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Costs of Horn Fly (Diptera: Muscidae) Control for Cow-calf Producers in Tennessee and Texas, 2016

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Abstract

Tennessee and Texas cow-calf producers were surveyed to assess their 2016 expenses for horn fly control methods. Cattle producers who were members of the Texas and Southwestern Cattle Raisers Association and Tennessee cattle producers who have participated in the Tennessee Agricultural Enhancement Program participated in the survey. Average horn fly management costs in Tennessee and Texas were $9.50/head and $12.40/head, respectively. An ordinary least squares regression and quantile regression were estimated to examine how horn fly costs are influenced by producer and farm demographics, seasonality of horn flies, producer horn fly perceptions, and management practices. When controlling for these variables, Tennessee and Texas cattle producers did not spend significantly different amounts on horn fly control methods. Horn fly costs were associated with producer and farm demographics, producer perceptions of horn flies, and management practices. For example, results indicate that horn fly management costs vary depending on a producer's level of education and income. Having Angus cattle and larger herd sizes were associated with lower costs per head spent on horn fly management. Producers who did not consider horn flies to be a problem until greater quantities of flies were present on the animal spent 15% less per head on managing horn flies. In terms of horn fly control methods, feedthrough insecticides increased horn fly costs the most, followed by using ear tags. This is the first known research to estimate horn fly management costs among cattle producers.

Key words: horn fly management costs, quantile regression, cattle survey

Horn flies (*Haematobia irritans* (L.)) are a common and significant pest of livestock in the United States (US) and are known to infest host animals such as cattle, sheep, goats, and horses (Bruce 1964, Greer and Butler 1973, Jones et al. 1988, Loftin and Corder 2010, Brewer et al. 2021). Horn flies are an ectoparasite and feed on the blood of their host 20–40 times per day. In cattle, this results in blood loss, pathogen introduction, decreased feed efficiency, reduced weight gains, hide damage, and decreased milk production among females (Campbell 1976, Kinzer et al. 1984, Clutter and Nielsen 1987, Arther 1991, Byford et al. 1992, Guglielmone et al. 1999, Mays et al. 2014). Other problems associated with horn flies in cattle include bovine teat atresia and the transmission of pathogens such as *Salmonella enterica* and mastitis-causing *Staphylococcus aureus* (Gillespie et al. 1999, Edwards et al. 2000, Oliver et al. 2005, Anderson et al. 2012, Ryman et al. 2013, Olafson et al. 2014).

Multiple studies have demonstrated the importance of managing horn fly populations within cattle herds. Horn flies can cause decreased weight gain in cattle; thus, proper horn fly management can eliminate this problem which could result in higher revenue for cattle producers (Campbell 1976, Haufe 1982; Sanson et al. 2003). Cocke et al. (1989) used ear tags to control horn flies and found that calves from tagged cows had an average weaning weight 27.5 pounds higher than calves from untagged cows. Weights gained from birth for male and female calves were found to be 14.7 pounds and 24.8 pounds more, respectively, than calves from untagged cows (Cocke et al. 1989). In another study, ear tagged yearling beef heifers were found to gain 50% more weight than heifers with no tags (Sanson et al. 2003).

Kinzer et al. (1984) found that Hereford steers with no fly infestations had 9% higher feed conversion than infested cattle. Finally, compared to cattle infested with horn flies, treated yearling steers and heifers gained 17.7% and 14.0% more weight, respectively (Haufe 1982, Kunz et al. 1984, Derouen et al. 1995). Kunz et al. (1991) is the only known study to quantify the monetary damages of horn flies to the US livestock industry, and they estimated the damages to be $876 million USD annually, which, adjusted for inflation to 2021 dollars, is $1.75 billion USD annually (U.S. Bureau of Labor Statistics 2021). To arrive at their estimate, Kunz et al. (1991) first estimated average daily gain and average total gain losses accrued to the US calves and stocker segments from horn flies. They next estimated how many heads of cattle in each of these segments were exposed to horn flies. They then multiplied this expected weight loss by the market value for stockers and calves to arrive at the total industry loss.

Given the negative consequences of horn flies, it is critical to examine the economic impact of horn flies on cattle production. One component of the economic impact that has yet to be examined is cattle producer management of horn flies; specifically, how much producers spend managing horn flies (e.g., insecticide costs, labor costs). Horn fly control methods include chemical delivery methods such as ear tags, pour-ons, sprays, and feedthroughs, as well as non-chemical methods such as the use of biological controls (e.g., parasitoids, entomopathogenic fungi, and BT technology), pasture management, and fly traps (Foil and Hogsette 1994, Brewer et al. 2021). Nontraditional control methods include the use of resistant breeds and zebra stripes painted on cattle (Steelman et al. 1993, Kojima et al. 2019). Brewer et al. (2021) provide a comprehensive review of chemical and nonchemical horn fly control methods. Horn fly populations vary with climate; thus, management strategies found to be effective in one region are not guaranteed to be successful in other parts of the country (Kunz 1980, Lancaster and Meisch 1986, Showler et al. 2014).

Costs associated with horn fly management vary depending on the control method(s) used and segment of the cattle industry (e.g., cow-calf, stocker, feedlot). In a popular press article, Benavidez (2020) estimated the costs per head for horn fly management through an online search of products for sale and assumed moderate to heavy horn fly pressure. In general, Benavidez (2020) estimated a possible management strategy for horn flies in the Southwest could consist of a combination of pour-on insecticides, ear tags, and feedthrough that would cost about $13 per head for cows and $24 per head for a cow-calf pair. While this provides an estimate of how much an effective horn fly management system might cost, no known research has investigated how producers are currently managing horn flies and the costs associated with their horn fly management programs. Therefore, we surveyed Texas and Tennessee cow-calf operators to determine how much they spend per head on horn fly management and what types of horn fly management approaches they utilize. Further, we determined factors that influence their horn fly management costs per head.

This information is important since producers likely have different horn fly management costs based on location, demographics, perceptions, and traditional practices. Results of this research will be informative to producers and researchers interested in the factors which affect producer decision making and horn fly management expenditures.

Materials and Methods

Survey Design

A survey of Tennessee and Texas cow-calf producers was conducted in 2017 to determine cow-calf producers' management practices of horn flies (This data has been used previously to determine producer's willingness-to-pay for horn fly resistant bulls [McKay et al. 2019b]). An online Qualtrics (www.qualtrics.com) survey was distributed by email to cattle producers participating in the Tennessee Agriculture Enhancement Program (TAEP) as well as members of the Texas and Southwestern Cattle Raisers Association (TSCRA). Producers were required to be 18 yrs or older to complete the survey. Eleven percent (464) of the 4,028 Tennessee producers and 8% (317) of the 3,882 Texas producers that were contacted responded to the survey. According to the USDA (2017) Census of Agriculture, there are 37,288 cattle farms in Tennessee and 152,882 cattle farms in Texas; thus, these email lists only represent 10% of the cattle farms in Tennessee and 2.5% of the cattle farms in Texas. The final response rate indicates that less than 1% of cattle producers in Tennessee and Texas are represented; however, this level of overall responses is consistent with several other published producer surveys (e.g., DeLong et al. 2017; McLeod et al. 2018; McKay et al. 2019a; Ellis et al. 2020).

The survey had University of Tennessee Institutional Review Board approval before distribution (UTK IRB-17-03931-XM). Producers were asked to 'Please estimate your total spending in 2016 for all horn fly management, control, and treatment of your entire herd. (Please include labor costs in your estimate).' Producers were also asked questions regarding their farmer and farm demographics and which methods they use to manage horn fly populations and parasitization (feeding) within their cattle herds. Questions regarding the month of fly prevalence and location of flies on cattle were also included in the survey. To determine how information about the horn fly and its effects on cattle impacted producer responses, an Information Treatment was included in the survey, which half of the survey participants saw and read while taking the survey. The Information Treatment can be read in the supporting online materials section.

Conceptual Framework and Hypothesized Results

An economic threshold (ET) is defined as the density of pests required before control measures should be implemented to prevent pest populations from exceeding the economic injury level (EIL) (Stern et al. 1959). For horn fly populations, ET levels are primarily numerically based and range from 10 to 230 flies per head, depending on geographic location, environmental factors, and the value of the cattle (Gordon et al. 1984, Arther 1991, Moon 2019). For most producers and veterinarians, horn fly treatments are applied to cattle to avoid harm.

Profit-maximizing producers use various management and treatment options to decrease the negative effects of horn flies within their cattle herds. How much producers spend managing horn flies likely varies depending on several factors. While no previous research has analyzed which factors affect horn fly management costs, the factors we hypothesize to affect horn fly management cost per animal include the producer and farm demographics, seasonality of horn flies, producer perceptions of horn flies, and producer horn fly management practices.

For producer i, we hypothesize that horn fly management cost per animal ($cost_i$) can be explained as a function (f) of the following factors:

$$cost_i = f\,(ProducerDEM_i,\ FarmDEM_i,\ Seasonality_i,\ Perceptions_i,\ MGMT_i,\ INFO_i) \quad (1)$$

where $cost_i$ is equal to the producer i's annual horn fly management costs per head, $ProducerDEM_i$ are variables associated with producer demographics for producer *i*, $FarmDEM_i$ are variables associated with farm demographics, $Seasonality_i$ is equal to one if the producer *i* reported the flies being abundant in a particular season, $Perceptions_i$ is variables specifically related to each producer's horn fly management perceptions (e.g., the severity of flies, disease occurrences, and insecticide effectiveness), $MGMT_i$ are producer *i*'s stated horn fly management practices (e.g., use of insecticides, ear tags, and feedthrough), and $INFO_i$ is a binary control variable identifying whether producer *i* was provided with the Information Treatment within the survey (1 = Information Treatment and 0 otherwise). The specific names, expected signs, and definitions of the variables appear in Table 1.

Several producer and farm demographics have been found to be important in explaining a variety of farm outcomes (e.g., DeLong et al. 2017, 2019, McLeod et al. 2018, McKay et al. 2019b, Ellis et al. 2020). DeLong et al. (2019) found that producer age and education level were associated with their decision of how to market a hypothetical Tennessee Certified Beef product. DeLong et al. (2017) found that the incidence of mastitis (as measured by bulk tank somatic cell count) among Southeastern dairy farms varied by on-farm income levels and state. Ellis et al. (2020) found that larger dairy farms were more likely to be operational. Since this is the first known research on horn fly management costs, we expect the following variables to be important control variables, but we are unsure of the expected sign: producers with a college degree or higher (*College*), producer age *(Age)*, income (*Income)*, state (*Tennessee*), gender (*Male*), and seasonality of horn fly abundance (*Spring*, *Summer*, *Fall*, *Winter*), information from Extension (*Extension*) and popular press articles (*Popular Press Articles*), and (*Horn Fly Problem*) (Table 1).

We expect producers who own Angus cattle (*Angus*) will have higher horn fly management costs because research shows that horn flies prefer to feed on cattle with dark hair color (Oliveira et al. 2013). Additionally, McKay et al. (2019b) found that farmers with Angus cattle were more likely to purchase a hypothetical bull that was resistant to horn flies compared to a bull that was not resistant to horn flies. As the percent of calves produced during spring months (*Spring Calves*) increases, horn fly management costs are expected to increase as well, due to horn fly populations typically peaking first in the spring (Lancaster and Meisch 1986). The level of horn fly intensity on the backs of cattle (*Horn Fly Intensity*) is hypothesized

Table 1. Names and definitions of dependent and independent variables.

Variable	Description	Hyp. Sign
Dependent variable		
HF treatment cost/head	Total horn fly management costs/herd size	NA
Producer demographics		
College	1 if college degree or higher	+/–
Age	Producer age	+/–
Income	Total household income[a]	+/–
Male	1 if producer is male	+/–
Farm demographics		
Angus	1 if the producer has Angus cattle	+
Tennessee	1 if the producer was in Tennessee	+/–
Total acres	Size of a farm in acres	–
Herd size	Total number of bulls, cows, and calves	–
Spring calves	Percent of calves in spring calving season	+
Seasonality of horn flies		
Spring	1 if flies abundant in March, April, or May	+/–
Summer	1 if flies abundant in June, July, or August	+/–
Fall	1 if flies abundant in September, October, or November	+/–
Winter	1 if flies abundant in December, January, or February	NA
Horn fly perceptions		
Horn fly intensity	Intensity of flies on backs of the animals[b]	+
Disease	Average severity within herd (pinkeye and mastitis)[c]	+
Horn fly problem	Number of flies before considered a problem[d]	+/–
Insecticide effectiveness	Horn fly insecticides effectiveness today versus 5 years ago[e]	–
Financial impact	Agreement that horn flies impose financial impact[f]	+
Consumer concerns	Agreement consumer pesticides concern is considered when selecting horn fly management options[f]	–
Horn fly management practices		
Use of insecticides	1 if uses insecticides (e.g., pour-on)	–
Use of ear tag	1 if uses ear tags	–
Use of feedthrough	1 if feeds insecticide to animal	+
Extension	1 if uses extension services for information	+/–
Popular press articles	1 if uses popular press articles for information	+/–
Information treatment	1 if the Information Treatment was seen, 0 otherwise	+/–

a 1 = less than $10,000 to 9 = $500,000 or greater.
b 1 = no problem to 5 = very intense problem.
c 1 = occurs infrequently or mildly to 3 = occurs frequently or intensely.
d 1 = low intensity (75), 2 = medium intensity (100-150), 3 = high intensity (200-350).
e 1 = much less to 7 = much more.
f 1 = strongly disagree to 4 = strongly agree.
NA means not applicable.
Hyp means hypothesized.

to increase horn fly management costs because it is assumed that as the fly infestation gets worse, producers will spend more money to pursue additional control methods. Prevalence of pinkeye and mastitis (*Disease*) is hypothesized to increase horn fly management cost as disease prevalence increases because it is assumed that producers would take additional measures to reduce the number of flies, in theory, to reduce the prevalence of pinkeye and mastitis. Although pinkeye-causing bacteria have not been found to be transmitted by horn flies, the mastitis-causing bacteria *Staphylococcus aureus* is transmissible by horn flies (Nickerson et al. 1995, Owens et al. 1998, Gillespie et al. 1999, Oliver et al. 2005, Ryman et al. 2013).

As the producer level of agreement with the statement 'horn flies impose significant financial impact on my operation' (*Financial Impact*) increases, it is hypothesized that horn fly management costs will also increase. It is assumed that producers who agree with this statement recognize the negative effects horn flies have on their herds; thus, they will implement control measures to minimize those negative effects. Benavidez (2020) estimated cow horn fly costs to average $2.41/head for pour-on insecticides, $2.19/head for ear tags, and $8.46/head for feedthrough. Therefore, we expect these methods (*Use of Insecticides*, *Use of Ear Tags*, *Use of Feedthrough*) to increase horn fly costs per head. The exact wording of this question is available in the Supp Materials (online) section. Briefly, *Use of Insecticides* was an inclusive term for any and all insecticides (e.g., ear tags, sprays, and feedthroughs), while *Use of Ear Tags* and *Use of Feedthrough* were more specific management options. A producer could have selected *Use of Insecticides* and not selected *Use of Ear Tags;* likewise, they could have selected *Use of Ear Tags* and not selected *Use of Insecticides*.

With respect to farm size (*Total Acres* and *Herd Size*), it is hypothesized that larger farms will have lower horn fly costs per head since, due to economies of scale, they can buy horn fly management products in bulk. Horn fly management costs are hypothesized to decrease as producers' assessment of insecticides today compared to five years ago (*Insecticide Effectiveness*) increases because it is assumed that producers who believe that insecticides are more effective today would be using less of them, thus, spending less money. Producers who agree with the statement 'consumer concern about pesticides is a consideration of mine when I select management options for horn flies' (*Consumer Concerns*) are hypothesized to have lower horn fly management costs since they may opt to not control for horn flies in their cattle populations.

Econometric Model

An ordinary least squares (OLS) regression was used to estimate which variables were associated with horn fly management costs per animal. Since the dependent variable was skewed to the right and not normally distributed (Figure 1), the log of $cost_i$ was taken to create a normal distribution of the data. The OLS regression model is represented by:

$$\log\left(cost_i^*\right) = \beta_0 + X_i\beta + \mu_i \tag{2}$$

where $cost_i^*$ is producer *i*'s horn fly cost per animal, X_i is a vector of explanatory variables, β is a vector of unknown parameters, and μ_i is the error term.

We also estimate a quantile regression to further examine producers' horn fly management cost per head for each horn fly cost quantile (Bekkerman et al. 2013). The quantile regression was estimated at the 25th, 50th, and 75th quantiles, φ, of the cost data. Thus, compared to the OLS regression, we are able to better understand the differences in producers who spend below average, the median amount, and above average amounts on horn fly management methods. It is likely the variables significant in determining spending amounts across these three types of spenders differ. The quantile regression model is represented by:

$$\log\left(cost\left(\varphi\right)i\right) = \beta_{i,0}\left(\varphi\right) + \beta_i X(\varphi) + \mu_i(\varphi) \tag{3}$$

where $cost_i$ is producer *i*'s reported horn fly management cost per animal, X is a vector of explanatory variables, β is a vector of unknown parameters, and μ_i is the error term.

Differences in means of the descriptive statistics between the two states were evaluated using the *ttest* command in *STATA* (StataCorp 2019) to obtain a better understanding of the respondents. The *STATA* command *regress* was used to estimate the OLS regression. The *STATA* command *sqreg* was used to estimate the quantile regression (Bekkerman et al. 2013, StataCorp 2019). Variance inflation factors (VIFs) were used to determine if multicollinearity was present in the regressions (Wooldridge 2012,

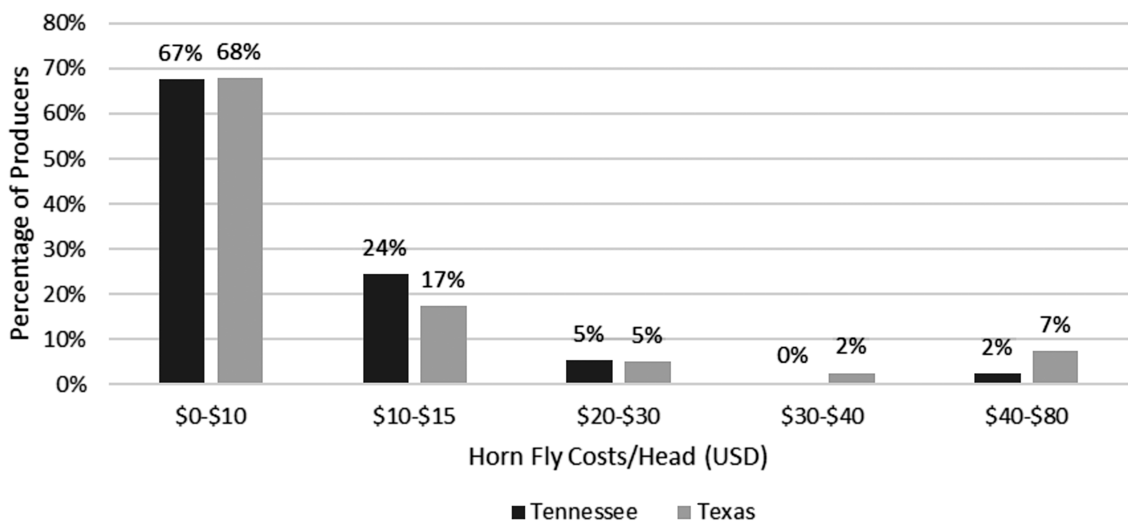

Fig. 1. Percent of producers with stated horn fly costs per head within each range (USD). Notes: Stated horn fly costs were obtained with the following question, 'Please estimate your total spending in 2016 for all horn fly management, control, and treatment of your entire herd. (Please include labor costs in your estimate).' Number of observations = 367.

StataCorp 2019). The *STATA* command *coldiag2* was also used to check for multicollinearity by estimating the Condition Indexes for the independent variables (Belsey et al. 1980, Hendrickx 2004, StataCorp 2019). The Breusch-Pagan test for heteroskedasticity (~heteroscedasticity) was also conducted using the *estat hettest* command in *STATA* (Breusch and Pagan 1979, Wooldridge 2012, StataCorp 2019). Of the 464 Tennessee and 317 Texas survey respondents, a total of 367 producers from both states answered all questions required for analysis.

Results

Survey Descriptive Statistics

Dependent and independent variable means, standard deviations, and *t*-tests results for differences in survey statistics between Tennessee and Texas producers are presented in Table 2. Descriptive statistics are presented and compared between states to better discuss the representativeness of the sample and to describe the independent variables in the regressions.

Tennessee producers spent an average of $9.50 per head on horn fly management, while Texas producers spent an average of $12.40 per head on horn fly management costs ($T = -1.88$; $df = 157$; $P = 0.061$). Compared to Texas producers, Tennessee producers reported they thought levels of fly abundance in spring and fall were lower, but the abundance of flies in Texas and Tennessee in the summer was reported as similar (Figure 2). The average Tennessee respondent was 57 years old, reported an average household income of $50,000–$99,000 per year, was male (92%), and earned a college degree or higher (59%). The average Texas respondent was 61 years old, reported an average household income of $100,000–$149,000 per year, was male (85%), and earned a college degree or higher (69%). In 2017, the average age of Tennessee farmers was 59 years old, while the average age of Texas farmers was 60 years old (U.S. Department of Agriculture, National Agricultural Statistics Service 2017). The average U.S. household income for farms was $115,588 in 2019 (Schnepf 2019). Male producers made up 65% and 62% of Tennessee's and Texas's total farms in 2017, respectively (U.S. Department of Agriculture, National Agricultural Statistics Service 2017).

The reported farm size for both Tennessee and Texas is higher than the 2019 average farm size of 155 acres and 512 acres, respectively (U.S. Department of Agriculture, National Agricultural Statistics Service 2020). The average Tennessee farm size (*Total Acres*) was 329 acres and respondents had, on average, 112 head of primarily Angus cattle (88%). The average Texas farm size was 2,625 acres and respondents had, on average, 206 head of primarily Angus cattle (60%). The reported herd size for both Tennessee and Texas is higher than the 2017 average herd size of 49 and 82, respectively (U.S. Department of Agriculture, National Agricultural Statistics Service 2017).

Table 2. Dependent and independent variable descriptive statistics for Tennessee and Texas

	Tennessee		Texas				
Variable	Mean	Std. dev.	Mean	Std. dev.	T–test	DOF	*P*–value
Dependent variable							
HF treatment cost/head	9.50	8.71	12.40	15.78	−1.88*	157	0.06
Producer demographics							
College	0.59	0.49	0.69	0.46	−1.92*	252	0.06
Age	56.54	11.96	60.94	10.77	−3.55***	262	0.00
Income	4.82	1.45	5.80	1.68	−5.50***	211	0.00
Male	0.92	0.27	0.85	0.36	1.83*	192	0.07
Farm demographics							
Angus	0.88	0.32	0.60	0.48	4.92***	175	0.00
Total acres	329.59	449.60	2,625.20	8,155	−3.09***	120	0.00
Herd size	111.76	118.33	205.55	330.13	−3.03***	135	0.00
Spring calves	53.10	46.15	64.38	73.49	−1.55	168	0.12
Seasonality of horn flies							
Spring	0.31	0.46	0.6	0.49	−5.25***	227	0.00
Summer	0.98	0.13	0.98	0.16	0.52	200	0.60
Fall	0.76	0.43	0.92	0.28	−4.33***	340	0.00
Winter	0.00	0.00	0.03	0.01	−1.75*	120	0.08
Horn Fly perceptions							
Horn fly intensity	3.15	0.65	3.43	0.59	−4.18***	262	0.00
Disease	1.27	0.38	1.10	0.29	4.87***	299	0.00
Horn fly problem	1.84	0.62	2.01	0.60	−2.54**	246	0.01
Insecticide effectiveness	4.03	1.56	4.29	1.51	−1.54	245	0.13
Financial impact	3.24	0.64	3.29	0.66	−0.68	230	0.50
Consumer concerns	2.92	0.82	2.74	0.97	1.78*	207	0.08
Horn fly management practices							
Use of insecticides	0.90	0.30	0.9	0.28	−0.60	259	0.55
Use of ear tag	0.59	0.49	0.34	0.48	4.69***	247	0.00
Use of feedthrough	0.55	0.50	0.55	0.50	−0.09	239	0.93
Extension	0.74	0.44	0.65	0.48	1.76*	221	0.08
Popular press articles	0.54	0.50	0.71	0.46	−3.18***	259	0.00
Information treatment	0.48	0.50	0.53	0.50	−0.89	239	0.38

Notes: *$P < 0.1$, **$P < 0.05$, ***$P < 0.01$. n = 246 for Tennessee and n = 121 for Texas. Std. dev. means standard deviation. DOF is Satterthwaite's degrees of freedom.

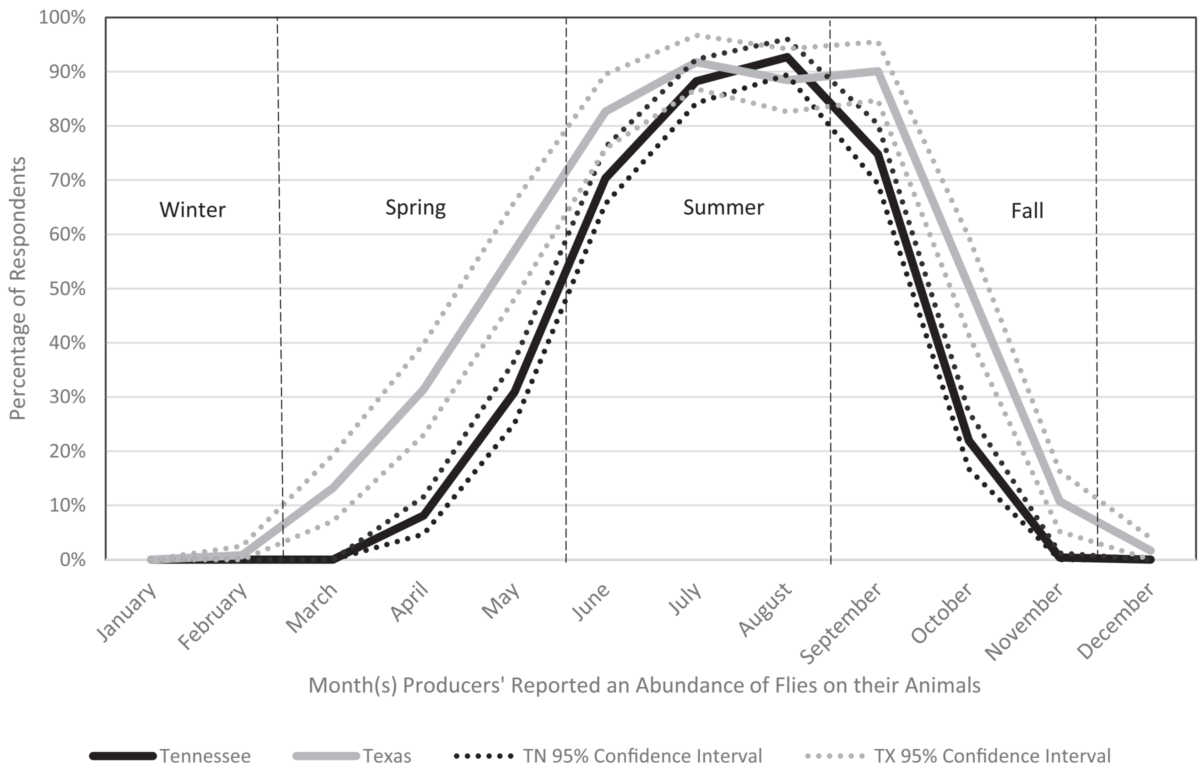

Fig. 2. Percentage of Tennessee and Texas respondents selecting certain months as having an abundance of flies on their animals and the associated 95% confidence intervals of estimates. Notes: The exact question producers were asked to obtain this information was, 'In what months are flies most abundant on your animals? (check all that apply).' Number of observations = 367.

Tennessee and Texas Regression Results

Results of the OLS and the quantile regressions are reported in Table 3. For the OLS and quantile regression, since the dependent variable has been log transformed, the estimated independent variable coefficients can be multiplied by 100 to estimate how a one-unit increase in the respective independent variable increases/decreases average horn fly costs on a percentage basis (Wooldridge 2012). For the quantile regression, producers in the 25th quantile spent less than $4.08 per head on horn fly management; producers in the 50th quantile spent between $4.08 and $6.75 per head on horn fly management; and producers in the 75th quantile spent between $6.75 and $12.20 per head on horn fly management.

Across all regressions presented in Table 3, the VIFs (i.e., the measure of multicollinearity in the regression) were all less than 10, the mean VIF was 1.21, and the Condition Indexes were all less than 29.32. Thus, no evidence of multicollinearity was found (Belsey et al. 1980). Results of the Breusch-Pagan test found that heteroskedasticity was not an issue (χ = 1.78; df = 1; P = 0.1824) (Breusch and Pagan 1979, StataCorp 2019).

Producer and Farm Demographics

Results of the OLS regression indicated that producers with a college degree or higher had 23% lower horn fly management costs per head than producers without a college degree (P = 0.013). As producer income levels rose, horn fly management costs per head increased by 7% (P = 0.028). Inconsistent with the hypothesized results, producers with Angus cattle spent 28% less than all other producers (P = 0.015). For each additional animal reported (bull, cow, calf) horn fly management costs decreased by 0.12% (P < 0.001), which was consistent with the hypothesis and the expectation that economies of scale would apply as herd sizes increase.

With respect to the quantile regression, for producers with horn fly management costs in the 25th quantile, as producer income levels rose, horn fly management costs per head increased by 7% (P = 0.057). For each additional animal reported (bull, cow, calf), horn fly management costs decreased by 0.15% (P = 0.033), which was consistent with the hypothesized sign. Meanwhile, for those producers in the 50th quantile with a college degree or higher, they had horn fly management costs per head 26% less than producers without a college degree (P = 0.037). For producers in the 50th quantile, each additional animal reported (bull, cow, calf) decreased horn fly management costs by 0.13% (P = 0.010), which was consistent with the hypothesized sign.

Producers in the 75th quantile of spending with a college degree or higher had horn fly management costs per head of 24% less than producers without a college degree (P = 0.081). Producers in this quantile with Angus cattle spent 44% less than all other producers (P = 0.045), which was unexpected given our hypothesis. For each additional animal reported (bull, cow, calf) for producers in this quantile, horn fly management costs decreased by 0.15% (P = 0.001), which was consistent with our hypothesis.

Seasonality of Horn Flies

For the OLS regression, the seasonality of horn flies (i.e., the seasons producers reported horn flies to be most abundant) was not associated with horn fly management costs. Meanwhile, for the quantile regression, those producers in the 25th quantile who reported an abundance of flies on their animals during spring compared to winter, spent 25% more than those who did not report an abundance of flies during these months (P = 0.070). Respondents in the 75th quantile of spending who reported an abundance of flies on their animals during the fall months of September, October, or

Table 3. Results of ordinary least squares and quantile regression of horn fly treatment cost/head

			Quantile regression					
	OLS		25%		50%		75%	
Variable	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE
Producer demographics								
College	−0.231**	0.09	−0.061	0.11	−0.261**	0.12	−0.238*	0.14
Age	−0.001	0.00	−0.001	0.01	−0.000	0.01	0.000	0.01
Income	0.067**	0.03	0.071*	0.04	0.064	0.05	0.077	0.05
Male	−0.218	0.14	−0.155	0.25	−0.286	0.24	−0.282	0.26
Farm demographics								
Angus	−0.278**	0.11	−0.138	0.18	−0.147	0.17	−0.445**	0.22
Tennessee	−0.009	0.12	0.300	0.21	−0.119	0.18	−0.224	0.17
Total acres	0.00	0.00	0.000	0.00	0.000	0.00	0.000	0.00
Herd size	−0.001***	0.00	−0.002**	0.00	−0.001***	0.00	−0.002***	0.00
Spring calves	−0.001	0.00	0.000	0.00	−0.000	0.00	−0.001	0.00
Seasonality of horn flies								
Spring	0.128	0.09	0.246*	0.13	0.110	0.12	0.043	0.14
Summer	0.026	0.32	−0.084	0.39	0.072	0.36	−0.226	0.49
Fall	0.183	0.12	0.014	0.14	0.048	0.14	0.373**	0.15
Horn Fly perceptions								
Horn fly intensity	0.086	0.07	0.029	0.09	0.114	0.08	0.045	0.10
Disease	0.106	0.13	−0.059	0.20	0.311	0.25	0.398*	0.21
Horn fly problem	−0.147**	0.07	−0.059	0.10	−0.191	0.12	−0.190	0.14
Insecticide effectiveness	0.028	0.03	0.029	0.05	0.055	0.05	0.052	0.04
Financial impact	0.102	0.07	0.097	0.10	0.027	0.12	0.140	0.12
Consumer concerns	0.028	0.05	−0.042	0.08	0.047	0.07	0.030	0.07
Horn fly management practices								
Use of insecticides	0.009	0.15	0.080	0.22	−0.004	0.18	−0.092	0.18
Use of ear tag	0.237***	0.09	0.243**	0.11	0.148	0.12	0.181	0.14
Use of feedthrough	0.324***	0.09	0.424***	0.12	0.258**	0.11	0.285**	0.13
Extension	−0.074	0.10	0.0327	0.14	−0.044	0.14	−0.084	0.13
Popular press articles	−0.077	0.09	−0.0882	0.14	−0.030	0.12	−0.087	0.14
Information Treatment	−0.042	0.09	−0.0226	0.13	−0.004	0.13	−0.169	0.14
Constant	1.368**	0.61	0.7298	0.80	1.297	0.86	2.104**	1.02
R^2	0.21		0.13		0.11		0.14	

Notes: *P < 0.1, **P < 0.05, ***P < 0.01. Pseudo R^2 is used for quantile regression. OLS is ordinary least squares, SE is standard error for OLS and Bootstrap standard error for the quantile regression. Number of observations = 367 for both regressions.

November spent 37% more than those who reported an abundance of flies in the winter months (P = 0.012).

Horn Fly Perceptions

For the OLS regression, a one unit increase in the intensity at which producers consider horn flies to be a problem resulted in a 15% decrease in horn fly treatment costs per head (P = 0.044). With regards to the quantile regression, producers in the 75th quantile of spending who reported pinkeye and mastitis in their herds had horn fly management costs 40% higher than those producers who did not report these diseases within their herds (P = 0.054). Meanwhile, none of the other producer perceptions about horn flies were significant in the OLS regression.

Horn Fly Management Practices

For the OLS regression, if a producer used ear tags to prevent and/or respond to an outbreak, this increased their horn fly costs by 24% (P = 0.008). If a producer used a feedthrough insecticide to prevent and/or respond to an outbreak, this increased their horn fly costs by 33% (P < 0.001). This is consistent with expectations that using feedthrough insecticides would increase horn fly costs more than using ear tags.

For the quantile regression, for producers in the 25th quantile who reportedly used ear tags to prevent and/or respond to an outbreak, this increased their horn fly costs by 24% (P = 0.033). Producers in this quantile who used a feedthrough insecticide to prevent and/or respond to an outbreak had increased horn fly costs of 42% (P < 0.001). Meanwhile, producers in the 50th quantile of spending who used a feedthrough insecticide to prevent and/or respond to an outbreak had increased costs of 26% (P = 0.022). Producers in the 75th quantile of spending who used a feedthrough insecticide to prevent and/or respond to an outbreak had increased horn fly costs of 28% (P = 0.030).

Discussion

No known research exists regarding the actual costs associated with managing horn flies. Thus, we surveyed Texas and Tennessee cow-calf operators to determine how much they spend per head on horn fly management ($12.40/head and $9.50/head, respectively). Specifically, more than 70% of producers reported using an insecticide (e.g., ear tag, feed through, bolus, organic insecticide) and costs associated with management approaches did not differ by state. We also determined producer and farm demographics, producer perception of horn fly populations, and management practices influenced producer's horn fly management costs per head.

As expected, several producer and farm demographics influenced horn fly management costs. More than half of Tennessee and Texas respondents reported having a college degree or higher (*College*). Earning a college degree was associated with decreased horn fly costs per head for the overall OLS regression, as well as the 50th and 75th quantiles, which is consistent with the findings of DeLong et al. (2019) that education level is a significant factor in producer decision making. Total household income (*Income*) was associated with increased horn fly management costs per head for the overall OLS regression as well as the 25th quantile. This could be due to producers with higher income levels having more disposable income to spend on horn fly control methods, or producers who spend more on horn fly management produce more profitable cattle which adds to their income.

Having Angus cattle was associated with lower horn fly management costs (in the OLS regression and the 75th quantile), although it was expected that those costs would be significantly higher due to research showing that horn flies prefer to feed on cattle with dark hair (Oliveira et al. 2013). This finding could be due to the fact that horn flies on dark haired animals are hard to see from a distance and producers might not be aware of flies on their animals unless they are in the field with them each day. Larger herd sizes were associated with lower horn fly management costs per head across the overall OLS regression and all quantiles of the quantile regression. This was consistent with the hypothesis that larger farms will have lower horn fly management costs per head due to economies of scale.

Since horn fly populations vary by season and location, we expected that horn fly management costs would also be impacted by the seasonal abundance of horn flies. Results of the quantile regression suggest that producers who reported an abundance of horn flies during the spring compared to winter, were associated with higher horn fly management costs per head in the 25th quantile. This was also true for producers who reported an abundance of horn flies during the fall compared to winter if they were in the 75th quantile.

Responding producers identified in the 75th quantile who reported seeing pinkeye and mastitis (*Disease*) within their herds were associated with having higher horn fly management costs per head. This outcome was consistent with expectations, as it was estimated that the prevalence of these diseases would lead producers to implement additional horn fly control methods. For the OLS regression, producers who did not perceive a horn fly problem until more flies were present on their animals were associated with having lower horn fly management costs per head. This most likely indicates that those producers are not as readily implementing horn fly control measures. Otherwise stated, this result indicates that if producers did not consider horn flies to be a problem until there were 200–350 flies on them, compared to only 75 flies, then they spent far less on horn fly control measures. This indicates that they might not be treating horn flies until they perceive them to be a problem, which might not be until there are 350 flies present on the animal. The other horn fly perception variables were not statistically significant in either the OLS or quantile regressions (e.g., *Insecticide Effectiveness, Financial Impact, Consumer Concerns, Horn Fly Intensity (backs of animals)*), which was contrary to expectations. Additionally, this perception might be causing a loss and flies are predating on their herd.

The horn fly management practices of ear tags and feedthroughs were found to be statistically significant in the OLS regression and many of the quantiles of the quantile regression. This was expected as these are two popular options for cattle producers. Results indicate that ear tag use increased costs by 23% and feedthrough use increased costs by 32%. This is consistent with (Benavidez 2020) who estimated feedthrough costs were higher than ear tag costs. In the survey, we did not include other horn fly management options (e.g., VetGun, fly vaccine) as they were and in some areas are still relatively novel when the survey was developed and released.

This research is a vital addition to previous literature that has explored the negative impacts of horn flies in cattle as well as the positive outcomes gained from implementing horn fly control measures. By providing insight into the factors influencing horn fly management costs per head, this study lays the foundation for further exploration of how producer spending on horn fly management contributes to the success of their horn fly management strategies. Additionally, knowing how much a producer spends to prevent and manage horn flies can help to develop useful economic thresholds and injury levels that can help save a producer from losses and expenditures. In other words, the upfront costs of $9.50–$12.40/head could save a producer from losses associated with unrealized gains due to reduced feed efficiency and unplanned expenditures (e.g., medical treatments associated with disease occurrence). It should be noted that one limitation of this research is relying on producers' self-reported expenses related to horn fly costs; thus, it is unknown if producers accurately accounted for all their horn fly management costs. For example, while we informed producers to include labor costs in the calculation, it is unknown if producers appropriately calculated their labors costs.

The question also still remains of whether producers who spend more on horn fly management actually have less of a perceived problem with horn flies. While we examined determinants of horn fly management costs per head, we did not evaluate the success of the producers' horn fly management programs. Future research should evaluate how horn fly management costs are associated with the actual and perceived control of horn flies on producers' farms. One limitation of this study is that the results could be biased by the specific cattle groups we surveyed (TAEP and TSCRA). Future research could also include the repetition of this survey in other cattle producing states and/or incorporate more questions regarding when (i.e., based on calendar or horn fly population levels) producers are implementing horn fly control measures.

Supplementary Data

Supplementary data are available at *Journal of Economic Entomology* online.

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