

A POPULATION MODEL OF *HELOPELTIS* IN BANGLADESH TEA

M. Ahmed*

(Bangladesh Tea Research Institute, Srimangal 3210
Maulvibazar, Bangladesh)

and

J.D. Mumford

(Biology Department, Imperial College at Silwood Park, Ascot, Berkshire, UK)

and

J. Holt

(Natural Resources Institute, Chatham, Kent, UK)

In Bangladesh, tea, *Camellia sinensis* (L.) O. Kuntze (family Theaceae), is grown contiguously in parts of Sylhet, Chittagong and Chittagong Hill Tracts in an area of about 47,000 ha. Among 29 recorded arthropod pests, tea mosquito bug, *Helopeltis theivora* Waterhouse is known to cause high crop loss in some seasons. *Helopeltis* population dynamics are affected by various biological and environmental factors. As a result, the population density of this pest in the tea agro-ecosystem varies throughout the crop season and from year to year. In this context, a computer simulation has been developed to assist with the management of *Helopeltis*. The model is based on experimental data from the Bangladesh Tea Research Institute. It has been constructed using proprietary spreadsheet software (AS-EASY-AS). The model simulates the population dynamics of the pest throughout the season. By using this population model, a planter can test potential control tactics when considering pest control action in tea estates.

INTRODUCTION

Tea (*Camellia sinensis*) is one of the major agricultural exports in Bangladesh. At present 156 tea estates in the country spread over an area of about 47,000 ha have a total production of about 45 million kg (Ali, 1990). Tea production in Bangladesh has been greatly hindered for many years because of extensive infestation of the crop by different pests (Sana, Ali and Haq 1978); twenty five insects and four mites have been recorded in Bangladesh tea. With the exception of *Helopeltis*, termites and red spider mites, most are either minor or sporadic pests.

The tea agro-ecosystem, architecture of tea plantations, variability of plant types and the interaction of various agro-techniques (e.g. sequential pruning cycle, permanence of shade trees, etc) have a significant impact on colonization and distribution of pests.

* The Institute does not necessarily endorse the views expressed in papers contributed by persons other than members of its staff.

Among the pests, *Helopeltis theivora*, commonly known as tea mosquito bug can cause high crop loss. *Helopeltis* population dynamics are affected by various biological and environmental factors and by crop management practices. The impact of current pest control measures is extremely variable.

Modelling approaches have been used widely to aid pest control decision making. A model may be any form of representation or abstraction of a system or process which will indicate the problems, organise the thoughts and create an understanding of the collected data. The model then communicates and tests the relationship and can make prediction for pest control (Starfield and Bieloch, 1986).

A prototype pest population model has been developed to allow estimates of damage for a range of conditions and management practices, and to determine action thresholds for different conditions. It is designed to improve insecticide application decision-making, hopefully leading to reductions in pesticide use. The preliminary model is based on laboratory information on the life cycle of *Helopeltis* (Table 1). The model has been constructed using proprietary spreadsheet software (AS-EASY-AS) running on an IBM compatible personal computer.

TABLE 1 – *Biological information on Helopeltis development and fecundity (figures in parenthesis indicate the number of five-day time periods used in the model).*

| Month. | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar |
|--------------------------------|-----------|-----------|-----------|----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| Fecundity (No.) | 110 | 280 | 400 | 500 | 600 | 660 | 580 | 150 | 150 | 140 | 40 | 80 |
| Incubation period (days) | 10 (2) | 8 (2) | 7 (1) | 6 (1) | 5 (1) | 6 (1) | 7 (1) | 11 (2) | 20 (4) | 23 (5) | 19 (4) | 12 (2) |
| Nymphal period (days) | 12 (2) | 11 (2) | 10 (2) | 9 (2) | 10 (2) | 11 (2) | 11 (2) | 23 (5) | 33 (7) | 34 (7) | 34 (7) | 24 (5) |
| Life cycle (days) | 22 | 19 | 17 | 15 | 15 | 17 | 18 | 34 | 53 | 57 | 53 | 36 |

A spreadsheet can be thought of as a large tabular grid of cells, each uniquely identified by a column and row coordinate. Each cell may contain a numeric value, text or a formula referencing information in other cells (Table 2).

TABLE 2 – An example portion of the spreadsheet model, showing columns A and AW to BA (columns B to AV and from BB on are not shown). Each cell contains a value, or a formula based on the equations shown in Table 3. For example, the cell AX6 contains the fecundity value for last five days of November (since AX1 is month 11)

| | A | AW | AX | AY | AZ | BA |
|----|--------------|----------|----------|----------|----------|----------|
| 1 | Month | 11 | 11 | 12 | 12 | 12 |
| 2 | | | | | | |
| 3 | dev egg | 2 | 2 | 4 | 4 | 4 |
| 4 | dev nymph | 5 | 5 | 7 | 7 | 7 |
| 5 | dev adult | 6 | 6 | 6 | 6 | 6 |
| 6 | fecundity | 150 | 150 | 150 | 150 | 150 |
| 7 | surv egg | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| 8 | surv nymph | 0.483612 | 0.513111 | 0.549095 | 0.689225 | 0.762908 |
| 9 | surv adult | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 |
| 10 | | | | | | |
| 11 | days | 235 | 240 | 245 | 250 | 255 |
| 12 | | | | | | |
| 13 | eggs 1 | 5.186694 | 2.673166 | 0.198021 | 0.178219 | 0.160397 |
| 14 | eggs 2 | 1.628731 | 1.037339 | 0.534633 | 0.039604 | 0.035644 |
| 15 | eggs 3 | 0 | 0 | 0.207468 | 0.106927 | 0.007921 |
| 16 | eggs 4 | 0 | 0 | 0 | 0.041494 | 0.021385 |
| 17 | eggs 5 | 0 | 0 | 0 | 0 | 0 |
| 18 | | | | | | |
| 19 | nymphs 1 | 1.114609 | 0.83572 | 0 | 0 | 0.031656 |
| 20 | nymphs 2 | 0.481612 | 0.571919 | 0.45889 | 0 | 0 |
| 21 | nymphs 3 | 0.503579 | 0.247121 | 0.314038 | 0.316279 | 0 |
| 22 | nymphs 4 | 0.272438 | 0.258392 | 0.135693 | 0.216443 | 0.241291 |
| 23 | nymphs 5 | 0 | 0.139791 | 0.141882 | 0.093523 | 0.165126 |
| 24 | nymphs 6 | 0 | 0 | 0.076759 | 0.097789 | 0.071349 |
| 25 | nymphs 7 | 0 | 0 | 0 | 0.052904 | 0.074604 |
| 26 | | | | | | |
| 27 | adults 1 | 0.062046 | 0 | 0 | 0 | 0.047614 |
| 28 | adults 2 | 0.025963 | 0.055842 | 0 | 0 | 0 |
| 29 | adults 3 | 0 | 0.023367 | 0.050258 | 0 | 0 |
| 30 | adults 4 | 0 | 0 | 0.02103 | 0.045232 | 0 |
| 31 | adults 5 | 0 | 0 | 0 | 0.018927 | 0.040709 |
| 32 | adults 6 | 0.981257 | 0 | 0 | 0 | 0.017034 |
| 33 | | | | | | |
| 34 | immigrants | 0 | 0 | 0 | 0 | 0 |
| 35 | | | | | | |
| 36 | total eggs | 6.815425 | 3.710505 | 0.940122 | 0.366244 | 0.225347 |
| 37 | total nymphs | 2.372239 | 2.052942 | 1.127261 | 0.776937 | 0.584026 |
| 38 | total adults | 1.069266 | 0.079209 | 0.071288 | 0.064159 | 0.105357 |

The prototype model

The model runs through a complete season, starting in April and ending in March. The biological information of *Helopeltis* is shown in Table 1. The life history of the pest is simplified and the simulation proceeds in discrete time steps of 5 days. Development periods are rounded, therefore, to the nearest 5 day unit (figures in parenthesis in Table 1).

Nymph mortality is also assumed to be dependent upon density, with mortality due to biological control agents and other factors, increasing as nymph density increased (Equation 10, Table 3).

TABLE 3 – Model equations

| | | | | |
|-----|-------|---|--|----------------|
| 1. | E_1 | = | $\sum_{k=1}^{kmax} A_k \cdot 0.5 \cdot (F/kmax) \cdot S_E$ | |
| 2. | E_i | = | $E_{(i-1)} \cdot S_E$ | (i < imonth) |
| 3. | E_i | = | 0 | (i = > imonth) |
| 4. | N_j | = | $\sum_{i=imonth}^{imax} E_i \cdot S_N$ | |
| 5. | N_j | = | $N_{(j-1)} \cdot S_N$ | (j < jmonth) |
| 6. | N_j | = | 0 | (j = > jmonth) |
| 7. | A_k | = | $\sum_{j=jmonth}^{jmax} N_j \cdot S_A + 1/kmax$ | |
| 8. | A_k | = | $[A_{(k-1)} \cdot S_A] + 1/kmax$ | (k < kmonth) |
| 9. | A_k | = | 0 | (k = > kmonth) |
| 10. | S_N | = | $1/[1 + \sum a \cdot N_j]$ | |

where:

| | |
|--------------------------|--|
| E_j, N_j, A_k | densities of eggs, nymphs and adults of age classes i, j and k, respectively |
| F | maximum fecundity in that month |
| S_E, S_N, S_A | survival of eggs, nymphs and adults, respectively, in each age class |
| imonth, jmonth kmonth | max age class of eggs, nymphs and adults in each month |
| l | adult immigrants in the five day time period |
| a | parameter controlling density dependence of nymph survival |

The development periods of the different stages, and the fecundity of the adults vary throughout the season (Table 1). Egg survival has been estimated as 0.2 (per 5 day time unit) because of continuous plucking, sequential pruning and natural mortality (the eggs are laid on the top of the young shoots which are plucked). Nymph survival is estimated to be higher because of their greater mobility, hence being more likely to escape plucking. Natural control agents can contribute to their mortality, but details are unknown. Adult survival is estimated as 0.9 (per 5 day time unit) (prior to reproduction) because of their mobility and their ability to hide in bushes and adjacent jungles, and also because of their negative phototropic nature so that they will be unlikely to be on the tops where they are plucked.

The number of eggs that are laid is simply the number of adult females in that time step multiplied by their fecundity for that time step. A 1:1 sex ratio is assumed.

The development times of the different stages vary throughout the season, so that eggs, for example, in August take just one time unit to develop but in January take five time units. Such variation in development periods is handled by the use of a conditional statement: if the age of the next egg age class is greater than the development time in that month then instead of the value being passed to the next egg age class it is passed to the first nymph age-class (Equations 2 and 3, Table 3). Similar conditional statements are used for the nymphal development (Equations 5 and 6, Table 3).

Finally, immigration can be included at any time, constituting a driving variable in the model. The total number of eggs, nymphs and adults in that time interval, regardless of age, are calculated at each iteration.

A schematic diagram of the *Helopeltis* population model is shown in Figure 1.

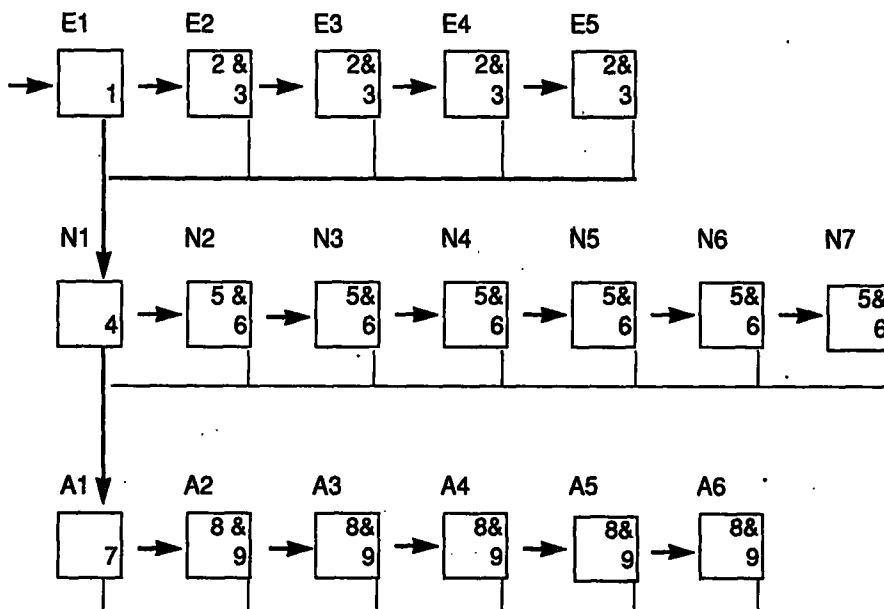


Fig. 1 - Schematic diagram of *Helopeltis* population model
E1...5, N1...7, A1...6 are age classes of eggs, nymphs and adults, respectively. Numbers refer to equations in Table 3; the equations define the density of insects in each age class.

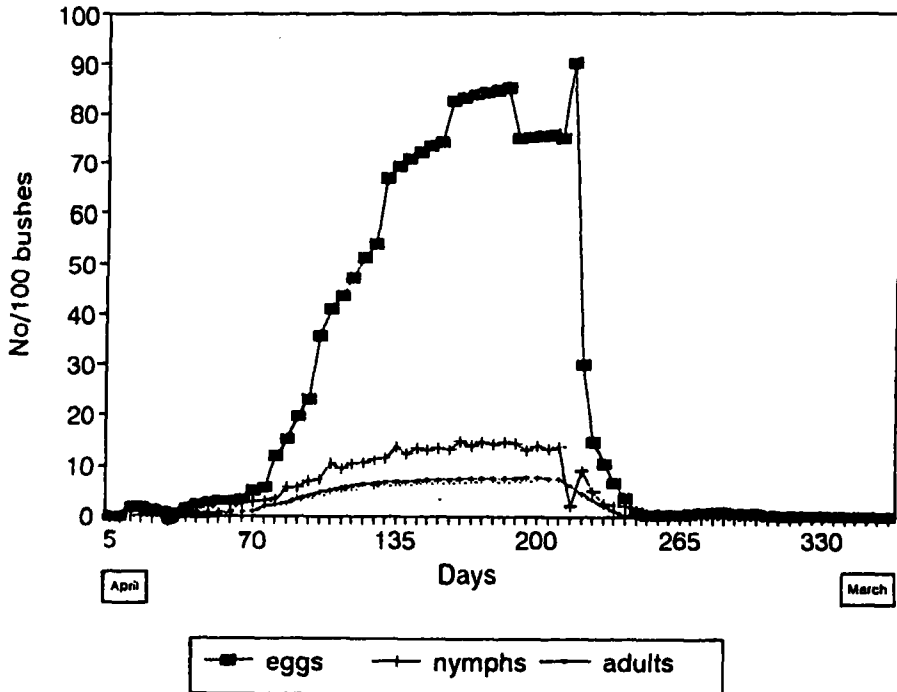


Fig. 2 – *Helopeltis* population

Output of the model

An example of output of the model indicates the population density of eggs, nymphs and adults from April to March (Fig. 2). The population is low during the early part of the season, increases rapidly to a peak in September, declines slightly in October, and quickly in November to become very low from December to March. This seasonal pattern appears to be due to high fecundity and short development times during June-October (Table 1). The starting population size was arbitrarily chosen.

Use of the model

The development and application of the model has helped to integrate information about *Helopeltis* biology in a way which can be useful for decision making. Fecundity, mortality and immigration can be changed for the different varieties of tea, for different seasons, or for different environments as chemical control could similarly be included, as could plucking and pruning mortality.

Before the model can be used in control decision making, some validation is needed. Comparisons between model output and field data on *Helopeltis* infestation will proceed as the next step in the modelling process.

In addition control decisions are usually based on the percentage of bushes infested. The relationship between *Helopeltis* population density and of bushes infested needs to be established.

As well as helping to schedule insecticide use, the model could also be used to indicate the role of immigration, important in barrier spraying to prevent *Helopeltis* migration.

A range of available control options can therefore, be evaluated to assist with *Helopeltis* management.

SUMMARY

The Bangladesh tea planter has very limited sources, for information on population fluctuations of *Helopeltis*. The planter is faced with uncertain events about the level of the pest. In this context, this population model indicates the trends of the population throughout the season. This will require the use of computers, however, and among the major constraints to implementation of the system in practical tea pest management, is the present unavailability of computers. Among the range of decision analysis techniques, population modelling offers the possibility of improving *Helopeltis* control decision making in tea at the garden level so that a planter can consider control measure, whenever and wherever necessary in tea estates.

REFERENCES

- AHMED, M. (1991). A decision analysis of tea pest management in Bangladesh. MSc thesis, University of London, UK. 110pp.
- ALI, M. A. (1990). Pest spectrum of Bangladesh tea and its management. *The Assam Tea News*, 79, 19-20.
- SANA, D. L., ALI, M. A. and HAQ, M. I. (1978). Tea management in Bangladesh. *Tea J. Bangladesh*, 14, 7-18.
- STARFIELD, A. M. and BLELOCH, A. L. (1986). Building models for conservation and wildlife management. MacMillan, New York, USA. 253pp.