CARTESIAN METHODS OF LOCATING SPOT INFESTATIONS OF THE PAPAYA FRUIT FLY *BACTROCERA PAPAYAE* DREW AND HANCOCK WITHIN THE TRAPPING GRID AT MAREEBA, QUEENSLAND, AUSTRALIA

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Summary

It is possible to use simple Cartesian methods to estimate the location of the source of flies caught on a grid of traps. If the epicentre is a true source then the catch per trap should fall from the epicentre according to a dispersal model. A method is given for estimating significant deviations from the predictions of the model so that it is possible to decide whether there is a single source or several sources for the flies caught with a small cluster of traps on a larger grid.

Examples from the Mareeba grid are given, showing simple and complex patterns of trap catches arising from locally single and locally multiple breeding sources respectively.

INTRODUCTION

When an infestation arises at a point, it can be expected that a propagule of flies emerges, disperses and matures in a way commonly shown for released teneral flies (Fletcher 1974; Teruya 1986). Thus a trap at or near the point of origin will catch the most flies and the mean catch per trap can be expected to fall exponentially with distance according to an 'inverse square' or similar relationship (Meats 1998).

If the map coordinates of the traps are known then it follows that the origin is most likely to be at or near the mean coordinate, when the mean is calculated from the coordinates of each fly caught. Catch per trap should then fall from this origin (as above), provided that the trapped flies all arise from the one source. If there are several origins (as can be expected as an infestation progresses through several generations) then the catch per trap is unlikely to show such a simple relationship.

It is the purpose of this paper to test this model with results obtained from the grid of 183 traps forming the Mareeba section of the monitoring grid of the Papaya fruit fly, *Bactrocera papayae* Drew and Hancock.

THE MAREEBA GRID

The grid used for this paper occupied an area with the rough shape of a triangle with sides of approximately 16 km each. It consisted of 13 sentinel traps that were installed in the district when *B. papayae* was first detected in Australia and 170 traps added 4 weeks later. The mean trap spacing was approximately 0.8 km although some traps were only 0.4 km apart and there were some patches without traps that were 1.5–2 km wide due to the inhospitable terrain.

Even in the first few weeks of operation it was apparent that the distribution of catches was exceedingly clumped with the highest numbers caught exceeding the mean by 10–20 fold. It was moreover, apparent that there was no single centre of infestation. High scoring clusters of traps were separated by several kilometres in some instances. Later, eradication efforts confirmed that flies were being generated from several localities in wild and cultivated fruit. However, some sources of flies were very difficult to locate, leading to delays in eradication of up to several months in some instances.

Prior to the detection of *B. papayae* in Australia (reared from fruit obtained near Cairns) there was no sentinel grid in operation. The situation at Mareeba (and elsewhere in the infested zone) was thus different from that usually encountered in a well monitored quarantine area where it can be expected that a new infestation can be detected almost immediately and before it spreads and establishes satellites.

The Cartesian method, used below, for localization of fly sources is best suited for single infestations. It is not guaranteed to work as well in a situation like that at Mareeba because the fringes of the distribution from one source may be augmented by flies dispersing from another. However, when the method fails due to the above cause it will be shown that the number and approximate locations of additional sources can be identified.

METHODS

Location of epicentres (potential sites of sources)

The initial 30 weeks of data from the full grid were examined and high scoring traps identified (those catching more than 20 flies). A 20 week period of maximum (usually total) capture was selected for each trap. Other traps within 2 km of each selected trap were also identified for the analysis. This process usually identified a group of traps (a cluster) with one to four catching high numbers near the centre with traps catching much lower numbers towards the periphery. The map coordinates for each trap were known.

Each fly caught in a given cluster of traps thus had a map location so that the mean east and south coordinates could be calculated to identify the epicentre. The mean coordinate ($\bar{x}$) for a given direction was calculated by two methods.

Method (1). The mean coordinate was found by

$$\bar{x} = \frac{\left[\sum_{i=1}^{i=g} n_i x_i\right]}{\sum_{i=1}^{i=g} n_i} \qquad (1)$$

where g = the number of traps in a cluster

n_i = the number of flies caught in the ith trap.

Method (2). The above equation was modified to use n_i^2 instead of n_i. This was an attempt to discount the influence of low scoring traps because it was thought that they may have been biased, being usually on the edges of a cluster and therefore possibly collecting some of their catch from a neighbouring source. In fact, the 2 methods gave very similar results with less than 100 m difference in location in any one case.

Estimation of trap catch at source

This method relies on the model of Meats (1998) derived from the data of Fletcher (1974). Briefly, it is assumed that a trap at the origin of an infestation will trap flies at a rate *(C)* expected of the density within a 200 m radius and that a trap at any other distance, d, will catch flies at a rate C_d according to the relation

$$C_{d(i)} = C \cdot \left(\frac{0.2}{d(i)}\right)^n \qquad (2)$$

where d is km and the exponent n is 2 for the Queensland fruit fly, *Bactrocera tryoni* (Froggatt) according to Fletcher (1974). This paper uses $n = 2$ as an approximate value for *B. papayae*.

When the epicentre is within 200 m of a trap, the catch for that trap is thus taken as the best estimate for a trap at the point of origin (the assumption being that the mean expectation for a trap within the 200 m radius is the same wherever it is within that radius). The expected catch per trap for the other traps is then calculated according to equation (2).

When the epicentre is further than 200 m from any trap, the numbers trappable at that point is estimated by back calculation.

$$C = \frac{\sum_{i=1}^{i=g} \left(\frac{d_i}{0.2}\right)^2 \cdot n^2_{d(i)}}{\sum_{i=1}^{i=g} n_{d(i)}} \qquad (3)$$

Equation (3) weights the contribution that each trap makes to the estimate according to the number of flies caught. Thus each fly caught contributes equally to the estimate. Ideally, we should use mean catch per annulus (Fletcher 1974) but we would normally not have enough traps in a cluster for this. The equation is thus a compromise.

Approximate confidence limits

The mean expectation for the way the catch per trap declines with distance from the epicentre is calculated by using equation (2). A curve is thus obtained (figs 1–4) descending at a declining rate with distance.

What sort of deviation may we reasonably expect from this curve if the flies actually did diffuse from one source? The extensive data of Teruya (1986) using point-releases at the centre of annulated grids to a distance of 1.2 km shows that the trap with the highest capture rate at a given distance captures approximately three times the mean for that distance. It can also be seen from these data that even with relatively high mean capture rates, some traps can be expected to catch zero flies. Thus as an approximation it would be reasonable to deduce that a trap catching over five times the mean expectation does not conform to the model that assumes all flies were derived from the estimated epicentre.

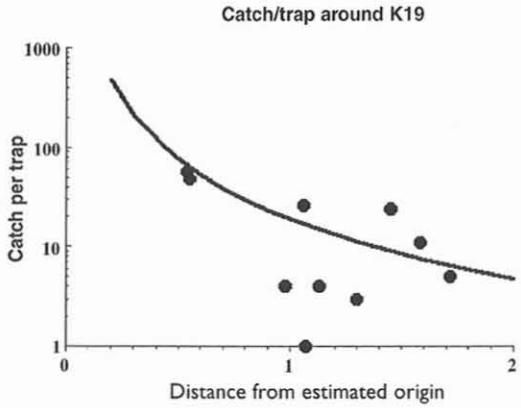

Figure 1. Catch per trap in the cluster of traps in the vicinity of K19.

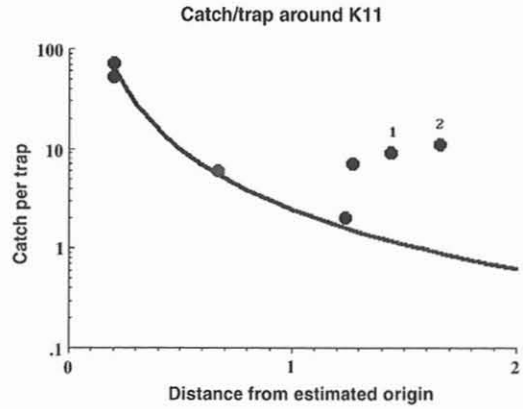

Figure 2. Catch per trap in the cluster of traps in the vicinity of K11. Traps with catches exceeding 5 times mean expectation are 1, MG 170: 2, MG 147.

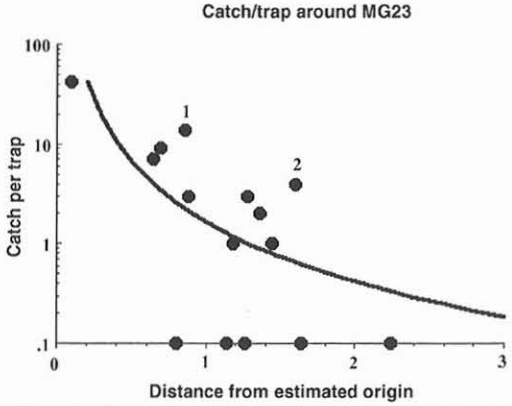

Figure 3. Catch per trap in the cluster of traps in the vicinity of MG23. Traps with catches exceeding 5 times mean expectation are 1, MG 33; 2, MG 32.

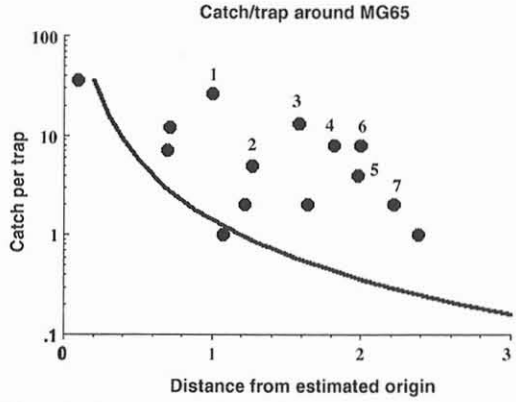

Figure 4. Catch per trap in the cluster of traps in the vicinity of MG65. Traps with catches exceeding 5 times mean expectation are 1, MG 79: 2, MG 66; 3, MG 63; 4, MG 52; 5, MG 49; 6 MG 77: 7, MG 81.

RESULTS AND DISCUSSION

Trap catches

Figures 1–4 give example results for clusters of trap catches in the vicinity of traps K19, K11, MG23 and MG65 respectively. Those points pertaining to traps catching 5 times the mean expectation are numbered.

The cluster graphed in figure 1 had an estimated epicentre over 400 m from the nearest traps; the expected catch at the epicentre was thus calculated using equation (3). The clusters graphed in figures 2–4 all had estimated epicentres within 200 m of a trap, thus equation (3) was not used.

All the traps in the cluster plotted in figure 1 conform to the model that there was a single source for the trapped flies. In no case was the catch more than five times the mean expectation.

Figures 2–3 suggest that at least 2 traps in each cluster were catching flies of a more local origin than the 'expected' epicentre in each case.

Figure 4 suggests that the cluster around MG65 probably had many sources of flies. This cluster is the one with results most unlike those expected from an early stage of an infestation. The cluster was part of a swathe of traps from north Mareeba to Biboohra that virtually all caught flies. The infestation on this part of the grid had obviously advanced from a series of isolated spot outbreaks to a series of merging populations.

Further development

More confident analyses could be made if we knew more precisely (a) the value of n in equation (2) for the fall of density with distance and (b) the variance associated with the catches of traps at any given

distance from a single point of origin. Both can only be established for *B. papayae* with work along the lines reported by Teruya (1986). This would ideally involve releasing flies at a point and recapture with annuli of traps at 0.2 km intervals from 0.2 km to around 2 km from the origin.

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