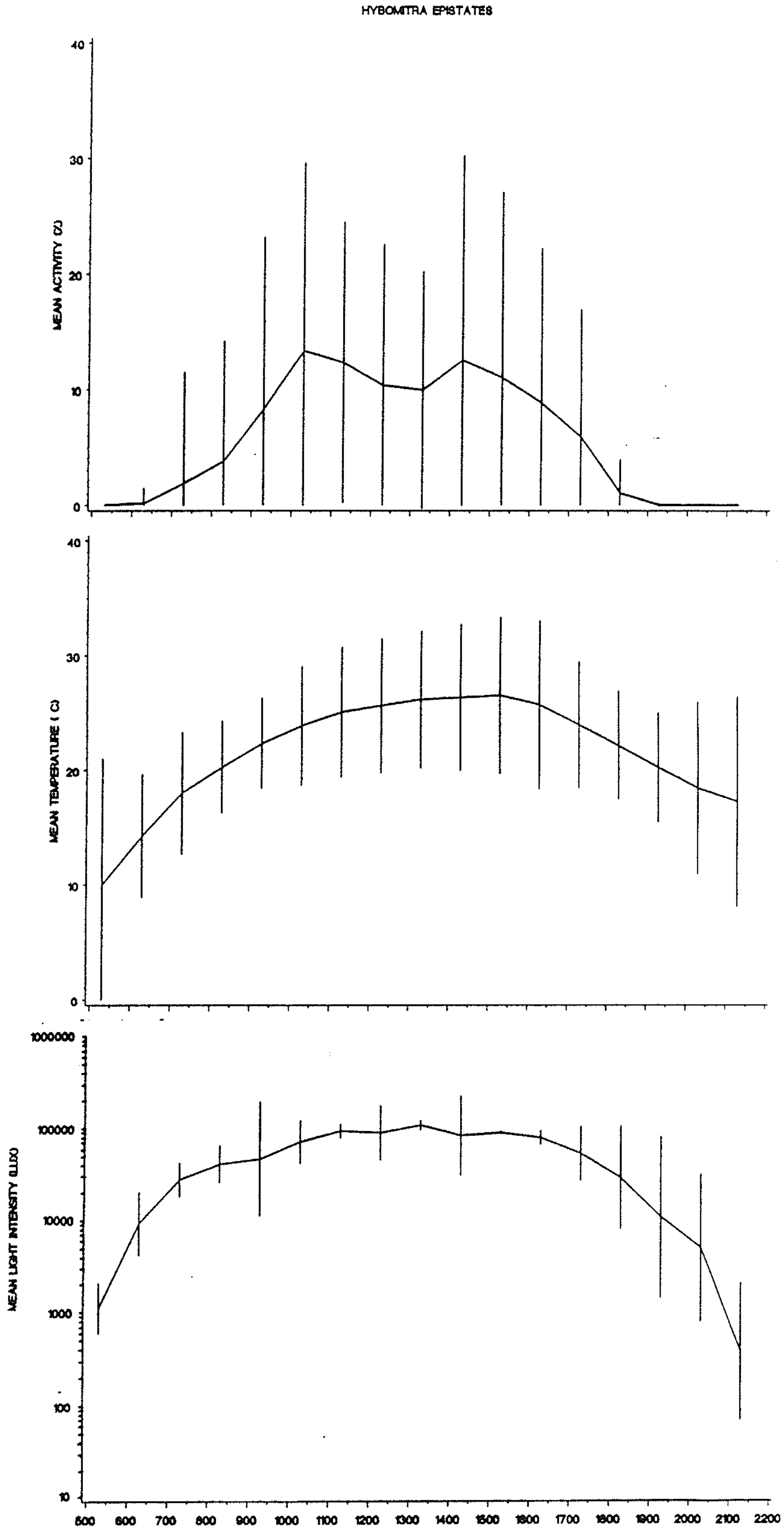

HYBOMITRA EPISTATES
MEAN ACTIVITY (%)
MEAN TEMPERATURE (C)
MEAN LIGHT INTENSITY (LUX)
TIME (HR)
0
10
20
30
40
10
100
1000
10000
100000
1000000
500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200

Figure 19: Mean (± standard error) profile of hourly percentages of total daily catch of Hybomitra pechumani, and coincident mean (± standard error) hourly temperature and light intensity profiles at Seven Sisters, Manitoba, in 1988.

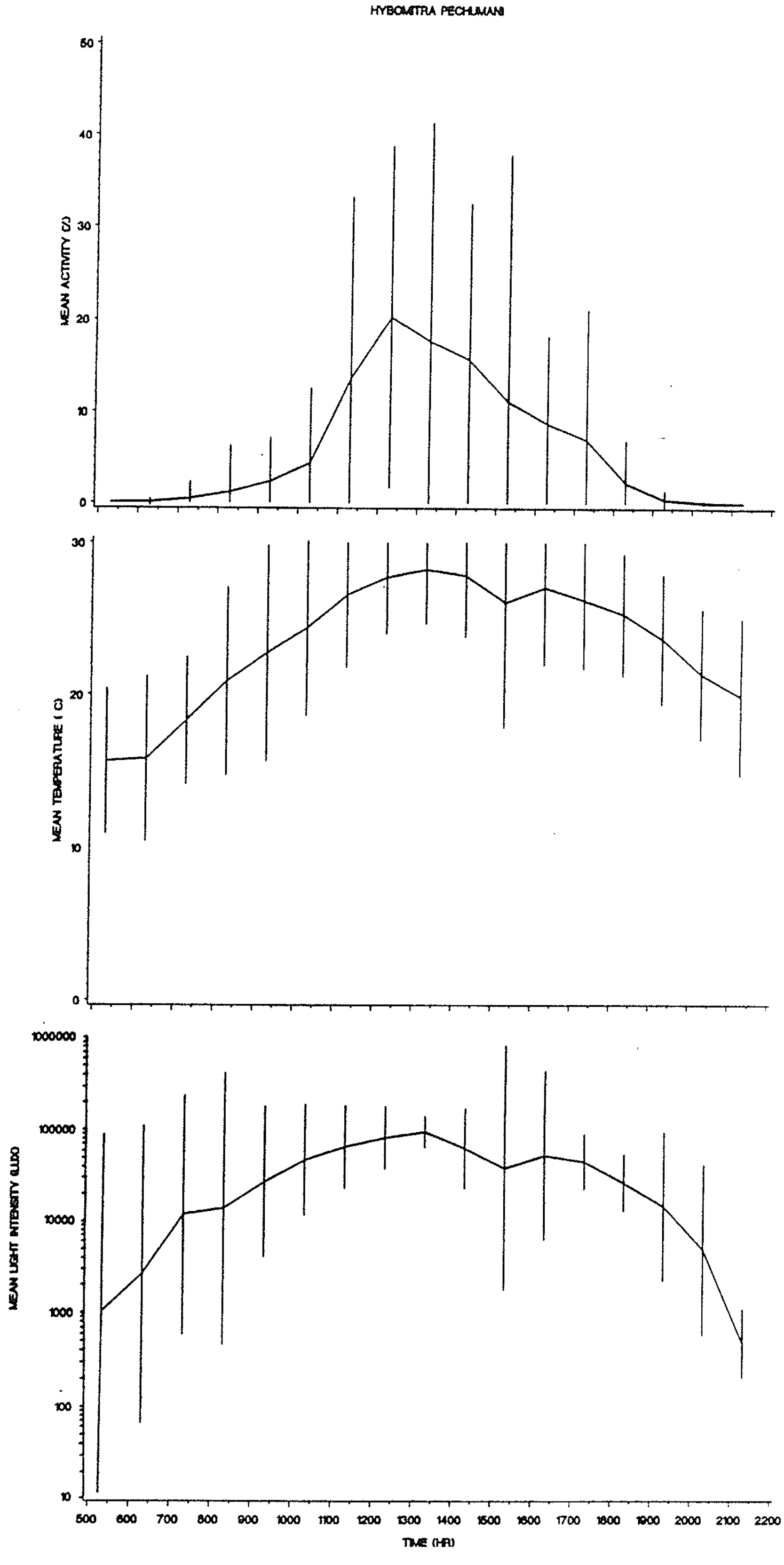

HYBOMITRA PECHUMANI
MEAN ACTIVITY (%)
MEAN TEMPERATURE (C)
MEAN LIGHT INTENSITY (LUX)
TIME (HR)
500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200

Figure 20: Mean (± standard error) profile of hourly percentages of total daily catch of *Hybomitra arpadi*, and coincident mean (± standard error) hourly temperature and light intensity profiles at Seven Sisters, Manitoba, in 1988.

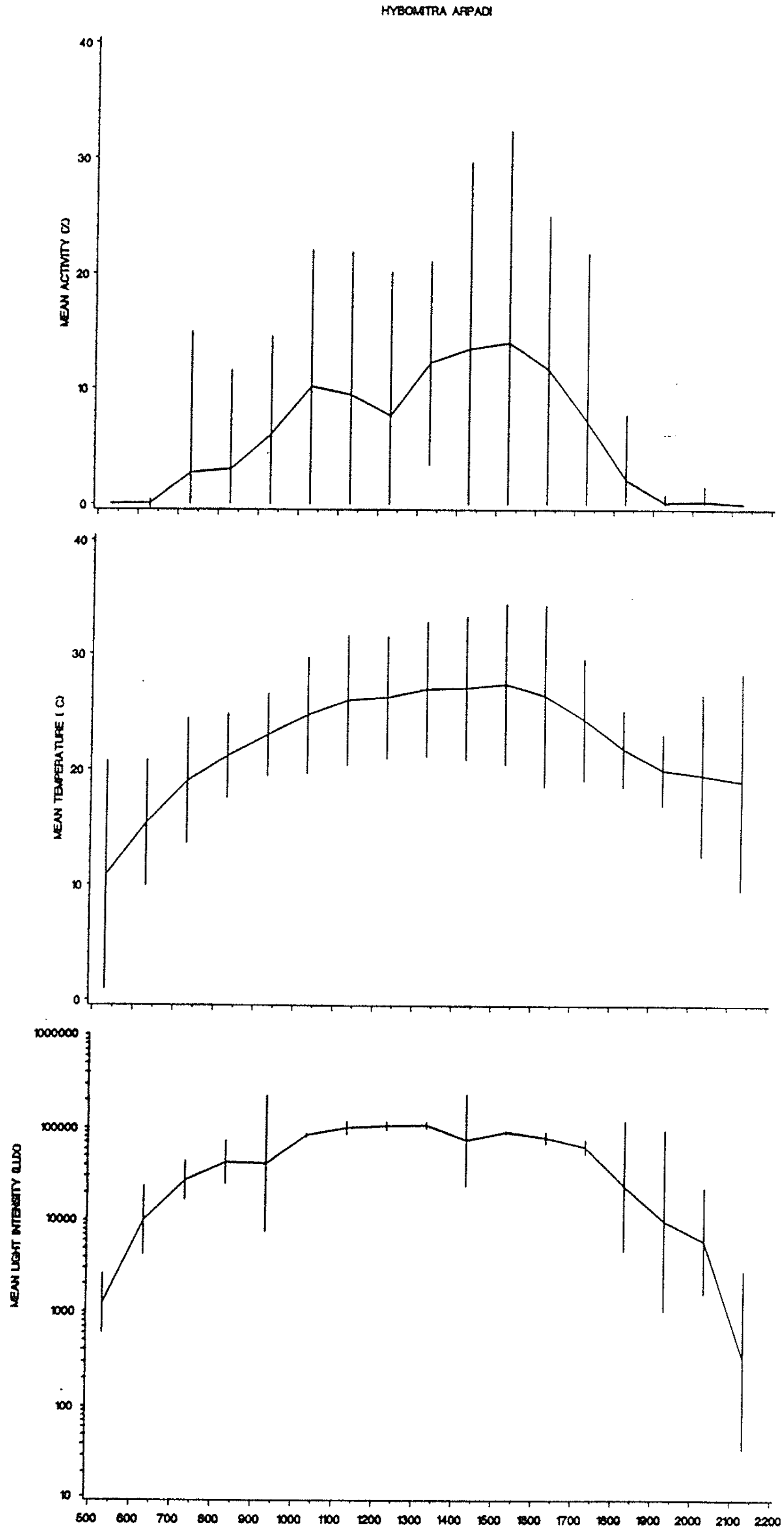

HYBOMITRA ARPADI
MEAN ACTIVITY (%)
MEAN TEMPERATURE (C)
MEAN LIGHT INTENSITY (LUX)
TIME (HR)
0
10
20
30
40
10
100
1000
10000
100000
1000000
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200

Figure 21: Mean (± standard error) profile of hourly percentages of total daily catch of *Hybomitra zonalis*, and coincident mean (± standard error) hourly temperature and light intensity profiles at Seven Sisters, Manitoba, in 1988.

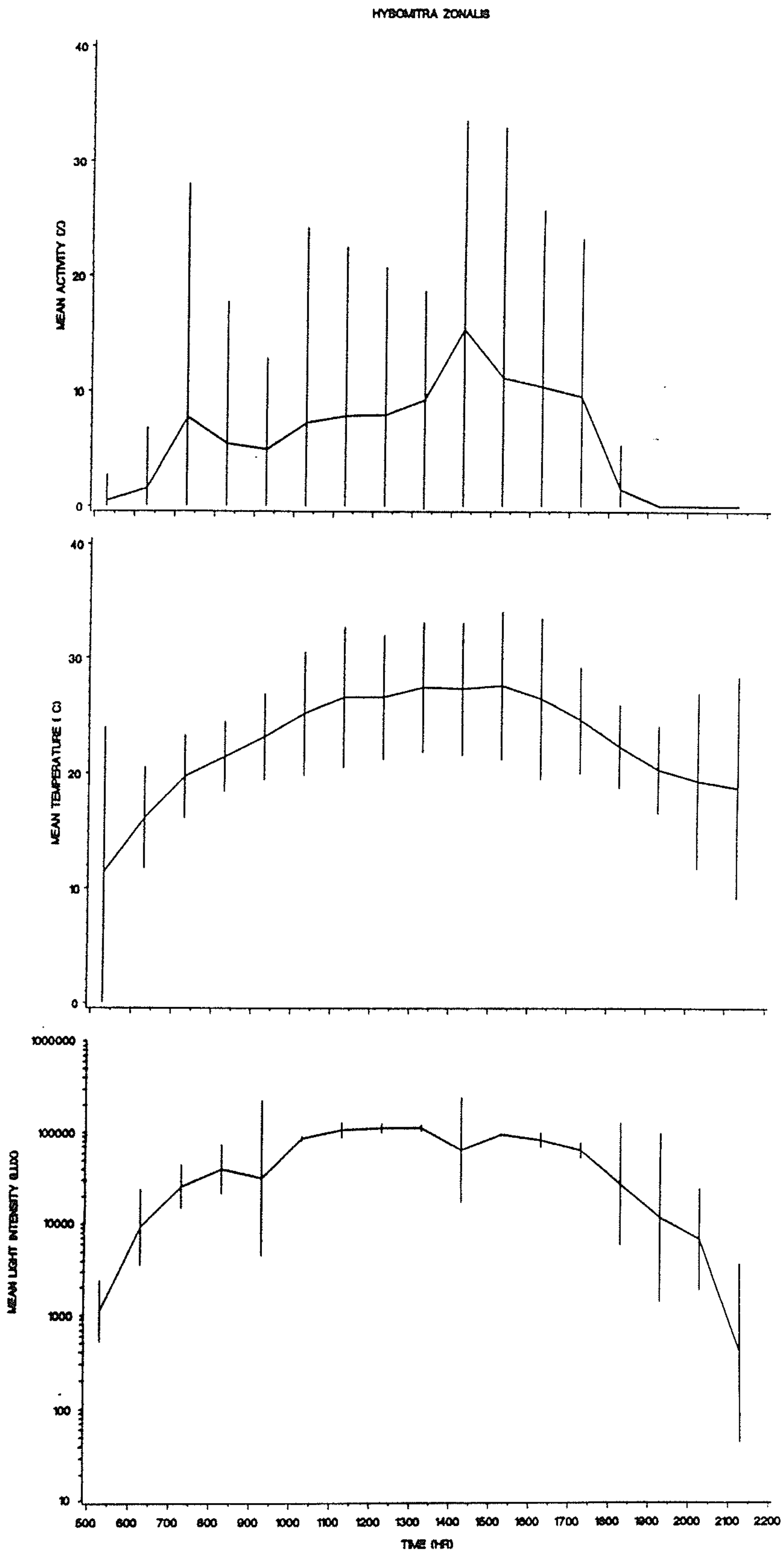

HYBOMITRA ZONALIS
MEAN ACTIVITY (%)
MEAN TEMPERATURE (C)
MEAN LIGHT INTENSITY (LUX)
TIME (HR)
0
10
20
30
40
10
100
1000
10000
100000
1000000
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200

Figure 22: Mean (± standard error) profile of hourly percentages of total daily catch of *Hybomitra lasiophthalma*, and coincident mean (± standard error) hourly temperature and light intensity profiles at Seven Sisters, Manitoba, in 1988.

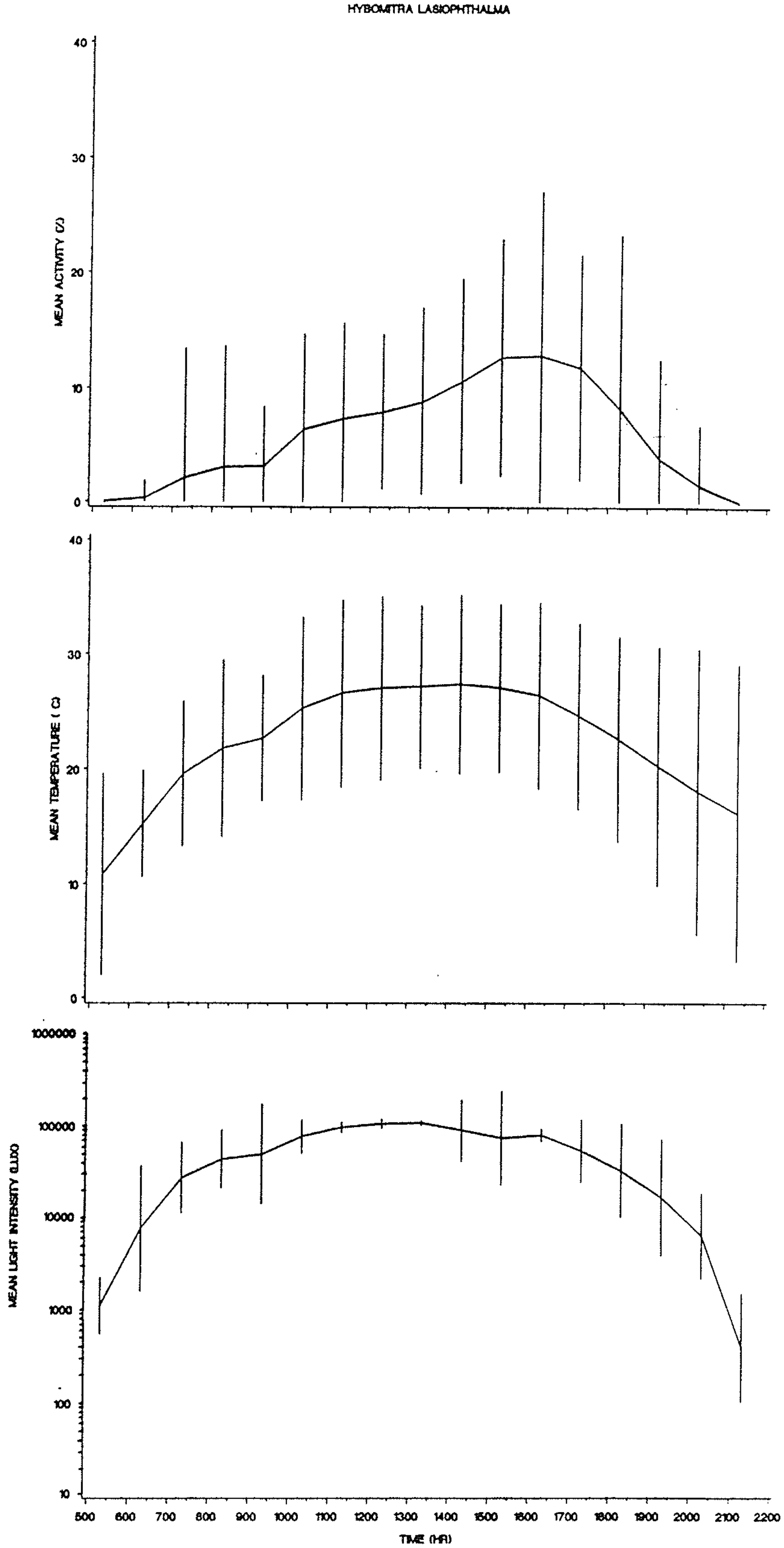

HYBOMITRA LASIOPHTHALMA
MEAN ACTIVITY (%)
MEAN TEMPERATURE (°C)
MEAN LIGHT INTENSITY (LUX)
TIME (HR)

Figure 23: Mean (± standard error) profile of hourly percentages of total daily catch of *Hybomitra affinis*, and coincident mean (± standard error) hourly temperature and light intensity profiles at Seven Sisters, Manitoba, in 1988.

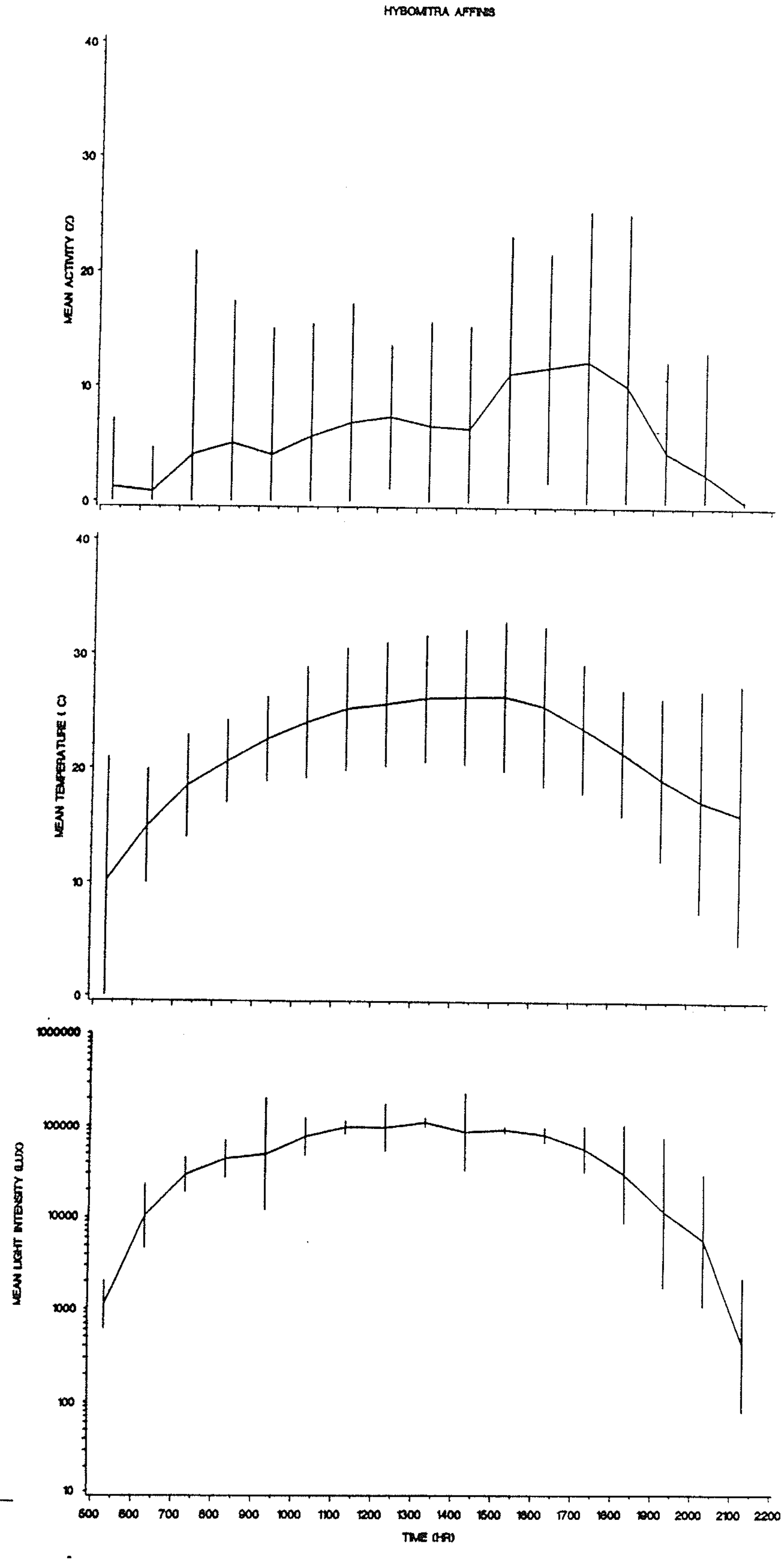

HYBOMITRA AFFINIS
MEAN ACTIVITY (%)
MEAN TEMPERATURE (C)
MEAN LIGHT INTENSITY (LUX)
TIME (HR)

Figure 24: Mean (± standard error) profile of hourly percentages of total daily catch of *Hybomitra illota*, and coincident mean (± standard error) hourly temperature and light intensity profiles at Seven Sisters, Manitoba, in 1988.

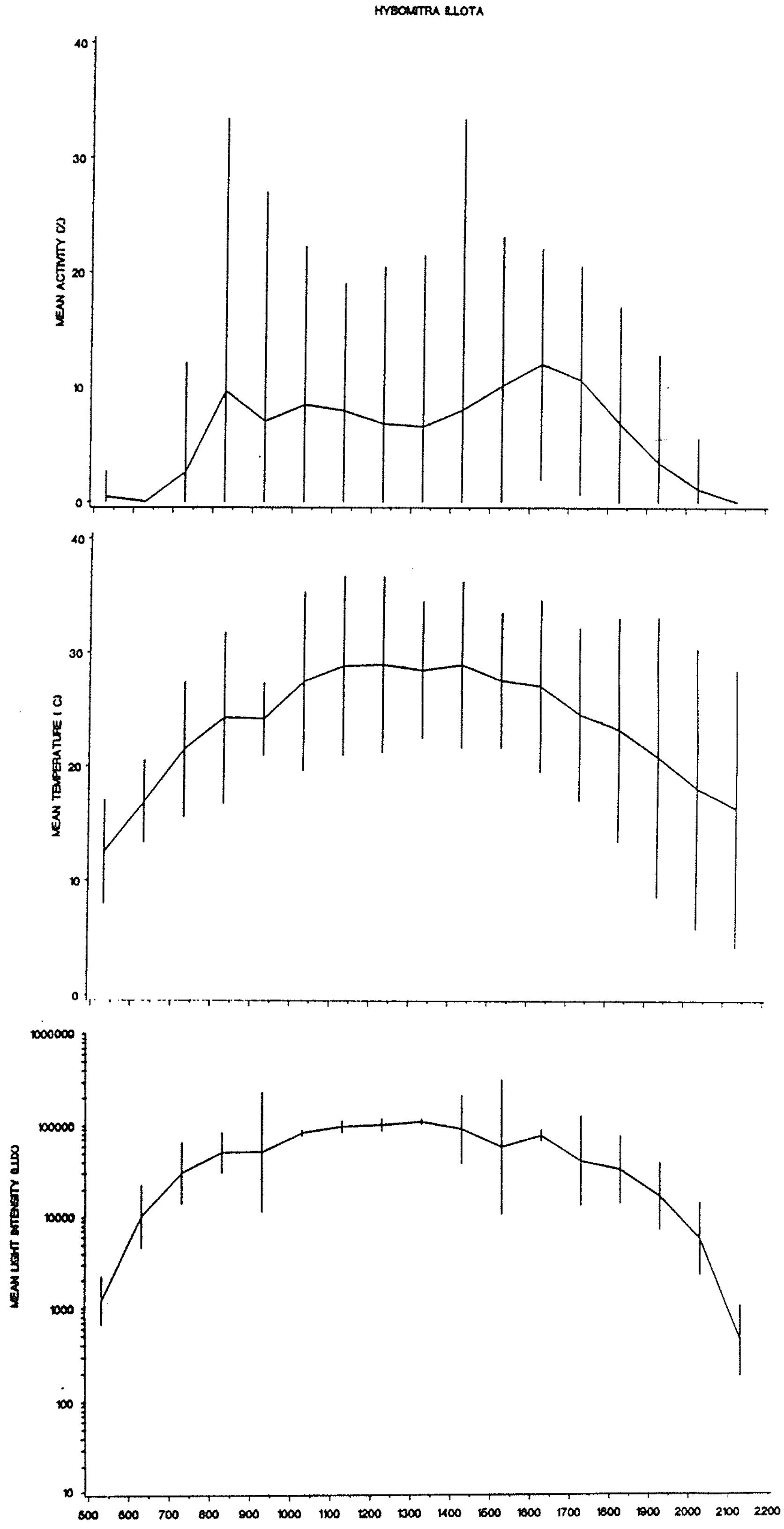

HYBOMITRA ILLOTA
MEAN ACTIVITY (%)
MEAN TEMPERATURE (C)
MEAN LIGHT INTENSITY (LUX)
TIME (HR)
0
10
20
30
40
10
100
1000
10000
100000
1000000
500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200

Figure 25: Mean (± standard error) profile of hourly percentages of total daily catch of *Hybomitra lurida*, and coincident mean (± standard error) hourly temperature and light intensity profiles at Seven Sisters, Manitoba, in 1988.

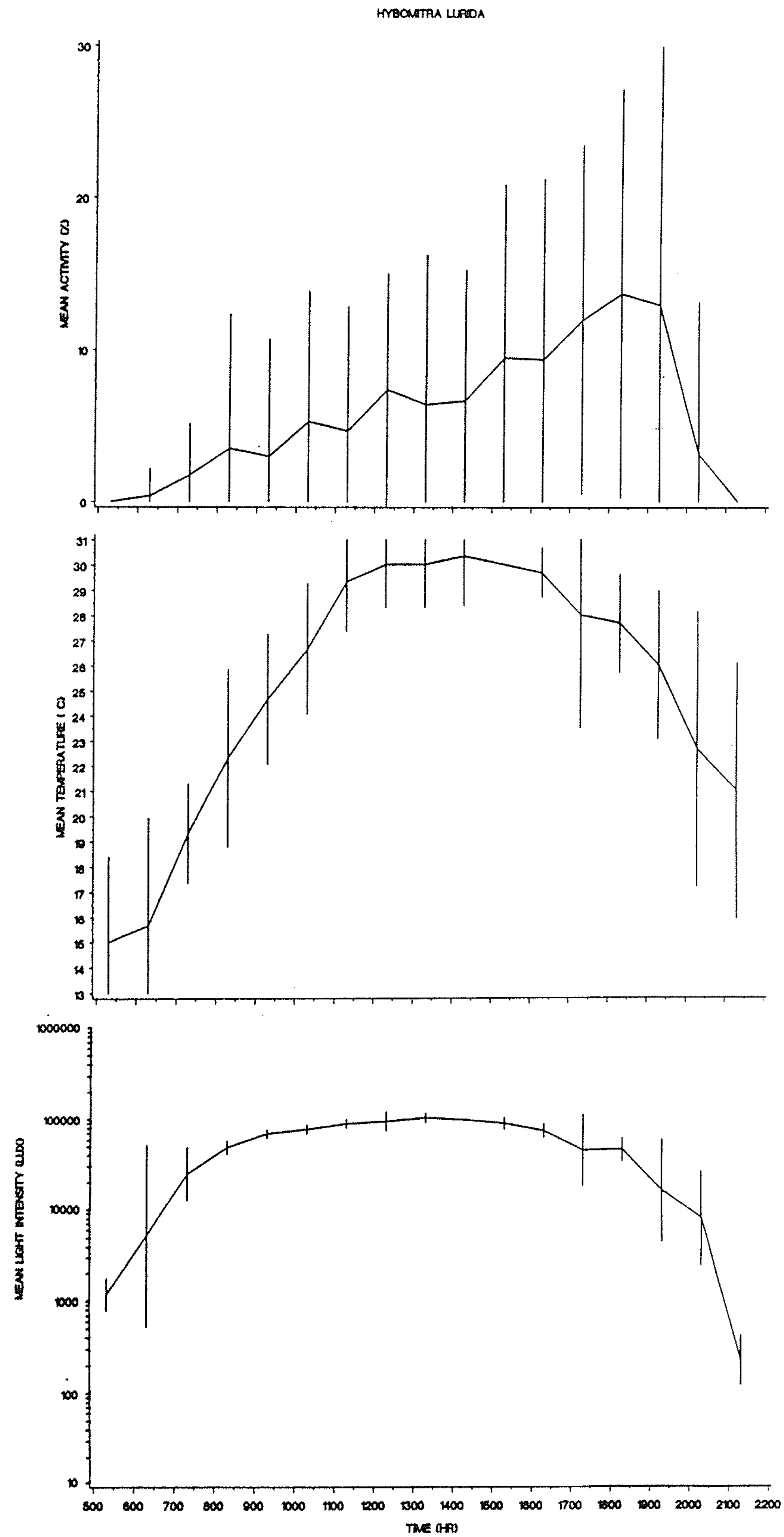

HYBOMITRA LURIDA
MEAN ACTIVITY (%)
MEAN TEMPERATURE (C)
MEAN LIGHT INTENSITY (LUX)
TIME (HR)

Figure 26: Mean (± standard error) profile of hourly percentages of total daily catch of Hybomitra nitidifrons nuda, and coincident mean (± standard error) hourly temperature and light intensity profiles at Seven Sisters, Manitoba, in 1988.

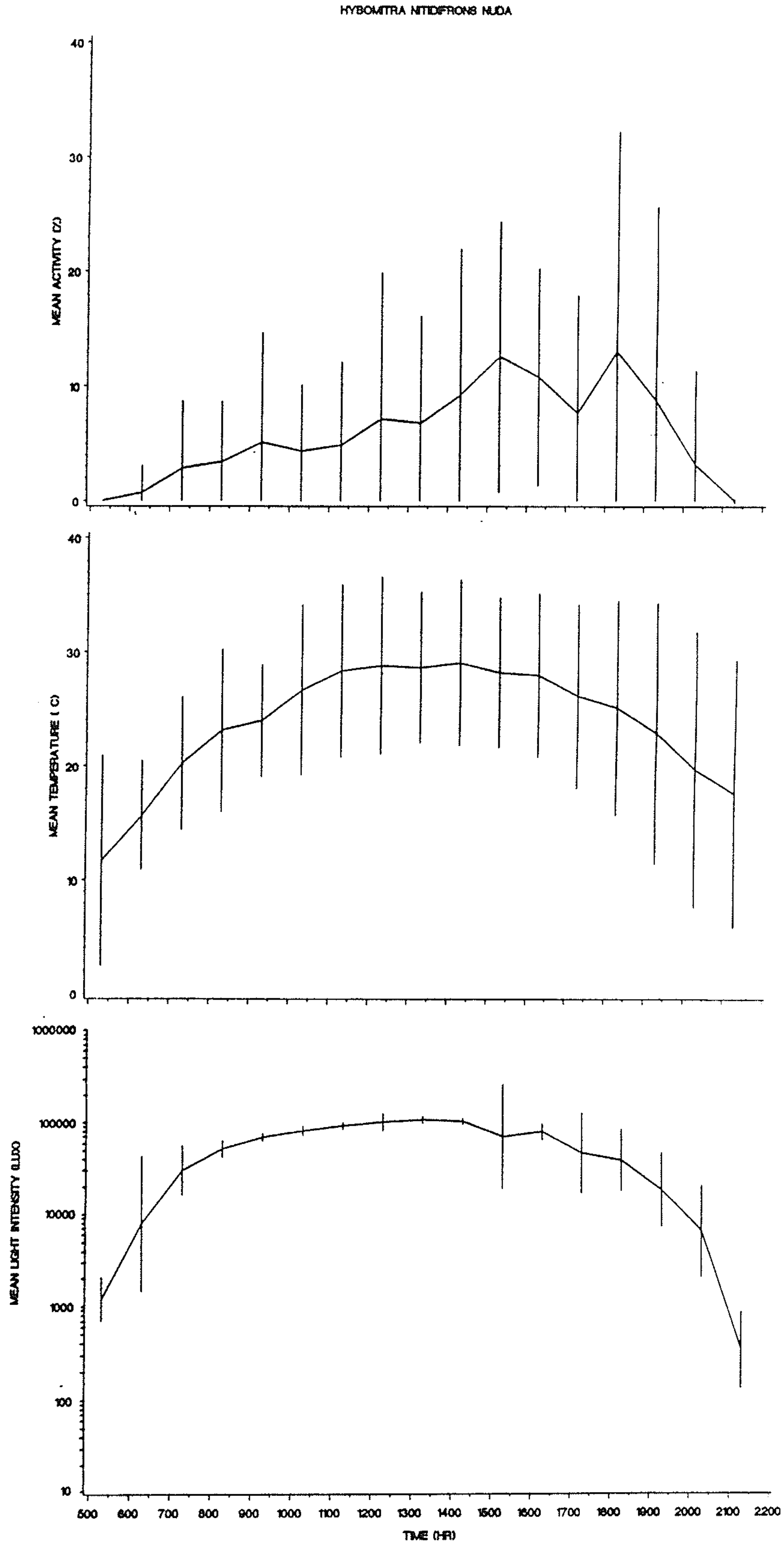

HYBOMITRA NITIDIFRONS NUDA
MEAN ACTIVITY (%)
MEAN TEMPERATURE (C)
MEAN LIGHT INTENSITY (LUX)
TIME (HR)

Figure 27: Mean (± standard error) profile of hourly percentages of total daily catch of *Hybomitra affinis*, and coincident mean (± standard error) hourly temperature and light intensity profiles at Churchill, Manitoba, in 1988.

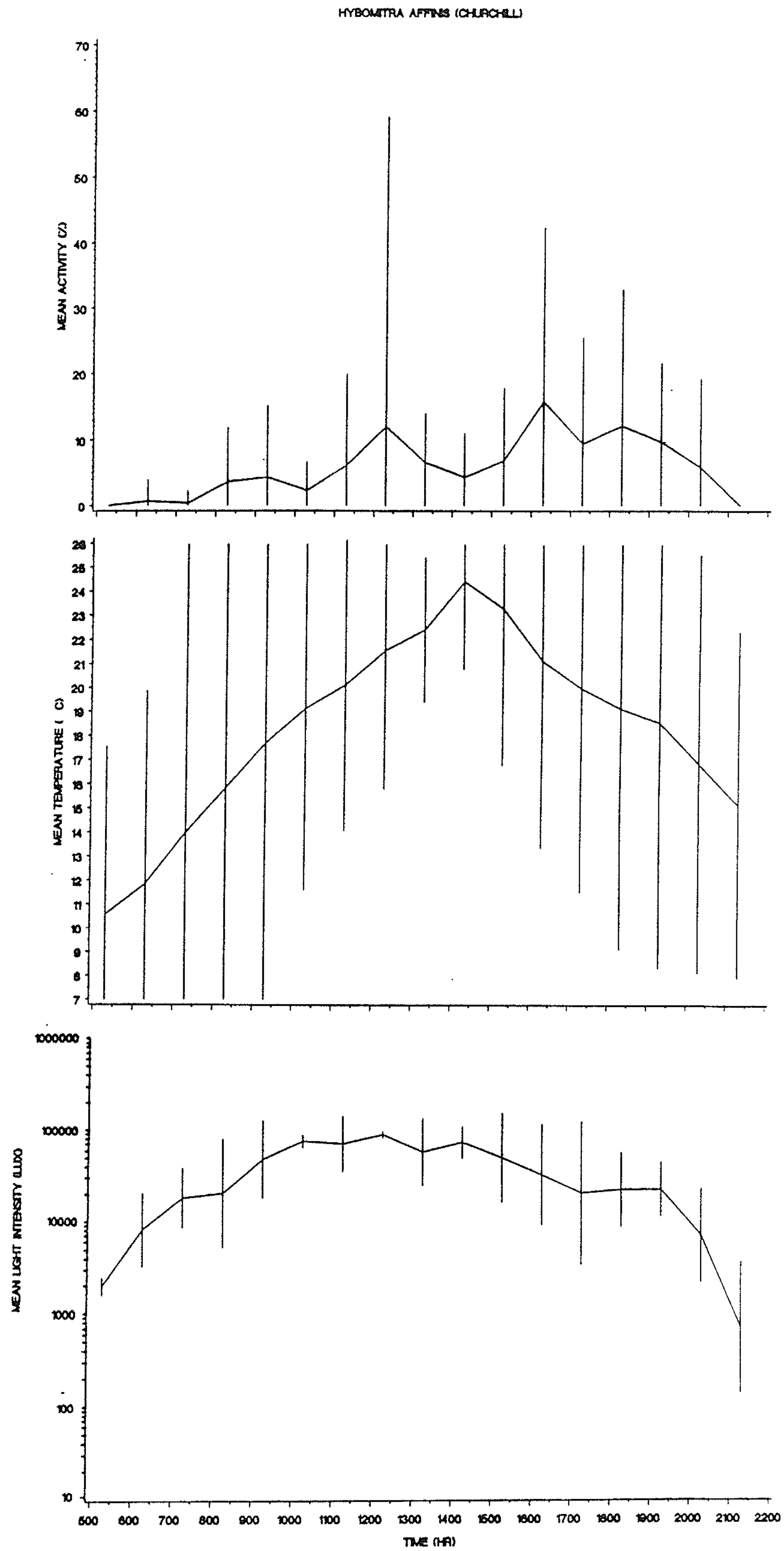

HYBOMITRA AFFINIS (CHURCHILL)
MEAN ACTIVITY (%)
0
10
20
30
40
50
60
70
MEAN TEMPERATURE (C)
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
MEAN LIGHT INTENSITY (LUX)
10
100
1000
10000
100000
1000000
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
TIME (HR)

Figure 28: Mean (± standard error) profile of hourly percentages of total daily catch of <u>Hybomitra frontalis</u>, and coincident mean (± standard error) hourly temperature and light intensity profiles at Churchill, Manitoba, in 1988.

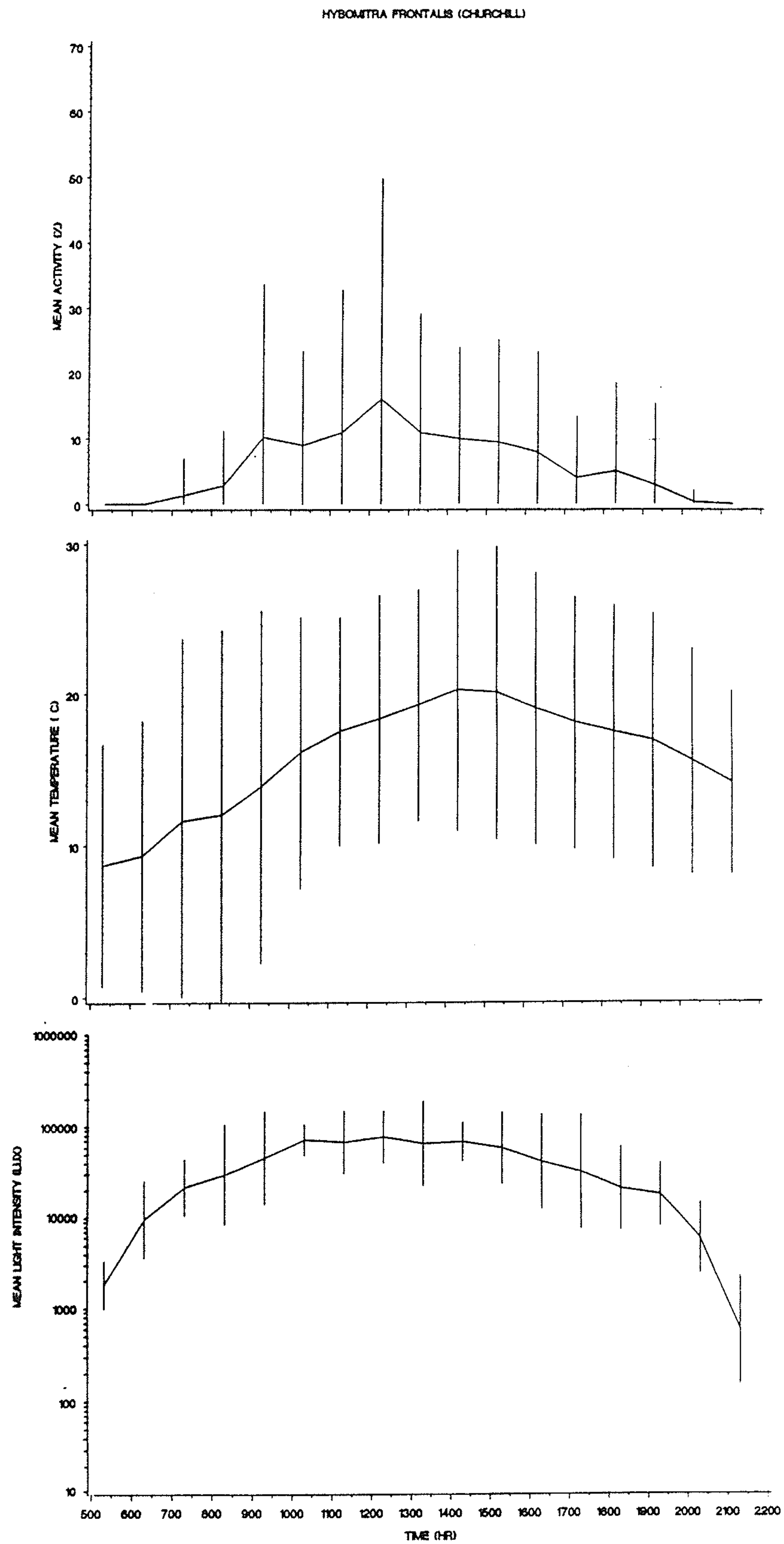

HYBOMITRA FRONTALIS (CHURCHILL)
MEAN ACTIVITY (%)
MEAN TEMPERATURE (C)
MEAN LIGHT INTENSITY (LUX)
TIME (HR)

Figure 29: Frequency of temperature values recorded for all trap-hours sampled (hatched bars), and for only those trap-hours during which tabanids were trapped (solid bars), for four tabanid species at Seven Sisters, Manitoba, in 1988.

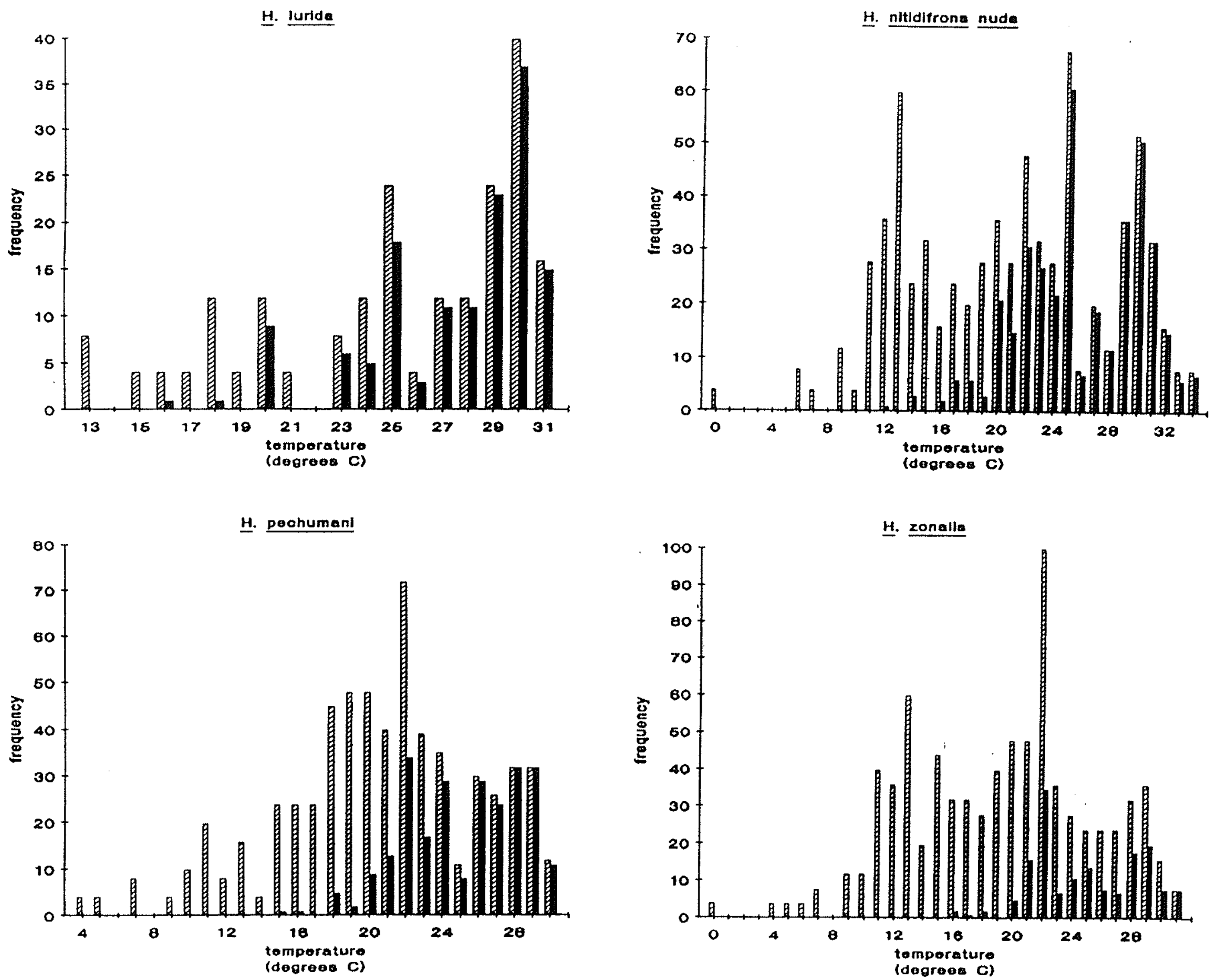
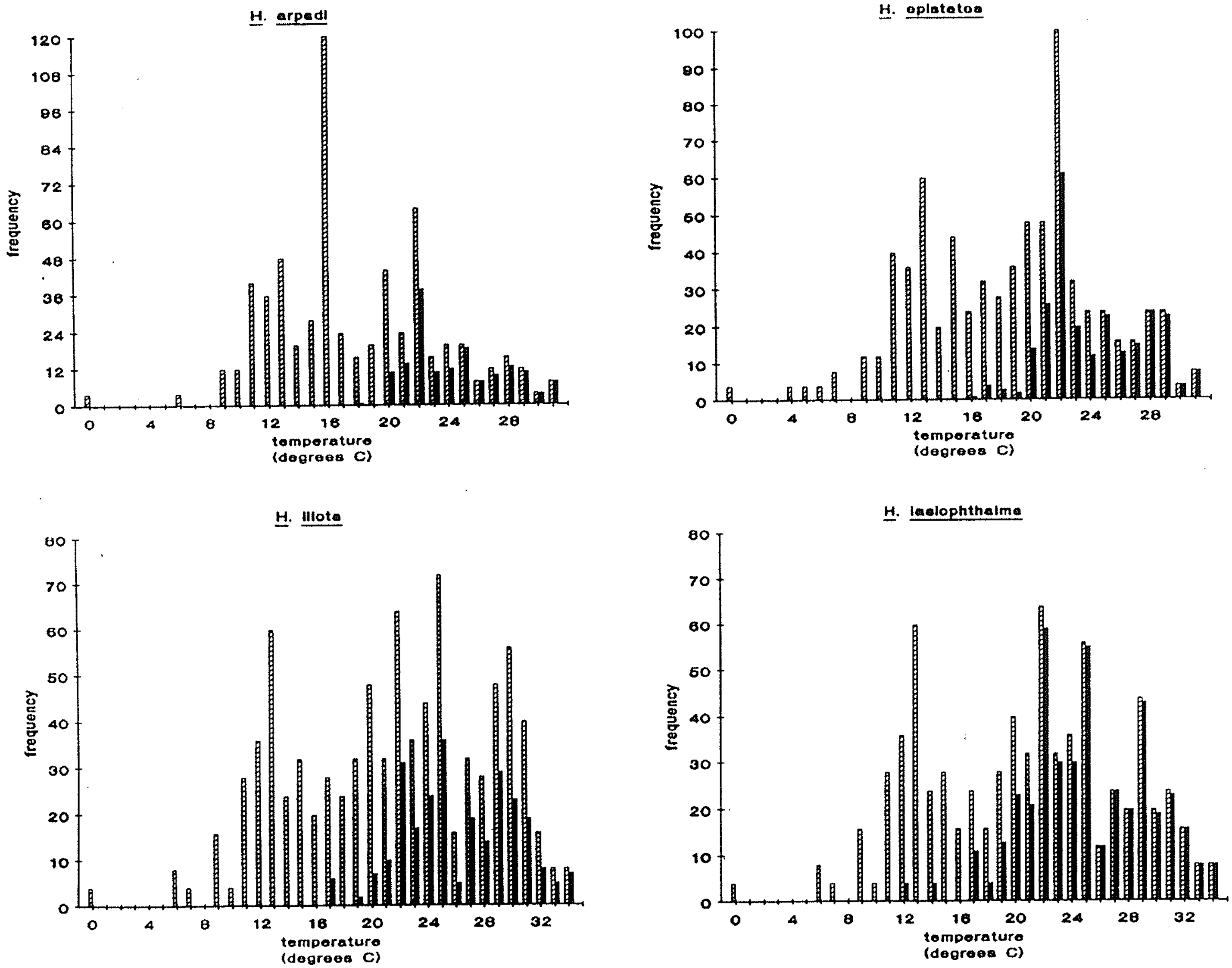
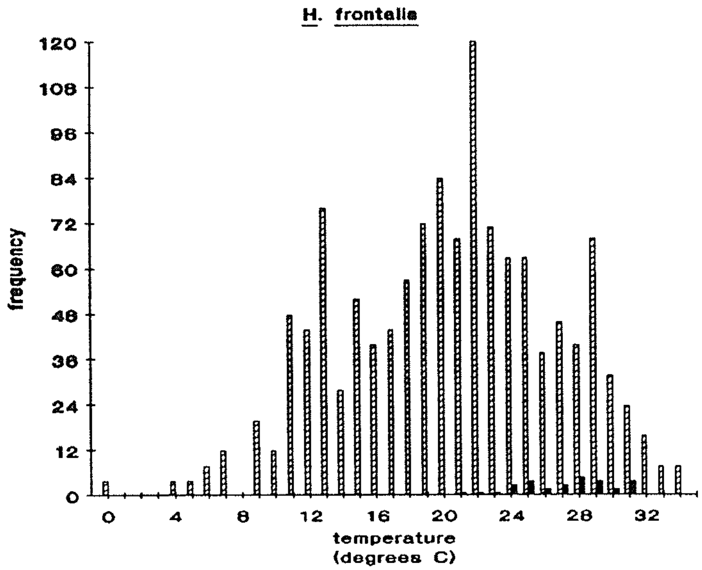

H. lurida
frequency
temperature (degrees C)
H. nitidifrons nuda
frequency
temperature (degrees C)
H. pechumani
frequency
temperature (degrees C)
H. zonalis
frequency
temperature (degrees C)

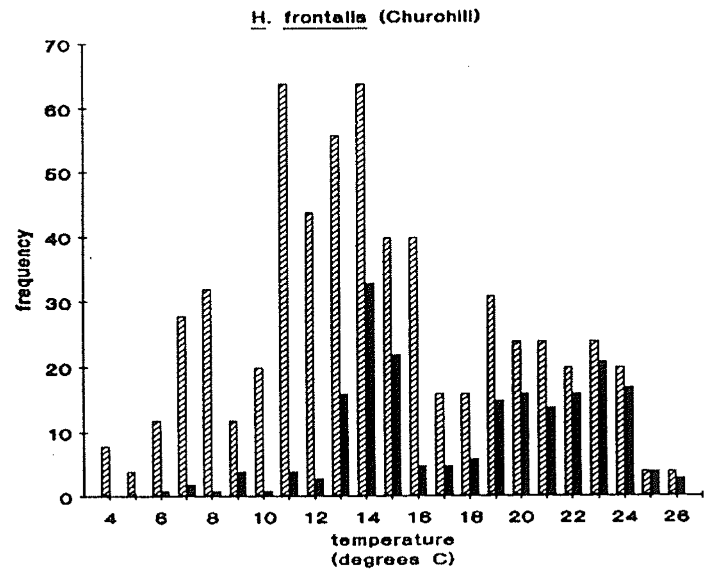
Figure 30: Frequency of temperature values recorded for all trap-hours sampled (hatched bars), and for only those trap-hours during which tabanids were trapped (solid bars), for four tabanid species at Seven Sisters, Manitoba, in 1988.

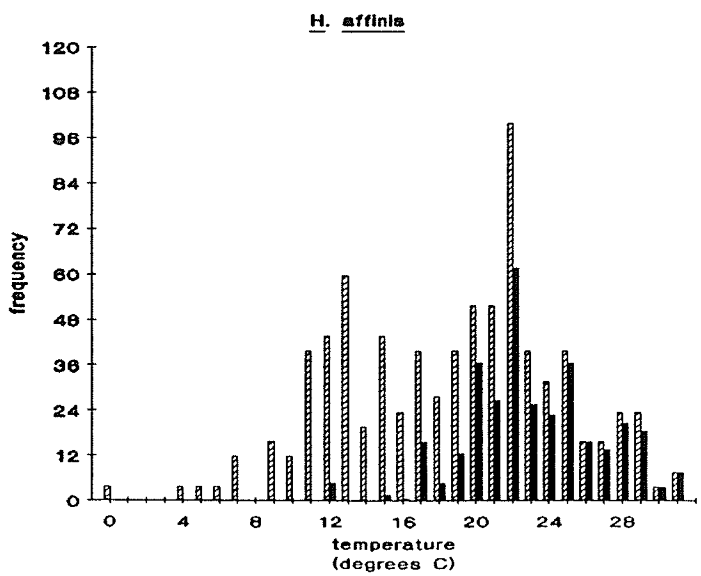


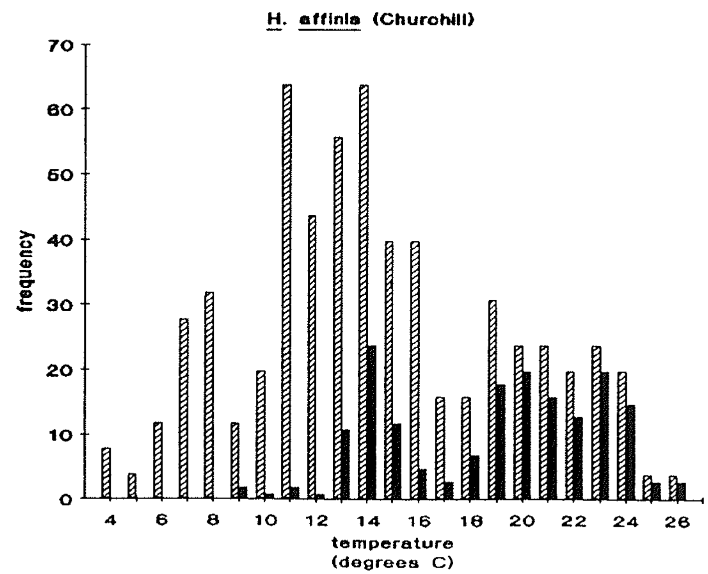
H. arpadi
120
108
96
84
72
60
48
36
24
12
0
frequency
0
4
8
12
16
20
24
28
temperature
(degrees C)
H. opistatoe
100
90
80
70
60
50
40
30
20
10
0
frequency
0
4
8
12
16
20
24
28
temperature
(degrees C)
H. illota
80
70
60
50
40
30
20
10
0
frequency
0
4
8
12
16
20
24
28
32
temperature
(degrees C)
H. lasiophthalma
80
70
60
50
40
30
20
10
0
frequency
0
4
8
12
16
20
24
28
32
temperature
(degrees C)

Figure 31: Frequency of temperature values recorded for all trap-hours sampled (hatched bars) and for only those trap-hours during which tabanids were caught (solid bars), for Hybomitra affinis and H. frontalis at Seven Sisters, Manitoba, and Churchill, Manitoba in 1988.


H. frontalis
frequency
0 12 24 36 48 60 72 84 96 108 120
0 4 8 12 16 20 24 28 32
temperature
(degrees C)


H. frontalis (Churchill)
frequency
0 10 20 30 40 50 60 70
4 6 8 10 12 14 16 18 20 22 24 26
temperature
(degrees C)


H. affinis
frequency
0 12 24 36 48 60 72 84 96 108 120
0 4 8 12 16 20 24 28
temperature
(degrees C)


H. affinis (Churchill)
frequency
0 10 20 30 40 50 60 70
4 6 8 10 12 14 16 18 20 22 24 26
temperature
(degrees C)

GENERAL CONCLUSIONS

1. Biweekly spray applications of permethrin (0.5% aqueous suspension, 1 L/animal) do not significantly increase the weight gain of beef heifers subject to severe attack by horse flies.

2. Numbers of host-seeking female horse flies at the Seven Sisters Grassland Project, as indexed by Manitoba Horse Fly Trap catches, were highest from late May through early July in 1987 and 1988.

3. Thirty-one species of Tabanidae were caught in MHFT at the Seven Sisters site. Ten *Hybomitra* spp. were common biting pests of cattle: *H. affinis*, *H. arpadi*, *H. epistates*, *H. illota*, *H. lasiophthalma*, *H. nitidifrons nuda*, *H. lurida*, *H. pechumani*, *H. trepida*, and *H. zonalis*.

4. The seasonal abundance peaks of the ten common species occurred in succession over the course of the summer. Peak numbers of *H. lurida* and *H. nitidifrons nuda* occurred in late May and early June, *H. illota*, *H. lasiophthalma*, *H. affinis*, *H. arpadi*, and *H. zonalis* in early to mid June, and *H. epistates* and *H. pechumani* in

late June to early July. There were two seasonal abundance peaks for *Hybomitra trepida*: one in mid to late June, and one in early August.

5. Per cent parity in *H. lasiophthalma* , *H. affinis*, *H. arpadi*, *H. zonalis*, *H. epistates*, *H. pechumani*, and *H. illota* increased from low levels (0-10%) at the beginning of the flight season, to high levels (80-100%) approximately four weeks later. For *H. lurida* and *H. nitidifrons nuda*, per cent parity increased much more rapidly over the flight season, reaching the 100 % level within two weeks of these species' first appearances in trap catches. Per cent parity in *H. trepida* increased to 100% after two months of flight activity, then decreased to 40% 2 weeks later. After another 2 weeks, parity was again 100%.

6. Diel patterns of host-seeking activity differed markedly among the nine tabanid species for which they were recorded. At Seven Sisters, daily activity of *H. epistates* and *H. pechumani* was highest around midday; *H. arpadi* and *H. zonalis* in early afternoon; *H. lasiophthalma*, *H. affinis*, and *H. illota* in late afternoon; *H. lurida* and *H. nitidifrons nuda* in early evening. At Churchill, *H. affinis* activity peaked in

late afternoon, while _H_. _frontalis_ was most active at midday.

7. At Seven Sisters, the onset of flight activity on most mornings was determined by temperature. A few tabanids were caught at temperatures as low as 12° C, but flight activity was limited until temperatures exceeded 20° C. Minor interspecific variation was apparent in temperatures at which flies first became active. Cessation of flight activity in late afternoon or early evening was determined on some occasions by temperature, while on other occasions light appeared to be of greater importance, depending on which of the two factors fell below threshold levels first. Evening threshold temperatures were comparable to those observed in morning. Little flight activity was recorded at light intensities below 5000 lux.

8. Tabanids at Churchill were active at lower temperatures than conspecifics at Seven Sisters. Trap catches of _H_. _affinis_ were made at 9° C, _H_. _frontalis_ at 6° C. _Hybomitra_ _frontalis_ was uncommon at Seven Sisters, and only caught at temperatures of 21° C or above. Tabanid activity at Churchill was limited until temperature exceeded 14° C.

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Appendix A: Producer, breed, birth date, and initial weight of beef heifers used in weight gain study at the Seven Sisters Grassland Project in 1987.

Producer:	Heifer#:	Breed:	Birth Date:	Initial Weight:	Herd:
K.Blocker	1	He	2/17/86	366	c
	2	He	3/ 1/86	362	t
	3	He	3/11/86	379	t
	4	He	3/19/86	316	t
	5	He	4/ 8/86	359	c
B.Blocker	6	He	2/26/86	340	c
	7	He	3/ 1/86	350	t
	8	He	4/ 3/86	325	c
A.Coates	9	Si	-	421	c
	10	Si	-	387	t
D.Kominski	11	Ch	2/22/86	427	c
	12	Ch	2/ 3/86	374	c
	13	Ch	2/ 4/86	431	t
	14	Ch	3/27/86	414	t
	15	Ch	2/26/86	399	t
A.Ferchuk	16	Si	3/ 3/86	360	c
	17	Si	4/27/86	385	c
	18	Si	4/14/86	331	t
	19	Si	3/18/86	359	c
R.Nichol	20	Ge	6/ 3/86	398	t
	21	ChxHe	4/ 1/86	439	c
	22	ChxHe	4/12/86	379	t
	23	Sh	5/14/86	324	c
D.Nichol	24	Si	4/18/86	324	t
	25	Ch	4/ 9/86	360	c
	26	Ch	4/11/86	422	t
N.Lussier	27	Si	2/17/86	438	c
	28	Si	2/13/86	410	c
	29	Si	3/ 1/86	438	c
	30	Si	3/ 2/86	442	t
L.Kurbis	31	AnxSi	1/20/86	413	t
	32	AnxSi	1/ 4/86	381	c
	33	AnxSi	3/22/86	338	t
	34	Si	1/19/86	340	t
	35	Si	4/ 1/86	360	c
W.Proceviat	36	RAxHe	3/16/86	339	t
	37	RAxHe	4/16/86	340	c
	38	RAxHe	4/19/86	305	c
	39	RAxHe	4/ 4/86	327	c
	40	RAxHe	4/18/86	313	t
B.Proceviat	41	RAxHe	4/28/86	300	c
	42	RAxHe	3/30/86	321	t
	43	RAxHe	3/26/86	351	t

Appendix A (cont'd)

Producer:	Heifer#:	Breed:	Birth Date:	Initial Weight:	Herd:
B. Proceviat	44	RAxHe	3/22/86	354	c
	45	RAxHe	3/23/86	357	c
A.Aime	46	PHe	3/13/86	310	c
	47	PHe	3/14/86	316	t
	48	PHe	3/16/86	335	t
	49	PHe	3/30/86	297	c
	50	PHe	5/ 1/86	312	t
L.Sikora	51	ChxHe	3/ 8/86	334	c
	52	ChxHe	3/ 9/86	372	c
	53	ChxHe	3/ 7/86	370	t
	54	ChxHe	3/24/86	319	t
	55	ChxHe	3/ 5/86	373	t

Note: Initial weights are in Kg

He = Hereford
PHe = Polled Hereford
Si = Simmental
Ch = Charolais
Ge = Gelbvieh
Sh = Shorthorn
An = Angus
RA = Red Angus
- = data not available
x = cross
t = treated (sprayed) herd
c = control (unsprayed) herd

Appendix B: Producer, breed, birth date, and initial weight of beef heifers used in the weight gain study at the Seven Sisters Grassland Project in 1988.

Producer:	Heifer#:	Breed:	Birth Date:	Initial Weight:	Herd:
K.Blocker	1	He	3/ 3/87	333	c
	2	He	3/12/87	360	t
	3	He	3/19/87	358	c
	4	He	3/ 2/87	356	t
	5	He	3/ 9/87	366	c
B.Blocker	6	He	3/13/87	404	t
	7	He	2/24/87	451	c
	8	He	2/15/87	389	t
A.Coates	9	Si	2/10/87	451	t
	10	Si	2/20/87	482	t
	11	Si	3/ 9/87	475	c
	12	Si	3/ 1/87	438	t
	13	Si	2/ 8/87	430	c
A.Ferchuk	14	Si	3/22/87	421	c
	15	Si	3/22/87	368	c
	16	Ch	3/13/87	388	t
	17	Si	3/12/87	416	c
	18	Ch	3/27/87	377	t
S.Brandt	19	-	3/19/87	335	c
	20	-	3/13/87	363	t
	21	-	3/12/87	381	c
	22	-	3/ 4/87	361	t
R.Krentz	23	Si	-	409	c
	24	Si	-	382	t
	25	Si	-	427	c
	26	Si	-	392	t
	27	Si	-	401	c
N.Lussier	28	Si	2/10/87	414	t
	29	Si	2/20/87	441	c
	30	Si	2/28/87	515	t
O.Kaminski	31	Ch	3/11/87	425	t
	32	Ch	4/14/87	517	c
	33	Ch	3/ 8/87	427	t
	34	Ch	4/14/87	408	c
T.Kaminski	35	-	-	386	t
O.&T.Kaminski	36	-	-	395	c
	37	-	-	533	t
	38	-	-	473	c
	39	-	-	373	t
	40	-	-	417	c
B.Proceviat	41	-	1/20/87	392	c
	42	-	2/25/87	349	t
	43	-	3/20/87	361	c

Appendix B (cont'd)

Producer:	Heifer#:	Breed:	Birth Date:	Initial Weight:	Herd:
B.Proceviat	44	-	3/15/87	393	t
W.Proceviat	45	-	-	362	c
	46	-	-	368	t
	47	-	-	321	c
	48	-	-	377	t
	49	-	-	302	c
R.Nichol	50	-	3/20/87	371	t
	51	-	-	358	c
	52	-	-	380	t
	53	-	-	365	c
R.Gauthier	54	Ch	4/16/87	460	c
	55	Ch	2/28/87	330	t
	56	Ch	4/28/87	362	c
	57	-	3/ /87	347	t
	58	-	3/ /87	382	c
	59	-	3/ /87	364	t
L.Sikora	60	-	3/ /87	335	t
	61	-	3/ /87	320	c
	62	-	3/ /87	388	t
	63	-	3/ /87	352	c
W.Kroker	64	-	-	332	c
	65	-	-	425	c
	66	He	-	422	t
A.Timko	67	-	-	385	t
	68	-	-	373	c
	69	-	-	425	t
	70	-	-	368	t
	71	-	-	480	t
	72	-	-	343	c

<u>Note</u>: Initial weights are in kg

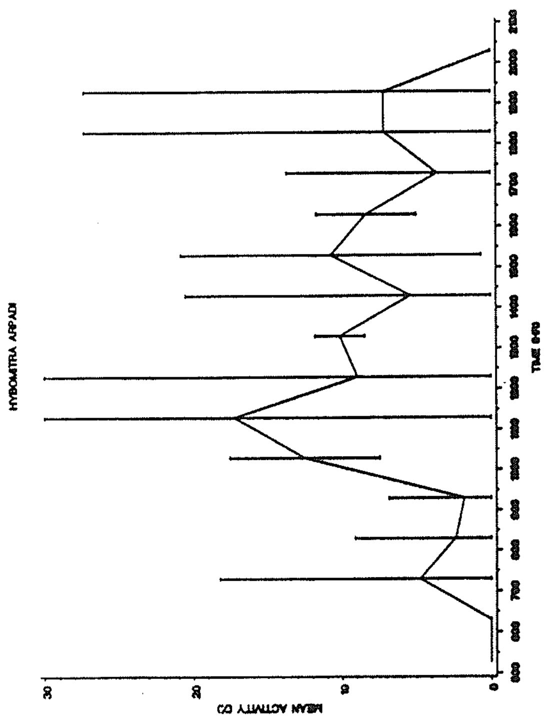
He = Hereford
Si = Simmental
Ch = Charolais
- = data not available
t = treated (sprayed) herd
c = control (unsprayed) herd

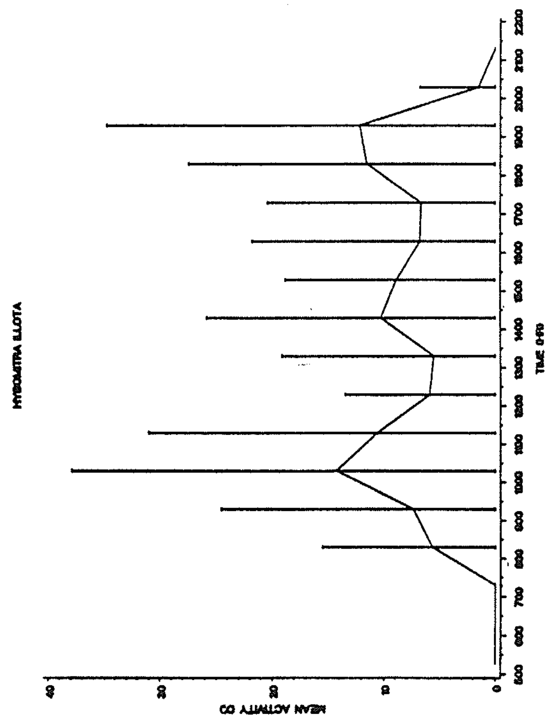
Appendix C: Principle characteristics of 9 predictive models of diel variation in number of tabanid captures as a function of meteorological factors (adapted from Auroi and Graf-Jaccottet (1983)).

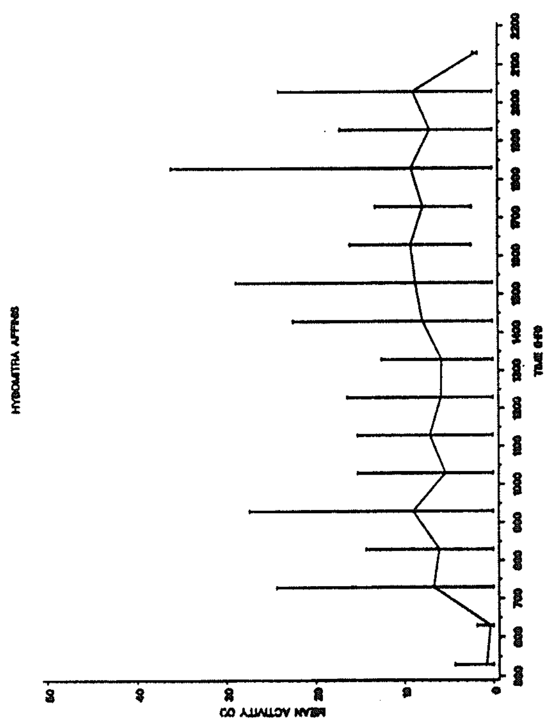
AUTHORS(S)	Joyce & Hansens 1968	Burnett & Hays 1974	Schulze *et al.* 1975	Dale & Axtell 1975		
LOCATION	New Jersey, USA	Alabama, USA	New Jersey, USA	N. Carolina, USA		
MODE OF CAPTURE	Adhesive panels	CO_2-baited malaise trap	Adhesive panels	Cage trap	Net sweeps	Net Sweeps
SPECIES	*I. nigrovittatus* *I. lineola*	34 spp.	*I. nigrovittatus*	*I. nigrovittatus*	*C. atlanticus*	*C. fuliginosus*
FACTORS CORRELATED WITH ACTIVITY	max. temp. avg. temp. cloud cover	atm. press. temp. evaporation evaporation^{-1} solar radiation^{-1} solar radiation wind speed^{1} temp. rel. humidity	cloud cover date^{3} temp.	hour of day light intensity$^{1/2}$ temp. temp.^{2} date wind speed	temp. light intensity rel. humidity^{2} rel. humidity	light intensity hour of day
FACTORS NOT CORRELATED WITH ACTIVITY	wind speed min. temp.	wind speed cloud cover precipitation reflected light	rel. humidity wind speed wind direction	rel. humidity	hour of day wind speed	temp. rel. humidity wind speed
NO. OF OBSERVATIONS	26	1060	15	310	310	248

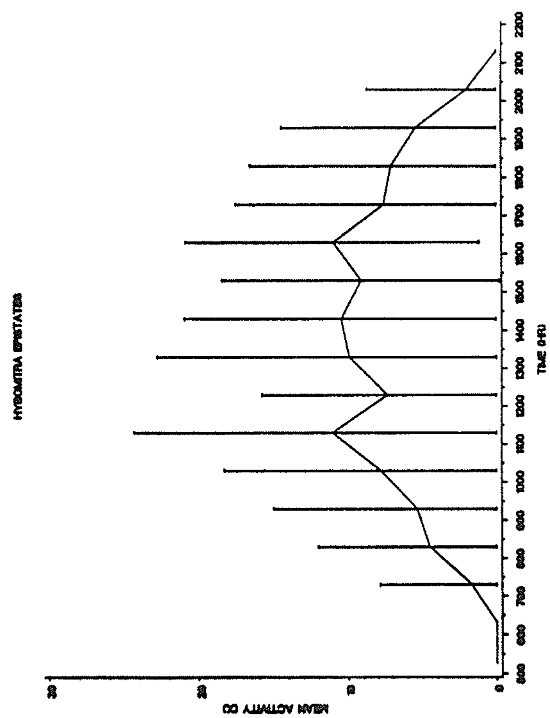
AUTHORS(S)	Alverson & Noblet 1977	Raymond 1979	Kneipert 1982
LOCATION	S. Carolina, USA	High Alps, Fr.	Vogelsberg. FDR
MODE OF CAPTURE	Adhesive panels, with CO_2	CO_2-baited MMPT, & net	Cage trap & net sweeps over cattle
SPECIES	many	many	many
FACTORS CORRELATED WITH ACTIVITY	atm. press. temp. rel. humidity	max. temp.	temp. rel. humidity light intensity cloud cover type of cloud storms precipitation fog wind speed wind direction
FACTORS NOT CORRELATED WITH ACTIVITY	light intensity wind speed wind direction cloud cover		date hour of day atm. press.
NO. OF OBSERVATIONS	151	17-33	638

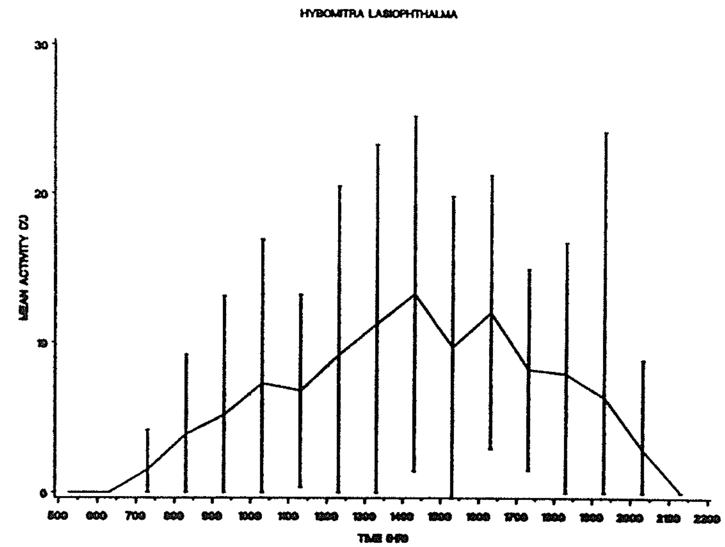
Appendix D: Mean (± standard error) profiles of hourly percentages of total daily catches of eight *Hybomitra* spp. at Seven Sisters, Manitoba in 1987.

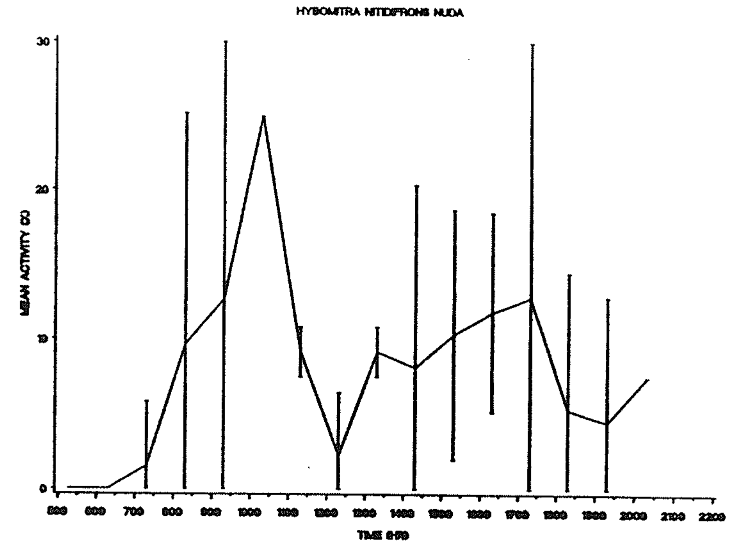

HYBOMITRA ARPADI
MEAN ACTIVITY CO
TIME (HR)

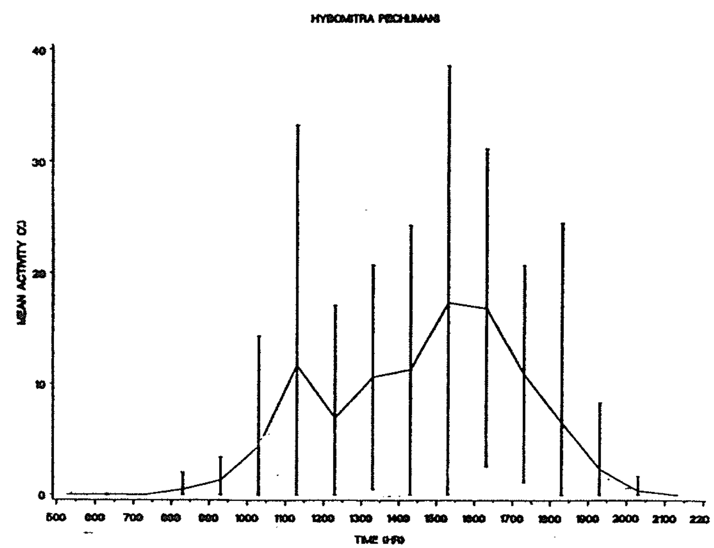

HYBOMITRA ILLOTA
MEAN ACTIVITY CO
TIME (HR)

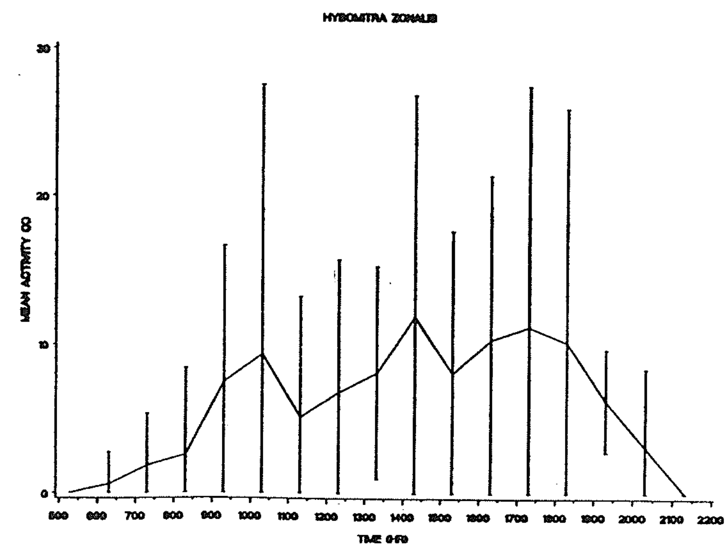

HYBOMITRA AFFINIS
MEAN ACTIVITY CO
TIME (HR)


HYBOMITRA EPISTATES
MEAN ACTIVITY CO
TIME (HR)


HYBOMITRA LASIOPHTHALMA
MEAN ACTIVITY
TIME


HYBOMITRA NITIDIFRONS NUDA
MEAN ACTIVITY
TIME


HYBOMITRA PECHUMANI
MEAN ACTIVITY
TIME


HYBOMITRA ZONALIS
MEAN ACTIVITY
TIME