Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.
Deterministic Model for Simulating the Predation of *Toxorhynchites rutilus rutilus* on *Aedes aegypti*
CONTENTS

Abstract ................................................................................................................................. 1
Introduction ............................................................................................................................. 1
Model description .................................................................................................................. 2
Results of simulation ............................................................................................................ 6
Conclusions ........................................................................................................................... 17
References ............................................................................................................................. 17
Appendix.—FORTRAN listing ............................................................................................. 19

ILLUSTRATIONS

Fig.
1. Flow chart and algorithm for *Aedes aegypti* computations ........................................ 3
2. Flow chart for *Toxorhynchites rutilus rutilus* computations ........................................ 4
3. Predator and prey distribution in containers .................................................................... 6
4. *Aedes aegypti* adult density per container with no control measures applied (no rain) .......... 7
5. *Aedes aegypti* adult density per container with no control measures applied (daily rainfall into every container) ............................................................... 7
6. *Aedes aegypti* immature density per container (no rain) ................................................... 8
7. *Aedes aegypti* immature density per container (daily rainfall into every container) ............ 8
8. *Aedes aegypti* adult density following contact adulticide application on day 90 (no rain) ........ 9
9. *Aedes aegypti* immature density following contact adulticide application on day 90 (no rain) 10
10. *Aedes aegypti* adult density following contact adulticide application when *Aedes aegypti* adult density exceeded seven adults per container (no rain) .................. 10
11. *Aedes aegypti* immature density following contact adulticide application when *Aedes aegypti* adult density exceeded seven adults per container (no rain) .................. 11
12. *Aedes aegypti* adult density following contact adulticide application when *Aedes aegypti* adult density exceeded four adults per container (no rain) ..................... 11
13. *Aedes aegypti* immature density following contact adulticide application when *Aedes aegypti* adult density exceeded four adults per container (no rain) ..................... 12
14. *Aedes aegypti* adult density following an adult predator release on day 98 that resulted in one predator egg in 80% of the containers positive for prey (no rain) .............. 12
15. *Aedes aegypti* immature density following release of one predatory larva per container on day 98 in 80% of the containers positive for *Aedes aegypti* (no rain) ............... 13
16. *Aedes aegypti* adult density following an adult predator release on day 98 that resulted in three predatory larvae per container in 80% of the containers positive for *Aedes aegypti* (daily rain) ............... 14

17. *Aedes aegypti* adult density following an adult predator release on day 107 that resulted in one predator egg per container in 60% of the containers positive for *Aedes aegypti* immatures (no rain) ............. 14

18. *Aedes aegypti* adult density following an adult predator release on day 107 that resulted in one predator egg per container in 80% of the containers positive for *Aedes aegypti* immatures (no rain) ............. 15

19. *Aedes aegypti* adult density following an adult predator release on day 107 that resulted in one predator egg per container in 90% of the containers positive for *Aedes aegypti* (no rain) ......... 15

20. *Aedes aegypti* adult density following contact adulticide application on day 90 and subsequent predator release on day 98 (no rain) ............. 16

21. *Aedes aegypti* adult density following a predator release and five subsequent contact adulticide applications on days 98, 101, 109, 113, and 117 when *Aedes aegypti* adult density exceeded four adults per container (no rain) ........................................... 16

**TABLES**

1. Parameters and their values for model computations ................. 2
2. Development times, average numbers, and percentages of immature *Aedes aegypti* per water-storage jar positive for *Aedes aegypti* in Bangkok, Thailand ........................................ 3
3. Larval development times of *Toxorhynchites rutilus rutilus* in the laboratory when fed *Aedes aegypti* immatures ........................................ 4
4. Larval life of *Toxorhynchites rutilus rutilus* in the laboratory when deprived of food ........................................ 5
5. Duration of development for instars of individually reared *Toxorhynchites rutilus rutilus* at 28°±1° C when fed diet of *Aedes aegypti* larvae or tropical fish food ........................................ 5
6. Number of *Aedes aegypti* per stage per container as reported by Southwood et al. (1972) and the number generated by the model ................. 9
7. Mean number of *Aedes aegypti* per container after contact adulticide application and after application when adult density exceeded seven or four adults per container ........................................ 9
Deterministic Model for Simulating the Predation of *Toxorhynchites rutilus rutilus* on *Aedes aegypti*

By Dana A. Focks,¹ Jack A. Seawright,¹ and Donald W. Hall²

ABSTRACT

A deterministic computer model detailing the interaction of the container-breeding mosquito *Aedes aegypti* (L.) and the predatory larva of *Toxorhynchites rutilus rutilus* (Coq.) is presented. Simulation runs involving the release of *Tx. r. rutilus* adults indicate that releases resulting in one larva per container are sufficient to reduce *Ae. aegypti* adult density 75% in 20 days. The slow development rate of predator immatures enables control to be maintained for several months. Simulations of predator release and the use of adulticides indicate that it is possible to obtain zero adult densities. Finally, the model demonstrates that the most important parameter in determining the degree of control established is the distribution of predator eggs. KEY-WORDS: *Aedes aegypti* (L.), computer simulations, insect control (biological), insect control (chemical), mathematical models, mosquitoes, *Toxorhynchites rutilus rutilus* (Coq.).

INTRODUCTION

Historically, mosquito control has involved source reduction and insecticides. Predicting the outcome of these measures is simple and straightforward. Currently, additional methods of mosquito control are being studied, some of which involve the interaction of two species. Difficulty in understanding the dynamics of the interaction between two species makes predicting the outcome of new methods complicated. Attempting to optimize a strategy that utilizes two different methods in conjunction, e.g., predators and insecticides, is particularly difficult. Therefore, computer-simulation models are becoming increasingly popular as a tool in the development and evaluation of new control strategies.

The purpose of this paper is to (1) present a deterministic computer model examining the interaction of *Aedes aegypti* (L.) and the predatory larva of *Toxorhynchites rutilus rutilus* (Coq.) and (2) simulate the population dynamics of *Ae. aegypti* under different control strategies involving the release of *Tx. r. rutilus* adults and the use of adulticides. Pertinent to this discussion is an explanation by Mertz (1970) of methods used in life-history analysis. The utility and rationale of simulation in developing control strategies were reported by Conway (1970), Haile and Weidhaas (1976), and Weidhaas (1974).

While many of the parameter values for *Tx. r. rutilus* are from laboratory experiments conducted under conditions obviously different from those expected in the field, there remains a very
real value in the model-building exercise. Characterizing the interaction of the two species highlights areas where additional information is needed. Also, simulating with the present model gives us insight into how best to approach a large-scale release experiment where prey control is to be attempted. Finally, the preliminary model gives us a framework within which to interpret the resulting experimental field data. The model is written in FORTRAN; the program listing is given in the appendix.

MODEL DESCRIPTION

The model described herein may be called a compartment model (Miller et al. 1973). Each stage of each species is represented by a number of storage registers within an array (an array is a group of registers). The registers represent 1-day age classifications of the various stages; a particular array represents the age distribution of a particular stage or instar. Except for the *Toxorhynchites rutilus* larval stage, the durations of various stages and instars are determined by the number of registers within a particular array. The model is made to cycle daily by replacing the contents of the next storage register with the contents of the previous register multiplied by the daily survival for that particular stage and species; the output of the terminal registers of one array (stage) is the input to the next array (stage). Most values of daily survival for both species are fixed during any particular simulation run (table 1); the daily survival for *Ae. aegypti* first and second instars is a density-dependent variable. The length of larval life of *Tx. r. rutilus* is also a variable, it being a function of the amount of prey available. Details of these variables are presented later in the paper.

The data used for the modeling of *Ae. aegypti* immatures were largely derived from Southwood et al. (1972) and for adults, from Sheppard et al. (1969). These life-table and ecological studies were conducted in Bangkok, Thailand, in hopes of correlating *Ae. aegypti* population dynamics with the known seasonal incidence of dengue hemorrhagic fever. Surprisingly absent from both studies was any information on fecundity and ovipositional patterns; estimates for these parameters were derived from data on *Ae. aegypti* in northern coastal Florida (unpublished data). The data for *Tx. r. rutilus* came from laboratory, outdoor-cage, and field experiments conducted by Focks and Seawright (1977).

According to Sheppard et al. (1969), the main *Ae. aegypti* breeding sites in Bangkok are the earthen or ceramic water-storage jars (about 100- to 200-liter capacity) found in association with all types of housing. These jars usually contain water throughout the year and are replenished with rainwater, tapwater, or riverwater. Southwood et al. (1972) state that the water-storage jars number about 150 per acre, and about 53% of these are positive for *Ae. aegypti* immatures at any particular time. Interestingly, both stud-

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SA</td>
<td>Daily adult survival</td>
<td>88</td>
</tr>
<tr>
<td>F</td>
<td>Fecundity</td>
<td>93</td>
</tr>
<tr>
<td>P</td>
<td>Successful pupation</td>
<td>90</td>
</tr>
<tr>
<td>SE</td>
<td>Daily egg survival</td>
<td>98</td>
</tr>
<tr>
<td>S</td>
<td>Daily survival for 3d and 4th instars and pupae</td>
<td>95</td>
</tr>
<tr>
<td>C</td>
<td>Density-dependent coefficient for calculating SI</td>
<td>0.01</td>
</tr>
<tr>
<td>SI</td>
<td>Density-dependent daily survival for 1st and 2d instars</td>
<td>0–100</td>
</tr>
<tr>
<td>AEDIST</td>
<td>Containers positive for <em>Aedes</em> immatures</td>
<td>53</td>
</tr>
</tbody>
</table>

*Toxorhynchites rutilus rutilus*

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAT</td>
<td>Daily adult survival</td>
<td>88</td>
</tr>
<tr>
<td>FT</td>
<td>Fecundity</td>
<td>1</td>
</tr>
<tr>
<td>SIT</td>
<td>Daily immature survival (larvae and pupae)</td>
<td>99</td>
</tr>
<tr>
<td>DISTBNN</td>
<td>Containers positive for <em>Toxorhynchites</em> larvae</td>
<td>50–90</td>
</tr>
</tbody>
</table>

1. See figure 1 for details.
ies reported remarkably stable densities and distributions of all stages from season to season. Adult densities of 1,100 per acre, or 7.3 adults per container, were reported. Table 2 presents the development times for immatures and the average numbers of immatures per container. Southwood et al. (1972) note that 20% of the embryonated eggs hatch without the flooding stimulus described by Christophers (1960) and that approximately 50% of the remaining eggs hatch with each subsequent reflooding. Since they reported no data on the frequency of jar flooding, our computer model simulates no-rain and daily-rain situations. A final feature of the population dynamics of Ae. aegypti in Bangkok is the density-dependent survival during the first two larval instars. The stability of the mean number of immatures per container appears to stem from a paucity of larval food (table 2); the number of new third-instar larvae is a consequence of the available food and not the number of newly hatched first-instar larvae. An algorithm for producing the observed larval densities, which is largely independent of oviposition or frequency of hatch, is detailed in figure 1.

The modeling of Tx. r. rutilus, with several exceptions, is similar to that for Ae. aegypti. Figure 2 reveals that (1) the three last immature stages are separated into three arrays, (2) eggs hatch independently of rainfall on the second day after oviposition, and (3) oviposition begins 6 days after eclosion and occurs daily thereafter. Figure 2 also shows laboratory-reared adult Tx. r. rutilus being released at 6 days of age.

The nature and mechanics of modeling the predation of Tx. r. rutilus on Ae. aegypti are pre-

---

**Table 2.—Development times, average numbers, and percentages of immature *Aedes aegypti* per water-storage jar positive for *Aedes aegypti* in Bangkok, Thailand**

<table>
<thead>
<tr>
<th>Stage</th>
<th>Mean development time (days)</th>
<th>Mean No. individuals per jar</th>
<th>Percentage of immatures per jar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eggs</td>
<td>4.0</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Larvae:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st- and</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2d-instar</td>
<td>5.2</td>
<td>20.0</td>
<td>51</td>
</tr>
<tr>
<td>3d-instar</td>
<td>3.2</td>
<td>9.5</td>
<td>24</td>
</tr>
<tr>
<td>4th-instar</td>
<td>6.5</td>
<td>8.0</td>
<td>20</td>
</tr>
<tr>
<td>Pupae</td>
<td>2.2</td>
<td>2.0</td>
<td>5</td>
</tr>
<tr>
<td>Total</td>
<td>17.1</td>
<td>39.5</td>
<td>100</td>
</tr>
</tbody>
</table>

1 Southwood et al. (1972).
2 Excluding eggs.

---

**Figure 1.—Flow chart and algorithm for *Aedes aegypti* computations. Letters within parentheses refer to daily survival values listed in table 1.**
Figure 2.—Flow chart for Toxorhynchites rutilus rutilus computations. Letters within parentheses refer to daily survival values listed in table 1.

Table 3.—Larval development times of Toxorhynchites rutilus rutilus in the laboratory when fed Aedes aegypti immatures

<table>
<thead>
<tr>
<th>Tx. r. rutilus instar</th>
<th>Average development time (days)</th>
<th>Average consumption of Ae. aegypti 1st and 2d instars (days)</th>
<th>Average development time</th>
<th>Average consumption of Ae. aegypti 3d and 4th instars and pupae (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Total Daily</td>
<td></td>
<td>Total Daily</td>
</tr>
<tr>
<td>1</td>
<td>1.2</td>
<td>6.4 5.3</td>
<td>1.2</td>
<td>64 53</td>
</tr>
<tr>
<td>2</td>
<td>2.6</td>
<td>6.6 2.5</td>
<td>2.6</td>
<td>66 25</td>
</tr>
<tr>
<td>3</td>
<td>8.0</td>
<td>80 7.5</td>
<td>3.8</td>
<td>80 2.1</td>
</tr>
<tr>
<td>4</td>
<td>32.0</td>
<td>320 18.8</td>
<td>8.0</td>
<td>73 9.1</td>
</tr>
<tr>
<td>Total</td>
<td>43.8</td>
<td>673</td>
<td>15.6</td>
<td>94</td>
</tr>
</tbody>
</table>

1 The numbers reported consumed are 1st- and 2d-instar prey, since early-instar predators cannot consume late-instar prey.
2 Estimated from 3 replicates.
The situation to be modeled is as follows:
(1) Third and fourth instars of *Tx. r. rutilus* develop faster on a diet of late instars and pupae than on a diet of early-instar prey. (2) All larvae develop at a rate proportional to the amount of prey available until the amount of prey exceeds that given in table 3. (3) All predator instars can survive without prey for a period of time, and if provided detritus, can develop at a very slow rate up to eclosion. (4) The daily immature survival (SIT) is constant, irrespective of diet (unpublished data).

In the model, first- and second-instar predators (array T12) are assumed to eat before third- and fourth-instar predators (T3 and T4, respectively) on any particular day. This assumption simplifies the programing of predation and does not, considering the relative amounts of prey consumed by each instar, introduce significant errors. The number of storage registers within arrays T12, T3, and T4 (16, 32, and 96, respectively) do not correspond directly to 1 day each. This is because the larvae are moved incrementally within an array as a function of prey size and numbers of prey available. If no prey is available, all the predators are incremented one register forward.

If the numbers of prey equal or exceed the numbers in table 3, the larvae are incremented 4, 8, and 12 registers forward in arrays T12, T3, and T4, respectively. Intermediate numbers of prey result in incrementing the predator arrays by an amount proportional to the available prey. The *Ae. aegypti* immature arrays in containers positive for *Tx. r. rutilus* (XA and YA) are updated daily for the effects of predation. Since cannibalism does not occur among the predators at the densities considered here, even when there is no prey, it is not modeled.

Following a release of *Tx. r. rutilus* adults, one would expect, on the basis of the distribution of *Ae. aegypti* larvae (53% positive) and an assumed predator distribution of 80% (unpublished data), to obtain four types of containers—42.4% positive for both species, 10.6% positive for *Ae. aegypti* only, 37.6% positive for *Tx. r. rutilus* only, and 9.4% containing neither species. Since it is assumed that no *Tx. r. rutilus* adults result

---

Table 4.—Larval life of *Toxorhynchites rutilus rutilus* in the laboratory when deprived of food

<table>
<thead>
<tr>
<th>Instar in which starvation began</th>
<th>No. individuals observed</th>
<th>Age at beginning of test (days)</th>
<th>Days before death</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9</td>
<td>0</td>
<td>6.9±0.3</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td>4 or 5</td>
<td>8.4±0.5</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>9 or 10</td>
<td>18.0±6.5</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
<td>13</td>
<td>59.0±22.4</td>
</tr>
</tbody>
</table>

1 Temperature of 27 °C.

2 Temperature of 27 °C during first 11 days, then raised to 30 °C.

One individual fasted 88 days.

---

Table 5.—Duration of development for instars of individually reared *Toxorhynchites rutilus rutilus* at 28 ±1 °C when fed diet of *Aedes aegypti* larvae or tropical fish food

<table>
<thead>
<tr>
<th>Instar</th>
<th>Mean development time (days)(^1) when fed—</th>
<th>Time increase, fish-food fed over prey fed (pet)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><em>Ae. aegypti</em> (n=48)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fish food (n=83)</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1.2</td>
<td>720</td>
</tr>
<tr>
<td>2</td>
<td>2.6</td>
<td>200</td>
</tr>
<tr>
<td>3</td>
<td>3.8</td>
<td>380</td>
</tr>
<tr>
<td>4</td>
<td>8.0</td>
<td>990</td>
</tr>
<tr>
<td><strong>Total ± standard deviation</strong></td>
<td><strong>15.6±1.4</strong></td>
<td><strong>690</strong></td>
</tr>
</tbody>
</table>

\(^1\) According to the arithmetic method of Southwood et al. (1972), each entry is the time required for half the population to molt to the next instar.
from oviposition into containers devoid of prey and since one type of container produces neither species, these containers are not specifically modeled in the program but are accounted for with scaling factors (fig. 3). To represent the salient features of the interaction in the field and to represent the resulting Ae. aegypti adult density, two containers, both positive for Ae. aegypti, are included in the model. Only one of these is interfaced with the predator subroutine. Ae. aegypti eclosion and Tx. r. rutilus oviposition are scaled by factors of DISTBN and AEDIST, respectively, to depict the frequency of the two containers in the field. Because of the scaling factors, the numbers of Ae. aegypti and Tx. r. rutilus adults are in terms of one container, and multiplying the output of adults by the number of containers per area gives an absolute population estimate.

RESULTS OF SIMULATION

Figures 4 and 5 represent model-generated Ae. aegypti adult densities per container for no-rain and daily-rain-into-every-container situations, respectively. Figures 6 and 7 depict the corresponding total number of Ae. aegypti immatures per container for the two rainfall situations. In each instance and in all subsequent simulation runs, the model program was initialized on day 1 with 7.4 1-day-old adult Ae. aegypti. The resulting numbers within each stage were largely inde-
Figure 4.—*Aedes aegypti* adult density per container with no control measures applied (no rain).

Figure 5.—*Aedes aegypti* adult density per container with no control measures applied (daily rainfall into every container).
Figure 6.—*Aedes aegypti* immature density per container (no rain).

Figure 7.—*Aedes aegypti* immature density per container (daily rainfall into every container).
dent of the number and stages used in initializing the model. The graphs were smoothed by plotting 4-day moving averages. The cyclic nature of the daily-rain situation in figures 5 and 7 dampened with time.

A comparison can be made from table 6 between the number of Ae. aegypti individuals per stage per container observed by Southwood et al. (1972) and the number of individuals per stage per container generated by the model when no control measures were applied. The total number of immatures per container generated by the model exceeded the total reported by Southwood et al. This disparity was allowed to remain because the difference was not large, especially in

<table>
<thead>
<tr>
<th>Stage</th>
<th>Southwood et al.</th>
<th>Model No rain</th>
<th>Model Rain</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Larvae:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st-and 2d-instar</td>
<td>9.5</td>
<td>30.0</td>
<td>70.0</td>
<td>50.0</td>
</tr>
<tr>
<td>3d-instar</td>
<td>9.5</td>
<td>8.0</td>
<td>5.0</td>
<td>6.5</td>
</tr>
<tr>
<td>4th-instar</td>
<td>8.0</td>
<td>8.0</td>
<td>5.0</td>
<td>6.5</td>
</tr>
<tr>
<td>Pupae</td>
<td>2.0</td>
<td>2.2</td>
<td>1.5</td>
<td>1.9</td>
</tr>
<tr>
<td>Total</td>
<td>20.0</td>
<td>39.5</td>
<td>64.9</td>
<td>64.9</td>
</tr>
</tbody>
</table>

Situation modeled is that all containers receive daily rain.

Table 7.—Mean number of *Aedes aegypti* per container after contact adulticide application and after application when adult density exceeded seven or four adults per container

<table>
<thead>
<tr>
<th>Stage</th>
<th>No treatment</th>
<th>Single application</th>
<th>7 Adults per container</th>
<th>4 Adults per container</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult</td>
<td>8</td>
<td>8</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Immature</td>
<td>49</td>
<td>49</td>
<td>28</td>
<td>21</td>
</tr>
</tbody>
</table>

1 See figures 8–13.
2 Daily immature survival (SI) of 75%.
3 Daily immature survival of 84%. 15 applications in 262 days.
4 Daily immature survival of 88%. 21 applications during period 98–360 days.

Figure 8.—*Aedes aegypti* adult density following contact adulticide application on day 90 (no rain). The result was 95% adult mortality with no residual effects.
Figure 9.—*Aedes aegypti* immature density following contact adulticide application on day 90 (no rain).

Figure 10.—*Aedes aegypti* adult density following contact adulticide application when *Aedes aegypti* adult density exceeded seven adults per container (no rain). Spraying at this density required 15 applications in 262 days (no rain).
the no-rain situation, and would have made the model more conservative in subsequent control simulations. Density-dependent first- and second-instar daily survival (SI) for the no-rain and daily-rain situations averaged about 75% and 50%, respectively.

The effects on *Ae. aegypti* population dynamics of contact adulticide application, which caused 95% mortality among the adults with no residual action, are presented in table 7 and figures 8-13. Figure 8 shows the overshoot of adults one generation later as a consequence of one contact adulticide application when *Ae. aegypti* adult density exceeded seven adults per container (no rain). Spraying at this density required 21 applications in 262 days. 

**Figure 11.** *Aedes aegypti* immature density following contact adulticide application when *Aedes aegypti* adult density exceeded seven adults per container (no rain).

**Figure 12.** *Aedes aegypti* adult density following contact adulticide application when *Aedes aegypti* adult density exceeded four adults per container (no rain). Spraying at this density required 21 applications in 262 days.
Figure 13.—*Aedes aegypti* immature density following contact adulticide application when *Aedes aegypti* adult density exceeded four adults per container (no rain).

Figure 14.—*Aedes aegypti* adult density following an adult predator release on day 98 that resulted in one predator egg in 80% of the containers positive for prey (no rain).
application. Figures 10 and 12 show the increased frequency of application required to maintain an increasingly lower adult density. Because of this type of situation, population suppression has usually involved the use of larvicides in addition to adulticides (Gould, et al. 1970, 1971).

Figure 14 shows the effects of a predator release on day 98 that resulted in one predator egg in 80% of the containers during a period of no rainfall. A 75% reduction in Ae. aegypti adult density occurred within 20 days. The Ae. aegypti adult blip beginning about day 170 resulted from the eclosion of the predator. The effects of the subsequent second generation of predators resulting from the release are shown after day 185 in figure 14.

Until actual field trials are made, the reality of the effects of a second generation will remain uncertain. The model does depict, however, smaller and smaller subsequent generations of predator. These results are consistent with known equilibrium densities of predator and prey in nature.

Figure 15 reveals that one predatory larva was sufficient to deplete a water-storage container in 6 to 8 days. The model further shows that continued oviposition by declining numbers of Ae. aegypti provided food, allowing the predator to develop and eclose in approximately 53 days.

Simulations involving larger adult releases that produced greater numbers of predator eggs per container did not appreciably alter the Ae. aegypti decline. This is understandable because one predator per container was sufficient to stop prey breeding in that particular container; therefore, the additional predators were superfluous. Larger numbers of predators per container further exacerbated the prey shortage, producing even longer development times. In the field, a variable number of predators per container would likely result in asynchronous predator eclosion.

Since rainfall increased the number of young prey larvae, five predators per container were required to eliminate Ae. aegypti breeding in containers positive for Tx. r. rutilus. Figure 16 shows the failure of three predators per container to establish control. Furthermore, the increased food supply caused shorter predator development times, which resulted in shorter periods of control from the first cohort of predators. The ramifications of this would depend on the results of subsequent generations of predators resulting from the original release. At any rate, the lower numbers of predators required in the dry season to initiate control indicate a logical time to attempt control.

Figures 17, 18, and 19 represent expected Ae. aegypti adult densities when the percentage of

(Continued on page 16.)

Figure 15.—Aedes aegypti immature density following release of one predatory larva per container on day 98 in 80% of the containers positive for Aedes aegypti (no rain). The blip at 160 days is a result of predator eclosion from the container.
Figure 16.—*Aedes aegypti* adult density following an adult predator release on day 98 that resulted in three predatory larvae per container in 80% of the containers positive for *Aedes aegypti* (daily rain).

Figure 17.—*Aedes aegypti* adult density following an adult predator release on day 107 that resulted in one predator egg per container in 60% of the containers positive for *Aedes aegypti* immatures (no rain).
Figure 18.—Aedes aegypti adult density following an adult predator release on day 107 that resulted in one predator egg per container in 80% of the containers positive for Aedes aegypti immatures (no rain).

Figure 19.—Aedes aegypti adult density following an adult predator release on day 107 that resulted in one predator egg per container in 90% of the containers positive for Aedes aegypti (no rain).
containers receiving one predator egg per container is 60%, 80%, and 90%, respectively. The preceding discussion and these figures lend support to the idea that the most important parameter determining the degree of control established is the distribution of predator eggs (DISTBN). It seems likely that energy would be well spent in improving predator distribution through release of smaller numbers of adults at more sites.

Simulations involving the use of adulticides
and predators revealed the following: (1) One adulticide application shortly before or after a predator release did not significantly decrease the resulting prey density nor increase the rate at which it was achieved (fig. 20). (2) Several applications 2 or 3 days apart after a predator release resulted in immediate and sustained prey densities near zero (fig. 21). These results reinforce our assumption that maintenance of control is a function of the efficacy of the resulting subsequent predator generations.

CONCLUSIONS

As stated previously, the computer model is a useful tool in evaluating and developing new control strategies. The utility of *Tx. r. rutilus* in controlling container-breeding mosquitoes will have to be demonstrated in the field rather than in a computer. Demonstrated here is the feasibility of control and a justification for larger scale fieldwork than has already been done.

Field data on predator distribution, the effects of second- and third-generation predators resulting from an initial release, and field-survival values for the immature predator stages will make it possible to develop an accurate stochastic model. This model, in turn, will facilitate the evaluation of a strategy involving insecticides, predators, and the sterile-male technique.

REFERENCES


Conway, G. R.


APPENDIX.—FORTRAN LISTING

REAL GRAPH(3000), DAY(360), SUMA(360), SUMTA(360),
1SUM1(360), SUM2(360), SUM3(360), X1(360), X2(360),
1X2(360), X4(360), X5(360), X6(360), X7(360)
DATA DAY, SUMA, SUMTA, SUM1, SUM2, SUM3, X1, X2,
1X3, X4, X5, X6, X7, 360, 360, 360, 360, 360
1360*0., 360*0., 360*0., 360*0., 360*0., 360*0., 360*0.,
1360*0.,
REAL H1(360), N2(360), B3(360), B4(360)
DATA B1, B2, B3, B4/360*0., 360*0., 360*0.,
REAL C1(360), C2(360), C3(360), C4(360)
DATA C1, C2, C3, C4/360*0., 360*0., 360*0.,
REAL D1(360)
DATA D1/360*0./
REAL N5(360), C5(360)
DATA N5, C5/360*0.,
REAL A(8), TA(7)
A & TA REPRESENT Aedes & Tox. adults

REAL E(6), X(5), Y(12)
Aedes immatures in containers without tox.
WHERE E=EGGS, X=STAGES 1 & 2 & Y=STAGES 3, 4 & PUPA.

REAL TEMP12(24), TEMP3(40), TEMP4(108)
DATA TEMP12, TEMP3, TEMP4/24*0., 40*0., 108*0./
REAL FT(6), TA(5), YA(12)
Aedes immatures in containers positive for tox.
FT=Ae*EGGS, XA=Ae*STAGES 1 & 2 & YA REPRESENTS STAGES 3-PUPA

REAL T12(24), T3(40), T4(108), TP(8), TE(3)
Toxorhynchites immatures arrays; T12=STAGES 1 & 2, T3=STAGE 3
T4=STAGE 4, TP=PUPA, & TE=EGGS

DATA A, TA/8*0., 7*0./
DATA E, X, Y/6*0., 5*0., 12*0./
DATA ET, TA, YA/6*0., 5*0., 12*0./
DATA T12, T3, T4, TP/24*0., 40*0., 108*0., 8*0./
DATA TE/3*0./
1=0

SA=0.98
SA=ADULT DAILY SURVIVAL
F=93
F=FECONDITY (EGGS/EATCH)
P=0.00
P=PROPORTION OF PUPATION WHICH IS SUCCESSFUL
SE=0.98
SE=DAILY EGG SURVIVAL
S=0.95
S=DAILY SURVIVAL FOR STAGES 3, 4 & PUPA
C=0.01
C=DENSITY DEPENDENT COEFFICIENT FOR CALCULATING
SI, WHERE SI=DAILY LARVAL SURVIVAL, STAGES 1 & 2.

***TOX. PARAMETERS***
SAT=0.88
SAT=DAILY ADULT SURVIVAL.
FT=1.0
FT=DAILY EGG PRODUCTION.
SIT=0.99
SIT=DAILY IMMATURE SURVIVAL, STAGES 1-PUPA.
DISTR=PROPORTION OF CONTAINERS POSITIVE FOR TOX. EGGS.
DISTRN=0.80

I=1000
1=1+1
I=0
MODIFY Aedes WITH 7.4 ADULTS/CONTAINER
I=1.50*1, A(1)=7.4
WHERE REPRESENTS AN ADULTICIDE APPLICATION CAUSING 95% MORTALITY
I=1.50*1, GOTO 1500
R=ADULT DENSITY WHEN ULV IS APPLIED
R=1000
SA=0.88
IF (SUMA(I-1)*GT*R) SA=0.05
IF(SA.EQ.0.05) GOTO 1500
GOTO 1501
1500 WRIF (6,1502) 1
1502 FORMAT (1X,13)
1501 CONTINUE
IF (I.EQ.107) TE(1)=1
***AEDES ADULTS***
A(8)=A(7)*SA
A(7)=A(6)*SA
A(6)=A(5)*SA
A(5)=A(4)*SA
A(4)=A(3)*SA+A(8)*SA
A(3)=A(2)*SA
A(2)=A(1)*SA
A(1)=(Y(12)*P*(1-DISTBN))+(YA(12)*P*DISTBN)
***AEDES LARVAE IN CONTAINERS WITHOUT TOX. LARVAE***
C
C FOLLOWING MOVES STAGES 3-PUPA
150
Y(12)=Y(11)*S
Y(11)=Y(10)*S
Y(10)=Y(9)*S
Y(9)=Y(8)*S
Y(8)=Y(7)*S
Y(7)=Y(6)*S
Y(6)=Y(5)*S
Y(5)=Y(4)*S
Y(4)=Y(3)*S
Y(3)=Y(2)*S
Y(2)=Y(1)*S
C
C FOLLOWING CALCULATES SI FOR STAGES 1 AND 2
SUM=X(1)+X(2)+X(3)+X(4)+X(5)
IF(SUM.EQ.0) SI=1.0
IF(SUM.EQ.0) GOTO 30
IF(SUM.LT.15) GOTO 10
IF(SUM.GT.120) GOTO 20
XNT=SUM*(EXP(-C*SUM))
SI=XNT/SUM
GCTC 30
10 SI=0.88
GOTO 30
20 SI=120/SUM
C
C FOLLOWING MOVES STAGES 1 AND 2
30 Y(1)=X(5)*SI
X(5)=X(4)*SI
X(4)=X(3)*SI
X(3)=X(2)*SI
X(2)=X(1)*SI
C
C THE FOLLOWING CONTROLS EGG HATCH & OVIPPOSITION
E(6)=E(5)*F(6)*SE
E(5)=E(4)*SE
E(4)=E(3)*SE
E(3)=E(2)*SE
E(2)=E(1)*SE
C
C AEDES OVIPPOSITION INTO TOX-FREE CONTAINERS
E(1)=A(4)*F*0.5
C
C EGG HATCH AS FUNCTION OF RAINFALL (IRAIN)
IF(IPAIN.EQ.1) GOTO 100
X(1)=E(5)*0.2
E(5)=E(5)*0.8
GCTC 200
100 X(1)=(E(6)*0.5+(E(5)*0.2)
E(6)=E(6)*0.5
E(5)=E(5)*0.8
GCTC 200
C
C ***AEDES LARVAE IN CONTAINERS WITH TOX. LARVAE***
C
C FOLLOWING MOVES STAGES 3-PUPA
151 YA(12)=YA(11)*S
YA(11)=YA(10)*S
YA(10)=YA(9)*S
YA(9)=YA(8)*S
YA(8)=YA(7)*S

20
YA(7) = YA(6) * S
YA(6) = YA(5) * S
YA(5) = YA(4) * S
YA(4) = YA(3) * S
YA(3) = YA(2) * S
YA(2) = YA(1) * S

following calculates six for stages 1 and 2
SOMA = XA(1) + XA(2) + XA(3) + XA(4) + XA(5)
IF(SOMA * EQ. 0) SIX = 1.0
IF(SOMA * EQ. 0) GOTO 31
IF(SOMA * LT. 15) GOTO 11
IF(SOMA * GT. 120) GOTO 21
XNTA = SOMA * (EXP(-C*SOMA))
SIX = XNTA / SOMA
GOTO 31

11 SIX = 0.88
GOTO 31
21 SIX = 120 / SOMA

following moves stages 1 and 2
31 YA(1) = XA(5) * SIX
XA(5) = XA(4) * SIX
XA(4) = XA(3) * SIX
XA(3) = XA(2) * SIX
XA(2) = XA(1) * SIX

the following controls egg hatch & oviposition
ET(6) = (ET(5) + ET(6)) * SE
ET(5) = ET(4) * SE
ET(4) = ET(3) * SE
ET(3) = ET(2) * SE
ET(2) = ET(1) * SE

Aedes oviposition into containers positive for tox.
ET(1) = A(4) * F * 0.5
egg hatch as function of rainfall (IRAIN)
IF(IRAIN * EQ. 1) GOTO 101
XA(1) = ET(5) * 0.2
ET(5) = ET(5) * 0.8
GCTC = 201
101 XA(1) = ET(5) * 0.5 + (ET(5) * 0.2)
ET(5) = ET(5) * 0.5
ET(5) = ET(5) * 0.8
201 CONTINUE

***below represents tox. immatures & their predation***
on Aedes larvae in the above section

the following interfaces 1 & 2-stage Aedes with 1 & 2-stage tox.
SMXA1 = 0
SMXA1 = NO. 1 & 2-stage AE. Larvae in AE./ TX. CONTAINER
DC 13 KN = 1.5
13 SMX(1) = XA(KN) + SMXA1
SMT12 = 0
SMT12 = NO. 1 & 2-stage TOX. Larvae
DC 71 N = 1.16
71 SMT12 = SMT12 + T12(M)
IF(SMXA1 * GT. SMT12 * 4) GOTO 29
IF(SMXA1 * EQ. 0) IZ = 1
IF(SMXA1 * EQ. 0) GOTO 39
IF(SMT12 * EQ. 0) GOTO 601
IZ = INT(SMXA1 / SMT12)
IF(IZ * EQ. 0) IZ = 1
DC 61 L = 1.5
61 XA(L) = 0
GOTO 39
29 IZ = 4
ATE = (4 * SMT12)
IF(ATF * EQ. 0) GOTO 39
BB = ATE / SMXA1
CC = 1 - BB
DC 52 K = 1.5
52 XA(K) = XA(K) * CC
39 CONTINUE
DC 41 J = 1.16
TEMP12(J + IZ) = T12(J) * SIJ
41 CONTINUE
DC 999 MM = 1.24
THE FOLLOWING INTERFACES 3&4- STAGE TOX. WITH ALL STAGES OF AEDES IMMATURES. MODEL ASSUMES AEDES 1&2-STAGE LARVAE ARE EATEN FIRST FOLLOWED BY 3,4&P-STAGE AEDES. NOTICE THAT FOR EACH DAY, THE 1&2-STAGE TOX. EAT FIRST.

T3(1)=T12(17)*T12(18)+T12(19)*T12(20)

CONTINUE

DC 400 K30=17,20
T12(K30)=0

CONTINUE

SMXA2=NO. AEDES LARVAE, STAGE 1&2, AVAILABLE AS FOOD.

SMYA=NO. 3,4& PUPAL-STAGE AEDES AVAILABLE AS FOOD.

NOTE-1 3,4 OR PUPA-STAGE AEDES IS EQUIVALENT TO 7,111

1 OR 2-STAGE AEDES LARVAE, TOTU=AMOUNT OF FOOD AVAILABLE.

ST3=NO. 3-STAGE TOX., ST4=NO. 4-STAGE TOX.

REQ3&4 ARE THE NO. CF AEDES EQUIV. NECESSARY TO MOVE 1 REGULAR DAY.

REQ3=ST3*14
REQ4=ST4*64
TREQ=PEQ3+PEQ4
IF(TOTU+EQ.0) IT3=1
IF(TOTU+EQ.0) IT4=1
IF(TOTU+EQ.0) GOTO 105
IF(TREQ+EQ.0) GOTO 108
IF(TFQ0+LE.TOTU) GOTO 115
DC 22 KK=1,5
XA(KK)=0

CONTINUE

DC 12 KI=1,12
YA(KI)=0

CONTINUE

Q=TOTU/TREQ

IT3&4 INCREMENT THEIR RESPECTIVE ARRAYS WHEN LESS THAN MIN. FOOD IS AVAILABLE.

IT3=INT(8*Q)
IT4=INT(12*Q)
IF (IT3,EQ.0) IT3=1
IF (IT4,EQ.0) IT4=1
GOTO 105

IT3=A
IT4=12

ITERATIONS FOR 3&4-STAGE TOX. WHEN AMPLE FOOD AVAILABLE.

BAL=TREQ-SMXA2

BAL HERE REPRESENTS THE NO. UNITS REQD. FROM YA.

IF(BAL,GT.0) GOTO 90
SIAX=ABS(BAL/SMXA2)
DC 91 MJ=1,5
91 YA(MJ)=YA(MJ)*SIAX

CONTINUE

DO 92 MJ=1,5
92 YA(MJ)=0
BAL=ABS(BAL)
SIYA=((SMY*7,111)-BAL)/(SMY*7,111)
DO 125 IN=1,12
125 YA(IN)=YA(IN)*SIYA

CONTINUE

DC 106 KJ=1,32
TEMP3(KJ+IT3)=T3(KJ)*SIT

CONTINUE

DC 999 #5=1,40
T3(M5) = TEMP3(M5)

CONTINUE DC 107 KM = 1, 96
TEMP4(KM) + T4 = T4(KM) + T3
CONTINUE DO 107 M6 = 1, 108
T4(M6) = TEMP4(M6)
CONTINUE T4(1) = 0
DC 555 LM = 33.40
T4(1) = T4(1) + T3(LM)
CONTINUE DO 401 K31 = 33, 40
T4(K31) = TEMP4(K31)
CONTINUE DO 402 K131 = 97, 108
T4(131) = 0
CONTINUE TA(7) = TA(7) + TA(6) * SAT
TA(6) = TA(6) * SAT
TA(5) = TA(5) * SAT
TA(4) = TA(4) * SAT
TA(3) = TA(3) * SAT
TA(2) = TA(2) * SAT
TA(1) = TA(1) * SAT
TE(3) = TE(3) + SAT
TE(2) = TE(2) + SAT

TCX, OVIPOSITION & EGGS
TE(1) = TA(7) * 0.5 * FT * AEDIST
T13(1) = TE(3)
C1(1) = Y(1) + Y(2) + Y(3) + Y(4)
C2(1) = Y(5) + Y(6) + Y(7) + Y(8) + Y(9) + Y(10)
C3(1) = Y(11) + Y(12)

C1, C2, C3 ARE THE NO. OF AE. STAGE 3, 4 AND PUPA IN CONTAINERS WITHOUT TX.

C4(1) = SI
C5(1) = SIX
SUMA & SUMTA ARE THE NO. OF AE. AND TOX. ADULTS.
SUMA(1) = 0
DO 801 J1 = 1, 8
SUMA(1) = SUMA(1) + A(J1)
CONTINUE SUMTA(1) = 0
DO 802 J2 = 1, 7
SUMTA(1) = SUMTA(1) + TA(J2)
DAY(1) = 1
D1(1) = 0
DC 903 J3 = 1, 5
803 D1(1) = D1(1) + X(J3)
X2(1) = 0
DO 804 J4 = 1, 12
804 X2(1) = X2(1) * Y(J4)
SUM1(1) = D1(1) + X2(1)
SUM1 = SUM OF AE. IMMATURES IN CONTAINERS WITHOUT TX. LARVAE.
X3(1) = 0
DC 805 J6 = 1, 5
805 X3(1) = X3(1) + XA(J6)
X4(1) = 0
DC 806 J7 = 1, 12
806 X4(1) = X4(1) + YA(J7)
SUM2(1) = X3(1) + X4(1)
SUM2 = SUM OF AE. IMMATURES IN CONTAINERS POSITIVE FOR TX. LARVAE.
X5(1) = 0
DC 907 J7 = 1, 16
807 X5(1) = X5(1) + T12(J7)
X6(1)=0
DO 808 J8=1,32
808 X6(1)=X6(1)+T3(JA)
X7(1)=0
DO 809 J9=1,96
809 X7(1)=X7(1)+T4(J9)
SUM3(1)=X5(1)+X6(1)+X7(1)
C
SUM3=SUM OF TX. LARVAE.
IF(1.LT.360) GOTO 1000
DO 308 I=1,357
308 X1(I)=(D1(I)+D1(I+1)+D1(I+2)+D1(I+3))/4
DO 304 I=1,357
304 B1(I)=(C1(I)+C1(I+1)+C1(I+2)+C1(I+3))/4
DO 305 I=1,357
305 B2(I)=(C2(I)+C2(I+1)+C2(I+2)+C2(I+3))/4
DO 306 I=1,357
306 B3(I)=(C3(I)+C3(I+1)+C3(I+2)+C3(I+3))/4
DO 307 I=1,357
307 B4(I)=(C4(I)+C4(I+1)+C4(I+2)+C4(I+3))/4
DO 501 I=1,357
501 SUMA(I)=(SUMA(I)+SUMA(I+1)+SUMA(I+2)+SUMA(I+3))/4
DO 502 I=1,357
502 SUMTA(I)=(SUMTA(I+1)+SUMTA(I+2)+SUMTA(I+3))/4
DO 503 I=1,357
503 SUM1(I)=(SUM1(I)+SUM1(I+1)+SUM1(I+2)+SUM1(I+3))/4
DO 504 I=1,357
504 SUM2(I)=(SUM2(I)+SUM2(I+1)+SUM2(I+2)+SUM2(I+3))/4
DO 505 I=1,357
505 SUM3(I)=(SUM3(I)+SUM3(I+1)+SUM3(I+2)+SUM3(I+3))/4
DO 471 I=1,357
471 P5(I)=C5(I)+C5(I+1)+C5(I+2)+C5(I+3))/4
C
BELOW PLOTS AE. ADULTS
CALL PLOT1 (3,51,10,111,10)
CALL PLOT2 (GRAPH,360.,0.,0.,20.,0.,)
CALL PLOT3 (1H*,DAY(1),SUMA(1),357)
WRITE (6,700)
700 FORMAT ('H1., 'AEDES ADULTS')
CALL PLOT4 (12,12HAEDS ADULTS)
WRITE (6,1200)
C
BELOW PLOTS TX. ADULTS
CALL PLOT1 (3,51,10,111,10)
CALL PLOT2 (GRAPH,360.,0.,0.,20.,0.,)
CALL PLOT3 (1H*,DAY(1),SUMTA(1),357)
WRITE (6,701)
701 FORMAT ('H1., 'TOXORHYNCHITES ADULTS')
CALL PLOT4 (11,11HTOX. ADULTS)
WRITE (6,1200)
C
BELOW PLOTS AE. IMMATURES IN CONTAINERS WITHOUT TX.
CALL PLOT1 (3,51,10,111,10)
CALL PLOT2 (GRAPH,360.,0.,0.,140.,0.,)
CALL PLOT3 (1H*,DAY(1),SUM1(1),357)
WRITE (6,702)
702 FORMAT ('H1., 'AE. IMMATURES IN CONTAINERS WITHOUT TX. IMMATURES')
CALL PLOT4 (15,15HAEDS IMMATURES)
WRITE (6,1200)
C
BELOW PLOTS AE. STAGE 1 & 2
CALL PLOT1 (3,51,10,111,10)
CALL PLOT2 (GRAPH,360.,0.,0.,140.,0.,)
CALL PLOT3 (1H*,DAY(1),X1(1),357)
WRITE (6,703)
705 FORMAT ('H1., 'AE. STAGES-1&2 IN CONTAINERS WITHOUT TX. LARVAE')
CALL PLOT4 (9,9HAEDS 1&2)
WRITE (6,1200)
C
BELOW PLOTS AE. STAGE 3
CALL PLOT1 (3,51,10,111,10)
CALL PLOT2 (GRAPH,360.,0.,50.,0.,)
CALL PLOT3 (1H*,DAY(1),B1(1),357)
WRITE (6,300)
300 FORMAT ('H1., 'AE. STAGE-3 IN CONTAINERS WITHOUT TX. LARVAE')
CALL PLOT4 (13,13HAEDS STAGE 3)
WRITE (6,1200)
C
BELOW PLOTS AE. STAGE- 4
CALL PLOT1 (3,51,10,111,10)
CALL PLOT2 (GRAPH,360.,0.,25.,0.,)
CALL PLOT3 (1H*,DAY(1),B2(1),357)
WRITE (6,301)
300 FORMAT ('H1., 'AE. STAGE-4 IN CONTAINERS WITHOUT TX. LARVAE')
CALL PLOT4 (13,13HAEDS STAGE 4)
WRITE (6,1200)
CALL PLOT4 (13,13HAEDES STAGE 4)
WRITE (6,1200)
BELOW PLOTS AE. PUPAE
CALL PLOT1 (3,51,10,111,10)
CALL PLOT2 (GRAPH, 360.0., 10..0.)
CALL PLOT3 (1H*, DAY(1), B3(1), 357)
WRITE (6,302)
CALL PLOT4 (11,11HAEDES PUPAE)
WRITE (6,1200)
BELOW PLOTS SIX
CALL PLOT1 (3,51,10,111,10)
CALL PLOT2 (GRAPH, 360.0., 10..0.)
CALL PLOT3 (1H*, DAY(1), B4(1), 357)
WRITE (6,303)
CALL PLOT4 (2,2HSI)
WRITE (6,1200)
BELOW PLOTS SIX
CALL PLOT1 (3,51,10,111,10)
CALL PLOT2 (GRAPH, 360.0., 10..0.)
CALL PLOT3 (1H*, DAY(1), B5(1), 357)
WRITE (6,450)
CALL PLOT4 (2,2HSI)
WRITE (6,1200)
BELOW PLOTS AE. IMMATURES IN CONTAINERS WITH TX.
CALL PLOT1 (3,51,10,111,10)
CALL PLOT2 (GRAPH, 360.0., 140..0.)
CALL PLOT3 (1H*, DAY(1), SUM2(1), 357)
WRITE (6,703)
CALL PLOT4 (15,15HAEDES IMMATURES)
WRITE (6,1200)
BELOW PLOTS TX, LARVAE
CALL PLOT1 (3,51,10,111,10)
CALL PLOT2 (GRAPH, 360.0., 20..0.)
CALL PLOT3 (1H*, DAY(1), SUM3(1), 357)
WRITE (6,704)
CALL PLOT4 (11,11HGX LARVAE)
WRITE (6,1200)
STOP
END
ENTRY