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TROLLING: A NOVEL TRAPPING METHOD FOR *CHRYSOPS* SPP. (DIPTERA: TABANIDAE)

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ABSTRACT

Trolling, a novel trapping method, was developed and tested for deer flies, *Chrysops* spp., and other Tabanidae. The trap is a plastic plant container coated with Tanglefoot that is mounted upside down on a rod in an apparatus attached to a vehicle. The vehicle is then driven "trolled" to attract Tabanidae. Trap movement, color, shape, dimension and size were evaluated to improve trap catch. Response by *Chrysops vittatus* Wiedemann/*C. pikei* Whitney and *C. macquarti* Philip to the trap's parameters are reported. The most effective trap is a 15 cm diameter pot (Lerio C-360, B-6, The Lerio Corp. Mobile, AL) painted bright blue, placed 1-2 m above the ground and moved at a speed of less than 3.13 m/sec. Response of *Chrysops* spp. to the trap indicated the hierarchy of behavioral stimuli to *Chrysops* spp. in order of importance to be height, movement, speed, dimensions, color, size, and contrast. No known tabanid attractants tested including CO_2, acetone or octenol increased trap captures and the insect repellent, DEET, N,N-diethyl-3-methylbenzamide, did not reduce trap captures. Other biological information derived during the trapping experiments is reported. The trolling trap appears very valuable to detect and monitor certain *Chrysops* spp. and other tabanid populations for scientific purposes. In addition the trap or modifications of it, mounted either on or near humans (hat or walking stick) or on vehicles, may be useful to reduce or eliminate attacks from *Chrysops* spp. or to suppress their activity for short time periods in small areas such as dooryards.

Key Words: *Chrysops vittatus*, *C. pikei, C. macquarti*, trap, Tabanidae, trolling

RESUMEN

Trolear, un novedoso método de captura, fue desarrollado y probado para moscas del genero *Chrysops* spp., y otros Tabanidae. La trampa consiste en un envase plástico para plantas recubierto con Tanglefoot que esta montado el revés sobre una barra en un aparato que va adherido a un vehículo. El vehículo posteriormente es manejado "troleado" para atraer Tabanidae. El movimiento de las trampas, color, forma, dimensión y tamaño fueron evaluados para mejorar la capacidad de captura de la trampa. La respuesta por parte de *Chrysops vittatus* Wiedemann/*C. pikei* Whitney y *C. macquarti* Philip a los parámetros de la trampa son reportados. La trampa más efectiva es un envase de 15 cm de diámetro (Lerio C-360, B-6, La Corp. Lerio, Mobile, AL) pintado de color azul brillante, colocado a 1-2m sobre el suelo y movida a una velocidad menor a 3.13 m/seg. La respuesta de *Chrysops* spp. a la trampa, indicaba la jerarquía del estimulo de comportamiento a *Chrysops* spp. en orden de importancia el cual era altura, movimiento, velocidad, dimensiones, color, tamaño, y contraste. Ningún atrayente para tabanidos conocido que se haya probado incluyendo CO_2 acetona o octenol, aumentó el numero de capturas en la trampas, y el repelente de insectos, DEET, N, N-dietil-3-metilbenzamida, no redujo el numero de capturas en la trampa. Otra información biológica obtenida durante los experimentos de trampeo se reportan. La trampa de troleado parece ser muy valiosa para detectar y monitorear ciertos *Chrysops* spp. y otras poblaciones de tabanidos para propósitos científicos. además la trampa o modificaciones de esta, colocadas tanto sobre o cerca de humanos (sombreros o bastones para caminar) o sobre vehículos, pueden ser útiles para reducir o eliminar ataques de *Chrysops* spp. o para suprimir su actividad por cortos periodos de tiempo en pequeñas áreas tal como patios de casa.

Detection and monitoring of tabanids (Diptera: Tabanidae) began when Hansens (1947) demonstrated that *Tabanus nigrovittatus* Macquart could be captured with black shingles coated with an adhesive material. Since then, many types of adult traps for monitoring tabanids, especially horse flies have been developed. The Manitoba fly trap was described and used by Thorsteinson (1958) and Thorsteinson et al. (1965). Black and red spheres and two- and three-dimensional silhouettes were used by Bracken et al. (1962) and Browne and Bennett (1980). Malaise traps (Smith et al. 1965, Wilson et al. 1966, Roberts 1971a,b), silhouette traps simulating cows (Wilson et al. 1966), red and black helium-filled spheres tethered 1.2-1.8 m above the ground (Snoddy 1970), modified Manning traps (Granger 1970), canopy traps (Catts 1970, French & Kline 1989, Hribar et al. 1991a), sticky traps (Hansens et al.1971), rigid canopy traps (Axtell et al. 1975), aerial netting (Tallamy et al. 1976, Cilek and Schreiber 1996), box traps (Wall & Doane 1980, Ailes et al. 1992), panel traps (Allan & Stoffalano 1986), two-tiered box traps (Jackson et al. 1993, French and Hagan 1995), and brown boards on the ground and white buckets in the air (Moore et al. 1996) have been used to successfully monitor many tabanid species. However, different trap types vary in their ability to capture deer flies (e.g., *Chrysops* spp.) or other tabanid subgroups (horse flies), but can provide diverse information about the behavior of individual species. Tallamy et al. (1976) compared Malaise traps to aerial netting and reported that the latter favored *Chrysops* spp. while Malaise traps were better indicators of tabanid diversity and species evenness. Neither trap alone should be used in tabanid community studies.

Trap color is important to tabanid attraction and landing. Black and red spheres (Bracken et al 1962, Snoddy 1970) were found to be superior to green and yellow spheres and white dappling or striping of black traps dramatically reduced attraction of *Tabanus illotus* (O.S.). Browne and Bennett (1980) reported that both *Chrysops* spp. and *Hybomitra* spp. were attracted to blue or red, but were consistently not attracted to black, yellow or white. Tabanids landed in the areas painted the attractive color on striped traps with alternating attractive and unattractive colors. Allan and Stoffalano (1986) reported that *T. nigrovittatus* preferred blue, black and red panel traps. Increased trap capture occurred when trap intensity was increased or decreased against a background. Wall and Doane (1980) used box traps of green, black or blue to trap *T. nigrovittatus* from 1970-1979 and indicated a measurable decrease in the flies over the trapping period. Moore et al. (1996) used brown boards on the ground and white buckets on poles to determine emergence, concentrations and flight periodicity of *T. abactor* Philip. Male flies preferred the boards while female flies preferred buckets (Moore et al. (1996).

Hribar et al. (1991b) showed that reduction of ultraviolet (UV) light increased catch of certain tabanids. However, Hribar and Foil (1994) retested the effect of UV reflectance of canopy traps on tabanids in Louisiana and concluded that UV had little effect on most species.

Odors have also been used to enhance trap response. Wilson et al. (1966) used carbon dioxide (CO_2) in silhouette traps and captured 23 species of female tabanids. Wilson (1968) using sticky traps with CO_2 on a pasture periphery significantly reduced tabanids on cattle in the pasture. Red and black helium-filled spheres tethered 1.2-1.8 m above the ground captured large numbers of *Chrysops niger taylori* Philip, but Snoddy (1970) determined that CO_2 was a poor attractant for deer flies. Using the canopy trap with CO_2, Catts (1970) reported capturing ca. 1000 tabanids per hour in Delaware. Roberts (1971a and b) used Malaise traps and elucidated a species-specific response to CO_2 rates by tabanids. Roberts (1976a) compared six types of traps with and without CO_2 for collection of tabanids including the Malaise, plexiglass and canopy traps. Based on the number of species captured, the Stoneville Malaise (Roberts 1971a) with CO_2 was the most efficient. Six *Tabanus* spp. and *C. flavidus* Wiedemann were captured in numbers suitable for statistical analysis (Roberts 1976a). French and Kline (1989) investigated the response of tabanids to canopy traps with CO_2 plus the tsetse fly attractant (Hall et al. 1984) 1-octen-2-ol (octenol) isolated from cattle. Octenol alone increased canopy trap catch three fold over traps without attractant. Octenol with CO_2 enhanced trap catch in total specimens and number of species captured. Both *Chrysops* spp. and *Tabanus* spp. were affected. Schreck et al. (1993) evaluated configurations of inflated vinyl beach balls in Malaise and canopy traps as possible insecticide-impregnated visual targets. Beach balls attracted 2× and 2-5× more flies respectively when used alone or when treated with octenol. Leprince et al. (1994) investigated tabanid response in Louisiana to Jersey bullocks and canopy traps baited with ammonia, octenol and CO_2. Odors did not significantly increase trap catch. The results of Leprince et al. (1994) were contrary to the findings of French and Kline (1989) and Hribar et al. (1991a), and suggest that there may be environmental, geographical and species differences in response to attractants by tabanids. Foil and Hribar (1995) tested the tsetse fly attractants acetone, and octenol + 3-*n*-propylphenol and 4-methylphenol (4:1:8 ratio) in canopy traps in Louisiana. Fourteen species or species groups of tabanids were captured in equal numbers to octenol and the mixture, response to acetone was similar to the control. Jackson et al. (1993) and French and Hagan (1995) used a two-tiered box trap to collect *T. nigrovittatus, C. fuliginosus* Wiedemann and *C. atlanticus* Pechuman. Octenol significantly increased the catch of *C. atlanticus.*

Despite the development of traps and the knowledge of tabanid behavior, effective monitoring and management methods, and even basic understanding of the behavior of the thousands of species of tabanids remain unknown. The objectives of this investigation were to develop and test a novel trapping method and to use the trap to characterize the behavior of selected tabanid species. The trap described herein is most effective against *Chrysops* spp. and the responses of three species trapped in large numbers near Monticello, Florida, *C. vittatus* Wiedemann, *C. pikei* Whitney and *C. macquarti* Philip, are reported.

METHODS AND MATERIALS

Trap development progressed over a series of experiments in an effort to exploit the observation of large numbers of deer flies (*Chrysops* spp.) chasing and landing on the side mirrors of a vehicle. Experiments were conducted during August-September, 1994, April-August, 1995, May-August, 1996, and May-August, 1998. All trap surfaces were covered with a thin layer of heated Tanglefoot (The Tanglefoot Co., Grand Rapids, MI 49504) applied with a small paint brush. Because *C. vittatus* and *C. pikei* are not possible to separate in the field, their counts were combined.

In preliminary experiments we determined that two-dimensional black silhouette traps against a completely white background and mounted on the top or on the sides of a moving vehicle would not induce tabanid species flying along side to land. Therefore, we developed the described "trolling" apparatus used for the experiments to mount traps on a vehicle.

All experiments were conducted using a 1992 Dodge Dakota Clubcab pickup, white with gray-striped side panels and black mirrors. An apparatus was mounted on the front and/or back of the truck to support the traps and enable rotation of traps among 7 different positions. The apparatus (Fig. 1) consisted of a 2.5 × 5.0 cm wooden lath base 1.8 m long with 2, 30 cm long pieces nailed perpendicularly on the bottom to serve as support braces. On the front of the vehicle each end of the base was strapped tightly to the truck wheel wells using bungi cords. On the back of the vehicle the apparatus was mounted into the standard holes in the truck bed. Along the length of the base at ca. 30 cm intervals from each end, two 10 penny nails were driven through the bottom of the wood lath ca. 2 cm apart so as to orient with their points vertically through the top side. Small wooden blocks each with a top centered hole and with 2 bottom holes to fit snugly over the nails were attached. Metal rods 30 cm long of ca. 5 mm wire were formed at the top into a L shape and the straight bottom was placed into the top hole in the wooden block. A small binder clip was fastened over the wire's L-shaped end for trap support. Plant pot traps were placed on the rods upside down by drilling 7 mm hole in the center of the bottoms. Position of the traps was changed by moving the traps from rod to rod after each replicate.

Experiments were replicated 5-15 times with each replicate consisting of driving the vehicle for 1-5 min. through an area containing deer flies. After each replication the captured flies were removed and recorded by species and trap. Trap position was rotated clockwise to the next adjacent position for the succeeding replication. Traps in the right end position were returned to the opposite left-end position. Replication generally was conducted such that each trap type was positioned in each test location 1-3 times.

Paints used for small pyramid and square shapes were Glidden Rust Master Enamel. Paints used for the plastic pots were TRU-TEST HI-G, high gloss enamel of the following colors, 105 Chinese red, U-48 Royal blue (darkest), U-9 Dutch blue (lightest), and FL-5 Neon blue (brightest), a TRU-TEST "Easy Color" fluorescent spray. Black was used as the natural color of the plastic pots.

Spectral reflectance of the blue traps (Fig. 2) was measured using a USB UV-VIS S2000 spectrometer with a DT-1000-MINI tungsten light source (Ocean Optics, Dunedin, FL). Percent reflectance was determined in comparison to a white Spectralon standard.

Traps were baited with candidate chemicals using the methods of Foil and Hribar (1995).

Data were analyzed using the SAS Proc GLM procedures. Means were separated by least significant difference test when a significant F was indicated by analysis of variance (SAS Institute 1999).

Experiment 1: Pyramid-shaped traps (Tedders & Wood 1994) ca. 30 cm in height and 15 cm wide at the base, made of clear plexiglass, unpainted cardboard or cardboard painted black, red, yellow, or white and coated with Tanglefoot were used. Eighteen replicates were conducted with one pyramid of each color mounted on both the front and back of the truck. Nine replicates were conducted by driving the truck forward and 9 by driving the truck backwards for a one minute bioassay. Captures were processed as described above. The data were analyzed as a three-way analysis of variance with direction (driving forward or backwards), position on the truck (front or back), and trap color as the factors.

Experiment 2: Black plant pots (15 cm) (Lerio C-650, B-6, The Lerio Corp., Mobile, AL) were compared in six replicates to the cardboard pyramid traps of plain brown cardboard, black or white.

Experiment 3: Black unpainted plant pots (Lerio) of 15, 17.5, and 20 cm were compared to flat squares of cardboard of 15, 17.5, and 20 cm on a side and painted black on both sides in eight replicates.

Experiment 4: Trap size was tested in this two part experiment. Black Lerio pots of 5, 7.5, 10, 12.5, 15, 17.5, and 20 cm in diameter were used. In part one trap sizes from 5-15 cm were tested in 15 replicates. In part two the trap sizes of 15, 17.5, and 20 cm were tested with 8 replicates.

Experiment 5: Red, U-48 Royal blue and black 15-cm pots were tested with 8 replicates. Two

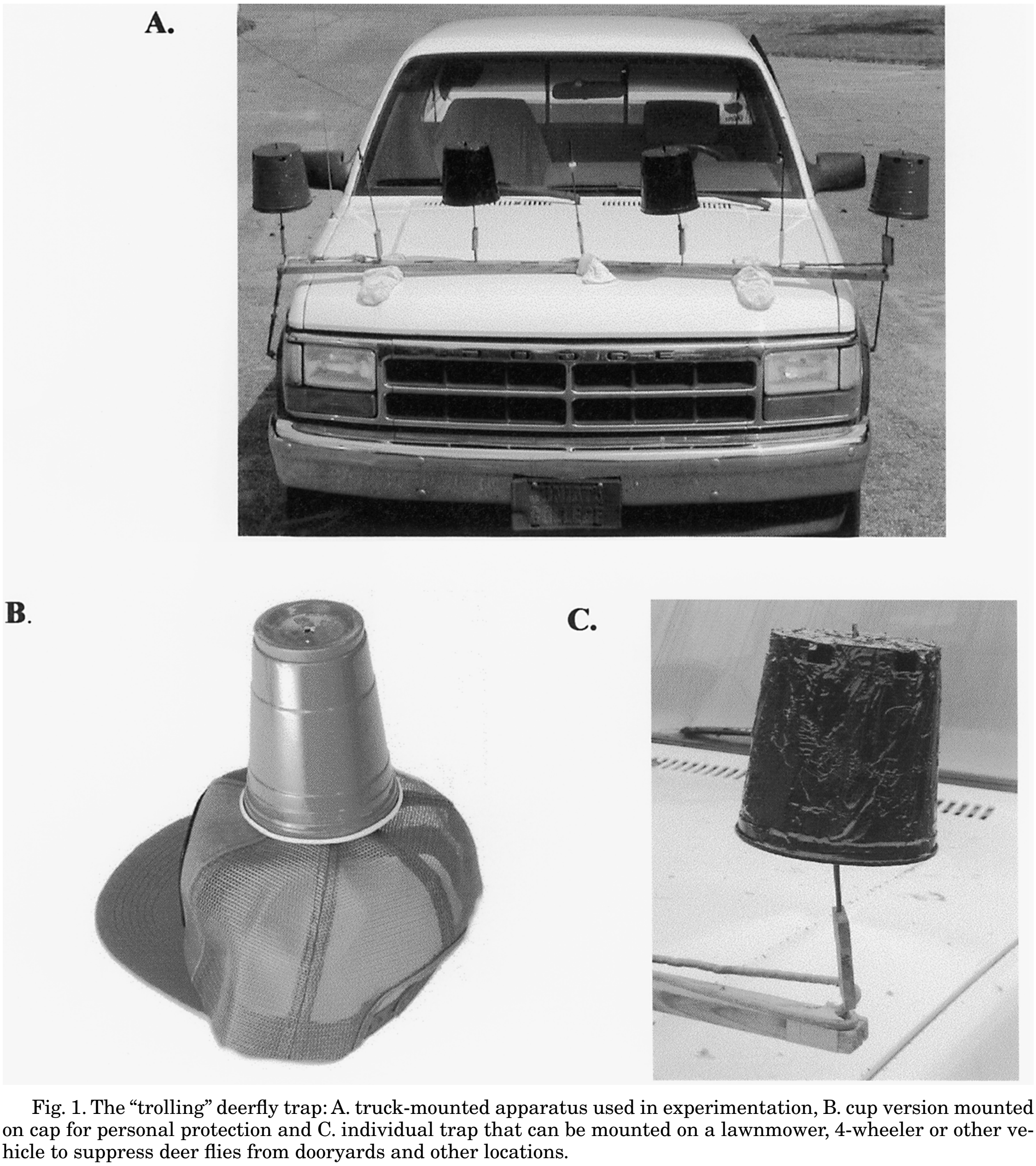

Fig. 1. The "trolling" deerfly trap: A. truck-mounted apparatus used in experimentation, B. cup version mounted on cap for personal protection and C. individual trap that can be mounted on a lawnmower, 4-wheeler or other vehicle to suppress deer flies from dooryards and other locations.

traps of each color were used and the pots of the 3 colors were grouped in two sets to begin the first replicate then randomized as described above.

Experiment 6: Plant pots (15 cm) were painted with one of three different blue paints. In ascending order of intensity (authors' vision, Fig. 2) the colors were: U-9 Dutch blue, FL-5 Neon blue, U-48 Royal blue. Ten replicates were conducted with 2 traps of each color randomized by position on the apparatus.

Experiment 7: Two 15 cm black pots were painted with 2.5 cm alternating vertical stripes of white and black. The striped pots were compared to two solid black pots in five replicates.

Experiment 8: The "size" test (expt. 4) was repeated using pots painted FL-5 Neon blue. Pots similar to those described in experiment 3 of sizes 5, 10, 15, 20, and 25 cm were compared in ten replicates.

Experiment 9: Background color under the trap. Cardboard fruit harvesting boxes ($25 \times 30 \times 45$ cm) were stapled to form a cup shape. The inside of one box each was painted white, FL-5 Neon blue or covered with aluminum foil. To pro-

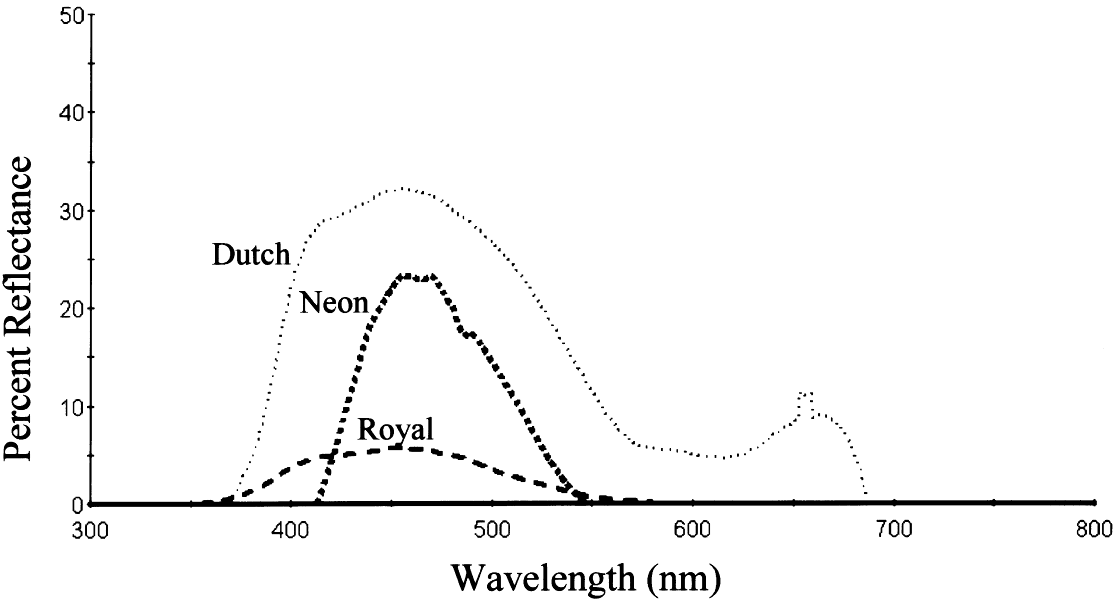

Fig. 2. Spectral reflectance patterns of three blue paints tested on traps for deer fly response. FL-5 Neon and U-48 Royal blues captured significantly more deer flies than U-9 Dutch blue (see text).

vide a trap background under the trap, the center of the cupped box was placed over the nails (fitted into the wood for holding the rods) on the truck-mounted apparatus which held the box in place. FL-5 Neon blue15 cm traps were placed on the rods as described above in the center of the background boxes. Fifteen replicates were conducted and trap position was changed after 5 replicates were completed so that each trap was similarly located next to the other 2 traps for 5 replicates, i.e., three blocks in time.

Experiment 10: Height above ground: A wooden lath of 5 × 5 cm was used to construct a 3.7 m pole that fit snugly into the stake holder on the truck bed. Another piece of lath drilled to hold the metal rod supporting the trap was nailed perpendicular to the pole at 3 heights: 150, 300 and 450 cm. A trap was also placed in the truck bed on a rod which was at 75 cm above the ground. Traps of 15 cm diameter painted FL-5 Neon blue were mounted on the perpendicular stakes at 150, 300, and 450 cm and 15 replicates were conducted.

Experiment 11: Silhouettes of 30 × 60 cm made of blue chloroplast sheeting (BBE Graphics Warehouse, Tampa, FL) were mounted under a trap placed at 150 cm above ground on the bed of the truck as described for the height experiment. Two silhouette traps were compared for each replicate. The silhouettes were placed either vertically or horizontally to mimic an animal body under the trap "head". Replicates were conducted with the silhouettes oriented differently or the same for side by side comparison of the effect on deer fly response.

Experiment 12: Attractants and repellents. Using the methodology of Hribar and Foil (1994) for elution devices and concentration ranges, CO_2 (2.5 l/min - open box of dry ice), acetone (500mg/hr), and octenol (0.5-5.0 mg/hr) were evaluated to determine the attraction and repellence to *C. vittatus*/*C. pikei*. CO_2 was investigated using controlled elution rates and dry ice in a variety of containers to produce a range of low to high volumes both on and around the traps. Ten replicates were also conducted using cannister CO_2 eluded through a flowmeter at the rate of 2.5 l/min. For octenol, 3 FL-5 Neon blue 15 cm pot traps were used with one trap containing the attractant and 2 traps serving as controls. Traps were separated on the apparatus by 50 cm (2 stations) and position was randomized after each of the 11 replications. The octenol with 98% purity was purchased from Sigma Chemical Co. Histological grade acetone was purchased from Fisher Scientific and was bioassayed as described for octenol with 7 replicates. N,N-diethyl-3-methylbenzamide, DEET, was tested using several elution methods: vials as with octenol after Hribar and Foil (1994) and larger dental wicks to provide higher concentrations. Results from the 8 replicates conducted with dental wicks are reported.

C. macquarti: Experiments (1) with color, size and background were conducted in April- May, 1997 when this early-emerging species was observed in relatively high numbers. Color and size were investigated together using 2 Lerio pots each, one black and the other FL-5 Neon blue, of diameter 7.5, 15, and 22.5 cm. The six pots were initially arranged on the truck apparatus with the traps of similar size and color adjacent and then randomized as described above for each of the 12 replicates. Experiment 2 testing background colors was conducted as described above for *C. vittatus*/*C. pikei* with 16 replicates. Populations of *C. macquarti* were much lower than *C. vittatus*/*C. pikei* and also more variable in space. Thus, the numbers of flies captured by traps in each replicate were more variable and trap counts often were zero. Therefore, the data were transformed before analysis of variance by taking the square root of trap capture number +1. The untransformed means are reported.

Results

Trap efficiency was ca. 95% or better as long as the Tanglefoot was fresh. Deer flies occasionally escaped from the Tanglefoot. Therefore, at the beginning and during the experiments as needed, the Tanglefoot was refreshed by rubbing the surfaces of two traps together.

The seasonal occurrence and emergence dates by years were: first detection of *C. vittatus*/*C pikei*—20 April 1995, 3 May 1996, 29 March 1997, and 9 April 1998. The last collection date for *C. vittatus*/*C. pikei* was 9 October 1998. We did not evaluate the diurnal activity of specific *Chrysops* spp, but we did collect *C. vittatus*/*C. pikei* from dawn to dusk and occasionally just after dark. *C. macquarti* emerged first in Spring and was present only from late March to early May in 1998. *C. macquarti* is also much less aggressive towards humans and smaller in size than *C. vittatus*/*C. pikei*. These data agree generally with Jones (1953) who reported two generations of *C. vittatus* in north Florida.

Experiment 1, colored pyramid traps: Colored pyramid traps mounted on the front on rear of the vehicle captured deer flies inefficiently relative to the numbers of *C. vittatus*/*C. pikei* that were flying around them. However, they indicated that dark colors were more attractive (F = 17.4; df = 5,216; P = 0.0001) (Table 1). Comparison by analysis of variance of the trap catch on the front and rear of the vehicle driven either forwards or backwards indicated no significant differences: direction (F = 0.92; df = 1, 216; P = 0.33) vehicle end (F = 1.39; df = 1,216; P = 0.24) but the interaction of direction x vehicle end was significant (F = 8.07; df = 1, 216; P = 0.005). The interaction was significant because the number of deer flies captured on the front (engine end) of the vehicle was larger when the vehicle was driven forward or backward. This result may indicate that heat from the engine or other characteristic of the vehicle front (white hood providing more contrast) may have enhanced attraction and/or landing.

Experiment 2, black plant pot vs colored pyramidal traps: Because the pyramidal traps were inefficient, but "trolling" appeared promising, we compared other potential trap types. Significant differences were determined by analysis of variance with F = 7.3; df = 3, 20; P = 0.0017 and LSD = 3.7. Black 15 cm plant pots captured 8.2 ± 2.3 (mean ± SEM) *C. vittatus*/*C. pikei*, in comparison to 5.2 ± 0.6 or less for the other pyramid traps (Table 1).

Table 1. Response of *Chrysops vittatus* Wiedemann/*C pikei* Whitney to pyramid traps of different colors and a 15 cm black plant pot when "trolled" on a moving vehicle.

	Experiment 1A	Experiment 2
Trap Type	Mean ± SE	Mean ± SE
Black pyramid	2.1 ± 0.33 A[a]	3.5 ± 0.8 A
Tan pyramid	1.5 ± 0.29 AB	5.2 ± 0.6 AB
Red pyramid	1.8 ± 0.27 B	—
Clear pyramid	0.2 ± 0.07 C	—
White pyramid	0.2 ± 0.06 C	0 ± 0 C
Yellow pyramid	0.2 ± 0.05 C	—
Black plant pot	—	8.2 ± 2.3 A

[a]Means in columns not followed by the same letter are significantly different as determined by LSD.

Experiment 3, two-dimensional squares vs plant pots of 3 sizes: Shape was significantly different (F = 42.3; df = 1,42; P = 0.0001), size was not significant (F = 2.8; df = 2,42; P = 0.074) and the shape x size interaction was significant (F = 4.92; df = 2,42; P = 0.012) indicating that the three-dimensional 15 cm pot trap captured significantly more (13.9 ± 2.2) than the 15 cm two-dimensional trap (1.4 ± 0.6). In this test the 15 cm black pot trap also captured significantly more *C. vittatus*/*C. pikei* than the 17.5 cm (7.5 ± 1.0) and 20 cm black pot traps (7.3 ± 1.5), LSD = 2.34.

Experiment 4, size and color interaction: This experiment was conducted in two parts. In evaluating black pot traps varying in size from 5-15 cm we found significant differences (F = 3.84; df = 4,70; P = 0.007) LSD = 3.44. In part two, evaluating traps of 15, 17.5, and 20 cm, we also found a significant size effect (F = 6.72; df = 2,21; P = 0.006) LSD = 2.2 (Table 2). The 15 cm pot trap captured significantly more *C. vittatus*/*C. pikei* in both experiments.

Experiment 5, 15 cm pots of red, black and blue: Blue traps captured significantly more *C. vittatus*/*C. pikei* than the red and black traps, (F = 21.5; df = 2,135; P = 0.0001) LSD = 1.56 (Table 3).

Experiment 6, 15 cm pots of 3 intensities of blue: FL-5 Neon blue and U-48 Royal blue pots captured significantly more *C. vittatus*/*C. pikei* than the U-9 Dutch blue traps, (F = 4.68; df = 2,59; P = 0.01) LSD = 1.54 (Table 3).

Experiment 7, 15 cm black pots with white stripes: Striped traps captured significantly less

TABLE 2. RESPONSE OF *CHRYSOPS VITTATUS* WIEDEMANN /*C PIKEI* WHITNEY TO BLACK AND NEON BLUE PLANT POT TRAPS OF DIFFERENT SIZES WHEN "TROLLED" ON A MOVING VEHICLE.

Size (cm)	Trap Color			
	Black	Black	Neon Blue	Neon Blue
5.0	2.4 ± 0.7 B[a]	—	1.9 ± 0.59 B	—
7.5	3.5 ± 0.7 B	—	—	—
10.0	4.2 ± 0.8 B	—	4.5 ± 0.93 A	—
12.5	4.3 ± 0.6 B	—	—	—
15.0	8.7 ± 2.3 A	8.0 ± 1.4 A	4.3 ± 0.94 A	7.1 ± 1.2 A
17.5	—	3.5 ± 0.8 B	—	—
20.0	—	4.0 ± 0.5 B	3.7 ± 0.68 AB	7.4 ± 1.6 A
22.5	—	—	—	—
25.0	—	—	3.8 ± 0.87 AB	4.9 ± 1.2 A

[a]Means in columns not followed by the same letter are significantly different as determined by LSD.

C. vittatus/*C. pikei* 1.72 ± 0.22 (total = 34) than the solid black traps (2.84 ± 0.39, total = 94) (F = 6.33; df = 1,18; P = 0.022) (Table 3). The overwhelming majority of the deer flies captured on the striped trap landed on the black areas and avoided the white.

Experiment 8, repeat of the size test with FL-5 Neon blue pot traps: Part one indicated a significant size effect (F = 1.59; df = 4, 45; *P* = 0.019) LSD = 2.32 (Table 2). Part two evaluating 15, 20, and 25 cm traps did not indicate significant size differences (F = 1.02; df = 2,29; *P* = 0.37). Trap captures in relation to FL-5 Neon blue trap size differed from the results obtained with the black traps in experiment 4 (Table 2).

Experiment 9, background contrast: A FL-5 Neon blue trap on a white background captured significantly more *C. vittatus*/*C. pikei* (16.7 ± 2.2) than traps with a FL-5 Neon blue background (11.6 ± 1.1) which captured significantly more than the traps with a background of aluminum foil (6.7 ± 1.0) (F = 10.49; df = 2,42; *P* = 0.0002) LSD = 4.44. In the blue trap with blue background treatment, some deer flies landed on the background which decreased trap capture.

Experiment 10, trap height. All *C. vittatus*/*C. pikei* deer flies were captured on the traps placed at 75 and 150 cm above ground. No deer flies were captured on traps placed higher.

Experiment 11: Blue silhouettes of 60 × 120 cm had no effect on fly response in any orientation relative to trap placement.

Experiment 12, response to odors: Response by *C. vittatus*/*C. pikei* to octenol (5.1 ± 1.5) was not significantly different from the unbaited control (5.2 ± 0.8) (F = 0.01; df = 1,31; *P* = 0.93). Similarly, no differences were found in response by *C. vittatus*/*C. pikei* in these bioassays to FL-5 Neon blue traps baited with acetone (11.9 ± 3.0 vs 10.6 ± 1.2), CO_2 (5.9 ± 1.1 vs 5.2 ± 0.9) or DEET (control -10.0 ± 2.8 vs DEET - 8.4 ± 3.1).

C. macquarti: Experiment 1, size and color interaction: The two-way analysis of variance indicated that color (F = 14.38; df = 1,66; *P* = 0.0003) had a significant effect on *C. macquarti* response with FL-5 Neon blue trap collection (11.4 ± 1.1) greater than black traps (6.5 ± 0.7). Size (10, 15, 22.5 cm) was not significant (F = 1.16, df = 2, 66; *P* = 0.32) nor was the color x size interaction (F = 1.81, df = 2, 66; *P* = 0.17).

Experiment 2, background contrast: Background color had a significant effect on trap response by *C. macquarti,* (F = 3.55; df = 2,45; *P* = 0.037) LSD = 0.57 with FL-5 Neon blue (6.81 ±

TABLE 3. RESPONSE OF *CHRYSOPS VITTATUS* WIEDEMANN /*C PIKEI* WHITNEY TO PLANT POT TRAPS OF DIFFERENT COLORS AND STRIPES WHEN "TROLLED" ON A MOVING VEHICLE.

Trap Type (15 cm)	Experiment 5	Experiment 6	Experiment 7
Black	3.43 ± 0.46 B[a]	—	2.84 ± 0.39 A
Red	3.87 ± 0.68 A	—	—
Neon Blue	8.10 ± 0.51 B	4.20 ± 0.60 A	—
Royal Blue	—	3.95 ± 0.62 A	—
Dutch Blue	—	2.05 ± 0.40 B	—
Black & White Stripes	—	—	1.72 ± 0.22 B

[a]Means in columns not followed by the same letter are significantly different as determined by LSD.

0.93) and white (6.69 ± 1.46) equal, but greater than response to traps with an aluminum foil background (3.63 ± 0.97).

Discussion

The specimens of *C. vittatus*/*C. pikei* and *C. macquarti* captured on traps in this study were almost all females with only a rare male. Parity of the females was not tested. Occasional samples of captured flies dissected for gut contents found about equal numbers with and without clear gut contents on any date. No dissected deer flies contained evidence of blood feeding.

The truck-mounted experimental apparatus containing the entire array of traps presented a moving attraction at a distance (ca. 10-15 m = maximum distance from the woods, most replicates were closer to vegetation) to responding flies which then selected a single trap on which to land. The distance from the woods in these bioassays is the distance that Phelps and Vale (1976) suggested was the maximum from which tabanids could detect a moving target. The truck-mounted trap design is analogous to the cluster design of Hribar et al. (1991b) and Hribar and Foil (1994) and provides more precise comparison of fly treatment preference for activation and landing cues than other designs that offer single trap replicates in separate locations. The trolling trap does not fully measure fly attraction, as attraction could occur without landing and capture.

The flight orientation pattern and degree of aggression exhibited by *Chrysops* spp. to the traps during trolling was variable, and while the causes were not measured in these experiments, these behaviors were most likely related to the time since emergence, feeding history and the prevailing weather conditions. During periods of relatively warm temperatures, deer flies at the time of the experiments predominantly flew straight into the trap from any direction attacking the trap in a manner similar to Vespidae defensive behavior. Some deer flies oriented from behind the trap and followed it for a short period of time before landing. This behavioral response could be induced by increasing the vehicle speed. Other orientation behavior included circling around several traps and then landing. Often captured deer flies tended to be in clusters on the traps which may have been the result of short range visual orientation to other flies that had been captured previously. However, an experiment placing either live or dead tabanids of different sizes and species on the traps in different places as bait prior to trolling (data not shown) had no effect on deer fly landing patterns. Generally, the first arriving deer flies landed on the trap positions at random, but tended to land on the top portions first and filled in other areas as available.

Movement of the traps was necessary to elicit deer fly landing. Both quality and quantity of trap movement were important. The method of trap suspension on the metal rods allowed the traps to rotate and to shake back and forth during trolling. Trolling on the moving truck provided angular displacement and velocity. A crude determination indicated that a speed of ca. 3.16 m/sec (7 mi/h) was the maximum vehicle velocity at which flying *C. vittatus*/*C. pikei* could land on the traps. This figure is within the range of the flight speed reported for tsetse flies (2.5-5m/s) (Gibson and Brady 1985). Deer flies, as do many hematophagous Diptera (Galun 1977), will follow a moving vehicle and will continue to circle it for a brief period after it stops moving. Occasionally, deer flies would land on traps after the truck became stationary. Manually rotating or shaking the traps after stopping the truck had little effect on deer fly landing on traps. Hanging traps such as blue balloons or pots swaying in the wind in the same area (as the stationary truck) also only occasionally induced deer flies to land.

No significant response by the *Chrysops* spp. to any behavioral chemicals tested (acetone, octenol, CO_2, DEET) were observed in these experiments. Trap movement, color and size either singularly or in combination were perhaps such strong stimuli to the *Chrysops* spp. tested that odorant effects were not detectable. For example, we were only able to detect the effect of trap size by using black traps that are less preferred than blue. Alternatively, because the traps measure landing behavior, the effects of attractants in our design perhaps were undetectable. Other species of tabanids including large horse fly species were regularly observed flying near the traps or the truck. However, very few were captured which may indicate that the trolling traps provided some of the primary attractive stimuli, (i.e., movement and color), but not the secondary or final landing cues (Gibson and Torr 1999). Nevertheless, the repellent DEET must ultimately affect fly landing behavior which was measurable in these bioassays. No repellent affect of DEET was observed. Moreover, true attractants if operative would in part serve to activate and draw flies from a greater distance to the trap vicinity while the landing behaviors would likely remain constant for the test species. As a result, if attractants were operative, higher numbers of flies in the test replicates using attractants (in comparison to other experiments without chemicals) would be expected. Higher numbers were not observed, however, the appropriateness of the trolling trap bioassay for determining the effects of chemicals on deer fly behavior remains for future research.

Many times during the course of the experiments, *C. vittatus*/*C. pikei* apparently were eliminated from local areas that had been repeatedly trolled. Lack of deer flies made it necessary to find populations at new locations. During these searches we trolled the traps through different landscape habitat types. We found that habitat characteristics affected deer fly presence and abundance as shown previously by Dale and Axtell (1976). *C. vittatus*/*C. pikei* was found almost exclusively on the edges of open areas adjoining woodlands (within 25-30 m of the borders) and in narrow road corridors through forests. *C. marquarti* was found further from the forest edge in more open habitats such as old fields with sparse tree density. The two species were found together in road corridors through areas adjacent to habitats described above.

The collective results of these experiments indicate the importance of habitat context and the hierarchy of stimuli determining the behaviors used in the orientation to and landing on hosts by *C. vittatus*/*C. pikei, C. macquarti* and presumably related *Chrysops* spp. Habitat characteristics such as amount of sunlight and vegetation pattern that may affect micro habitats of perches where the species were found during trolling were different and deserve further research enabled by trolling traps. Height of deer fly flight above ground as indicated by orientation to traps was always less than 3.0 m. Roberts (1976b) captured 70% of tabanids in Malaise traps with openings at less than 1.8 m above ground and Snoddy (1970) and Schulze et al. (1975) reported similar flight patterns by other tabanids.

C. vittatus/*C. pikei* and *C. macquarti* were strongly attracted to movement of 3-dimensional objects and would rarely land on stationary targets. However, other horse fly species have been captured effectively using flat panels (Allan and Stoffalano 1986, Moore et al. 1996). Moving targets may be more attractive to most tabanids (Phelps and Vale 1975). Quality of movement is important to the captured *Chrysops* spp. such that angular displacement is required to elicit landing. Movement of the trap without angular displacement—stationary placement with rotation or shaking—often attracted deer flies in low numbers, but induced landing only in a few cases when the deer flies had just followed the moving vehicle.

Deer flies preferred the 3-dimensional traps presumably due to the increased reflectiveness of the surface as shown by Thorsteinson et al. (1966). Deer fly response to traps was also strongly affected by color and size and the interaction of color with size was evident in the results of experiments 1A, 2, 4, 6, and 8 (Table 2). Blue was preferred over black and red, which were preferred over traps of clear plexiglass, yellow and white. Trap spectral reflectance patterns indicated that intensity and ultraviolet (UV) light may be important determinants of *Chrysops* spp. behavior (Fig. 2). FL-5 Neon blue captured the highest numbers of deer flies and was of medium intensity, the most saturated (pure) blue and reflected no UV. Royal blue had the lowest intensity and also reflected a low level of UV. Dutch blue reflected a high percentage of UV and was the most intense (brightest). Color is primary and size is secondary in the behavioral hierarchy as indicated by the significant interaction in the behavioral response to size of the less preferred black traps (Table 2).

Contrast was also an important determinant of deer fly behavior. A white background providing the most contrast increased trap catch significantly. Aluminum foil which provides high contrast but reflects ca. 80% UV (Allan and Stoffolano 1986) significantly decreased trap catch for *C. vittatus*/*C. pikei* and *C. macquarti* and these results agree with reports by Allan and Stoffolano (1986) for *T. nigrovittatus* and the results of the blue series (Exp. 6, Fig. 2) above. The addition of white stripes to black traps also significantly reduced trap collection (95 *C. vittatus*/*C. pikei* on the black traps vs 34 on black and white striped traps).

Although silhouettes have been shown to be important cues for tabanids (Phelps & Vale 1976) including *Chrysops* spp. in the presence of CO_2 (Browne & Bennett 1980), we found no effect when traps were trolled with silhouettes without CO_2.

A Malaise trap run concurrently with these studies and placed along the edge of a forest with central swampy areas (the edges and road through the middle of this ca. 2 ha area were used for trolling) indicated that the trolling trap did not catch all of the *Chrysops* spp. present in our trap/trolling locations. However, we apparently captured most *Chrysops* spp. present that generally attack humans in the area. *Diaclorus ferrugatus* (F.) was not captured by trolling, although this species also attacks humans usually around the lower legs. Other species regularly captured included *C. geminata* Wiedemann, *C. dorso-vittatus* Hine, and the *C. flavidus* Wiedemann complex. *C. davisus* Walker, *Tabanus trimaculatus* Palisot de Beauvois, *T. pumilus* MacQuart, and *T. fulvulus* Wiedemann were captured occasionally. Approximately 30 *Chrysops* spp. have been captured by using the Malaise trap in Monticello, Florida (Mizell & Roberts 1997-1999, unpublished).

Many humans are allergic to deer fly bites and often develop painful boil-like areas in response to tabanid bites. Even in the absence of allergic reactions, deer flies are a nuisance and bites are painful. Our results provide an inexpensive method to reduce attacks by certain deer fly species and to suppress deer fly populations in small areas such as dooryards. Placing a small blue trap covered with Tanglefoot such as a plastic drinking cup attached to a hat either worn or carried on a walking stick, exploits the deer fly's tendency to attack the highest point on the target animal, and suppresses or eliminates most deer fly species that land on the body. Because deer flies are ambush predators, placement of traps on a lawnmower, 4-

wheeler, or other vehicle will enable trapping-out in small areas such as dooryards for a few days or so until new deer flies re-colonize the area.

As with all tabanid traps developed to date, the trolling trap has limitations. The trap catches predominately female *Chrysops* spp., but only a few other tabanids. The trap requires specific movement (angular displacement) in order to attract deer flies and has the added disadvantage of requiring a sticky substance to trap landing insects. However, cleanup of Tanglefoot is easy with soaps containing d-limonene. During this study many other unidentified species of biting flies were captured on the trolling trap. As such our trolling trap offers a novel method to detect and collect *Chrysops* spp. and perhaps many other Dipteran species, and may be useful to investigate a variety of scientific questions heretofore unattainable. In addition, the simple, economical methodology has great potential for demonstration of basic insect behavior to science students of all ages.

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