actual amount (total dose) that corresponds to the LC_{50} values. The effect of exposure time becomes more apparent when these estimates are compared. The LC_{50} values correspond to 0.0098 and 0.0102 mg of actual test material at the 90 and 120 min exposure times respectively. This is ca. one-half the amount required for a 60 min exposure (0.0188 mg) and ca. one-fifth and one-sixth the amount required for 30 and 15 min exposure periods respectively (0.047 and 0.064 mg). There is a difference of one order of magnitude between the amount required at 24 hr (0.001 mg) and that for the 90 and 120 min exposures.

A similar trend was apparent from LC_{90} values except for the 30 min exposure period. This value was greater than for the 15 min interval. This inconsistency may have been caused by sorption of the toxicant to the wax coating of test cups. This factor did not appear to be responsible for the other differences observed because if some temephos became bound, it would have tended to mask rather than enhance differences related to different exposure times. Thus, the differences observed in this study may have underestimated the true dose-time effect.

When LC_{90} values were used to estimate the total quantity of Abate 200E which must be applied during a given treatment duration (i.e., concentration × time), the 60 and 90 min intervals were lowest. They yielded estimates that were ca. 35% lower than the value for a 15 min exposure.

The similarity of the observed differences to those observed in some other studies (Frommer et al. 1980, Muirhead-Thomson 1977) also tend to support the interpretation that exposure time may be an important factor influencing the toxicity of Abate 200E. Thus, more thorough investigations utilizing flow-through and field tests appear to be warranted.

References Cited

Barr, A. J., J. H. Goodnight, J. P. Sall and J. T. Helwig. 1976. A user's guide to SAS 76. SAS Institute, Inc., Raleigh, NC.

Frommer, R. L., S. C. Hembree, J. H. Nelson, M. P. Remington and P. H. Gibbs. 1980. The susceptibility of *Simulium vittatum* larvae (Diptera:Simuliidae) to *Bacillus thuringiensis* var. *israelensis* in the laboratory. Mosq. News 40:577–584.

Hembree, S. C., R. L. Frommer and M. P. Remington. 1980. A bioassay apparatus for evaluating larvicides against black flies. Mosq. News 40:647–650.

Jamnback, H. and R. Means. 1966. Length of exposure period as a factor influencing the effectiveness of larvicides for blackflies (Diptera:Simuliidae). Mosq. News 26:589–591.

Muirhead-Thomson, R. C. 1977. Comparative tolerance levels of black fly (*Simulium*) larvae to permethrin (NRDC 143) and temephos. Mosq. News 37:172–179.

Muirhead-Thomson, R. C. 1978. Relative susceptibility of stream macroinvertebrates to temephos and chlorpyrifos, determined in laboratory continuous-flow systems. Arch. Environm. Contam. Toxicol. 7:129–137.

POTENTIAL OF A TEMPERATE ZONE *TOXORHYNCHITES* FOR THE BIOLOGICAL CONTROL OF TROPICAL CONTAINER-BREEDING MOSQUITOES[1]

R. M. TRIMBLE

Research Station, Agriculture Canada, Vineland Station, Ontario L0R 2E0

For seventy years now, entomologists have considered using predaceous *Toxorhynchites* Theobald larvae for the biological control of container-breeding, vector mosquitoes (Steffan 1975). Those advocating their potential usefulness have stressed the following aspects of their biology (National Academy of Sciences 1973). First, the adults are non-blood sucking; second, all four larval instars are predaceous and the larvae are voracious; third, prior to pupation the larva often kills, but does not consume, all other inhabitants of its container; and fourth, females can seek out and oviposit in habitats that cannot be reached for conventional chemical control.

Attempts to use *Toxorhynchites* in classical biological control programs have not been successful for several reasons (Steffan 1975). Introductions of this mosquito onto islands where it formerly did not occur have not always resulted in its successful establishment. Where releases have resulted in establishment, the predator was not effective in keeping vector populations below the disease-transmission threshold. This is because, although the predator population exhibits a numerical response to increases in prey density, the temporal delay of this response always permits prey populations to increase to a large, and usually unacceptable size before their numbers are reduced by predation (Trpis 1973).

The potential usefulness of *Toxorhynchites* as a biological control agent is therefore likely to be confined to inundative release programs. Using *Toxorhynchites* in this way would involve the release of large numbers of gravid females prior to or during the preadult development of vector mosquito populations. The released females would then disperse and oviposit in the developmental sites of vector mosquitoes. However, *Toxorhynchites* larvae have a relatively long development time compared to that of vector larvae; and vector outbreaks are often difficult to forecast. These two factors could make inundative releases of *Toxorhynchites* ineffectual because, if outbreaks could not be predicted more than 2½ to 3 weeks in advance, there would not be sufficient time for the completion of *Toxorhynchites* prerelease development.

The biological characteristics of one of the three temperate species of *Toxorhynchites* could be exploited to facilitate the timing of inundative releases. *Toxorhynchites rutilus septentrionalis* (Dyar and Knab) occurs between 30 and 40 degrees north latitude in eastern North America (Trimble and Smith 1975).

---

[1] Presented at the joint annual meeting of the California Mosquito and Vector Control Association and the American Mosquito Control Association at the Capital Plaza Holiday Inn, Sacramento, California on 21 April 1982.

Throughout this range it overwinters as a fourth-instar larva in a photoperiodically induced state of diapause (Trimble and Smith 1979). In populations from both Lake Charles, Louisiana (30°13′ N, 93°12′ W), and Newark, Delaware (39°41′ N, 75°45′ W), exposure of the egg and first three larval instars to 19°C and to 12 hours of light per day arrests development in 80% of the larvae (Trimble and Smith 1979). Diapause is both photoperiodically maintained and terminated, so that pupation and emergence occur when daylength is extended from 12 to 16 hours (Bradshaw and Holzapfel 1975, 1977; Trimble, unpublished). Increasing the temperature from 19 to 27°C along with increasing the number of hours of daylight significantly shortens the postdiapause development period and results in highly synchronous adult emergence (Bradshaw and Holzapfel 1977; Trimble, unpublished).

If temperature and photoperiod were controlled, fourth-instar *Tx. r. septentrionalis* could be induced to enter, and could be held in, a state of developmental arrest until an outbreak of vector mosquitoes was forecasted. At this time the development of large numbers of "stockpiled" predators could be reactivated, and highly synchronous inundative releases could be accomplished. Maintaining a "predator bank" as suggested, as opposed to attempting to rear larvae from eggs as required, would have another advantage in addition to facilitating the timing of inundative releases. Rearing large numbers of predator females immediately before a forecasted vector outbreak would require only the periodic use of extensive facilities and labor. However, stockpiling predator larvae could be undertaken on a continuing basis, thereby reducing the required amount of rearing equipment.

The photoperiodic induction of larval diapause in *Tx. r. septentrionalis* is temperature compensated, and the degree to which temperature affects the photoperiodic response varies over this insect's range of distribution. For example, whereas a high temperature of 27°C completely overrides the diapause inducing effects of "short days" in the Lake Charles population, about 20% of Newark population larvae enter diapause when growing under a "short day," high temperature regime (Trimble and Smith 1979).

Insect diapause has a genetic basis and for most species studied the photoperiodic response curve is very responsive to artificial selection (Tauber and Tauber 1981). Therefore, it is likely that through selective breeding a "strain" of *Tx. r. septentrionalis* could be developed in which all individuals enter diapause under the short day, high temperature regime. When developing in or relatively near the equatorial tropics, where the duration of daylight varies little from 12 hours all year long, larvae of this strain would enter diapause. Because diapausing larvae continue to feed at a reduced rate (McCrary 1965[2], Trimble and Smith 1979), their effect on prey populations would be effectively extended. Such a strain might be similarly effective in those subtropical latitudes where the rainy and hence mosquito-plagued season coincides with days having 12 or less hours of light. Additional research will be required to determine if such a strain could be developed and if so, for how long and at what rate the larvae would continue to feed under natural, tropical conditions.

The oviposition behavior of *Tx. r. septentrionalis* may also enhance its effectiveness as a biological control agent for container-breeding vector mosquitoes. Whereas some species of *Toxorhynchites* are very specific in their selection of an oviposition site (Steffan and Evenhuis 1981), *Tx. r. septentrionalis* will oviposit in a wide variety of both natural and man-made container habitats (Basham et al. 1947, Breeland et al. 1961). This behavior would facilitate the control of a vector with a similarly eclectic oviposition behavior, a good example being peridomestic and domestic populations of *Aedes aegypti* (L.) (Christophers 1960). However, the oviposition behavior of *Tx. r. septentrionalis* should be further investigated to determine if any as yet unidentified preference for specific heights, vegetation type or level of illumination would limit its effectiveness. For example, there is some evidence that the larvae of *Tx. r. septentrionalis* cannot tolerate water with a high organic or bacterial content (Trimble, unpublished). Should this be the case, their application could, in some situations, be limited considerably.

The two other temperate zone *Toxorhynchites*, the Ethiopian *Toxorhynchites brevipalpis* Theobald which extends south to 32 degrees latitude, and the Eurasian *Toxorhynchites christophi* (Portschinsky) which occurs as far north as 54 degrees latitude (Steffan and Evenhuis 1981), may also have a photoperiodically controlled larval diapause. If so, their developmental arrest should be studied to determine if it could be manipulated to facilitate the timing, and to extend the effectiveness, of inundative releases. In addition, their oviposition behavior and the effect of water quality on their larvae should also be studied to identify any potential limitations to their usefulness as biological control agents in a tropical or subtropical climate.

To summarize, predaceous larvae of the genus *Toxorhynchites* have potential for use in inundative releases against tropical, container-breeding mosquitoes. The North American species *Tx. r. septentrionalis* overwinters as a fourth-instar larva in a photoperiodically controlled state of diapause, and diapausing larvae continue to feed at a reduced rate. I have suggested that these two features of this insect's biology could be manipulated to facilitate the timing and extend the effectiveness of inundative releases. The two other temperate zone *Toxorhynchites, Tx. brevipalpis* and *Tx. christophi*, should also be studied with a view to using them in a manner similar to that suggested for *Tx. r. septentrionalis*.

ACKNOWLEDGMENT

The author is grateful to Philip S. Corbet and one anonymous reviewer for their very helpful comments on this paper.

Literature Cited

Basham, E. H., J. A. Mulrennan and A. J. Obermul-

[2] McCrary, A. B. 1965. The effect of photoperiod, temperature, and food on diapausing and developing larvae of *Toxorhynchites rutilus* (Coq.). M.Sc. Thesis, University of North Carolina, Chapel Hill. 49 pp.

ler. 1947. The biology and distribution of *Megarhinus* Robineau-Desvoidy in Florida. Mosq. News 7:64–66.

Bradshaw, W. E. and C. M. Holzapfel. 1975. Biology of treehole mosquitoes: photoperiodic control of development in northern *Toxorhynchites rutilus* (Coq.). Can. J. Zool. 53:889–893.

Bradshaw, W. E. and C. M. Holzapfel. 1977. Interaction between photoperiod, temperature, and chilling in dormant larvae of the tree-hole mosquito, *Toxorhynchites rutilus* (Coq.). Biol. Bull. 152:147–158.

Breeland, S. G., W. E. Snow and E. Pickard. 1961. Mosquitoes of the Tennessee Valley. J. Tenn. Acad. Sci. 36:249–319.

Christophers, S. R. 1960. *Aedes aegypti* (L.). The yellow fever mosquito. Its life history, bionomics and structure. Cambridge University Press. 738 pp.

National Academy of Sciences. 1973. Mosquito control. Some perspectives for developing countries. National Academy of Sciences, Washington, D.C. 63 pp.

Steffan, W. A. 1975. Systematics and biological control potential of *Toxorhynchites* (Diptera:Culicidae). Mosq. Syst. 7:59–67.

Steffan, W. A. and N. L. Evenhuis. 1981. Biology of *Toxorhynchites*. Annu. Rev. Entomol. 26:159–181.

Tauber, C. A. and M. J. Tauber. 1981. Insect seasonal cycles: genetics and evolution. Annu. Rev. Ecol. Syst. 12:281–308.

Trimble, R. M. and S. M. Smith. 1975. A bibliography of *Toxorhynchites rutilus* (Coquillett) (Diptera: Culicidae). Mosq. Syst. 7:115–126.

Trimble, R. M. and S. M. Smith. 1979. Geographic variation in the effects of temperature and photoperiod on dormancy induction, development time, and predation in the tree-hole mosquito, *Toxorhynchites rutilus septentrionalis*. Can. J. Zool. 57:1612–1618.

Trpis, M. 1973. Interaction between the predator *Toxorhynchites brevipalpis* and its prey *Aedes aegypti*. Bull. W.H.O. 49:359–365.

OCCURRENCE OF *ANOPHELES BARBERI* IN MASSACHUSETTS

EDWARD D. WALKER

Department of Entomology, University of Massachusetts, Amherst, MA 01003

The distribution of *Anopheles barberi* Coquillett, a tree hole breeding mosquito, includes 30 states of the midwestern and eastern United States, the District of Columbia, and southern Ontario and Quebec (Darsie and Ward 1981, Zavortink 1969). The northeastern limit of this species' distribution in the United States is held to be eastern New York. This note reports the occurrence of *An. barberi* in Massachusetts, which is the first record of this species in Massachusetts and New England.

On August 13, 1982 at about 1400 hr a single female *An. barberi* was captured while it attempted to bite the author. The mosquito was collected on the University of Massachusetts campus in Amherst, Hampshire County. Subsequent collection attempts at this site yielded no more *An. barberi*. I have not previously encountered this species, despite recent extensive collections in western Massachusetts of mosquito larvae from tree holes and discarded tires, and adults from forested areas with treeholes.

This collection record brings to 46 the total number of mosquito species known to occur in Massachusetts (Darsie and Ward 1981). The specimen has been deposited in the University of Massachusetts insect museum.

I thank B. A. Harrison of the Walter Reed Biosystematics Unit, Smithsonian Institution for verifying the identification.

References Cited

Darsie, R. F., Jr. and R. A. Ward. 1981. Identification and geographical distribution of the mosquitoes of North America, north of Mexico. American Mosquito Control Association, Fresno, California. 313 pp.

Zavortink, T. J. 1969. Mosquito studies (Diptera: Culicidae). XIX. The treehole *Anopheles* of the New World. Contr. Am. Entomol. Inst. 5(2):1–35.

TIME/CONCENTRATION IMPACT OF THE *SIMULIUM* LARVICIDE, ABATE, AND ITS RELEVANCE TO PRACTICAL CONTROL PROGRAMS

R. C. MUIRHEAD-THOMSON

Department of Zoology, Royal Holloway College (University of London), Egham, Surrey, TW 20 OEX, U.K.

INTRODUCTION

For the last seven years research has been conducted in this laboratory on the reactions of *Simulium* larvae, and select non-target macroinvertebrates to larvicides used practically or experimentally in the World Health Organization Onchocerciasis Control Program (OCP). In the absence of any corresponding laboratory phase of evaluation in that program, it was hoped that the tests with European stream fauna would establish some general principles of use to that project.

The laboratory technique of choice for *Simulium* larvae was the miniature simulated stream, well designed for assessing the effect of the short, 10–15 min, field application rates. A second technique, the rapid through-flow system, was used for studying a range of non-target macroinvertebrates, usually for standard exposures of 1 hr. This also provided an alternative method of testing *Simulium* larvae along with non-targets in the same vessel (Muirhead-Thomson 1981).

In the course of this investigation two findings provide an essential introduction to the present communication. (1) The first series of experiments using Abate® (temephos) [Procida 200 EC (emulsifiable