OPERATIONAL AND SCIENTIFIC NOTES

AN IMPROVED CONSTANT FLOW DEVICE FOR DISPENSING LIQUID MOSQUITO LARVICIDES TO FLOWING WATER[1]

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Recent research employing liquid formulation of *Bacillus thuringiensis* serotype H-14, (*B.t.i.*), for control of *Psorophora columbiae* (Dyar and Knab) larvae in rice fields has brought about a need for automatic delivery of the formulation at a constant rate. Years ago various devices were utilized for dispensing nonphytotoxic oils or emulsifiable DDT solutions (Dunham 1940, Geib and Smith 1949, Knowles and Fisk 1945, Wisecup et al. 1946). Gahan et al. (1955) devised a system that created a static head of liquid independent of the quantity in the main container. This system produced uniform flow rates. Oils and insecticidal chemicals are no longer used on rice fields. A need to improve and alter the device of Gahan et al. (1955) arose because the diluted *B.t.i.* formulation would not reliably flow through a metal orifice at rates of 50–80 ml/min (reason undetermined) and because of costs of metal valves, nozzle tips and pipe which have greatly increased since 1955. Use of this method by a mosquito abatement district would require large numbers of dispensing containers and low cost is essential. The purpose of this paper is to present an economical and reliable constant flow device to use with flowable concentrate *B.t.i.* formulations.

DESCRIPTION OF THE OPERATING PRINCIPLE AND THE DEVICE. The basic principle utilizes a nearly constant height of liquid column to the outlet orifice; gravity creates the pressure for the flow through the orifice. The flow is a function of viscosity, orifice size and height of the liquid column. The constant height of the liquid column over the orifice (or "static head") is created in a 1″ (2.5 cm) diameter vertical reservoir of pipe outside the main container connected horizontally to it by a supply pipe. Liquid flows from the main container through the horizontal pipe into the vertical tube which is open to the atmosphere. The flow of liquid from the container to the outside reservoir creates a partial vacuum inside the sealed main container, resulting in a cessation of flow. Liquid flows out the bottom of the vertical tube through the hole in the stopcock, or the hole drilled in the solid cap (Fig. 1). As the level of liquid in the vertical reservoir drops below the liquid level in the horizontal connecting tube, air is momentarily allowed to return to the main container. The partial vacuum created inside the main container by removal of some of the liquid is therefore reduced, allowing more liquid to flow out the tube to the vertical reservoir. As more liquid flows into the vertical reservoir tube the horizontal tube is filled, closing off the air return into the main container. The process results in a "bubbling" of air back into the main container at regular intervals, a small fluctuation in the height of the static head (3 to 5 mm) and uniform flow from the orifice until no more liquid is available.

The basic device is constructed from polyvinylchloride (PVC) tubing. (Fig. 1). A 1″ (2.5 cm) hole is cut in the container cap (B). A 1″ (2.5 cm) PVC male threaded adapter (A) with a 1″ (2.5 cm) O-ring (C) is inserted through the hole, with the threads projecting outside the cap. Then a 1″ (2.5 cm) PVC female threaded adapter 2″ (5. cm) long (D) is tightened onto the threads, sealing the cap to prevent leakage. The vertical static head reservoir is formed by connecting a 1″ (2.5 cm) PVC tee (F) to (D) by a short (¾″) (1.9 cm) piece of 1″ (2.5 cm) PVC pipe (E).

Construction of the variable flow rate device is shown in Fig. 1. The 1″ (2.5 cm) tee reservoir (F) is reduced by two PVC reducers (G and H), stepping from 1 to ¾″ (2.5 to 1.9 cm) (G); then from ¾ to ½″ (1.9 to 1.3 cm) (H); finally a ½ to ⅜″ (1.3 to 0.9 cm) threaded reducer is inserted (I). A short piece of ⅜″ (0.9 cm) plastic tubing (J) is used to connect to a 4 mm orifice Teflon® stopcock (K). The rate of flow can be adjusted by opening or closing the stopcock.

The fixed flow rate device is shown by the insert in Fig. 1. This device is much simpler and more economical than the variable flow rate device. A piece of 1″ (2.5 cm) PVC pipe (E) is fitted into the 1″ (2.5 cm) PVC tee (F) serving as the vertical reservoir. A 3½ to 4″ (8.3 to 10.2 cm) length will suffice. A hole is drilled into a 1″ (2.5 cm) PVC diam. cap (L) which is fitted onto the end of the pipe. All the fittings are pressure fitted by hand. No leakage occurred in any of the tests.

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[1] Mention of a trademark, proprietary product or vendor does not constitute a guarantee or warranty of the product by the U. S. Department of Agriculture and does not imply its approval to the exclusion of other products or vendors that may also be suitable.

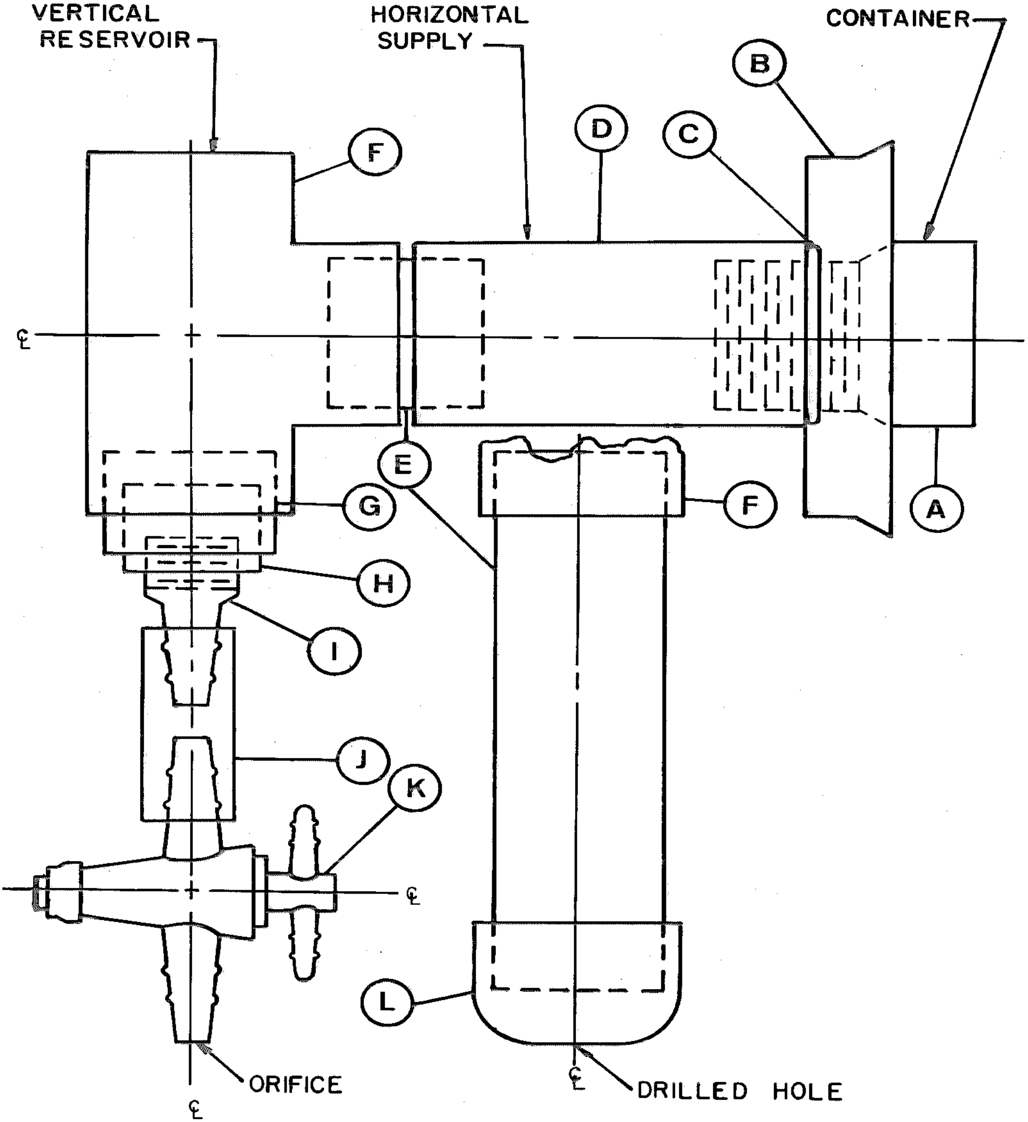

Fig. 1. Constant flow device with variable orifice or fixed orifice (insert). A. 1″ (2.5 cm) PVC male-threaded adapter; B. Cap from 5 gallon plastic container; C. 1″ (2.5 cm) "O" Ring; D. 1″ (2.5 cm) PVC female threaded adapter; E. 1″ (2.5 cm) PVC pipe; F. 1″ (2.5 cm) PVC TEE; G. 1″ to ¾″ (2.5 to 1.9 cm) PVC Reducer; H. ¾″ to ½″ (1.9 to 1.3 cm) PVC Reducer; I. ½″ to ⅜″ (1.3 to 0.9 cm) PVC Threaded Reducer; J. ⅜″ (0.9 cm) plastic tubing; K. 4 mm Teflon stopcock; L. 1″ (2.5 cm) PVC Cap.

The orifice in the cap (L) is drilled with various size bits, depending upon the flow rate desired and the formulation used. The caps can be easily interchanged. Small adjustments in flow rate between that obtained by a different drill bit diameter can be attained by lengthening or shortening the 1″ (2.5 cm) PVC pipe connecting the cap to the tee.

The cost of materials purchased on the open market in January 1982 at Lake Charles, LA, was $11.03 for the variable flow stopcock device and $2.23 for the fixed flow model using the cap with a drilled hole.

Results of flow rate tests. A 3.8 liter (5 gallon) capacity plastic container was used for dispensing formulated *B.t.i.* in rice fields for control of *Ps. columbiae* larvae. The cap was located on the top at the periphery. The container was laid on its side for dispensing a diluted formulation. When the container was level, about 1.4 liters (3 pints) remained after the flow stopped. A slight tilt towards the cap allowed all but ca. 0.5 liter (1 pint) to flow out of the jug. The actual time required to empty the container was observed in eight tests using the stopcock device. The expected vs actual times averaged 266 ± 21.7 min vs. 274 ± 23.4 min. In 3 tests using the drilled cap the expected vs actual times were 260 ± 0.0 vs. 259 ± 4.0 min.

A test was conducted in the laboratory to determine the relative importance of three variables to the flow rate. The variables were the diameter of the orifice, the height of the static head and the dilution ratio of the formulation. The flow rate in ml/min was determined for each test condition. All combinations of the levels of each variable were tested. The orifice sizes were 0.04″ (1.016 mm), 0.041″ (1.041) mm), 0.042″ (1.072 mm), and 0.046″ (1.168 mm). Heights of the static head in the test were 10.0, 11.5, 13.5, 15.5 and 18.5 cm. Concentrations of formulation were 0.0 (water only), 3%, 10%, and 30%. Multivariate analysis by stepwise regression correlation was performed using the model: Flow rate = X (orifice size) + x_2 (height of static head) + x_3 (formulation) + a. Analysis of the data for the correlation coefficient (R^2 value) of each variable independent of the others to the flow rate showed the orifice diameter to have the greatest effect ($R^2 = 0.71$), the static head of next lesser importance ($R^2 = 0.13$) and the concentration of the formulation the least important ($R^2 = 0.09$), for a total of 93% of the variance accounted for by these three variables. The best equation values were: $10{,}734.94\ X + 3.45\ X_2 + 74.84\ X_3 - 493.54$. Therefore, the size of the orifice should be selected first in construction of the flow device to attain the general flow rate desired. Next, the appropriately diluted formulation should be placed in the container and final calibration achieved by adjustment of the height of the static head.

A sample calibration table is presented as Table 1. Flow rates (ml/min) of a 30% TEKNAR[2] suspension in water are presented for 4 orifice sizes, each with 5 static head heights. These data provide guidelines for initial selection of an appropriate combination of orifice size and column height for a desired flow rate. The combination of orifice and column height must be calibrated with the specific formulation and dilution to be dispensed to obtain the desired flow rate.

Acknowledgment. The author recognizes the assistance of Mr. O. R. Willis of the Gulf Coast Mosquito Research Laboratory and the assistance of Alan Inman and Chris Polk of the Jefferson Davis Parish Mosquito Control District in testing the device.

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Table 1. Flow rates (ml/min) of a 30% concentration of TEKNAR[2] in water for 4 orifice sizes and 5 heights of liquid column.

Column ht (cm)	Orifice size			
	0.040″ (1.016 mm)	0.041″ (1.041 mm)	0.042″ (1.072 mm)	0.046″ (1.168 mm)
10.0	32	36	40	80
11.5	38	38	40	90
13.5	66	48	48	100
15.5	50	56	60	120
18.5	54	60	62	132

[2] A flowable concentrate formulation of *B.t.i.* produced by Sandoz, Inc., 480 Camino Del Rio South, San Diego, CA 92108.

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DO MOSQUITOES FEED ON TROUT?[1]

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In searching unfamiliar literature for documented occurrences that may have led the public to the conviction that effective mosquito control was possible, this reviewer encountered a number of highly interesting items that he believes should be made easily available to current mosquito research and control workers. One such, Mrs. C. B. Aaron writing in the Lamborn Prize Essays (Lamborn 1890), discusses harmful effects of mosquitoes on page 37, as follows: "Perhaps the most surprising charge made against them (Mosquitoes) is that of Murray, who states that he has observed the imago of *Culex* light upon baby trout which come to the surface of the water, and literally pump out their unsuspecting little brains before they could escape."

Fortunately, Mrs. Aaron gave a reference (Murray 1885), and after some difficulty the long out-of-print paper by C. H. Murray was located in an old bulletin. The paper is reprinted here in full, in the belief that this lead should be followed up, and either confirmed, or if it should be that C. H. Murray misinterpreted what he saw, then any evidence so indicating should be interpreted and published.

Further credibility is given the Murray report by Dr. L. O. Howard, who stated on page 35 of his book (1901) as follows: "Moreover, there are several instances on record in which mosquitoes have been seen puncturing the heads of young fish." Unfortunately, he did not cite references, so it is impossible to determine if he was referring only to the same reports of Mrs. Aaron and C. H. Murray (Mrs. Aaron was an entomologist, and Mr. Murray evidently was a prospector and amateur naturalist, but I have been unable to determine if he had any specific training in biological observation, although his statement is indeed detailed and appears to represent keen observation).

(From page 243,
Bulletin of the United States
Fish Commission,
Vol. 5, for 1885:)

"60 YOUNG TROUT DESTROYED BY MOSQUITOES."

By C. H. Murray.
(From a letter to Prof. S. F. Baird)

"In the middle or latter part of June, 1882, I was prospecting on the headwaters of the Tumichie Creek, in the Gunnison Valley, Colorado. About 9 o'clock in the morning I sat down in the shade of some willows that skirted a clear but shallow place in the creek. In a quiet part of the water where their movements were readily discernible, were some fresh-hatched brook or mountain trout, and circling about over the water was a small swarm of mosquitoes. The trout were very young, still having the pellucid sack puffing out from the region of the gills, with the rest of the body almost transparent when they would swim into a portion of the water that was lighted up by direct sunshine. Every few minutes these baby trout—for what purpose I do no know, unless to get the benefit of more air—would come to the surface of the water, so that the top of the head was level with the surface of the water. When this was the case a mosquito would light down and immediately transfix the trout by inserting its proboscis, or bill, into the brain of the fish, which seemed incapable of escaping. The mosquito would hold its victim steady until it had extracted all the life juices, and when this was accomplished, and it would fly away, the dead trout would turn over on its back and float down the stream. I was so interested in this before unheard-of destruction of fish and I watched the depredations of these mosquitoes for more than half an hour, and in that time over twenty trout were sucked dry and their lifeless bodies sent floating away with the current. It was the only occasion when I was ever witness to the fact, and I have been unable by inquiry to ascertain if others have observed a similar destruction of fish. I am sure the fish were trout, as the locality was quite near the snow line, and the water was very cold, and no other fish were in the stream at that altitude. From this observation I am satisfied that great numbers of trout, and perhaps infant fish of other varieties in clear waters, must come to their death in this way; and if the fact has not

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[1] This item has been taken from a portion of the paper presented at the 1980 Annual Meeting of the AMCA, at Salt Lake City, April 13–17, 1980.

been recorded it is important to those interested in fish culture."

A not-very-closely-related report, also by Mrs. Aaron on page 47 of the Lamborn Prize Essays and quoting other authors (Biro 1884, Riley 1888), gives data on the destruction of fish by dragonflies: "Biro states that nearly 50,000 young fish were destroyed by a species of Libellulinae in a pond in Hungary. Riley and Howard mention a case where the larvae of *Anax junius* Drury were found feeding on young carp."

The Lamborn Prize Essays particularly, and the Howard book also, give a number of most interesting additional items. These references are fully worth rereading, in the light of the advanced technology that has been evolved in nearly a hundred years since.

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APPENDIX

In response to the above note, Willis W. Wirth, Systematic Entomology Laboratory, USDA, c/o National Museum of Natural History, Washington, DC 20560, has provided the following commentary which is published with his permission:

"As long as the subject has been raised and the question asked: Do mosquitoes feed on trout? I would like to comment that this is probably unlikely.

"I do not question the accuracy of Mr. Murray's observations: An insect similar to a mosquito, which he took to be mosquitoes, fed on hatchling trout in Tumichie Creek, Colorado. I raise the possibility that another nematocerous dipteran, similar in size and appearance to a mosquito, with well known and adapted predaceous habits was the predator.

"Very common predaceous midges about the same size as a large mosquito at such elevations in mountain creeks are the Blephariceridae. Their predaceous habits on small adult insects are well known. The literature should be checked for any report of their preying on invertebrates and other small animals at the water surface.

"Empidid flies are less similar to adult mosquitoes but their predaceous habits on aquatic insects are well known. Most of them capture adult insect prey in flight. Antony Downes at Ottawa has published notes on such habits and has many more unpublished observations. He has also kept records on blephariceridids. I myself have seen empidid flies of the subfamily Clinocerinae feeding on blackfly larvae at the water margin of rocky streams in Inyo County, California.

"The larger midges of predaceous Ceratopogonidae such as *Palpomyia* or some genera of Sphaeromiini also prey on adult midges over the surface of mountain streams in the west. Larger species of *Atrichopogon* midges are very abundant resting and swarming at the margins of mountain streams: their adult feeding habits are various, some take insect carrion, others take blood from beetles and other adult insects. There is one report of their feeding on earthworms. Their size, habitat and habits make them prime suspects in the instance observed by Mr. Murray.

"All this points out the need for present workers to actually make new observations in similar situations to verify Murray's observations, or to find out definitely what insects are involved in feeding on trout hatchlings."

ROCK HOLE BREEDING *HAEMAGOGUS* MOSQUITOES ON MONOS ISLAND, TRINIDAD, WEST INDIES

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The mosquito genus *Haemagogus* is represented on Monos Island, Trinidad, West Indies by 3 species, *Hg. janthinomys* Dyar, *Hg. celeste* Dyar and Nunez Tovar and *Hg. equinus* Theobald (Heinemann et al. 1980). These species are known to breed primarily in tree holes

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[1] Published with approval from the Ministry of Health and Environment, Trinidad and Tobago, W.I.

and in cut or damaged bamboo internodes (Arnell 1973). The genus plays an important role in the transmission of sylvan or jungle yellow fever in neotropical America (Arnell 1973).

During September, 1982 an extensive mosquito survey was conducted on Monos Island, one of the several islands situated off the northwestern peninsula of Trinidad. Larvae and pupae of all 3 species of *Haemagogus* were collected from a rock hole. In addition, larvae of *Hg. celeste* were taken from water in an abandoned tire. These represent the first records of these species from such habitats. All immature specimens were transported to the Insect Vector Control Division Laboratory, St. Joseph, where they were reared to adults and identified. The results are as follows: *Haemagogus janthinomys:* two 4th instar larvae and 3 pupae, *Hg. celeste:* two 3rd instar larvae and *Hg. equinus:* two 4th instar larvae were collected from a rock hole at Grand Fond Valley on September 19, 1982. Associated with these were larvae of *Limatus durhamii* Theobald and *Culex originator* Gordon and Evans.

Haemagogus celeste: two 4th instar larvae were collected from an abandoned tire at Morris Bay Valley on September 17, 1982. Associated with these were ten 3rd instar larvae of *Aedes aegypti* (Linn).

The collection of these 3 *Haemagogus* species on Monos Island does not represent new records (see Manuel 1965, Heinemann et al. 1980), but unexpected was the aquatic source of the immature stages. Previously, Chadee et al. (1981) had reported the finding of *Hg. equinus* breeding in abandoned tires and in household containers on Tobago, W.I. and now we find that *Hg. celeste* may use the tire habitat.

It should be noted, however, that no tree hole collections were made on September 19, 1982, so that transference of larvae from tree hole to rock hole through contaminated equipment was not possible.

In addition to the aquatic collections, adults of the 3 *Haemagogus* species were readily taken during human-bait captures at points close to Morris Bay, Grand Fond Valley, Dumas Bay, Balmoral Bay and at Biscayne Bay. Specimens of *Hg. janthinomys, Hg. celeste* and *Hg. equinus* have been deposited in the Insect Reference Collection at the Caribbean Epidemiology Centre (CAREC).

The author wishes to thank Dr. E. S. Tikasingh, Entomologist/Parasitologist at the Caribbean Epidemiology Centre, P. O. Box 164, Port of Spain, Trinidad for confirming the *Haemagogus* identifications. In addition, I thank Messrs. R. C. Perad, N. Andalcie, E. C. Peru, W. Ramdath and R. Manwah for field assistance. Special thanks are also due to Dr. Eugene Laurent, Principal Medical Officer, (Environment Health) for his help and encouragement during this study.

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PSOROPHORA HOWARDII, AN ADDITION TO THE CHECKLIST OF NEW JERSEY MOSQUITOES[1]

JAMES McNELLY[2] AND
WAYNE J. CRANS[3]

Psorophora howardii Coquillett is a mosquito of the southeastern U.S. that has been reported as far north as Delaware in the eastern portion of its range (Darsie and Ward 1981). Larvae of *Ps. howardii* are most often found in temporary rainpools and are predacious on the immature stages of other mosquitoes utilizing the habitat (Carpenter and LaCasse 1955). Development is rapid and several generations are possible when rainfall is abundant during the breeding season (Siverly 1972).

On June 4, 1982, approximately twenty 3rd instar *Ps. howardii* were collected from a shaded rainpool in the Fishing Creek area of southern Cape May County, New Jersey by Cape May County Mosquito Commission personnel. The exact site is several miles east of the town of Villas and is south of the Delaware record of *Ps. howardii* reported by Lake (1963). Several

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[1] New Jersey Agricultural Experiment Station, Publication No. D-40101-1-83. Supported by U.S. Hatch Act.

[2] Cape May County Mosquito Extermination Commission, P.O. Box 66, Cape May Court House, NJ 08210.

[3] Mosquito Research and Control, Box 231, Cook College, Rutgers University, New Brunswick, NJ 08903.

specimens were reared to the adult stage for confirmation of species. An adult specimen has been deposited in the collection of the Headlee Research Laboratories at Rutgers University.

The most recent checklist of New Jersey mosquitoes included 52 species (Crans 1967). Since that time, additions have been made by Crans (1970), Zavortink (1972), Lesser et al. (1977) and Ehrenberg (1983). The addition of *Ps. howardii* brings the New Jersey list to 59, including the following species:

Genus *Aedes* Meigen

1. *Aedes abserratus* (Felt and Young)
2. *Aedes atlanticus* Dyar and Knab
3. *Aedes atropalpus* (Coquillett)
4. *Aedes aurifer* (Coquillett)
5. *Aedes canadensis canadensis* (Theobald)
6. *Aedes cantator* (Coquillett)
7. *Aedes cinereus* Meigen
8. *Aedes communis* (De Geer)
9. *Aedes dorsalis* (Meigen)
10. *Aedes dupreei* (Coquillett)
11. *Aedes excrucians* (Walker)
12. *Aedes fitchii* (Felt and Young)
13. *Aedes flavescens* (Müller)
14. *Aedes grossbecki* Dyar and Knab
15. *Aedes hendersoni* Cockerell
16. *Aedes implicatus* Vockeroth
17. *Aedes intrudens* Dyar
18. *Aedes mitchellae* (Dyar)
19. *Aedes provocans* (Walker)
20. *Aedes punctor* (Kirby)
21. *Aedes sollicitans* (Walker)
22. *Aedes spencerii spencerii* (Theobald)
23. *Aedes sticticus* (Meigen)
24. *Aedes stimulans* (Walker)
25. *Aedes taeniorhynchus* (Wiedemann)
26. *Aedes triseriatus* (Say)
27. *Aedes trivittatus* (Coquillett)
28. *Aedes vexans* (Meigen)

Genus *Anopheles* Meigen

29. *Anopheles atropos* Dyar and Knab
30. *Anopheles barberi* Coquillett
31. *Anopheles bradleyi* King
32. *Anopheles crucians* Wiedemann
33. *Anopheles earlei* Vargas
34. *Anopheles punctipennis* (Say)
35. *Anopheles quadrimaculatus* Say
36. *Anopheles walkeri* Theobald

Genus *Culex* Linnaeus

37. *Culex erraticus* (Dyar and Knab)
38. *Culex pipiens* Linnaeus
39. *Culex restuans* Theobald
40. *Culex salinarius* Coquillett
41. *Culex tarsalis* Coquillett
42. *Culex territans* Walker

Genus *Culiseta* Felt

43. *Culiseta inornata* (Williston)
44. *Culiseta melanura* (Coquillett)
45. *Culiseta minnesotae* Barr
46. *Culiseta morsitans* (Theobald)

Genus *Coquillettidia* Dyar

47. *Coquillettidia perturbans* (Walker)

Genus *Orthopodomyia* Theobald

48. *Orthopodomyia alba* Baker
49. *Orthopodomyia signifera* (Coquillett)

Genus *Psorophora* Robineau-Desvoidy

50. *Psorophora ciliata* (Fabricius)
51. *Psorophora columbiae* (Dyar and Knab)
52. *Psorophora cyanescens* (Coquillett)
53. *Psorophora discolor* (Coquillett)
54. *Psorophora ferox* (von Humboldt)
55. *Psorophora howardii* Coquillett
56. *Psorophora mathesoni* Belkin and Heinemann

Genus *Toxorhynchites* Theobald

57. *Toxorhynchites rutilus septentrionalis* (Dyar and Knab)

Genus *Uranotaenia* Lynch-Arribálzaga

58. *Uranotaenia sapphirina* (Osten Sacken)

Genus *Wyeomyia* Theobald

59. *Wyeomyia smithii* (Coquillett)

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A METHOD FOR DETERMINING POND INUNDATION HEIGHT FOR USE IN SALT MARSH MOSQUITO CONTROL

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The addition of ditches provides effective long-term mosquito control in salt marsh management programs. However, economic and environmental costs (Resh and Balling 1983) associated with ditching require accurate determination of which ponds produce mosquitoes and should be ditched. Although regular monitoring of ponds for the presence of mosquito larvae is a reliable approach, it is impractical in marshes that contain numerous ponds. A cost-effective alternative is to use environmental factors that are correlated with mosquito presence to predict which ponds will produce mosquitoes. In a study of environmental factors that influence *Aedes dorsalis* (Meigen) and *Aedes squamiger* (Coq.) populations in San Francisco Bay salt marshes, pond inundation height, i.e. the minimum tidal height above mean lower low water (MLLW) necessary to inundate a marsh pond, was significantly correlated with occurrence and abundance of mosquito larvae (Balling and Resh 1983).

The pond inundation height is best determined by using surveying techniques from a nearby tidal benchmark. Unfortunately, there are often no nearby benchmarks, or there is reason to suspect that recorded benchmark elevations are no longer reliable due to land subsidence or mechanical disturbance. In lieu of surveying, an acceptable estimate can be obtained by using the height of a particular high tide (either taken from tide table predictions or, preferably, measured by a nearby tide gauge) as a reference datum from which heights of other ponds can be calibrated. This is possible because differences in inundation height within and between marshes are essentially constant (Marmer 1951). Although the following procedure was used to estimate pond inundation heights in marshes around the San Francisco Bay, this method is applicable in any area with recorded or predicted tidal heights.

DATA COLLECTION. *Marker construction.* Staple a strip of heavy-duty, waterproof tape (e.g. heating-duct tape) vertically, with the adhesive side exposed, to a long stake. Sprinkle potassium dichromate crystals or some other water-soluble, easily visible, non-toxic substance along the length of the tape. Dissolution of the potassium dichromate on the tape will give a measure of the local tidal height.

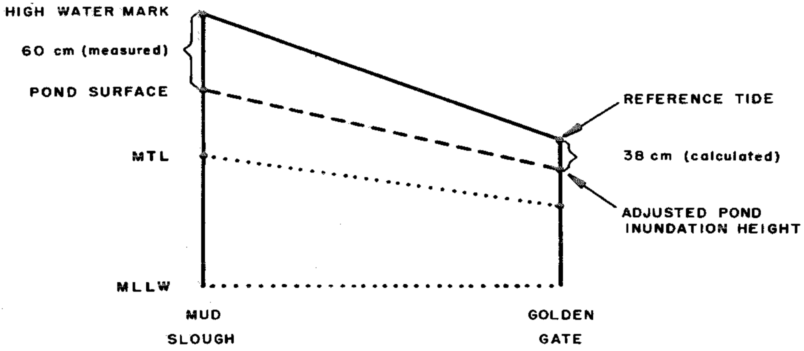
Marker placement. Prior to a series of inundating tides, and at a time when wind speeds are low, implant the stake in the pond; leave the upper portion of the stake sufficiently high above the marsh surface to exceed the height of the expected tide.

Measurements. After the tide has flooded the marsh and receded, allow sufficient time (12–24 hr) for the pond to drain down to, but not evaporate beyond, basin-full level. Then, measure the difference between the pond surface and the high water mark on the stake (the high tide reference datum), which is indicated by the line of undissolved potassium dichromate on the tape.

Replication. This procedure should be repeated for several different high tides to establish the most accurate estimate.

CALCULATION OF POND HEIGHT. The height of the tide (taken from tide tables or a tide gauge) minus the difference between the high water mark on the tape and the level of the pond surface will give an estimate of the pond inundation height equivalent to that obtained from surveying.

If tide tables are used, the inundation height must be adjusted for differences in diurnal tidal ranges (due to systematic differences in bay and channel morphometry) between the tidal reference station and the marsh. As an example, consider that a tide is 186 cm high (above MLLW) at the Golden Gate reference station in San Francisco Bay (where the tidal range is 174 cm) and 60 cm above the surface of a basin-full pond at Mud Slough (where the tidal range is 277 cm; for locations see Balling and Resh 1983, Fig. 1). The difference between the two tidal ranges indicates that the tide is higher at Mud Slough than at the Golden Gate; that is, a 1.0 unit increase in tidal height at the Golden Gate reference station corresponds to a 1.59 (277 cm/174 cm) unit increase at Mud Slough. Therefore, the 60 cm difference between the high water mark on the stake and the pond surface would be equivalent to a 38 cm difference (60 cm/1.59) at the Golden Gate reference station. After subtracting this 38 cm from the known height of the tide at the reference station (in this example, 186 cm), the



DISTANCE FROM HIGH WATER MARK DOWN TO POND SURFACE		TIDAL RANGE CORRECTION		HEIGHT CORRECTION		TRUE TIDAL HEIGHT AT REFERENCE STATION		ADJUSTED POND INUNDATION HEIGHT
-60	÷	(2.77 ÷ 1.74) = 1.59	=	-38	+	186	=	148

Fig. 1. An example of the calculations used for determining the adjusted pond inundation height based on the method described in this paper; MLLW = mean lower low water, MTL = mean tide level.

adjusted pond inundation height for the pond at Mud Slough is estimated to be 148 cm (Fig. 1). Diurnal tidal ranges for many areas can be obtained from the National Ocean Survey (e.g. 1981, Table 2).

Based on this method, inundation heights for ponds in different marshes around an estuary or along a coastline can be adjusted to the same reference station. Thus, a regional value for the mosquito production threshold can be established (e.g. Balling and Resh 1983).

PRECAUTIONARY MEASURES. The predicted tidal heights reported in tide tables are based upon long term (i.e. 19 yr) data records for reference stations. Therefore, the predictions usually differ from empirical measurements. Differences between actual and predicted values can result from constant winds and a long fetch that push tides higher on the downwind side of an embayment, variations in barometric pressure that depress tides in one area relative to another, and unusually high or low river discharges that affect tidal height. With regard to estimating pond inundation height, these influences can be minimized by using high tides that occur in the late evening or early morning, since wind speeds are generally lowest at these times, and by applying the method during the dry season (in a Mediterranean climate), or after an appropriate post-storm period (which will be different for each estuary).

If empirical tidal data are available for the reference station, or if a tide gauge is used to measure tidal height at the pond, then tide tables are not required. However, tide gauge data must be adjusted to the 19-yr epoch; tide table predictions include this correction and need not be adjusted.

Given appropriate consideration of these precautions, a satisfactory estimate of pond inundation height can be obtained from tide tables, and thus can be included in determining a pond's potential for mosquito production (Balling and Resh 1983).

We thank J. N. Collins for assistance in developing this methodology. Support for this research was provided by the University of California Mosquito Research Funds.

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MODIFICATION OF NEW JERSEY LIGHT TRAP FOR MULTIPLE SAMPLE COLLECTION

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The Desplaines Valley Mosquito Abatement District situated in the western suburbs of Chicago, Illinois has utilized a network of standard New Jersey type light traps to monitor adult mosquito activity since 1941. Prior to 1977, individual nightly trap samples were limited to those nights where physical collections by laboratory staff could be made on the following morning. Weekend samples, typically from Friday to Sunday night, were combined into one killing bottle by nature of the New Jersey type trap. Partition type traps of either the falling disc (Horsfall 1962) or turntable type (Standfast 1965) were available for multiple sample collection, and in part provided the basis for this undertaking. An apparatus for multiple sample collection, specifically for three 24-hr periods, is described.

A standard New Jersey type light trap is positioned over an apparatus (Figs. 1 and 4) which changes the killing bottle at designated 24 hour intervals. The apparatus is electrically controlled by an escapement mechanism (Standfast 1965) with linear motion of the bottle carriage in lieu of previous turntable styles.

The main plate and bottle carriage are fabricated from ⅛″ thick aluminum plate for durability to weather exposure, yet minimizing component weight factors. The basic configuration of the bottle carriage is indicated in Figs. 2 and 5. A hinged cover is included on the carriage to prevent unauthorized tampering with samples collected. The carriage slides along the base of the main plate along two parallel "tracks" constructed of 1″×⅛″ flat aluminum strips positioned equidistant from the plate surface by a ½″×3/16″ flat aluminum strip sandwiched between the wider strip and main plate. Two ½″×3/16″ flat aluminum strips are bent to a flat-bottom U configuration and attached at each end of the main plate to

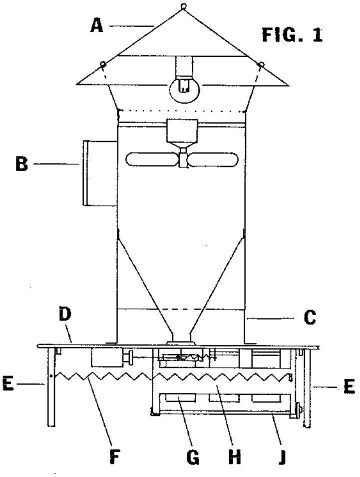
FIG. 1

FIG. 3

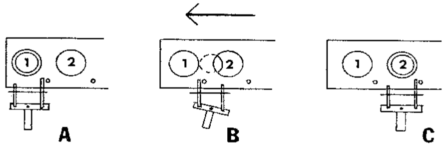

FIG. 2

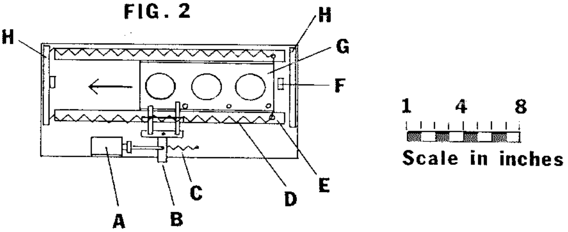

Fig. 1. Diagramatic representation of light trap modification; A. New Jersey light trap, B. timer switch, C. light trap leg, D. main plate, E. support leg, F. bottle carriage spring, G. killing bottle, H. bottle carriage, J. security cover.

Fig. 2. Diagram of modification components, bottom view; A. solenoid, B. escapement mechanism, C. escapement return spring, D. bottle carriage spring, E. track, F. carriage stop, G. bottle carriage with security cover removed, H. support leg.

Fig. 3. Sequence of operation; A. solenoid in open position, B. solenoid activated in closed position, C. solenoid returns to open position.

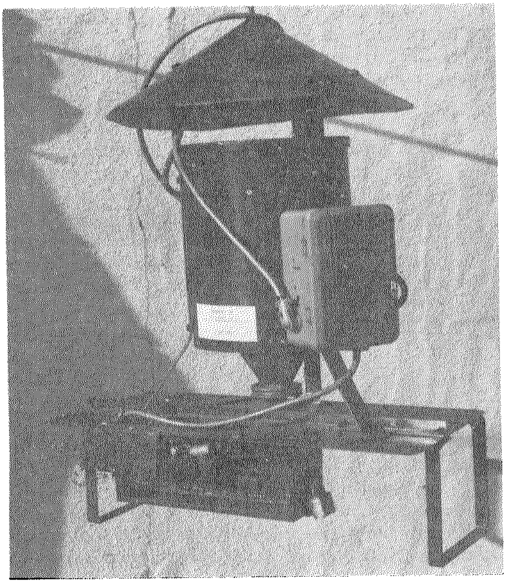

Fig. 4. New Jersey type light trap positioned over collection apparatus.

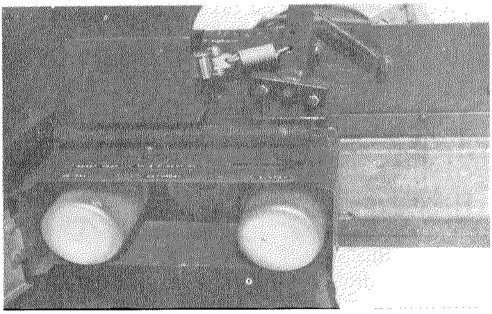

Fig. 5. View of escapement mechanism and bottle carriage.

serve as attachment points for the linear springs and as support legs for the trap during periods of transport or winter storage.

Two linear springs provide the source of motion to the bottle carriage. An escapement type mechanism controls carriage motion per sequence indicated in Fig. 3. The solenoid (Dormeyer #2536-M-1 with one $^1/_{16}''$ stroke) indicated operates on 120 VAC. When the solenoid closes, the carriage advances until it is stopped by pin 2 of the escapement mechanism. When the solenoid opens, the carriage continues its cycle until it is stopped by pin 1. At this point, the next killing bottle is aligned with the hole in the main plate.

The solenoid is controlled by a microswitch (Unimax #2TMT15-4 with standard lever) located within the main time switch box on the light trap. The basic time switch (Inter-Matic #T171 "Skipper") utilized is of a commercially available selective day of operation style. Although various configurations of time switch are available, all utilize a secondary "day wheel" which advances one position every 24 hr and into which pins or the equivalent are inserted to eliminate specified days of operation. Although this feature is not desired for daily operation of the light trap, minor modification to shorten these pins will bypass their intended function. These pins provide a convenient contact point for a microswitch located adjacent to the wheel. Thus the modified pins are used exclusively to control bottle carriage transfer at any designated 24 hour interval. The only human intervention necessary is a manual setting of the bottle carriage to position 1 prior to desired operation.

Ten New Jersey type light traps were modified by our District during 1977 as outlined. The traps were modified as described for under $50 each, with all materials obtained through a larger hardware store. The traps have operated without fault to date. Yearly, pre-season inspections were made of all traps with necessary cleaning and lubrication of all pivot and slide points.

The apparatus described is not limited to the standard New Jersey type light trap. It can easily be adapted to the American style trap (Mulhern 1953) or made smaller for use on CDC or other live-catch style traps. The apparatus described was designed for specific collections over typically unattended weekend periods. However, flexibility exists to expand both interval and number of collections for specific program needs.

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