IMPACT OF TABANIDAE ON BEEF CATTLE

By

MICHAEL JOSEPH PERICH

Bachelor of Science
Iowa State University
Ames, Iowa
1979

Master of Science
Oklahoma State University
Stillwater, Oklahoma
1982

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the degree of
DOCTOR OF PHILOSOPHY
May, 1985

IMPACT OF TABANIDAE ON BEEF CATTLE

Thesis Approved:

Russell Wright
Thesis Adviser

Keith Lusby

J. Alexander Ham

Richard Berberet

Ronald W. McNew

Norman N. Durham
Dean of the Graduate College

ACKNOWLEDGMENTS

I wish to express my sincere appreciation to my major adviser, Dr. Russell E. Wright for his support and guidance through this study and my career at Oklahoma State University. I also wish to thank the members of my committee, Drs. Richard C. Berberet, Jakie A. Hair, Keith Lusby, and Ronald McNew for their advice and criticisms.

A special thank you to Dr. Lusby and the Animal Science staff at the Oklahoma State University Range Cow Research Center for all the material and physical assistance.

For their physical and moral support, I am indebted to Lisa Colburn, Jimmy Kiser, Curtis Kiser, Franco Vian, Paul Rensner, Lynita Cooksey and Steve Presley.

I express my sincerest gratitude and love to all my family both living and now deceased, who have sacrificed all their lives so that I might accomplish my goals.

Finally, to my dearest wife, Bunni, I have no words adequate enough to express my gratitude and love for all her patience, support, understanding, and love throughout the pursuit of this degree. It is to Bunni and my family that I dedicate this work.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Early reports of the effects of arthropods on livestock production usually associated losses in production with the most abundant pest present. Bishop (1913) attributed the 40 to 60% decrease in milk production in dairy cattle to Stomoxys calcitrans (L.) (stable fly), the most abundant pest. Laake (1946) reported producers felt that Haematobia irritans (L.) (horn fly) made it unprofitable to feed cattle in feedlots between June and September in Kansas. Freeborn and Regan (1928) found a 14% milk reduction in untreated animals, and attributed 1.4% of the reduction to horn flies, 3.33% to house flies and 9.26% to stable flies. The allotted percent reductions were based on the percentage each species comprised of the total on the cattle.

Granett and Hansens (1956, 1957) reported that horn flies, stable flies, house flies and mosquitoes caused economical reduction in milk production. Bruce and Decker (1958) reported that each stable fly caused a 0.7% reduction in butterfat and total milk production. Cheng and Kesler (1961) in a three year study found that horn flies, house flies, face flies and two species of horse flies caused no significant effect on milk production and concluded that the quantity of pasture and supplemental feeding compensated for fly attack.

Scharff (1962) reported moderate to light infestations of Haematopinus eurysternus Nitzsch caused no significant weight gain difference, but that heavy infestations of *H. eurysternus* did cause significant weight gain differences. Kettle (1974) reported that neither *Linognathus vituli* (L.) nor *Bovicola bovis* (L.) caused any significant difference in weight gain or hair coat condition. The nutritional level and general health of animals can be very important when determining the effects insects especially lice have on cattle (Roberts 1938). Steelman et al. (1972) showed that large mosquito populations had no significant effect on weight gains in cattle on a high energy diet, but did cause significant lack of weight gain in animals on a low energy diet.

Several studies have shown greater weight gains in beef cattle protected from fly attack by insecticides. Cheng (1958) reported a 0.33 to 0.67 lbs/animal/day difference in gain between animals protected and exposed to horn and stable flies. Cutkomp and Harvey (1958) reported greater weight gains (0.25 and 0.67 lbs/head/day) for cattle protected from horn and stable flies in two of the three years, but in the third year of the study found unprotected animals gained 0.32 lbs/head/day more than protected animals. Campbell (1976) found a 12.9 lbs/calf advantage in weaning weights for calves whose dams were protected from horn flies compared to calves weaned from unprotected cows. Harvey and Brethour (1979) reported that yearling steers protected from horn flies in a six year study gained 5 and 3 kg/head more than unprotected steers during early and late grazing periods, respectively. Haufe (1982) reported an 18% increase in gain for animals protected from horn flies by insecticide impregnated eartags, while Kunz et al. (1984) reported an 11 to 14.3% increase in gain for treated animals in a similar test. Schmidtman et al. (1981) found no difference in weight gains in dairy cattle exposed to and protected from face flies.

All the previously cited studies were done with animals maintained on pasture where it is difficult to regulate feed intake and to determine the impact of a single pest species or species complex. Studies in which these variables were controlled have been done to better estimate the exact impact of some pest species. Steelman et al. (1972, 1973) showed that mosquito populations in Louisiana caused significant reduction in weight gains in unprotected cattle as compared to cattle protected by screen cages. Campbell et al. (1977) released stable flies into a screened pen containing cattle and found that stable flies caused 0.20 lbs/head/day difference in gain with animals on a growing ration and a 0.50 lbs/head/day difference with animals on a finishing ration. In a similar study Campbell et al. (1981) found that house flies did not affect animal performance under feedlot conditions. Arends et al. (1982) also found that the non-blood sucking face fly did not affect weight gain in growing beef cattle.

Despite these studies there is little quanitative data on the effect of external parasites on beef cattle performance and no economic thresholds for these pests were established. In his review on the effects of external and internal arthropod parasites have on domestic livestock production, Steelman (1976) emphasizes the need to establish economic thresholds for arthropod pests of livestock.

The family tabanidae is comprised of a large group of haematophagus flies with many species that are important pests of humans and livestock. Tabanids can potentially cause losses in livestock production through annoyance associated with their feeding as reviewed by Steelman (1976), mechanical transmission of disease agents (Krinsky 1976) and blood loss (Tashiro and Schwardt 1949; Gooding 1972; Hollander and Wright

1980a). Twenty-three species of Tabanidae have been collected in north central Oklahoma, with six species comprising 97.7% of the total captured over four years (Wright et al. 1984). The seasonal abundance and daily activity cycles for the eight most abundant species have been determined (Hollander and Wright 1980b) along with their preferred feeding sites and average blood meal size (Hollander and Wright 1980b).

Though tabanids are known to be painful biters and appear to be of great annoyance to cattle, there is little information available to describe their influence on the performance of cattle. Bruce and Decker (1951) in a 38 day trial attributed a 20 to 30 pound gain difference due to tabanid attack on beef cattle. Roberts and Pund (1974) found that cattle treated for horn flies and tabanids, gained 0.20 to 0.23 lbs/animal/day more than untreated animals.

Despite the reports estimating the damage caused by horse flies, there is little data concerning the impact tabanids have on cattle. Bruce and Decker (1951) reported that three species, *Tabanus sulcifrons* Macquart, *T. lineola* F. and *T. quinquevittatus* Wiedemann reduced butterfat by 13% in dairy cattle and reduced weight gains by 20 to 30 pounds in beef cattle. Muradov (1975) found that haematophagus flies including tabanids reduced weight gain by 6.5 kg or 13% less than that in protected animals. Everett et al. (1977) determined that tabanids caused slight, but consistent damage to the leather quality of cattle hides and concluded that their damage could be considered significant. Roberts and Pund (1974) reported a 0.20 to 0.23 lbs/animal/day advantage in gain for cattle protected from horn flies and tabanids.

The need to more accurately determine if tabanid attack reduces weight gain was pointed out in a workshop on livestock pest management in 1979 (Anonymous 1979). Economic threshold is defined as "the density at which control measures should be applied to prevent an increasing pest population from reaching the economic injury level" (Stern 1973). The only economic threshold established for livestock has been for Louisiana mosquito populations on beef cattle (Steelman and Schilling 1977). Such a threshold for horse flies on beef cattle has not been determined, due to the lack of an economically feasible control procedure and the difficulty in determining the daily attack rate. Despite the difficulties in finding effective control procedures for horse flies, it should be attempted to determine the effect of populations of horse flies on beef cattle.

Several studies have sampled for species diversity and seasonal abundance of Tabanidae (Allen and Pechuman 1977; Blickley 1977; Blume et al. 1972; Burnett and Hays 1977; Davies and Sanders 1981; Golini and Wright 1978; Hollander and Wright 1980b; MacKerras 1955; Mullens et al. 1980; Thompson 1967). Everett and Lancaster (1968) and Roberts (1972) both compared cow baited traps with CO_2 traps and found that the same species were attracted to both traps. Hollander and Wright (1980b) found a highly significant correlation between CO_2 baited Malaise trap catches and the number of tabanids feeding on a cow.

There are limited data on the correlation between the number of host animals and the number of tabanids attacking them. Duncan and Vigne (1979) found that as the herd size of Camargue horses increased there was a reduction in the number of tabanids attacking a horse within the herd. Most estimates of tabanid attack rate on herds have been made by visual counts on animals in the herd for a short time (Bay et al. 1976; Bruce and Decker 1951; Harris and Oehler 1976; Roberts and Pund 1974).

This type of estimation is inaccurate and has limited precision, because they were based only on one count made weekly, which did not consider the different behavioral patterns and seasonal cycles of different species even within the same area. Precise sampling procedures are needed to more accurately estimate the tabanid attack on animals.

The objectives of this study were to estimate effects of horse flies on weight gain and feed efficiency of beef cattle, and to develop accurate and precise sampling procedure for determining the tabanid attack rate on beef cattle.

CHAPTER II

IMPACT OF HORSE FLIES (DIPTERA: TABANIDAE) ON BEEF CATTLE

Introduction

Horse flies and deer flies of the family Tabanidae have been associated with losses in livestock production. The estimated annual loss in production due to tabanid attack and control costs on beef cattle in the U.S. was $40 million, of which $30 million was attributed to reduction in weight gains (Anonymous 1979). Increased energy requirements caused by irritation and blood loss from tabanid attack are believed to be the primary sources of reduced gains.

Bruce and Decker (1951) in a 38 day study reported that tabanid attacks reduced gains of beef cattle by 9.07 kg (20 lbs.) to 13.06 kg (30 lbs.). Roberts and Pund (1974) reported a 0.09 to 0.10 kg per animal per day (0.20 to 0.23 lbs/animal/day) difference in gain between cattle protected from horn flies and tabanids and those not protected. It has been reported that other biting flies, *Haematobia irritans* (L.) (Kinzer et al. 1984; Kunz et al. 1984) and *Stomoxys calcitrans* (L.) (Campbell et al. 1977) caused a reduction in gain in beef cattle. Steelman (1976) emphasized there was little reliable information on the impact of horse flies on cattle and that such information was needed. The objective of this study was to determine the impact horse flies have on weight gains and feed utilization in beef cattle in Oklahoma.

Materials and Methods

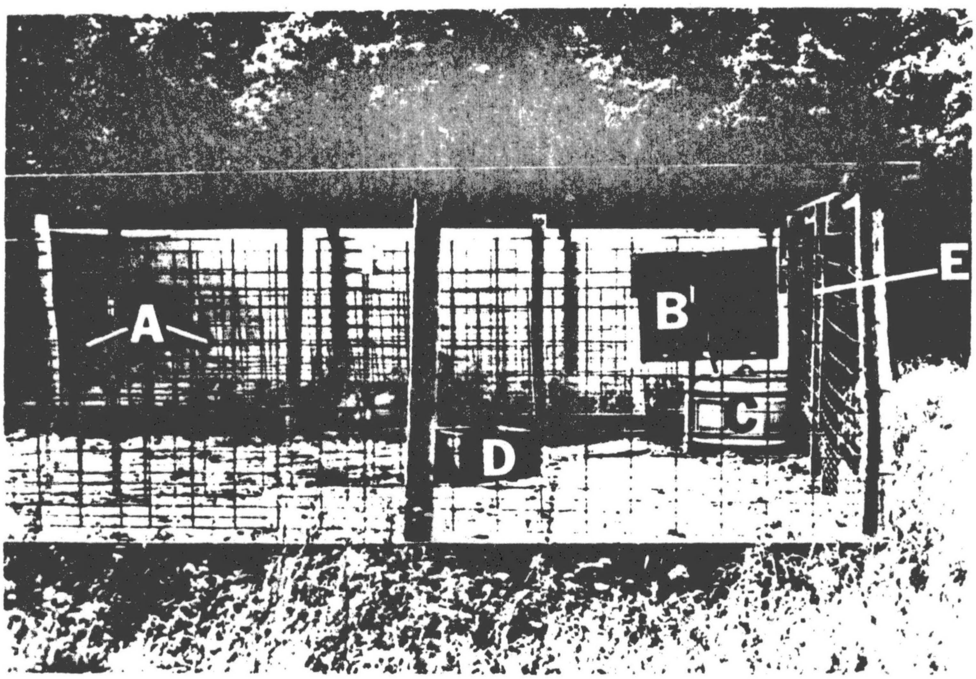
In 1982, six pens (6.1 X 8.5 X 1.8m) were constructed at the edge of a post oak (*Quercus stellata* Wangenh.) and blackjack oak (*Quercus marilandica* Muenchh.) cross timber area, where the seasonal occurrence and relative abundance of Tabanidae was known (Hollander and Wright 1980; Wright et al. 1984). Two additional pens were constructed in 1983 at the same location. The pen design was similar to that of Arends et al. (1982) (Fig. 1) except they were divided in half with 1.5 X 4.9m steel wire cattle panels (Fig. 1A). Each pen was partially shaded by trees.

Three pens and four pens in 1982 and 1983 respectively, were made fly proof with presewn Lumite® (Chicopee Manufacturing, Cornelia, Georgia) screened cages. Bottoms of the cages were fastened to the pens as described by Arends et al. (1982). Three pens in 1982 and four in 1983 were not covered so that animals in these pens were exposed to the natural tabanid population.

In both years, yearling Hereford heifers from the same herd were paired by weight to form six pairs in 1982 and eight pairs in 1983. Each pair constituted a replicate based on weights taken after a 12h withdrawal from feed and water. Animals in a pair were randomly assigned to either an open or a screened pen. During the 84 day test each year, animals were weighed at three 28 day intervals following a 12h shrink. Feed conversion (feed efficiency, FE) and average daily gains (ADG) were used to measure animal performance. The experimental design of the study was a completely randomized block design with the data analyzed by the analysis of variance (ANOVA) procedure (SAS, 1982).

Animals were individually fed a ration formulated to produce an average gain of 0.68 kg per day, a typical rate of gain for growing

Figure 1. Cattle pen (6.1 by 8.5 by 1.8m), used to hold heifers in the tabanid impact study. (A), Wire cattle panel dividing the pen; (B), Water barrels; (C), Water tank; (D), Individual feed box; (E), Gate; (F), Screen covered pen in background.


A
B
C
D
E

heifers on summer pasture in Oklahoma. The ration consisted of: 40% ground corn, 25% alfalfa meal pellets, 21.75% cottonseed hulls, 3% cane molasses and 0.25% salt. Water was provided free choice by gravity flow automatic waterers (Fig. 1B). The daily feed allotment was based on the weight of the lighter of the pair at the beginning of each 28 day period (Table 1). Each member of a replicate pair (exposed and protected) received the same amount of feed each day for each 28 day test period.

Manure was removed from pens three times a week to prevent the attraction and breeding of horn flies and house flies (*Musca domestica* L.). Population levels of horn flies and stable flies attacking the animals were recorded in both years. In 1983, all cattle including fly protected animals were lightly sprayed weekly to bi-weekly with a 1% dichlorvos mixture to maintain populations of these pests at low levels.

The number of horse flies that fed on each animal was recorded at half hour intervals from 9:00AM to 9:00PM CDT for 30 days in 1982 and 22 days in 1983. The daily horse fly attack rate was expressed as the average number of tabanids attacking an animal per day based on the summation of the 24 half hour counts. Hourly temperature readings were recorded inside all pens during fly count periods with a Tele-thermometer® (YSI, Yellow Springs, Ohio) to determine if exposed and protected heifers were being subjected to different temperature stress.

Results and Discussion

The tabanid attack rate in both years exhibited a distinct pattern. During the first 28 days, the initial attack rate was low and increased sharply the last 10 days of this period as the tabanid population increased (Fig. 2A). The peak tabanid attack rate occurred throughout the

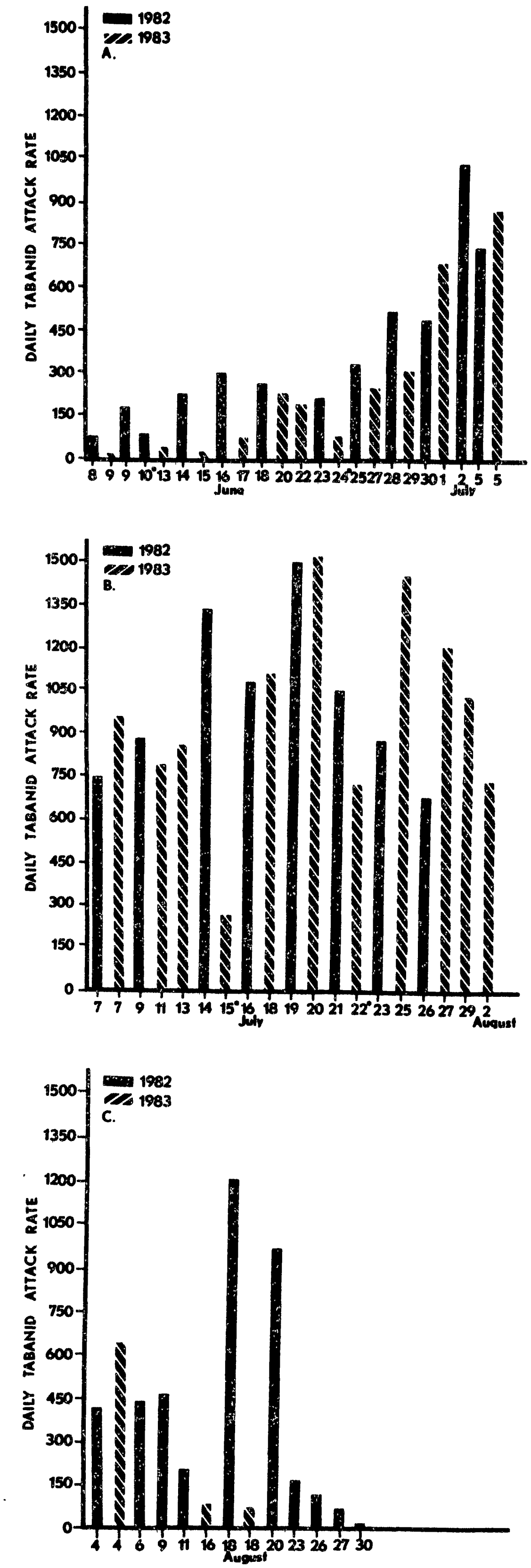
TABLE 1

AMOUNT OF FEED FED TO EACH ANIMAL PER DAY BASED ON THEIR WEIGHT AT THE BEGINNING OF EACH 28 DAY PERIOD TO ACHIEVE A 0.68 KG/DAY GAIN[1/]

Animal Weight (kg)	Feed Amount (kg)	Animal Weight (kg)	Feed Amount (kg)
102.1	3.6	192.8	5.8
113.4	3.9	204.1	6.0
124.7	4.1	215.5	6.3
136.1	4.5	226.8	6.5
147.4	4.7	238.1	6.8
158.8	5.0	249.5	7.0
170.1	5.3	260.8	7.2
181.4	5.5	272.2	7.5

1/ The level of gain expected from animals maintained on pasture grazing.

Figure 2. The daily total number of horse flies observed attacking six heifers in 1982 and eight heifers in 1983 for three 28 day periods. (A), First 28 day period; (B), Second 28 day period; (C), Third 28 day period. The * signifies days when counts were done in inclement weather.


1982
1983
A.
DAILY TABANID ATTACK RATE
1500
1350
1200
1050
900
750
600
450
300
150
0
8 9 9 10* 13 14 15 16 17 18 20 22 23 24* 25 27 28 29 30 1 2 5 5
June
July
1982
1983
B.
DAILY TABANID ATTACK RATE
1500
1350
1200
1050
900
750
600
450
300
150
0
7 7 9 11 13 14 15* 16 18 19 20 21 22* 23 25 26 27 29 2
July
August
1982
1983
C.
DAILY TABANID ATTACK RATE
1500
1350
1200
1050
900
750
600
450
300
150
0
4 4 6 9 11 16 18 18 20 23 26 27 30
August

second 28 day period (Fig. 2B). During the last 28 days (third period) the attack rate decreased during both years, although there was a sudden increased attack rate from August 18th to August 23rd druing 1982 (Fig. 2C). Animals remained in the pens throughout the 3rd period in both years although few horse flies were present after Aug. 18 in 1983. The seasonal occurrence and abundance of all species in these two years was similar to that reported by Wright et al. (1984). Six species comprised 99.4% of the tabanids found attacking the heifers (Tabanus abactor Philip, T. atratus F., T. equalis Hine, T. mularis Stone, T. subsimilis Bellardi and T. sulcifrons Macquart). The attack rate consistently decreased on days of inclement weather.

The temperature difference between screened and open pens was never greater than 0.5°C. The average number of stable flies per animal at any observation time during a day was 11 in 1982 and two in 1983, which are below the 50 flies/animal/day level reported to cause reduced weight gains in cattle on growing rations (Campbell et al. 1977). The average number of horn flies per animal at any observation time during a day was 72 in 1982 and 19 in 1983 and were below the levels of horn flies reported to cause significant decreased weight gains (Kinzer et al. 1984; Kunz et al. 1984).

In 1982, heifers exposed to horse flies for the 84 day trial gained 6.7 kg/animal less ($P<0.10$) than heifers protected from horse flies and had a significantly higher feed conversion ratio ($P<0.10$) (Table 2) which indicates they were 13.0% less efficient in feed conversion. In 1983, heifers exposed to horse flies gained 8.4 kg/animal less ($P<0.05$) and had a significantly higher feed conversion ratio ($P<0.10$) (Table 3)

TABLE 2

AVERAGE DAILY GAINS (ADG-KG) AND FEED EFFICIENCY (FE)[1/] FOR SIX PAIRS OF HEREFORD HEIFERS EXPOSED AND PROTECTED FROM TABANIDS IN 1982

	1st 28 Days			2nd 28 Days			3rd 28 Days			84 Day Total			
	ADG (kg)	FE	$\bar{X}$ attack[2/] rate	ADG (kg)	FE	$\bar{X}$ attack[2/] rate	ADG (kg)	FE	$\bar{X}$ attack[2/] rate	ADG (kg)	Gain (kg)	FE	$\bar{X}$ attack[2/] rate
Protected	0.54	7.64	0	0.78	5.53	0	0.64	7.54	0	0.65	54.6	6.69	0
Exposed	0.44	9.44	58	0.67	6.17	158	0.61	7.96	63	0.57	47.9	7.56	90
Difference	0.10	1.80		0.11*	0.64		0.03	0.42		0.08*	6.7	0.87*	

1/ Feed efficiency, total feed consumed/total animal gain.

2/ Average number of tabanids attacking an animal per day based on 288 counts in the first period, 192 counts in the second period, 240 counts in the third period and 720 counts for the total 84 day trial.

* Significant at ($P \leq 0.10$) based on 11 degrees of freedom, $F > 4.06$ ANOVA.

TABLE 3

AVERAGE DAILY GAINS (ADG-KG) AND FEED EFFICIENCY (FE)[1/] FOR EIGHT PAIRS OF HEREFORD HEIFERS EXPOSED AND PROTECTED FROM TABANIDS IN 1983

	1st 28 Days			2nd 28 Days			3rd 28 Days			84 Day Total			
	ADG (kg)	FE	$\bar{X}$ attack[2/] rate	ADG (kg)	FE	$\bar{X}$ attack[2/] rate	ADG (kg)	FE	$\bar{X}$ attack[2/] rate	ADG (kg)	Gain (kg)	FE	$\bar{X}$ attack[2/] rate
Protected	0.71	8.85	0	0.72	9.09	0	0.78	9.30	0	0.73	61.3	8.66	0
Exposed	0.56	11.48	28	0.62	11.07	117	0.71	9.96	9	0.63	52.9	10.32	66
	0.15	2.63		0.10	1.98		0.07	0.63		0.10**	8.4	1.66**	

1/ Feed efficiency, total feed consumed/total animal gain.

2/ Average number of tabanids attacking an animal per day based on 264 counts in first period, 264 counts in the second period, 72 counts in the third period and 600 counts for the total 84 day trial.

* Significant at ($P \leq 0.10$) based on 15 degrees of freedom, $F > 3.59$ ANOVA.

** Significant at ($P \leq 0.05$) based on 15 degrees of freedom, $F > 5.59$ ANOVA.

which indicates they were 19.2% less efficient in feed conversion than protected heifers.

The greatest differences in animal performance occurred during the first two 28 day periods in both years, when the exposed animals were subjected to high tabanid populations (Tables 2 and 3, Figs. 2A and B). The smallest differences in animal performance occurred during the third 28 day period when tabanid populations were declining (Tables 2 and 3, Fig. 2C). Greater difference in ADG and FE occurred in the first period with a lower tabanid attack rate as compared to the second period. The rapid increase in the number of tabanids attacking the cattle just prior to the end of the first period (Fig. 2A) probably caused a sudden increase in irritation and annoyance which produced a greater expenditure of energy in attempts to dislodge the flies.

Data from both years were pooled, set as a factorial and analyzed by analysis of variance to determine if there was any year by treatment interaction. No year by treatment interaction was found and the pooled data were then analyzed for differences between exposed and protected heifers (ANOVA). Pooled analysis showed ADG differences between protected and exposed animals was 0.09 kg/animal/day ($P<0.01$), with a 1.32 kg feed/kg gain difference ($P<0.01$) (Table 4). Because feed intake was regulated, the difference in FE between heifers protected and exposed to tabanids probably resulted from an increase in the maintenance energy requirement caused by tabanid stress.

Differences in heifer performance between exposed and protected heifers can probably be attributed to tabanid attack because other than attack by tabanids, all animals were treated the same. The stress caused by initial tabanid attack on beef cattle was the most critical in

TABLE 4

COMBINED 1982 AND 1983 AVERAGE DAILY GAIN (ADG-KG), TOTAL GAIN (KG) AND FEED EFFICIENCY (FE) FOR 14 PAIRS OF HEREFORD HEIFERS EXPOSED AND PROTECTED FROM TABANIDS FOR AN 84 DAY PERIOD FROM JUNE THROUGH AUGUST

	ADG (kg)	Total Gain (kg)	FE[1/]
Protected	0.69	57.96	7.82
Exposed	0.60	50.40	9.14
Difference	0.09*	7.56*	1.32*

1/ Feed efficiency, total feed consumed/total animal gain.

* Significant at ($P \leq 0.01$) based on 27 degrees of freedom, $F > 9.06$ ANOVA.

terms of direct damage to the host animal. Animals exposed to tabanid attack for both years gained 7.6 kg less (0.09 kg/animal/day) (Table 4) than protected animals which is similar to data reported by Roberts and Pund (1974). At an average market price of $60/cwt, the weight gain lost due to tabanid attack would have resulted in a loss of $10.08 per animal. Heifers exposed to tabanids for both years on the average needed 1.32 kg more feed to put on 1 kg of gain as compared to protected heifers. This degree of potential loss suggests that tabanids are an economically important pest of beef cattle in north central Oklahoma.

CHAPTER III

EVALUATION OF METHODS FOR ESTIMATING THE NUMBER OF TABANIDAE (DIPTERA) ON BEEF CATTLE

Introduction

Several studies have estimated the relative abundance of tabanid populations in an area: (Allen and Pechuman 1977; Blickley 1977; Blume et al. 1972; Burnett and Hays 1977; Davies and Sanders 1981; Golini and Wright 1978; MacKerras 1955; Mullens and Gerhardt 1980; Thompson 1967; Wright et al. 1984). Only a few studies have attempted to correlate the relative abundance of horse flies as measured by traps to the numbers attacking cattle (Everett and Lancaster 1968; Hollander and Wright 1980a; Roberts 1972). Most estimates of the number of tabanids attacking cattle have been quick whole animal counts made while evaluating insecticides (Bay et al. 1976; Bruce and Decker 1951; Harris and Oehler 1976; Roberts and Pund 1974). Accuracy of estimates of fly numbers feeding on animals is influenced by herd size (Duncan and Vigne 1979), time of day (Hollander and Wright 1980b), season of year (Wright et al. 1984) and the stop and start feeding behavior of horse flies.

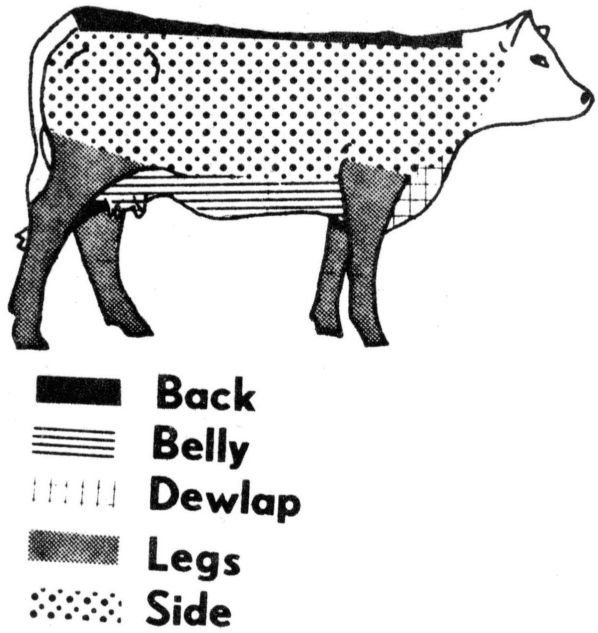
Many species of Tabanidae prefer to feed on particular body regions of livestock (Blickle 1955; Hollander and Wright 1980b; Jones and Anthony 1964; Mullens and Gerhardt 1979; Philip 1931, Thompson and Pechuman 1970). For such species, it may be possible to develop an accurate estimation of the total number of tabanids feeding on an animal by counting only those feeding in preferred areas. The objectives of this study were to determine if counts made of horse flies feeding in preferred areas could accurately estimate the total number of horse flies on an animal, and determine if Malaise trap catches accurately estimate the number of horse flies attacking herds of cattle in north central Oklahoma.

Materials and Methods

In 1982, three open pens (6.1 X 8.5 X 1.8m) were constructed at the edge of a post oak (*Quercus stellata* Wangenh.) and blackjack oak (*Quercus marilandica* Muenchh.) cross timber area, where the seasonal occurrence and relative abundance of Tabanidae were known (Hollander and Wright 1980a; Wright et al. 1984). An additional pen was constructed in 1983 at the same location. Horse fly counts were made on six and eight yearling Hereford heifers, in 1982 and 1983 respectively, which were maintained two per pen from June to late August. Pens were within 100m of each other.

The number of horse flies feeding in five preferred areas on each heifer (Hollander and Wright 1980b) were counted twice hourly from 9:00AM to 9:00PM CDT at two to three day intervals for 30 days in 1982 and 22 days in 1983. The five areas selected are designated (Fig. 1): back, the area from tail set to the neck; belly, the abdominal area below the rib cage from rear leg stifle to the front elbow; dewlap, the dewlap and brisket; legs, the outside area of closest legs and inside of furthest legs as an animal is viewed from one side; side, area remaining exclusive of the head and tail. Horse flies were counted by species in each of

Figure 1. A schematic drawing of a cow depicting the five areas on which horse fly counts were made.


Back
Belly
Dewlap
Legs
Side

these areas, from approximately one to two meters at which distance species were easily recognized.

The Malaise trap design was similar to that of Hollander and Wright (1980a) and was located approximately 180 m from the pens in a similar habitat area. The Malaise trap was baited with compressed CO_2 gas (Wright et al. 1984) and operated while counts were being made on heifers. Trap catches were sorted to species and compared with the total number of that species feeding on the heifers.

In 1982, horse flies were counted on six animals, 24 times per day on 30 days, for a total of 4320 animal observations, and in 1983, horse flies were counted on eight animals, 24 times per day on 22 days, for a total of 4224 animal observations. Data for the summed daily counts by species per animal for both years were analyzed by analysis of variance procedure (ANOVA). A linear model was constructed using SAS (1982) for each species, with the daily total number of that species on the entire animal as the dependent variable regressed on the number of that species counted on preferred feeding area. For _T. abactor_, _T. mularis_ and _T. subsimilis_ there was a total of 356 summed daily counts. There was a lower total of 144 and 206 summed daily counts for _T. equalis_ and _T. sulcifrons_ respectively, because these two species did not occur for the entire 84 days. For species that exhibited the same preferred feeding location and seasonal occurrence, area counts per half hour count period per animal were combined for both years, averaged, analyzed by analysis of variance procedure (ANOVA). A linear model was constructed using SAS (1982), with the average number of those species per count period on the entire animal as the dependent variable regressed on the average number of those species counted in the preferred feeding area per count period.

The accuracy of estimating the average number of horse flies at one count period on an animal in a herd was tested over four count periods for six randomly selected days (Table 1) using a chi-square test. Data from trap catches were summed for each day by species, analyzed by analysis of variance procedure (ANOVA). A linear model was constructed using SAS (1982), with the sum of all horse flies by species counted on all animals as the dependent variable regressed on the total number of horse flies by species captured in the trap.

Results and Discussion

Six species of horse flies (*Tabanus abactor* Philip, *T. atratus* F., *T. equalis* Hine, *T. mularis* Stone, *T. subsimilis* Bellardi and *T. sulcifrons* Macquart) comprised 99.4% of the horse flies caught in the trap and counted on heifers. Positive correlations were found between five horse fly species feeding in specific areas per day and these species feeding on entire animals per day. Several of the regression points for each species were hidden under the other regression point, or under the regression line (Figs. 1 and 2). Counts made of any species feeding on the belly and dewlap did not accurately represent the number feeding on an entire animal per day.

There was a high correlation between the number of *T. abactor* feeding on the legs per day (r^2 = 0.882) (Fig. 2A) and the side per day (r^2 = 0.734) (Fig. 2B) compared to the number feeding on an entire animal per day. There was also a high correlation between the number of *T. sulcifrons* feeding on the back per day (r^2 = 0.840) (Fig. 2C) and the side per day (r^2 = 0.774) (Fig. 3D) and the number feeding on entire animals per day. *Tabanus equalis* was active only in the evening, but

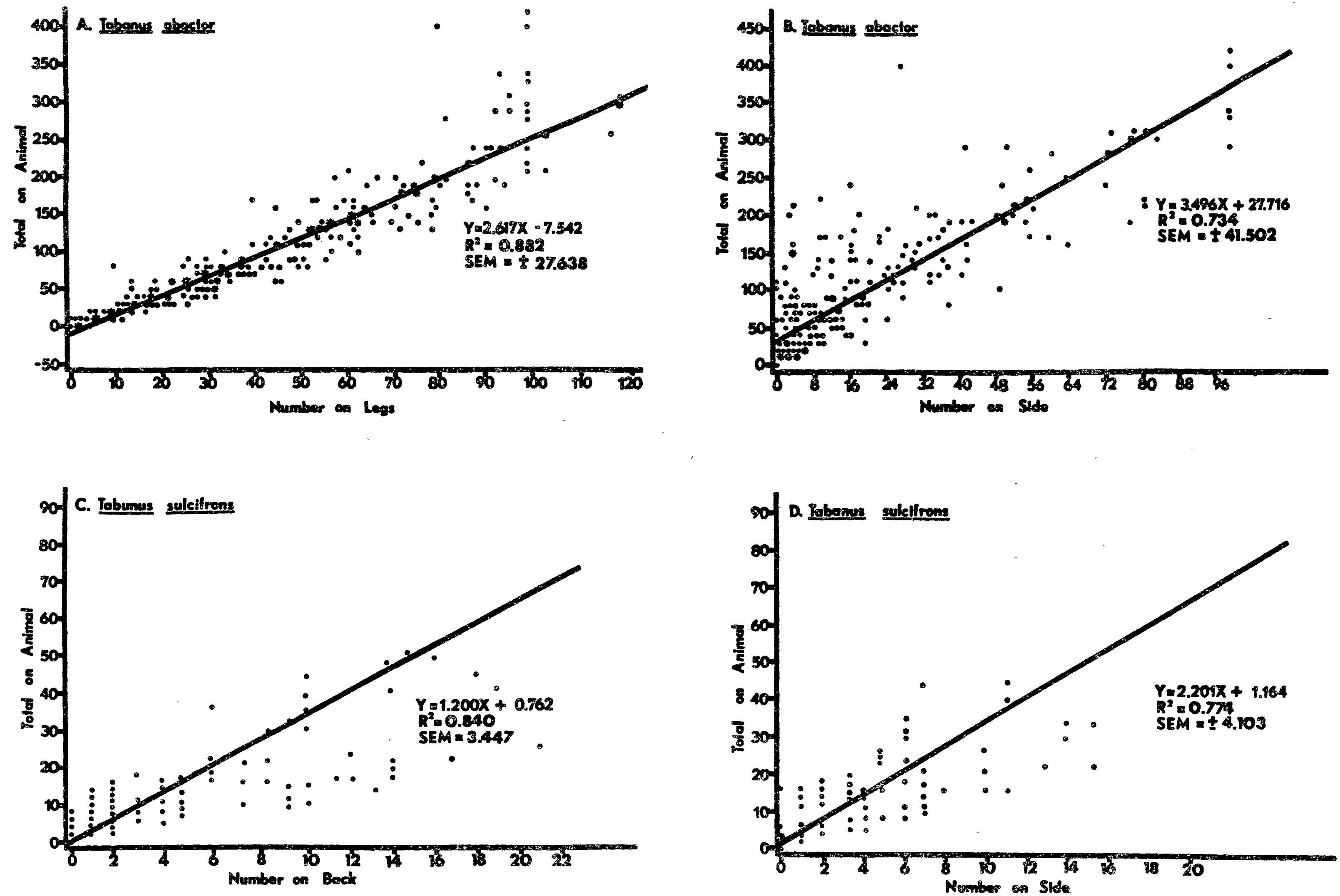
TABLE 1

AVERAGE NUMBER OF HORSE FLIES COUNTED AT FOUR COUNT PERIODS ON THE LEGS, BACK, ENTIRE HEIFER AND PREDICTED AVERAGE NUMBER PER HEIFER FOR SIX RANDOMLY SELECTED DAYS IN 1982 AND 1983

Period	Avg. No. on legs	Avg. No. on back	Avg. No. on a heifer	Predicted Avg. No. on a heifer	Total No. on all heifers	Avg. No. per day per heifer
6/28/82						
1:00	1.00	0.17	3.67	2.80		
3:00	1.33	0	2.50	3.55	505	84.2
5:00	2.33	0	4.33	6.34		
7:00	1.33	0	4.33	3.55		
7/19/82						
1:00	4.00	1.00	11.83	12.00		
3:00	4.33	0.33	10.50	11.66	1474	245.7
5:00	5.67	0.33	19.33	15.66		
7:00	2.00	0.50	8.00	5.50		
8/18/82						
1:00	5.00	0.83	10.83	13.79		
3:00	5.17	0.50	12.00	14.26	1194	199
5:00	4.33	0.67	15.33	11.92		
7:00	7.83	0.17	18.83	21.69		
6/27/83						
1:00	0.63	0	1.00	1.60		
3:00	0.50	0	1.50	1.23	237	29.6
5:00	0.63	0	1.38	1.60		
7:00	0.13	0	0.38	0.20		
7/20/83						
1:00	0.63	0	1.38	1.58		
3:00	2.75	0	4.65	7.51	837	104.6
5:00	1.50	0.13	5.38	4.03		
7:00	0.88	0	3.13	2.30		
8/2/83						
1:00	1.63	0	2.75	4.39		
3:00	2.25	0.75	5.63	6.15		
5:00	2.50	0	5.63	6.82		
7:00	2.75	0.38	4.88	7.51		

1/ The number of horse flies on the outside of the legs and inside of the other two as viewed from one side of the heifer.

Figure 2. Correlations between the number of a species counted on an area of an animal per day and the total number of that species counted on the entire animal per day. Each point represents 24 counts summed for each day. (A), *T. abactor* on the legs and entire animal; (B), *T, abactor* on the side and entire animal; (C), *T. sulcifrons* on the back and entire animal; (D), *T. sulcifrons* on the side and entire animal.


A. Tabanus abactor
Total on Animal
Number on Legs
Y=2.617X - 7.542
R² = 0.882
SEM = ± 27.638
B. Tabanus abactor
Total on Animal
Number on Side
Y = 3.496X + 27.716
R² = 0.734
SEM = ± 41.502
C. Tabanus sulcifrons
Total on Animal
Number on Back
Y = 1.200X + 0.762
R² = 0.840
SEM = 3.447
D. Tabanus sulcifrons
Total on Animal
Number on Side
Y = 2.201X + 1.164
R² = 0.774
SEM = ± 4.103

the number feeding on the back per day ($r^2 = 0.627$) (Fig. 3A) and the side per day ($r^2 = 0.692$) (Fig. 3B) were highly correlated to the number feeding on an entire animal per day. *Tabanus mularis* and *T. subsimilis* had positive correlations between the number feeding on the legs per day ($r^2 = 0.692$) and $r^2 = 0.730$) respectively, and the number feeding on entire animals per day (Figs. 3C, D). *Tabanus atratus* consistently fed on the back only and were easily seen, making a correlation unnecessary.

There was a high correlation between the average of combined counts of *T. abactor*, *T. mularis* and *T. subsimilis* feeding on the legs of all the animals at one count period and the average number of these species on all the animals at that same time ($r^2 = 0.936$) (Fig. 4). Since these species were present during the same season and time of day, an accurate estimation of the average number of these species on animals at one time from an average of counts made on the legs at one count period was possible. Most counts made on the legs were in the range of zero to ten. An estimation of the average number of *T. abactor*, *T. mularis* and *T. subsimilis* feeding on animals at one count period was calculated by the regression equation (Fig. 4). For example, when the average of all counts made per count period on the legs was 5.5, an average of 15.2 of these species were predicted to be feeding per animal at that time.

Populations of *T. equalis* and *T. sulcifrons* did not occur at the same time, thus individual counts made on the back never included both species. The average number of all horse flies feeding on the backs at one count was never greater than one. Thus, the arithmetic mean of counts made on the back, accurately represented the average number of all species feeding on the back per animal at that count period.

Estimation of the average number of all horse flies per animal at

Figure 3. Correlation between the number of a species counted on an area of an animal per day and the total number of that species counted on the entire animal per day. Each point represent 24 counts summed for each day. (A), *T. equalis* on the back and entire animal; (B) *T. equalis* on the side and entire animal; (C), *T. mularis* on the legs and entire animal; (D) *T. subsimilis* on the legs and entire animal.

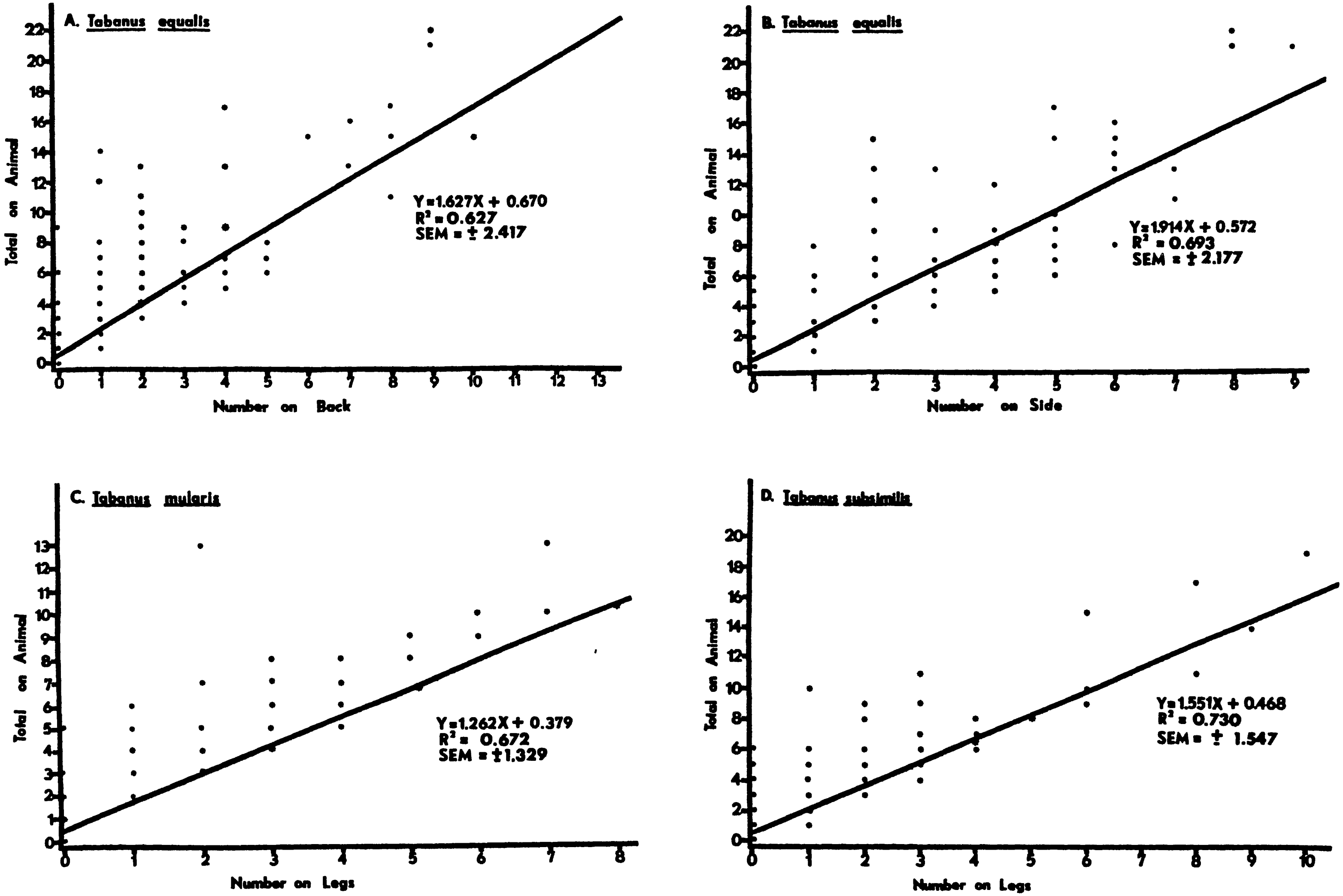
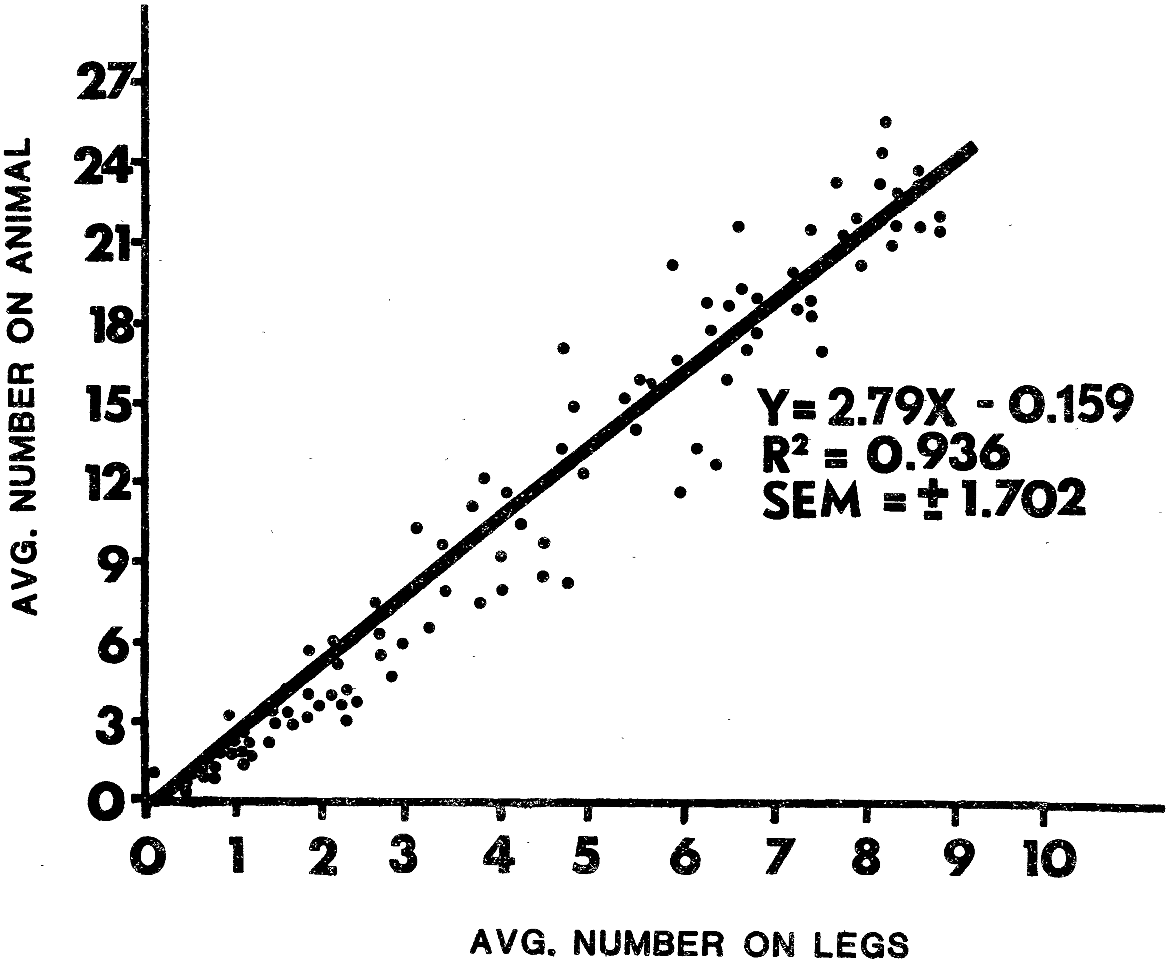

A. Tabanus equalis
Y=1.627X + 0.670
R² = 0.627
SEM = ± 2.417
Total on Animal
Number on Back
B. Tabanus equalis
Y=1.914X + 0.572
R² = 0.693
SEM = ± 2.177
Total on Animal
Number on Side
C. Tabanus mularis
Y=1.262X + 0.379
R² = 0.672
SEM = ± 1.329
Total on Animal
Number on Legs
D. Tabanus subsimilis
Y=1.551X + 0.468
R² = 0.730
SEM = ± 1.547
Total on Animal
Number on Legs

Figure 4. Correlation between the average number of _T. abactor_, _T. mularis_ and _T. subsimilis_ on the legs per count period and the average number of these species on the entire animal per count period.



AVG. NUMBER ON ANIMAL
0
3
6
9
12
15
18
21
24
27
Y= 2.79X - 0.159
R² = 0.936
SEM = ± 1.702
0 1 2 3 4 5 6 7 8 9 10
AVG. NUMBER ON LEGS

one count period was determined from the summation of the predicted average number of T. abactor, T. mularis, and T. subsimilis per animal, from the regression equation (Fig. 4), and the arithmetic mean of all horse flies counted on the back. For example, when the predicted average number of those species which prefer feeding on the legs was 15, based on an average count of 5.5 on the legs (Fig. 4) and the mean of counts made on the back was one, the estimated average of all horse flies per animal at that count period was 16. The predicted number of horse flies on an animal was not significantly different ($P \geq 0.99$, df = 23; χ^2 test) from the actual number of horse flies on an animal (Table 1). Thus, the estimated number of horse flies for a count period did accurately reflect the number of horse flies on a heifer at that count period.

Daily Malaise trap catches and animal counts are relative sampling methods used to measure relative densities of horse flies in a habitat area at a particular time period. Correlations between the number of horse flies of a species caught in the Malaise trap and those feeding on six and eight heifers in 1982 and 1983, respectively (Table 2), indicated that higher numbers of a species caught in the trap reflected the higher number of that species feeding on the animals for T. abactor, T. equalis and T. sulcifrons. However, the number of a species captured in the trap for 12 h could not be used to estimate the total for that species which attacked each animal over this time period. This was because the trap collected horse flies continuously for 12 h, while counts made every half hour did not include the total number of horse flies attacking the animals during that time.

Tabanus mularis and T. subsimilis had a low correlation in both years (Table 2), between the number captured in the trap and the number

TABLE 2

CORRELATION BETWEEN THE TOTAL NUMBER OF HORSE FLIES BY SPECIES CAPTURED IN THE TRAP AND THE TOTAL NUMBER COUNTED ON SIX AND EIGHT ANIMALS IN 1982 AND 1983 RESPECTIVELY

Species	Year 1982		1983	
Tabanus abactor	Y= 3.17+1.11X	r^2=0.905	Y=1.71+1.43X	r^2=0.723
T. equalis	Y= 2.64+2.34X	r^2=0.709	Y=3.54+5.48X	r^2=0.764
T. mularis	Y= 4.90+0.42X	r^2=0.287	Y=3.48+0.95X	r^2=0.427
T. subsimilis	Y=11.50+0.03X	r^2=0.001	Y=2.74+0.69X	r^2=0.405
T. sulcifrons	Y= 3.32+0.55X	r^2=0.841	Y=5.94+0.31X	r^2=0.658

counted on all animals. Thus, the trap could not be used to indicate the relative increase or decrease in the number of those two species attacking the animals.

No single correlation for both years for any species could be made because the slopes of the regression lines for the correlations between the number of each species caught in the trap and that species feeding on animals were different for the two years (Table 2). This indicated that the Malaise trap catch of one year can not be used to estimate the relative horse fly attack rate on animals the following year. Malaise traps have been used to sample populations of horse feeding on cattle, but such data has not been used to estimate the number of specimens per animal (Anderson et al. 1974, Everett and Lancaster 1968; Hollander and Wright 1980a; Roberts 1976; Thompson 1969).

In conclusion, a quick and accurate estimation of the total number of horse flies feeding on an animal at one count period can be made from counts made on the legs and back. Counts should be made between 1:00 and 7:00PM CDT, in order to include the major activity period of most species in north central Oklahoma. An additional count should be made between 8:00 and 9:00PM CDT when *T. equalis* occurs (Wright et al. 1984). If the daily activity periods, seasonal occurrences and preferred feeding locations of horse flies are known, the described procedures could be used to estimate the average number feeding on an animal for other geographical areas.

This index estimates only the average number of horse flies on a cow at a particular point in time. However, the described index in this study, can be used to estimate the average number of horse flies on a herd of cattle from counts made on 15 to 20 animals in the herd. A count of all animals in a herd would be impractical due to the movement of cattle, movement of the horse flies and the changes in the habitat animals would encounter with movement. We hope to further validate this index by using unpublished data, in which hourly counts of the total number of horse flies feeding on an animal for several hour durations have been made.

Malaise trap catches can only estimate the relative increase or decrease in the number of horse flies attacking animals. The number of horse flies captured in the trap per day can not be used to directly estimate the number attacking the animals per day. Malaise trap catches made in one year can not be used to predicate the number of horse flies on animals the following years.

LITERATURE CITED

Allen, W.A. and L.L. Pechuman. 1977. New geographical and seasonal distribution records for forty four species and subspecies of tabanids from Virginia.

Anderson, J.R., W. Olkowski and J.B. Hoy. 1974. The response of tabanid species to CO_2-baited insect flight traps in northern California. Pan-Pacific Entomol. 50:255-268.

Anonymous. 1979. Proceedings of a workshop on livestock pest management: to assess national research and extension needs for integrated pest management of insects, ticks and mites, affecting livestock and poultry. Kansas State University Press, Manhattan, Kan. 322 pp.

Arends, J.J., R.E. Wright, K.S. Lusby and R.W. McNew. 1982. Effect of face flies (Diptera: Muscidae) on weight gains and feed efficiency in beef heifers. J. Econ. Entomol. 75:794-797.

Bay, D.E., N.C. Ronald and R.L. Harris. 1976. Evaluation of a synthetic pyrethroid for tabanid control on horses and cattle. Southwest. Entomol. 1:198-202.

Bishop, F.C. 1913. The stable fly (Stomoxys calcitrans) an important livestock pest. J. Econ. Entomol. 6:112-126.

Bickley, W.E. 1977. Diversity of tabanid fauna in two Maryland counties (Diptera: Tabanidae). Proc. Entomol. Soc. Wash. 79:620-621.

Blickle, R.L. 1955. Feeding habits of Tabanidae. Entomol. News. 66: 77-78.

Blume, R.R., J.A. Miller, J.L. Eschle, J.J. Matter and M.C. Pickens. 1972. Trapping tabanids with modified Malaise traps baited with CO_2. Mosq. News. 32:90-95.

Bruce, W.N. and G.C. Decker. 1951. Tabanid control on dairy and beef cattle with synergized pyrethrins. J. Econ. Entomol. 44:154-159.

Bruce, W.N. and G.C. Decker. 1958. The relationship of stable fly abundance to milk production in dairy cattle. J. Econ. Entomol. 51:269-274.

Burnett, A.M. and K.L. Hays. 1977. Seasonal and diurnal distributions of adult female horse flies (Diptera: Tabanidae) at Gold Hill, Alabama. Agric. Exp. Stn. Goldon Hill, Alabama. Circular No. 237.

Campbell, J.B. 1976. Effect of horn fly control on cows as expressed by increased weaning weights of calves. J. Econ. Entomol. 69: 711-712.

Campbell, J.B., D.J. Boxler, J.I. Shugart, D.C. Clanton and R. Crookshank. 1981. Effects of house flies on weight gains and feed efficiency on yearling heifers on finishing rations. J. Econ. Entomol. 74: 94-95.

Campbell, J.B., R.G. White, J.E. Wright, R. Crookshank and D.C. Clanton. 1977. Effects of stable flies on weight gains and feed efficiency of calves on growing or finishing ration. J. Econ. Entomol. 70: 592-594.

Cheng, Tien-Hsi. 1958. The effect of biting fly control on weight gain in beef cattle. J. Econ. Entomol. 51: 275-278.

Cheng, Tien-Hsi and E.M. Kesler. 1961. A three year study on the effect of fly control on milk production by selected and randomized dairy herds. J. Econ. Entomol. 54: 751-757.

Cutkomp, L.K. and A.L. Harvey. 1958. The weight responses of beef cattle in relation to control of horn and stable flies. J. Econ. Entomol. 51: 72-75.

Davies, S.G. and D.P. Sanders. 1981. Seasonal and geographical distribution of Tabanus abactor Philip in the Texas rolling plains. Southwest. Entomol. 6: 81-86.

Duncan, P. and N. Vigne. 1979. The effect of group size in horses on the rates of attacks by blood sucking flies. Anim. Behav. 27: 623-625.

Everett, A.L., R.W. Miller, W.J. Gladney and M.V. Hannigan. 1977. Effects of some important ectoparasites on the grain quality of cattle hide leather. J.A.L.C.A. 72: 6-23.

Evertt, R. and J.L. Lancaster Jr. 1968. A comparison of animal and dry ice-baited traps for the collection of tabanids. J. Econ. Entomol. 61: 863-864.

Freeborn, S.B. and W.M. Regan. 1928. The relation of flies and fly sprays to milk production. J. Econ. Entomol. 21: 494-501.

Golini, V.E. and R.E. Wright. 1978. Relative abundance and seasonal distribution of Tabanidae (Diptera) near Guelph, Ontario, Can. Entomol. 110: 385-398.

Gooding, R.H. 1972. Digestive processes of haematophagous insects. I. A Literature review. Quaestiones Entomol. 8: 5-60.

Granett, P. and E.J. Hansens. 1956. The effect of biting fly control on milk production. J. Econ. Entomol. 49: 465-467.

Granett, P. and E.J. Hansens. 1957. Further observation on the effect biting fly control on milk production on cattle. J. Econ. Entomol. 50: 332-336.

Harris, R.L. and D.D. Oehler. 1976. Control of tabanids on horses. Southwest. Entomol. 1: 194-197.

Harvey, T.L. and J.R. Brethour. 1979. Effects of horn flies on weight gains of beef cattle. J. Econ. Entomol. 72: 516-518.

Haufe, W.O. 1982. Growth of range cattle protected from horn flies (Haematobia irritans) by eartags impregnated with fenvalerate. Can. J. Anim. Sci. 62: 567-572.

Hollander, A.L. and R.E. Wright. 1980a. Impact of tabanids on cattle: Blood meal size and preferred feeding sites. J. Econ. Entomol. 73: 431-433.

Hollander, A.L. and R.E. Wright. 1980b. Daily activity cycles of eight species of Oklahoma Tabanidae (Diptera). Environ. Entomol. 9: 600-604.

Jones, C.W. and D.W. Anthony. 1964. The Tabanidae of Florida. USDA. Tech. Bull. 1295. 85 pp.

Kettle, P.R. 1974. The influence of cattle lice (Damalina bovis and Linognathus vituli) on weight gain in beef animals. N.Z. Vet. J. 22: 10-11.

Kinzer, H.G., W.E. Houghton, J.M. Reves, S.E. Kunz, J.O. Wallace and N.S. Urguhart. Influence of horn flies on weight loss in cattle with notes on prevention of loss by insecticide treatment. Southwest. Entomol. 9: 212-217.

Krinsky, W.L. 1976. Animal disease agents transmitted by horse flies and deer flies (Diptera: Tabanidae). J. Med. Entomol. 13:225-275.

Kunz, S.E., J.A. Miller, P.L. Sims and D.C. Meyerhaeffer. 1984. Economics of controlling horn flies (Diptera: Muscidae) in range cattle management. J. Econ. Entomol. 77: 657-660.

Laake, E.W. 1946. DDT for the control of the horn fly in Kansas. J. Econ. Entomol. 39: 65-68.

MacKerras, I.M. 1955. The classification and distribution of Tabanidae (Diptera). Aust. J. Zool. 3: 439-509.

Mullens, B.A. and R.R. Gerhardt. 1979. Feeding behavior of some Tennessee Tabanidae. Environ. Entomol. 8: 1047-1051.

Mullens, B.A. and R.R. Gerhardt. 1980. Faunal composition and seasonal distribution of tabanids in three geographic regions of eastern Tennessee (Diptera: Tabanidae). Proc. Entomol. Soc. Wash. 82: 48-58.

Muradov, M.M., A.A. Davletklycher and B. Bercliev. 1975. The effect of blood-sucking flies on weight gain of livestock. Veterinariia. 8:26-27.

Philip, C.B. 1931. The Tabanidae of Minnesota. Minnesota Agric. Exp. Stn. Tech. Bull. 80 132 pp.

Roberts, F.H. 1938. Cattle lice: Their economic importance in Queensland. Aust. Vet. J. 14: 55-58.

Roberts, R.H. 1972. The effectiveness of several types of Malaise traps for the collection of tabanids and Culicidae. Mosq. News. 32: 542-547.

Roberts, R.H. 1976. The comparative efficiency of six trap types for the collection of Tabanidae (Diptera). Mosq. News. 36: 530-535.

Roberts, R.H. and W.A. Pund. 1974. Control of biting flies on beef steers: Effect on performance in pasture and feedlot. J. Econ. Entomol. 67: 232-234.

SAS. 1982. User's Guide: Statistics. SAS Inst. Inc., Cary, N.C. 584 pp.

Scharf, D.K. 1962. An investigation of cattle louse problem. J. Econ. Entomol. 55: 584-588.

Schmidtmann, E.T., M.E. Valla and L.E. Chase. 1981. Effect of face flies on grazing time and weight gain in dairy heifers. J. Econ. Entomol. 74: 33-39.

Steelman, C.D. 1976. Effect of external and internal arthropod-parasites on domestic livestock production. Ann. Rev. Entomol. 21: 155-178.

Steelman, C.D. and P.E. Schilling. 1977. Economics of protecting cattle from mosquito attack relative to injury thresholds. J. Econ. Entomol. 70: 15-17.

Steelman, C.D., T.W. White and P.E. Schilling. 1972. Effect of mosquitoes on the average daily gain of feedlot steers in southern Louisiana. J. Econ. Entomol. 65: 462-466.

Steelman, C.D., T.W. White and P.E. Schilling. 1973. Effects of mosquitoes in two average daily gain of Hereford and Brahman breed steers in southern Louisiana. J. Econ. Entomol. 66: 1081-1083.

Stern, V.M. 1973. Economic thresholds. Ann. Rev. Entomol. 18:259-280.

Tashiro, H. and H.H. Schwardt. 1949. Biology of the major species of horse flies of central New York. J. Econ. Entomol. 42: 269-272.

Thompson, P.H. 1967. Abundance and seasonal distribution of the Tabanidae (Diptera) of Great Swamp, New Jersey. Ann. Entomol. Soc. Am. 60: 1255-1270.

Thompson, P.H. 1969. Collecting methods for Tabanidae (Diptera). Ann. Entomol. Soc. Am. 62:50-57.

Thompson, P.H. and L.L. Pechuman. 1970. Sampling populations of *Tabanus quinquevittatus* about horses in New Jersey, with notes on the identity and ecology. J. Econ. Entomol. 63: 151-155.

Wright, R.E., R.K. Whittle, M.J. Perich and A.L. Hollander. 1984. Seasonal occurrence of horse flies (Diptera: Tabanidae) in north-central Oklahoma. J. Kan. Entomol. Soc. 57: 209-215.

VITA 2

Michael Joseph Perich

Candidate for the Degree of

Doctor of Philosphy

Thesis: IMPACT OF TABANIDAE ON BEEF CATTLE

Major Field: Entomology

Biographical:

Personal Data: Born in Omaha, Nebraska, June 17, 1957, the son of Andrew John and Rita Theresa Perich.

Education: Graduated from Ralston High School, Ralston, Nebraska, in May, 1975; received a Bachelor of Science degree with a major in Chemistry, Zoology, and Entomology, from Iowa State University of Science and Technology, Ames, Iowa, May 1979; completed requirements for Master of Science degree with a major in Entomology from Oklahoma State University, December, 1982; completed requirements for the Doctor of Philosophy degree with a major in Entomology at Oklahoma State University, May, 1985.

Professional Experience: Nuclear chemist, Ft. Calhoun Nuclear Power Plant, O.P.P.D., Ft. Calhoun, Nebraska, summer 1979; Graduate Research Assistant, Department of Entomology, Oklahoma State University, Stillwater, Oklahoma, 1979 to present; Graduate Teaching Assistant, Department of Entomology, Oklahoma State University, Stillwater, Oklahoma, January 1985 to present.

Professional Organizations: Entomological Society of America, Associate Member of American Registry of Professional Entomologists, American Society of Animal Scientists, Sigma Xi, Phi Eta Sigma.