

RESEARCH ARTICLE

Spatial Distribution, Seasonality and Trap Preference of Stable Fly, *Stomoxys Calcitrans* L. (Diptera: Muscidae), Adults on a 12-Hectare Zoological Park

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Although this study was originally designed to compare the efficacy of two different stable fly traps within 10 sites at a 12-ha zoological park, seasonal and spatial population distribution data were simultaneously collected. The two traps included an Alsynite fiberglass cylindrical trap (AFT) and a blue-black cloth target modified into a cylindrical trap (BCT). Both traps were covered with sticky sleeves to retain the attracted flies. Paired trap types were placed at sites that were 20–100 m apart. Distance between trap pairs within sites ranged from 1 to 2 m, and was limited by exhibit design and geography. Both trap types reflect/refract ultraviolet (UV) light which attracts adult *S. calcitrans*. During this 15-week study, AFTs captured significantly more stable flies than the BCTs at 8 of the 10 sites. Of the 12,557 stable flies found on the traps, 80% and 20% were captured by AFTs and BCTs, respectively. The most attractive trap site at the zoo was at the goat exhibit where most stable flies were consistently captured throughout the study. This exhibit was 100 m from the other exhibits, next to a small lake, and adjacent to a field containing pastured exotic ungulates, rhea and ostrich. Stable fly populations peaked in early June then slowly decreased as the last trapping date approached. We believe this to be the first seasonality data collected at a zoological park. Results demonstrate the use of urban zoos by stable flies and the need to develop environmentally friendly stable fly management systems for zoos. Zoo Biol. 33:228–233, 2014. Published 2014. This article is a U.S. Government work and is in the public domain in the USA.

Keywords: alsynite fiberglass; sticky traps; UV light; cloth target; cylinder traps

INTRODUCTION

Stomoxys calcitrans (L.) is a biting fly of extreme economic importance [Bishopp, 1913; Taylor et al., 2012] and can cause adverse economic effects on host animals [Campbell et al., 2001]. Both males and females feed on blood, often, but not always, derived from ungulates (e.g., livestock-including cattle, goats, sheep, and equines) [Hafez and Gamal-Eddin, 1959]. Although adults feed on nectar for maintenance [Jarzen and Hogsette, 2008; Taylor and Berkebile, 2008], both sexes require blood meals for reproduction and longevity [Jones et al., 1992]. Preferred breeding media are decaying fibrous plant materials, such as hay [Broce et al., 2005].

Within zoological parks, hosts may include practically any accessible animal (e.g., sheep, goats, cows, camels, equines, primates, canids, and felids) [Hogsette and Farkas, 2000]. In many animals, for example, cheetahs and

wolves, stable fly feeding creates open lesions on the ear tips, typical of the damage seen with dogs [Farkas and Gyurcsó, 2006]. Humans and animals can be bitten when stable flies are present in large numbers [Rugg, 1982]. Although stable flies are known to be a problem in zoological parks [Hogsette and Farkas, 2000], we are only familiar with the study by Rugg [1982] in Australia. If the seasonality and

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distribution of stable flies in zoological parks were known, this could facilitate control efforts.

Alsynite fiberglass traps (AFTs) have been the standard trap used to survey and manage stable fly populations for a number of years [Hogsette and Ruff, 1990]. These traps are made of corrugated Alsynite fiberglass formed into cylinders [Broce, 1988] and covered with transparent adhesive-coated sleeves. Traps are typically placed between 30 and 90 cm above the ground and as close as possible to target animal sites selected for evaluation. AFTs reflect light in the ultraviolet (UV) range (~ 360 nm) that is visible and attractive to *S. calcitrans* [Agee and Patterson, 1983; Hogsette, 2008].

Blue-black cloth targets were adapted from Nzi traps developed in Africa to attract and capture tsetse flies (*Glossina* spp.) [Foil and Younger, 2006], which transmit trypanosomes that cause sleeping sickness in humans and Nagana in animals. *S. calcitrans* are attracted to and will land preferentially on blue/black cloth targets [Mihok et al., 1995; Mihok, 2002]. Flies remain on targets for an average of 30 sec which is long enough to acquire a lethal dose if targets have been treated with lambda-cyhalothrin [Foil and Younger, 2006]. The blue-black color contrast may mimic natural forest edges where stable flies alight to rest and digest their blood meals; *S. calcitrans* are also attracted to the blue/black fabric combinations because the fabric reflects light in the UV range [Mihok et al., 2006]. Pesticide-impregnated blue/black cloth targets have been evaluated as management devices [Foil and Younger, 2006], but blue/black cloth targets have not been evaluated after being modified into sticky traps for capturing *S. calcitrans*.

The primary objective of this study was to evaluate the efficacy of blue-black cloth targets modified into sticky traps (BCTs) to capture *S. calcitrans*. BCTs were compared with AFTs at 10 selected sites for 15 weeks at a zoological park near Washington, DC. Results elucidate relative trap efficacy, and stable fly distribution at the zoo and seasonality in northern Virginia.

MATERIALS/METHODS

The study site was a 12-ha zoological park near Reston, VA, just west of Washington, DC (Fig. 1). The zoo was large enough for the study but small enough to allow traps to be placed in selected sites throughout the property. The zoo is an urban zoo with little or no animal agriculture nearby.

The AFTs consisted of corrugated Alsynite fiberglass panels (66×33.5 cm high) formed into cylinders (20-cm dia) (Biting Fly Trap, product #BFT197, Olson Products, Inc., Medina, OH) covered with adhesive-coated clear plastic sleeves (STIKY Sleeves, product #12-1227-SSR, Olson Products, Inc., Medina, OH) held in place with paper clips. The BCTs were AFTs covered (after being placed onto a stake without a sticky sleeve) with cloth targets which were half blue and half black with a vertically oriented seam where the blue and black cloths were sewn together. The cloth targets, when affixed to the AFTs with paper clips, completely covered the outer surface of the AFT. When

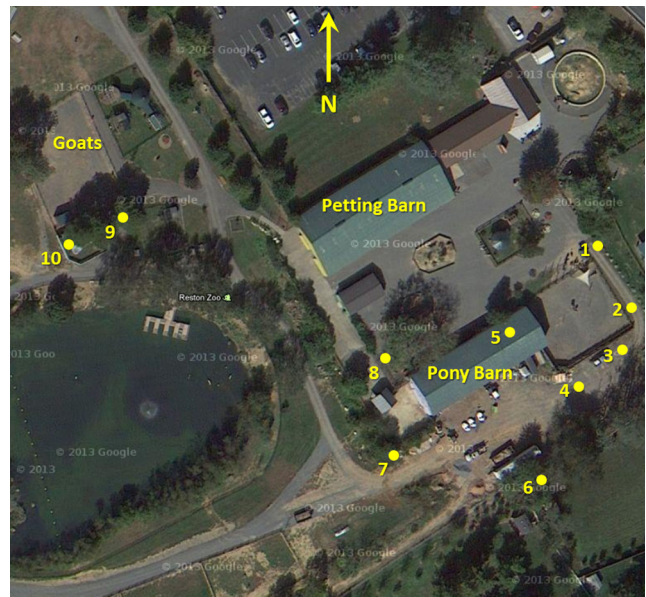


Fig. 1. Satellite image showing approximate placement sites of paired AFT and BCT traps at the Reston Zoo, Reston, VA.

viewed from opposite sides, half of the BCT was either blue or black. Materials used to make the BCT targets were SEW Classics Bottom weight 65% polyester 35% cotton fabrics; Black fabric = 057 inch, 10238, RN# 35055, 43B - 861, 1565-09; 2 yards; Blue (Royal) fabric = 057 inch, 10171, RN# 35055; 1.8 m. BCTs were covered with the same clear adhesive-coated plastic sleeves used on the AFTs. AFTs and BCTs were affixed to stakes from 30 to 120 cm above the ground (Table 1).

AFTs and BCTs were placed in the field for 15 weeks from 30 May 2011 through 5 September 2011. At the end of each week, flies were counted and used sticky sleeves were removed from traps and replaced with unused sleeves. Pairs of AFTs and BCTs were placed from 1 to 2 m apart within 10 selected sites (10 replicates of 20 traps) (Fig. 1, Table 1). Spacing within sites was subject to the constraints of topography, exhibit design and access. Traps

TABLE 1. Global Positioning System (GPS) coordinates^a for trap sites, and trap elevations and heights

Site	GPS coordinate	GPS elevation	Trap height (cm)
1	N38°58.298' W077°18.741'	317.2'	45.7
2	N38°58.299' W077°18.739'	292.8'	40.6
3	N38°58.300' W077°18.743'	340.8'	40.6
4	N38°58.296' W077°18.748'	292.1'	40.6
5	N38°58.306' W077°18.766'	305.8'	55.9
6	N38°58.281' W077°18.752'	320.1'	106.7
7	N38°58.282' W077°18.783'	314.3'	48.3
8	N38°58.290' W077°18.786'	333.9'	40.6
9	N38°58.316' W077°18.846'	307.3'	40.6
10	N38°58.312' W077°18.846'	321.2'	40.6

^aDevice: Garmin GPS72 S/N 89394068.

were placed as close as possible to sites where animals were likely to rest, sleep, and graze. Ideally, traps would have been placed directly within animal enclosures, but animal and visitor interactions with traps had to be avoided. Therefore traps were placed out of reach of visitors and zoo animals.

Fly capture data were subjected to the General Linear Model procedure (GLM) (SAS 2003) to determine the effects of trap type, trap site and week number on the numbers of stable flies captured. Means were separated with the Ryan-Einot-Gabriel-Welsh multiple range test (SAS 2003) and unless otherwise stated, $P=0.05$. Insect capture data were transformed with $\log_{10}(n+1)$ prior to analysis but back transformed values are shown in text and tables.

RESULTS

A total of 12,557 adult stable flies were captured during the 15-wk study. The main effects model was significant ($F=10.23$, $df=159,299$, $P<0.0001$) for site, week and trap, with significant interactions between all three variables as would be expected. When weekly values for flies captured were analyzed by trap type, it was found that the AFTs captured significantly more flies (29.4 ± 0.1) than the BCTs (6.5 ± 0.1). The same was true when 15-wk data were analyzed by site, with the exception of site 5, where no significant difference occurred (data not shown). AFTs captured approximately four times more stable flies than BCTs.

If trap type and week are overlooked, significantly more stable flies were captured at sites 9 and 10 (goats) than at the other sites during the 15-wk study (Table 2). Broad significance groupings for weekly site means are indicative of the degree of variation plus the low number of degrees of freedom (Table 3). However, when site numbers are ranked weekly according to the mean values of flies captured in those sites, sites 9 and 10 were ranked either first or second (out of 10 sites) for 12 and 10 weeks, respectively, of the 15-wk study (Fig. 2). Sites most attractive to stable flies after sites 9 and 10 were site 5 (pony barn), sites 1 and 2 (east end of the paddock), and sites 7 and 6 (the dumpsters) (Table 2). Significantly fewer flies were captured at sites 4 and 3 (south side of paddock) and site 8 (porcupine) than elsewhere on the zoo property (Table 2).

If trap type and site are overlooked, significantly more stable flies in three significance groupings were captured during weeks 1–7 than during the remainder of the study (Table 2). Stable fly populations increased during the first 2 weeks of the study, peaked during the third week (13 Jun), began to decrease gradually through week 7, then dropped into single digits after week 9 (Table 2).

DISCUSSION

An initial concern when making the decision to use the Reston Zoo for the study site was the possibility that *S. calcitrans* populations might not be present in numbers

TABLE 2. Mean (\pm SE) numbers of stable flies captured by site ($n=30$) and by week ($n=20$) during the 15-week trapping period at the 12-hectare zoological park

Site ^a	Mean \pm SE	Week ^b (2011)	Mean \pm SE
9	47.3 \pm 0.3a	3	47.2 \pm 0.3a
10	43.9 \pm 0.2a	2	38.1 \pm 0.4a
5	36.7 \pm 0.3ab	6	35.1 \pm 0.3ab
1	23.9 \pm 0.3bc	4	31.1 \pm 0.4ab
2	16.8 \pm 0.3cd	5	27.8 \pm 0.4ab
7	14.5 \pm 0.3d	7	24.0 \pm 0.4abc
6	10.9 \pm 0.3d	1	19.0 \pm 0.4bc
4	4.0 \pm 0.3e	9	13.1 \pm 0.4cd
3	3.9 \pm 0.3e	8	9.9 \pm 0.4de
8	2.9 \pm 0.2e	11	8.9 \pm 0.4def
		13	7.5 \pm 0.4def
		15	6.6 \pm 0.3defg
		10	5.7 \pm 0.4efg
		14	4.5 \pm 0.3fg
		12	3.4 \pm 0.3g

Means in columns followed by the same letter are not significantly different [$P<0.05$; Ryan–Einot–Gabriel–Welsh Multiple Range Test (SAS Institute, 2003)].

^aSites 1–4 = paddock; site 5 = pony barn; site 6–7 = dumpster; site 8 = porcupine; sites 9–10 = goats.

^bWeek 1 = (ending in) May 30; week 2 = Jun 7; week 3 = Jun 13; week 4 = Jun 20; week 5 = Jun 27; week 6 = Jul 4; week 7 = Jul 11; week 8 = Jul 18; week 9 = Jul 25; week 10 = Aug 1; week 11 = Aug 8; week 12 = Aug 16; week 13 = Aug 23; week 14 = Aug 30; week 15 = Sep 5.

required to produce meaningful data. This concern soon abated as the initial site inspection proved otherwise. Given that the facility has been in operation for several decades, it was ideal because of the various potential *S. calcitrans* hosts on site. This is an urban zoo with limited sites available for the development of immature stable fly populations, so the origin of the adult populations remains unknown. The highest weekly number of flies captured was 386 on an AFT at site 9 on June 7. Rugg's [1982] maximum daily catch was 782.

We hypothesized that BCTs would be more effective than AFTs in attracting *S. calcitrans*. This seemed obvious after Foil and Younger [2006] reported that *S. calcitrans* adults landed on Blue (Royal) and black cloth targets at rates six times greater than they landed on Alsynite. Foil and Younger [2006] also found no significant difference between mean numbers of stable flies captured on their Blue (Royal) fabric and on the Phthalogen blue fabric, which is the standard used for cloth traps in Africa (reflectance peak \sim 466 nm). However, placing an Olson sticky sleeve over the fabric used for the BCTs somehow reduced the qualities that make the BCTs attractive when not covered. In one study, AFTs with an adhesive applied directly to the surface of the fiberglass captured almost twice as many stable flies as AFTs covered with sticky sleeves [Hogsette and Ruff, 1996]. Thus, sticky sleeves reduced the attraction of Alsynite cylinder traps and must do the same in some manner for the BCTs.

Out of necessity, AFTs and BCTs were placed between 1 and 2 m apart at the 10 trapping sites. When traps are placed

TABLE 3. Weekly mean numbers (\pm SE) of stable flies captured by site ($n = 2$ /site)

Site ^a	Week (2011) ^b							
	1	2	3	4	5	6	7	8
1	29.2 \pm 2.8ab	52.0 \pm 1.8abc	73.0 \pm 1.3ab	75.8 \pm 2.0a	86.1 \pm 1.4ab	44.0 \pm 2.5a	34.2 \pm 3.4ab	21.1 \pm 2.7ab
2	15.6 \pm 4.5ab	31.0 \pm 3.0abc	59.4 \pm 1.4ab	59.0 \pm 2.5a	46.2 \pm 2.0ab	17.7 \pm 5.3a	28.8 \pm 2.0ab	18.2 \pm 2.9ab
3	6.8 \pm 0.6ab	14.4 \pm 1.2bc	15.4 \pm 0.6abc	16.7 \pm 1.2a	10.5 \pm 0.7ab	11.5 \pm 1.1a	9.7 \pm 0.8ab	2.2 \pm 0.6ab
4	6.6 \pm 2.8ab	8.2 \pm 1.3cd	12.5 \pm 0.9bc	5.8 \pm 5.8a	17.4 \pm 0.8ab	10.3 \pm 1.8a	10.5 \pm 0.7ab	2.5 \pm 2.5ab
5	50.4 \pm 1.7a	112.5 \pm 0.4a	104.1 \pm 0.2ab	102.9 \pm 0.1a	126.9 \pm 0.1a	74.5 \pm 0.0a	85.8 \pm 0.2a	25.3 \pm 0.3ab
6	37.1 \pm 0.8a	85.2 \pm 0.4ab	76.3 \pm 0.5ab	10.2 \pm 2.7a	14.8 \pm 2.9ab	35.5 \pm 1.0a	14.3 \pm 2.1ab	4.0 \pm 4.0ab
7	41.7 \pm 1.3a	87.9 \pm 1.8ab	80.8 \pm 1.7ab	55.4 \pm 1.8a	35.5 \pm 2.0ab	39.1 \pm 0.8a	8.5 \pm 0.9ab	9.2 \pm 1.6ab
8	1.8 \pm 0.4b	1.0 \pm 1.0d	5.0 \pm 5.0c	6.8 \pm 0.9a	2.7 \pm 0.9b	30.0 \pm 0.0a	2.9 \pm 0.3b	0.4 \pm 0.4b
9	52.4 \pm 1.2a	156.4 \pm 1.5a	105.9 \pm 2.1ab	58.0 \pm 1.4a	17.5 \pm 8.3ab	103.5 \pm 0.8a	143.4 \pm 1.2a	71.3 \pm 2.1a
10	26.5 \pm 1.0ab	126.3 \pm 0.4a	160.5 \pm 0.7a	73.7 \pm 0.7a	88.4 \pm 0.9ab	86.9 \pm 0.8a	105.2 \pm 1.3a	35.1 \pm 0.8ab

Site	Week (2011)							
	9	10	11	12	13	14	15	
1	8.8 \pm 3.9ab	5.6 \pm 0.7abc	53.0 \pm 0.0a	6.8 \pm 2.9abc	21.0 \pm 1.5a	10.8 \pm 2.9a	13.5 \pm 1.1a	
2	14.7 \pm 1.6ab	5.0 \pm 2.0abc	32.6 \pm 3.2ab	7.3 \pm 1.1abc	8.2 \pm 2.1a	4.3 \pm 4.3a	6.6 \pm 2.8a	
3	1.0 \pm 1.0b	0.0 \pm 0.0c	28.2 \pm 3.7ab	0.7 \pm 0.7d	1.0 \pm 1.0a	0.0 \pm 0.0a	6.5 \pm 0.9a	
4	1.2 \pm 0.7b	0.7 \pm 0.7c	18.5 \pm 1.0ab	0.4 \pm 0.4d	4.8 \pm 0.9a	1.5 \pm 1.5a	2.5 \pm 0.2a	
5	81.0 \pm 0.1a	13.7 \pm 0.6ab	15.8 \pm 1.8ab	3.0 \pm 1.0bcd	3.9 \pm 3.9a	8.2 \pm 0.5a	26.2 \pm 0.4a	
6	13.3 \pm 1.0ab	5.0 \pm 2.0abc	6.6 \pm 2.8ab	1.0 \pm 1.0cd	6.2 \pm 2.6a	1.2 \pm 1.2a	4.2 \pm 0.7a	
7	14.1 \pm 0.3ab	5.0 \pm 0.5abc	2.9 \pm 2.9ab	1.5 \pm 1.5cd	5.2 \pm 1.1a	7.7 \pm 1.2a	6.8 \pm 1.6a	
8	3.9 \pm 0.6b	1.8 \pm 0.4bc	2.0 \pm 2.0b	1.2 \pm 1.2cd	2.2 \pm 0.6a	8.5 \pm 0.4a	0.0 \pm 0.0a	
9	66.6 \pm 1.1a	48.1 \pm 1.7a	1.7 \pm 1.7b	22.0 \pm 1.3a	28.3 \pm 3.2a	14.0 \pm 2.0a	13.8 \pm 2.7a	
10	74.4 \pm 0.5a	34.1 \pm 0.3a	1.2 \pm 1.2b	14.5 \pm 0.9ab	40.6 \pm 1.3a	5.9 \pm 0.7a	12.9 \pm 0.7a	

Means in columns followed by the same letter are not significantly different [$P < 0.05$; Ryan–Einot–Gabriel–Welsch Multiple Range Test (SAS Institute, 2003)].

^aSites 1–4 = paddock; site 5 = pony barn; site 6–7 = dumpster; site 8 = porcupine; sites 9–10 = goats.

^bWeek 1 = (ending in) May 30; week 2 = Jun 7; week 3 = Jun 13; week 4 = Jun 20; week 5 = Jun 27; week 6 = Jul 4; week 7 = Jul 11; week 8 = Jul 18; week 9 = Jul 25; week 10 = Aug 1; week 11 = Aug 8; week 12 = Aug 16; week 13 = Aug 23; week 14 = Aug 30; week 15 = Sep 5.

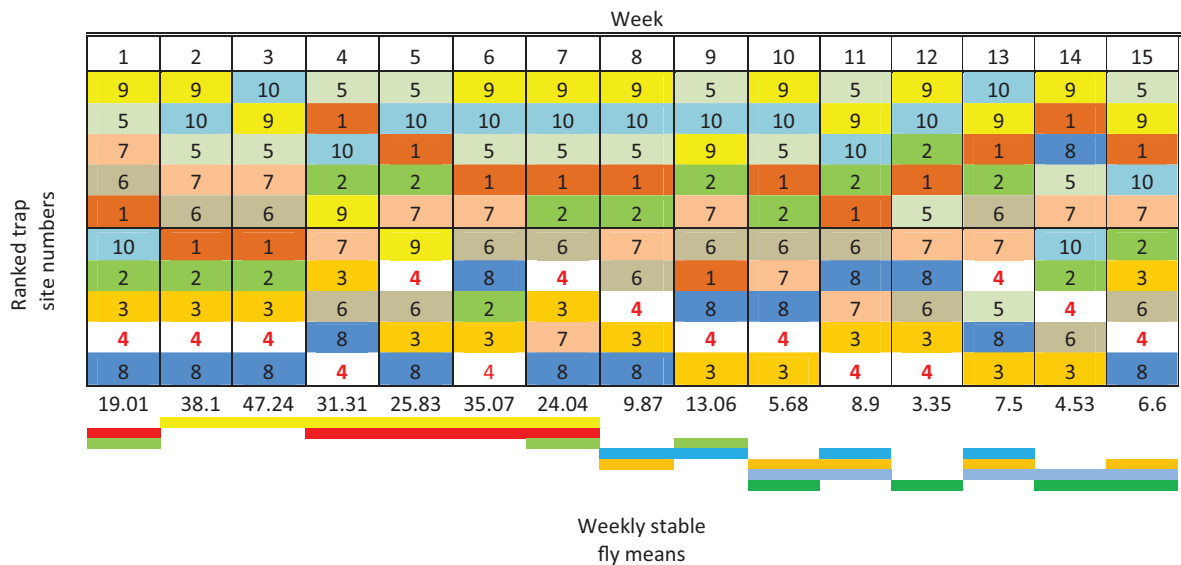


Fig. 2. Trap site numbers, ranked in decreasing order by mean numbers of flies captured weekly, showing changes in stable fly distribution among sites during the 15-week study. Seasonal distribution is represented by the weekly stable fly means shown beneath their respective columns followed by colored lines to represent significance groupings among weeks.

fewer than 6 m apart, they tend to work together instead of independently [Pickens, 1994]. Thus if the attractive qualities of the AFTs and BCTs were remotely similar, mean fly captures by both traps at the 10 sites should be similar. However, this occurred only at site 5, where mean cumulative numbers of flies captured were not significantly different. Site 5 was unique in that both trap types were placed inside of a building (Fig. 1). Although the Pony Barn was open to the Pony Paddock, this structure had fluorescent lights approximately 4.6 m above-ground. These lights could have affected the wavelengths reflected from the traps and the traps could have been used more equitably as fly perching sites when compared with traps at the other nine sites. The reduced attraction of the BCTs is so great that they would not be useful as a tool for capturing stable flies. However, selection of a clear sticky sleeve that does not interfere with the reflective qualities of the BCT might solve this problem.

The goat enclosure was apparently the most attractive site at the zoo for stable fly adults based on the large numbers of flies consistently captured by traps placed around this exhibit (Fig. 2). The only other sites that could be expected to be competitive are those near the ponies (sites 1–5). Although goats and ponies are known to be hosts for the stable fly [Hogsette and Farkas, 2000], it is curious that the goat exhibit was in this case more attractive. With similar numbers of animals in both exhibits and a high level of sanitation found throughout the zoo, other factors may have influenced this phenomenon.

Fly breeding of any kind was rarely seen at the zoo, and the occasional larva we found did not account for the numbers of flies captured on our traps. Adult populations were apparently dispersing to the zoo from external sources. Washington, DC, where there is no animal agriculture, is east of the zoo and there is very little animal agriculture west of the zoo within a 16-km radius. Stable flies can fly 8 km per hr [Hogsette et al., 1989] so dispersal from external sources cannot be dismissed [Hogsette and Ruff, 1985], especially when prevailing winds are from the west. The goat exhibit is on the west side of the zoo separated from the other exhibits by about 100 m (Fig. 1). What is not shown on the zoo map is a large field adjacent to the goat exhibit where small numbers of Bison, Camel, Ostrich, Rhea, Ankole-Watusi, Wildebeest, and Zebra are on open pasture. It was not possible to put fly traps in this area. If the adult stable fly populations were arriving at the zoo from the west, they would encounter these animals first. Excess flies could move over to the goats and from there over to the ponies. To the west of the goats is a lake, and bodies of water are known to be used as aggregation sites for stable fly adults [Hogsette et al., 1987]. Additional research is needed to determine the potential sources of the stable fly adult populations in this urban area and better define their arrival and dispersal patterns at the zoo.

The seasonality data reported herein are the first reported for stable flies collected from a zoological park. Rugg [1982] in Australia looked strictly at population reduction but not at seasonality. Although the first few weeks

of the fly season passed before our trapping began, a major portion was recorded. The fly population peaked around June 13, decreased slightly, had a lesser peak around July 4, and then populations gradually decreased. The length of the season and the June peak are similar to other seasonality curves at latitudes close to that of Washington, DC [Burg et al., 1990; Broce et al., 2005; Taylor et al., 2007]. This is in contrast to seasonality curves in Florida, where the greatest stable fly activity is usually between November and April [Romero et al., 2010], and in Alberta, Canada, where population peaks do not occur until August and September [Lysyk, 1993]. It would be beneficial to trap for one or two more seasons at the Reston zoo so the curves could be compared for year-to-year variation.

This study demonstrates how urban zoos can be aggregation sites for adults of *S. calcitrans*. Although the Reston zoo has few true exotic animals, it has a collection of animals that are attractive to stable flies, similar to the herds of cattle and horses seen in more rural areas. Management systems for zoos must be developed so the animals and visitors can be protected from the painful bite of the stable fly.

CONCLUSIONS

1. The BCTs did not catch enough stable flies to be useful in a trapping program. The attractive qualities of the cloth targets are essentially eliminated by wrapping them in sticky sleeves.
2. The sites at the zoo where the most stable flies were consistently captured were at the goat exhibit. This was either because of the attractive nature of the exhibit or because flies tended to aggregate at this exhibit before moving farther into the zoo. Attractive Self-Marking Devices [Hogsette, 1983] could be used to study the movement of stable flies throughout the zoo.
3. During the study, stable flies peaked in June and then began to decrease in numbers. This indicates that fly interventions should be in place in early May as adults begin to appear.

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