RELATIVE ATTRACTIVENESS OF THE SONIC WEB AND THE HORSE TO *Stomoxys calcitrans*

By

TRACEY LYNN TAM

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Tracey Lynn Tam

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Chair: Saundra H. TenBroeck
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The stable fly, *Stomoxys calcitrans*, is a blood-sucking, ectoparasite that causes irritation and distress to livestock and humans. In this study, broodmares and Sonic Web traps were evaluated at the University of Florida Horse Teaching Unit (HTU) for their relative attractiveness to stable flies. On each day of the study, a broodmare was dusted with colored fluorescent dust and tied to a post. Sonic Web traps (Applica Consumer Products, Inc., Miami Lakes, Fla.) were placed at the four cardinal compass points 3.7, 7.3, or 14.6 meters from the post in 3 separate 4-hour experiments. Then two broodmares coated with fluorescent dust were released in a 55.3 by 47.4 meter rectangular paddock; and eight Sonic Web traps were placed along the perimeter 24.1 meters from each other (2 per side) and 28.7 meters from the center of the paddock. Sticky sleeves were placed on the Sonic Web traps when each experiment began, collected after 4 hours, and evaluated under a black light to determine the presence of dust on the stable flies. Once the sleeves were evaluated, 5 marked and 5 nonmarked stable flies were randomly chosen

from each sleeve to be tested with Quik-Cult (Laboratory Diagnostics Co. Inc., Morganville, NJ), a tape test with drops used to evaluate blood in the fly's abdomen.

Of the stable flies captured, 88.2% were unmarked, indicating that the flies visited the traps before feeding on the horses. We assumed that all stable flies captured on the Sonic Web traps either came to them directly or came to them after visiting the horse(s). This was supported by the fact that flies dusted with two different dust colors were captured only on 3 experiment days. Numerically more flies were captured on the South trap at the 3.7 m distance; while the North trap captured the most flies at the other three distances. This is due to the location of the feeding barn in relation to trap placement. There were numerical and significant differences when sound combinations were run at each of the distances due to the traps interfering with each other. The number of Signal Green marked stable flies caught on the traps was significantly greater than flies marked with any other color. The percentage of marked and unmarked stable flies with a blood meal was 27.7 and 26.7. This indicated that the flies took blood meals from the dusted horse or another horse nearby.

The final experiment evaluated sound, trap position, and open or closed configuration of the superstructure of the Sonic Web. When the superstructure was open, traps captured twice as many flies than when it was closed, regardless of sound or trap placement. Sound had no effect on trap efficacy when analyzed by itself. The trap in position 2 captured significantly more flies than the trap in position 1. When all three combinations were analyzed together, combination 5 (trap 1open/on, trap 2 open/off) captured significantly more flies than the other seven combinations.

CHAPTER 1
REVIEW OF LITERATURE ON THE STABLE FLY
Stomoxys calcitrans Linnaeus, 1758 (Muscidae)

Morphology

The stable fly, *Stomoxys calcitrans L.,* is a well-known cosmopolitan member of the Stomoxynae subfamily of the Muscidae (Zumpt, 1973). It is a haematophagous pest that causes irritation to livestock, wildlife, humans and horses. The stable fly resembles the common house fly, *Musca domestica,* but stable flies have piercing, sucking mouthparts with a long, thin proboscis pointing forward from under the head. This is composed of the labium with short labella, the hypopharynx, and the labrum (Zumpt, 1973). Key characteristics to the stable fly are the arista hairs found only on the dorsal side of the antenna (Zumpt, 1973). The wing veination of the stable fly is quite different from other muscidae having a slight bend upward on vein M1+2 unlike the slight curve to the house fly (Castro, 1967). The stable fly has four longitudinal black stripes on the thorax and a larger checkered (tessellated) abdomen than that of the house fly (Foil and Hogsette, 1994).

Nutrition

Stable flies can feed on a variety of animals and are commonly called the biting house fly. Both sexes are viscous blood-feeders drawing blood quickly and feeding to full capacity in 3 to 4 minutes (Harwood & James, 1979). Bailey and Meifert (1973) observed that the adult stable fly usually approaches a host only to feed.

The female is anautogenous, requiring several blood meals to complete ovarian development; and Parr (1962) reports that the average blood meal (25.8 mg) is three times the average body weight (8.6 mg). Ordinarily, the stable fly changes positions frequently or flies from one animal to another, where the meal is continued (Harwood & James, 1979). There are three phases in the stable fly's search for a host. They are the appetitive-searching phase (driven by endogenous rhythms and hunger); followed by the activation and orientation phases, when the stable flies encounter the chemical stimuli (kairomones) indicating the presence of a host. Attraction occurs when the insect (having located a host) begins to feed (Lehane, 1991). The stable flies are diurnal; while most other blood-sucking insects, such as mosquitoes, are nocturnal (Lehane, 1991). Holloway & Phelps (1991) have found that *Stomoxys calcitrans* has a bimodal diurnal pattern of feeding, locating hosts by responding to carbon dioxide and octenol. Temperature was the most important weather factor. The stable flies' highest biting activity was observed to be at about 30°C;, whereas at 14°C the flies were no longer attracted to host animals (Zumpt, 1973).

Castro (1967) observed that stable flies predominately feed on large animals, such as, cattle, horses, hogs, sheep, goats, and humans. Stable flies also love to bite dogs especially on their ears (Hogsette et al. 1987). The stable flies tend to feed on the lower extremities, such as below the knees and hocks of animals, but can move to the sides and back if the populations are too high on the lower extremities (Foil and Hogsette, 1994). The stable fly has been observed feeding at dawn and in the late afternoon under natural conditions, but can feed at any time during the daylight hours (Mitzmain, 1913). Stable flies can also feed on nectar for immediate energy needed for flight, but cannot successfully produce eggs when a blood meal is not readily available (Jones et al. 1985).

Mating Habits

Adults assemble on sunlit objects from which the males dart out after flying females and engage in aerial interactions (Buschman and Patterson, 1981). According to Buschman and Patterson (1981), males mount the females in the air or on the ground with copulation occurring on a perch. The same male can mate with more than one female, but females cannot be coupled with more than one male (Zumpt, 1973). Buschman and Patterson (1981) found that flies used the observed basking stations not only for mating, but also for thermoregulation when ambient temperatures were too high or too low.

Life Cycle

After taking a blood meal, the female stable fly will seek out a suitable oviposition site (such as soggy, loose, and porous hay or manure) and scatter the eggs throughout the media. The ideal temperature is between 22°C and 28°C (Zumpt, 1973). Zumpt (1973) noted that the number of eggs laid by one female was low during the cold months, but rose to about 120 eggs at 25°C, and to about 200 eggs at 30°C. The growth period varies significantly depending on the temperature, humidity, and other conditions in the environment. The eggs of the stable fly are about 1 mm long and 0.2 mm wide and are curved on one side and straight and grooved on the other side (Harwood and James, 1979). The eggs of the stable flies hatch 12-24 hours after being laid (Foil and Hogsette, 1994). The hatching larva force open the operculum and emerges rapidly in about 14 seconds (Parr, 1962). There are three larval stages.

According to Parr (1962) the newly emerged larva measures an average of 1.08 mm in length, and grows to 1.7 mm; the second instar attains a length of 2.80 mm; and the third instar is 11.12 mm when fully grown. The nutritive value of the medium and temperature play large roles in the duration of the larval stages (Parr, 1962). The larvae of the stable fly have posterior spiracles that are roughly triangular, widely separated from each other and situated near the periphery (Harwood and James, 1979). The stable fly larva takes approximately 6 to 26 days to develop (Harwood and James, 1979). The pupal development takes place inside the puparium, which is the hardened cuticle of the fully-grown larva (Castro, 1967). The reddish-brown puparia are 6 to 7 mm long and barrel shaped; and pupal development lasts about 5 to 26 days (Harwood and James, 1979). Once the stable fly emerges, the body elongates. The fly has a pale gray color and crumpled wings; and the mouthparts are bent posteriorally between the forelegs (Castro, 1967). According to Castro (1967), within 30 minutes the body is darker, the wings expand, the proboscis folds forward, and the insect is ready to fly away. To successfully produce her first batch of eggs, the female requires several blood meals from a host (Foil and Hogsette, 1994). The female stable fly can begin mating 3-5 days after emerging and can begin laying eggs when 5-8 days old (Foil and Hogsette, 1994).

Stable flies are strong fliers; and can fly considerable distances with the help of the wind. Bailey et al. (1973) found that stable flies can travel up to 2 miles (3.2 km) in search of a blood meal. Foil and Hogsette (1994) reported that stable flies were captured on West Florida beaches 225 km from inland marking sites.With this flight range, the flies could be coming from different locations (such as Alabama and Georgia) and ending up at Florida beaches by the direction of the wind, wind speed, and temperatures (Hogsette and Ruff, 1985).

Health Risks

The stable fly is generally not considered important as a vector of animal or human diseases (Castro, 1967). However, Horsfall (1962) states that because the flies tend to probe the skin of one or more animals in their feeding, they can serve as carriers of pathogens. *Stomoxys calcitrans* can transmit numerous pathogenic organisms, including those causing cutaneous leishmaniasis, anthrax, brucellosis, equine infectious anemia, and bovine diarrhea virus (Greenburg, 1971).

Economic Impact As a Livestock Pest

Stable flies occur wherever livestock is present, either around shelters or outdoors. Harwood and James (1979) describe the most important sources of annoyance to livestock as injury of various sorts: worry resulting from mass attacks of the flies, loss of blood, loss of flesh, lowered milk production and reduced butter fat content, reduced vitality (making the animals more susceptible to disease) loss of pasturing time, and actual damage to the victim's tissues and hide caused by the bite itself. When cattle are under attack by stable flies they may quit eating, crowd in bunches, and run around wasting energy, which then causes them to have heat stress and weight loss (Foil and Hogsette, 1994). The effect of stable flies upon the productivity of dairy cattle can severely decrease their milk production and have serious economic effects on the dairy herdsman. According to Bruce and Decker (1958), there was an average production loss of 0.7% per fly per cow from the stable flies.

Campbell et al. (1987) found that the economic threshold for feedlot cattle against stable flies, when weight gain, feed efficiency, and cost of control with insecticides are considered, is less than two per leg on feeder heifers. Total losses to the producer was estimated at $8.51 per animal with 5 stable flies per front leg, with reduced feed efficiency accounting for 88% of the total loss. Lameness was noted in horses due to the continuous stomping and swollen and stiff joints in other animals were common (Zumpt, 1973).

Impact as a Human Pest

Stable flies can be a big disturbance to humans on the beaches and engaged in other outdoor activities. On the Gulf beaches and other waterways in the late summer and early fall, large numbers of stable flies appear from the northerly winds which can make staying outdoors unpleasant (Hogsette et al, 1987). Fishermen on boats have complained about stable fly annoyance (Hogsette and Ruff, 1985). Newsom (1977) estimates that these infestations may cost the Florida tourist industry a million dollars a day in lost revenues.

Pathogens

Stable flies are persistent biters, and often engage in interrupted feedings. A large number of pathogens have been recorded due to the flies interrupted feeding habits (Harwood and James, 1979). They are the intermediate host of nematode worms, including *Setaria cervi,* a parasite of cattle, and of several species of *Habronema*, stomach parasites of horses (Greenburg, 1973). The infective larvae of *Habronema microstoma* interfere with the ability of the fly to penetrate the skin with the proboscis and take a normal blood meal (Zumpt, 1973).

Another disease transmitted by the stable flies is *Trypanosoma evansi*, the cause of surra. This disease is always fatal to horses and mules, often affect's camels and dogs seriously, and is asymptomatic in cattle (Harwood and James, 1979).

Tabanids and stable flies are able to transmit a viral disease known as equine infectious anemia to equine species (Foil and Hogsette, 1994).

Control

According to Schreck et al. (1975) the current aim of pest control research is to emphasize selective, environmentally acceptable methods for dealing with noxious pests. Apart from physical barriers like screens placed in human and animal houses, various control measures have been developed. These include chemical compounds, traps, ecological modifications of the environmental conditions, utilization of parasites and predators, and the sterile male technique (SMT) (Zumpt, 1973). In addition, much can be done to reduce stable fly populations by managing the amount of rotting, wet manure and straw material around the premises. These types of materials can be hauled off, spread thin to dry out, composted, or burned to kill the maggots (Harwood and James, 1979). In addition, roosting sites may be treated with residual sprays (Zumpt, 1973).

Biological control agents affecting stable flies are generally identical or similar to those attacking house flies, but they seem to exert minimal control with the exception of some hymenopterous parasites (Harwood & James, 1979). A study done by Miller et al. (1993) showed that the release of parasitoid wasps outdoors at an individual farm did not reduce the stable fly populations. Greene et al. (1989) suggests that using a parasite species can work in most situations but a survey of the habitat location is key in the developing population of the parasites.

Dung beetles, belonging to the family Scarabaeidae, help to scatter the faeces, which in turn dries rapidly and allows for ants to prey on the maggots (Zumpt, 1973).

Harwood and James (1979) pointed out that reproductive manipulation (SMT) may have some distinct possibilities because the stable fly populations tend to be focal in nature, easily reared, and the female apparently mates only once. Buschman and Patterson (1981) contemplate that if wild males are more successful than laboratory-reared sterile males in holding favorable waiting stations, they could account for many more matings than their numbers indicate. Since both sexes are vicious blood feeders the sterile male technique is not ideal in controlling the stable flies.

Williams (1973) found that a box trap containing an inverted plastic cone positioned inside a plywood box was effective on sandy beaches. However, the box trap was not as effective along inland sites as other traps. Although cumbersome at times because of the eight surfaces, the Williams trap, a translucent fiberglass sticky panel, has been found to be highly effective for monitoring *Stomoxys calcitrans* (Williams, 1973).

Broce (1988) invented the new commercial cylindral design to the Alsynite plastic traps that uses a cheaper, thinner plastic with less adhesive than the old Williams traps. He found that the new trap was equal to the Williams traps in catching house flies but fewer stable flies were caught due to the smaller surface area. Hogsette and Ruff (1990) supported Broce's findings and found that the cylinder trap captured fewer total flies, but more flies per cm^2 than any of the Williams traps used in their experiments.

The use of carbon dioxide, ultraviolet light, and plexiglass were all tested as attractants with an electrocutor grid to find the most effective combination against stable flies. The electrocutor grid trap with carbon dioxide attractant has proved highly selective against *Stomoxys calcitrans* during the winter in north central Florida (Schreck et al, 1975).

There are several cues, such as, visual, thermal, and chemical that stable flies use in search of hosts. There are several traps for stable flies, which incorporate many of these cues. Hoy (1969) found that the Malaise traps baited with CO_2 caught 3 times as many stable flies than did either of the CO and control Malaise traps. Cilek (1999) used the Alsynite Cylinder traps with various volatile substances, such as dry ice, acetone, and octenol, and found that CO_2 from the dry ice was a very powerful attractant for collecting stable flies. The only draw back to these types of traps is the use of CO_2 as dry ice can be costly.

The Sonic Web trap (Applica Consumers Products, Inc., Miami Lakes, Fla.) is a non-pesticide device designed to lure biting insects such as mosquitoes, flies, and biting midges by the use of an acoustical heartbeat, color, pattern, heat, and light. Once the insects fly into the Sonic Web, adhesive sleeves trap them. More research still needs to be performed on this trap to test its efficiency.

When using any trap, placement is key. Traps should be placed where stable flies are assembling, in a place that is easy to service, and out of the way of workers and animals to avoid being trampled or tripped on (Hogsette and Ruff, 1987). Sonic Web traps are expensive, approximately $199.99.

Insecticides should be used as a last measure in fly control, not only because sanitation is more permanently effective, but also because insecticide resistance can develop (Harwood & James, 1979).

Cilek and Greene (1994) found that in a Kansas, feedlot resistant stable flies were found where insecticide use was minimal. They thought the insecticide-resistant stable flies came from nearby feedlots not using proper management practices against biting flies.

Permethrin-impregnated yarn can also be used to reduce stable fly numbers (Hogsette and Ruff, 1996). Tseng and Hogsette (1986) found that a distance of 2.54 cm between strands and in a continuous coil not crisscrossed yielded maximum catch as compared to the strands being laid right next to each other. This yarn can be left in a field for about 3 months and can be placed on several traps (Foil and Hogsette, 1994).

Proper sanitation, such as spreading manure out to dry, composting, and burning manure is key to reducing the number of stable flies that successfully mate and reproduce. Proper use of insecticides and traps in conjunction with reducing the breeding media can be effective in decreasing stable fly populations.

Conclusion

Stable flies can cause severe economic losses in the livestock industry especially to horses. These persistent blood-feeders pierce their proboscis into the lower extremities, which is quite painful to the animals. There are several traps being sold commercially that are reported to trap the stable flies before they attack horses, but do they really work? In this experiment we looked at the relative attractiveness between the horse and Sonic Web traps in relation to the stable flies. The purpose of this experiment was to determine if Sonic Web traps would keep the stable flies from taking a painful blood meal from horses.

CHAPTER 2
MATERIALS AND METHODS

Experiments were performed at the University of Florida Horse Teaching Unit (HTU), a 26 hectares farm located 4.8 km south of the Gainesville campus (Figure 1). Air temperature was recorded daily prior to each experiment, with a minimum of 15.6°C required for the experiment to be conducted. This was necessary because stable flies are more active above 15.6°C. Sonic Web (Applica Consumer Products, Inc., Miami Lakes, Fla.) prototype and commercial traps were used to capture stable flies. Insects fly into the Sonic Web traps and are captured on an adhesive sleeve.

Four broodmares were randomly selected from the HTU's breeding herd for use in the experiments. Fluorescent colored dust; Corona magenta, Horizon blue, Arc yellow, or Signal green (Day-Glo Color Corp., Cleveland, Ohio) was used on horses to mark flies that visited the horse before the trap (Figure 2). Horses were dusted at the start of each experiment from the point of the shoulder back to the hip and downwards because stable flies tend to bite their hosts on the lower extremities (Figure 3). Each horse was dusted with the same color of fluorescent dust throughout all of the experiments to avoid cross-contamination.

After each experiment, horses were led to a wash rack > 90 meters from the experiment paddock and bathed with soap and water to prevent marking of flies between experiments. After washing, horses were released in a paddock not used in the experiments.

Figure 1. Aerial view of the University of Florida Horse Teaching Unit, Gainesville, Florida.

Figure 2. Four dusters used to apply fluorescent dust to horses.

Figure 3. Dusting the horse with one of the four fluorescent colored dusts.

To conduct tethered experiments, dusted horses were tied to a freestanding fence post. Sonic Web traps were placed at the four cardinal compass points and hay was given to the horse during the 4-hour experiment period (Figures 4 and 5).

Sticky sleeves were placed on the Sonic Web traps when each experiment began. Trapping days were randomly assigned sound off for all traps, on for all traps, or on for one trap at a time (Figure 6). After a 4-hour exposure period the sleeves were collected. A long-wave ultraviolet (UV) light was used to determine the presence of fluorescent dust on the stable flies. The total number of marked and unmarked stable flies were counted and recorded.

A 4-week preliminary experiment was conducted from September 30th to October 28th 2002 , Monday through Thursday from eight o'clock AM to twelve noon. Each day a horse was tethered to a post that was 6.1 m North of a feeding barn and inside a 46.7 m by 14.6 m rectangular paddock located North of the feeding barn. Sonic Web traps were 3.7 m from the post (Figure 7). In the subsequent tethered experiments, which were conducted from February 12th to March 27th 2003, the broodmares were dusted and tied to a post in a 55.3 by 47.7 m rectangular paddock located South of the feeding barn. Horses were given hay to pacify them during the 4-hour time period. Sonic Web traps were placed 7.3 m and then 14.6 m from the post at the four cardinal compass points (Figures 8 and 9).

Non-tethered experiments were conducted March 28th to April 8th 2003. Two broodmares were coated with the same fluorescent dust and released in a 55.3 by 47.7 m rectangular paddock located South of the feeding barn.

Figure 4. Prototype of the Sonic Web trap with the sticky sleeve.

Figure 5. Commercial Sonic Web trap with the sticky sleeve and flies, with superstructure open.

Figure 6. Components of the prototype Sonic Web traps

Figure 7. Tethered horse with Sonic Web traps placed 3.7 m from the post (Sept. 30-Oct. 28, 2002).

Figure 8. Tethered horse with Sonic Web traps placed 7.3 m from the post (Feb. 12-March 27, 2003). Note Sonic Web prototype North and South, and Sonic Web commercial models with superstructure open, East and West.

Figure 9. Tethered horse with Sonic Web traps placed 7.3 m from the post (Feb. 12-March 27, 2003). Note Sonic Web traps are inside the fence.

Eight Sonic Web traps were placed along the perimeter 24.1 m from each other (2 per side) and 28.7 meters from the center of the paddock at the four cardinal compass points (Figure 10).

After all sleeves were evaluated under the UV light, 5 dusted and 5 non-dusted stable flies were randomly chosen from each sleeve for testing with Quik-Cult (Laboratory Diagnostics Co. Inc.), a tape and indicator solution used to determine if the stable flies had recently taken a blood meal. The Quik-Cult tape was cut into small pieces and each of the flies was placed on its own piece of tape. A spoon was used to crush the flies and one drop of the indicator solution was placed on each tape/stable fly combination. Forceps were then used to examine the Quik-Cult tape. A blue color on the Quik-Cult tape was an indication of a recent blood meal while no color on the tape indicated no blood meal residue.

In a final trapping experiment that ran for 16 days, two commercial Sonic Web traps were placed 112.8 m apart and evaluated in 8 different combinations, trap positions (1 or 2, sound on or off and superstructure open or closed Figures 5 and 11) for 16 days (Table 1).

Where appropriate, data were analyzed with GLM procedures, and Duncan test (SAS Institute 2003) was used for separation of means. Unless otherwise stated, $P \leq 0.05$.

Figure 10. View of Sonic Web traps in the Northwest corner of the paddock placed 28.7 m from the center of the paddock in the final horse experiment (March 28-April 8). Note that the Sonic Web traps are outside the fence, simulating a real-life situation.

Figure 11. Commercial Sonic Web trap with the sticky sleeve and flies, with superstructure closed.

Table 1. Combinations, Trap position, status and sound used to evaluate the Commercial Sonic Web traps for 16 days.

Combinations	Trap Position	Status	Sound
1	1	Open	Off
1	2	Open	On
2	1	Closed	Off
2	2	Closed	On
3	1	Open	Off
3	2	Closed	On
4	1	Closed	Off
4	2	Open	On
5	1	Open	On
5	2	Open	Off
6	1	Closed	On
6	2	Closed	Off
7	1	Closed	On
7	2	Open	Off
8	1	Open	On
8	2	Closed	Off
1	1	Open	Off
1	2	Open	On
2	1	Closed	Off
2	2	Closed	On
3	1	Open	Off
3	2	Closed	On
4	1	Closed	Off
4	2	Open	On
1	1	Open	Off
1	2	Open	On
2	1	Closed	Off
2	2	Closed	On
4	1	Closed	Off
4	2	Open	On
3	1	Open	Off
3	2	Closed	On

CHAPTER 3
RESULTS

Of the total number of stable flies caught by the Sonic Web traps in the tethered and non-tethered experiments, 88.2% were unmarked. At trap distances of 3.7,7.3,14.6, and 28.7 meters, the percentage of unmarked stable flies was 58.9, 78.3, 89.8, and 92.9, respectively (Table 2).

There was no significant difference ($P \leq 0.05$) between numbers of flies captured by trap 1 (prototype) and trap 2 (the commercial model in the open position), with means of 56.7 and 52.7, respectively. As expected in all experiments, there was a significant day effect on stable flies captured because of cyclic variation in the Stable fly population.

Looking at the overall data with distance omitted, significantly ($P \leq 0.05$) more flies were captured on the North trap, followed by the West, South, and East traps. In individual experiments, significantly ($P \leq 0.05$) more flies were captured on the South trap at the 3.7 m trap distance; numerically more flies were captured on the North trap at the other trap distances (Table 3).

There was no significant difference between the mean number of stable flies caught when the sound of the Sonic Web traps was on or off; the same was true at all trap distances throughout the experiments (Table 4).

There was a significant overall difference in the experiments when sound data were analyzed as 3 on/off combinations. At the 3.7-m trapping distance, only combination 1was used, so no comparisons could be made.

Table 2. Mean percentage of unmarked, total, and the mean number (±SE) of stable flies per trap caught by the Sonic Web traps at each distance.

Distance (m)	% Unmarked	Total	Mean flies/trap
3.7	58.9 C	893	223.3 (±16.1)
7.3	78.3 B	742	185.5 (±13.7)
14.6	89.8 B	2526	631.5 (±27.0)
28.7	92.9 A	2861	715.3 (±39.8)

Note: Means followed by the same letter are not significantly different ($P \leq 0.05$; Duncan's multiple range test [SAS Institute 2003])

Table 3. Mean number (+SE) of stable flies trapped by the Sonic Web trap due to the location of the traps.

Distance (m)	Location			
	North	South	East	West
3.7	6.8 (+2.1) C	25.4 (+6.9) A	10.3 (+4.0) BC	13.4 (+4.3) B
7.3	28.1 (+7.0) A	18.5 (+4.8) A	25.4 (+6.0) A	20.8 (+6.6) A
14.6	66.8 (+12.6) A	43.9 (+11.1) A	53.8 (+6.3) A	46.1 (+8.6) A
28.7	128.6 (+26.7) A	69.8 (+10.6) B	63.5 (+9.7) B	95.8 (+17.5) AB

Note: Means in the same rows followed by the same letter are not significantly different (*P*=0.05; Duncan's multiple range test [SAS Institute 2003])

Table 4. Mean number ($\pm$SE) of stable flies trapped by the Sonic Web trap with sound on or off.

Distance (m)	On	Off
3.7	10.5 ($\pm$3.1) A	15.1 ($\pm$3.1) A
7.3	23.5 ($\pm$13.0) A	22.4 ($\pm$3.0) A
14.6	46.4 ($\pm$5.9) A	58.8 ($\pm$8.0) A
28.7	100.4 ($\pm$23.4) A	87.8($\pm$10.5) A

Note: Means in the same rows followed by the same letter are not significantly different ($P \geq 0.05$; Duncan's multiple range test [SAS Institute 2003])

There was no significant difference between the mean numbers of flies trapped at the 7.3-m distance using combinations 1 and 2 (Table 5). At the 14.6-m distance, combinations 1 and 3 captured significantly more flies than combination 2. At the 28.7-m distance there was no significant difference between combinations 1 and 3.

Overall, the Sonic Web captured significantly ($P \leq 0.05$) more stable flies that were marked Signal green. The same was true at the 3.7-m distance (Table 6).

There was no significant difference in the mean numbers of flies based on color captured at the other trapping distances. The percentage of marked and unmarked stable flies with a blood meal was 27.7 and 26.7, respectively.

The final experiment compared the effects of sound, trap location and the open or closed configuration of the Sonic Web superstructure, traps in the open position with a mean of 88.6 captured significantly ($P < 0.05$) more flies as in the closed position with a mean of 37.9, regardless of trap location or the presence or absence of sound. Sound had no effect ($P > 0.05$) on the numbers of flies captured when analyzed by itself. A mean of 63.6 flies was captured when the traps were on and a mean of 62.9 flies was captured when the traps were off. However, the trap at location 2, with a mean of 77.4, captured significantly more flies ($P > 0.05$) than the trap at location 1, with a mean of 49.1.

However when the effects of location, sound and superstructure status were analyzed in combination, combination 5 (trap 1 open/on, trap 2 open/off) captured significantly more flies than the other seven combinations (Table 7). This was followed by combination 7 (trap 1 closed/on, trap 2 open/off) which captured nearly twice as many flies as the next highest combinations.

Table 5. Mean number (±SE) of stable flies trapped by the Sonic Web traps in three on/off combinations.

Distance (m)	Combinations[a] 1	2	3
3.7	-	-	-
7.3	23.5 (±4.3) A	22.9 (±4.3) A	-
14.6	59.0 (±7.4) BA	41.1 (±5.8) B	63.3 (±14.0) A
28.7	92.2(±12.2) A	-	85.9 (±15.0) A

Note: Means in the same rows followed by the same letter are not significantly different (*P*=0.05; Duncan's multiple range test [SAS Institute 2003])

[a]combination 1= one trap on, others off; combination 2= all traps on; combination 3= all traps off.

Table 6. Mean numbers (+SE) of marked stable flies trapped by the Sonic Web traps

Distance (m)	Colored Dust			
	Signal green	Corona magenta	Arc yellow	Horizon blue
3.7	8.3 (+2.1) A	1.3 (+0.3) B	2.0 (+0.9) B	0.7 (+0.3) B
7.3	5.3 (+1.3) A	5.1 (+1.1) A	3.3 (+1.5) A	2.4 (+1.1) A
14.6	7.6 (+2.0) A	4.3 (+1.6) A	7.1 (+2.0) A	3.0 (+0.7) A
28.7	6.4 (+1.0) A	4.1 (+1.1) A	4.3 (+1.6) A	7.2 (+1.5) A

Note: Means in the same rows followed by the same letter are not significantly different (P=0.05; Duncan's multiple range test [SAS Insitute 2003])

Table 7. Mean number (±SE) of stable flies trapped by the Sonic Web with 8 different combinations of open/closed or on/off.

Combination	Mean[a]
5	221.5 (±12.5) A
7	153.5 (±57.5) B
1	81.5 (±24.3) C
8	54.0 (±33.0) CD
3	48.2 (±11.2) CD
6	40.0 (±13.0) D
4	27.8 (±12.7) D
2	23.5 (±7.2) D

Note: [a]Means followed by the same letter are not significantly different (*P*=0.05;)(Duncan's multiple range test [SAS Institute 2003])
Combination 1- Trap 1 open/off Trap 2 open/on
Combination 2- Trap 1 closed/off Trap 2 closed/on
Combination 3- Trap 1 open/off Trap 2 closed/on
Combination 4 -Trap 1 closed/off Trap 2 open/on
Combination 5- Trap 1 open/on Trap 2 open/off
Combination 6- Trap 1 closed/on Trap 2 closed/off
Combination 7- Trap 1 closed/on Trap 2 open/off
Combination 8- Trap 1 open/on Trap 2 closed/off

CHAPTER 4
DISCUSSION

The trapping results indicate that the Sonic Web traps were successful in attracting stable flies in the presence of the horse. The 88.2% unmarked stable flies caught on the traps means the flies visited the trap before visiting the horse under the conditions of this study. We assumed that all flies either went directly to the traps and were captured (unmarked flies) or flew past the traps, fed on the dusted horse, and then became captured (marked flies). During the course of this study 3 experimental days had more than one dust color on the stable flies.

The Sonic Web traps are a non-pesticide trapping device used to safely reduce the number of stable flies affecting horses. Thus the traps can be used to provide a high degree of fly protection for horses. No other experiments demonstrating comparisons between Stable fly traps and hosts could be found in the literature.

Stable flies tend to assemble and rest on nearby vertical objects in between blood meals (Buschman and Patterson's, 1981). This was found to be true at the 3.7-m trapping distance with the number of marked stable flies significantly higher than the number trapped at the other three distances. Fewer marked flies captured at 7.3, 14.6 and 28.7 meters from the horse was likely because the traps were too far away to use as a resting site. The significant effect of trap location on the number of stable flies caught can be explained by the presence of the feeding barn, which is an aggregation site for the flies.

Hogsette et al. (1987) and Gentry (2002) found that the trap closest to the feeding barn consistently produced a higher catch of stable flies compared to any other trap location. This supports the results of the current study where the trap closest to the feeding barn always captured the most stable flies (Table 3). When looking at the final trapping experiment without the horses, the trap in location 2, by the feeding barn, captured more stable flies than the trap in location 1 due to the location effect of the feeding barn as previously mentioned.

The effects of sound in these experiments were difficult to determine. Only at the 14.6-m trapping distance, when all three sound combinations were compared, did it appear that the combination producing the most sound, i.e. combination 2, caught the fewest flies (Table 5). According to the inventors of the Sonic Web, the traps should be placed at least 90 m apart, as closer placement will cause traps to interfere with one another. However, at the 14.6-m distance, there was a significant difference ($P \leq 0.05$) in the numbers of stable flies captured when one trap was on or when all traps were off.

The significantly ($P \leq 0.05$) larger number of green marked stable flies caught is not likely a color effect. Hogsette (1983) found that the fluorescent colored dust used to mark the stable flies had no attractiveness to the flies, thus the colored dust on the horses was not considered to increase the attractiveness of the horse itself. Also, in the preliminary study we found no significant ($P \leq 0.05$) difference between the horses in their attractiveness to the stable flies. Thus, the difference may be due to the fact that the days when the highest numbers of stable flies trapped coincided with the days when Signal green was used (Figure 12).

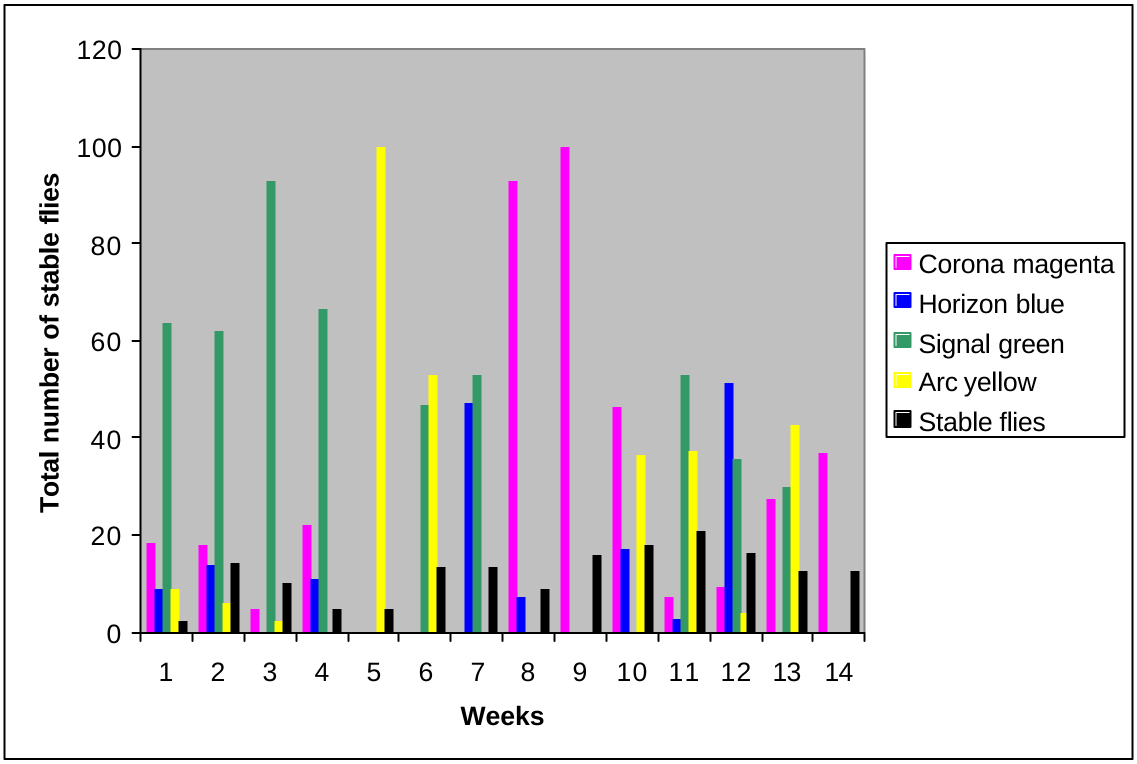

Figure 12. Weekly number of marked stable flies compared with weekly background stable fly populations (/100).

The percent of marked stable flies with blood in the gut was similar to the percent of unmarked stable flies having blood in the gut due partially to the fact that low numbers of marked stable flies were trapped on the days when blood meal examinations were made. We can assume that the marked stable flies took a blood meal from the dusted horse and then became captured on the Sonic Web traps. The unmarked stable flies with blood in their guts likely took a blood meal from another horse on the farm but then were captured by the Sonic Web traps surrounding the dusted horse. Blood can be detected in the gut with Quik-Cult approximately 56 hours after feeding in a laboratory setting at 20°C (Broce, unpublished). We started the experiments when the temperature reached 15.6ºC, which is the temperature at which stable flies begin to fly. Therefore when the experiments began, the flies were probably taking their first blood meal for the day. This would indicate that in the conditions of my study the stable flies blood meal could be detected approximately 12 hours from their last feeding, i.e., the previous afternoon. With the number of horses so close together on the HTU, it is probable that most stable flies have evidence of blood in their guts during the daylight hours.

During the experiments the Applica company sent us commercial Sonic Web models to use instead of the prototype Sonic Web models. When comparing the commercial model with the superstructure open and the prototype at the 7.3, 14.6, and 28.7 m trap distance, there was no significant ($P \geq 0.05$) difference. So in the final trapping experiment without the horses we tested the commercial Sonic Web traps with the superstructure either open or closed. The open position captured twice as many stable flies as the closed position.

However, it was observed when the superstructure was closed that stable flies were using the super structure as a resting site instead of flying directly into the sticky sleeves. When the superstructures were open, flies flew into the sticky sleeves and were captured.

When sound was analyzed alone, the on/off configurations had no effect on the trap counts. However, when sound was analyzed in 8 different combinations, that included trap location, and superstructure position, combination 5 caught the most stable flies because both superstructures on both traps were open and the trap in location 1 was on and the trap in location 2 was off. Hogsette (Unpublished) also found that this trap combination (without superstructures) caught the most stable flies.

Temperature and moisture significantly impact stable fly numbers according to Berry and Campbell (1985). Fluctuations in relative humidity, radiation, and wind physically increase the loss of moisture from the stable flies, which decreases feeding rates. In the final experiment the lack of rain is the likely cause for the decrease in numbers of stable flies (Figure 13).

Results indicate that the Sonic Web traps can be used to reduce the numbers of stable flies feeding on horses. Using the Sonic Web traps in conjunction with other control methods would further reduce the number of stable flies affecting horses. Trap placement is key to maximize higher capture rates and to prevent the stable flies from feeding on the horses. The inventors of the Sonic Web traps state that 1 trap per acre is sufficient for capturing the nuisance biting pests, however we have no data to support this claim for stable flies at this time.

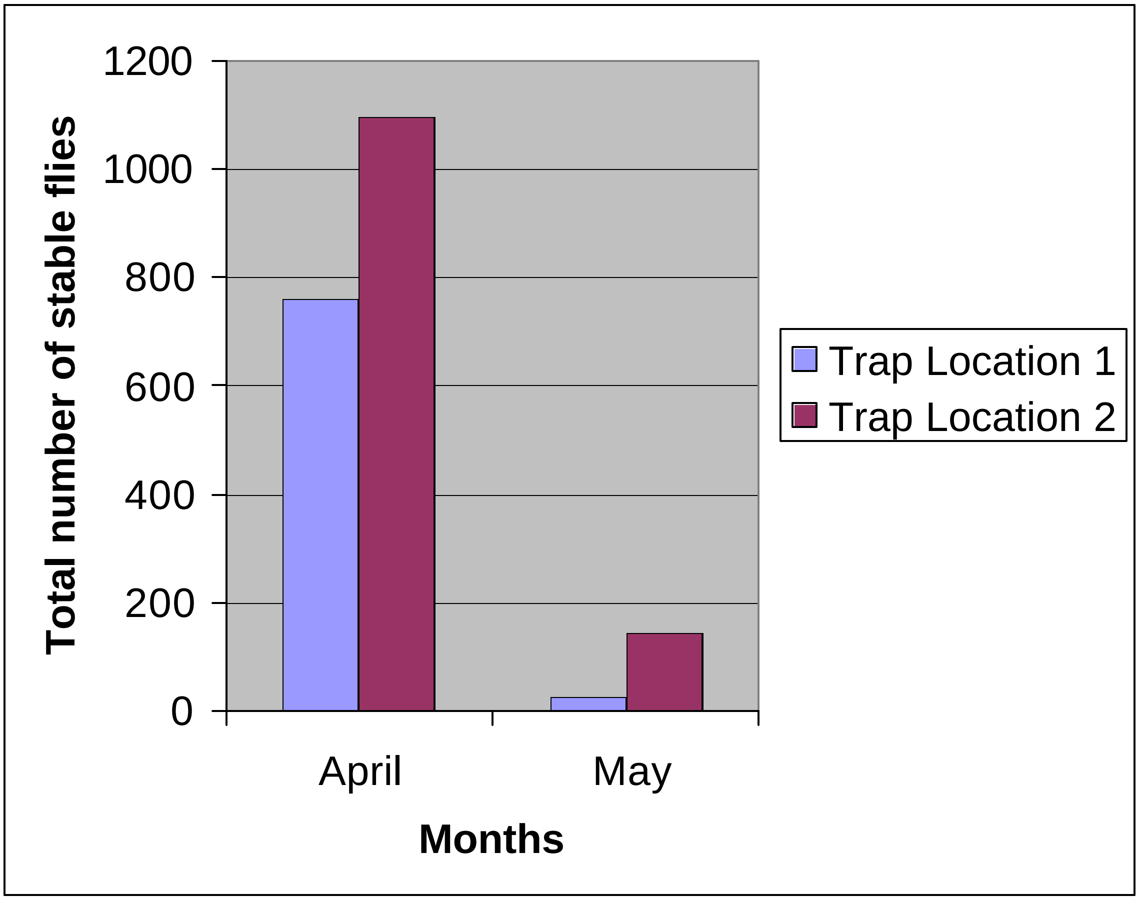

Figure 13. The total number of stable flies trapped by the Sonic Web for the final experiment.

LITERATURE CITED

Bailey, D.L. and D.W. Meifert. 1973. Feeding Incidence of Stable Flies on Beef Cattle, as Influenced by Temperature, Relative Humidity, and Light. Environmental Entomology 2: 1125-1126.

Bailey, D.L., T.L. Whitfield, and B.J. Smittle. 1973. Flight and Dispersal of the Stable Fly. Journal of Economic Entomology 66: 410-411.

Berry I.L. and J.B. Campbell. 1985. Time and Weather Effects on Daily Feeding Patterns of Stable Flies (Diptera: Muscidae). Environmental Entomology 14: 336-342.

Broce, A.B. 1988. An Improved Alsynite Trap for Stable Flies, *Stomoxys calcitrans* (Diptera: Muscidae). Journal of Medical Entomology 25: 406-409.

Bruce, W.N. and G. C. Decker. 1958. The Relationship of Stable Fly Abundance to Milk Production in Dairy Cattle. Journal of Economic Entomology 51: 269-274.

Buschman L.L. and R.S. Patterson. 1981. Assembly, Mating, and Thermoregulating Behavior of Stable Flies under Field Conditions. Environmental Entomology 10: 16-21.

Campbell, J.B., I.L. Berry, D.J. Boxler, R.L. Davis, D.C. Clanton, and G.H. Deutscher. 1987. Effects of Stable Flies (Diptera: Muscidae) on Weight Gain and Feed Efficiency of Feedlot Cattle. Journal of Economic Entomology 80:117-119.

Castro, J.D. 1967. Chemical Sterilization of the Stable Fly, *Stomoxys calcitrans*(Linne), with Metepa and Hempa. Ph.D. dissertation, University of Florida, Gainesville, FL.

Cilek, J.E. 1999. Evaluation of Various Substances to Increase Adult *Stomoxys calcitrans* (Diptera:Muscidae) Collections on Alsynite Cylinder Traps in North Florida. Journal of Medical Entomology 36: 605-609.

Cilek, J.E. and G.L. Greene. 1994. Stable Fly (Diptera:Muscidae) Insecticide Resistance in Kansas Cattle Feedlots. Journal of Economic Entomology 87: 275-279.

Foil, L.D. and J.A. Hogsette. 1994. Biology and Control of Tabanids, Stable Flies and Horn Flies. Revenue of Science Technology 13: 1125-1158.

Gentry, A. B. 2002. Evaluation of protection systems and determination of seasonality for mosquito and biting flies at the University of Florida Horse Teaching. Master of Science dissertation, University of Florida, Gainesville, FL.

Greenburg, B. 1971. Flies and Disease. Vol. I. Ecology, Classification and Biotic Associations. Princeton Univ. Press, Princeton

Greenburg, B. 1973. Flies and Disease. Vol. II. Ecology, Classification and Biotic Associations. Princeton Univ. Press, Princeton

Greene, G.L., J.A. Hogsette, and R.S. Patterson. 1989. Parasites that Attack Stable Fly and House Fly (Diptera:Muscidae) Puparia during the Winter on Dairies in Northwestern Florida. Journal of Economic Entomology 82: 412-418.

Harwood, and James. 1979. Entomology in Human and Animal Health. MacMillan Publishing Co., Inc. New York. Pgs. 248-296.

Hogsette, J.A. 1984. Effect of Fluorescent Dust Color on the Attractiveness of Attractant Self-Marking Devices to the Stable Fly (Diptera:Muscidae). Journal of Economic Entomology 77: 130-132.

Hogsette, J.A., and J.P. Ruff. 1985. Stable fly (Diptera:Muscidae) migration in Northwest Florida. Environmental Entomology 14: 170-175.

Hogsette, J.A., and J.P. Ruff. 1987. Comparison of two sampling methods for determination of the age structure of a population of *Stomoxys calcitrans* (L.) International Conference on Medical and Veterinary Dipterology. Ceske Budejovice, Czechoslovakia. Pgs. 258-261.

Hogsette, J.A., and J.P. Ruff. 1990. Comparative Attraction of Four Different Fiberglass Traps to Various Age and Sex Classes of Stable Fly (Diptera:Muscidae) Adults. Journal of Economic Entomology 83: 883-886.

Hogsette, J.A., and J.P. Ruff. 1996. Permethrin-Impregnated Yarn: Longevity of efficacy and potential use on cylindrical fiberglass stable fly (Diptera:Muscidae) traps. Journal of Economic Entomology 89: 1521-1525.

Hogsette, J.A., J.P. Ruff, and C.J. Jones. 1987. Stable fly biology and control in Northwest Florida. Journal of Agricultural Entomology 4: 1-11.

Holloway, M.T.P. and R.J. Phelps. 1991. The response of *Stomoxys* spp. (Diptera:Muscidae) to traps and artificial host odours in the field. Bulletin of Entomological Research 81: 51-55.

Horsfall, W.R. 1962. Medical Entomology. Arthropods and Human Disease. The Ronald Press Co. New York. Pg. 467

Hoy, J.B. 1970. Trapping the Stable Fly by using CO2 or CO as Attractants. Journal of Economic Entomology 63: 792-795.

Jones, C.J., J.A. Hogsette, R.S. Patterson, and D.E. Milne. 1985. Effects of Natural Saccharide and Pollen Extract feeding on Stable fly (Diptera:Muscidae) longevity. Environmental Entomology 14: 223-227.

Lehane, M.J. 1991. Biology of Blood-Sucking Insects. Chapman and Hall. New York. Pgs. 208.

Miller, R.W., L.G. Pickens, and W.E. Potts. 1993. Journal of Agricultural Entomology 10: 189-196.

Mitzmain, M.B. 1913. The Bionomics of *Stomoxys calcitrans* Linnaeus; a preliminary account. Phillipp. Journal of Science 8: 29-48

Newson, H.D. 1977. Arthropod Problems in Recreation Areas. Annual Review of Entomology 22: 333-353.

Parr, H.C.M. 1962. Studies of *Stomoxys calcitrans* (L.) in Uganda, East Africa. II. Notes on life-history and behaviour. Bulletin of Entomological Research 53: 437-443.

Schreck, C.E., K. Posey, and H.K. Gouck. 1975. Evaluation of the Electrocutor Grid Trap Baited with Carbon Dioxide against the Stable Fly, *Stomoxys calcitrans* (L.) (Diptera: Muscidae). Journal of Medical Entomology 12: 338-340.

Tseng, J.M., J.A. Hogsette, and R.S. Patterson. 1986. Effect of yarn on attractiveness of the William trap to *Stomoxys calcitrans* (Diptera:Muscidae) adults. The Florida Entomologist 69: 261-262.

Williams, D.F. 1973. Sticky Traps for Sampling Populations of *Stomoxys calcitrans*. Journal of Economic Entomology 66: 1279-1280.

Zumpt, F. 1973. The Stomoxyine Biting Flies of the World. Gustav Fischer Verlag. Stuttgart. Pgs. 137-152.

BIOGRAPHICAL SKETCH

Tracey Lynn Tam was born on August 24, 1978, in Fullerton, California. She graduated from Melbourne Central Catholic High School in June 1997, and received an Associate of Arts degree from Brevard Community College in May 1999. In August 1999, she entered the University of Florida and earned her Bachelor of Science degree in animal science biology in December 2001. She graduated with a Master of Science degree in animal sciences from the University of Florida in December 2003. Tracey plans on pursuing a career in education.