THE EFFECTS OF TABANIDAE (DIPTERA) ON THE BEHAVIOR OF WOOD BISON AT WATERHEN, MANITOBA

by

Susan B. Morgan

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ABSTRACT

The effects of horse flies (Tabanidae:Diptera) on the behavior of a confined herd of wood bison (*Bison bison athabascae*) was determined, and possible fly control methods investigated. Bison were observed and behavior, group size, habitat selection and irritation levels recorded. A modified Manitoba Horse Fly Trap was used to determine fly activity.

Bison spent less time grazing and more time resting and ruminating when horse flies were active and temperatures were above 19°C. Large groups of bison formed when fly activity was high. When horse flies were active, bison spent significantly more time in open, denuded habitat.

Two methods of controlling tabanids were tested. Use of permethrin spray had no effect on time spent grazing and resting and ruminating or on habitat selection, but did result in lower overall irritation levels. The use of Manitoba Horse Fly Traps to reduce fly activity was investigated with inconclusive results.

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Chapter I

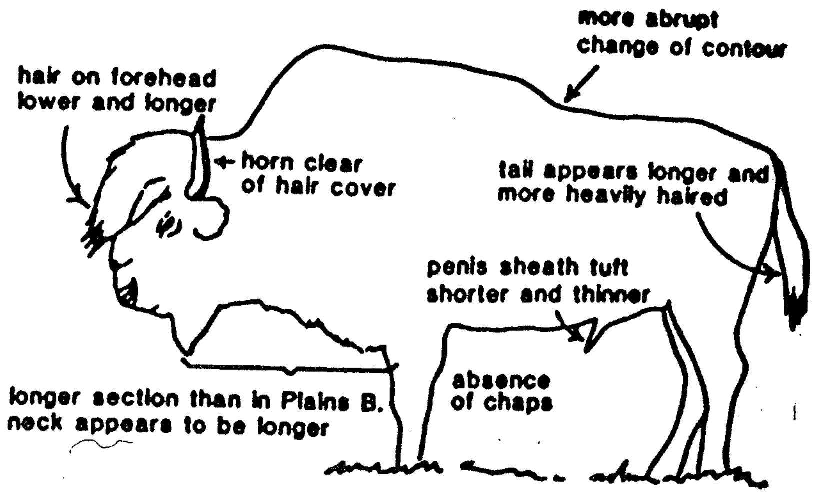
INTRODUCTION

The wood bison (*Bison bison athabascae* Rhoads) is a subspecies of North American bison (Reynolds *et al*. 1984). In 1984, a herd was established in Waterhen, Manitoba as part of an effort to help preserve the subspecies from extinction. The herd population was drawn from wildlife parks and zoological gardens in western Canada and Toronto. During the first summer the animals were stressed by the change in their environment. Nutrition levels were different, there were temperature and weather differences, and there were large numbers of biting flies. Berezanski (1986) reported that when horse flies (Tabanidae: Diptera) were present, the bison spent less time grazing. The death of a yearling bull was attributed to malnutrition and anemia caused by stress and blood loss associated with horse fly attack. The concern over the possible effect of tabanids on herd health and reproductive ability led to this study. This paper is a report on the effects of horse flies on bison behavior patterns, and contains recommendations on possible methods of reducing these effects.

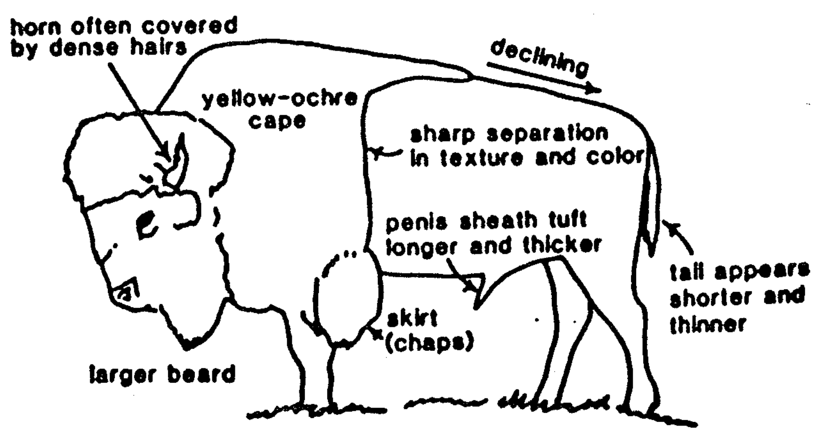
1.1 HISTORY OF THE WOOD BISON

Wood bison differ from plains bison (Bison bison bison Linnaeus) in morphology, pelage and skeletal measurements (Figure 1). The wood bison is larger, more elongated in front, darker in color, and has denser fur and a more elongated back contour than the plains bison (Rhoads 1897; Graham 1922; Soper 1941; Reynolds et al. 1984).

The distribution of the wood bison prior to the arrival of European settlers included most of the boreal regions of British Columbia, Alberta, Saskatchewan, the Northwest Territories and the Yukon Territory (Figure 2). The coniferous forests and aspen parkland with interspersed meadows and plains supported a very plentiful population of wood bison (Hearne, 1795 in Soper 1941). By 1893, when the wood bison became protected by law, it was estimated that less than 500 animals were left (Allen 1900). Protection was not enforced until 1897, when the North West Mounted Police began to patrol an area, now a part of Wood Buffalo National Park, where the wood bison remained (Soper 1941; Leonard 1982). By 1922, when the park was established, there were an estimated 1,500 to 2,000 wood bison in the area. Between 1925 and 1928 the federal government imported 6,673 plains bison from Wainwright Buffalo Park, Alberta. As a result of rapid hybridization between the two types, pure wood bison were thought to be extinct by 1940. Then in 1957, a herd of apparently pure wood bison was discovered in an area isolated



Wood Bison



Plains Bison

Figure 1: Basic pelage and morphological differences between the two subspecies of bison. (Reynolds et al. 1984).

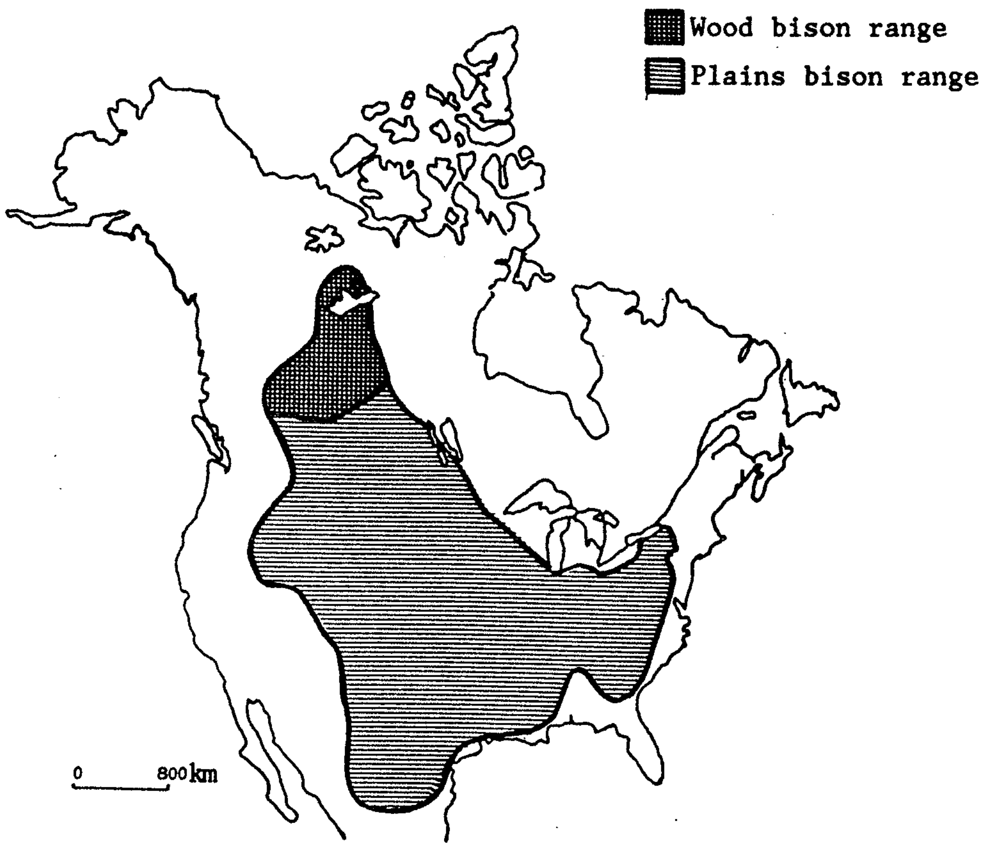


Figure 2: Historic distribution of plains bison and wood bison. (after Berezanski 1986).

from the nearest hybrid herd by more than 75 miles (120 km), and it was determined that they represented the pure wood bison type (Calef 1984).

In an effort to avoid losing the genotype through hybridization, 18 animals were transferred to the Mackenzie Bison Sanctuary in 1962, and 23 were transferred to Elk Island National Park in 1965 (Calef 1984). The wood bison rehabilitation program commenced in 1975 as a joint effort of the Canadian Wildlife Service, Parks Canada and territorial and provincial agencies from western Canada (Reynolds _et al_. 1984). The primary objectives of the program are:

- to reestablish a minimum of three free ranging, self-perpetuating populations of wood bison in areas within their historic range;
- to protect and preserve the gene-pool by dispersing small breeding herds to zoological gardens and parks.

One of these sites is Waterhen, Manitoba (Figure 3). In February 1984, a cooperative effort involving the Canadian Wildlife Service, the Manitoba Department of Natural Resources Wildlife Branch and the Waterhen Indian Band brought 34 wood bison to a 9 mi^2 (22.81 km^2), compound near Waterhen Lake. Eighteen animals were added to the herd in March 1985. Appendix A contains the age, sex and origin of the transferred animals.

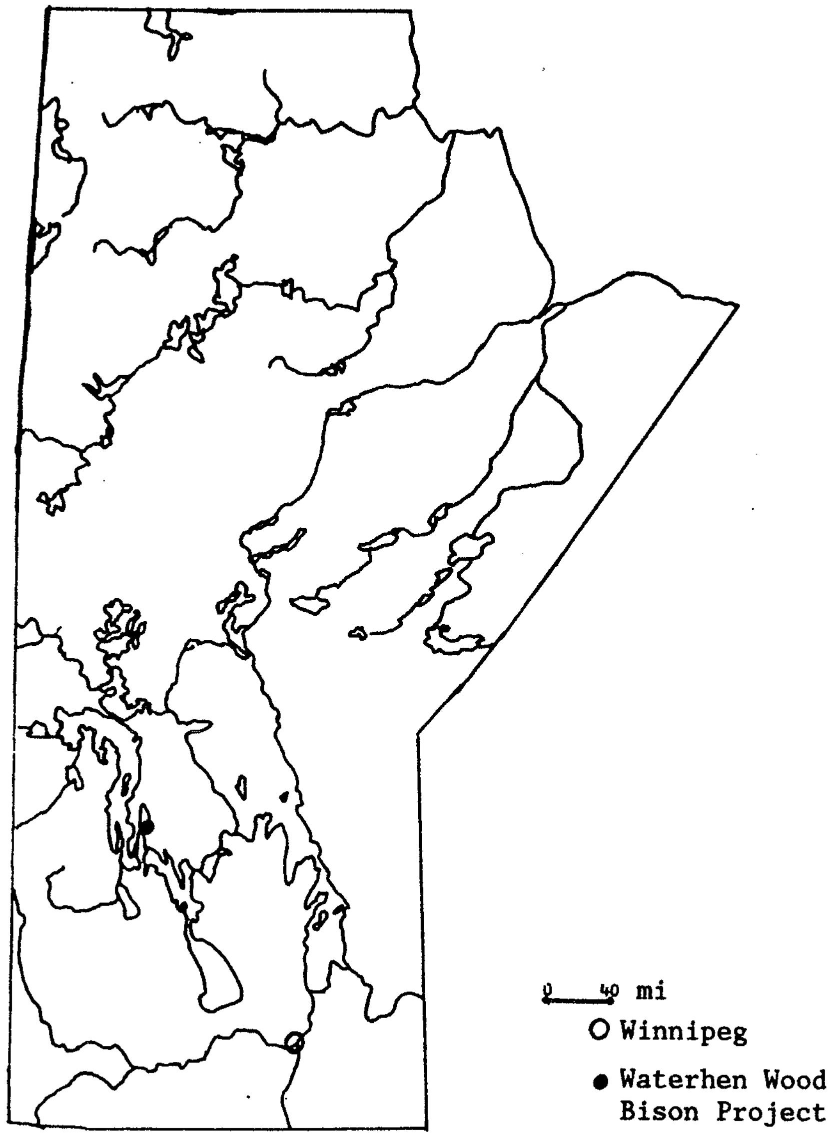


Figure 3: The Waterhen Wood Bison Project, Waterhen, Manitoba.

In the first year of operation the bison were held in a 1 mi^2 (2.59 km^2) area. Ten calves were born during the summer. One was lost soon after birth - possibly to a large predator (Berezanski 1986). At the beginning of May 1985, there was a total of 61 animals at Waterhen; 28 were in the study area, while 15 mature bulls were held separately, and 18 recently arrived animals had not yet been introduced to the main herd.

1.2 IMPACT OF BITING FLIES

The impact of high populations of tabanids on the behavior of the bison in 1984 was unexpected. During the months when horse flies were present the bison spent less time feeding and altered their selection of resting habitat (Berezanski 1986). Other biting flies, such as mosquitoes and black flies, were present and may have affected the bison as well. Their effect was considered, but not studied in this report.

There are relatively few quantitative studies of how biting flies affect the behavior of large mammals (Ralley 1986). Although some studies on the response of wild mammals to tabanids exist, the greatest body of work deals with domestic cattle. The adverse effects of biting flies on cattle include weight loss, reduced weight gain, reduced milk production, fetal abortion, and livestock death, as well as indirect losses caused by disease-producing organisms transmitted by biting flies (Steelman 1976). Diseases carried by horse flies include anthrax, brucellosis, encephalitis and anaplasmosis (Krinsky 1976). The combination of blood loss, energy loss and loss of grazing time during sustained horse fly attack can result in reduced weight gains and milk production (Steelman 1976). Blood loss can be considerable since tabanids imbibe up to 700 mg of blood in one feeding (Krinsky 1976). Both black flies and mosquitoes are known to kill large herbivores (Danks 1981).

1.3 CONTROL OF BITING FLIES

Population control of biting flies is difficult. In general, insect control methods include chemical, cultural, biological, genetic, repellent/attractant and mechanical/physical means. Biological, genetic and cultural controls are costly and may take years to develop. Mechanical control of horse flies by using box traps has been investigated in the salt marshes on the east coast with some success (Wall and Doane 1980). Chemical controls include aerial spraying for adults, treatment of larval habitat and the application of insecticide on the host animal. The Manitoba Insect Control Guide (1986) recommends animal sprays and insecticide impregnated ear tags as fly control methods, but there are no satisfactory control methods for horse flies on cattle.

1.4 OBJECTIVES

The objectives of this study were to determine what effects the tabanid population at Waterhen had on bison behavior, and what control measures would be effective.

To meet these objectives, tabanids were collected and species composition determined. The bison were observed and their behavior, group size and irritation levels recorded. Temperature and weather information were obtained from CFB Gypsumville, 65 km east of the Waterhen project site. The relationships between fly abundance, animal behavior and temperature and weather conditions were analyzed. Changes in bison behavior were related to increases in fly activity and temperature.

Two methods of controlling tabanids were tested; the application of the insecticide permethrin and the use of the Manitoba Horse Fly Trap. When permethrin was applied to the bison its effectiveness could not be determined because subsequent rain showers washed off the chemical. The large scale use of Manitoba Horse Fly Traps to reduce fly populations was investigated, with inconclusive results.

This study was limited to one season of investigation. It is not an attempt to conclusively evaluate the fly populations occurring in the area, or the effect of each individual fly species on the bison.

Chapter II

REVIEW OF RELATED LITERATURE

2.1 EFFECTS OF BITING FLIES

Biting flies are significant livestock pests. They interfere with normal feeding activities and cause blood loss, reduced weight gains, increase susceptibility to disease and may spread anaplasmosis, anthrax, tularemia, bluetongue and other diseases (Drummond *et al*. 1981). The most important biting flies are the horn fly (*Haematobia irritans* L.), the stable fly (*Stomoxys calcitrans* L.), horse flies and deer flies (Tabanidae), black flies (Simuliidae) and mosquitoes (Culicidae) (Danks 1981). Total cattle losses to biting flies are estimated to be $31 million per annum in Minnesota (Noetzel *et al*. 1985), and over $1 billion per annum for the United States as a whole (Drummond *et al*. 1981).

In the first summer of occupancy at the Waterhen site, extreme annoyance to the bison by Tabanidae was noted (Berezanski 1986). The bison used open areas for daytime resting and rumination during June and July, when tabanids were abundant. Grazing activity occurred mainly at dawn, dusk and during rainfall, when horse fly activity was reduced. At the end of July, the number of flies dropped noticeably.

Subsequently, the animals began to feed more during the day and to rest in forested areas. Duncan and Cowtan (1980) reported that horses in Camargue, France responded to horse flies in a similar manner. The horses used resting areas on high or bare ground during the daylight hours of the summer. Fly densities were lower in these areas than in vegetated areas, and the horses suffered fewer fly attacks.

Collins and Urness (1982) found that both elk, (Cervus elaphus nelsoni), and mule deer, (Odicoileus hemionus hemionus), were greatly disturbed by horse fly attacks, but responded in different ways. Mule deer stay in the same general area and run short distances to escape accumulated flies. Elk do not remain in one area when they run from flies, and may move several kilometers during the day. The distress of one elk usually stimulates the same behavior in others, so that when one runs, all run. Both elk and mule deer selected habitat where there was less fly activity. The animals compensated for time lost during fly attacks by grazing more during the cooler part of the day and at night. Comfort, escape and avoidance movements are energetically costly and so horse flies may have a great impact on both elk and mule deer (Collins and Urness 1982).

The response of cattle to tabanids is typified by constant rippling of skin, increased leg and tail movements, stamping of hooves and licking behavior (Magnarelli and Anderson 1980). As well, cattle will crowd together, thereby reducing the surface area exposed to attacking tabanids (Lewis and Leprince 1981). Cattle have also been observed to run in an attempt to avoid tabanids (Hocking 1952; Lewis and Leprince 1981).

Hollander and Wright (1980a) estimated that total blood loss to tabanids could exceed 200 ml/day/animal. Miller (1951) estimated that cattle bitten 50 times an hour for 10 hours by Hybomitra affinis (Kirby) would lose 75 ml of blood, and under similar conditions, there would be a 13 ml loss to Tabanus septentrionalis (Lw.). Hansens (1979) reviewed work by various authors on blood loss due to horse fly attack. Philip (1931) estimated a blood loss of 300 ml from a constant population of 50 flies feeding over a 10 hour period. Blood loss of 59-352 ml/day was calculated in a similar manner by Tashiro and Schwardt (1949; 1953). Soboleva (1956) reported losses of 40 to 200 mg of blood from the feeding of a single fly. He also reported qualitative changes in blood, namely a decrease in haemoglobin and erythrocytes and an increase in leucocytes following the feeding of numerous flies.

Although blood loss is a major consequence of the attack of biting flies, the energy and time spent avoiding and resisting attack may also have an important and detrimental impact (Hollander and Wright 1980a). Physiological effects other than blood loss involve disease transmission and various allergic reactions (Miller 1951; Danks 1981). There is also the possibility of infection of the wounds (Lewis and Leprince 1981). The psychological effects of biting flies may be no less serious than the physiological effects (Hocking 1952).

The United States Department of Agriculture estimated that annual losses to cattle production caused by horse flies in 1965 totaled $40 million, of which $30 million was attributed to reductions in weight gains, and $10 million to reduced milk production (Steelman 1976). In Minnesota, the estimated yearly loss from 1981 to 1983 was $100,000 (Noetzel _et al_. 1985).

Garnett and Hansens (1956) found that the control of tabanids on dairy cattle resulted in an increase in milk production. Bruce and Decker (1951b) reported that farmers estimated their losses due to horse flies at 25-40% of production. Both milk flow and butterfat content were reduced during horse fly attack (Bruce and Decker 1951b). One hundred percent reductions in milk production have been recorded after three weeks of sustained tabanid attack (_in_ Steelman 1976). The losses were a result of a combination of blood loss, energy loss, and loss of grazing time.

The control of horse flies increases weight gains in beef cattle. In a 38 day trial, animals treated with an emulsion containing 0.125 pyrethrins and 2.5% piperonyl butoxide gained 29-30 lb (13-13.6 kg) more than untreated animals

(Bruce and Decker 1951a). Yearling Hereford heifers attacked by an average of 90 and 60 horse flies per animal per day for 84 days gained 0.08 and 0.10 kg per day less than heifers protected from fly attack (Perich et al. 1986). Roberts and Pund (1974) reported a 0.09 to 0.10 kg per animal per day difference in weight gain between cattle protected from horse flies and horn flies, and those not protected.

2.2 LIFE HISTORY OF BITING FLIES

Immature mosquitoes, black flies and tabanids are fully aquatic. Mosquito larvae inhabit still waters, and the pupae are free swimming (Danks 1981). Immature black flies are restricted to flowing water, and many spin under-water cocoons while in the pupal stage (Fredeen 1977; Danks 1981). Tabanid larvae are aquatic or semi-aquatic (Danks 1981). During the brief pupal stage, they move to drier habitats (Danks 1981).

Populations of tabanid larvae can be large; Miller (1951) estimated one study area near Churchill, Manitoba to have 200,900 larvae per acre. He also reported that larvae fed on snails, slugs, tipulid larvae, annelids, other dipterous larvae, and each other. Cameron (1926) found that species of Chrysops could be reared by keeping the larvae in soil rich in decaying organic matter.

Nectar-feeding by adults can represent an important intake of energy prior to host-seeking activity (Lewis and Leprince 1981). Miller (1951) suggested that the majority of tabanids in northern areas feed on nectar only. Lewis and Leprince (1981) found that, in 1978 and 1979, at least 88.9% and 91.9%, respectively, of female tabanids collected had fed on nectar prior to attempting to feed on livestock.

For many species of tabanids, and most of those exhibiting host seeking behavior, a blood meal is required prior to egg production and deposition. Selectivity of feeding sites on cattle varies within and among species, with some similarities on the generic level (Magnarelli and Anderson 1980; Hollander and Wright 1980a). Magnarelli and Anderson (1980) found that 82% of Chrysops females chose the head region, Hybomitra females generally preferred the sides and backs, and Tabanus spp. appeared on all designated body regions including bellies and legs. Mullens and Gerhardt (1979) noted that feeding in areas of thick hair may be available only to large strong tabanids with longer mouthparts or very small flies that are able to burrow between the hairs. Hollander and Wright (1980a) found that the density of tabanids on a feeding site did not appear to limit the number of additional landings.

Tabanids are visually attracted to their targets, and can be trapped using a target such as the black sphere used with the Manitoba Horse Fly Trap (Figure 4). Bracken and Thor-

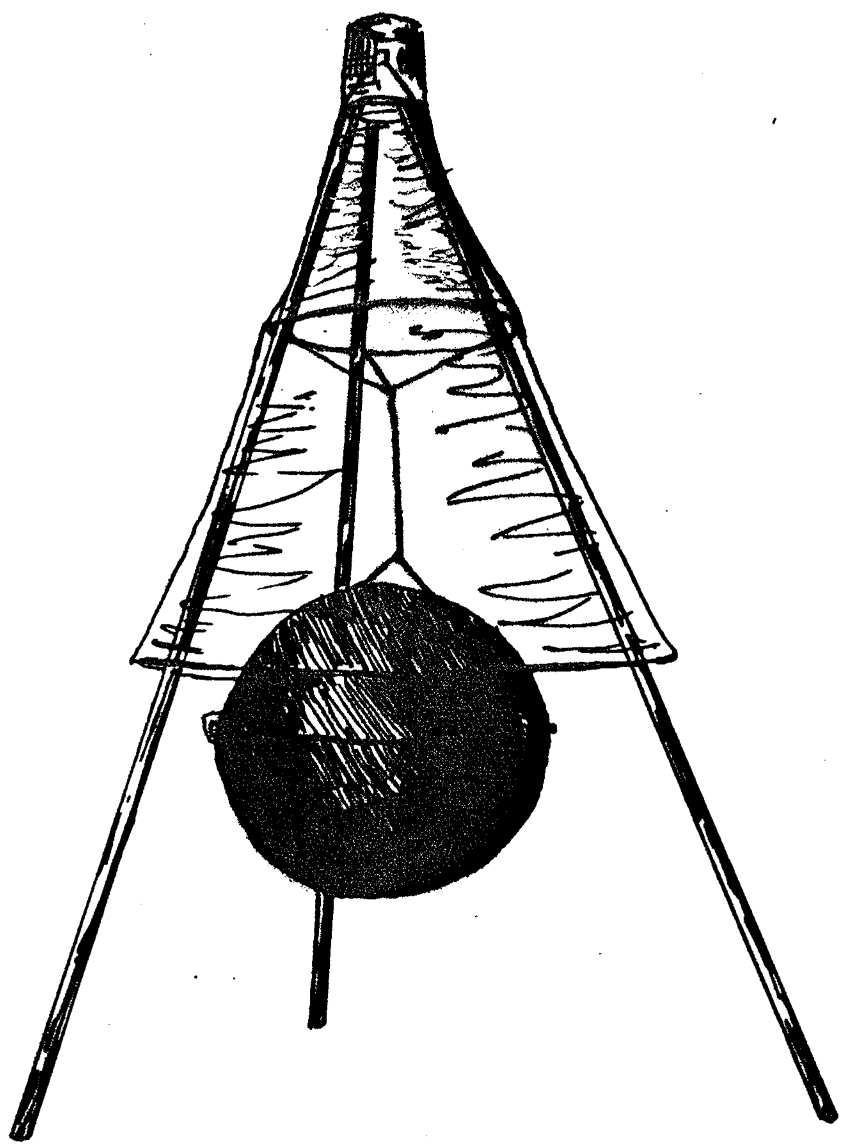


Figure 4: The Manitoba Horse Fly Trap with spherical decoy target. (after Thorsteinson et al. 1965).

steinson (1965) summarized the factors that influence attractiveness (Table 1). Thorsteinson et al. (1966) showed that the shape of the target was important. Attractiveness increases with the number of reflecting faces that direct sunlight along paths parallel to the ground.

TABLE 1

Factors affecting the attractiveness of the Manitoba Horse Fly Trap.

Factor	Effect on Attractancy
Diameter of decoy	Attractancy is not increased by enlarging diameter beyond 30.7 cm
Space between traps	No difference found when spacing was increased from 3 to 66 meters
White discontinuity in appearance of black decoy silhouette	Small decreases in black area by striping or dappling drastically reduces attractancy
Surface temperature of decoy	Decoys simulating warmth of mammalian hosts apparently not more attractive than similar objects at ambient temperature
Movement of decoy	Undecided (results equivocal)
Role of canopy	Does not add to attractancy of a maximally attractive decoy component

Bracken and Thorsteinson (1965)

Howell *et al*. (1949) stated that livestock are more readily attacked by horse flies in woody or shrubby areas than in other places. Sheppard and Wilson (1977) found tabanid host seeking activity to be highest in the open, within 130 m of woods. Resting areas of host seeking females were reported to be at the woods edge, high in the trees.

Generally, North American tabanids are active in daylight, although the time of day when they are most active varies between species (Hollander and Wright 1980b). Burnett and Hays (1974) found the factors which most influenced horse fly activity were (in descending order): barometric pressure, temperature, evaporation and evaporative change per hour, total sky radiation change per hour, total sky radiation and wind velocity change per hour, and relative humidity and temperature change per hour. Increases in temperature and wind velocity and decreases in barometric pressure and cloud cover are related to increases in trap catch. There is a positive correlation with evaporation and total sky radiation, and a negative correlation with relative humidity. Joyce and Hansens (1968) found that fly activity correlated positively with daily maximum temperature, and negatively correlated with cloud cover. They found no correlation between trap catch and either wind speed or daily minimum temperature. Alverson and Noblet (1977) found that wind direction and light intensity had no effect on tabanid flight activity, while both barometric pressure and temperature were positively correlated, and relative humidity was negatively correlated.

2.3 CONTROL MEASURES

Biting fly attack can be reduced or prevented in two basic ways: by local suppression of populations, and by devices that protect the individual (Danks 1981). Hansens (1979) stated that control of Tabanidae has yet to be achieved.

Box trap use over a ten year period on Cape Cod, Mass. has had a noticeable and measurable decrease in the nuisance level of tabanids around the perimeter of marshes (Wall and Doane 1980). Anderson and Kneen (1969) showed that temporary flooding of salt marshes could control tabanid populations when flooding was timed to correspond with larval-pupal moults. There is potential for the use of the sarcophagid Macronychia spp. as a biological control of tabanids (Thompson and Love 1979).

Granulated insecticides have been used to control tabanid larvae. Dieldrin, when used as a larvicide, reduced populations for at least one year after application, whereas DDT, aldrin, and BHC gave good initial kills but were ineffective as residuals (Hansens 1956). Two aerial applications of DDT at a rate of 1 lb/acre (1.1 kg/ha) gave a 95% seasonal reduction in adult flies (Gerry 1949). DDT, lindane, and dieldrin at the same dosage gave unsatisfactory results when used for Canadian forest species of Chrysops and Tabanus (Brown and Morrison 1955). Howell et al. (1949) studied the effect of aerial spray application of methoxychlor, DDT, toxaphene and chlordane at a rate of 2 lb/acre (2.2 kg/ha) on 10 acre (4.07 ha) plots of wooded area. They found no appreciable effect on fly populations. Hansens (1981) used large capacity mist blowers to spray field edges in 15 to 23 m swaths with resmethrin and permethrin. As little as 0.015 kg/ha of resmethrin and 0.028 kg/ha of permethrin gave at least a 95% reduction of annoyance from deer flies for 4 hours, and over 60% reduction for 24 hours. Similar results were obtained with 0.0078 kg/ha of the two compounds applied with an ultra low volume (ULV) spray in 30 to 45 m swaths. Flies moved into the sprayed areas by the day after treatment. Application using an air blast sprayer of resmethrin at 0.025 to 0.05 lb/acre (0.0275 to 0.055 kg/ha) active ingredient (ai) can be expected to provide greatly reduced deer fly annoyance for one to two days (Hansens 1980).

The protection of individual stock animals by use of insecticides has been investigated. Bruce and Decker (1951b) found that the use of pyrethrins in a automatic micro-sprayer gave good control of tabanids. The micro-sprayer is described in detail in Bruce and Decker (1951a). Harris (1976) studied the toxicity of 23 insecticides to three species of tabanids in the laboratory (Table 2). Harris and

Oehler (1976) tested the toxicity of the eight most effective of these insecticides in the field. Horses were sprayed with an aerosol sprayer at 1% ai and flies were exposed to the hair for ten minutes. Toxaphene, Ravap, Compound 4072, Propoxur and Chlorpyrifos results in no kill for one or both species of tabanids when tested 1 day post treatment. The three formulations of permethrin are effective at the same dosage. Permethrin gave better than 80% kill for both species for 14 days. In a related study, an emulsifiable concentrate and a dust formulation of the synthetic pyrethroid permethrin were evaluated on horses and cattle for control of three species of horse flies (Bay et al. 1976). Water emulsion sprays applied at rates of 0.05 and 0.1% ai caused 90% mortality of exposed flies for 9 and 14 days post treatment on cattle, and 12 and 18 days on horses. Dust applied to cattle and horses caused 90% mortality of horse flies for 10 and 12 days, respectively.

Permethrin may act as a repellent for horse flies (Miller pers. comm.). In a study of the repellent action of permethrin, cypermethrin, and resmethrin when applied to cattle, resmethrin did not provide sufficient repellency against black flies (Shemanchuk 1981). Aqueous solutions of cypermethrin at doses of 2 and 4 mg ai/kg animal weight repelled black flies for at least 5 days. Aqueous solutions of permethrin, applied at rates of 1, 2 and 6 mg ai/kg animal weight, effectivly repelled flies for 2, 10 and 11 days,

TABLE 2

Toxicity (%mortality) of different doses of insecticides to three species of tabanids

	T. subsimilis µg/fly				*T. sulcifrons* µg/fly			*T. proximus* µg/fly		
Insecticide	10	1	0.1	0.01	10	1	0.1	10	1	0.1
Carbaryl	100	100	26	0	75	0	0	40	0	
Chlorpyrifos	100	100	96	0	100	100	20	100	100	33
Compound 4072	100	100	90	0	100	100	0	100	100	20
Coumaphos	100	100	0	0	100	100	0	40	0	
Crotoxyphos	100	100	15	0	100	25	0	83	67	0
Crufomate	5	5	15	0						
Diazinon	100	100	5	15						
Dichlorvos	100	100	61	0	100	75	0	100	83	0
DDT	100	90	0	0						
Dimethoate	100	100	0	0	50	0	0	100	0	0
Dioxathion	100	19	14	0						
Ethion	84	5	5	0						
FMC 33297	100	100	97	28	100	100	11	100	100	0
Malathion	100	100	10	0	100	0	0	100	20	0
Methoxychlor	100	75	0	0	0	0	0	0		
Naled	100	100	7	0						
Phosmet	100	28	0	0						
Propoxur	100	100	81	0	100	100	0	100	67	33
Pyrethrins	100	100	47	40	100	80	0	100	100	40
Ronnel	100	61	0	6						
Stirofos	100	100	42	0	100	60	0	100	100	0
Toxaphene	100	35	0	0						
Trichlorfon	100	0	0	0						

from Harris (1976).

respectively. A ready to use dust applied at doses of 1, 2 and 4 mg ai/kg effectivly repels for 4, 5 and 8 days, respectively. The repellent effect of cypermethrin and permethrin was due to very rapid intoxication of the flies on contact with the treated hair.

The Manitoba Insect Control Guide (1986) currently recommends the use of permethrin to control black flies, and dichlorvos, pyrethrin and ronnel to control mosquitoes on beef cattle. They have no recommendations for the control of horse flies.

Chapter III

METHODS

3.1 SITE DESCRIPTION

The Waterhen project site is located in central Manitoba, in Range 14 West, Township 35. The entire area is 9 mi^2 (22.81 km^2) and is surrounded by a 2 m, page-wire and post fence. One mi^2 (2.59 km^2) had been fenced off from the surrounding area and was used in this study (Figure 5).

The site is within the Interlake Plain subdivision of the Interior Plains physiographic map. It is underlain by Paleozoic limestones and dolostones of the Devonian, Silurian, and Ordovician periods. The site has a drumlinized ridge and swale topography. The broad, parallel swales are composed of shallow to deep organic deposits over glacial till. The ridges consist of calcareous loamy till materials (Fraser et al. 1985). Aspen forest on the ridges creates a closed habitat. It is dominanted by aspen (Populus tremuloides Michx) communities, but small stands of jack pine (Pinus banksiana Lamb), black spruce (Picea mariana [Mill] BSP), white spruce (P. glauca [Moench] Voss), and paper birch (Betula paperifera Marsh) are present. A characteristic Carex fen community, dominated by water sedge (C. aqua-

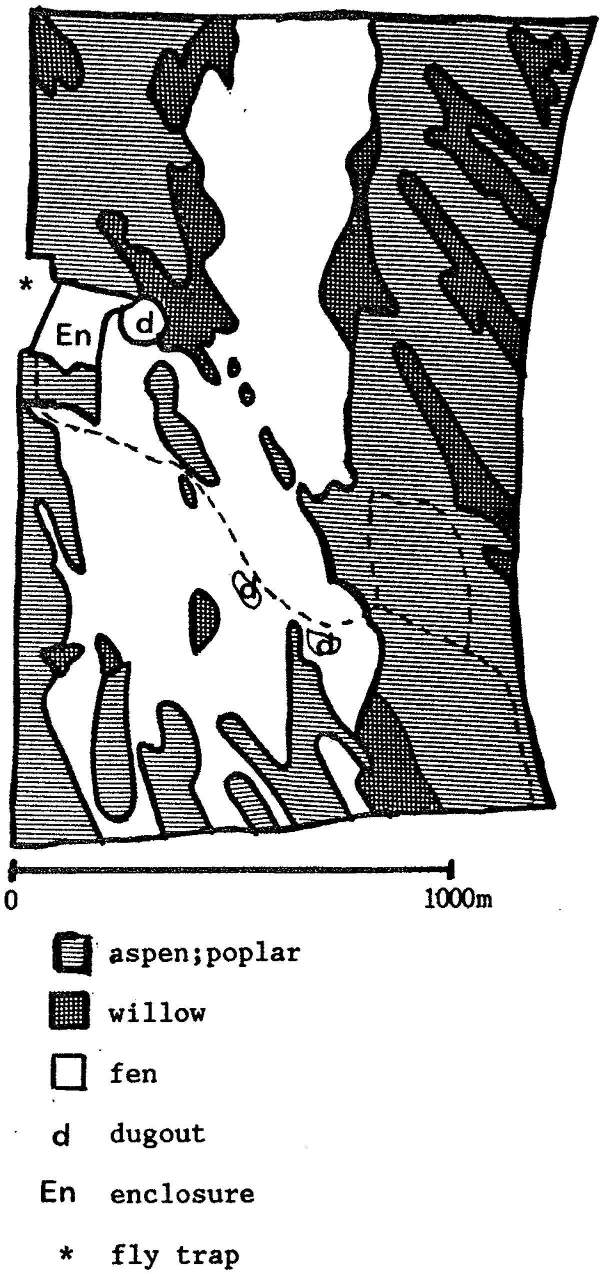


Figure 5: The Waterhen wood bison site used in this study, showing vegetation cover types. (after Berezanski 1986).

tilis Wahl) occurs in the swales and comprises most of the open habitat (Berezanski 1986). The drainage pattern of the study site is towards the north into Waterhen Lake. A gravel road runs through the site, and across the main sedge fen.

3.2 DAILY FLY CATCH

Horse flies were collected using a modified Manitoba Horse Fly Trap (Figure 6), and total catch was used as an index of tabanid activity. The same trap, in the same location, as seen in Figure 5, was used for all sampling to ensure internal consistency. The trap was located outside the compound and was emptied each morning. The flies were then frozen. Flies were counted and sorted by species using Pechuman *et al*. (1960) in the laboratory. Daily fly catch was calculated for catches of over 500 flies by subsampling. Three subsamples of about 10 g were taken from each sample, weighed, and sorted by species. The average number of flies per gram of the 3 subsamples was used to calculate the numbers of flies in the sample. The average species composition of the 3 subsamples was used to determine the species composition of the daily catch. Daily fly catches ranged from 0 to 8,257, and were categorized as no fly activity (0), moderate activity (1 to 1000), and high activity (over 1000).

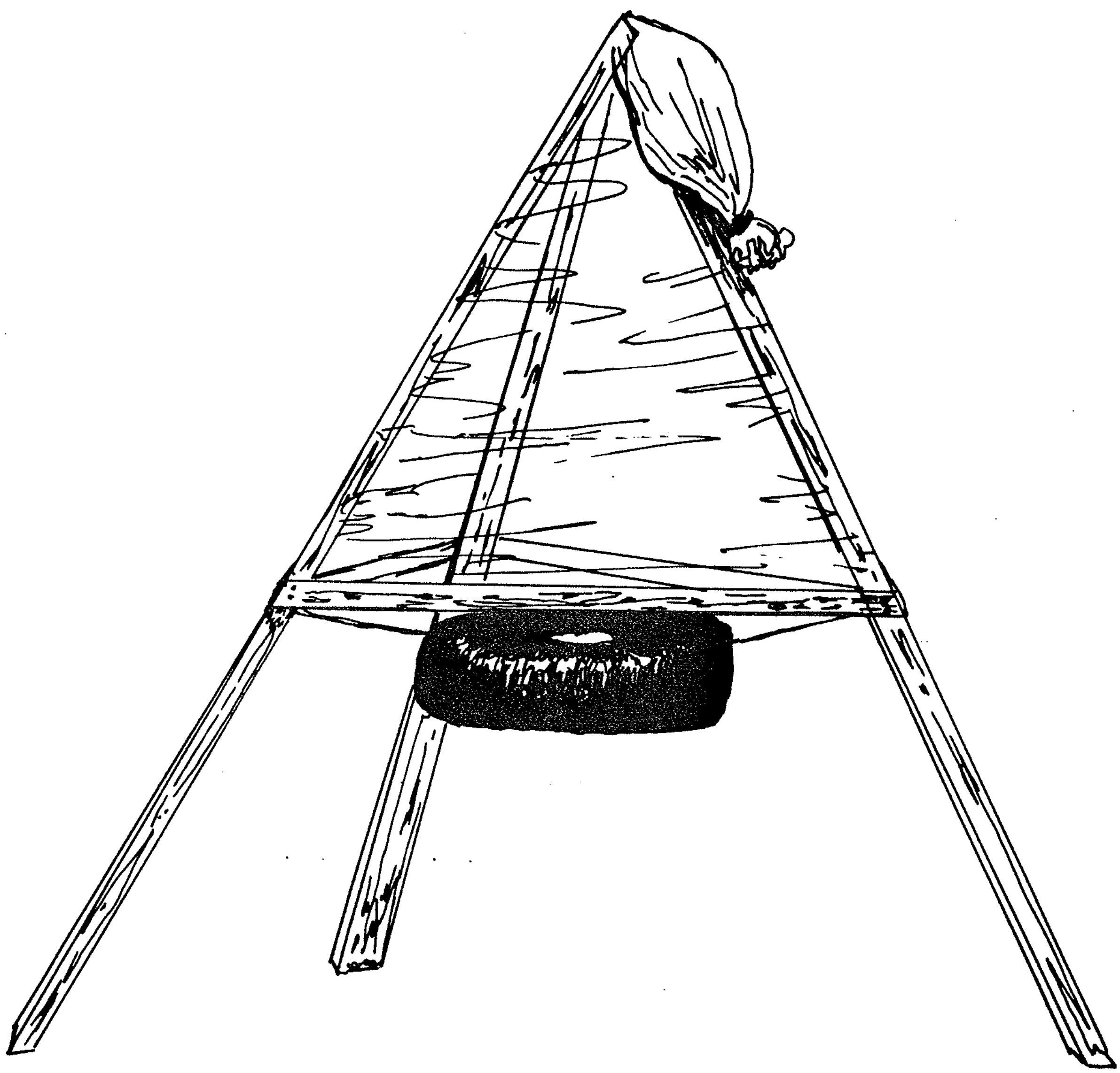


Figure 6: Modified Manitoba Horse Fly Trap used to collect tabanids at Waterhen, Manitoba, 1985.

3.3 TEMPERATURE AND WEATHER

Temperature and weather data were obtained from CFB Gypsumville, 65 km east of the project site. Appendix B contains mean monthly temperature and precipitation for Gypsumville, and a synopsis of temperatures from May to August in 1984 and 1985. Weather categories were clear, scattered cloud cover (<50% of the sky covered), broken cloud cover (>50% of the sky covered), overcast (100% of the sky covered), and raining. Temperatures were grouped as under 10°C, 10° to 19°C, and over 19°C.

3.4 BISON BEHAVIOR

From 14 May to 15 July 1985, individuals or groups of bison were located whenever possible between dawn and dusk. Observations consisted of 10 minute intervals during which all habitats selected by the bison, the total number and overall irritation level of the group, and all behaviors that occurred were recorded. Group size, behavior and irritation level were recorded in tabular form. Habitat selections were plotted on a map of the area. Observations of bison were made by eye or with 7x-15x35 binoculars for as long as the bison remained in view. Because of the bisons' unpredictable nature, observations were made from a car or from the fence line, and sampling was limited to areas accessible from the road or fence.

3.4.1 Behavior Categories

Behavior categories included: grazing, ruminating and resting, wallowing or scratching, travelling, and social behavior. Social behavior included playing and dominance behavior, such as mounting and fighting. Grazing included all feeding activities on sedges, grasses, hay, forbs or other feed stuff.

3.4.2 Habitat Selection

Habitats were categorized as open, road, edge, enclosure, and closed (Figure 5). These were defined as follows:

- open - untreed habitat in the fen areas;
- closed - aspen forest occurring on ridges;
- edge - ecotonal habitat within 10 m of where forested ridges met fen habitat in the swales;
- road - all areas on the road that could not be defined as edge habitat;
- enclosure - the area used as a holding pen, the corrals, and the fenced area containing the dugout.

3.4.3 Irritation Level

Irritation level was determined using a scale that ranged from 0 to 4. The levels are defined as:

- 0 - no interruption of bison activity by comfort movements;

- 1 - comfort movements (such as tail swishing, foot stamping, and licking) occurred but there was no interruption of normal activities;
- 2 - interruption of normal activity, (for example a ruminating animal getting up to stamp and lick, making repeated short movements to other locations, then laying down again) occurred for under 25% of the 10 minute observation interval;
- 3 - interruption of normal activities occurred for over 25% of the 10 minute observation interval;
- 4 - stampeding, or apathy and exhaustion.

3.5 STATISTICAL ANALYSIS

Chi-square (x^2) analysis was used to determine if bison behavior, habitat selection, group size, or irritation level differed at different levels of fly activity, and at different temperatures. Changes in bison behavior, habitat selection, and group size at different irritation levels were also tested using x^2 tests.

Discriminant analysis was used to analyze the validity of the irritation scale. Discriminant analysis is a type of multivariate analysis which can be used to investigate the similarities and differences between groups (Sokal and Rohlf 1981). Multivariate analysis deals with the simultaneous variation of two or more groups. In this case, the correlation between irritation, daily fly catch, temperature and group size was used to determine if irritation level was related to the other variables. Discriminant analysis was used because although irritation was related to the other variables individually, it could be better described by showing the relation of all four variables at once. SPSSx (SPSS Inc. 1986) was used for all statistical tests. Graphics were produced using SAS-GRAPH (SAS Institute 1985).

3.6 CONTROL METHODS

3.6.1 Permethrin Spray

The effectiveness of permethrin spray to reduce horse fly irritation was tested. Permethrin was applied at an approximate rate of 3.4 mg ai per animal. It was applied using an 8 gallon Bean Power sprayer (Trojan Model) on 10 July, 1985.

Forty-three of the 47 bison in the study site were confined in the enclosure. They were then herded into the corral system with a forestry 'skidder' and a pickup truck. Because the animals were very agitated, they were not put through the chutes and sprayed one by one. Instead, they were sprayed in groups of 2 to 6 in small pens. Thirty-three animals were sprayed. One cow was injured while being chased into the corrals, and had to be euthanized. Spraying did not recommence. The unsprayed animals were kept separate from the treated animals, but not used as a comparison because they did not remain in the study site. As well, a cow, which was in poor condition, and a companion animal were kept separate from the other sprayed animals.

The 31 treated animals were observed in the same manner as previously described. Their behavior and habitat selection were observed for 4 days after spraying, on 11, 12, 13, 15 July, and compared to that observed on 4 days prior to spraying, 23 June and 1, 2, 8 July.

A x^2 test was used to determine if bison behavior, habitat selection, group size and irritation level changed after the animals were sprayed. Fly catch before spraying was compared to that obtained after spraying using a student t-test in order to determine if a change in fly activity was responsible for any observed changes in the bisons' behavior pattern.

3.6.2 Manitoba Horse Fly Trap

Wall and Doane (1980) have shown that the nuisance level of tabanid populations was reduced by the use of box traps over a 10 year period. The use of the Manitoba Horse Fly Trap to reduce local horse fly populations in the Gypsumville area was investigated with the cooperation of Dr. Peter Kalden. Dr. Kalden had established eight to ten horse fly traps on his game ranch the previous year, and claimed to have decreased the amount of fly irritation to the ranch animals.

Two horse fly traps of similar construction to that at Waterhen were used to determine if tabanid populations were lower on Dr. Kalden's land than on neighboring land. One was set in a horse pasture on Dr. Kalden's land, and the other was set near a cow pasture 3.9 km away. The two traps were emptied every 3 to 4 days. The samples were stored, and trap catch calculated in the same manner as previously described. The total fly catch and the average fly catch of each trap were then compared to determine if fly activity was lower on Dr. Kalden's land.

Chapter IV

RESULTS

4.1 DAILY FLY CATCH AND SPECIES COMPOSITION

A total of 21 fly samples were collected at the Waterhen site. Weights of the samples ranged from 39 to 631 g. Tabanids were also present in the area on 18, 21, 22 May, and 11, 13, 15, 21 June, but no fly catch was obtained.

Fourteen different species of horse flies were collected and identified at Waterhen (Table 3). The majority of individuals captured belong to the genus Hybomitra. Hybomitra epistates (O.S.), H. affinis, H. illota (O.S.), H. lasiophthalma (Macq), and H. nuda (McD) were the most frequently caught species. Hybomitra epistates was the most abundant species at Waterhen. It was present on all days trap catches were made and comprised from 14.3 to 85.6 per cent of the catch. Other Hybomitra species present were H. frontalis (Walker), H. lurida (Fallen), H. zonalis (Kirby), H. pechumani (Teskey and Thomas) and H. arpadi (Szilady). Small numbers of Chrysops exitans (Walker), C. sackeni, Tabanus similis, (Macq.) and T. marginalis (Fab.) were also present in the trap catches.

TABLE 3

Total horse fly catch and species representation in the Waterhen area, 1985

Date	Total	% Composition						
		H.affinis	H.epistates	H.illota	H.lasio-phthalma	H.nuda	unident-ified	other*
June 23	662	2.2	35.1	8.6	50.3	2.0	1.8	
24	0	-	-	-	-	-	-	
25	0	-	-	-	-	-	-	
26	119	1.7	28.6	32.8	34.5	2.5	-	
27	29	-	20.7	27.6	41.4	-	10.3	
28	0	-	-	-	-	-	-	
29	14	-	14.3	28.6	57.1	-	-	
30	1296	<1.0	58.3	9.1	25.2	4.4	1.9	1,2
July 1	3434	1.2	63.8	11.4	22.8	<1.0	-	3
2	6202	1.0	45.0	15.1	36.9	<1.0	<1.0	3,4,5
8	3978	2.0	80.5	5.7	9.5	-	2.2	
9	2836	<1.0	77.5	5.3	8.9	<1.0	6.7	3,6
10	4222	-	83.8	6.0	10.2	-	-	
11	8257	<1.0	77.2	7.0	13.9	-	-	3,7
12	1429	<1.0	73.9	11.6	5.0	<1.0	8.2	
13	879	<1.0	80.7	10.4	1.0	1.5	6.0	
14	672	<1.0	74.3	9.1	2.2	<1.0	13.5	
15	4857	-	74.6	10.9	8.0	1.0	5.0	7,8
16	4279	<1.0	79.6	5.2	2.3	-	3.5	9
17	2318	1.0	85.6	8.2	2.8	-	2.4	
18	427	1.4	80.8	4.9	1.8	<1.0	10.1	3,10

* 1 <1% H.frontalis 2 <1% H.nuda (male) 3 <1% C.exitans 4 <1% H.lurida
5 <1% H.zonalis 6 <1% H.pechumani 7 <1% T.similis 8 <1% T.marginalis
9 9% H.arpadi 10 <1% C.sackeni

4.2 RESULTS OF BEHAVIOR STUDY

The observed frequency of recorded bison behavior, habitat selection, group size and irritation level changed with increases in tabanid activity as indicated by fly catch. Since observations made on days when fly catch was high included times when flies were less active, such as early in the morning when temperatures were low, the effects of irritation levels and temperature on behavior and habitat selection were also considered. In May, a total of 228 observations were made in 8 days. The number of observations in a day ranged from 7 to 38 (mean 28). In June, 397 observations were made in 13 days. The daily number of observations ranged from 6 to 56 (mean 30.5). In July, 398 observations were made in 7 days. The number of observations in a day ranged from 14 to 79 (mean 56.9).

4.2.1 Changes Related to Increased Fly Catch

Bison spent significantly less time grazing (x^2=40.62; df=2; p<0.01) and more time resting and ruminating (x^2=90.55; df=2; p<0.01) as daily fly catch increased (Figure 7). Fly activity did not influence the frequency of social (x^2=5.25; df=2; p>0.01) and travelling behavior (x^2=2.16; df=2; p>0.01). Wallowing was most frequently observed when there was moderate fly activity and least frequently observed when there was no fly activity (x^2=16.75; df=2; p<0.01).

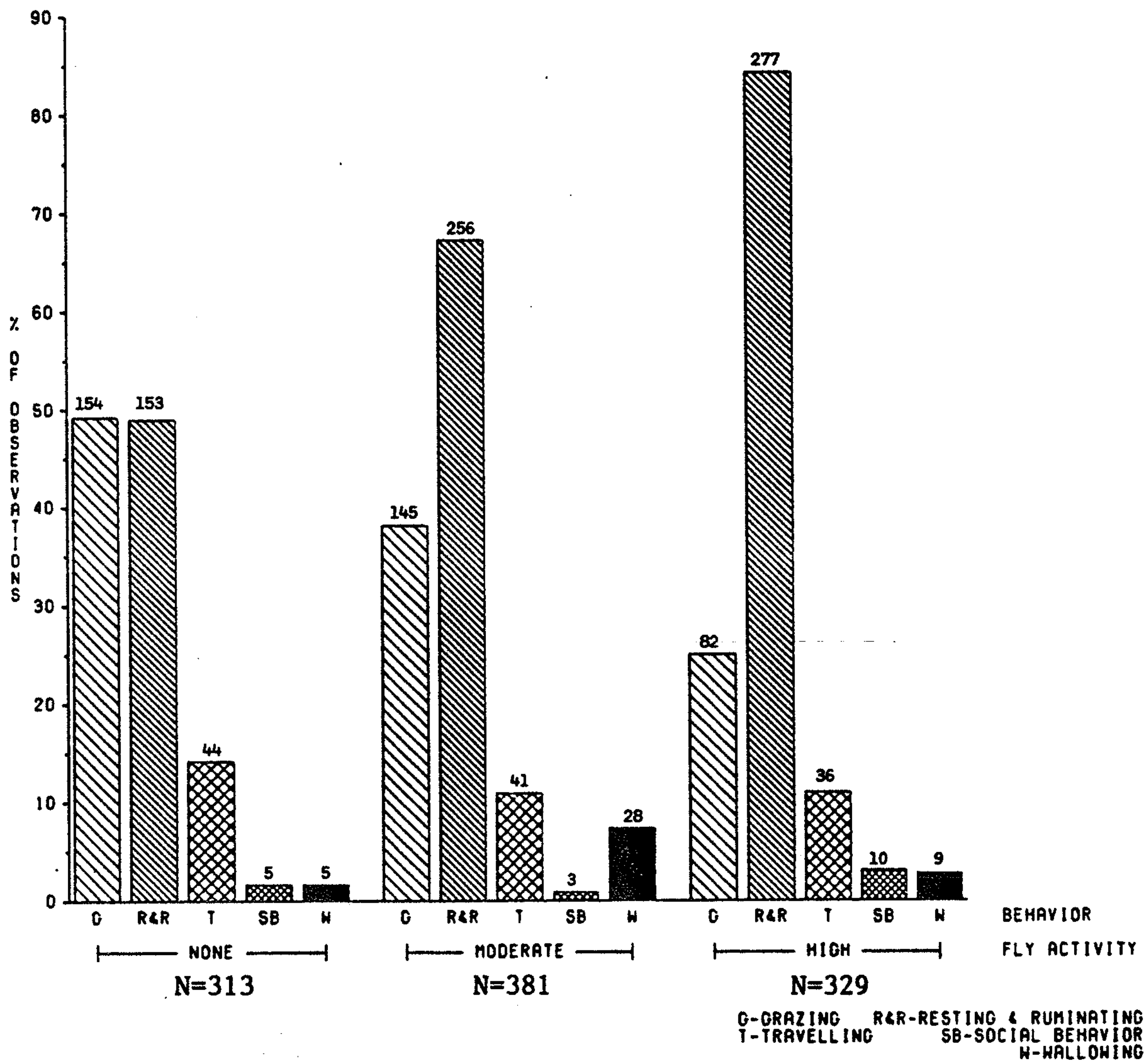


Figure 7: Percent frequency of behavior observed at Waterhen in 1985 when fly activity was high, moderate, and none.

The amount of time the bison spent in the enclosure (x^2=348.34; df=2; p<0.01) increased when fly activity was moderate and high. In many instances the bison remained in the enclosure throughout the day, arriving 7:00 to 8:00 am, and leaving at 8:00 to 9:00 pm. Selection of open habitat increased when fly activity was moderate and decreased when fly activity was high (x^2=45.40; df=2; p<0.01). Selection of road (x^2=34.55; df=2; p<0.01), edge (x^2=218.28; df=2; p<0.01), and closed (x^2=50.47; df=2; p<0.01) habitats decreased dramatically when fly catch was moderate and high (Figure 8).

As fly catch increased, bison formed larger groups (x^2=387.55; df=4; p<0.01; Figure 9). There was no significant difference in the frequency at which groups of 16 to 30 bison occurred (x^2=0.92; df=2; p>0.01). This may not, however, be a direct result of the increase in fly activity. The bison showed a strong preference for the enclosure, and it may be the selection of this habitat that caused the formation of large groups.

Higher irritation levels occurred more frequently when fly activity increased (x^2=728.42; df=6; p<0.01; Figure 10). Irritation level 2 occurred only when there were moderate and high levels of fly activity. Irritation level 3 occurred when there was high fly activity. Level 4 occurred only once, on 2 July, when daily fly catch was 6,200, and is included with level 3 for ease of analysis.

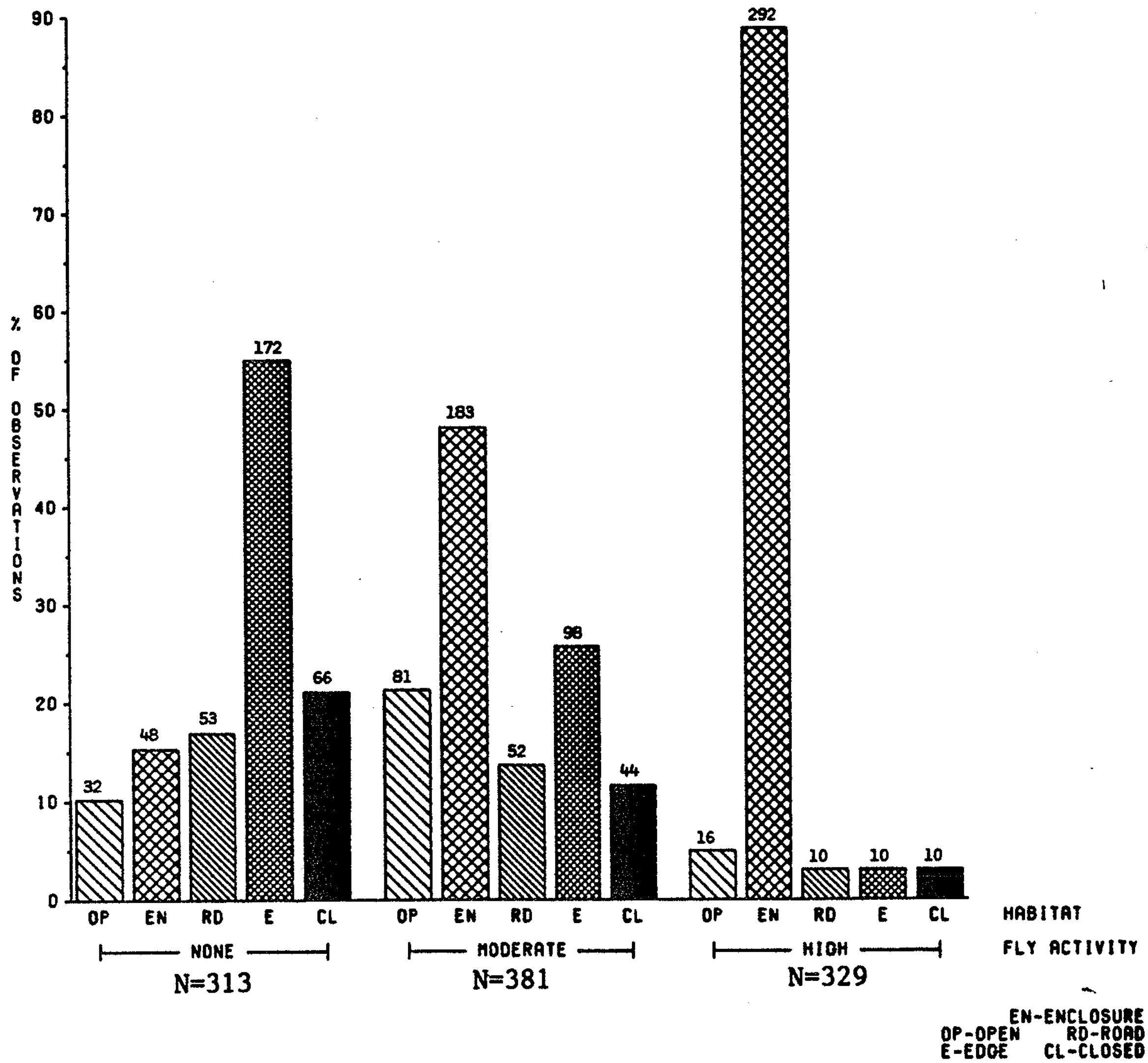


Figure 8: Percent frequency of habitats selected by bison at Waterhen in 1985 when fly activity was high, moderate, and none.

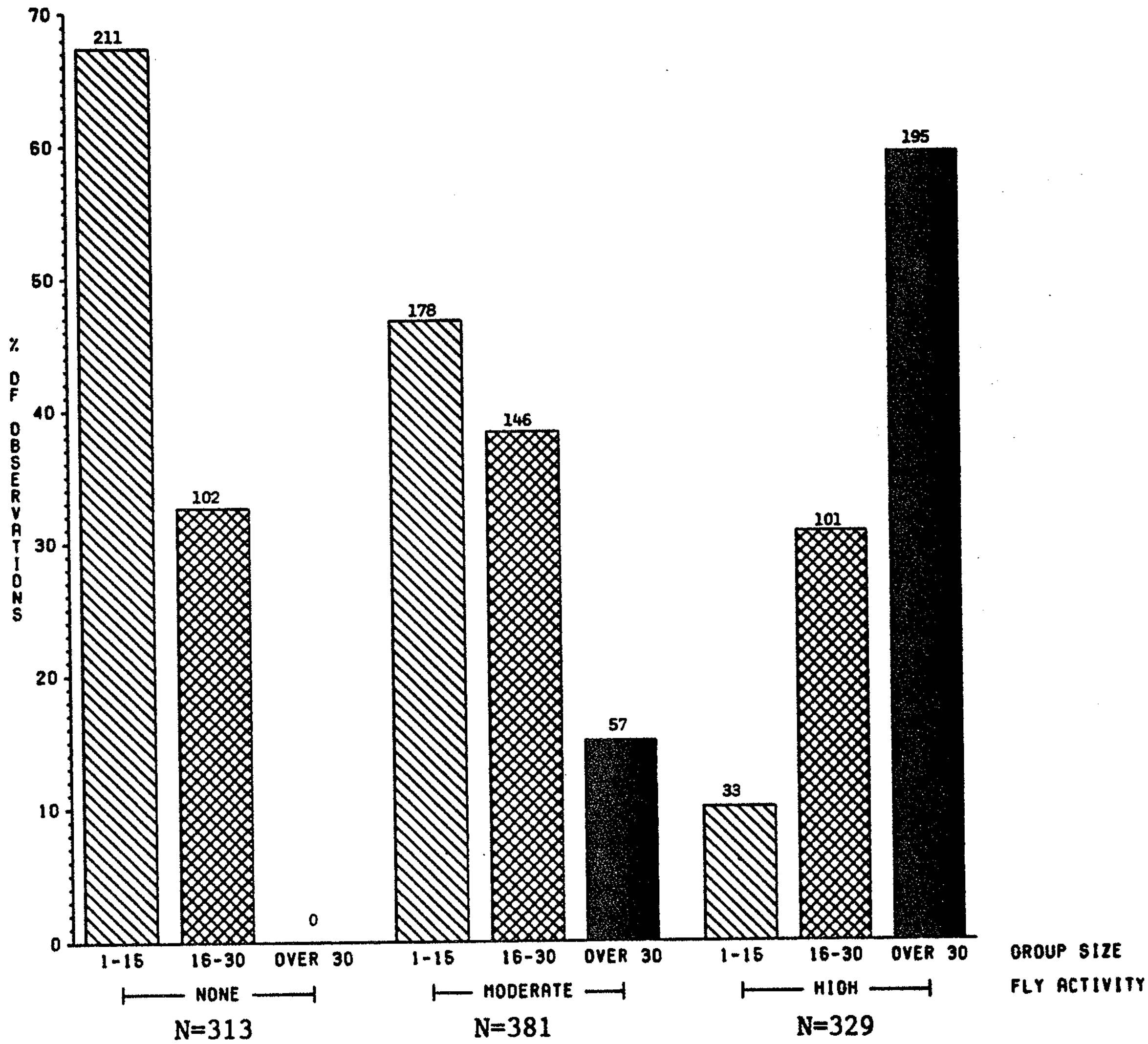


Figure 9: Percent frequency of wood bison group sizes observed at Waterhen in 1985 when fly activity was high, moderate, and none.

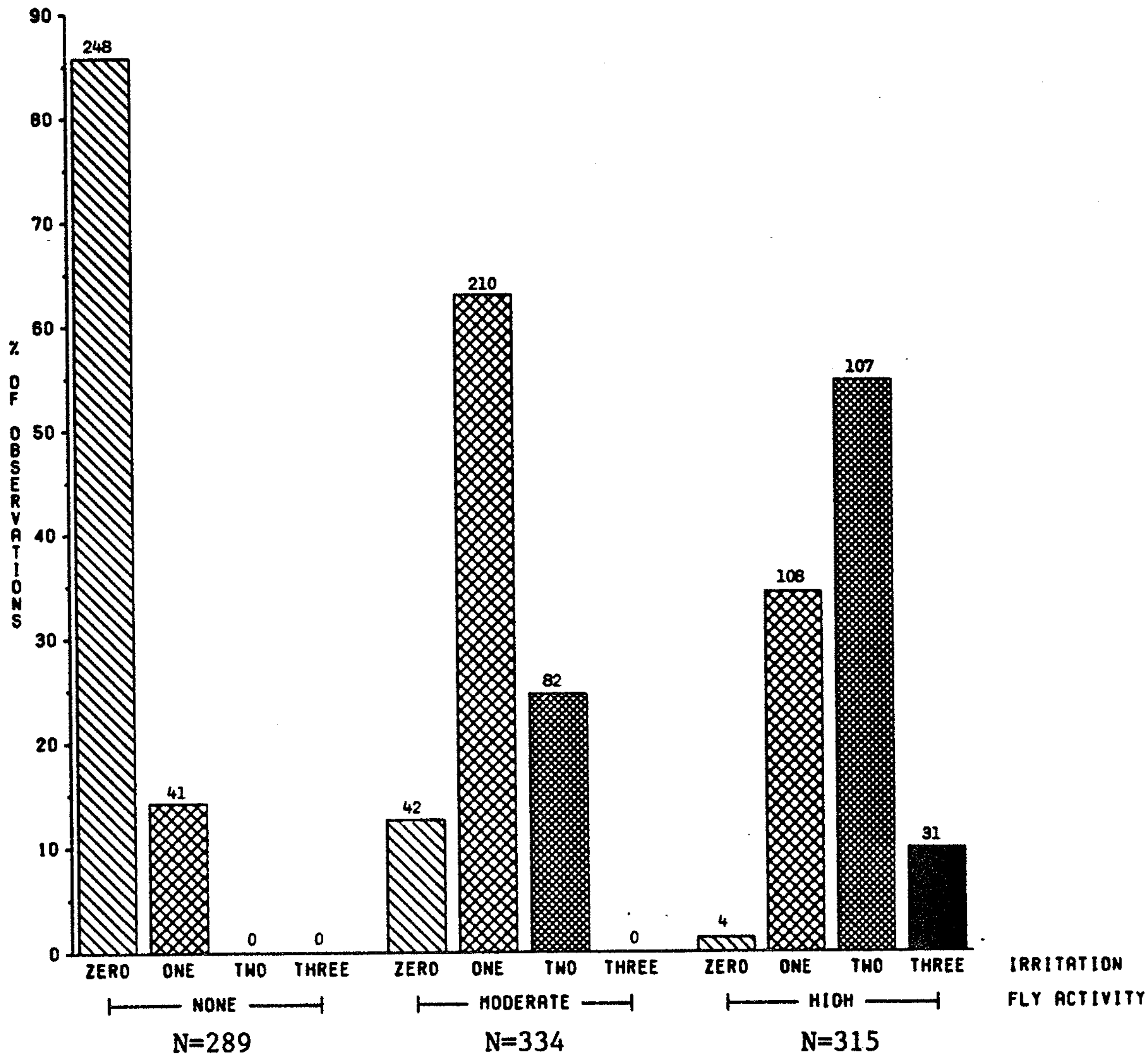


Figure 10: Percent frequency of bison irritation levels at Waterhen in 1985 when fly activity was high, moderate, and none.

4.2.2 Changes Related to Increased Temperatures

Total daily fly catch was not separated according to time of day, and therefore cannot be used to specifically indicate fly activity at any given time. Temperature is used as an indicator of fly activity since horse flies are known to be more active at higher temperatures (Burnett and Hays 1974; Alverson and Noblet 1977). Temperature, and therefore fly activity was greatest from 10 am to 4 pm.

Bison spent less time grazing (x^2=30.63; df=2; p<0.01), and more time resting and ruminating (x^2=40.55; df=2; p<0.01) at higher temperatures (Figure 11). There were no significant changes in the frequency of travelling (x^2=3.39; df=2; p>0.01) and social behavior (x^2=4.46; df=2; p>0.01). Wallowing was most frequently observed when temperatures were between 10 and 19°C (x^2=16.18; df=2; p<0.01).

The enclosure was the most frequently selected habitat when temperatures exceeded 10°C (x^2=175.33; df=2; p<0.01). Bison used open habitat most frequently when temperatures were 10° to 19°C and least frequently when temperatures exceeded 19°C (x^2=34.35; df=2; p<0.01). Selection of edge (x^2=99.95 df=2 p<0.01), and closed (x^2=63.93; df=2; p<0.01) habitats decreased as temperature increased (Figure 12). There was no significant change in the selection of road habitat.

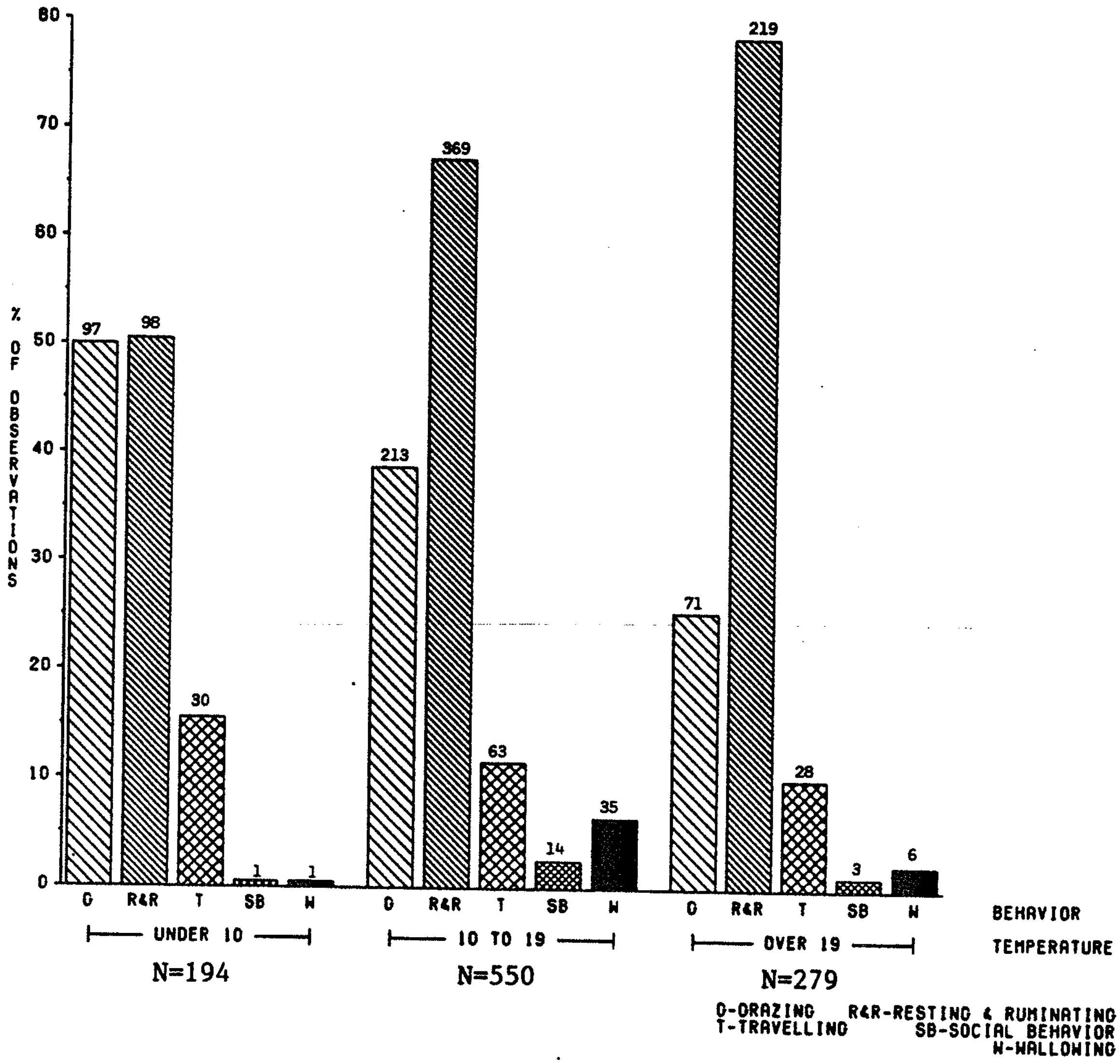


Figure 11: Percent frequency of bison behavior observed at Waterhen in 1985 at temperatures under 10°C, 10° to 19°C, and over 19°C.

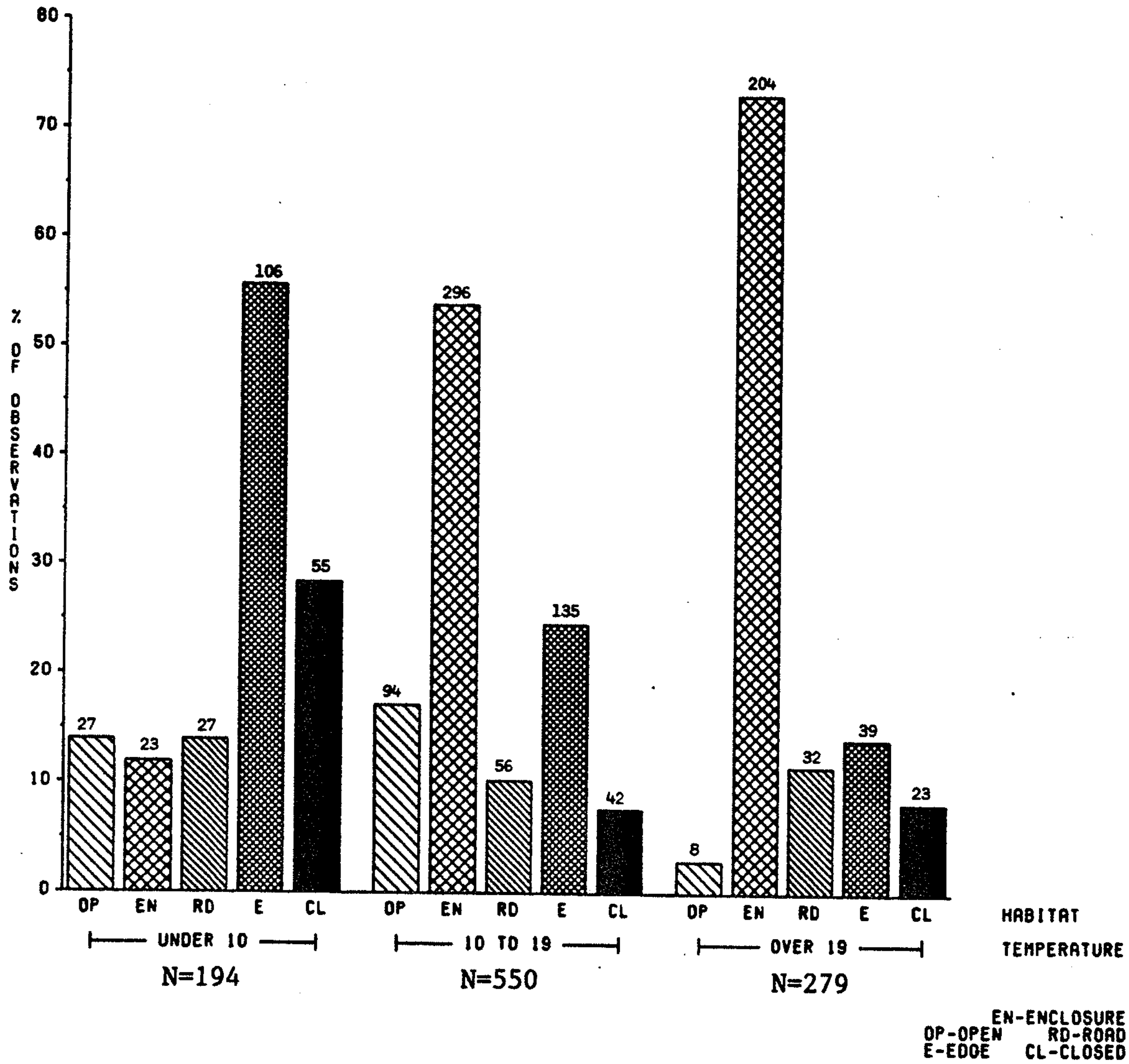


Figure 12: Percent frequency of habitats selected by bison at Waterhen in 1985 at temperatures under 10°C, 10° to 19°C, and over 19°C.

4.2.3 Changes Related to Increased Irritation

Discriminant analysis was used to determine the validity of observed irritation levels. Irritation level 4 occurred only once, and was grouped with level 3 for ease of analysis. Higher mean daily fly catch, mean temperature, and mean group size were associated with greater irritation levels (Table 4). Temperature was the variable most strongly correlated with irritation, and fly number was the second most strongly correlated. This means that irritation was in fact related to temperature and fly activity, and was valid as a measure of the effect of tabanids on bison.

TABLE 4

Within irritation level means of daily fly catch, temperature, and bison group size recorded at Waterhen, 1985.

Irritation level	Mean		
	fly catch	temperature	group size
0	6.6	9.5	14.9
1	193.8	16.4	19.1
2	343.9	19.9	32.0
3	544.9	21.9	37.4

The bison grazed less frequently (x^2=50.63; df=3; p<0.01) and spend more time resting and ruminating (x^2=74.27; df=3; p<0.01) at higher levels of irritation (Figure 13). The small decrease in percent frequency of resting and ruminating at irritation level 3 was not significant (x^2=0.6; df=1; p>0.01). Irritation did not appear to have a significant relationship with travelling (x^2=7.95; df=3; p>0.01) or social behavior (x^2=2.96 df=3; p>0.01). Wallowing (x^2=18.10; df=3; p<0.01) occurred most frequently at irritation levels 1 and 2. Irritation levels 2 and 3 were most often observed when the bison were in the enclosure ((x^2=248.35; df=3; p<0.01). Closed (x^2=40.77; df=3; p<0.01) and edge (x^2=214.85; df=3; p<0.01) habitats were selected less often when irritation levels were 2 and 3. There was no significant relationship between the use of road (x^2=5.27; df=3; p>0.01) and open (x^2=4.81; df=3; p>0.01) habitats and irritation level (Figure 14).

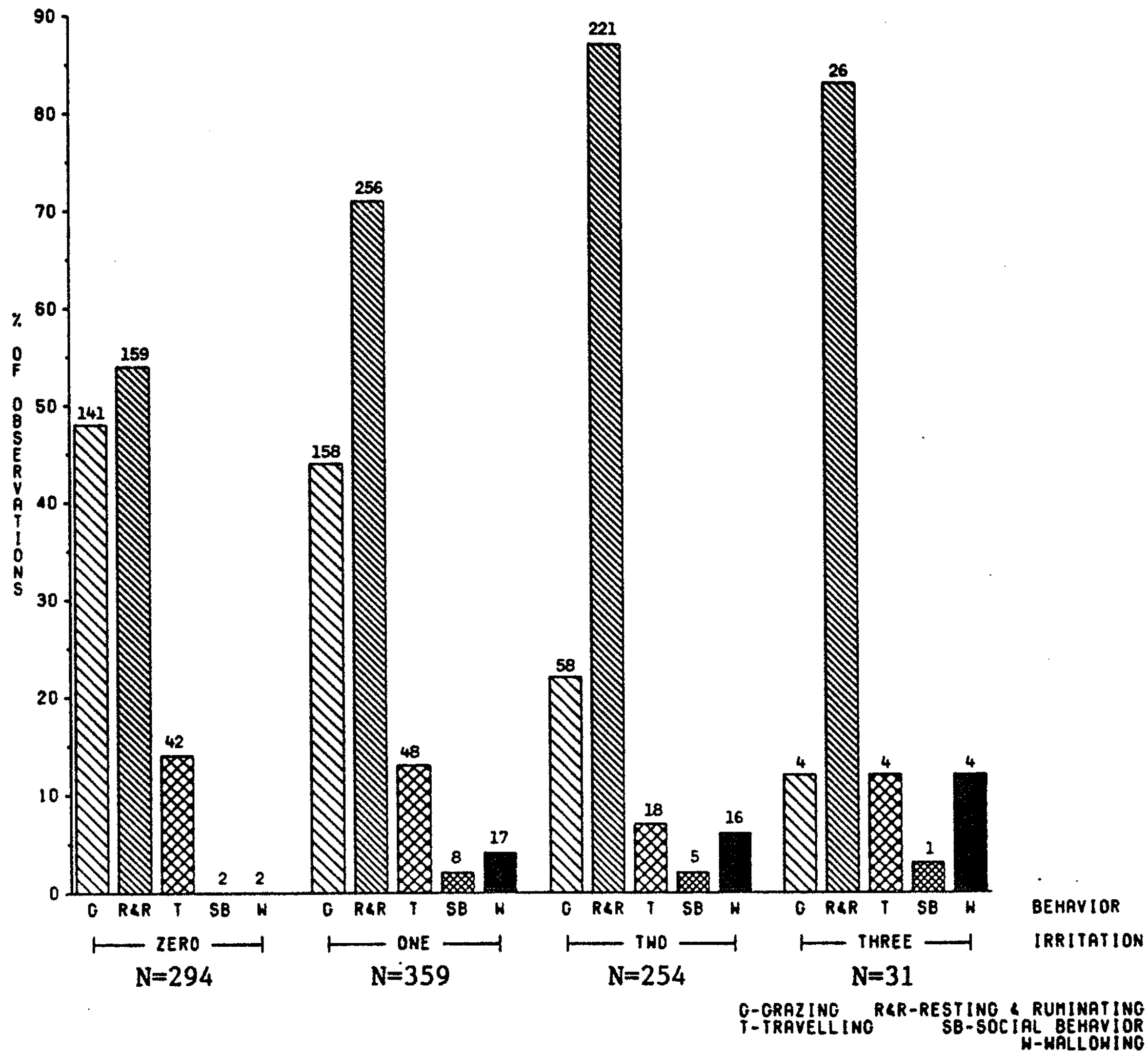


Figure 13: Percent frequency of bison behavior observed at Waterhen in 1985 at different irritation levels.

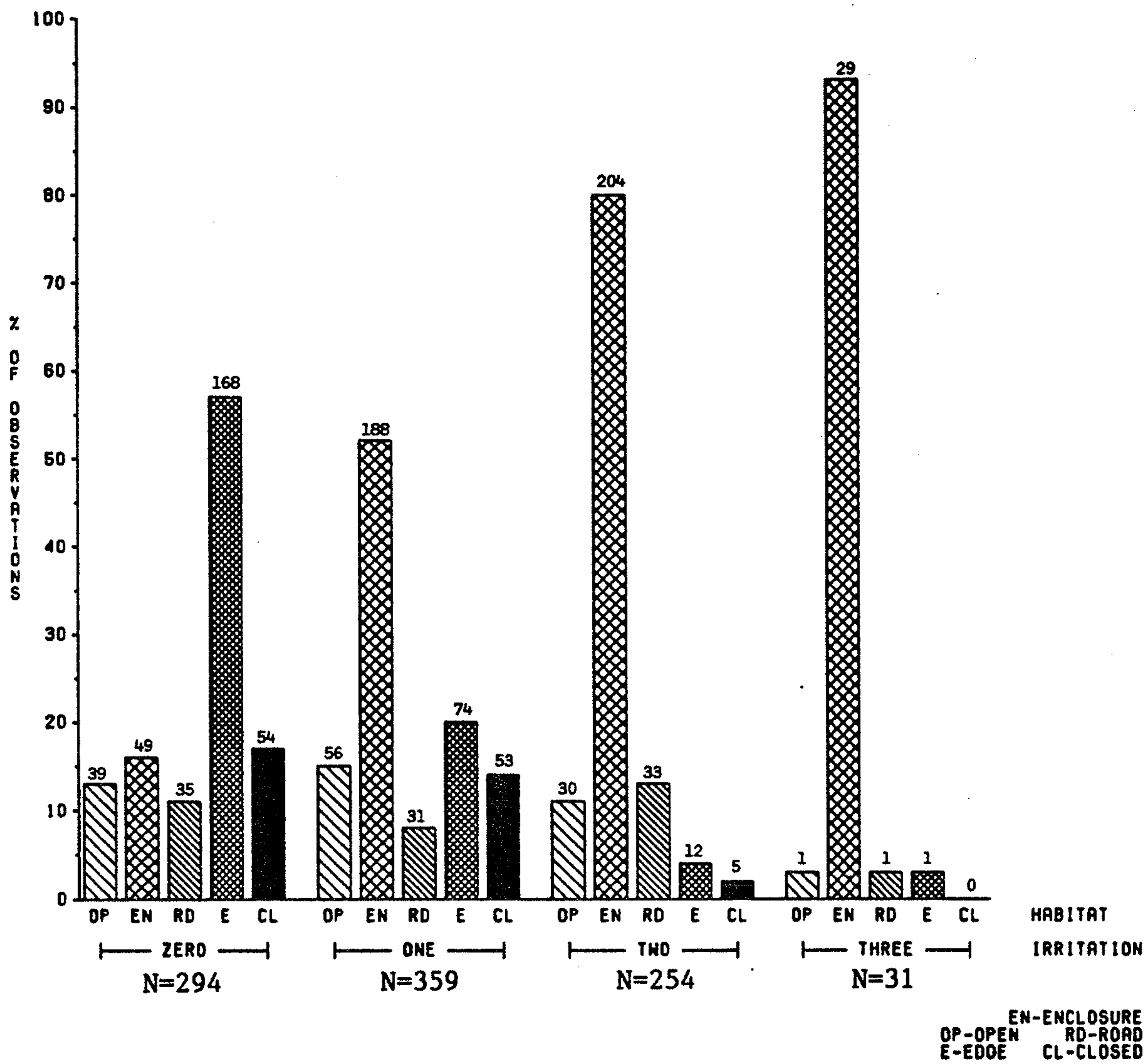


Figure 14: Percent frequency of habitats selected by bison at Waterhen in 1985 at different irritation levels.

4.3 RESULTS OF CONTROL METHODS

4.3.1 Permethrin Spray

A total of 253 observations made prior to spraying were used to indicate the behavior of the animals when not treated. The number of observations per day ranged from 46 to 79 (mean 63.25). One hundred ninety-six observations were made after the animals had been sprayed. The number of observations per day ranged from 14 to 69 (mean 49). Fly catch exceeded 500 on all 8 days. Mean fly catch did not differ between the control and treated groups ($t=0.14$; $df=6$; $p>0.01$; Table 5). Any differences in bison behavior, habitat selection, or irritation level were probably not caused by changes in fly activity, and may be attributable to the effect of the permethrin.

TABLE 5

Daily fly catch before and after treatment of bison with permethrin at Waterhen, 1985.

Prior to Spraying		After Spraying	
Date	Fly Catch	Date	Fly Catch
June 23	662	July 11	8257
July 1	3434	12	1429
2	6202	13	879
8	3978	15	4855
mean=3569.0 sd±2278.07		mean=3854.75 sd±3421.72	

Comparison using a x^2 test indicates that the treatment with permethrin did not alter bison behavior or habitat selection (Table 6). Irritation levels were lower overall after spraying. The frequency at which irritation levels occurred, and the frequency at which they would be expected if the treatment with permethrin had no effect are presented with x^2 values in Table 7.

In addition to the cow whose injury interrupted spraying, a 4 year old bull was injured by other bison while in the holding pen, and later died. Manitoba Agriculture Veterinary Services diagnosed the cause of death to be trauma and probable terminal *Clostridium septicum* infection.

TABLE 6

Chi-Square values comparing behavior and habitat selection of bison at Waterhen in 1985, before and after treatment with permethrin.

variable	x^2	probability
grazing	3.24	0.07
ruminating	4.10	0.04
travelling	0.01	0.94
wallowing	6.59	0.01
social behavior	0.31	0.58
open	4.14	0.04
edge	0.08	0.78
closed	0.0	1.00
enclosure	0.01	0.91
road	0.01	0.93

TABLE 7

Crosstabulation of treatment with permethrin by irritation levels exhibited by bison at Waterhen, 1985.

actual count (expected count)	Irritation level			
	0	1	2	3
not treated	9 (11.6)	68 (94.4)	131 (115.9)	31 (17.1)
treated	12 (9.4)	103 (76.6)	79 (94.1)	0 (13.9)

x^2=47.30 df=3 p<0.01

4.3.2 Manitoba Horse Fly Trap

Five pairs of samples were collected. Sample sizes are listed in Table 8. In all instances the total trap catch and average daily trap catch of the trap on Dr. Kalden's land (the test trap) was greater than that of the trap on neighboring land (the control trap).

TABLE 8

Total and average daily fly catch in the Gypsumville area in 1985, comparing an area where horse flies had been intensively trapped to an area where no trapping had occurred.

	Total Trap Catch		Average Daily Catch	
Dates	Control	Test	Control	Test
June 22-26	326	788	109	263
June 29-July 3	2575	3316	644	829
July 3-7	3580	8884	895	2221
July 7-11	2250	4066	563	1017
July 11-14	918	2233	306	744

Chapter V

DISCUSSION

5.1 TABANID ABUNDANCE AND SPECIES COMPOSITION

Distribution and seasonal abundance of tabanids may be affected by annual variation in climate and differences in soil and vegetation types (Hanec and Bracken 1964). The distribution of *Hybomitra*, which was the most abundant genus collected at Waterhen, is mainly northern, where habitat substrata are primarily organic (Teskey 1969).

Hanec and Bracken (1964) described the geographic distribution of Tabanidae (Diptera) in Manitoba. *Hybomitra epistates* is widespread throughout Manitoba and has been found to be extremely numerous in some locations (Hanec and Bracken 1964). *Hybomitra illota* and *H. lasiophthalma* are also widely distributed and are most numerous in northern areas, although *H. lasiophthalma* is less abundant than *H. illota* (Hanec and Bracken 1964). *Hybomitra nuda* appears to favor forest or partially wooded areas while *H. lurida* was captured only in heavily treed areas where evergreens predominate (Hanec and Bracken 1964). *Hybomitra affinis* and *H. zonalis* are rare throughout most of Manitoba (Hanec and Bracken 1964). Smith *et al.* (1970) classified *H. affinis*,

H. *arpadi* and H. *lasiophthalma* as preferentially forest species, although they were also found in other habitats, while H. *nuda* was found exclusively in forest habitats.

The species belonging to the genus *Tabanus* are rare in Manitoba except for T. *similis* (Hanec and Bracken 1964). This species seems to prefer open country or lightly wooded areas (Hanec and Bracken 1964). Smith *et al*. (1970) found T. *similis* to be more common around aquatic habitats and uncommon in woodland sites. *Tabanus marginalis* was found mostly in swampy areas (Hanec and Bracken 1964). Both species were present in very small numbers at Waterhen.

Chrysops species are found in relatively small numbers in forested areas, although certain species are abundant in non-forested areas (Smith *et al*. 1970). *Chrysops exitans* was predominant in the northern areas of Manitoba (Hanec and Bracken 1964). *Chrysops sackeni* was extremely rare in Manitoba, and was only found in the Whiteshell area (Hanec and Bracken 1964).

Horse flies were less numerous at Waterhen in 1985 than 1984 (Berezanski pers. comm.). It is not known why populations fluctuate. Probable factors are changes in larval habitat, available sources for blood meals, and sufficient habitat for oviposition (Ralley 1986). As well, the temperature and weather conditions affect the activity of tabanid populations. Lower average temperatures and increased precipitation in 1985 could have caused the reduced fly activity seen in that year.

The relative abundance of species trapped may not reflect the degree to which they attack the bison. Smith *et al*. (1970) found that although *H. epistates* was by far the most abundant species trapped in Algonquin Park, other species were seen to attack moose with more frequency. Moose were the preferred host of various species of *Hybomitra* whereas they were bitten by relatively few species of *Chrysops*, and these in small numbers only (Smith *et al*. 1970). Species found to prefer moose and deer to man included *H. affinis*, *H. arpadi*, *H. epistates*, *H. lasiophthalma*, *H. lurida* *H. nuda*, and *H. zonalis*. *Hybomitra illota* and *T. marginalis* attacked man more frequently than moose or deer (Smith *et al*. 1970).

5.2 BISON BEHAVIOR STUDY

5.2.1 Bison Behavior

The general response of the bison to increased fly activity was to spend less time grazing, and more time resting and ruminating. When there was no fly activity the bisons' behavior pattern during the day was similar to that described in the literature. Banfield (1974) stated that bison are mostly diurnal and that feeding begins at dawn and continues intermittently throughout the day until nightfall. Soper (1941) described the bison as being most active in the morning and late afternoon, while at midday they rested, ruminated, groomed and sought water.

When fly activity and temperature were high, the bison spent considerably less time grazing. It is not known if this response is a result of one factor or the other or a combination of the two. Feeding is more energetically costly than other activities, such as standing, walking, or resting (Webster 1983). In cattle, grazing time begins to decrease at temperatures above 26°C (Arnold and Dudzinski 1978). Rate of gain and milk production are reduced in most breeds of cattle at temperatures above 25°C (Webster 1983). Heat stress causes appetite reduction in cattle, and may be alleviated by the feeding of a low fiber diet during cooler times of the day (Webster 1983). Physiological responses to high ambient temperatures include sweating and panting (Andersson 1977). Darkened coat color, which would indicate sweating, was not observed in the bison in 1985.

Increased fly activity, which is known to coincide with increased temperatures, appears to be the major cause of the observed decrease in grazing activity. Berezanski (1986) reported that a large increase in bison feeding activity occurred when tabanid activity ceased in August, 1984. Harvey and Launchbaugh (1982) reported that horn flies (*Haematobia irritans*) caused beef steers to graze less during the day, and more during the night. Collins and Urness (1982) found that elk and mule deer compensated for grazing time lost during fly attacks by grazing more during the cooler part of the day and night. Whether or not the bison compensated in a similar manner could not be determined as the bison could not be observed at night. Periods of nighttime feeding activity by bison were reported by McHugh (1958), however, these were relatively short, usually singular, and was evidently non-cyclical. Banfield (1974) found that most nocturnal activity took place on moonlit nights in the winter.

Van den Brink (1980) reported that bison showed more feeding and less resting behavior on rainy days than on warm days. The Waterhen bison displayed a similar increase in grazing activity on rainy days. On two separate occasions grazing activity appeared to be stimulated by sudden rain showers during days when fly activity was high. In 1984, rain fell on nine occasions when bison were normally resting, and in seven cases this stimulated feeding (Berezanski 1986).

In general, cycles of feeding alternate with periods of non-feeding activity in a manner similar to cattle (McHugh 1958). Cattle ruminate for from 4 to 9 hours daily, or approximately 75% of the time spent grazing (Hafez 1982). The time spent ruminating depends on the quality of feed (Arnold and Dudzinski 1978). The Waterhen bison grazed and ruminated for about equal amounts of time when there was no fly activity and when temperatures were low. This may have been because the animals were easier to locate and keep in sight while they were ruminating than when engaged in other behaviors.

Resting and ruminating was the most frequently observed behavior when fly activity was moderate or high and when temperatures were high. The proportion of resting time cattle spend lying down decreases as temperatures increase (Arnold and Dudzinski 1978). Since resting and ruminating behavior increased as temperature increased, it is possible that this was a result of increased fly activity. Animals could be observed resting and ruminating for over 80% of the time spent in view while fly activity was high. The posture of the animal while lying down protected its belly and legs from fly attack. It also made it easier for the animals to lick the groin and flank areas and protect them as well.

Red deer attracted fewer biting flies when lying down than when standing up (Espmark and Langvatn 1979). Tabanids are visually attracted to their targets, and the attractiveness of a target increases with the number of reflecting faces that direct sunlight parallel to the ground (Thorsteinson et al. 1965). When the bison were lying down they may have presented a less visually attractive target to the flies, and as a result, suffered a lower rate of attack.

Rumination usually took place while the bison were lying down, but occasionally bison were observed to ruminate while standing. Resting and ruminating behavior was usually continuous when there was no fly activity. The animals would lie down for 2 to 4 hours, very rarely getting up. In most cases they seemed calm and could be observed to steadily chew their cud with chin extended and eyes half closed. When fly activity was high this was not the case. Individuals would lie down and get up continuously, often to stamp and lick and to move to a different location. Often larger animals would force smaller ones to get up and would lie down in the vacated spot. This aggressive behavior was similar to the rank indicating behavior described by Reinhardt (1985b). While such behavior is a normal part of bison social structure, an increase in aggressive behavior may be a result of the aggravation and annoyance caused by tabanid attack. The frequent change of position is energetically costly; six position changes in a 10 minute period requires the same energy as 10 minutes of feeding (Arnold and Dudzinski 1978).

Wallows and wallowing are frequently noted in both wood and plains bison (Allen 1900, Graham 1922, various authors _in_ Soper 1941). The purpose of wallowing has not been fully explained. Soper (1941) stated that the principal wallowing season in Wood Bison National Park coincided with maximum heat and insect activity, although some wallowing occurred from spring until fall. He suggested that wallowing was chiefly induced by insect irritation, but that it also had a cooling effect. Reinhardt (1985a) found no evidence that wallowing served to get rid of insects. Some authors have linked wallowing with breeding behavior (McHugh 1958, Lott 1974). Reinhardt (1985a) found no correlation between wallowing and breeding activity. Wallowing was described as a self-grooming behavior, and was correlated with shedding, suggesting that rolling on the ground helped relieve itching skin irritations (Reinhardt 1985a).

Wallowing and scratching behaviors were more commonly seen in May than in June and July at Waterhen. This suggests that it was related to the shedding season rather than to fly activity. Although wallowing was seen to increase at irritation levels 2 and 3, it cannot be conclusively stated that wallowing was related to fly activity. Wallowing was most frequently seen when temperatures were between 10 and 19 ^{o}C, and when fly activity was moderate, and least frequent at temperatures under 10^{o}C and when there was no fly activity. Wallowing did not seem to have a cooling effect since animals did not wallow more frequently as temperature increased.

5.2.2 Habitat Selection

The Waterhen wood bison strongly preferred the enclosure when fly activity was moderate and high. The enclosure was the selected habitat during 88.8% of all observations when fly activity was high, and 48.0% of all observations when fly activity was moderate. Edge habitat was most frequently selected when there was no fly activity. This is similar to the resting habitat choices observed by Berezanski (1986) in 1984 during months when horse flies were active. Berezanski (1986) found that the selection of open habitat, which included the enclosure, was 95.3% and 88.3% for the months of June and July, respectively. Edge and closed habitats combined were selected 4.7 and 11.7% of the time in the same months. In the month of August, when fly activity was insignificant, the selection of open habitat decreased, while edge and closed habitat selection increased to 51.5% of observed choices. Berezanski (1986) suggested that the choice of enclosure and road habitats was related to the availability of wallowing sites. This was not supported by the present study as wallowing did not occur more frequently in the enclosure than in other areas.

Howell et al. (1949) reported that livestock are more readily attacked by horseflies in woody or shrubby areas than in other places, while Sheppard and Wilson (1977) found tabanid host seeking activity was highest within 130 m of woods. The preference for open habitat in response to tabanid activity has been observed by Collins and Urness (1982) in elk, and by Duncan and Cowtan (1980) in horses. Duncan and Cowtan (1980) showed that the choice of open habitat had the effect of reducing the number of fly attacks per animal.

The ground of the enclosed area was denuded, and a dark brown in color. When the bison were lying down they were not distinct from the ground and possibly were less visible to the flies. Although this would not eliminate fly attack, it is probable that fly attack was reduced. A lower rate of fly attack for these reasons would explain why the bison selected the enclosure over other available open habitats. How the animals learned this is speculative, but if the selection of the enclosure reduces fly attack then its selection is being positively reinforced, and will be repeated.

5.2.3 Group Size

Bison normally form three types of groups during the year (Reynolds *et al*. 1984). These were categorized as:

- mixed, matriarchal, or cow groups containing cows, calves, immature animals and sometimes a few bulls;
- bull groups, consisting of only a few mature bulls, or a solitary bull;
- large breeding groups, which form during the rut, and are a combination of the first two groups.

In most cases adult males in the Waterhen herd remained with the mixed group. The reason for this may have been related to fly avoidance behavior. Group size in horses affects both the number of tabanids observed on individuals and the number of bites the horses received (Duncan and

Vigne 1979). More flies were observed on individuals in small groups than in large groups.

Large groups of bison were more frequently seen in the enclosure than in any other habitat. Possibly herding behavior had the effect of reducing the number of flies on individual animals. This would explain the increase in group size when flies were active. The herd might then select the enclosure to further reduce the rate of fly attack. Conversely, it may be that increased selection of the enclosure by individuals resulted in the increased group size observed at moderate and high levels of fly activity.

5.3 IMPACT OF TABANIDS ON BISON REPRODUCTION

The breeding season for bison generally occurs between July and October (Soper 1941; Fuller 1966; Banfield 1974). The variability in the onset and duration of the rut may be related to variation in climate, photoperiod, habitat, population density, and genetic expression (Reynolds et al. 1984). During this period, herd size increases as bull groups join the mixed groups (Soper 1941; McHugh 1958; Lott 1974; Reynolds et al. 1984).

Stress caused by tabanids in 1984 may be one of the causes of the reproductive failure observed in 1985. The three calves born in 1985 were offspring of cows brought to Waterhen from the Toronto Metropolitan Zoo in spring 1985. None of the cows brought to Waterhen in 1984 had conceived (Payne pers. comm.). While there are several possible explanations for the reproductive failure, the effect of biting flies on feeding behavior is probably significant. Poor nutrition prior to breeding can reduce conception rates in cattle (Bearden and Fuquay 1980) and may similarly affect bison.

5.4 CONTROL METHODS

5.4.1 Permethrin Spray

The bison were less irritated after spraying, but there was no significant difference in habitat selection and behavior from that observed prior to treatment. While the bison would spend less energy on comfort movements if they were less irritated, it is not known if this alone would translate into a significant improvement in their condition. Certainly there seems to be no advantage in spraying if it does not result in an increase in grazing time or allow the bison to make use of more nutritious habitats.

The effects of permethrin spray would have been easier to determine if the bison had been divided into two groups, one sprayed and one unsprayed. Then any change in fly population, temperature, or weather could have been disregarded since both groups would have been similarly affected. In this study, the lower irritation level observed after spraying may have been a result of factors other than the spray.

The advantages of chemical spraying appear to be minimal and the disadvantages of handling the bison considerable. Two animals died as a direct result of handling. In addition, handling is known to be very stressful to bison. A report on the response of bison to handling during a vaccination program in Wood Buffalo National Park indicated handling resulted in physical injury, the separation of cow-calf units and stress related myopathies (Hudson *et al*. 1976). Goring and crushing when the animals were crowded into close quarters were the main sources of injury (Tennessen and Hudson 1977). The separation of cows and calves was a result of high speed handling (Tennessen and Hudson 1977), and was not a factor at Waterhen.

Stress related myopathy, also known as white muscle stress syndrome, or overstraining disease, occurred within one to two weeks after handling (Hudson *et al*. 1976). Pain, stiffness, and muscular dysfunction are symptomatic, with paralysis and prostration occurring in severe cases (Hudson and Stelfox 1976). Muscles in the limbs, back and heart are affected, and show light grey portions and lesions upon examination (Hudson *et al*. 1976). Acute stress and usually, but not always, overexertion are the causes of this metabolic disorder (Hudson *et al*. 1976).

In Wood Buffalo National Park, lower general noise levels during handling and lower ambient temperatures reduced the occurrence of stress related myopathies (Tennessen and Hudson 1977). Recommendations made by Tennessen and Hudson (1977) to lower stress were:

- to reduce noise levels by minimizing the amount of shouting;
- to avoid close confinement and crowding of animals;
- to time handling to coincide with cool weather, for example in the spring or fall, or in the early morning during the summer;
- to use a water sprinkling system to cool down the animals;
- to brief personnel on handling strategies, as bison require different handling methods than domestic cattle.

If further investigations into insecticide use at Waterhen were made, an alternative method of application would have to be developed. Ideally, the method would not result in any stress to the bison. Some alternative methods of insecticide application are:

- spraying in the chutes, following the recommendations made by Tennessen and Hudson (1977). While this might result in less stress than occurred in 1985, it would still be stressful to the animals.
- spraying the unconfined animals from the back of a truck using either an electrostatic sprayer, or a conventional sprayer. While this would eliminate the stress of handling the animals, uniform application could not be guaranteed.

- suspended dust bags. If the animals were to continue to use the enclosure during horse fly attacks, a dust bag suspended over the entrance would allow for the application of an insecticide as they entered. This would have the advantage of applying the chemical when needed, however, since the bison are all different ages and sizes, it would be difficult to ensure uniform application. It is also likely that the bag would get caught on the bisons' horns and be damaged.
- oilers. This device is not effective unless the animals rub against it. There is no way of knowing if any of the bison would be so inclined, and if they were, if the oiler would survive the attention.

5.4.2 Manitoba Horse Fly Trap

Fly activity on land where horse flies were extensively trapped was not lower than on neighboring land where no trapping occured. This does not necessarily mean that trapping did not decrease fly activity. There are many reasons why fly activity could be higher on land where trapping occurred. The trap may have been near a breeding site, or an area where horse flies are particularly numerous. Flies may have been more attracted to the horses in the test pasture than the cattle by the control trap.

The effects of trapping could be cumulative, and may become more evident over time. The irritation level of animals in the trapped and untrapped areas were not considered in this study. A comparison of irritation levels, behavior, or weight gains of animals in trapped and untrapped areas may have been a better indicator of the effectiveness of trapping than was trap catch.

In other cases where extensive trapping of horse flies has resulted in reduced nuisance levels, reductions in fly populations had been thought to be unlikely since most of the females entering the traps had already laid fertile eggs (Wall and Doane 1980).

5.5 SUMMARY REMARKS

Fourteen species of tabanids were collected at Waterhen in 1985. The majority of species captured belonged to the genus *Hybomitra*, while only small numbers of *Chrysops* and *Tabanus* were collected. The composition of the trap catch may not be an accurate reflection of the degree to which they attacked the bison.

When horse flies were present bison behavior differed from that observed when there were no flies. Large groups of bison congregated in the enclosure and spent most of the day resting and ruminating when flies were present. Although it is possible that the behavioral response was a result of higher temperatures, this is unlikely.

The bisons' behavioral response to tabanids may reduce fly attack. The bison selected a habitat which makes them less visible to the flies, and as distant as possible from the woods edge where flies are more abundant. The formation of large groups may reduce the incidence of attack on individuals. In addition, the reduction in grazing activity when flies were abundant may allow the animals to conserve energy. However, this behavior has a negative impact as well; while the animals may be decreasing their energy output, they are also limiting their energy input. The decrease in the amount of grazing activity observed, and the subsequent reduction in nutritional levels is a serious concern if the bison population is to increase. Loss of grazing time during the day may be compensated for by increased grazing at night, but this could not be studied at Waterhen as the bison were not observed at night. The use of radio collars, or other methods of remote sensing might be used to overcome this problem.

While the behavioral response of the bison is apparent, why the flies elicit this response is speculative, and is yet to be studied. A possible method of doing so would be to compare landing counts of tabanids on animals in large and small groups, as was done by Duncan and Vigne (1979), and on individuals in different habitats as in Duncan and Cowtan (1980).

The use of permethrin spray to reduce tabanid attack on bison was largely unsuccessful. There was no change in bison behavior other than lower irritation levels, that would indicate a reduction in tabanid attack after spraying. Spraying was highly stressful and resulted in the death of two animals. The other control method studied, the use of the Manitoba Horse Fly Trap to reduce fly activity, is as yet unproven. A comparison of trap catches did not indicate any decrease in fly populations. Future research on the irritation level, or weight gain of animals in trapped and untrapped areas might determine the effectiveness of this method.

One of the problems in determining the impact of tabanids on bison is the difficulty in quantitatively measuring the bisons' responses. A study of their behavior cannot directly answer the question of what effects the tabanids have on weight gain, fertility, and general herd health. Frequent handling to determine weight gain, or loss is not a realistic method, since the stress caused by this would be counterproductive.

This same reasoning limits the possibility of further research into the effectiveness of insecticide spray. While such information would be helpful, a method of application other than the spraying of individual animals as done in 1985 would be necessary.

Chapter VI

CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

High populations of horse flies were observed at Waterhen during the summer of 1985. These populations had a significant effect on the behavior and habitat selection of the wood bison. Bison spent less time grazing and more time resting and ruminating when horse flies were active. It could not be determined if the bison compensated for lost grazing time by grazing at night. When tabanids were active, bison showed a strong preference for the enclosure, an open habitat denuded of vegetation. The use of all other habitats declined at these times. Large groups of bison formed when fly activity was high, but it could not be determined if this was in response to the flies, or as a result of habitat preference.

The use of permethrin did not result in any change in observed behavior, other than generally lower irritation levels. The costs of spraying in terms of stress to the bison from handling outweighed the benefits in terms of relief from fly attack. Spraying is not recommended as a method of tabanid control.

Two years of intensive trapping of tabanids using the Manitoba Horse Fly Trap did not result in lower fly populations; however, this method of control may decrease the nuisance level of tabanids in the vicinity of the traps. Further investigations into the use of horse fly traps are recommended.

6.2 RECOMMENDATIONS

- Open and denuded habitat should be developed for the bison throughout the project area.
- Supplemental feeding of hay to the breeding herd during horse fly attacks is recommended. The increase in nutrition prior to the rut should increase the reproductive rate of the herd. The animals that are to be released to form a free ranging herd, should not be fed, as they will not have the benefit of supplemental feeding after release.
- Application of an insecticidal spray to bison is not recommended because of the low efficacy of insecticides against tabanids, and because of the stress involved in handling the bison.
- The effects of extensive trapping on the nuisance level of horse flies should be further investigated. If trapping could be shown to reduce nuisance levels it could be useful as a low cost, environmentally safe control method.

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Appendix A

SEXES AGES AND ORIGIN OF WATERHEN WOOD BISON 1985

Males

Year of Birth	Number	Origin
1984	*	Waterhen, Manitoba
1983	2	Banff
1983	1	Calgary Zoo
1983	4	Toronto Metropolitan Zoo
1982	3	Banff
1982	2	Moose Jaw Wild Animal Park
1982	3	Toronto Metropolitan Zoo
1981	1	Banff
1981	1	Moose Jaw Wild Animal Park
1981	2	Toronto Metropolitan Zoo
1980	1	Moose Jaw Wild Animal Park
1978	1	Moose Jaw Wild Animal Park
1978	1	Toronto Metropolitan Zoo
?	2	Moose Jaw Wild Animal Park
?	3	Toronto Metropolitan Zoo
Total males	27	

* the sex of the yearling bison could not be determined

Females

Year of Birth	Number	Origin
1984	*	Waterhen, Manitoba
1984	2	Toronto Metropolitan Zoo
1983	1	Calgary Zoo
1983	2	Banff
1983	2	Toronto Metropolitan Zoo
1983	1	Wildlife Reserve of Western Canada
1982	1	Valley Zoo
1982	1	Banff
1982	2	Moose Jaw Wild Animal Park
1982	1	Toronto Metropolitan Zoo
1981	1	Wildlife Reserve of Western Canada
1981	1	Moose Jaw Wild Animal Park
1980	1	Moose Jaw Wild Animal Park
1979	1	Moose Jaw Wild Animal Park
1977	1	Wildlife Reserve of Western Canada
?	4	Moose Jaw Wild Animal Park
Total females	22	

* the sex of the yearling bison could not be determined

Appendix B

MEAN MONTHLY TEMPERATURE AND PRECIPITATION AND MONTHLY SYNOPTICS AT GYPSUMVILLE.

TABLE 9

Mean Monthly Precipitation at Gypsumville.

Month	Mean Monthly Rainfall mm	Mean Monthly Snowfall cm	Mean Monthly Total mm
January	0.2	20.0	22.1
February	0.6	13.5	13.8
March	1.2	18.6	18.9
April	9.5	7.6	17.3
May	32.8	1.5	34.0
June	58.7	0.1	58.8
July	63.6	0.0	63.6
August	63.6	0.0	63.6
September	51.4	0.1	51.3
October	18.4	3.2	25.1
November	1.3	17.8	25.9
December	0.0	19.7	24.0
Yearly	301.3	102.1	418.4

Fraser *et al*. (1985)

TABLE 10

Mean Monthly Temperature at Gypsumville.

Month	Mean Daily Maximum °C	Mean Daily Minimum °C	Mean Monthly °C
January	-15.3	-26.0	-20.7
February	-10.6	-22.9	-16.8
March	-2.6	-14.8	-8.7
April	7.9	-4.2	1.9
May	16.5	3.5	10.1
June	21.3	8.8	15.1
July	23.9	12.0	18.0
August	22.3	10.2	16.3
September	16.7	5.6	11.1
October	8.7	-0.2	4.3
November	-1.7	-9.8	-5.8
December	-11.1	-21.1	-16.1
Yearly	6.3	-4.9	0.7

Fraser *et al*. (1985)

TABLE 11

Synopsis of Mean Monthly Temperatures at Gypsumville in 1984 and 1985.

	Mean Temperature Month/Year							
	May		June		July		August	
Hour	1984	1985	1984	1985	1984	1985	1984	1985
0000	4.8	7.9	13.2	10.2	16.0	13.6	17.2	12.3
0600	4.4	7.8	13.4	10.2	15.4	13.5	15.8	12.1
1200	12.5	16.1	20.4	15.4	22.6	21.8	24.1	18.6
1800	12.3	14.7	20.1	16.1	23.0	21.8	24.0	18.1

from Environment Canada Atmospheric and Environment Service, 1984; 1985.