COMPARISONS OF LIGHT TRAPS FOR MONITORING ADULT *CULICOIDES VARIIPENNIS* (DIPTERA: CERATOPOGONIDAE)[1]

FREDERICK R. HOLBROOK AND RONALD J. BOBIAN

U.S. Department of Agriculture, Agricultural Research Service, Arthropod-borne Animal Diseases Research Laboratory, P.O. Box 3965, University Station, Laramie, WY 82071-3965

ABSTRACT. From 1984 to 1986 tests were conducted to evaluate 4 trap types (ABADRL baffle trap, New Jersey trap, CDC trap, and updraft trap) with or without an incandescent light source, a suction fan or dry ice (as a source of CO_2) for sampling adult *Culicoides variipennis*. The fewest flies were caught in the CDC and updraft traps. The New Jersey trap with suction, a strong light source and dry ice caught most flies, due to a significant increase in nulliparous females. The same New Jersey trap without dry ice caught the highest proportion of flies that had taken at least one bloodmeal. This trap would therefore be recommended for use in trapping for virus assay under epizootic conditions.

INTRODUCTION

The biting midge, *Culicoides variipennis* (Coquillett), is the common vector of bluetongue virus (BTV) in ruminants in the United States (Price and Hardy 1954, Jones and Foster 1978). Included in research on the biology, ecology and behavior of this insect at our laboratory are investigations to develop specialized survey techniques for the immature and adult stages.

There have been few comparisons of trapping methods for *Culicoides* spp. Belton and Pucat (1967) tested traps with incandescent bulbs or white or black light fluorescent tubes. Holbrook (1985) evaluated traps with incandescent light sources with or without dry ice as a source of carbon dioxide (CO_2). Jamnback and Watthews (1963) compared landing rates and light trap catches. Rowley and Jorgensen (1967) tested light traps with incandescent bulbs or black light fluorescent tubes. Service (1974) evaluated suction traps. Tanner and Turner (1975) and Zimmerman and Turner (1983, 1984), compared black light fluorescent tube traps, vacuum traps, and animal-baited traps.

Among these studies only those by Holbrook (1985), Rowley and Jorgensen (1967), and Zimmerman and Turner (1983, 1984) have included information on *C. variipennis*. Rowley and Jorgensen (1967) found that a trap with a 15 w fluorescent black light tube (voltage not given) caught 11 times as many adults as a New Jersey trap with a 110 v, 40 w incandescent light and 55 times as many adults as a 6 v battery-operated New Jersey trap with a 50 candlepower lamp. Zimmerman and Turner (1983) reported that a black light trap caught about the same number of female *C. variipennis* as an animal-baited drop trap, but about twice as many females as a vacuum trap; parous rates in the black light and animal-baited traps did not differ. Nelson (1965) reported that adding dry ice as a source of CO_2 attracted large numbers of adults. No data were presented comparing catches without CO_2; however, a preponderance of nongravid females was interpreted as evidence of host-seeking. Lillie et al. (1979) reported that adding dry ice to baffle traps with one or two 6 v light bulbs increased catches of *C. variipennis* females 13-fold. Holbrook (1985) reported that a 12 v CDC miniature light trap with a CM-47 light bulb and dry ice caught 17 times as many females as the same trap without dry ice. The catch consisted almost exclusively of host-seeking (nulliparous and parous empty) females. Below we describe field trials conducted from 1984 through 1986 to evaluate a variety of trap types as sampling tools for adult *C. variipennis*.

MATERIALS AND METHODS

The traps selected for the 1984 comparisons were: 1) modified baffle trap (Lillie et al. 1979, Holbrook 1985), designated as the ABADRL standard baffle trap, with a 50 w, 30 v incandescent bulb as a light source, and operated at 24 v for safety; 2) baffle trap as in (1) above, with ca 200 g of dry ice double wrapped in paper bags and suspended above the trap cover; and 3) 6 v CDC trap (Model 512, John W. Hock Co., Gainesville, FL) without a light source but with dry ice provided in the same manner as in (2) above.

The traps selected for the 1985 comparisons were: 1) ABADRL standard baffle trap; 2) 110 v New Jersey mosquito light trap (Hausherr's Machine Works, Toms River, NJ) with a 40 w incandescent bulb; and 3) the same New Jersey trap as in (2) above with bagged dry ice as previously described.

The traps selected for the 1986 comparisons were: 1) ABADRL standard baffle trap; 2) 110

---

[1] This paper reports the results of research only. Mention of a commercial or proprietary product does not constitute a recommendation or an endorsement of this product by the U.S. Department of Agriculture.

v New Jersey light trap with a 40 w incandescent bulb; and 3) 12 v updraft trap (Fig. 1).[2] The body of the updraft trap consisted of a 30.5-cm length of opaque polyvinyl chloride plastic pipe (15.2-cm inside diam) with a 23-cm diam rain cover. An inverted plastic funnel (26-cm mouth diam, 2.6-cm neck inside diam) was attached to the bottom of the body with two 5 w incandescent bulbs mounted below the mouth of the funnel on a metal strip; a screen (3-mm mesh) at the mouth of the trap excluded large insects. A 14-cm diam 3-blade propeller driven by an electric motor was mounted 4 cm from the upper rim of the trap body to provide the updraft of air to draw the insects through the neck of the funnel. The trap cage consisted of a plastic cylinder 10 cm diam × 9 cm height with a removable screened top and a fixed bottom plate with a 4.4 cm diam hole in the center. A plastic cylinder 4.4 cm outside diam, 3.7 cm inside diam × 3 cm height protruded into the cage,and the neck of the funnel was milled to fit snugly into this entrance. The opening into the cage was provided with a counterbalanced cover that lifted when the fan was in operation but closed under its own weight if the fan stopped, thus preventing accidental loss of insects. The trap was wired dually for continuous operation or for control by a photosensitive cell.

The experimental design was similar to that described by Holbrook (1985), with 3 trapping sites located in a 90 km^2 area on the western drainage of the South Platte River northeast of Denver.[3] In 1984 and 1985, site 1 was a dairy cattle dry lot with one permanent and several intermittent *C. variipennis* larval sites on the premise. Site 2 was centrally located 0.5–0.7 km from 4 small farm ponds with permanent and intermittent larval sites. At site 3, the nearest potential larval site was 1.1 km to the southwest. In 1986, sites 1 and 2 were the same as those used in 1984 and 1985, but site 3 was relocated and was 0.3 km from a farm pond. At each site, a trap was placed at the midpoint of each of 3 sides of a large barn or storage structure to reduce direct competition but allow sampling from the same *C. variipennis* adult population on a given night. Traps were operated from 0.5 h before sunset to 0.5 h after sunrise for 3 nights over a 7-day period and were rotated to a new side of the structure each trapping night to reduce position effects. Trapping periods were: 1984, 7 periods (21 trap nights), June 14 to September 13; 1985, 8 periods (24 trap nights), June 4 to September 12; and 1986, 9 periods (27 trap nights), July 6 to September 3.

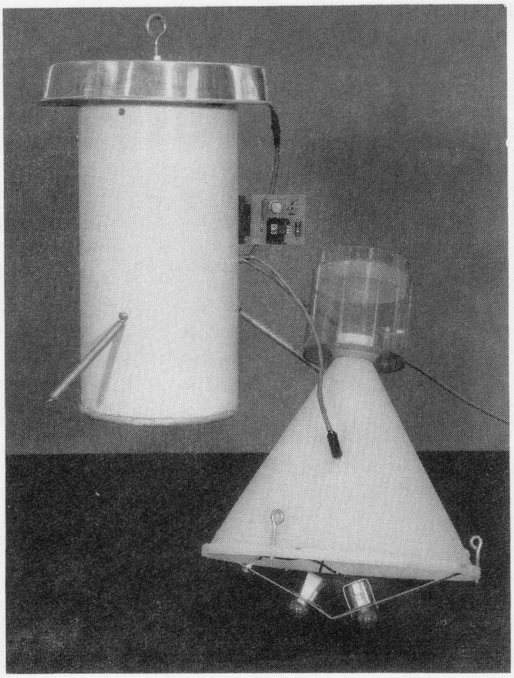

Fig. 1. Twelve-volt updraft trap with two-watt light bulbs.

Insects were collected into ethylene glycol or 70% ethanol and preserved in 70% ethanol for sorting. Parity of females (nulliparous, parous empty, engorged and gravid) was determined by the method of Potter and Akey (1978). Data were transformed to log (X + 1) and compared by analyses of variance and Fisher's least significant difference tests in a statistical program (Statview 512+, Brainpower Inc., Calabasas, CA).

RESULTS

Total catches of *C. variipennis* were similar in 1984 and 1985, followed by a 5- to 6-fold increase in the catch of females and a 7- to 9-fold increase in the catch of males in 1986. In 1984, there were no significant differences in the catches of females between periods, whereas in 1985 and 1986, differences were present (1985: F = 3.64; df = 7, 144; $P < 0.001$; 1986: F = 22.10; df = 8,162; $P < 0.0001$), with the highest catches recorded during July of both years. The results of all tests are summarized in Table 1.

---

[2] Personal communication, H. A. Standfast, Commonwealth Scientific and Industrial Research Organisation, Australia (CSIRO), Division of Tropical Animal Science, Long Pocket Laboratories, Meiers Rd., Indooroopilly, Queensland, Australia.

[3] Sites were located in Sections 1 (1985 and 1986), 35 (1985 and 1986) and 36 (1986) of the Johnstown, Colorado Quadrangle (N4015-W10452.5/7.5) and in Section 33 (1985) of the Gowanda Quadrangle (N4007.5-W10452.5/7.5), 7.5 Minute Series, Geologic Survey, U.S. Department of the Interior.

Table 1. 1984–86. Total catches of male and female *Culicoides variipennis*, and numbers and percentages of nulliparous (N), parous empty (P), engorged (E) and gravid (G) females in the catches. Traps were as follows: as a standard, 24 v ABADRL baffle trap, 30 v, 40 w light (1), with dry ice (2); 6v CDC trap, no light source (3); 110 v New Jersey trap, 40 w bulb (4), with dry ice (5); 12 v updraft trap, two 5 w light bulbs (6). Catches within groups within years followed by the same letter show that mean catches per trap night are not significantly different.

	Total caught		Female parity							
			Number				Percent			
Trap	Male	Female	N	P	E	G	N	P	E	G
				1984 (21 trap nights)						
1	148a	269a	81b	77a	12a	99a	30c	29a	4a	37a
2	139a	326a	165a	99a	15a	47b	51b	30a	5a	14b
3	3b	52b	38c	14b	0b	0c	73a	27a	0a	0c
				1985 (24 trap nights)						
1	43b	161b	48b	56a	6a	49a	30b	35a	4a	30a
4	64b	173b	50b	58a	4a	59a	29b	34a	2a	34a
5	118a	396a	185a	107a	9a	95a	47a	27a	2a	24a
				1986 (27 trap nights)						
1	745a	1,247a	335a	224a	44a	644a	27a	18a	4a	52a
4	1,093a	1,940a	684a	523a	29a	704a	35a	27a	2ab	36a
6	265b	324b	146b	49b	1b	128b	45a	15a	<1b	40a

In 1984, the standard baffle traps or standard baffle traps with dry ice caught similar total numbers of male or female *C. variipennis*, and both caught significantly more males ($F = 23.52$; df = 2, 144; $P < 0.0001$) and females ($F=24.98$; df=2, 144; $P < 0.0001$) than the CDC traps without light but with dry ice. The catches of nulliparous females in the 3 trap types were significantly different ($F = 13.44$; df = 2, 144; $P < 0.0001$). The standard baffle traps and the standard baffle traps with light and dry ice caught similar total numbers of parous empty females, and both caught significantly (approximately 5 times) more than the CDC traps without light, but with dry ice ($F = 16.25$; df = 2, 144; $P < 0.0001$). The standard baffle traps or standard baffle traps with light and dry ice caught small numbers of engorged females throughout the season, representing approximately 5% of the seasonal catch of both trap types. The standard baffle traps caught significantly more gravid females ($F = 23.48$; df = 2, 144; $P < 0.0001$) than did the standard baffle traps with light and dry ice. The CDC traps without light but with dry ice caught neither engorged nor gravid females.

In 1985, the standard baffle traps and New Jersey traps with light caught equal numbers of males and females, and both caught significantly fewer males ($F = 3.48$; df = 2, 144; $P < 0.03$) and females ($F = 7.49$; df = 2, 144; $P < 0.0001$) than did the New Jersey traps with light and dry ice. The latter caught significantly more nulliparous females ($F = 13.22$; df = 2, 144; $P < 0.0001$) than both the standard baffle and New Jersey traps with light only, which were equal. Total catches of parous empty or gravid females were not significantly different for all three trap types. Engorged females represented 2–4% of the catches of the 3 trap types.

In 1986, the catches of males and females in the New Jersey traps and the standard baffle traps were again statistically similar, and both caught significantly more males and females than updraft traps ($F = 14.73$; df = 2, 240; $P < 0.001$). The catches of nulliparous, parous empty and gravid females were similar for the standard baffle and New Jersey traps, and both caught significantly more flies than the updraft traps (nulliparous, $F = 19.32$; parous empty, $F = 26.92$; gravid, $F = 24.77$; all, df = 2, 162; all, $P < 0.0001$). Engorged flies represented 3% of the catches in the standard baffle traps and 2% in the New Jersey traps, while only one engorged female (0.3%) was caught in the updraft traps.

From 1984 to 1986 there were no significant differences in the percentages of females which were nulliparous, parous empty or gravid caught per trap night in the standard baffle traps. Consequently, there were no differences for host-seeking females (nulliparous + parous empty) or for females that had digested at least one bloodmeal (parous empty + gravid). The standard baffle traps caught means of 56% females presumably engaged in host-seeking (29% nulliparous + 27% parous empty) and 67% females that had digested at least one bloodmeal (27% parous empty + 40% gravid). Of the females caught in the New Jersey traps with light in 1985 and 1986, means of 62% engaged in host-seeking (32% nulliparous + 30% parous empty) and 65% that had digested at least one bloodmeal (30% parous empty + 35% gravid) were not significantly different from the mean percentages for the catches in the standard baffle traps for those same years.

In 1984, the standard baffle traps with dry ice caught 21% more female *C. variipennis* than the same traps without dry ice. The former caught an equal number of parous empty females, significantly more nulliparous females (F = 13.44; df = 2, 144; $P < 0.0001$) and significantly fewer gravid females (F = 23.48; df = 2, 144; $P < 0.0001$). The 81% host-seeking females (51% nulliparous + 30% parous empty) caught in the standard baffle traps with dry ice was significantly greater (F = 12.24; df = 1, 30; $P < 0.001$) than the 59% host-seeking females (30% nulliparous + 29% parous empty) caught in the standard baffle traps. Of females that had digested at least one bloodmeal, the 44% (30% parous empty + 14% gravid) in the standard baffle traps was significantly less than the 66% (29% parous empty + 37% gravid) in the standard baffle traps with dry ice.

In 1985, the New Jersey traps with dry ice caught 128% more total females than the same traps without dry ice. Those traps with dry ice caught equal numbers of parous empty or gravid females as the traps without the dry ice, but significantly more nulliparous females (F = 13.22; df = 2, 144; $P < 0.0001$). Of host seeking females, the 74% (47% nulliparous + 27% parous empty) caught in the traps with dry ice was significantly greater (F = 5.93; df = 1, 30; $P < 0.02$) than the 63% (29% nulliparous + 34% parous empty) in the traps without dry ice. Of females with at least one bloodmeal, the 51% (27% parous empty + 24% gravid) caught in the traps with dry ice was significantly less than the 68% (34% parous empty + 34% gravid) caught in the traps without dry ice.

DISCUSSION

The trends of trap catches during 1985 and 1986 were representative of those we have previously observed for *C. variipennis* in the irrigated high plains of Eastern Colorado. Typically, *C. variipennis* populations peak in June or early July, decline in August during the hottest, driest portion of the summer, and a small peak then occurs in September.

The effects of light source on the parity of female *C. variipennis* taken in traps was noted by Holbrook (1985), who reported that the standard baffle traps caught about equal numbers of females engaged either in host-seeking or egg-laying. With lower catches during 1984 and 1985, the standard baffle trap caught about two-thirds host-seeking females and one-third gravid females. In 1986, when the highest catches were recorded, the relative proportions were similar to those previously reported.

Carbon dioxide alone did not attract gravid female *C. variipennis* and appeared to act as a repellent in combination with incandescent light. In 1984, when no gravid females were caught in the traps with dry ice and no light source, 14% gravid females were caught in the traps with dry ice and light; and 37% gravid females were caught in the traps with light alone. In 1985, with the addition of a suction fan, traps with dry ice and light caught 24% gravid females, significantly more than the traps without fans in 1984; traps with light alone caught 35% gravid females, similar to the catch of the traps without fans in 1984. In the 1984 tests, the incandescent light appeared to attract the gravid females, but more than half were then repelled by the CO_2. The presence of the fans in 1985 increased the proportion of the gravid females captured, indicating the repellency occurred in close proximity to the trap.

The CO_2, perhaps perceived as host exhalations, appeared to serve as an attractant for females seeking a bloodmeal. There was also an apparently greater preference for CO_2 by nulliparous females (those seeking their initial bloodmeal) than by parous empty females. In 1984, when traps with dry ice as the sole attractant caught only host-seeking females, the ratio of nulliparous females to parous empty females was 3:1. In both 1984 and 1985, this ratio was 2:1 in traps with dry ice and light, and 1:1 in traps with light only.

Holbrook (1985) also pointed out that traps in which a higher percentage of parous insects are collected would be preferred for virus assay. In the present as well as earlier tests, a strong light source increased the proportion of gravid female *C. variipennis.* Addition of dry ice greatly increases the percentage of nulliparous flies and decreases the percentage of gravid flies, although this decrease can be overcome partially by the presence of a suction fan. New Jersey traps with or without dry ice would therefore appear to be the most effective we have evaluated for making live collections of female *C. variipennis* for virus assay, since the fan present in this trap is necessary to prevent insects from escaping. Consider as an illustration that if 1,000 female *C. variipennis* were caught in a New Jersey trap with light only, our results indicate that about 700 could be expected to have taken at least one bloodmeal. Further, the same trap with dry ice added would catch about 2,000 females, of which about 1,200 could be expected to have taken one or more bloodmeals. During an epizootic of a disease such as bluetongue, large populations of

C. variipennis could be expected; and trap catches of this species should be high, thus the New Jersey trap without dry ice would be a satisfactory choice. Also, CO_2 as dry ice or in pressurized tanks is often difficult to obtain under field conditions; and its use complicates the servicing and operation of traps. In studies of populations of *C. variipennis* under enzootic conditions, there are often fewer insects present. Addition of CO_2 to achieve greater insect catches with improved chances for virus isolation would be more justifiable.

In summary, the catches of female *C. variipennis* in these field trials indicate that, under normal conditions, incandescent light traps (with or without a suction fan) catch about equal proportions of nulliparous, parous empty and gravid flies. A suction fan increases the total catch when populations are high. Carbon dioxide as dry ice increases the proportion of flies in the catch that are host-seeking, particularly of nullipars, and decreases the proportion of gravid flies. This apparent repellency also appears to be very limited in range. Traps with a strong incandescent light source and a fan (with or without dry ice) increase catches of female *C. variipennis* and are recommended for virus assay.

ACKNOWLEDGMENTS

We are particularly grateful to the cooperators on whose premises these studies were conducted. From USDA-ARS, we thank G. Richardson for statistical advice, H. A. Rhodes for assistance in running the traps and sorting collections, W. A. Tabachnick and C. N. McKinnon for assistance in data processing and analyses and N. C. Bozek for manuscript preparation.

REFERENCES CITED

Belton, P. and A. Pucat. 1967. A comparison of different lights in traps for *Culicoides* (Diptera: Ceratopogonidae) Can. Entomol. 99:267–272.

Holbrook, F. R. 1985. A comparison of three traps for adult *Culicoides variipennis* (Ceratopogonidae). J. Am. Mosq. Control Assoc. 1:379–381.

Jamnback, H. and T. Watthews. 1963. Studies of populations of adult and immature *Culicoides sanguisuga* (Diptera: Ceratopogonidae). Ann. Entomol. Soc. Am. 56:728–732.

Jones, R. H. and N. M. Foster. 1978. Relevance of laboratory colonies of the vector in arbovirus research—*Culicoides variipennis* and bluetongue. Am. J. Trop. Med. Hyg. 27:168–177.

Lillie, T. H., R. H. Jones, W. G. Marquardt and R. G. Simpson. 1979. A lightweight, portable, and inexpensive baffle trap for collecting *Culicoides variipennis* (Diptera: Ceratopogonidae). Mosq. News 39:675–677.

Nelson, R. L. 1965. Carbon dioxide as an attractant for *Culicoides*. J. Med. Entomol. 2:56–57.

Potter, H. W. and D. H. Akey. 1978. Pigmentation associated with oogenesis in the biting midge, *Culicoides variipennis:* changes in abdominal tergite patterns. Mosq. News 38:499–504.

Price, D. A. and W. T. Hardy. 1954. Isolation of the bluetongue virus from Texas sheep—*Culicoides* shown to be a vector. J. Am. Vet. Med. Assoc. 124:255–258.

Rowley, W. A. and N. M. Jorgensen. 1967. Relative effectiveness of three types of light traps in collecting adult *Culicoides*. J. Econ. Entomol. 60:1478–1479.

Service, M. W. 1974. Further results of catches of *Culicoides* (Diptera: Ceratopogonidae) and mosquitoes from suction traps. J. Med. Entomol. 11:471–479.

Tanner, G. D. and E. C. Turner, Jr. 1975. Seasonal abundance of *Culicoides* spp. as determined by three trapping methods. J. Med. Entomol. 12:87–91.

Zimmerman, R. H. and E. C. Turner, Jr. 1983. Host-feeding patterns of *Culicoides* (Diptera: Ceratopogonidae) collected from livestock in Virginia, USA. J. Med. Entomol. 20:514–519.

Zimmerman, R. H. and E. C. Turner, Jr. 1984. Dispersal and gonotrophic age of *Culicoides variipennis* (Diptera: Ceratopogonidae) at an isolated site in southwestern Virginia, USA. J. Med. Entomol. 21:527–535.