

## A comparison of the Nzi, Horse Pal® and Bite-Lite® H-traps and selected baits for the collection of adult Tabanidae in Florida and North Carolina

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Received 17 July 2017; Accepted 28 October 2017

**ABSTRACT:** Despite the veterinary and medical importance of horse flies, deer flies, and yellow flies, only a few trap types have been evaluated to monitor adult population dynamics. Currently, three trap types are being utilized (H-trap, Horse Pal® (HP), and Nzi trap), but no head-to-head comparisons have been reported. Thus, we conducted comparative trapping studies in Florida and North Carolina. At two study sites in Florida, the efficacy of all three trap types was compared, but only the H-trap and HP were compared in North Carolina. Although trap type was significant at all sites, the trap type which caught the most specimens was not the same. In Florida at the Lower Suwannee Wildlife Refuge (LSWR) site, the H-trap caught the most specimens (2,006), followed in decreasing order by Nzi (938) and HP (541). At the Cedar Ridge Ranch site, the Nzi caught significantly more specimens (1,439) than the H-trap (215) and HP (161), which were not significantly different from each other. In North Carolina, the H-trap caught approximately twice as many specimens as the HP (1,458 vs 720). These trap comparison studies were followed up by a study on the efficacy of various bait combinations: (No Bait (NB), dry ice only (DI), Trap Tech Lure (TTL) only, and DI + TTL), which was conducted only at the two Florida sites with H-traps. At both sites, bait combinations significantly affected trap collections. One pattern (DI + TTL > DI > TTL > NB) was recorded at the LSWR, while at the Cedar River Ranch the pattern was DI > DI + TTL > TTL > NB. Our data showed that trap type and bait combination significantly influence overall adult tabanid abundance as well as individual species composition. *Journal of Vector Ecology* 43 (1): 63-70. 2018.

**Keyword Index:** Horse flies, deer flies, biting fly, yellow flies, attractants.

### INTRODUCTION

The family Tabanidae includes horse flies, deer flies, and yellow flies, all of which have veterinary and medical importance. Large tabanid populations have a significant economic impact on livestock production and outdoor activities because of the blood-feeding habits of the females of most species (Krinsky 1976, Hansens 1979, Foil and Hogsette 1994, Goodwin and Drees 1996). These flies have been implicated in the biological transmission of ehrlichiosis of deer and elk as well as mechanical transmission of anaplasmosis, anthrax, bovine leukemia, tularemia, Equine Infectious Anemia (EIA), vesicular stomatitis, bovine leukemia, and hog cholera (Goodwin and Drees 1996, Foil et al. 1983). In addition, severe tabanid attacks disrupt the normal feeding activities of livestock and may contribute to poor weight gain and/or milk production (Goodwin and Drees 1996). The painful bites of feeding female tabanids cause severe irritation for horses, and their persistent attack may make horses unmanageable, perhaps endangering themselves or their handlers. Horses dislodge biting tabanids by tail swishing, muscle twitching, and head tossing. As a result, the larger flies may feed on several host animals in close proximity (Davies 1990), increasing their potential to transmit the pathogens which cause EIA and other diseases (Issel and Foil 1984, Issel et al. 1988, Foil et al. 1983, Buxton et al. 1985). Certain horse flies (Wall and Doane 1980) and deer flies (Cilek and Medrano 2000) can also be annoying pests of people, especially coastal wetland species. Some are known to feed readily on humans and often inhabit areas frequented by tourists. This may

result in a negative economic impact by limiting the use of golf courses, campgrounds, fishing areas, and recreation areas used for hunting and other leisure activities (Hansens 1979, Zettel-Nalen et al. 2015).

During preliminary studies to establish baseline data on species composition, relative abundance, and seasonal patterns of mosquitoes and biting flies at several study sites where livestock and wildlife are abundant, we observed that tabanids were prevalent pests. Although we had very effective traps to monitor mosquito and ceratopogonid adults at these sites, we did not have an effective trap to collect tabanids. Thus, the major objective of this study was to evaluate three tabanid collection traps, the relative efficacy of which has not been determined in multi-comparative studies. In addition to efficacy, a robust trap that would endure the challenges of the environment was required. Two study sites in Florida and a third site in coastal North Carolina were selected to conduct these trapping studies. A secondary objective was to evaluate the influence of selected baits used in conjunction with the traps.

### MATERIALS AND METHODS

#### Study sites

The first Florida site was the Lower Suwannee Wildlife Refuge (LSWR) (N 29.21983, W 83.03002), where we have been conducting mosquito and biting fly research for ca. 30 years. The LSWR is a 53,000-acre (21,448-ha) wildlife refuge established in 1979 to protect one of the largest undeveloped river delta

systems in the United States. It includes 20 miles (32 km) of the Suwannee River estuary and 20 miles (32 km) of Gulf of Mexico coastline. The Suwannee River and nearby bottomland hardwood swamps, pine forests, cypress domes, tidal creeks, and vast salt marshes provide habitat for thousands of creatures every year. The refuge's undisturbed coastal salt marshes, tidal creeks, and tidal flats are some of the most productive ecosystems in the world. These wetland habitats provide many developmental sites for mosquitoes, biting midges, and tabanids. The diversity of vertebrate fauna found nearby provides a variety of hosts for the many species of biting flies.

The second study site was Cedar Ridge Ranch (N 29.12918, W 83.00139), a 40-acre (16-ha) horse boarding facility that offers year-round boarding for up to six horses, and includes a round pen, uncovered panel stalls with a 1.22 m entry gate, a corral suitable for up to four horses, and four fenced grazing areas averaging 2 ha each. Pastures are of Bahia/Bermuda mix. This study site was selected in part due to its proximity to the 2,023 ha Cedar Key Scrub State Reserve. At the Reserve's western edge are salt marshes on the Gulf of Mexico, which, moving inland, give way to a succession of freshwater swamps, hardwood forests, pine flatwoods, and scrub. The scrub is dominated by species such as sand live oak (*Quercus geminata*), myrtle oak (*Q. myrtifolia*), and Chapman's oak (*Q. chapmanii*), along with rusty lyonia (*Lyonia ferruginea*) and saw palmetto (*Serenoa repens*). There are many areas of shallow waters and creeks, including tidal creeks associated with the salt marshes. This variety of important habitats (salt marsh, pine flatwoods, and sand pine scrub) provides habitat for the production of a diversity of biting fly species (tabanids, biting midges, and mosquitoes). The third study site was located within the Jonaquins Landing development in Beaufort, NC (N 34.93894, W 76.6314), which is near a salt marsh. Three residential properties (yards) in the development were utilized for trapping.

### Traps

Three trap types were included in our Florida studies. The Horse Pal® (HP) (Newman Enterprises, Omro, WI) described by Watson et al. (2007) as a modified Manning trap, is a box-style canopy trap. The HP trap consists of a four-sided pyramid with a square 61-cm long skirted base, a black ball (circumference = 127 cm), and four legs (Figure 1a). The HP trap is 1.68 m tall and constructed from tan marine grade canvas, fiberglass screen, plastic coated steel legs, and other premium materials designed for many seasons of use.

The Bite-Lite® H-trap (Bite-Lite, LLC, Bethel, CT 06801, <http://www.bite-lite.com>) is a conical plastic hood trap attached to a single-legged frame constructed from corrosion-proof steel (dipped in hot zinc) with an anti-rotation ground anchor (Figure 1b). Flies are attracted to a black ball (circumference = 148.5 cm) suspended beneath the plastic hood, which guides the flies upwards into a centrally located plastic collection device. All plastic parts (conical hood and collection device) are UV-proof.

The third trap, the Nzi trap (Figure 1c), is a 1-m cloth triangular blue/black target-interception trap with two blue wings, constructed after Mihok (2001, 2002) and Mihok et al. (2006). This trap was developed for tsetse fly control (Mihok 2002) in Africa, and the original traps were made from phthalogen blue IF3GM cotton. Because this fabric was unavailable when our

traps were constructed, we substituted Sunbrella® Pacific Blue and Sunbrella® Black fabrics (Glen Raven Custom Fabrics, Glen Raven, NC) with white polyester mosquito mesh as recommended by Mihok et al. (2006). We called the resulting trap the Nzi-SB. Another modification to the original design was the addition of webbing ties sewn onto the corners of traps to secure the trap to PVC support poles (Figure 1c). The Nzi trap has proven to be an effective trap for capturing biting flies in North America (Mihok et al. 2006, Mihok and Carlson 2007). All three of these traps were included in the Florida studies, but only the HP and H-traps were compared in the North Carolina studies.

### Experimental design

A series of experiments ( $n = 3$  complete rotations) using a 3 x 3 Latin square design (Cochran and Cox 1957) were conducted at both Florida sites in 2014 to compare the efficacy of the three trap types. Three sampling stations, located a minimum of 50 m apart, were established at each study site. Traps were unbaited throughout these experiments. Traps were randomly assigned to one station at each study site on the first day of each replicate and trap contents were collected at 24 h intervals. After contents were collected, traps were rotated clockwise to the next station. Trap collections were taken to the laboratory and specimens identified either to a known species or an unknown *Tabanus* (e.g., T?1) or *Chrysops* (e.g., Chry2) species. Traps at the Cedar Ridge Ranch were placed outside the pasture fence where they could not be damaged by the horses. At LSWR traps were located along a hiking trail.

In the two Florida study sites, we evaluated the H-trap in a 4 x 4 Latin square rotation of four replicates with the following treatments: No Bait (NB)(control), the Trap Tech® Lure (TTL), dry ice (DI), or DL + TTL. TTL (Bedoukian Research, Inc., Danbury, CT) contains 250 mg of R-1-octen-3-ol and 1,900 mg of ammonium bicarbonate that was slowly released from a plastic dispenser. The DI was placed in a 1.9 liter insulated Igloo container attached by rope near the top under the conical canopy portion of the H-trap (Figure 1b). The TTL dispenser was attached at the same location. Four sampling stations located at least 50 m apart were selected at each study site. At LSWR trap positions were hidden from each other by the dense vegetative cover of trees and shrubs, but at Cedar Ridge Ranch trap stations were in plain sight of each other because pasture grass was the only vegetative cover.

In 2015 the efficacy of the H-trap and HP trap was compared from June through September in 3 yards at the Beaufort, NC, site. The first HP trap (HP-1) was set up in a back yard of a residence located about 4.5 – 6.1 m from the edge of the salt marsh and about 9.1 m from a tidal creek. The first H-trap (H-1) was also set up in the backyard of a residence located about 183 m from the previous residence. This trap was also about 4.5 – 6.1 m from the marsh edge and about 9.14 m from the tidal creek. The second HP (HP-2) and H-trap (H-2) traps were set up at a third residence located about 183 m from the second residence. Horse Pal-2 was set up in the front yard about 91 m from the marsh edge and tidal creek. H-trap-2 was in the back yard of this residence and about 18.29 m from the marsh edge and tidal creek. These traps were not rotated.



Figure 1. A.) Horse Pal Trap. B.) H-Trap. C.) SB Nzi Trap.

### Statistical analysis

Data were subjected to GLM (SAS 2013) after transformation by  $\log_{10}(n + 1)$ . Transformed values were used for the analyses but back transformed values are shown in the text and tables. The main effects model for all analyses was: Flies captured = treatment + species + location + replication. Means were separated with the Ryan-Einot-Gabriel-Welsh multiple range test (SAS 2013) and

unless otherwise stated,  $P = 0.05$ .

### RESULTS

#### Trap comparison studies

*Lower Suwannee Wildlife Refuge.* There were 3,485 specimens collected consisting of 14 species from four genera (Table 1). The

Table 1. Mean numbers ( $\pm$  SE) of tabanid species captured by each of three trap types at the Lower Suwannee Wildlife Refuge near Cedar Key, FL, May 20 – June 10, 2014 ( $n = 9$ ); *T. ?* = an unknown *Tabanus* species. Means in columns followed by the same letter are not significantly different [ $P < 0.05$ ; Ryan-Einot-Gabriel-Welsch Multiple Range Test (SAS Institute 2013)].

Species	H-trap	Horse Pal	Nzi-SB
<i>Tabanus lineola</i> complex	89.97 $\pm$ 1.02a	38.18 $\pm$ 0.44a	49.99 $\pm$ 0.47a
<i>Diachlorus ferrugattus</i>	2.18 $\pm$ 0.40b	0.64 $\pm$ 0.26b	2.44 $\pm$ 0.145b
<i>T. petiolatus</i>	1.12 $\pm$ 0.24bc	0.79 $\pm$ 0.18b	0.26 $\pm$ 0.12c
<i>Chrysops</i> 2	-	1.16 $\pm$ 0.08b	-
<i>Chlorotabanus crepuscularis</i>	0.63 $\pm$ 0.31bc	0.17 $\pm$ 0.11b	-
<i>T. americanus</i>	0.42 $\pm$ 0.20bc	-	-
<i>T. ?6</i>	0.13 $\pm$ 0.0.13c	-	-
<i>T. ?2</i>	0.08 $\pm$ 0.08c	-	-
<i>T. ?3</i>	0.08 $\pm$ 0.08c	-	-
<i>T. ?8</i>	-	1.16 $\pm$ 0.08b	-
<i>T. ?9</i>	0.08 $\pm$ 0.08c	-	-
<i>T. ?10</i>	0.08 $\pm$ 0.08c	1.16 $\pm$ 0.08b	-
<i>Chrysops vittatus</i>	-	1.16 $\pm$ 0.08b	-
<i>T. ?7</i>	-	0.13 $\pm$ 0.13b	-
<i>T. ?</i>	0.22 $\pm$ 0.15bc	-	-

Table 2. Mean numbers ( $\pm$  SE) of tabanid species captured by each of three trap types at Cedar Ridge Ranch, a horse boarding facility located near Cedar Key, FL, May 19 – June 9, 2014 ( $n = 9$ ); *T. ?* = an unknown *Tabanus* species. Means in columns followed by the same letter are not significantly different [ $P < 0.05$ ; Ryan-Einot-Gabriel-Welsch Multiple Range Test (SAS Institute 2013)].

Species	H-trap	Horse Pal	Nzi-SB
<i>Tabanus lineola</i> complex	9.61 $\pm$ 0.52a	4.24 $\pm$ 0.18a	24.64 $\pm$ 0.66a
<i>Diachlorus ferrugattus</i>	4.27 $\pm$ 0.35b	3.10 $\pm$ 0.74a	18.54 $\pm$ 1.11a
<i>T. petiolatus</i>	0.32 $\pm$ 0.20c	-	0.13 $\pm$ 0.13b
<i>Chrysops</i> 2	0.17 $\pm$ 0.11b	0.17 $\pm$ 0.11c	-
<i>Chlorotabanus crepuscularis</i>	0.13 $\pm$ 0.13c	0.46 $\pm$ 0.23b	1.34 $\pm$ 0.48b
<i>T. ?6</i>	0.08 $\pm$ 0.08c	-	-
<i>T. ?2</i>	0.08 $\pm$ 0.08c	-	-
<i>T. ?3</i>	0.08 $\pm$ 0.08c	-	0.17 $\pm$ 0.17b
<i>T. atratus</i>	0.08 $\pm$ 0.08c	-	0.26 $\pm$ 0.12b
<i>Chrysops vittatus</i>	0.08 $\pm$ 0.08c	0.08 $\pm$ 0.08b	0.13 $\pm$ 0.13b
<i>T. ?1</i>	-	-	0.08 $\pm$ 0.08b
<i>T. ?4</i>	-	-	0.08 $\pm$ 0.08b
<i>Chrysops</i> 3	-	-	0.08 $\pm$ 0.08b
<i>T. ?5</i>	-	-	0.08 $\pm$ 0.08b

Table 3. Comparative efficacy of two trap types for capturing tabanid species (mean  $\pm$  SE) in Beaufort, NC, June 8 - October 8, 2015 ( $n = 32$ ). CDK (*Chrysops* dark color), Thorhstr (*Tabanus* with horizontal stripes), Tdkthor (*Tabanus* with dark colored thorax), TSTRIPES (*Tabanus* with two adjacent dotted stripes), UNKN (*Tabanus* unidentifiable to species type). Means in rows followed by the same letter are not significantly different [ $P < 0.05$ ; Ryan-Einot-Gabri-Welsch Multiple Range Test (SAS Institute 2013)].

Species	H-trap	Horse Pal
<i>Tabanus lineola</i> complex	4.69 $\pm$ 0.34a	3.23 $\pm$ 0.31a
<i>Chrysops celatus</i>	1.72 $\pm$ 0.25a	0.19 $\pm$ 0.09b
<i>Diachlorus ferrugatus</i>	0.33 $\pm$ 0.29a	0.09 $\pm$ 0.06b
<i>T. nigrovittatus</i>	0.98 $\pm$ 0.25a	1.15 $\pm$ 0.26a
CDK	0.87 $\pm$ 0.21a	0.17 $\pm$ 0.08b
<i>T. petiolatus</i>	0.17 $\pm$ 0.07a	0.26 $\pm$ 0.08a
Thorhstr	0.12 $\pm$ 0.08a	0.15 $\pm$ 0.06a
Tdkthor	0.08 $\pm$ 0.06a	0.11 $\pm$ 0.08a
<i>T. imitans</i>	0.07 $\pm$ 0.04a	0.14 $\pm$ 0.04a
TSTRIPES	0.06 $\pm$ 0.04a	0.04 $\pm$ 0.04a
<i>T. atratus</i>	0.04 $\pm$ 0.03a	0.09 $\pm$ 0.04a
UNKN	0.04 $\pm$ 0.03a	0.08 $\pm$ 0.05a
<i>T. nigripes</i>	0.02 $\pm$ 0.02a	0.06 $\pm$ 0.04a
<i>T. americanus</i>	0.00 $\pm$ 0.00a	0.04 $\pm$ 0.03b

H-trap caught the most specimens (2,006), followed in decreasing order of abundance by the Nzi-SB (938) and HP (541). The main effects model was significant for trap type ( $F = 70.10$   $df = 21, 377$ ;  $P < 0.001$ ,  $R^2 = 80.53$ ) but not for location, day and replicate. The H-trap and HP caught 11 and nine different species, respectively, and the Nzi-SB caught only three species. The most abundant species collected was *Tabanus lineola* Fabricius complex (Tlc, 3,331); followed in decreasing order of abundance by *Diachlorus ferrugatus* (Fabricius) (DF, 89); *T. petiolatus* Hine (TP, 26); *Chlorotabanus crepuscularis* (Becquaert) (Chlorcrep, 13); *T. americanus* Forster (Tamer, 6); *T. atratus* Fabricius (Tatrat, 6); T? 4 (3); T?6 (2); T?7 (2); Chry2 (2); T?10 (2); T?8 (1); *Chrysops vittatus* Wiedemann (ChryV, 1); and T?9 (1).

**Cedar Ridge Ranch.** A total of 1,815 specimens were caught consisting of 14 species and four genera (Table 2). The four genera were the same as those collected at LSWR, but the species composition was different. The mean number of specimens caught by the Nzi-SB trap (11.42  $\pm$  4.17) was significantly greater ( $F = 30.97$ ,  $df = 22, 377$ ;  $P < 0.0001$ ,  $R^2 = 65.74$ ) than those captured by the H-trap (1.71  $\pm$  0.51) and the HP trap (1.28  $\pm$  0.69), with the latter two traps not significantly different from each other. The Nzi-SB caught the most specimens (1,439), followed by the H-trap (215) and HP (161). The Nzi-SB collections of Tlc (24.64  $\pm$  0.66) and DF (18.54  $\pm$  1.11) were not significantly different from each other but were significantly greater than all other species collected ( $F = 15.22$   $df = 19, 125$ ;  $P < 0.0001$ ,  $R^2 = 73.18$ ). The H-trap collected significantly more Tlc (9.61  $\pm$  0.52) than all other species ( $F = 17.70$ ,  $df = 19, 125$ ;  $P < 0.0001$ ,  $R^2 = 76.04$ ). The HP collections of

Tlc (4.24  $\pm$  0.18) and DF (3.10  $\pm$  0.74) were significantly greater than all other species collected but were not significantly different from each other ( $F = 9.74$   $df = 19, 125$ ;  $P < 0.0001$ ,  $R^2 = 64.98$ ). The H-trap caught ten species, the Nzi-SB nine species, and the HP five species. Species caught at this site that were not caught at LSWR were T?1, T?2, T?3, T?5, and Chry3; species not caught at this site that were caught at LSWR were *T. americanus*, T?7, T?8, T?9, and T?10. DF was the most abundant species collected at Cedar Ridge Ranch (1,020) followed in decreasing order by Tlc (726); Chlorcrep (41); TP (7); ChryV (5); Chry2 (4); T?1 (3); T?3 (2); T?4 (2); Chry3 (1); T?2 (1); T?5 (1); T?6 (1); and Tatrat (1).

**North Carolina.** A total of 2,178 specimens were collected at this site in 2015 consisting of 13 species in three genera. The H and HP traps caught 12 and 13 species, respectively (Table 3). No *Chlorotabanus* were collected. Overall, the H-trap caught ca. twice as many specimens as the HP (1,458 vs 720). The Tlc was the most abundant species collected by both trap types. *Tabanus americanus* was not collected by this trap type. In decreasing order of abundance, the species collected by the H-trap included Tlc (686) > DF (256) > *C. celatus* Pechuman (204) > *T. nigrovittatus* Macquart (176) > *Chrysops* dark colored (CDK) (99) > Thorhstr (*Tabanus* with horizontal stripes) (12) > *T. petiolatus* (9) > Tdkthor (*Tabanus* with dark colored thorax) (5) > TIM (*T. imitans* Walker) (3) = TSTRIPES (*Tabanus* with 2 adjacent dotted stripes) > *T. atratus* (2) > *T. nigripes* Wiedemann (1). Two specimens collected in the H-trap were too damaged to be identified (UNKN). All thirteen species were collected by the HP. The decreasing order of abundance of species collected by the HP was Tlc (434) > *T. nigrovittatus* (198) > DF (17) > *C. celatus* (14) > *T. petiolatus* (13) > *T. imitans* (10) > Tdkthor (dark colored thorax) (9) > Thorhstr (*Tabanus* with horizontal stripes) (7) > *T. atratus* (4) > *T. nigripes* (3) = CDK (3) > *T. americanus* (2) = TSTRIPES (*Tabanus* with two adjacent dotted stripes). In North Carolina, the mean number of tabanids caught by the H trap (0.48  $\pm$  0.05) was significantly more overall than the HP trap (0.29  $\pm$  0.03) ( $F = 18.12$ ,  $df = 29, 89$ ;  $P < 0.0001$ ). *Tabanus lineola* complex was the most abundant species in both trap types. *Chrysops celatus* and *Diachlorus ferrugatus* were the next two most abundant species in the H-traps and *Tabanus nigrovittatus* was the second most frequently collected species in the HP traps.

### Influence of selected baits

**Lower Suwannee Wildlife Refuge.** Bait treatments significantly affected trap collections ( $F = 115.88$ ,  $df = 33, 1407$ ,  $P < 0.0001$   $R^2 = 73.57$ ) at this site. Collection means, presented in decreasing order, were all significantly different from each other, tabanid species overlooked: DI + TTL (1.08  $\pm$  0.08), DI (0.89  $\pm$  0.07), TTL (0.37  $\pm$  0.05), and No Bait (0.20  $\pm$  0.03). This same pattern was observed numerically for the Tlc, TP, and *T. gracilis* Wiedemann (TG) species, however significance levels varied (Table 4). The number of tabanid species collected by bait treatment at LSWR was: DI + TTL (19) > DI (17) > TTL (12) > No Bait (6).

**Cedar Ridge Ranch.** Baits also significantly affect trap collections ( $F = 48.51$ ,  $df = 30, 1215$ ,  $P < 0.0001$ ,  $R^2 = 55.12$ ) at the Cedar River Ranch. Collection means from traps baited with DI (0.203  $\pm$  0.03) and DI + TTL (0.201  $\pm$  0.03) and those baited with TTL (0.091  $\pm$  0.02) or with No Bait (0.076  $\pm$  0.02) were significantly different; however, collections from the former

Table 4. Mean numbers ( $\pm$  SE) of tabanid species captured with H-traps either unbaited (NB) or baited with the TrapTech Lure (TTL), dry ice (DI), or dry ice + Trap Tech Lure (DI + TTL) at Lower Suwannee Wildlife Refuge study site near Cedar Key, FL, July 21 – August 21, 2014 ( $n = 16$ ); *T. ?* = an unknown *Tabanus* species. Means in rows (upper case letters) or columns (lower case letters) followed by the same letter are not significantly different [ $P < 0.05$ ; Ryan-Einot-Gabriel-Welsch Multiple Range Test (SAS Institute 2013)].

Species	NB	TTL	DI	DI + TTL
<i>Tabanus lineola</i> complex	7.80 $\pm$ 0.18Da	36.77 $\pm$ 0.15Ca	83.78 $\pm$ 0.23Ba	149.64 $\pm$ 0.17Aa
<i>T. petiolatus</i>	0.70 $\pm$ 0.17Cc	2.31 $\pm$ 0.23Bb	45.21 $\pm$ 0.12Ab	66.92 $\pm$ 0.12Ab
<i>Chrysops celatus</i>	0.22 $\pm$ 0.10d	0.35 $\pm$ 0.09c	1.42 $\pm$ 0.24cd	1.80 $\pm$ 0.26d
<i>T. gracilis</i>	1.24 $\pm$ 0.18Bb	1.68 $\pm$ 0.19Bb	2.21 $\pm$ 0.23Bc	5.48 $\pm$ 0.16Ac
<i>Diachlorus ferrugatus</i>	0.14 $\pm$ 0.07d	0.28 $\pm$ 0.12c	0.65 $\pm$ 0.15de	0.41 $\pm$ 0.12ef
<i>T. ?2</i>	-	-	-	0.07 $\pm$ 0.07f
<i>T. ?8</i>	-	0.04 $\pm$ 0.04c	0.36 $\pm$ 0.11de	0.14 $\pm$ 0.07ef
<i>T. ?10</i>	-	0.11 $\pm$ 0.11c	1.32 $\pm$ 0.33cd	2.03 $\pm$ 0.32d
<i>Chrysops 3</i>	-	0.22 $\pm$ 0.10c	0.22 $\pm$ 0.12e	0.14 $\pm$ 0.10ef
<i>Chrysops cincticornis</i>	-	0.09 $\pm$ 0.06c	0.22 $\pm$ 0.10e	-
<i>T. ?13</i>	0.04 $\pm$ 0.04b	-	-	-
<i>T. ?18</i>	-	-	0.17 $\pm$ 0.13e	0.12 $\pm$ 0.08ef
<i>T. ?11</i>	-	0.04 $\pm$ 0.04c	0.54 $\pm$ 0.27de	1.01 $\pm$ 0.27de
<i>T. ?16</i>	-	-	0.14 $\pm$ 0.10e	-
<i>T. atratus</i>	-	0.04 $\pm$ 0.04c	0.04 $\pm$ 0.04e	0.09 $\pm$ 0.06ef
<i>T. americanus</i>	-	-	0.72 $\pm$ 0.15de	0.76 $\pm$ 0.14def
<i>T. ?4</i>	-	-	0.09 $\pm$ 0.06e	0.24 $\pm$ 0.09ef
<i>T. ?19</i>	-	-	0.04 $\pm$ 0.04e	0.09 $\pm$ 0.06ef
<i>T. ?12</i>	-	-	-	0.20 $\pm$ 0.15ef
<i>T. ?9</i>	-	-	-	0.04 $\pm$ 0.04f
<i>Chrysops 2</i>	-	-	0.17 $\pm$ 0.13e	0.12 $\pm$ 0.12ef
<i>Chrysops vittatus</i>	-	0.04 $\pm$ 0.04c	-	-
<i>Chlorotabanus crepuscularis</i>	-	-	-	0.12 $\pm$ 0.08ef

and latter bait pairs were not significantly different. *Tlc* was the most abundant species collected ( $\Sigma = 536$ ) and the bait collection means followed the pattern described above and shown in Table 5. No other species was collected in numbers sufficient for analysis among treatments. A total of 18 species was collected, the most by traps baited with DI (16), followed by traps baited with DI + TTL (12), and traps baited with TTL or No Bait (5 species each).

## DISCUSSION

Overall, the H-trap caught the most specimens and the greatest number of species. This trap was considerably easier to service by just removing/lifting off the entire collection container. Conversely, the collection container of the HP trap often came apart while removing it, and that could have resulted in losing part of the collection if care was not taken. During these trials, we found

that the H-trap was more stable during very windy conditions (>30 mph). Although the experiments reported herein were not affected, there were several times between experiments that the HP and Nzi-SB were blown over by very windy conditions, but H-traps remained intact. This observation was further supported during ongoing studies when tropical storm Hermine (sustained winds of 39-73 mph with wind gusts of 74-110 mph) ravaged Cedar Key causing severe wind damage to homes and businesses but did no damage to seven H-traps that had been left in the field during the storm.

When we paired traps with baits, dry ice, and TTL, the abundance and diversity of collected tabanid species increased in H-traps. These results are consistent with those reported in previous studies where CO<sub>2</sub> and octenol were shown to improve overall capture rates but with the caution that relative responses to different attractants does vary among species (Wilson et al. 1966,

Table 5. Mean numbers ( $\pm$  SE) of tabanid species captured with H-traps either unbaited (NB) or baited with the TrapTech Lure (TTL), dry ice (DI), or dry ice + the Trap Tech Lure (DI + TTL) at Cedar Ridge Ranch horse boarding facility near Cedar Key, FL, July 14 – August 21, 2014 ( $n = 16$ ) *T. ?* = an unknown *Tabanus* species. Means in rows (upper case letters) or columns (lower case letters) followed by the same letter are not significantly different [ $P < 0.05$ ; Ryan-Einot-Gabriel-Welsch Multiple Range Test (SAS Institute 2013)].

Species	NB	TTL	DI	DI +TTL
<i>Tabanus lineola</i> complex	1.96 $\pm$ 0.23Ba	2.52 $\pm$ 0.17Ba	5.97 $\pm$ 0.34Aa	5.86 $\pm$ 0.42Aa
<i>T. petiolatus</i>	-	0.04 $\pm$ 0.04b	0.36 $\pm$ 0.13b	0.52 $\pm$ 0.17b
<i>Chrysops celatus</i>	0.19 $\pm$ 0.08b	0.09 $\pm$ 0.06b	0.25 $\pm$ 0.11b	0.20 $\pm$ 0.11b
<i>T. gracilis</i>	0.04 $\pm$ 0.04b	0.14 $\pm$ 0.07b	0.17 $\pm$ 0.09b	0.24 $\pm$ 0.09b
<i>Diachlorus ferrugatus</i>	0.04 $\pm$ 0.04b	0.14 $\pm$ 0.07b	0.15 $\pm$ 0.10b	-
<i>T. ?1</i>	-	-	0.15 $\pm$ 0.10b	-
<i>T. ?8</i>	-	-	0.14 $\pm$ 0.07b	-
<i>T. ?14</i>	-	-	0.09 $\pm$ 0.06b	-
<i>T. ?10</i>	-	-	0.09 $\pm$ 0.06b	0.24 $\pm$ 0.09b
<i>Chrysops 3</i>	-	-	0.04 $\pm$ 0.04b	0.04 $\pm$ 0.04b
<i>T. ?13</i>	0.04 $\pm$ 0.04b	-	0.04 $\pm$ 0.04b	-
<i>T. ?15</i>	-	-	0.04 $\pm$ 0.04b	0.09 $\pm$ 0.06b
<i>T. ?11</i>	-	-	0.04 $\pm$ 0.04b	0.04 $\pm$ 0.04b
<i>T. atratus</i>	-	-	0.04 $\pm$ 0.04b	-
<i>T. americanus</i>	-	-	0.04 $\pm$ 0.04b	0.22 $\pm$ 0.12b
<i>T. ?12</i>	-	-	0.04 $\pm$ 0.04b	0.04 $\pm$ 0.04b
<i>T. ?9</i>	-	-	-	0.04 $\pm$ 0.04b
<i>Chrysops 2</i>	-	-	-	0.07 $\pm$ 0.07b

Roberts 1977, French and Kline 1989, Leprince et al. 1994, Mihok and Mulye 2010). Octenol, a component of ox breath, has been shown to be an olfactory stimulant for a number of hematophagous insects, including tabanids (French and Kline 1989, Leprince et al. 1994). R-octenol is a key component of TTL. CO<sub>2</sub> has been shown to be an effective attractant for tabanids in the form of either dry ice or as gas released from cylinders in various studies (Roberts 1971, Leprince et al. 1994).

Mihok (2002) compared the Nzi trap with canopy traps (the latter as described by Thorsteinson et al. 1965) that were similar in design to the current H-trap and HP traps. In that study, the Nzi trap consistently caught 4.5 times more tabanids than canopy traps, with a 1.5-fold increase in species richness compared with the canopy trap. The most recently reported study which compared the Nzi trap with other trap types was conducted in Croatia (Mikuska et al. 2016). In this study, the relative efficiency of three trap types (Box, Canopy, and Nzi) all baited with octenol as an attractant was evaluated. Results showed that the Box trap, which is similar in design to the HP, had higher trapping efficiency compared with the Nzi or Canopy traps. Nzi traps provided a catch rate 4.65 times greater than the Canopy traps, and the Box traps had a catch rate 11.77 times greater than the canopy traps. Based on Shannon-Wiener diversity indices, Nzi traps were better suited for diversity survey with higher indices than either Box or Canopy

traps. In our studies, the Nzi trap significantly outperformed the canopy traps only in an open environment free of trees and brush.

Mikuska et al. (2016) suggested that these results may be attributed to two features of trap construction and design: trap opening size/position and attractant release rate. Box traps have a 1 m<sup>2</sup> opening on the bottom of the trap and the trap is placed 50 cm above the ground; this large, accessible opening allows tabanids to enter the trap from all sides. In contrast, Nzi traps have an opening only half of the size (0.5 m<sup>2</sup>) of the Box trap opening which may limit accessibility. Furthermore, because Nzi traps are set on the ground, their opening serves to intercept the flight of tabanids coming from only one direction. During the conduct of this study the authors concluded that, in addition to yielding higher catch rates, the robust construction of the Box traps made them more practical for long-term tabanid surveillance. They also concluded, that the Nzi traps required constant maintenance due to grasshopper damage to the fabric that made their routine field use rather difficult, but they were more stable than Canopy traps.

The HP is considered as a box-style canopy trap with a black decoy (Thompson 1969). The decoy (black ball) is considered to have a significant impact on the quantity of the tabanids collected in the trap. The only published study that we could find utilizing the HP was conducted on horse farms in North Carolina (Watson et al. 2007). In their report, Watson et al (2007) pointed out that

the HP trap has evolved from the Manitoba/Manning trap line. The HP fly trap is a commercially available version of this type of trap. Watson et al. (2007) conducted a two-year study to examine differences between the HP and another commercially available horse fly trap, known as the Epps Biting Fly Trap (Farnum Co., Phoenix, AZ) at three horse farms located in central North Carolina. Although the HP captured more flies than the Epps trap, the HP was the preferred trap for relative ease in handling.

In summary, few studies have been published comparing trap efficiency of various trap types for the collection of Tabanidae. Gibson and Torr (1999) stated in a review that an optimal survey trap for all species is difficult to achieve. Although we believe that the H-trap is the best monitoring trap for our study sites, it did not collect some minor species collected by either the HP or Nzi traps. Therefore, we plan to conduct further field studies of refinements with the H-trap such as color, alternative decoys, and attractants.

#### Acknowledgments

We thank Joyce Urban for constructing the Nzi-SB traps. Alec Springsteen (Fork Union Military Academy, Fork Union, VA 23055) assisted with trap collections in Beaufort, NC. This work was supported in part through Material Transfer Research Agreement (491-6615-452) with Bedoukian Research, Inc., Danbury, CT.

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