THE RELATION OF 'PERCENTAGE OF POSITIVE TRAPS' TO THE NEGATIVE BINOMIAL DISTRIBUTION AND TO PROGRESS IN THE ERADICATION OF *BACTROCERA PAPAYAE* DREW & HANCOCK (DIPTERA:TEPHRITIDAE) IN NORTHERN QUEENSLAND

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Summary

Catches of fruit flies in male lure traps are highly variable, but follow the negative binomial distribution. The proportion of positive traps is often used as an index of progress in a control or eradication campaign, but care is required in the interpretation of this index. Part of the problem is that the proportion of positive traps does not seem to be sensitive to changes in mean catch per trap. The basic characteristics of the distribution explains most of the difficulties. Firstly, the average catch per fortnight per trap (C/T) must be low, <1, before the proportion of positives (PP) declines below 0.3: the PP drops to 0.1 when C/T drops to 0.1, with both PP and C/T having virtually identical values below 0.1. Secondly, C/T must be <1 before the proportion of traps with >3 drops below 0.1. In Australia, when *B. tryoni* is detected within the quarantine zones, most trap catches are within this range.

INTRODUCTION

In area-wide programs to eradicate insect pests, such as tephritid fruit flies, there is a need to develop an easily calculated index to monitor the progress of the campaign. Catches of fruit flies in male lure traps are variable temporally as well as spatially (Cowley *et al.* 1990). In any situation where the adult fly density is low, as in an area of marginal suitability or an eradication campaign, zeros frequently occur, as well as higher catches (O'Loughlin *et al.* 1983; Cowley *et al.* 1990; Perepelicia *et al.* 1996).

Meats (1998a) described a method to interpret the trapping rates of cuelure traps, related to the catching power of grids of different sizes. Meats (1998b) described a Cartesian method to estimate the infested site from a grid of methyl eugenol male lure traps. The proportion of positive traps (PP), rather than catch per trap (C/T) have been used to monitor numbers of fruit flies (Cowley *et al.* 1990; Perepelicia *et al.* 1996). Fruit fly populations are not evenly distributed, so the placement of traps relative to the site of infestation influences both the proportion of zero catches and the mean catch (Clift and Meats 1997).

The data obtained from a series of male lure traps can be referred to as 'overdispersed' (Clift and Meats 1997) and the negative binomial distribution is often fitted to such data (Bliss and Fisher 1953). When sets of trap counts are fitted to the negative binomial distribution, the k values found are low, ranging from >1 to below 0.1 (Clift and Meats 1997), indicating highly clustered populations (Bliss and Fisher 1953).

Mite numbers on apple leaves also often follow the negative binomial distribution and Pielou (1960) related the proportion of uninfested leaves to average count for a range of k values. He was mainly concerned with evaluating the effectiveness of miticides and used the number of mite free leaves from a sample of 100 to rate the level of control from excellent down to poor. Despite the problems of the clustered distribution of adult fruit flies, fixed grids of traps do allow comparisons over time (Meats 1998a) with changes in the proportion of positive traps, but care is needed in the interpretation.

Trapping data from the eradication program for the papaya fruit fly, *Bactrocera papayae* Drew and Hancock (PFF) was available for study. Steiner traps, fitted with methyl eugenol as the male attractant, (Steiner *et al.* 1965) were used to monitor PFF numbers. We describe the relationship between the mean catch per trap (C/T) proportions of positive traps (PP) and discuss the use of PP as a measure of progress in the PFF eradication campaign in Far North Queensland.

METHODS AND MATERIALS

Data Used

Fortnightly totals for three selected grids, Stratford (suburb of Cairns), Mareeba and Mossman, within the entire PFF Far North Queensland trapping grid from October 1995 to May 1997, representing up to 42 values per trap, were used. The observed frequency distribution of catches for the three grids was determined for each fortnight, each mean calculated and the proportion positive traps determined. Individual trap catches per fortnight ranged from 0 to 48, with considerable variation in the maximum value in any particular fortnight.

Studies using the Negative Binomial Distribution

The terms, from zero up to three, of the negative binomial distribution are given by:

$$\text{Pr of } 0 = \left(1+\frac{\bar{x}}{k}\right)^{-k}$$

$$\text{Pr of } 1 = \left(\frac{k}{1}\right)\left(\frac{\bar{x}}{\bar{x}+k}\right)\left(1+\frac{\bar{x}}{k}\right)^{-k}$$

$$\text{Pr of } 2 = \left(\frac{k}{1}\right)\left(\frac{k+1}{2}\right)\left(\frac{\bar{x}}{\bar{x}+k}\right)^{2}\left(1+\frac{\bar{x}}{k}\right)^{-k}$$

$$\text{Pr of } 3 = \left(\frac{k}{1}\right)\left(\frac{k+1}{2}\right)\left(\frac{k+2}{3}\right)\left(\frac{\bar{x}}{\bar{x}+k}\right)^{3}\left(1+\frac{\bar{x}}{k}\right)^{-k}$$

These equations were used to determine the expected proportion of traps with 0, 1, 2, 3 or greater for a range of k values, 0.05, 0.1, 0.2 or 0.5 and a wide range of $\bar{x}$, from 0.001 up to 1000. All calculations were done using FigP® Ver 6.0c. The calculated probabilities of >0, the proportion of positive traps, and probability of >1, 2 or 3 were compared to observed values from a subset of the trapping data. The graphs were done using FigP® ver 6.0c.

RESULTS

The observed proportion of positive traps over 30 fortnights for Stratford (suburb of Cairns) Grid, Mareeba Grid and Mossman Grid are plotted on a log/log scale as figure 1a, as expected positive traps for a range of *k* values and mean C/T per fortnight. The observed proportion of traps having greater than 1, 2 or 3 flies per fortnight for the same grids are plotted on log/log scales as figures 1 b–d respectively, as the expected proportions for k=0.2 and a range of mean C/T per fortnight.

The three trapping grids selected showed a wide range of trap catches, with mean catch per trap varying between 0.01 and 10.7. The actual trap counts could be described using the negative binomial distribution but the distribution of points across a tenfold range of k values indicated the observed variation in individual k values was greater than that used to produce figure 1a.

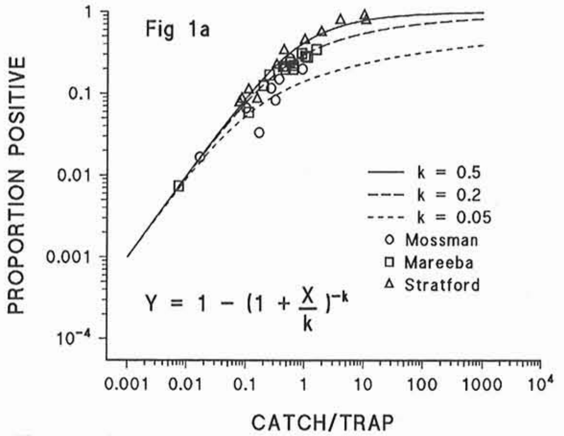

Figure 1a. Observed proportion of positive traps from three PFF trapping grids plotted against mean catch per trap. Expected proportions of positive traps for a range of *k* values over a wide range of mean catch per trap are also shown.

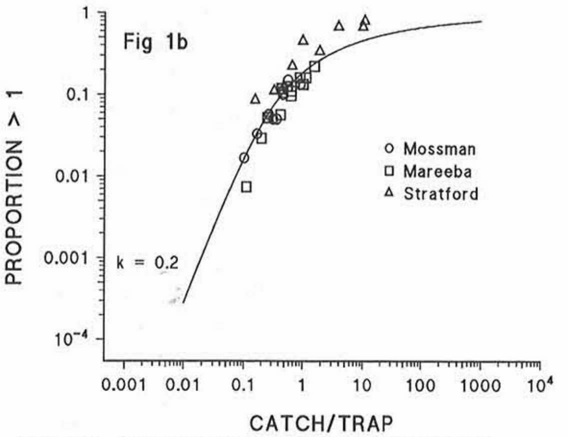

Figure 1b. Observed and expected proportions of traps catching more than one PFF male per fortnight for one *k* value.

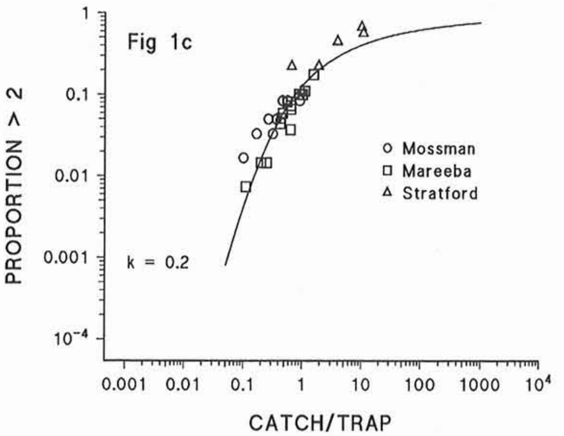

Figure 1c. Observed and expected proportions of traps catching more than two PFF males per fortnight for one *k* value.

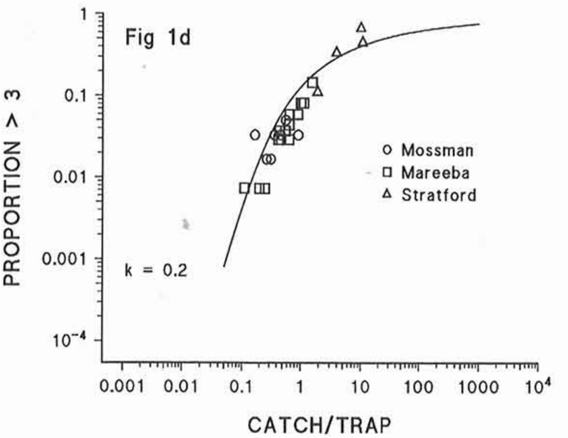

Figure 1d. Observed and expected proportions of traps catching more than three PFF males per fortnight for one *k* value.

At low catches per trap, <0.1 flies per trap, the expected proportions converge over a wide range of *k* values, suggesting that, at these low trap catches, the precise value of *k* is of little importance. At such low values of C/T, PP and C/T are approximately equal.

The results for observed and expected proportions of positive traps confirms that there must be a substantial reduction in PFF population, to below an average of one fly per trap before the proportion of positive traps noticeably declines. Observed and expected proportions of traps with >1, 2 or 3 flies per trap show a similar pattern, yet even at an average trap catch of 0.7 males per trap, 10% of traps would be expected to catch over three flies. The population needs to be reduced to 0.1 males per trap before the incidence of catches greater than three drops to one percent.

DISCUSSION

The distribution of fruit flies within an area is in discrete patches (Clift and Meats 1997). This results in highly variable catches from a series of male lure traps (Cowley *et al.* 1990; Bateman 1991; Meats 1996) and the low *k* values (Clift and Meats 1997). The variable *k* values observed over the thousand fold range of mean trap catches examined, between 0.01 and 10 indicates that fitting a common *k* value is not valid over all the data. Pielou (1960) reached a similar conclusion with counts of the mite *P. ulmi*.

At low values of C/T, below 0.1, as occurs in an eradication situation, the convergence of the expected proportions over a tenfold variation in *k* value suggests almost any contagious distibution will satifactorally describe the data. The value for PP becomes virtually identical to the value of C/T at values less than approximately 0.1, indicating that at low values, PP is an efficient estimate of C/T.

At higher densities, the low *k* values indicate extreme clustering (Bliss and Fisher 1953; Clift and Meats 1997). This is consistent with the observed incidence of zero catches when the mean catch is as high as 10 (fig. 1a) and catches of over 3 flies per trap when the mean is below 0.5 flies per trap.

Pielou (1960) was the first to plot mean density (Y axis, log scale) against percentage leaves with one or more mites (X axis, linear scale). Our report used log/log scales, but placed the mean trap catch on the X axis and the proportion on the Y axis. We believe this graphical representation is easier to interpret. The range of both mean trap catch and proportions expected presented as figure 1a–d is very wide compared to both observed PFF trap catches and to other reports (reviewed by Meats 1996) of trap catches for *B. tryoni* flies.

We therefore believe the following conclusions to be relevant to any natural density of *Bactrocera* species likely to be encoutered.

CONCLUSIONS

1. The typical variation in catches in male lure traps for *Bactrocera* flies is consistent with extreme clustering of adult flies.
2. The use of the negative binomial distribution to describe the trap catches over a wide variation in mean catches is valid, but a common k value cannot be used.
3. The observed variation in individual trap catches over a wide range of mean C/T is consistent with the negative binomial distribution with very low *k* values.
4. At low mean C/T, below 0.1 flies per trap, almost any contagious distribution will fit the data.
5. There will be little reduction in PP as C/T decline from 10 to 1, therefore PP is not suitable to indicate early progress of an eradiction program. Below a mean catch of 0.1, PP and CT are essentially equal, therefore PP is very suitable to indicate progress of eradication.

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