EFFECTIVENESS OF COLOURED UNBAITED STICKY TRAPS FOR MONITORING DISPERSAL OF GAMMA-IRRADIATED QUEENSLAND FRUIT FLY *BACTROCERA TRYONI* (FROGGATT) (DIPTERA: TEPHRITIDAE)

C. W. Weldon

Fruit Fly Research Centre, School of Biological Sciences A08, University of Sydney, NSW 2006, Australia
Email: cweldon@bio.usyd.edu.au

Summary

Sticky (unbaited) trap catches of irradiated *Bactrocera tryoni* were approximately 12% of those of pot-type traps baited with cuelure. Sticky traps painted with daylight fluorescent yellow or green were equally effective but were no better than unpainted (control) sticky traps for capturing *B. tryoni*. No association was identified between recaptures in sticky traps and host status of the tree in which the trap was placed. Sticky traps may be useful for detecting the location of emergence foci of endemic flies but were insufficiently sensitive to offer an alternative to current monitoring techniques.

Key words: Pest management, cuelure, sterile insect technique.

INTRODUCTION

Queensland fruit fly (*Bactrocera tryoni*, Froggatt) is a major horticultural pest in eastern Australia. Gravid females oviposit in the fruits of over one hundred species of native and introduced plants, including citrus, stonefruits and apples (Hancock *et al*. 2000), with subsequent fruit damage by developing larvae. Control of this insect in Australia is an expensive exercise and exceeded $A125 million in 1991 (Yonow and Sutherst 1998). Potential losses in the absence of control, based on data collected in Adelaide, could be greater than 80%, representing a value exceeding $A800 million (Sutherst *et al.* 2000).

Earlier papers indicate that *B. tryoni* possesses high dispersal capabilities. The maximum recorded dispersal distance from a sterile fly release at Wangaratta, Victoria, was 94 km, although the average recapture distance was considerably less (MacFarlane *et al.* 1987). The release at Wangaratta involved a large number of flies (470,000) so this result is not unexpected considering that trap recaptures are density-dependant (Fletcher 1974a, Meats 1998a). Knowledge of the dispersal patterns of released sterile flies is important for effective implementation of sterile insect technique (SIT). In theory, dispersal of individuals through a homogeneous environment from a single point in space will result in a two-dimensional Gaussian distribution that can be predicted by simple diffusion (eg. see Turchin 1998). According to this principle, sterile fly density will be highest immediately around a release site, and decrease approximately exponentially with distance. In *B. tryoni* it has been found that recapture rate per trap declines as the reciprocal of the square of the distance, conforming to an 'inverse square rule' (Fletcher 1974b, Meats 1998b). At some distance away from the release site, the density of sterile flies will drop below a level where sterile male-wild female encounters are sufficient to control population growth. If release sites are spaced too far apart the area-dilution effect will result in voids within the target area where sterile male density is below the threshold required to limit matings by fertile males. Meats (1996) estimated that if release rates were sufficient to achieve a sterile:wild ratio of 100:1 at the release point, the ratio would drop to only 25:1 at a distance 0.5 km and 4:1 at 1 km.

The most commonly used attractant in traps deployed to monitor populations of *B. tryoni* is cuelure (*p*-(3-oxobutyl) phenyl acetate). Cuelure is highly attractive to sexually mature male *B. tryoni*, and immature females to a lesser extent (Drew 1987). Drew (1987) suggested that this response is due to its chemical similarity with a female feeding attractant and the male sex attractant, 2-butanone. However, inseminated sexually mature females, that do not require mates, are repelled by the high cuelure concentration used in cuelure traps (Dalby-Ball and Meats 2002, Drew 1987, Hill 1986) and males form the majority of trap captures (Meats *et al*. 2002). Given that cuelure is ineffective in the field for attracting immature male and adult female *B. tryoni* it is necessary to identify a better method to monitor dispersal of these animals. This is particularly important given that undirected dispersive movement is predominantly associated with the post-teneral phase (Bateman and Sonleitner 1967, Fletcher 1973).

Performances of traps baited with alternative lures based on food odour have been compared with cuelure traps in other studies (Hill 1986, Meats *et al*. 2002). Yeast-based food lure traps capture low numbers of male and female flies but overall are much less successful than cuelure traps for detecting fly populations. It has been found that flat sticky traps painted with daylight fluorescent colours Saturn Yellow, Lime, Blaze Orange and Emerald attract tephritid fruit flies (Hill and Hooper 1984). The most attractive colours caught significantly more males than females (Hill and Hooper 1984). The aim of this study was to examine the effectiveness of a simple, unbaited sticky trap in monitoring dispersal of irradiated *B. tryoni*. Capture rates and sex ratios of sticky traps painted with daylight fluorescent colours previously shown to be most attractive to *B. tryoni* (yellow and green) were compared with cuelure trap captures.

MATERIALS AND METHODS

Source and treatment of flies

Irradiated sterile *B. tryoni* were obtained as pupae from the mass rearing facility at Camden, New South Wales. Between 36,000 and 60,000 pupae in plastic trays of sawdust mixed with fluorescent pigment powder (Fiesta ®, FEX Series, Astral Pink 1) were allowed to emerge in 50 L black storage bins (Nally Crates, Viscount Plastics (NSW) Ltd.) covered with mesh fabric that was secured over the top of the bin by black nylon elastic. During emergence, a small quantity of fluorescent pigment adhered to the ptilinum enabling identification of released flies when examined under blue light (475 nm). Adults were transported to Richmond in an air-conditioned vehicle and released from a single point on three occasions during the 2001/2002 fruit fly season (September 2001, March and April 2002). To ensure that human movements did not assist fly dispersal, cages were carried from the car to the release point, and flies were removed by hand from all equipment and persons before leaving the release point.

Site description, trap types and deployment

The study was conducted at the Hawkesbury Campus of the University of Western Sydney, near Richmond, New South Wales. The property has a mixed orchard containing various species and varieties of citrus, stonefruits and pears, as well as ornamental trees. Management practices in the orchard are restricted to grass-mowing and pruning.

A grid of 88 cuelure traps was used to monitor dispersal of *B. tryoni* and provide a positive control for the study (Figure 1). Traps were placed within the canopy of host and non-host trees, sampling a distance of 3 – 465 m from the release point. The trap was a disposable pot-type lure trap made of clear plastic (Lynfield trap) (Cowley *et al*. 1990). Approximately 2 mL of a cuelure and malathion mix (8:1), was placed on three dental rolls held in place at the centre of the trap by a clip. The trap was suspended by a piece of wire tied onto a metal loop incorporated with the lid. The base of the traps had four 2 mm water drainage holes. There were four 25 mm entry holes 90° apart in the clear plastic trap body. Cuelure traps were inspected at weekly intervals, with contents emptied into labelled plastic vials for transport back to the laboratory. Trap captures were examined under blue light with a dissecting microscope to identify marked individuals.

Sticky traps consisted of 150 mm plastic petri dishes suspended within the tree canopy by wire. The bottom surface of the dish was painted with daylight-fluorescent yellow (chartreuse), daylight-fluorescent green (Solver ®, Flat Acrylic Scenic paint) or left unpainted before being coated with an adhesive (Rentokil ®, Tac-Gel Formula 3). One trap of each colour was placed in each tree at every third lure-trap location (Figure 1), with positions rotated weekly within the tree. Traps were inspected at weekly intervals for one month, and removed and replaced when *B. tryoni* captures were observed. Removed traps were transported back to the laboratory for observation under blue light to identify marked individuals. Traps with high coverage of non-target insects were also removed and replaced, although this was usually not necessary.

Data analysis

Due to low recapture rates in both cuelure traps and sticky traps, weekly recapture data were pooled into monthly periods. Trap recaptures were expressed as a proportion to standardise for the number of flies released in each monthly cohort. Comparison of trap effectiveness was performed using three-way, mixed model analysis of variance. Factor 1 (fixed) was trap, with four levels (positive control = cuelure trap, yellow, green, negative control = no colour). Factor 2 (fixed) was sex, with two levels (male, female). Factor 3 (random) was cohort. This procedure was repeated with cuelure trap recaptures excluded from the analysis. Chi-squared analysis was performed to test for an association between sticky trap effectiveness and tree type (citrus, stone fruit, pomes, non-host) in which it was positioned.

RESULTS

Cuelure traps consistently recaptured more sterile *B. tryoni* than sticky traps. Sterile flies were caught up to 436 m from the release point in cuelure traps. Sticky trap recaptures of both sexes were limited to sticky traps located within approximately 80 m of the release point. Location and number, relative to the release point, of released sterile (red-marked) and unmarked *B. tryoni* is shown in Figure 1. Recaptures of marked *B. tryoni* on sticky traps were only made in the first week after release and represented an average estimated recapture rate of 0.1%. The average estimated recapture rate of cuelure traps was 1.3%. In September 2001, a large number of unmarked flies were captured on sticky traps within the vicinity of the release point one week after release. The three (yellow, green and unpainted) sticky traps at the trap location closest to the release point captured a combined total of 53 unmarked flies (Figure 1). The origin of these flies is probably a pupal release conducted simultaneously with the adult release that was scattered and washed free of marking powder by a storm. Captures of small numbers of unmarked *B. tryoni*, ranging from 1–5 flies, were found at trap locations greater than 80 m away from the release site during the September 2001 and March 2002 releases (Figure 1). Chi-squared tests on pooled capture data indicated that there was no significant association between sticky trap captures and tree type (χ^2 = 5.161, df = 3, p > 0.1).

Mean (± 1 s.e.) *B. tryoni* recaptures in cuelure and sticky traps after each release are shown in Figure 2. Average male:female ratio captured in cuelure traps was 375:1, but 1:1 for all sticky trap colours. Analysis of variance including cuelure trap recaptures indicated a significant difference between trap treatments, with sticky trap captures being much lower than cuelure trap captures (F =10.697, df = 3, p

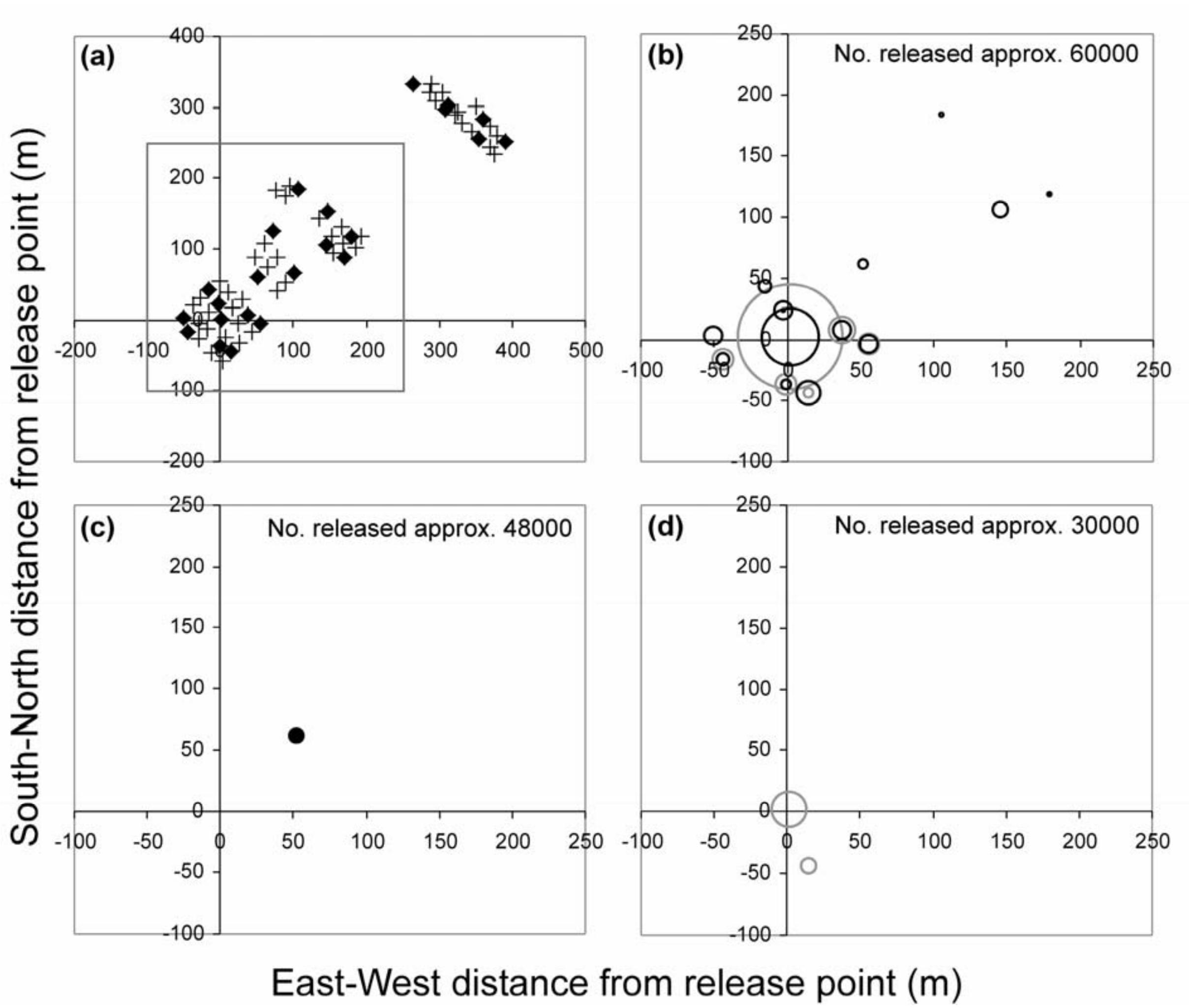

Figure 1. Location and number of released sterile (red-marked) and unmarked *B. tryoni* relative to the release point. (a) Lure (+) and sticky trap (♦) locations relative to release point. The area indicated by the square in (a) is enlarged in (b), (c) and (d). (b) Sticky trap captures following September 2001 release. (c) Sticky trap captures following March 2002 release. (d) Sticky trap captures following April 2002 release. Circle diameter represents the pooled number of flies captured on yellow, green and unpainted sticky traps at each trap location. Marked captures one week after release (o); marked captures two weeks after release (•); unmarked captures one week after release (o); unmarked captures two weeks after release (•).

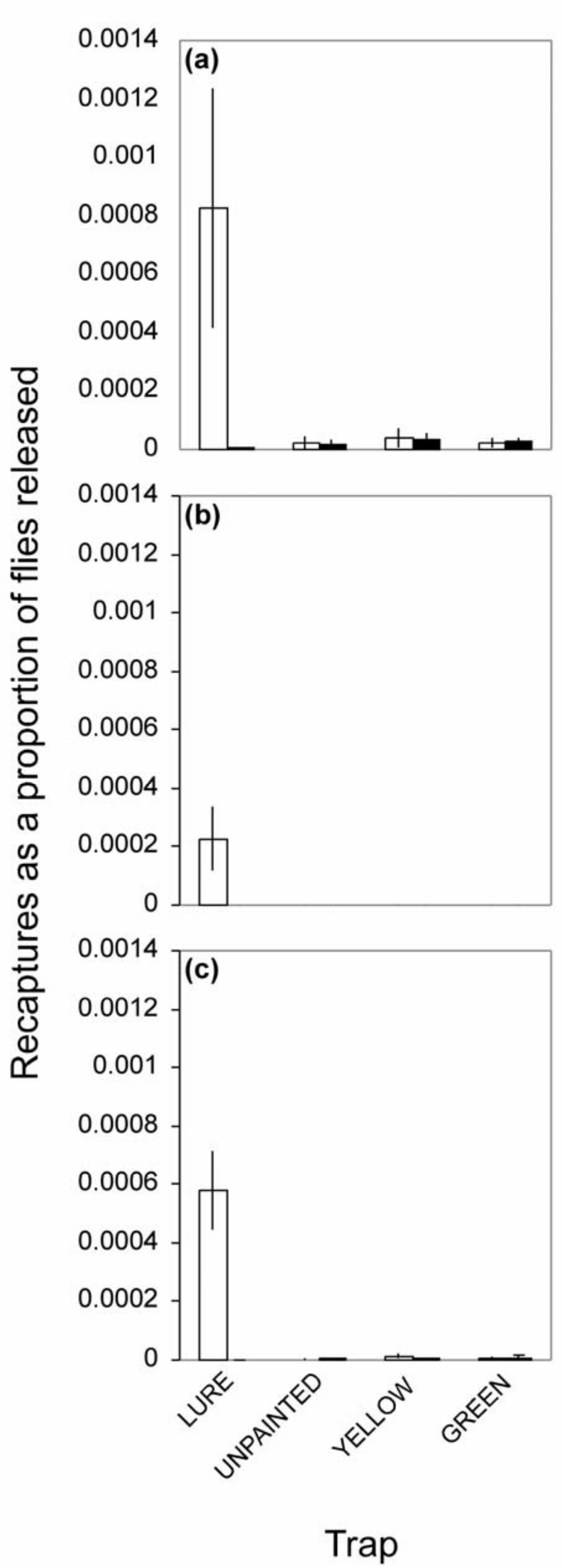

Figure 2. Mean (± 1 s.e.) *B. tryoni* male and female recaptures in lure and sticky traps. (a) Recaptures following September 2001 release. (b) Recaptures following March 2002 release. (c) Recaptures following April 2002 release. Male (☐); Female (■).

< 0.01). There was no significant difference between male and female recaptures despite the large number of males captured in cuelure traps. Recaptures were not significantly different between releases. There was a very highly significant interaction between trap recaptures and sex ($F = 9.938$, $df = 3$, $p < 0.01$) (Figure 2).

Where cuelure trap recaptures were excluded from the analysis, daylight fluorescent yellow and green sticky traps were not significantly better than unpainted sticky traps for capturing *B. tryoni* ($F = 2.018$, $df = 2$, $p > 0.05$). There was no significant difference between male and female recaptures. A very significant difference in recaptures was found between releases ($F = 36.010$, $df = 2$, $p < 0.01$), with more flies being recaptured in September/October 2001 than March and April 2002. A non-significant interaction between trap type and sex ($F = 1.662$, $df = 2$, $p > 0.05$) indicates that no colour was found to be more attractive to female *B. tryoni*.

DISCUSSION

For the purpose of monitoring dispersal of *B. tryoni,* cuelure traps are the standard against which other trap types must be compared to determine their effectiveness. Coloured, unbaited sticky traps were found to be relatively ineffective for monitoring dispersal of sterile *B. tryoni*. Even within 200 m of the release point, sticky traps captured, on average, only 12% as many flies as were captured by cuelure traps within the first week of trapping.

Use of sticky traps painted with colours assumed to be attractive to insects should increase captures to levels higher than the probability of chance landings. Sticky trap colours in previous studies and pest-monitoring practice have been chosen to mimic that of host fruits or foliage. Unbaited and baited sticky red spheres have been used to monitor the apple maggot fly, *Rhagoletis pomonella* (Tephritidae) (Duan and Prokopy 1994, Prokopy 1968). Unbaited, bright yellow-green tennis ball fruit models are attractive to *B. tryoni*, although fruit models baited with amyl acetate and cuelure proved to be more attractive to females and males, respectively (Dalby-Ball and Meats 2002). Hill and Hooper (1984) found that daylight fluorescent Saturn Yellow on flat rectangular sticky traps (15 x 20 cm) was significantly better at attracting *B. tryoni* than other colours in the absence of olfactory cues. This was attributed to a peak reflected wavelength (540 nm) similar to that of green leaves (550 nm). Hill and Hooper (1984) also found that male captures outnumbered female captures, although it was suggested that this might have reflected population composition rather than a differential rate of attraction. In the study reported here the use of painted daylight fluorescent yellow and green sticky traps did not increase recaptures of *B. tryoni* relative to unpainted sticky trap controls (Figure 2). Also, neither sex was found to be more responsive to either colour in preference to unpainted sticky traps (Figure 2). Although the number of recaptures on sticky traps in September/October 2001 was higher than in both March and April 2002, seasonality of sticky trap performance is beyond the scope of this paper owing to a lack of temporal replication.

In an experiment investigating the effect of fruit abundance within a tree canopy on the behaviour of wild and cultured *B. tryoni*, Dalby-Ball and Meats (2000) found that neither sex of a laboratory strain of *B. tryoni* responded differentially to trees with differing amounts of fruit. This behaviour was in contrast to the tendency of both male and female wild *B. tryoni* to accumulate in fruiting host trees (Dalby-Ball and Meats 2000). The results presented in this study showed that there was no association between recaptures of sterile *B. tryoni* in sticky traps and host status of the tree in which the trap was placed. This supports the concerns raised by Dalby-Ball and Meats (2000) that released sterile flies used in sterile insect technique may not tend to accumulate in fruiting trees as wild flies are expected to do.

Despite their shortcomings in monitoring dispersal of *B. tryoni*, sticky traps may provide an indication of emergence foci. Captures of moderate numbers of unmarked flies at locations distinct from the release point were made on two occasions during the period of this study (Figure 1). These captures in September/ October 2001 and March 2002 presumably reflect emergence sites of flies endemic to the orchard. The pupal stage of *B. tryoni* is completed in soil after fruit infested with larvae drops to the ground. After eclosion, and wing expansion and hardening, *B. tryoni* adults fly from the ground to nearby vegetation. At this early stage of dispersal local density of newly emerged flies would be relatively high, with an associated high probability of fly captures on sticky traps by chance.

Knowledge of the location of emergence foci may be of benefit to *B. tryoni* control. Regular (weekly) monitoring of sticky traps would provide evidence of a fly incursion at least one week earlier than cuelure traps, owing to the time required for adult males to reach sexual maturity and begin responding to cuelure. The time delay between fly emergence and cuelure response corresponds with the period of highest dispersal of *B. tryoni* (Bateman and Sonleitner 1967, Fletcher 1973). Therefore, earlier detection using sticky traps has the potential to reduce the area requiring control measures, and enable intensification of control efforts in a localised area.

ACKNOWLEDGMENTS

I thank Swada London for their generosity in donating fluorescent pigment samples for marking of flies during my research project. Sterile flies were provided by NSW Agriculture on behalf of the Tri-State Fruit Fly Committee. I thank the School of Science, Food and Horticulture, University of Western Sydney, for use of their orchards on the Hawkesbury Campus. My supervisor, Dr Alfie Meats, and Dr Alan Clift provided information, support and encouragement.

REFERENCES

Bateman, M.A. and Sonleitner, F.J. (1967). The ecology of a natural population of the Queensland fruit fly, *Dacus tryoni*. I. The parameters of the pupal and adult populations during a single season. *Australian Journal of Zoology* **15**: 303-335.

Cowley, J.M., Page, F.D., Nimmo, P.R. and Cowley, D.R. (1990). Comparison of the effectiveness of two traps for *Bactrocera tryoni* (Froggatt) (Diptera: Tephritidae) and implications for quarantine surveillance systems. *Journal of the Australian Entomological Society* **29**:171-176.

Dalby-Ball, G. and Meats, A. (2000). Effects of fruit abundance within a tree canopy on the behaviour of wild and cultured Queensland fruit flies, *Bactrocera tryoni* (Froggatt) (Diptera: Tephritidae). *Australian Journal of Entomology* **39**: 201-207.

Dalby-Ball, G. and Meats, A. (2002). The role of foliage in differential landing of the Queensland fruit fly, *Bactrocera tryoni* (Froggatt) (Diptera: Tephritidae) on odoriferous and odourless fruit models. *General and Applied Entomology* **31**: 31-34.

Drew, R.A.I. (1987). Behavioral strategies of fruit flies of the genus *Dacus* (Diptera: Tephritidae) significant in mating and host-plant relationships. *Bulletin of Entomological Research* **77**: 73-82.

Duan, J.J. and Prokopy, R.J. (1994). Apple maggot fly response to red sphere traps in relation to fly age and experience. *Entomologia Experimentalis et Applicata* **73**: 279-287.

Fletcher, B.S. (1973). The ecology of a natural population of the Queensland fruit fly, *Dacus tryoni*. IV. The immigration and emigration of adults. *Australian Journal of Zoology* **21**: 541-565.

Fletcher, B.S. (1974a). The ecology of a natural population of the Queensland fruit fly, *Dacus tryoni*. VI. Seasonal changes in fruit fly numbers in the areas surrounding the orchard. *Australian Journal of Zoology* **22**: 353-363.

Fletcher, B.S. (1974b). The ecology of a natural population of the Queensland fruit fly, *Dacus tryoni*. V. The dispersal of adults. *Australian Journal of Zoology* **22**: 189-202.

Hancock, D.L., Hamacek, E.L., Lloyd, A.C. and Elson-Harris, M.M. (2000). *The distribution and host plants of fruit flies (Diptera: Tephritidae) in Australia*. Department of Primary Industries, Queensland.

Hill, A.R. (1986). Reduction in trap captures of female fruit flies (Diptera: Tephritidae) when synthetic male lures are added. *Journal of the Australian Entomological Society* **25**: 211-214.

Hill, A.R. and Hooper, G.H.S. (1984). Attractiveness of various colours to Australian tephritid fruit flies in the field. *Entomologia Experimentalis et Applicata* **35**: 119-128.

MacFarlane, J.R., East, R.W., Drew, R.A.I. and Betlinski, G.A. (1987). Dispersal of irradiated Queensland fruit flies, *Dacus tryoni* (Froggatt) (Diptera: Tephritidae), in south-eastern Australia. *Australian Journal of Zoology* **35**: 275-281.

Meats, A. (1996). Demographic analysis of sterile insect trials wih the Queensland fruit fly *Bactrocera tryoni* (Froggatt) (Diptera: Tephritidae). *General and Applied Entomology* **27**: 2-12.

Meats, A. (1998a). Predicting or interpreting trap catches from natural propagules or releases of sterile fruit flies. An actuarial and dispersal model tested with data on *Bactrocera tryoni*. *General and Applied Entomology* **28**: 29-38.

Meats, A. (1998b). The power of trapping grids for detecting and estimating the size of invading propagules of the Queensland fruit fly and risks of subsequent infestation. *General and Applied Entomology* **28**: 47-55.

Meats, A., Clift, A.D. and Perepelicia, N. (2002). Performance of permanent and supplementary traps for Mediterranean and Queensland fruit flies in South Australia 1975-2001: Comparison of male lure and food lure traps. *General and Applied Entomology* **31**: 53-58.

Prokopy, R.J. (1968). Visual responses of apple maggot flies, *Rhagoletis pomonella*: orchard studies. *Entomologia Experimentalis et Applicata* **49**: 25-36.

Sutherst, R.W., Collyer, B.S. and Yonow, T. (2000). The vulnerability of Australian horticulture to the Queensland fruit fly, *Bactrocera* (*Dacus*) *tryoni*, under climate change. *Australian Journal of Agricultural Research* **51**: 467-480.

Turchin, P. (1998). *Quantitative analysis of movement: measuring and modelling population redistribution in animals and plants.* Sinauer Associates, Sunderland.

Yonow, T. and Sutherst, R.W. (1998). The geographical distribution of the Queensland fruit fly, *Bactrocera* (*Dacus*) *tryoni*, in relation to climate. *Australian Journal of Agricultural Research* **49**: 935-953.