USE OF DRY ICE TO INCREASE MOSQUITO CATCHES OF THE CDC MINIATURE LIGHT TRAP

VERNE F. NEWHOUSE, ROY W. CHAMBERLAIN, J. GIBSON JOHNSTON, AND W. DANIEL SUDIA [1]

It has been found that dry ice suspended above or beside the CDC Miniature Light Trap, used for live collection of mosquitoes for arbovirus tests, greatly increases the total number of mosquitoes collected and appreciably broadens the species spectrum. Although the efficiency of this combined technique (light trap plus carbon dioxide) has been known for more than 30 years, little practical use has been made of it. As early as 1934, Headlee reported that the delivery of carbon dioxide gas (not as dry ice) over the standard New Jersey light trap for only two hours each evening increased the catch of the trap by 400 to 500 percent. In 1941 he reported additional studies utilizing dry ice as the source for carbon dioxide. Both of these efforts were directed toward actual mosquito control and as such proved impractical. In 1943, Huffaker and Back evaluated the New Jersey light trap, with and without dry ice, in respect to its reliability for proportional estimation of heterogenous mosquito populations. The total catch, all species combined, was increased 8-fold by use of dry ice, but some species were attracted in far greater proportion than their relative abundance, as estimated by various other methods. Therefore, they concluded that the technique was unreliable for quantitative population estimation.

The carbon dioxide-supplemented light trap was first used by Reeves and Hammon to collect living mosquitoes for arbovirus research (1942). Their light trap was a heavy, bulky machine, however, with high electrical power requirements, which probably was a factor in their decision to develop carbon dioxide-baited traps without a light source. These, the well-known "lard-can traps," were used to determine the selective attraction of different concentrations of carbon dioxide for various mosquito species as well as to capture specimens for virus studies (Reeves, 1951; Bellamy and Reeves, 1952; Reeves, 1953).

The recent development of the CDC Miniature Light Trap (Sudia and Chamberlain, 1962), a compact, light-weight, battery-powered unit, and the present

[1] Communicable Disease Center, Public Health Service, U. S. Department of Health, Education and Welfare, Atlanta, Georgia 30333.

availability of dry ice in most parts of the country make the combined use of light and carbon dioxide practical for arbovirus field surveys.

MATERIALS AND METHODS. Small blocks of dry ice weighing between 1 and 2 pounds each (made by sawing a standard 50-pound block into either 36 or 27 equal pieces, a service available at most dry ice suppliers) were wrapped in a double layer of newspaper and suspended by a string above or beside the trap so that escaping carbon dioxide gas dispersed almost directly from the trap site. If smaller pieces were used, they were wrapped additionally in a layer of aluminum foil for greater insulation. On rainy nights foil was used routinely. The traps were turned on and baited between 3:00 and 7:00 p.m. and the mosquitoes removed the following morning from 6:30 to 9:00 a.m. A small amount of dry ice usually remained when this schedule was followed. Earlier baiting was avoided since the mid-day heat caused such rapid sublimation of the carbon dioxide that the supply would not last the night.

The comparative tests reported here comprise 188 trap nights, 72 with the dry ice supplement and 116 without. Part of these were in the Everglades National Park, Florida (44 trap nights with dry ice and 62 without), part in the vicinity of Waycross, Georgia (24 trap nights with and 50 without), and the remainder near Rosehill, eastern North Carolina (4 trap nights with and 4 without). In the Florida and Georgia tests individual traps were run with and without dry ice on alternate nights; also, traps in a series 100 to 300 feet apart were baited alternately. This procedure tended to compensate for possible differences due to location and daily weather conditions. At times, however, several traps in a series were all supplemented with dry ice to determine whether they competed adversely with each other.

The sampling was done at different times to determine effects of carbon dioxide under varying conditions. The Florida Everglades collections were made in April, 1965, a dry period of low mosquito abundance. Those in Waycross, Georgia, were made in May during a period of full moonlight, a condition usually unfavorable for light trap catches. The Rosehill, North Carolina, samples were taken in August, 1965, as part of an investigation of eastern encephalitis in horses. Additional collecting was done in both Florida and Georgia and random observations were also made during other collecting trips in Florida, Georgia, North Carolina, Virginia, Maryland and New Mexico in the summer and early fall months.

RESULTS AND DISCUSSION. One of the problems associated with live collection of mosquitoes for arbovirus tests has been to obtain significantly large samples of a great many species. The combined carbon dioxide-light trap techinque largely solves this problem. The carbon dioxide helps to attract mosquitoes into the operational range of the light trap and greatly increases its effectiveness. The light trap with its fan mechanism is more efficient than a similarly baited "lard-can trap" since capture is not dependent upon mosquitoes finding their way through the entry cone. The attraction of the carbon dioxide is very strong, as evidenced by the fact that some mosquitoes are occasionally found frozen to the ice if it is left unwrapped, and significant numbers of diurnal mosquitoes are drawn so close to the trap as to be caught during daylight hours.

Tables 1, 2 and 3 summarize the results of comparative dry ice-light trap tests in the south Florida Everglades, south Georgia, and eastern North Carolina. Dry ice increased the Florida catch over 4-fold and the Georgia and North Carolina catches approximately 6-fold. It is of interest that the overall increases obtained compare closely with Headlee's increases of 4- to 5-fold. These findings have also been substantiated by random observations made throughout the summer and early fall in other areas. For example, dry ice

TABLE 1.—Comparison of light trap catches made with and without a dry ice supplement, Everglades National Park, Florida, April, 1965, during a dry period of low mosquito abundance.

Species	62 trap nights without dry ice		44 trap nights with dry ice		
	Total mosq.	Mosq. per trap night	Total mosq.	Mosq. per trap night	Fold increase
Aedes infirmatus	5	.08	41	.93	11.6
Aedes taeniorhynchus	535	8.6	3505	79.6	9.3
Aedes triseriatus	..	..	1	.02	..
Anopheles atropos	..	..	3	.06	..
Anopheles crucians	903	14.5	882	20.0	1.3
Anopheles quadrimaculatus	15	.24	24	.54	2.3
Anopheles walkeri	..	..	1	.02	..
Culex (Melanoconion) sp.	232	3.7	934	21.2	5.7
Culex nigripalpus	546	8.8	1418	32.2	3.7
Culex salinarius	3	.04	36	.81	20.3
Mansonia indubitans	4	.06	4	.08	1.3
Mansonia perturbans	..	..	1	.02	..
Psorophora confinnis	4	.06	17	.38	6.3
Uranotaenia lowii	47	.75	50	1.1	1.5
Uranotaenia sapphirina	15	.24	7	.15	..
Wyeomyia mitchellii	3	.04	35	.79	19.8
Total Mosquitoes	2312		6959		
Av. Mosq./trap night		37		158	
Av. fold increase					4.3

TABLE 2.—Comparison of light trap catches made with and without a dry ice supplement, vicinity of Waycross, Georgia, May, 1965, during a full moonlight period.

Species	50 trap nights without dry ice		24 trap nights with dry ice		
	Total mosq.	Mosq. per trap night	Total mosq.	Mosq. per trap night	Fold increase
Aedes atlanticus-tormentor	15	.3	145	6.0	20
Aedes canadensis	25	.5	637	26.5	53
Aedes dupreei	1	.02	4	.16	8
Aedes infirmatus	2	.04	2	.08	2
Aedes mitchellae	..	..	16	.66	..
Aedes triseriatus	..	..	20	.83	..
Anopheles crucians	4404	88.0	6611	275.4	3.1
Anopheles quadrimaculatus	7	.14	10	.41	2.9
Culex (Melanoconion) sp.	70	1.4	107	4.5	3.2
Culex p. quinquefasciatus	..	..	1	.04	..
Culex restuans	1	.02	2	.08	4.0
Culex salinarius	14	.28	118	4.9	17.5
Culex territans	6	.12	9	.37	3.1
Culiseta melanura	518	10.3	305	12.7	1.2
Mansonia perturbans	1882	36.4	11519	479.9	13.2
Psorophora ciliata	..	..	2	.08	..
Psorophora confinnis	7	.14	10	.41	2.9
Uranotaenia sapphirina	86	1.7	45	1.8	1.1
Wyeomyia sp.	3	.06	..	..	..
Total mosquitoes	7041		19563		
Av. mosq./trap night		139		815	
Av. fold increase					5.9

TABLE 3.—Comparison of light trap catches made with and without a dry ice supplement, Rose Hill area, eastern North Carolina, during epidemic survey, August, 1965.

Species	4 trap nights without dry ice		4 trap nights with dry ice		
	Total mosq.	Mosq. per trap night	Total mosq.	Mosq. per trap night	Fold increase
Aedes atlanticus-tormentor	4	1	84	21	21
Aedes canadensis	1	.25	6	2.5	10
Aedes fulvus pallens	..	..	4	1	..
Aedes triseriatus	..	..	4	1	..
Aedes vexans	1	.25	8	2	8
Culex (Melanoconion) sp.	..	..	3	.75	..
Culex p. quinquefasciatus	5	1.3	11	2.8	2.2
Culex salinarius	11	2.8	39	9.8	3.5
Culex territans	1	.25	..	..	..
Anopheles crucians	11	2.8	20	5	1.8
Anopheles punctipennis	3	.75	15	3.8	5
Culiseta melanura	58	14.5	178	44.5	3.1
Psorophora ciliata	1	.25	..	..	..
Psorophora confinnis	7	1.8	20	5	2.8
Psorophora ferox	9	2.3	302	75.5	32.8
Uranotaenia sapphirina	7	1.8	9	2.3	1.3
Total mosquitoes	119		703		
Av. mosq./trap night		30		177	
Av. fold increase					5.9

occasionally increased catches of some species in Florida and Georiga, such as *Aedes taeniorhynchus* (Wied.) and *Mansonia perturbans* (Walker) approximately 10-fold or more.

In Florida in April the number of species collected was increased by 25 percent, *A. triseriatus* (Say), *An. atropos* (D. & K.), *An. walkeri* (Theo.) and *M. perturbans* being collected in traps supplemented by dry ice but not in the nonsupplemented traps. In Georgia, in May, the number of species was increased by 21 percent, with *A. mitchellae* (Dyar), *A. triseriatus, Culex pipiens quinquefasciatus* (Say) and *Psorophora ciliata* (Fab.) taken only in the dry ice-baited traps. In North Carolina the number of species was increased by 19 percent, the additional species being *A. fulvus pallens* (Ross), *A. triseriatus* and *C. (Melanoconion)* sp. However, time and geographical location must be considered in evaluating such results since certain of these species are common at other times of the year or under other climatic conditions and may then be caught in nonsupplemented traps.

In his study on effects of varying amounts of carbon dioxide upon mosquito attraction, Reeves (1953) noted a positive relationship between amount of carbon dioxide and number of *A. nigromaculis* (Lud.) attracted, but an inverse relationship with *C. p. quinquefasciatus.* The present tests were not designed to measure possible repellent effects of carbon dioxide. However, the amounts used were apparently below a repellent level since an increased catch was apparent for essentially all species that were captured in significant numbers with the possible exceptions of *C. territans* (Walker) and *Uranotaenia sapphirina* (O. S.). It is of interest that these two species are believed to feed primarily upon cold-blooded vertebrates.

Placement of the carbon dioxide supplemented light traps was of less importance in insuring a good catch than was the case for traps operating with light alone. Supplemented light traps hung in exposed locations produced satisfactory catches whereas it was usually necessary to place the unsupplemented CDC trap under partial cover to assure optimum yield. Dry ice-baited traps did not reduce the catch of unbaited traps nearby. Neither were the numbers of mosquitoes caught per trap reduced by baiting several traps in a series, indicating that they did not "steal" from each other.

Certain species of mosquitoes are light-trapped only occasionally or in small numbers throughout most of the year either because they are weakly attracted to light or are primarily diurnal in habit. Being able to trap significant numbers of such species for virus tests may enhance arbovirus investigations. In the south Georgia area, for instance, the number of *A. canadensis* (Theo.) trapped in May (table 2) was increased 53 fold when dry ice was added, and an arbovirus isolation was made[2] which may otherwise have been missed. Other examples are found in two daytime biters, *P. ferox* (Humb.) and *A. triseriatus,* which are rarely taken in routine light trap collections in large enough numbers for virus survey purposes. By baiting the light traps with dry ice several hours before nightfall, these species are sufficiently attracted to comprise at times the major ones represented in the total collection. *P. ferox* made up 43 percent of the dry ice-baited catch in North Carolina in August (table 3), an increase over non-supplemented traps of 33-fold. Many were caught during daylight hours; others apparently remained in the vicinity of the traps and were caught during the dusk period.

Mosquitoes captured in late afternoon are exposed for a longer time to the drying effect of the light trap fan, and may also suffer from confinement at higher temperatures. They should therefore be removed from the traps as early as possible the following morning.

Of equal importance to the increased size and variety of the catch with use of dry ice is the considerable saving in time and manpower for collection of a significant sample. Field trips previously requiring a week or more may be reduced to only 2 or 3 days with comparable numbers of mosquitoes caught. The increased collecting efficiency is of special value during epidemic investigations when time is limited and collecting conditions may not be optimal.

It is realized that this method may be impractical in certain areas outside of the United States where dry ice is very expensive or unavailable. However, since the carbon dioxide acts primarily as an animal bait simulant. (Reeves, 1951), a live animal rather than dry ice should serve effectively in combination with light. An increased catch of mosquitoes was noted in British Columbia by one of us when a rabbit and light were combined in a trap of the lard can type. Also, on other occasions, more mosquitoes were caught in CDC light traps mounted above a sentinel chicken pen in Georgia and in the immediate vicinity of a human biting catch-station in the Florida Everglades than in other light traps in the general vicinity.

SUMMARY. The use of dry ice as a carbon dioxide supplement to the CDC Miniature Light Trap increased the catch by at least 4-fold and increased the number of species trapped 20 to 25 percent. By this method significant numbers of certain diurnal species and others not greatly attracted to light were caught, as well as greater numbers of the more commonly light-attracted species. In arbovirus ecological studies, this method produces more adequate samples for virus tests than traps utilizing light alone. It can be particularly valuable for more efficient collection of vector species during certain arbovirus epidemics when large samples must be obtained quickly.

ACKNOWLEDGMENTS. The authors wish to express their appreciation to Mrs. Donna Miller, Mrs. Joyce Dennard and Miss Ruth Gogel of the CDC Arbovirus Vector Laboratory, Atlanta, Georgia, for their capable technical assistance in this study.

---

[2] Unpublished data (Newhouse).

Literature Cited

BELLAMY, R. E., and REEVES, W. C. 1952. A portable mosquito bait-trap. Mosquito News 12(4):256–258.

HEADLEE, T. J. 1934. *In* Jour. Proc. 21st Ann. Meet. New Jersey Mosq. Ext. Assoc. pp. 30–31.

HEADLEE, T. J. 1941. *In* Jour. Proc. 28th Ann. Meet. New Jersey Mosq. Ext. Assoc. p. 10.

HUFFAKER, C. B., and BACK, R. C. 1943. A study of methods of sampling mosquito populations. Jour. Econ. Ent. 36(4):561–569.

REEVES, W. C. 1951. Field studies on carbon dioxide as a possible host stimulant for mosquitoes. Proc. Soc. Exper. Biol. & Med. 77:64–66.

REEVES, W. C. 1953. Quantitative field studies on a carbon dioxide chemotropism of mosquitoes. Amer. Jour. Trop. Med. Hyg. 2(2):325–331.

REEVES, W. C., and HAMMON, W. McD. 1942. Mosquitoes and encephalitis in the Yakima Valley, Washington. IV. A trap for collecting live mosquitoes. Jour. Inf. Dis. 70:275–277.

SUDIA, W. D., and CHAMBERLAIN, R. W. 1962. Battery-operated light trap, an improved model. Mosquito News 22(2):126–129.