Analysis of movement of Qfly, particularly related to the use of Sterile Insect Technique (SIT) in eradication programs

Dr A. Meats & Dr A. D Clift
University of Sydney

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FINAL REPORT

PROJECT AH01014 (01/09/2001-31/05/2003)

Analysis of movement of Qfly, particularly related to the use of Sterile Insect Technique (SIT) in eradication programs

Fruit fly outbreaks and treatments in the Riverina section of the FFEZ 1997-2000

Dr A. Meats and Dr A.D. Clift
Fruit Fly Research Centre, University of Sydney

FRUIT FLY RESEARCH CENTRE
University of Sydney

NSW Agriculture

Horticulture Australia

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Purpose of report

The quarantined fruit growing areas of the Riverina region of NSW suffered serious incursions of the Queensland fruit fly in the seasons 1996-7 to 1998-9 and a region-wide outbreak in the season 1999-2000. This report is an account of the results of an analysis of the data from surveillance traps on how the flies spread throughout the region and on the effectiveness of the control campaign using the sterile insect technique (SIT) that was used on a large scale for the first time in the region in the 1999-2000 season.

Principal Investigators:

Dr A Meats*, Fruit Fly Research Centre, University of Sydney
Dr A.D. Clift Fruit Fly Research Centre, University of Sydney

*Address: Fruit Fly Research Centre, AO8, University of Sydney, NSW 2006, Australia
E-mail: awm@bio.usyd.edu.au, Telephone: + 61 2 9351 2207, FAX: + 61 2 9351 4119

Collaborative Investigators:

Mr D.C. Dominiak, NSW Agriculture, Orange.
Ms Merryl Robson, Fruit Fly Research Centre, Sydney.

Funding: Horticulture Australia Ltd Industry Levy

Collaborating Institutions: Department of Agriculture NSW; Fruit Fly Research Centre, University of Sydney

A. Meats
A.D. Clift

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Media Summary

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The use of the sterile insect release technique (SIT) started in September 1999 and was discontinued by early January 2000. The release strategy appears to have had no precedent and ignored previous knowledge and experience. It was consequently inept and ineffectual. Effort was spread too thinly, too unevenly and terminated too soon. The present mass production facility for sterile fruit flies is far too small to service even half of the Riverina and consideration should be given to expanding it and to establishing an interstate review panel to audit the conduct of SIT campaigns serviced by the facility. Continuing effort must be made to maintain area freedom in the Riverina because the pandemic of 2000 shows how fast an unregulated population can increase in this area, an expansion which would impinge on the integrity of other areas of the FFEZ.

Technical Summary

The quarantined fruit growing areas of the Riverina region of NSW suffered serious incursions of the Queensland fruit fly in the seasons 1996-7 to 1998-9 and a region-wide outbreak in the season 1999-2000. This report examines in detail how the flies spread throughout the region and comments on the conduct and effectiveness of the control campaign using the sterile insect technique (SIT) that was used on a large scale for the first time in the Riverina in the 1999-2000 season.

Only two flies were detected in the 1995/1996 season and the following spring of 1996 was free of infestations. From the beginning of 1997, repeated fruit fly incursions into orchards at Hillston and Yenda were followed by outbreaks in nearby towns and orchards. They appeared in most towns and orchard districts in the Riverina by early 1999 when control was obviously lost. All existing infestations survived the winter of 1999 and more appeared in spring. The distribution of new infestations suggests that there were many instances of infested fruit being carried within the Riverina. The summer of 1999/2000 was almost consistently wet and humid with the climate being similar to the coastal areas where fruit flies thrive. The Riverina consequently suffered a population explosion of fruit flies, a situation that would take much time and effort to rectify.

In the spring of 1999/2000 the treatment of infestations with the traditional bait and cover sprays was replaced in many areas with the use of the sterile insect release technique (SIT). The latter started in September 1999 and was discontinued by early January. The trapping records in the SIT treated areas for both wild and sterile flies during the period September to March show that there was no discernible difference in wild fly trappings between areas where traps detected the highest number of sterile flies and those where low numbers or none were detected. The release strategy appears to have had no precedent and ignored previous knowledge and experience. It was consequently inept and ineffectual. Effort was spread too thinly, too unevenly and terminated too soon. Only enough flies were supplied to treat 20-30 square km per week, yet attempts were made to treat may times this amount. There was no augmentation of the traps in arrays with 1 km spacing so we have no idea how flies were distributed in such areas. There no evidence on the 1 km arrays of an attempt to release flies at intervals of about 400 m. Even with 0.4 km arrays, the distribution of recaptures among traps was very uneven with many traps having low or zero scores and with means consequently being low with coefficients of variation unacceptably high. We present new data on how flies distribute themselves after release and these serve to emphasise that releases further apart than 400 m would be ineffectual.

We recommend that the mean recapture rate per trap should be at least 100 but ideally, release rate should be adjusted so no more than one in nine traps recaptures fewer than 50 sterile flies per week. The present mass production facility for sterile fruit flies is far too small to service even half of the Riverina and consideration should be given to expanding it and to establishing an interstate review panel to audit the conduct of SIT campaigns serviced by the facility. Continuing effort must be made to maintain area freedom in the Riverina because the pandemic of 2000 shows how fast an unregulated population can increase in this area and threaten the integrity of the other areas of the FFEZ.

Introduction

The two major fruit fly pests in Australia.

The Queensland fruit fly (Qfly), *Bactrocera tryoni* (Froggatt), (Diptera: Tephritidae) and the Mediterranean fruit fly (Medfly), *Ceratitis capitata* (Wiedemann), are endemic in Australia along the eastern and western coasts respectively. Zones that are non-endemic and also quarantined to exclude both species are the Fruit Fly Exclusion Zone (which straddles the borders of South Australia, Victoria and NSW), the remainder of South Australia, Tasmania and parts of Western Australia; the remainder Western Australia quarantines against Qfly. Certain areas within these zones are designated by interstate and international trade agreements as having 'area freedom' from fruit flies so that produce can be exported without post-harvest treatment for these insects (Anon. 1997).

Incursions happen despite quarantine and are detected by surveillance traps and as infested fruit. If they are deemed large enough, 'area freedom' status is suspended and eradication measures are used.

The dispersal and establishment of invading propagules of tephritid fruit flies

Fruit flies of a given species that are introduced in infested fruit into an area that is free of that species will disperse as young adults from the point of introduction and could take from 1-2 days to several weeks (depending on species and temperature) to mature, mate and infest more fruit. Dispersal can happen for the whole of the pre-maturation period as well as thereafter. In the case of *endemic populations*, flies will encounter others of the same species dispersing from other directions. In the case of an *invading propagule*, the flies will disperse into a mate–free void, so that only the few that stay around the origin will be at sufficient density to encounter each other and breed (Meats 1998 *a*, 1998 *b*). However, once mated, a female fly can travel to any distance that is possible within its lifetime and spread the infestation as a new generation. Thus, we should expect that occurrences of adults in a normally fly-free zone would be clustered around the origin and that occurrences of larvae would be even more clustered. Maelzer (1990 a) analysed data from outbreaks of Medfly and Qfly in Adelaide that occurred between 1948 and 1987 and showed that the overwhelming majority of sites (household gardens) infested with larvae in any season were within a radius of 0.8 km or less. Meats *et al* (2003*a*) examined data from 75 infestations of Medfly and 286 of Qfly that have occurred in quarantined and normally fly-free zones in Australia from 1974 to 2000. They found that the radius of occurrence of both adult male flies and infested fruit was almost always less than 1 km and most reported detections of fruit flies involved the trapping of very few flies. Moreover, 18% of Medfly infestations and 71% of Qfly infestations that were detected were not large enough to be classified as outbreaks and died out without any treatment.

However, just as fruit fly incursions are the result of human agency, we should expect that sometimes fruit flies are spread from the original point of introduction by human agency. (see later).

Surveillance and the response to incursions

The density of surveillance traps for both species is related to the perceived risks of a fruit fly occurring (with spacing at 0.4 km in urban areas, 1 km in production areas and sparsely elsewhere). The type of response to the detection of fruit flies is related to the number trapped in a fortnight. Thus, a response can entail one of the following: (i) no action, (ii) increased trap density (supplementary traps), (iii) local restrictive and eradication measures and the declaration of a suspension zone. The latter is an area within a given radius of the origin (15-80 km depending upon the intended market) for which 'area freedom' status is suspended.

For Qfly, the trigger for setting supplementary traps is 2 male flies within 2 weeks (except in South Australia where it is 1 male fly) or the trapping of a female fly or the finding of larvae. Supplementary traps are set within a 200 m radius. The trigger for outbreak declaration (regardless of whether or not supplementary traps are set) is 5 male flies within 1 km within 2 weeks or 1 female or the detection of larvae. There is a localized restriction of the movement of fruit in addition to the imposition of the wider 'suspension zone' mentioned above. A formula is then applied to establish the criteria (involving a period free from the detection of flies) for the re-instatement of area-freedom status. Localized spraying is restricted to spot spraying with baited formulations and since 1993, bait spraying for two weeks, followed by the release of sterile insects for 8-12 weeks has been the practice (at least in South Australia).

The Fruit Fly Exclusion Zone (FFEZ)

Major fruit growing areas are within the Fruit Fly Exclusion Zone (FFEZ), an area of 180,000 square km covering the borders of three states, NSW, Vic and SA. Management is coordinated by the 'Tri-State Agreement', which has allowed the FFEZ to be maintained as a designated fly-free area, for the export of high-quality fruit to overseas markets. Irrigated horticulture within the zone normally has a natural protection from fruit fly infestation because the surrounding non-irrigated areas (with the exception of the small towns within it) are too dry to support any significant source of contagion. This buffer zone is now termed the Risk Reduction Zone (RRZ).

Recent research by the Fruit Fly Research Centre has established the following in the case of the Queensland fruit fly:

(1) DNA microsatellite analysis shows that several outbreaks in the FFEZ originated from flies that came from the regions surrounding the FFEZ rather than further afield.

(2) There is DNA evidence of two instances where outbreak flies were descendants of outbreak flies of the previous season.

(3) Outbreaks can also originate at the initial stopping places for seasonal workers in production areas (notably the Hillston and Yenda districts).

(4) Analyses of historical data and subsequent modelling have also shown that the *unaided* dispersal powers of both the major pest species (Mediterranean and Queensland fruit flies) are limited in the sense that they are unlikely to both fly of their own accord *and* start a new population propagule more than 2 km from their origin (Maelzer, 1990 ab, Meats, 1998ab, Meats *et al.* 2003a).

Clarifying the reasons for breaches of quarantine

It follows from the above that when we see an infestation in the FFEZ we know it has been introduced *in infested fruit by a member of the public* or (more rarely) *has been spread by similar means from another infestation.* Hence travel (and consequent transport of infested fruit) is important to the problem on a local as well as a wider scale. The probability of people carrying infested fruit into the FFEZ in a given season by a given route is most likely related to:

(a) the size of the fruit fly population in the town where the fruit was grown;

(b) whether the climate in that season in that area had been favourable to the growth of fruit fly populations and

(c) the frequency of journeys (including those of itinerant workers) along the given route into the FFEZ and if roadside inspection stations operate, how long they operate.

SIT and the Queensland fruit fly

The use of the sterile insect technique (SIT) in Australia against the Queensland fruit fly, *Bactrocera tryoni* (Froggatt), was reviewed by Meats (1996). SIT is now used to eradicate 'spot' infestations that occur in the FFEZ, the RRZ and Adelaide. SIT for spot infestations are in such small areas (1-5 km^2) that they do not normally suffer from immigration of further wild flies and the target flies are at very low numbers so that high ratios of sterile to wild insects would be easily obtained with the minimum the 'coverage' rate of 60 000 sterile males per square km per week (Meats; 1996). Trials in 1995/6 - 1997/8 in small towns centred at Trangie to the north west of Dubbo, NSW (HRDC Project CT 95027) were conducted in conditions of wild fly abundance similar to those prevailing in the Riverina in 1999 / 2000. The results of this project are given by Meats *et al*, (2003 b) and we can conclude that release rates should be adjusted to give a sterile to wild ratio of 100:1. That is, we should aim for an average recapture rate per trap of approximately 100 sterile flies per week even when no wild flies are being caught.

Methods

Wild fly records

The current data base program, PestMon, integrates data from every trap, each of which has its own unique barcode, National Trap Number (NTN) and GPS location. An almost insurmountable problem was that this program did not exist in the early part of the period under study and went through several changes to reach a relatively stable state in July 2000 which is near the end of the period pertinent to this study. Thus we had to integrate information from sources without a common basis, some were just paper records, often as copies of faxes; others were in an informal computer spreadsheet but where no GPS locations were known. There was also the additional problem that some data came from traps that were either discontinued or installed later in the study period.

Alan Clift, after discussions with Richard Walker, and agreement with Horticulture Australia Limited, travelled to Orange (NSW Agriculture Head Office) in March 2002 and collected all fly data held by NSW Agriculture to September 2000. The main components consisted of a data set of outbreak flies compiled 8 February 2000 (DB 1) and a PestMon data set (DB 2) considered by NSW Ag to be reliable after July 2000 which had National Trap Numbers (NTNs) and GPSs for all traps in the Fruit Fly Exclusion Zone (FFEZ). PestMon also included some Riverina trap records from periods before July 2000. There were other data prior to July 2000 in faxes received by NSW Ag Head Office from Regional Inspectors whenever a fly outbreak was declared.. It may be noted that some flies which were not part of an outbreak were not always in any of these data sets. All summary notes, faxes and other information held at by NSW Ag were accumulated by the Fruit Fly Research Centre (FFRC) into a single spreadsheet (DB3) and checked.

The fly data-base (DB 4) already compiled by the FFRC from 1992 included flies sent by Regional Inspectors of NSW Agriculture. The data had been in an Excel file spreadsheet until 1999 when it was transposed to FileMakerPro to allow fields for fly bodies and DNA preparations whenever they were made of flies received from NSW Ag and the annual sampling of areas outside FFEZ (considered endemic). This database (DB 5) was scrutinised for any entries that coincided with the NSW Ag dataset.

The Riverina records from databases DB 3 and DB5 were then fused to a single spreadsheet (DB 6) and checked again against the contributing individual databases. NSW Ag in July 2002 formally agreed through Horticulture Australia Limited to provide information on all NTN street address locations (old and new) as part of SPIRT project C00107756 and the present HAL project. On receiving this information from NSW Ag the NTNs of all flies received by FFRC from NSW Ag were deduced from locations provided by Regional Inspectors at the time of sending the flies. Whenever the location did not coincide with a known NTN, the nearest NTN was used with an S to indicate supplementary trap. If no location had been provided initially (*ie* address only as town) the central town NTN was used. In a similar way all NTNs from PestMon were given the associated street location.

The many discrepancies were resolved by requesting more information from NSW Agriculture. In any conflict of data, it was considered that parsimony was most appropriate. Great effort was expended to ensure there was no double counting of flies from towns when some flies were received by FFRC, but more were noted on sheets held by either NSW Agriculture or PestMon. The fly received was considered most reliable. However, should a fly be received from a location with an NTN and the NSW Ag database recorded a fly within two days of the trapping date of the received fly, this was considered the same entry. PestMon was considered more reliable than faxed sheets whenever there was a conflict. This was not a trivial exercise. The final product (DB 7) was used for demographic analysis.

Sterile fly recapture records

Sterile flies were released from September 1999 around Narrandera and from October 1999 around Griffith and in Hillston. The recapture records had been entered in PestMon by the time we want to have access to them. Thus the only problems here were (a) converting the information from the PestMon format (eg see Appendix C2) to a conventional spreadsheet format that was suitable for analysis and (b) establishing where and when traps were discontinued or installed. The latter was important in the case of analysing sterile recapture data because a zero return for a trap deflates any measure of efficiency so it is essential to be assured that a zero return is genuine rather than the result of a trap not being active at the time. Thus transposition and checking trap locations and activity were also very time-consuming but necessary for meaningful analysis.

The sterile fly data was analysed to obtain mean weekly trapping rates for certain areas and to calculate a measure of the efficiency of the coverage (*ie* dispersion). For this, we calculated the coefficient of variation (CV) of capture rates of given sets of traps. CV is found by dividing the standard deviation with the mean. This is only useful if the data pertains to a set of similar traps which had the same release regime and similar spacing. Many sites in PestMon (even towns) had sets of traps listed that included both of the common types of spacing (usually 400m centrally and 1km peripherally). Arrays with 1 km spacing are only just acceptable for surveillance purposes (Meats, 1998b) and are hence quite inadequate for measuring dispersion of released sterile flies. Thus for calculating CVs we chose only the town traps with 400 m arrays and excluded outliers and traps with greater spacing.

Measuring dispersal ability over short distances (< 500 m).

Newly emerged adult flies from laboratory colonies were allowed to disperse from one point within an array of cuelure traps in an orchard on the campus of the University of Western Sydney at Richmond, which is on the north western fringe of the Sydney conurbation. The release was in the centre of a block of peach trees in autumn (after harvest). The block was large enough to enable the placement of 25 cue lure traps in a 5 × 5 grid array with a spacing of 20 m. Other blocks of fruit trees on the campus enabled the placement of similar (but smaller) grids at greater distances from the release point, so that 68 sites were used extending to a distance of 480 m. The insects were transported to the field as pupae and placed in containers inside a broccoli box of about 26 L capacity (450x300x190 mm). It was made of polyurethane foam that had four holes (100 mm diameter) in the sides that allowed the flies to escape on emergence. The box was placed on the ground under a tree canopy and sheltered from sun and rain by a small awning; ants and other predators were prevented from entering by a polybutane barrier that was applied to the sides of the box beneath the exit holes.

One lot of flies was self-marked having the *whitemarks* phenotype whereby the sclerites that normally would have been yellow were white (Meats *et al.* 2002). The other lot was marked with a fluorescent powder. The powder was 'Astral Pink' from the 'E' series of Swada (London) Ltd) and was applied at 0.5g per 1000 pupae with the latter also mixed with an equal volume of sawdust that was fine enough to pass through a sieve with a 1.5 mm mesh. The self-marked flies were also mixed with sawdust, but with no fluorescent powder. The emerging flies were thus marked in the ptilinial suture similarly to the way sterile flies for SIT are marked (Dominiak *et al* 2000).

The results were expressed as catch per trap as a percentage of the total caught in the first 50 m. In the case of the first release every trap caught flies so its result was calculated uniquely. In the case of the second release, where fewer flies were involved, some traps beyond 440 m caught zero flies. In such cases, catch per trap was based on the combined result for sets of adjacent traps, at least one of which caught flies. This procedure, although preserving the mean trend, tended to reduced the standard deviation (and hence the coefficient of variation) of the flies caught beyond 440m from the second release.

Measuring climatic variables

Climatic data were obtained from *MetAccess* (Donnelly *et al.* 1997) using the techniques of SILO (Mullen and Beswick 2000, Beswick *et al.* 2000). These data were used to run the CLIMEX program (Yonow and Sutherst 1998) for the three release years. CLIMEX generates many indices pertinent to the biology of the Queensland fruit fly: Moisture Index (MI), Growth Index (GI), Temperature Index (TI) and the stress indices, Cold Stress (CS) and Dry Stress (DS).

The chief climatic influence on fruit fly populations over most of their range in summer is rainfall (Bateman, 1968; Meats, 1981). The effect of rainfall can however be offset by evaporation, so the dry stress index of Yonow and Sutherst (1998) is perhaps more appropriate, especially for the inland regions. Dry stress levels are the outcome of the balance of rates of rainfall and evaporation, with the latter being influenced in turn by temperature.

The other chief influence is the winter climate. This is rarely due to the direct effects of cold on survival - repeated frosts must be quite severe for this (Meats and Fitt, 1987). It is more generally due the imposition of a 'breeding gap' by periods when the daily maximum temperature does not exceed 20°C (Meats and Khoo, 1976). The length of the breeding gap is critical to bioclimatic potential (Meats, 1981, 1989)

Results

The spread and increase of wild flies 1997-2000

Figure 1 gives the summary data for the whole of the Riverina section of the FFEZ. Note that there is always a winter gap because flies are rarely trapped when the daily maximum temperature is below 20° C.

If we look at the main areas separately (Tables 1a and 1b) we see that the outbreak was virtually universal from the beginning of the 1999/2000 season but that in certain areas it had been building for up to 3 years. It appears that there were 3 routes to contagion with infestations in every half season at Hillston orchards, Griffith and Yenda respectively. It is not possible to say with great certainty if these were continuing infestations or a sequence of separate breeches. However, At Hillston, there were flies trapped each half season in one orchard and each half season from early 1998 in another and from most locations, including the town from late 1998. At the orchards to the east of Yenda there were detections every half season among traps 2132- 2145. At Griffith, trappings were few and in widely separated places up to very late in 1999 so the sequence there was probably of separate events up to that time (infestation was possibly *via* Yenda).

Figures 2a-2c give the time sequence in more detail. The same sequence plotted as catch per trap is given in Appendix A(3) Figures A11- A13.

A series of pictorial sequences showing the spatial relations and growth of the propagules is shown in Appendix A (1) Figures A 1- A 8

Finally the accumulated catches of traps in Griffith and Narrandera is shown in Appendix A (2) Figures A 9 and A 10 respectively.

What is clear from Figures A 1 - A 10 is that the outbreaks were not a case of a simple spread from one or a few points - a pattern that Qfly could achieve of its own accord. The actual pattern is one of several discontinuities and suggests that infested fruit was transported within the region.

Figure 1 Weekly totals of wild flies trapped in whole of Riverina part of the FFEZ (for district by district comparison of wild flies see Figures 2a - 2c)

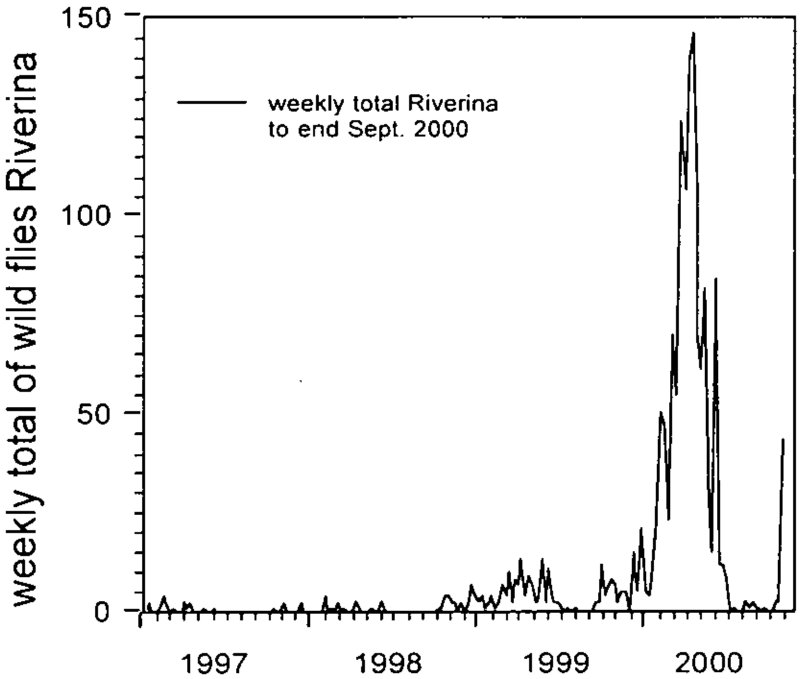


Table 1 a

NUMBER OF WEEKS WITH POSITIVE TRAPS (for wild flies)

LOCATION	1997	1997	1998	1998	1999	1999	2000
	Jan-June	July-Dec	Jan-June	July-Dec	Jan-June	July-Dec	Jan-June
Hillston orchards	1	2	4	6	6	8	16
Hillston town	1			3	4	4	7
Goolgowi + district					2	6	18
Tharbogang - Lake Wyangan				1	3	4	15
Beelbangera + orchards					1		12
Griffith	2	1	1	1	2	5	20
Hanwood + orchards			1	3	6	4	9
Yenda + orchards	7	1	4	1	7	1	18
Barellan, Kamara, Ardlethan				2	3		19
Stoney point					1	4	8
Leeton			1		2	4	14
Corbie hill orchards			2		8	6	8
Narrandera (district)	1				1 (6)	4	19 (3)
Jerilderie + district					8	6	13
Deniliquin					2	1	10
Hay				1	4	2	10
Column totals	12	4	13	18	66	59	218

Table 1 b

NUMBER OF WILD QLY IN EACH HALF SEASON

LOCATION	1997	1997	1998	1998	1999	1999	2000
	Jan-June	July-Dec	Jan-June	July-Dec	Jan-June	July-Dec	Jan-June
Hillston orchards	1	2	5	9	11	27	123
Hillston town	2			10	6	8	17
Goolgowi + district					2	18	110
Tharbogang - Lake Wyangan				1	4	6	54
Beelbangera + orchards					1		24
Griffith	2	2	1	1	3	10	292
Hanwood + orchards			1	4	9	5	14
Yenda + orchards	12	1	5	2	7	1	75
Barellan, Kamara, Ardlethan				2	5		129
Stoney point					1	10	37
Leeton			1		2	6	99
Corbie hill orchards			2		17	10	29
Narrandera (district)	1				2 (11)	4	183 (4)
Jerilderie + district					28	12	80
Deniliquin					2	1	50
Hay				2	8	2	53
Other sites	1			1	6	6	45
Column totals	19	5	15	32	125	126	1418
Grand total 1740							

Key to terms:

Goolgowi district: Merriwagga, Rankins Springs.
Narrandera district: Paynters Siding, Grong Grong.
Jerilderie district: Berrigan, Finley,
Other sites: Coleambally, Darlington Point + orchards, Whitton, Mathoura, Yoogali, Merungle Hill, Stanbridge, Wamoon, Cudgel, Yanco.

Sites with no trappings: Balranald, Moama, Urana, Wakool, Nericon, Ellimo, Bilbul.

Figure 2a Weekly totals trapped in specified

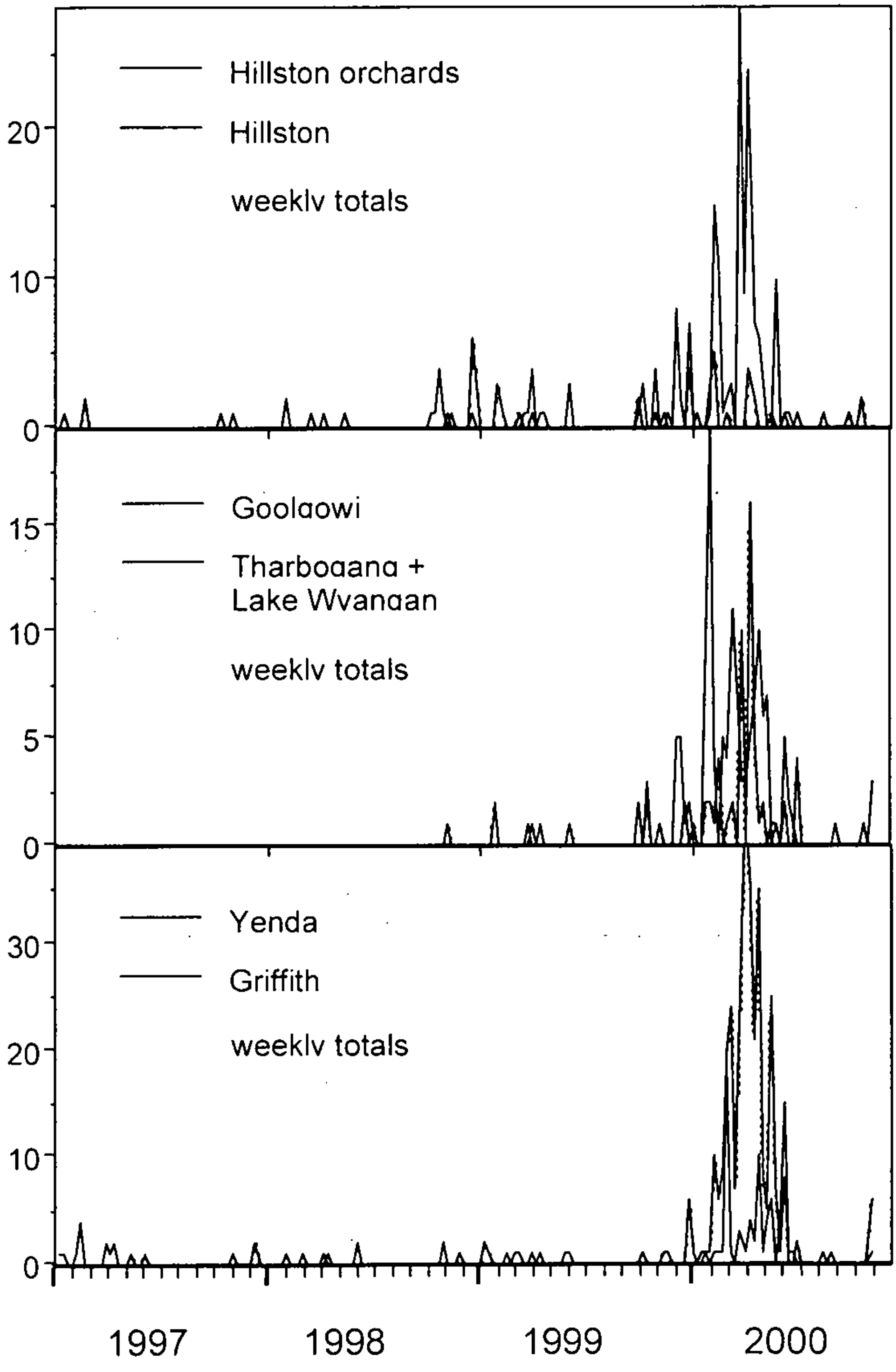


Figure 2b Weekly totals trapped in specified areas

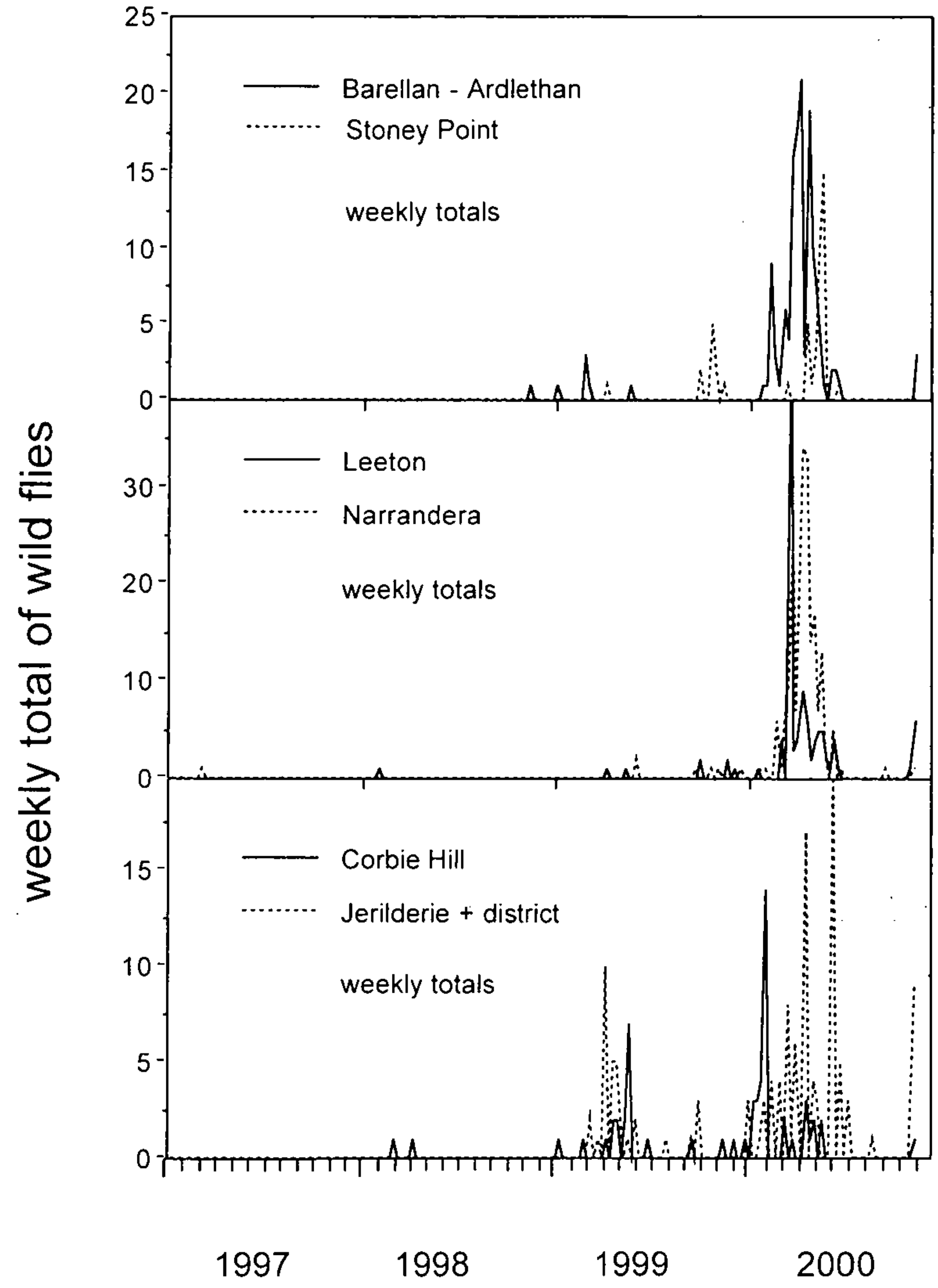
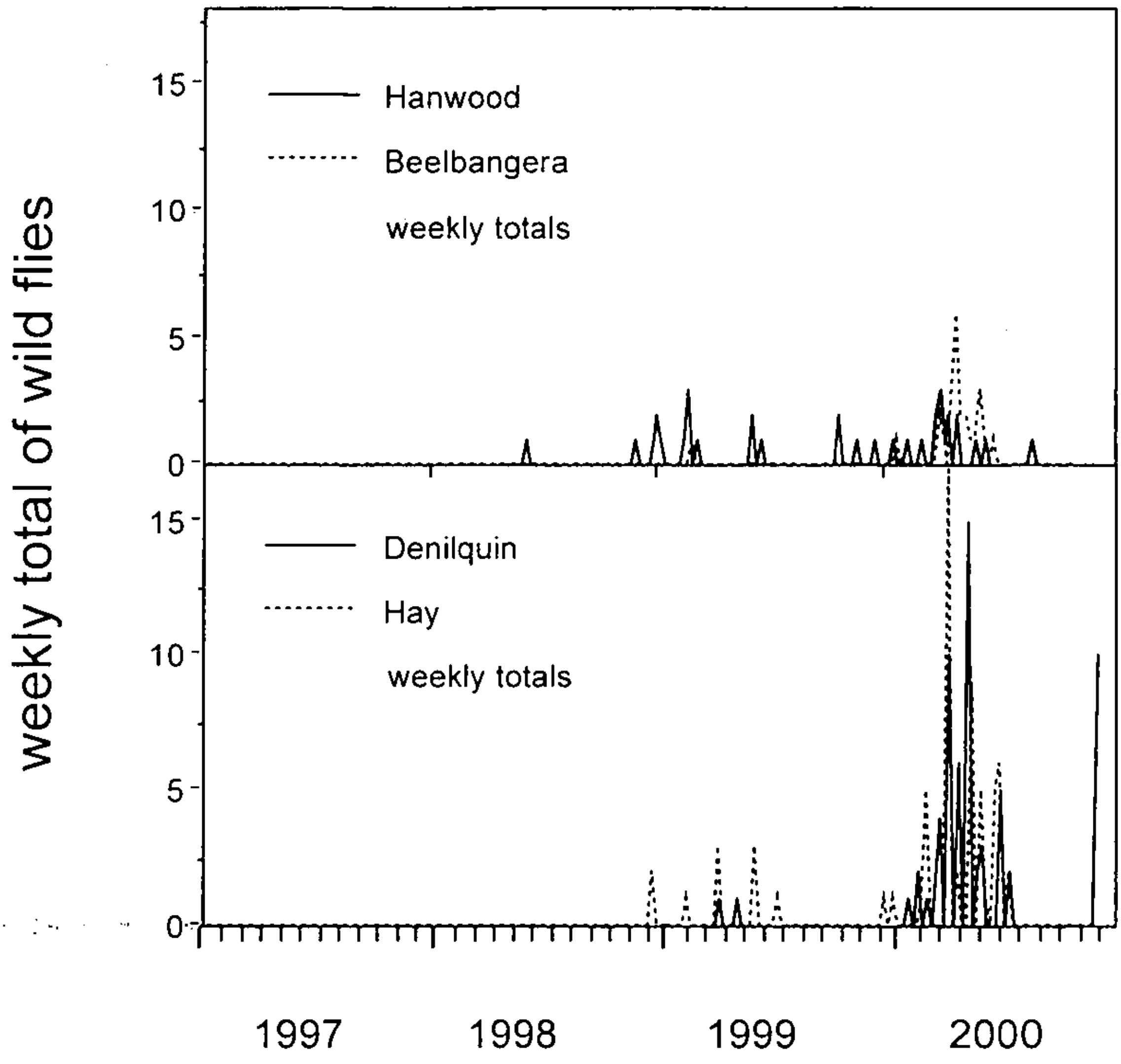


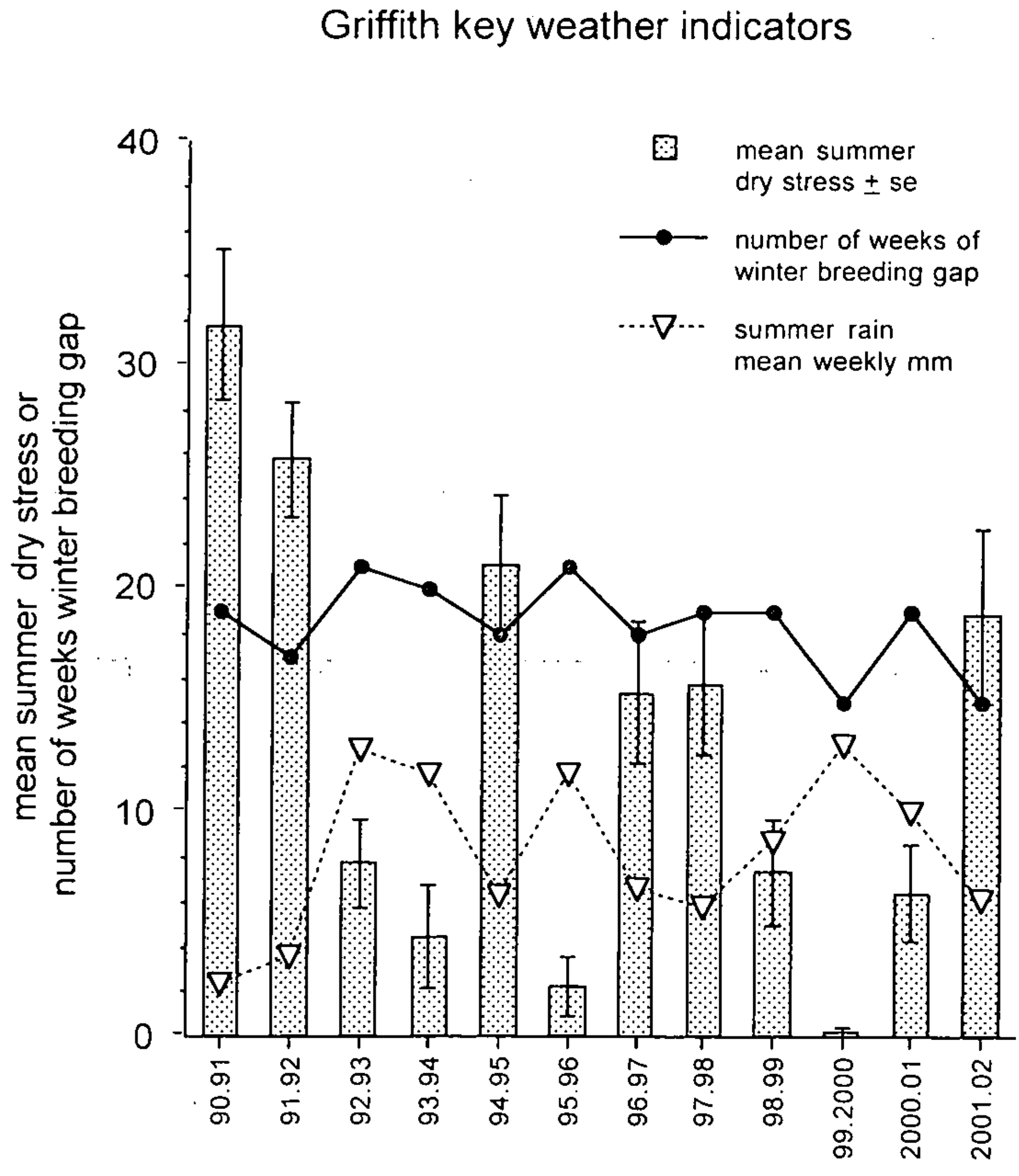
Figure 2c Weekly totals trapped in specified areas



Key weather factors in the Riverina 1990-2002

Figure 3 indicates the trend in 3 significant indicators. Note that the 1999/2000 season is the only one preceded with a short breeding gap with an almost zero level of summer dry stress and weekly average summer rainfall equivalent to the highly favourable score of Meats (1981).

Figure 3 Key weather indicators taken from records for Griffith. 'Summer' refers to 26 weeks which for any season are the last 13 weeks of one calendar year and the first 13 weeks of the next. 'Winter breeding gap' refers to a period of the winter preceding the relevant season.



Measuring dispersal ability over short distances (< 500 m).

This part of the investigation was done to re-inforce the recommendations of Meats (1996) who concluded that SIT with Qfly should be done with releases no further apart than 400m. If flies conformed to the 'inverse square rule' in the form given by Meats (1998a) then should flies be released to achieve a local ratio of steriles to wild of S/W = x up to distance d_1 then the ratio at distance d_2 will be $x\,(d_1/d_2)^2$ if the density of wild flies is the same at distance d_2. Thus if releases are made to give a ratio of S/W = 100/1 for a given density of wild flies within a radius of 200 m, then for the same density of wild flies the ratio achieved by dispersal of steriles will be 25/1 at 0.4 km, 4/1 at 1 km, 1/1 at 2 km and only 0.16/1 at 5 km. The basis of this model has been confirmed several times for Qfly for distances over 500m (eg see review and analysis by Meats, 1998a) but no detail has hitherto been available on what happens closer to the point of release.

Figure 4 shows the results of two releases of laboratory-reared Qfly within an array of closely spaced (20m apart) cuelure traps. The data fit neither a power model nor an exponential model very well because there is no discernible decline in flies trapped up to about 150m. The decline in numbers trapped is quite discernible at 200m and beyond. The mean catch per trap for each release was respectively about 3 and 4 times greater in the first 150 m than it was around the 200m mark (t- test, $p \leq 0.0001$).

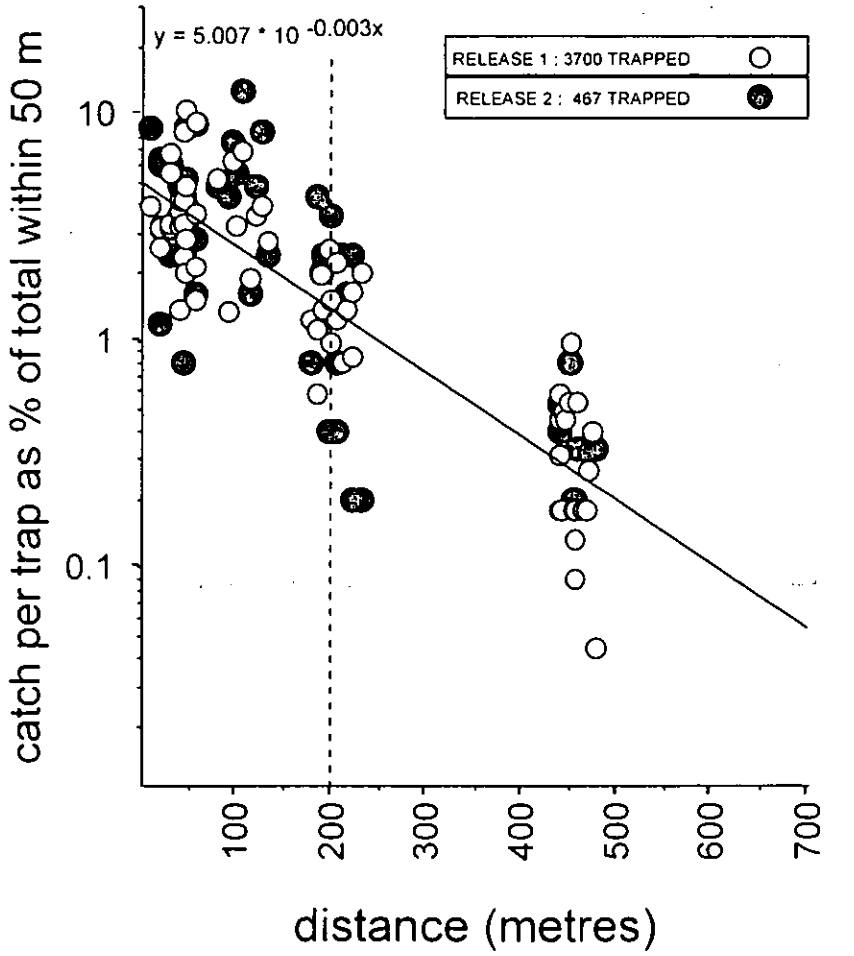
Because of the scatter of points, the fit to a power model (shown) is probably as good as any one model with a simple mathematical function could achieve with the data within the range investigated. However, we know that beyond 200m the inverse power model is best (see above) thus a combination of two models would probably provide a description that would be the closest to the true nature of fruit fly distribution. Accordingly, we suggest that the Weibull model would probably give a good fit to the first part of the curve where there is a level distribution followed by a slow decline, but the trend from 200m would probably fit the inverse square model (see also, Clift *et al*, 1998).

The variation between trap catches was in fact a lot smaller than seen with trap arrays with 0.4 or 1.0 km spacing. Table 2 summarises the overall performance of our 20m array and shows that the coefficient of variation was well under 1.0.

Table 2 Recapture data for short-range dispersal trials of lab-reared Qfly on arrays with 20 m trap spacing at Richmond, NSW (see Fig. 3).

	NUMBER FLOWN	% RECAPTURE	TOTAL RECAPTURE	CV TRAP CATCH 0 -140 m	CV TRAP CATCH 170 - 230 m
RELEASE # 1	25,000	14.8	3,700	0.54	0.59
RELEASE #2	3,650	12.8	467	0.39	0.84

Figure 4 Short-range dispersal of lab-reared Qfly at Richmond, NSW (released on emergence, trapped from 7 days later)



Sterile Qfly: distribution, monitoring and dispersion

Sterile flies were released from September 1999 around Narrandera and from October 1999 around Griffith and at Hillston. Unfortunately, deliveries were discontinued at the end of December with the exception of the sending of one batch to Griffith on 5 January 2000 (see Appendix C1).

Many releases were made in districts with 1 km arrays (eg Hillston Orchards, Tharbogang, Lake Wyangan, Corbie Hill, Merungle Hill, Stoney Point, Cudgel, Grong Grong). In some districts, there was a mix of 0.4 km and 1 km arrays (small towns such as Yenda having 0.4 km spacing while their environs had 1 km spacing) and even with bigger towns, their large 0.4 arrays gave way to 1 km arrays at their peripheries. In no case (with the exception of Hillston town) could we ascertain exactly how the release points were distributed (*ie* midway between traps, just next to them or some other arrangement).

To assess dispersion, we can use the results of the trials centred at Trangie for comparison (HRDC Project CT 95027). Accordingly, we give some of the results (Table 3) from the releases at Gilgandra where there were 31 traps spaced at 400m and weekly releases were made from cages at the midpoints between the traps. These results can then be compared with those obtained at Leeton, Narrandera, Hillston and Griffith (Tables 4-7). The dispersion of trap catches was generally bad, with some traps catching large numbers of sterile flies and some catching few or none. There was also a large variation from week to week even where trap catches were high on average.

Table 3

Distribution of trap catches of sterile flies on an array with 400 m spacing in trials at Gilgandra, NSW. Data from project CT95027

trap\ date	30/12/96	17/3/97	10/11/97	16/3/98	96-98 AVERAGE
1	184	30	14	15	28
2	0	0	2	4	3
3	290	136	0	0	15
4	62	151	293	88	33
5	0	0	49	0	4
6	112	0	83	105	15
7	441	1107	71	5	102
8	46	1	0	18	18
9	736	410	41	7	51
10	367	604	79	130	61
11	22	0	418	312	52
12	294	975	235	817	97
13	0	0	737	0	36
14	0	0	0	84	29
15	3	17	76	16	8
16	0	0	11	59	2
17	8	25	17	0	6
18	0	0	0	625	26
19	2	0	0	162	22
20	0	0	193	210	46
21	25	0	270	180	37
22	25	218	655	336	61
23	159	0	55	0	27
24	25	0	504	0	39
25	0	450	213	109	71
26	12	38	847	37	30
27	224	132	551	621	102
28	0	0	12	7	3
29	156	83	495	55	63
30	0	150	821	31	54
31	0	0	5	5	37
MEAN	**103**	**146**	**218**	**130**	
CV	**1.65**	**1.93**	**1.24**	**1.60**	

Table 4

Leeton dispersion of sterile flies (400 m array)

trap\date	23/11/99	6-8/12/1999	17-20/12/1999	29/12/99
2370	2	4	1	45
2371	3	4	2	960
2372	4	21	0	19
2373	1143	153	681	4
2374	7	0	0	4
2375	2	19	3	59
2376	248	319	119	549
2377	0	0	43	65
2378	0	140	106	100
2379	1	10	0	67
2380	4	0	2	0
2381	8	10	72	299
2382	1	3	4	0
2383	4	38	10	5
2384	13	14	28	76
2385	15	108	49	273
2386	1	22	0	0
2387	235	29	11	95
2388	138	0	0	18
2389	6	3	0	15
2390	0	3	3	9
2391	0	19	18	19
2392	1	10	5	33
2393	23	99	91	0
2394	32	48	38	26
2395	1	50	0	3
2397	8	10	2	10
2398	1	1	0	0
2399	3	5	0	0
2400	47	89	29	106
2401	1	60	1	88
MEAN	**63**	**41.3**	**42.5**	**95.1**
CV	**3.34**	**1.60**	**2.90**	**2.08**

Table 5

Narrandera dispersion of sterile flies (400 m array)

trap\date	22/11/99	6/12/99	30,31/12/99	19/1/00
2512	0	4	2	6
2513	1	9	10	6
2514	268	0	14	0
2515	0	1	3	5
2516	0	4	9	34
2517	0	0	0	23
2518	2	10	2	0
2519	0	2	0	11
2520	0	20	115	294
2521	6	65	46	187
2522	0	0	3	13
2523	21	9	0	594
2524	0	8	0	0
2525	54	1	0	0
2526	21	667	0	47
2528	0	11	0	10
2529	4	24	0	0
2530	4	11	0	33
2531	0	36	15	65
2532	1	19	34	40
2533	143	0	301	49
2534	2	8	11	16
.2535	32	112	46	0
2536	300	208	78	77
2537	7	42	20	38
2538	4	0	0	0
2539	0	31	6	11
2540	0	15	4	38
2541	4	18	5	56
MEAN	**30**	**46**	**25**	**57**
CV	**2.52**	**2.75**	**2.38**	**2.11**

Table 6

Hillston dispersion of sterile flies (400 m array)

trap\date	26/11/99	1/12/99	8/12/99
2291	1	0	2
2292	124	515	303
2294	0	134	4
2296	8	51	68
2297	11	24	47
2299	0	1	4
2301	4	21	30
2302	0	36	32
2304	0	236	144
2305	0	25	53
2306	54	1	0
2307	2	6	4
2325	0	0	0
2326	0	0	0
MEAN	**14.6**	**75**	**49.4**
CV	**2.37**	**1.9**	**1.69**

Table 7

Griffith dispersion of sterile flies (400 m array)

trap\date	15-16/11/99	29-30/11/1999	20-23/12/1999	10/1/00
2002	1	4	11	0
2003	0	1	0	0
2004	0	0	0	1
2005	1	0	0	0
2006	0	0	0	0
2007	0	36	0	8
2008	0	2	0	4
2009	0	1	0	0
2010	0	0	0	0
2011	0	0	0	0
2012	0	0	1	0
2013	0	0	0	0
2014	0	0	0	0
2015	0	0	0	0
2016	0	0	0	0
2017	0	0	0	0
2019	8	6	14	11
2020	0	5	1	1
2021	0	11	0	0
2022	76	3	6	1
2023	0	0	0	0
2024	10	23	8	5
2025	27	58	18	5
2026	0	0	0	1
2027	11	27	16	1
2028	6	8	2	1
2029	6	5	3	1
2030	33	280	300	18
2031	4	3	9	0
2032	1	5	0	0
2033	0	9	17	6
2034	2	9	1	0
2035	27	24	15	2
2036	0	0	2	0
2037	1	1	0	0
2038	0	1	0	0
2039	1	1	0	0
.2040	0	0	0	0
2041	0	7	0	0
2042	0	1	4	11
2043	1	181	16	8
2044	4	23	4	9
2045	0	1	0	2
2046	0	7	6	0
2047	0	15	14	24
2048	1	81	94	1
2049	0	0	21	17
2050	8	0	11	130
2051	5	39	15	38
2052	4	12	9	16
2053	2	4	4	3
2054	14	82	20	42
2055	3	7	1	0
2056	0	16	22	23
2057	20	4	9	59
2058	67	390	205	0
2059	0	1	1	0
2060	1	1	0	2
2061	0	1	0	1
2062	1	0	0	1
2063	0	1	1	1
2064	0	1	2	13
2065	1	8	1	0
2066	0	0	1	2
2067	0	1	8	1
2068	0	0	0	0
2069	0	1	0	0
2070	0	2	0	0
2071	0	0	0	0
2073	0	1	0	0
2074	1	3	1	0
2076	0	1	0	0
2081	0	0	0	0
2082	0	0	0	0
2083	0	0	0	0
MEAN	**4.64**	**18.87**	**11.92**	**6.27**
CV	**2.78**	**3.14**	**3.57**	**2.84**

Sterile flies: comparing spatial distribution of recaptures

As explained earlier, the monitoring of sterile fly releases is an exercise in self delusion if trap spacing is greater than 0.4 km. Thus comparisons here are limited to 0.4 km town arrays, with any outlying traps excluded.

The CVs obtained in the Riverina towns (Tables 4-7). were largely worse than those obtained at Gilgandra. during the HRDC Project CT 95027 (Table 3). This means that there were far too many traps with zero or very low recapture rates (indicating that coverage and therefore any population control was absent or grossly inadequate in too many places). A CV of 1.0 would indicate that the standard deviation equals the mean and in such a case we should expect on average that about one in six traps would have a zero or very low return. The greatest we should aim for is one in nine where on average we would expect a trap with a zero or very low return would be surrounded by eight traps with a much better score. The 1 in 9 result corresponds to a deviation of 1.22 times the mean, thus in order to achieve it we would need a CV of 0.816.

A result that may work to our advantage is that for Gilgandra, only one of the six possible pair-wise comparisons yields a significant correlation coefficient ($p<0.05$). The tendency for serial correlation is higher in the Riverina cases but they are much closer together in time because of the very short release period (hence not fully independent). The intervals between the Gilgandra samples were larger so there was no 'carry over effect' from one period to another and we could conclude that low scoring may be a temporary phenomenon for traps and that blank spots in any sterile fly coverage may be filled.

Sterile flies: temporal trends and subsequent appearance of wild flies

Results for selected traps are shown for Griffith (Table 8a and 8b). Traps were selected on the basis of having caught large numbers of sterile flies or relatively large numbers of wild flies or both kinds. There is no pattern in the apparent release response to wild flies or the subsequent eruption of further wild flies. This can be linked with the fact that the recapture rate of sterile flies was never high enough to indicate that the release rates could have any measurable effect. The eruptions of wild flies therefore happened regardless of the presence of the sterile flies.

Further examples are given in the more extensive Appendix B Tables B1 - B13 for Corbie Hill, Leeton, Stoney Point, Wamoon, Yanco, Narrandera and Paynters Siding. Again, it is obvious how patchy the sterile recapture rates were, with adjacent traps sometimes having quite different results. This phenomenon is even more pronounced with the arrays with 1 km spacing.

Table 8a

Temporal trends in trapping of wild and sterile flies.
Wild (W) and sterile (S) catches by selected traps at Griffith. Traps identified by four digit code. (see also Map 2)

DATE	Griffith 2003		Griffith 2005		Griffith 2007		Griffith 2019		Griffith 2020		Griffith 2021	
	W	S	W	S	W	S	W	S	W	S	W	S
25/10/1999	0											
1/11/1999	0					2		1				
8/11/1999	0							2		2		
15/11/1999	0							8				
22/11/1999	0					5		7		9		
29/11/1999	0	1				36		6		5		11
6/12/1999	0	8				41		18		11		9
13/12/1999	0					11		7		2		
20/12/1999	0					11		14		1		
27/12/1999	0				1	12		6		2		
3/01/2000	0	1		1		39		16		6		
10/01/2000	0					8		11		1		
17/01/2000	0		3	1		17		2		2		
24/01/2000	0					76						
31/01/2000	0					3						1
02/08/2000	0		3			2	1		3			
14/02/2000	0		2		14				4		1	
21/02/2000	2				1				2			
28/02/2000	0		13				1				2	
6/03/2000	4		1		16				2		12	
13/03/2000	10		2		3		1		5		9	
20/03/2000	7			1	4		2	2	2		2	1
27/03/2000	7		4		6		2		5		3	
3/04/2000	0				1		2				1	
10/04/2000	0				1							
17/04/2000	3				14				1		3	
24/04/2000	2				1							
1/05/2000												
8/05/2000												

Table 8b

Temporal trends at Griffith (continued).

DATE	Griffith 2022		Griffith 2035		Griffith 2042		Griffith 2056		Griffith 2061		Griffith 2062	
	W	S	W	S	W	S	W	S	W	S	W	S
25/10/1999				1								
1/11/1999	4		1	20	1			3				
8/11/1999				5				3				
15/11/1999		76		27		1						1
22/11/1999		66		6				4		1		
29/11/1999		3		24		1		16		1		
6/12/1999		11		77	2	9	3	19		3		
13/12/1999		5		15		1		20		1	1	
20/12/1999		6		15		4		67				
27/12/1999		4		7								
3/01/2000				11						1		1
10/01/2000		1		2	1	12		31		1		1
17/01/2000				4	3	1			1		1	1
24/01/2000		1				1		29			3	
31/01/2000		1						3			3	
02/08/2000		1						1			3	
14/02/2000	1											
21/02/2000												
28/02/2000					1				1			
6/03/2000	1											
13/03/2000												
20/03/2000	1											
27/03/2000	1				1				1			
3/04/2000							1					
10/04/2000												
17/04/2000	1											
24/04/2000												
1/05/2000												
8/05/2000												

Discussion

The spread and increase of wild flies 1997-2000

Why was there such a massive increase in fruit fly numbers in early 2000? The rainfall was almost consistently in the favourable range (Bateman, 1968; Meats, 1981)for the whole summer period of 1999/2000. The mean weekly value and standard deviation of rainfall was 13 ± 3.56 mm. and dry stress was virtually zero (Figure 3). In such conditions we should expect an increase of the multiple (but not in the same absolute numbers) we see each year in favourable coastal regions such as Sydney (eg see Fletcher, 1974). But obviously, this would only happen if flies were there in the first place. The 1995/1996 season was almost as favourable yet only 2 flies were trapped (one in April 1996 and one in May, both in the same Hillston orchard) The reason for the contrast was probably that the preceding season, 1994/1995, was very dry (see Figure 3) and only about 20 flies were trapped (and the infestations presumably successfully dealt with as there were no detections in the following spring) whereas in the season before 1999/2000 weather was not so harsh as 1994/1995 and 157 flies were trapped.

From early 1997 the control system was under increasing pressure starting with a chain of infestations at Hillston orchard and the east Yenda district. In the last half of the 1998 / 1999 season, control was lost in all areas, so that in early 2000, the increase in fruit fly numbers in the Riverina was spectacular because the weather was as wet and as favourable as it normally is in the endemic coastal zone.

So if we are looking for reasons for the 1999/2000 outbreak, we must look to earlier times and seek reasons for a failure to control at Hillston orchards and Yenda orchards. It has recently been suggested , following our report into suspension zones (Meats *et al*, 2001) that detections in production areas should be followed by the installation of 400m trap arrays. We agree with this and go further to suggest that such arrays be permanent in 'problem areas' and a special effort be made to discover sources of infestation. Intensive insecticidal responses should be considered in any localised 'hot spots' that are discovered in this search because the risk to the public does not arise in such places because they are under the full control of the producer.

The maps in Appendix A show a discontinuous pattern of infestations that suggests that infested fruit was often transported within the region. This problem becomes critical at times like 1999/2000. Much effort is spent attempting to prevent infested fruit from entering the Riverina but it appears that at critical times there should be an effort to discourage movement of infested fruit within the region.

The supply of sterile flies

Appendix C1 shows that 58 million sterile pupae were sent to the Riverina between 07/09/1999 and 05/01/2000, an average of about 3.2 million per week. Quantities varied from week to week but the most were sent during the period 09/11/1999 to 14/12/1999 when an almost consistent amounts of about 5.4 million were sent per week. Of course, only half would have been males and we would expect the number of males to have actually 'flown' to have been about 2 million per week during those six weeks. At the old recommended rate of 60 000 males per square km per week this would have been sufficient to treat 33 square km; but at the rate suggested by the results of project CT 95027 of 100 000 per week, it was enough for only 20 square km. In spite of this, an attempt was made to treat 60 square km worth of towns and up to 150 square km of orchard districts. Given that no attempt was made to treat some towns and districts with sterile flies, it is clear that if such a pandemic happens again, it would require at least 25 million sterile males per week or the delivery of over 50 million pupae per week.

Because supplies of sterile flies are going to be limited, we suggest rationalising the use of two types of treatment. Orchards are large tracts of host plants, each usually with one owner and where access and permission to use insecticides should be easy to obtain. These are these are in areas with 1 km trap arrays that are not well suited to the monitoring of sterile populations. Towns are a series of very small holdings, often with less than 3 host trees each. Rights of access and permission to use insecticides are increasingly difficult to obtain in towns and moreover town sites are generally more favourable to fruit fly survival due to backyard and garden irrigation. Given these circumstances, it may be rational to release sterile flies chiefly in towns and use insecticide treatments in orchards to gain maximum value from the available resources.

Monitoring and sterile fly coverage in treated areas.

Obviously, whereas 1 km arrays are acceptable for surveillance in times of area freedom, they are grossly inadequate for monitoring SIT. The potential errors involved are too great when using a 1 km array where flies may be up to 707 m from the nearest trap (Meats, 1998b,c). Only trap arrays with a maximum spacing of 0.4 km will give sufficient precision. Thus for SIT, extra traps should be installed when needed.

Similarly, release points should be no further apart than 0.4 km and at the midpoints between the traps. There have been logical grounds for releasing flies at maximum intervals of 400m (Sproule *et al* 1992, Meats, 1996, 1998 bc) and the preceding section of this report provides a practical demonstration. For Medfly, it has long been the practice to use continuous spatial distribution through aerial releases or 'roving' ground releases from moving vehicles (Nadel *et al.*, 1967; Howell *et al*, 1975; Cunningham *et al*, 1980) but ground releases at fixed points at approximately 400m intervals are sufficient for strong fliers such as many *Bactrocera* species.

Also, effort must be made to distribute sterile flies evenly between points. An analogy with insecticide or fungicide cover sprays is appropriate here. With cover sprays there will be poor control if several times the required amount is sprayed in some patches and none in others.

The Gilgandra results of HRDC Project CT 95027 indicated that a ratio of sterile flies to wild should be in excess of 80:1, probably 100:1. Thus releases should be at such a level that recaptures are at a rate of about 100 per trap per week. An average of this amount is probably not sufficient because variation between traps would mean that coverage is inadequate, even zero, in patches. This is more than likely if the coefficient of variation exceeds 1.0. Thus the aim should be to have a mean recapture rate above 100 per trap per week and a CV of less than unity.

Control at Gilgandra was never achieved despite the mean recapture rate per trap per week being above 100 thus it appears that a CV of 1.6 is inadequate. A result of over 2.0 as in most of the Riverina returns is therefore grossly inadequate, but most means were poor as well. Obviously, a good result is more readily achieved if the mean is higher that 100. Ideally, the weekly frequency at which traps recapture less that 50 sterile flies should be no more than 1 in 9 so that there is a good chance that any low scoring trap is surrounded by high scoring ones. However, in such a case, we will be wasting flies by having too many in some places in order to have the minimally sufficient quantity in others. To an extent, this is unavoidable, but the effect can be kept to a minimum if effort is made to distribute flies evenly and to release extra in patches with poor recapture rates.

Sometimes, a poor recapture rate may be due to placing the trap in a poor position; so we suggest that alternative points should be tried with the temporary placement of supplementary traps.

Finally, the dimensions of the grids should be big enough to account for the fact that flies would tend to disperse off a small grid in all directions. Thus, even with the smallest 'spot' treatment, the release area and its 0.4 km spaced trapping grid should be at least 1 sq. km in extent - at least big enough to be three (preferably four) traps in extent in any direction (if permitted by the terrain and vegetation). If sufficient traps are not present as part of the normal surveillance grid, they should be installed for SIT.

Technical transfer

This project was commissioned to investigate what happened when existing technology apparently did not work. There was therefore no technology to transfer. We did however find that technology was not applied appropriately and we have identified key deficiencies. Steps to improve application of existing knowledge are therefore given as recommendations.

Recommendations

We give these in full as a response to the findings of this report, although, because of the lapse of time since October 2000 and the subsequent experience of the SIT team, some of the following may have been adopted already.

Wild flies

(1) Detections of wild flies in production areas should be followed by the installation of 0.4 km trap arrays for monitoring treatment.

(2) The dimensions of such arrays should be big enough to account for the fact that flies would tend to disperse off a small grid.. Thus, even with the smallest 'spot' treatment (whether by insecticide or SIT) the release area and its 0.4 km spaced monitoring grid should be at least 1 sq km in extent - at least big enough to be three (preferably four) traps in extent in any direction (if permitted by the terrain and vegetation).

(3) For production areas, arrays at 0.4 km should be permanent at problem sites and a special effort should be made to discover sources of infestation.

(4) For these areas, intensive insecticidal responses should be considered in any localised 'hot spots' that are discovered in this search because the risk to the public does not arise in such places because they are under the full control of the producer.

(5) Much effort is spent attempting to prevent infested fruit from entering the Riverina but it appears that at critical times there should be an effort to discourage movement of infested fruit within the region.

Monitoring and sterile fly coverage in treated areas.

(6) Release points should be no further apart than 0.4 km and at the midpoints between the traps.

(7) Effort must be made to distribute sterile flies evenly between points.

(8) The aim should be to have a mean recapture rate above 100 per trap per week and a coefficient of variation between them of less than unity. Ideally, the weekly frequency at which traps recapture less that 50 sterile flies should be no more than 1 in 9.

(9) Sometimes a poor recapture rate at a given trap may be due to the placing of the trap in a poor position, so alternative points should be tried with the temporary placement of supplementary traps.

The supply of sterile flies

(10) Sterile flies should not be released in inadequate amounts. This practice has obviously given rise to a false sense of security and has distracted attention from the need to apply effective alternative treatments. Areas to be treated with SIT should be selected on the basis of how many sterile flies can be delivered each week and how easy it is to use alternative methods. It would be wasteful to treat large areas of orchards with sterile insects and it should be easier to get permission to use insecticide in orchards than it is in towns. Thus it would be better to reserve most SIT effort for urban areas. Other areas outstanding would also have to be treated with alternative methods.

Rolling reviews of the SIT

(11) Crises, even ones much smaller than the one we have just reviewed, especially when they are the result of mis-applied technology, could be ameliorated, if not avoided if there was an advisory committee along the lines of the one that was appointed for the successful Papaya Fruit Fly eradication campaign in northern Queensland. This would involve the meeting of a review panel at least once per year to audit the conduct and results of all Qfly SIT campaigns. To succeed, it would require full disclosure of information and at least the participation of both scientific and management representatives from NSW, SA, WA and Victoria.

Maintaining area freedom in the Riverina

Continuing effort must be made to maintain area freedom in Riverina because the pandemic of 2000 shows how fast an unregulated population can increase in this area and would threaten the integrity of the other areas of the FFEZ.

Acknowledgments

We would like to thank our collaborative investigators and their support staff. This report could not have been done without access to the databases and invaluable help sorting out the discrepancies. We also thank Ms Julie Edgerton for technical assistance with the dispersal trials. Any conclusions, opinions and any mistakes are our own.

A Meats & A.D. Clift.

References

Anon. (1997). *Code of Practice for Management of Queensland Fruit Fly.* Standing Committee on Agriculture and Resource Management, Department of Primary Industries, Canberra.

Bateman MA (1968) Determinants of abundance in a population of the Queensland fruit fly. *Symposium of the Royal Entomological Society of London* **4**, 119-131.

Beswick A, Moodie K, Bange M, Mullen C. (2000) The SILO patched point data set – case studies in its use. Climate Science: Farming Land and Water. 13th Australia New Zealand Climate Forum, Hobart April 10-12, p 9.

Clift, A.D., Meats, A. and Gleeson, P.J. (1998) A dispersal model for papaya fruit fly. *Proc. 6th Australasian Applied Ent Res Conference*, Brisbane.

Cunningham, R.T., Routhier, W., Harris, E.J., Cunningham, G., Johnson, L., Edwards, W., Rosander, R, and Vettel, W.G. (1980) Eradication of Medfly by Sterile Male release. *Citrograph* **65**: 63-69.

Dominiak B C, McLeod LJ, Landon R, Nicol, H. I. (2000) Development of a low-cost pupal release strategy for Sterile Insect technique (SIT) with Queensland fruit fly and assessment of climatic constraints for SIT in rural New South Wales. *Australian Journal of Experimental Agriculture* **40**, 1021-1032.

Donnelly JR, Moore AD, Freer M (1997) GRAZPLAN: Decision support systems for Australian Grazing Enterprises – I. Overview of the GRAZPLAN project, and a description of the MetAccess and LambAlive DSS. Agricultural Systems. **54**, 57-76.

Fletcher BS (1974) 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. *The Australian Journal of Zoology* **22**, 353-363.

Howell, J.F., Cheikh, M., Salah, H.B., Crnjanski, P., Pils, W. and Harris, E.J. (1975) Suppression of the Mediterranean Fruit Fly in Tunisia with released sterile insects. *Journal of Economic Entomology*, **68**: 244-246.

Maelzer DA (1990 a) Fruit fly outbreaks in Adelaide, S.A., from 1948-49 to 1986-87. I. Demarcation, frequency and temporal patterns of outbreaks. *Australian Journal of Zoology* **38**, 439-452.

Maelzer DA (1990 b) Fruit fly outbreaks in Adelaide, S.A., from 1948-49 to 1985-86. II. The phenology of both pestilent species. *Australian Journal of Zoology* **38**, 555-572.

Meats A (1981) The bioclimatic potential of population of the Queensland fruit fly (*Dacus tryoni*) in Australia. *Proceedings of the Ecological Society of Australia* **11**, 151-161.

Meats A (1984) Thermal constraints to successful development of the Queensland fruit fly in regimes of constant and fluctuating temperature. *Entomologia Experimentalis et Applicata* 36, 55-59.

Meats, A. (1989) Bioclimatic potential. In: *Fruit Flies: Biology, natural enemies and control.* (eds. A.S. Robinson and G.H.S. Hooper) Elsevier World Crop Pest Series, Rotterdam. Vol 3B 241-252.

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

Meats A (1998a) Predicting or interpreting trap catches resulting 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 & Applied Entomology* **28**, 47-55.

Meats A (1998c) A quality assurance measure for field survival rates of released sterile flies based on recapture rates. *General and Applied Entomology* **28**, 39 –46.

Meats, A., Clift A. D. and Robson, M. K.. (2001) *Technical Assessment of Fruit Fly Outbreaks and Suspension Zones for Medfly and Qfly in Australia.* Final Contract Research Report for South Australian Department of Primary Industries, Department of Primary Industry and Energy, Agriculture Western Australia, NSW Agriculture, Department of Natural Resources & Environment Victoria. FFRC, University of Sydney, Australia 56 pp.

Meats, A., Clift A. D. and Robson, M. K. (2003a) Incipient founder populations of Mediterranean and Queensland fruit flies in Australia: the relation of trap catch to infestation radius and models for quarantine radius. *Australian Journal of Experimental Agriculture* **43**, 407-417.

Meats, A., Duthie, R,. Clift, A. D., & Dominiak, B. C. (2003b) Trials with variants of the Sterile Insect Technique (SIT) for suppression of populations of the Queensland fruit fly in small towns neighbouring a quarantine (exclusion) zone. *Australian Journal of Experimental Agriculture* **43**, 389-395.

Meats, A. & Fitt, G.P. (1987) Survival of repeated frosts by the Queensland fruit fly, *Dacus tryoni*: experiments in laboratory simulated climates with either step or ramp fluctuations of temperature. *Entomologia Experimentalis et Applicata*, **45**: 9-16.

Meats, A. & Khoo K.C. (1976) The dynamic of ovarian maturation and oocyte resorption in the Queensland fruit fly (*Dacus tryoni*) in constant and rhythmic temperature regimes. *Physiological Ent.*, **1**:213-221.

Meats, A., Maheswaran, P., Frommer, M., and Sved, J. (2002)_Towards a male-only release system for SIT with the Queensland fruit fly, *Bactrocera tryoni,* using a genetic sexing strain with a temperature-sensitive lethal mutation.. *Genetica* 116: 97-106.

Mullen C, Beswick A. (2000) Meteorological data for climate science from SILO. Climate Science: Farming Land and Water. 13th Australia New Zealand Climate Forum, Hobart April 10-12, p 35.

Nadel, D. J., Monro, J., Peleg, B.A., and Figdor, H.C.F. (1967) A method of releasing sterile Mediterranean Fruit Fly adults from aircraft. *Journal of Economic Entomology*, **60**: 899-902.

Sproule, A.N., Broughton, S. and Monzu, N. (eds.) (1992) Queensland fruit fly eradication campaign. Report. Department of Agriculture, Western Australia, Perth, 216 pp.

Yonow T, Sutherst RW (1998) The geographical distribution of the Queensland fruit fly, *Bactrocera (Dacus) tryoni*, in relation to climate. *Australian Journal of Agricultural Research* **49**, 935-95

APPENDIX A

(1) A series of pictorial sequences showing the spatial relations and growth of infestations 1996-2000.

(2) Maps of accumulated catches by location at Griffith and Narrandera.

(3) Figures of weekly catches of wild flies in specified areas on a catch per trap basis.

Figure A1

Riverina Traps Jul-Dec 1996

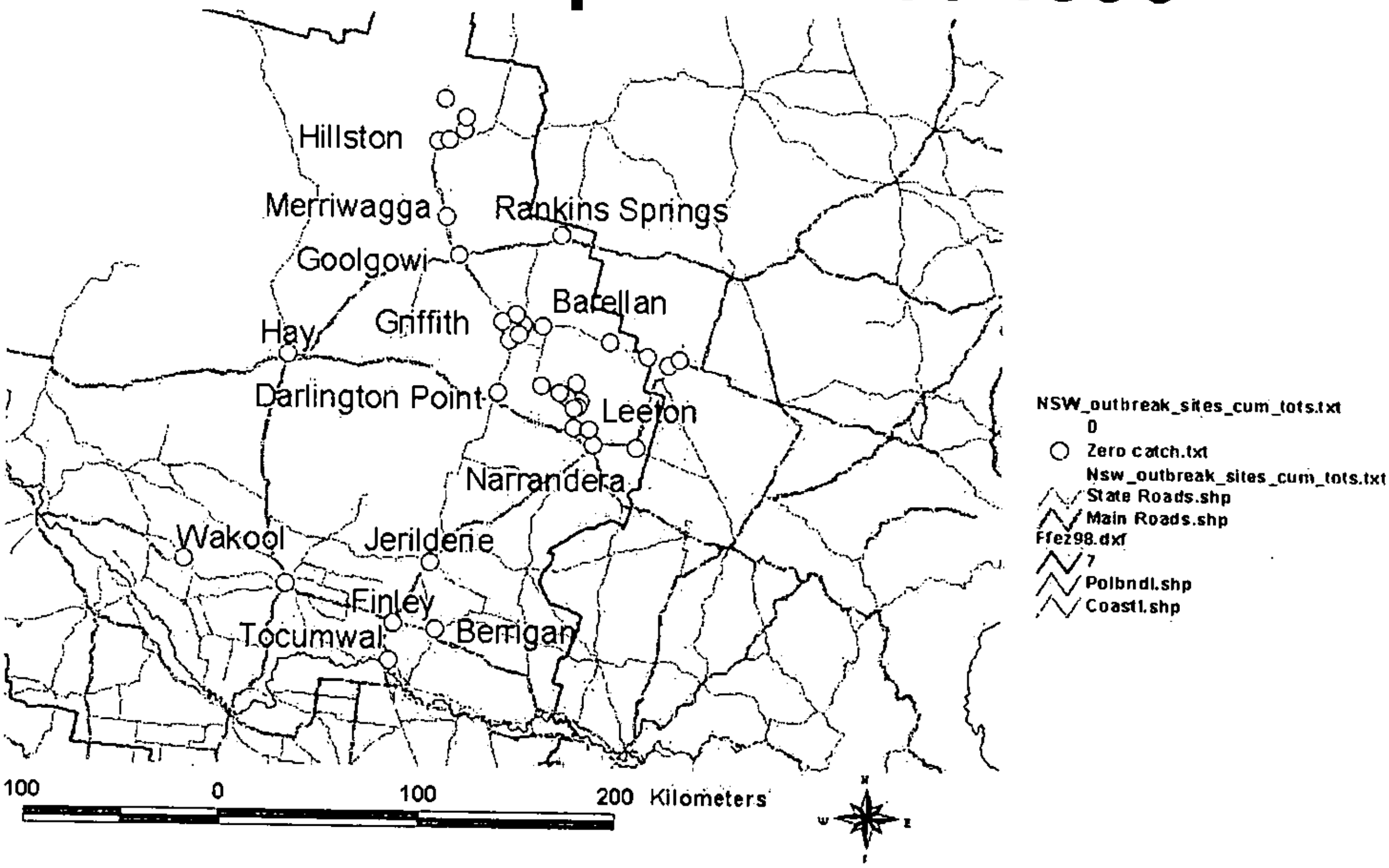


Figure A2

Riverina Traps Jan-Jun 1997

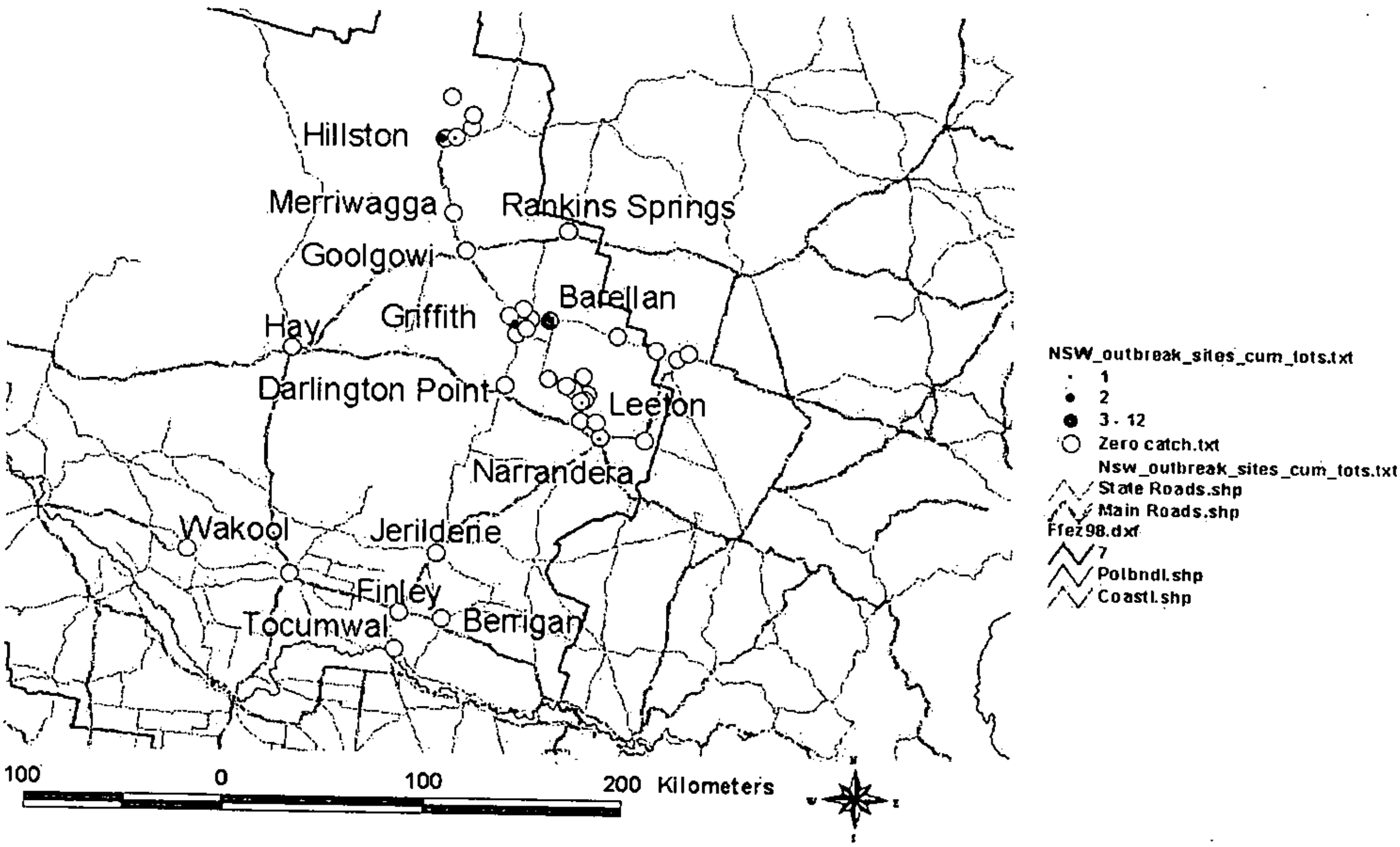
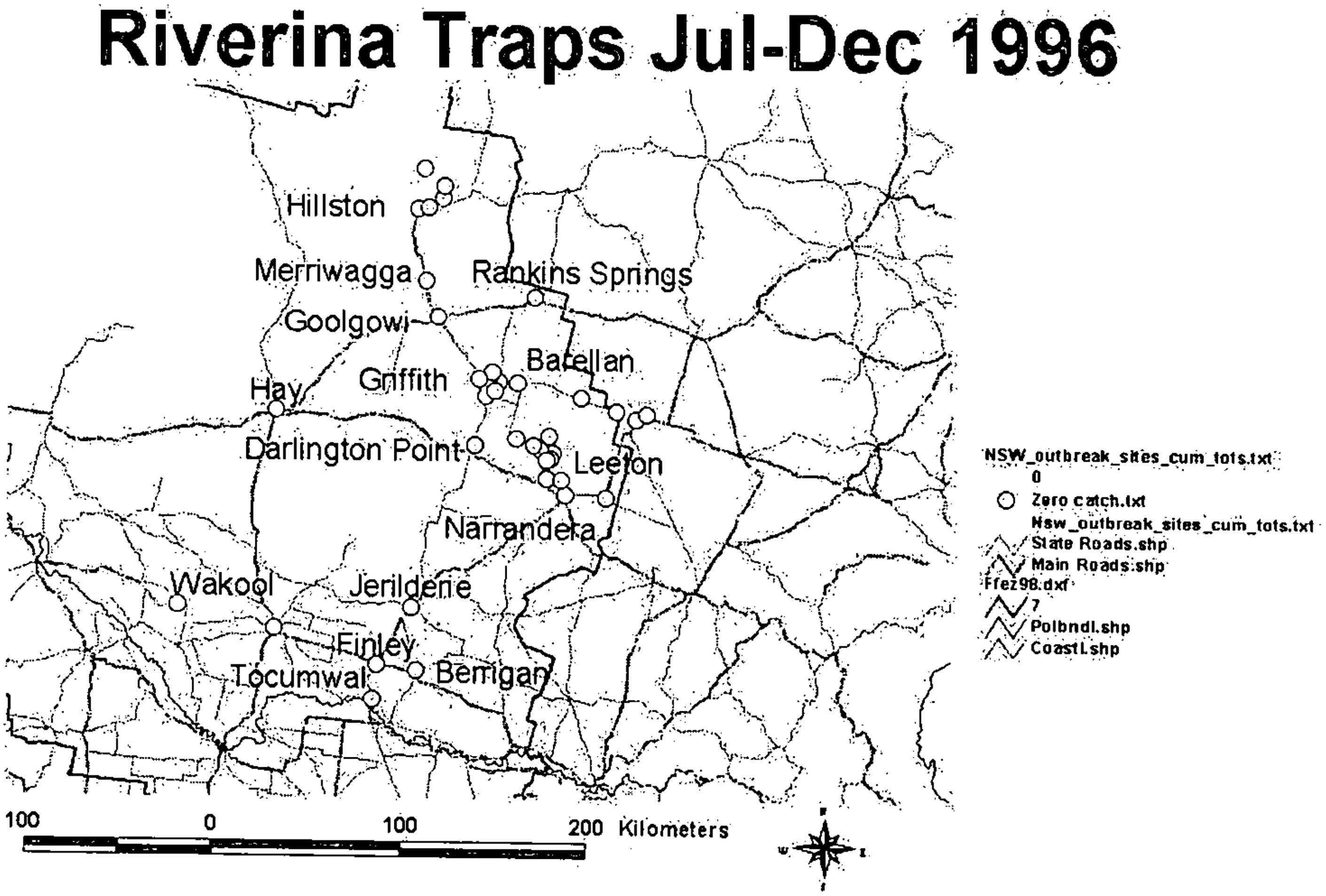


Figure A1



Riverina Traps Jul-Dec 1996
Hillston
Merriwagga
Rankins Springs
Goolgowi
Barellan
Hay
Griffith
Darlington Point
Leeton
Narrandera
Wakool
Jerilderie
Finley
Tocumwal
Berrigan
100
0
100
200 Kilometers
NSW_outbreak_sites_cum_tots.txt
0
Zero catch.txt
Nsw_outbreak_sites_cum_tots.txt
State Roads.shp
Main Roads.shp
Ffez98.dxf
7
Polbndl.shp
Coastl.shp

Figure A2

Riverina Traps Jan-Jun 1997

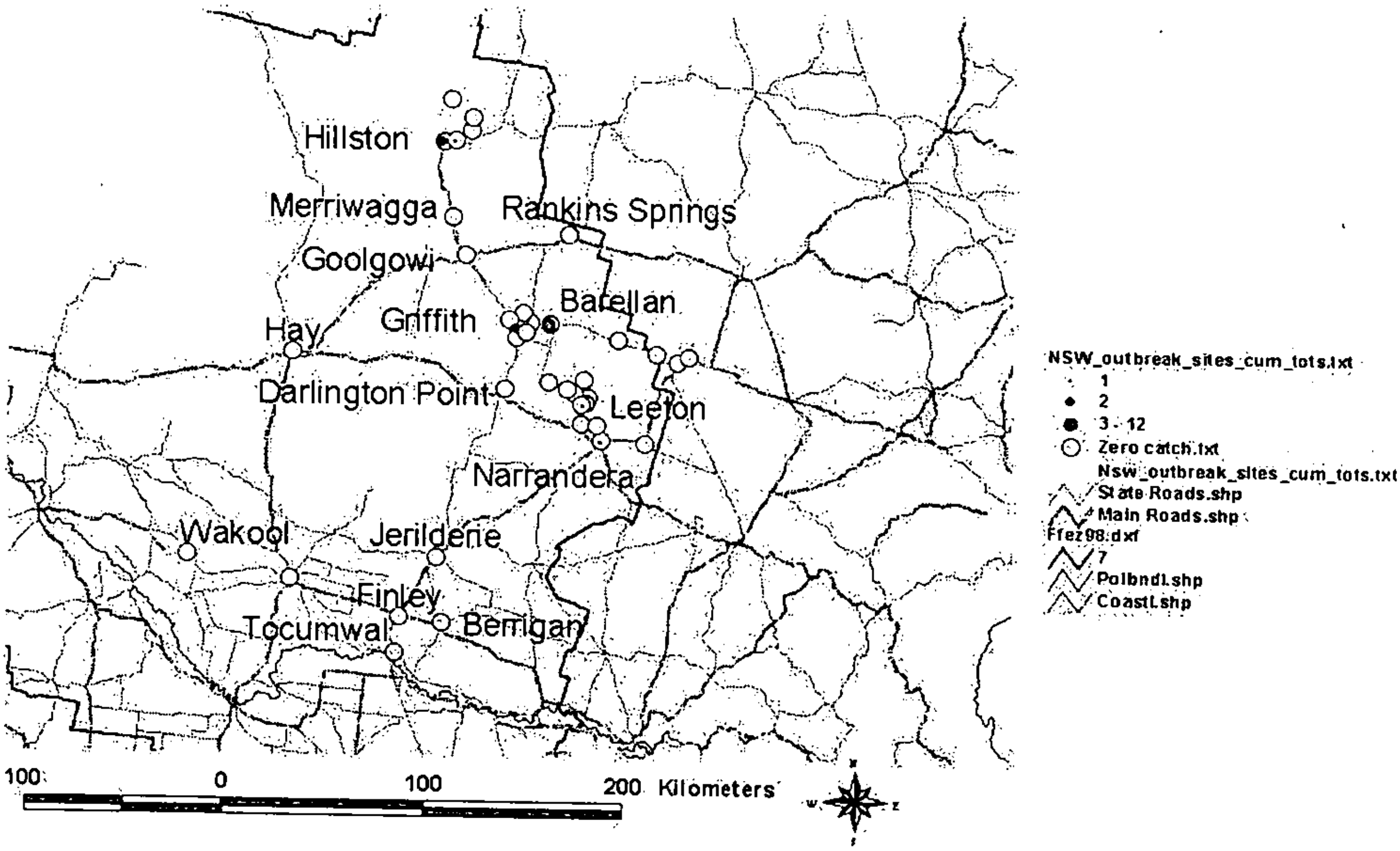


Figure A3

Riverina Traps Jul-Dec 1997

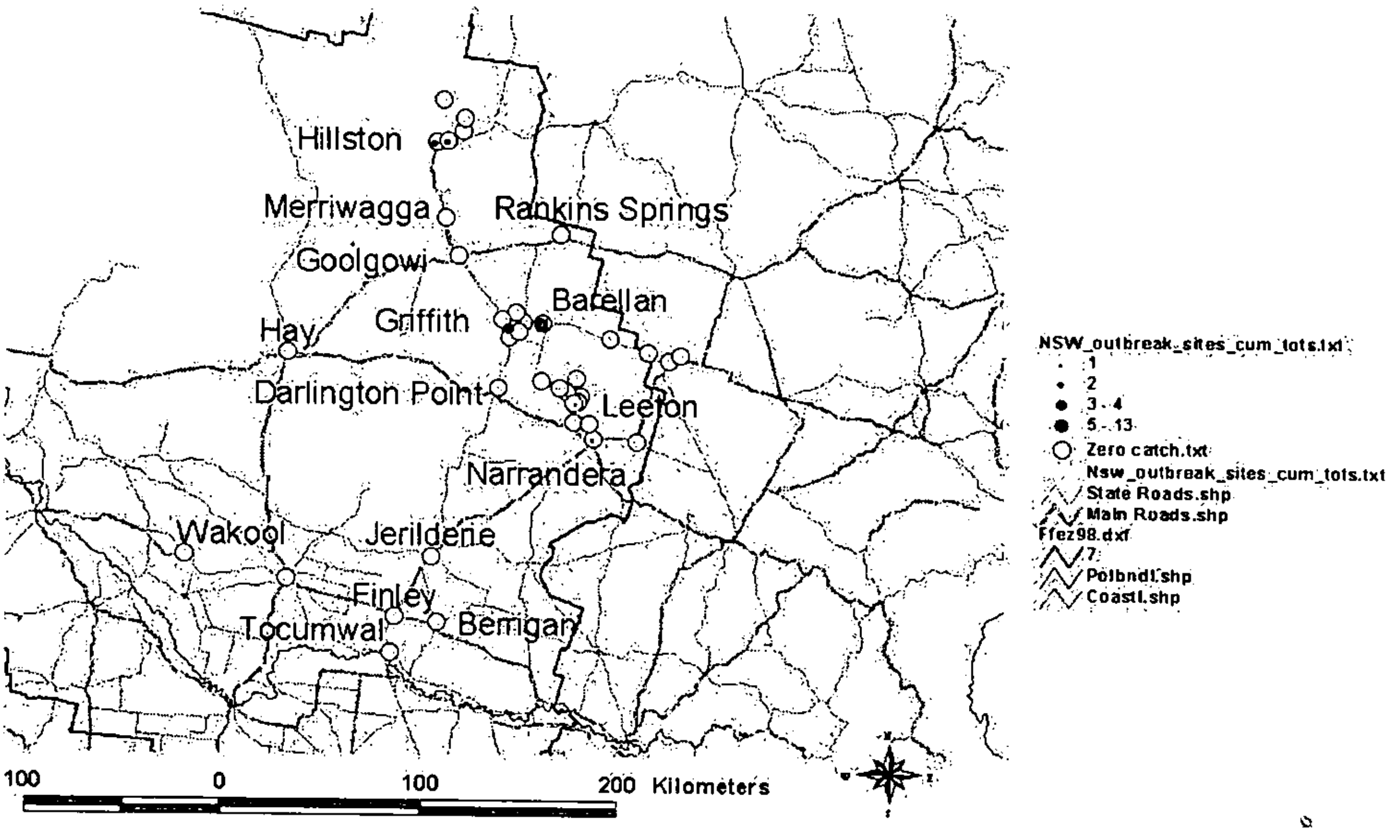
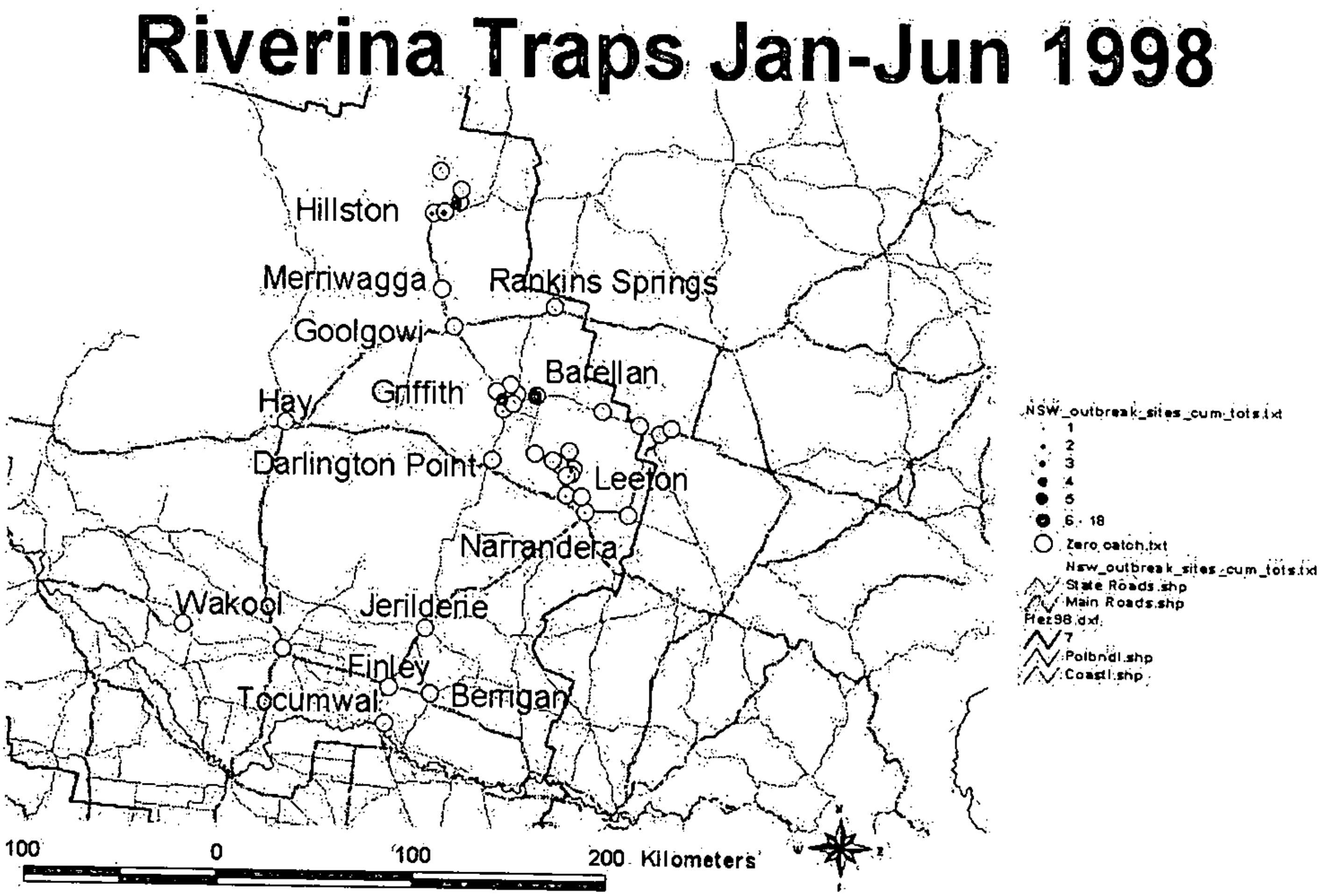


Figure A4



Riverina Traps Jan-Jun 1998
Hillston
Merriwagga
Rankins Springs
Goolgowi
Barellan
Hay
Griffith
Darlington Point
Leeton
Narrandera
Wakool
Jerilderie
Finley
Tocumwal
Berrigan
100
0
100
200 Kilometers
NSW_outbreak_sites_cum_tots.txt
1
2
3
4
5
6 - 18
Zero catch.txt
Nsw_outbreak_sites_cum_tots.txt
State Roads.shp
Main Roads.shp
7
Polbndl.shp
Coastl.shp

Figure A5

Riverina Traps Jul_Dec 1998

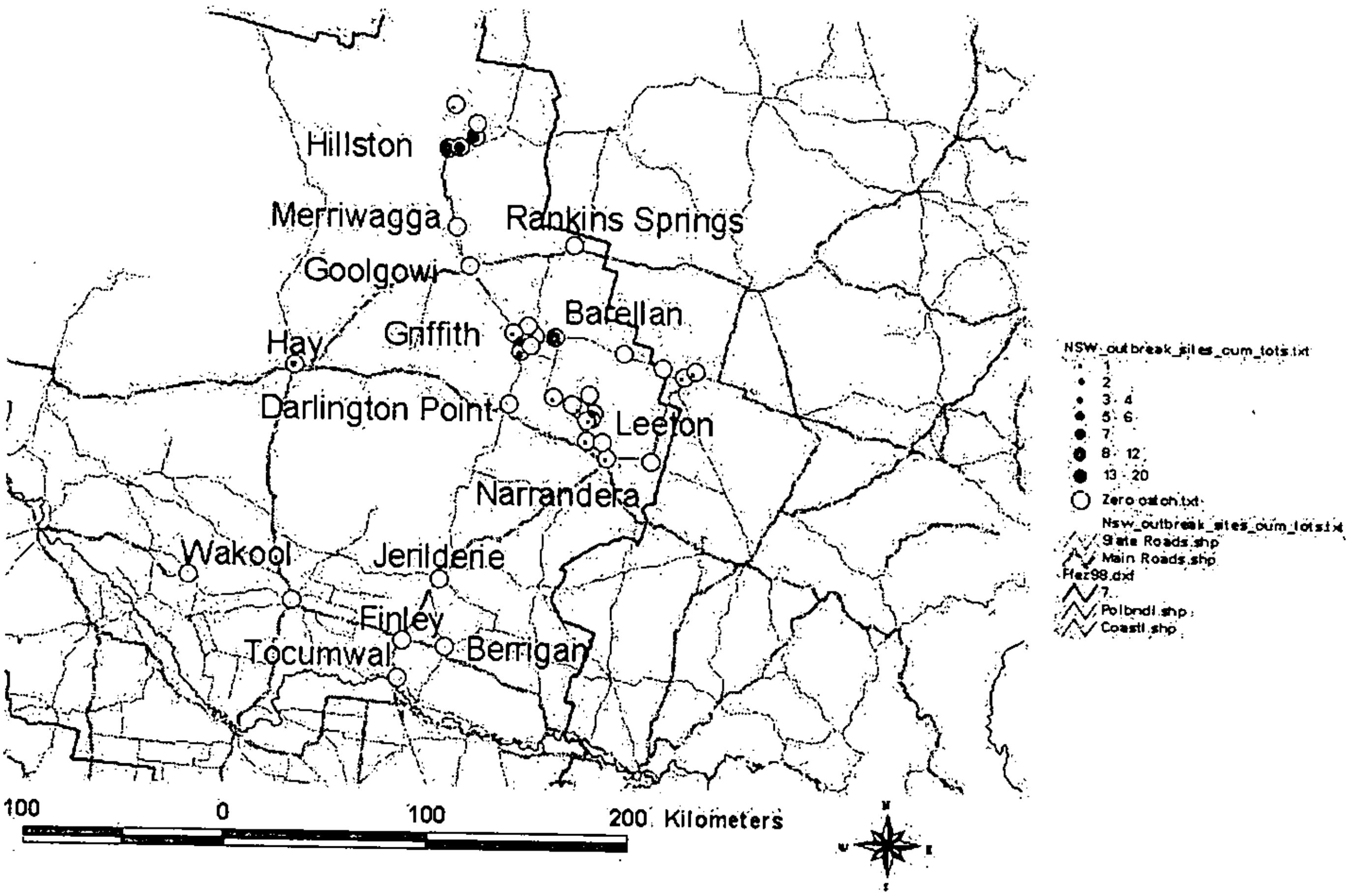


Figure A6

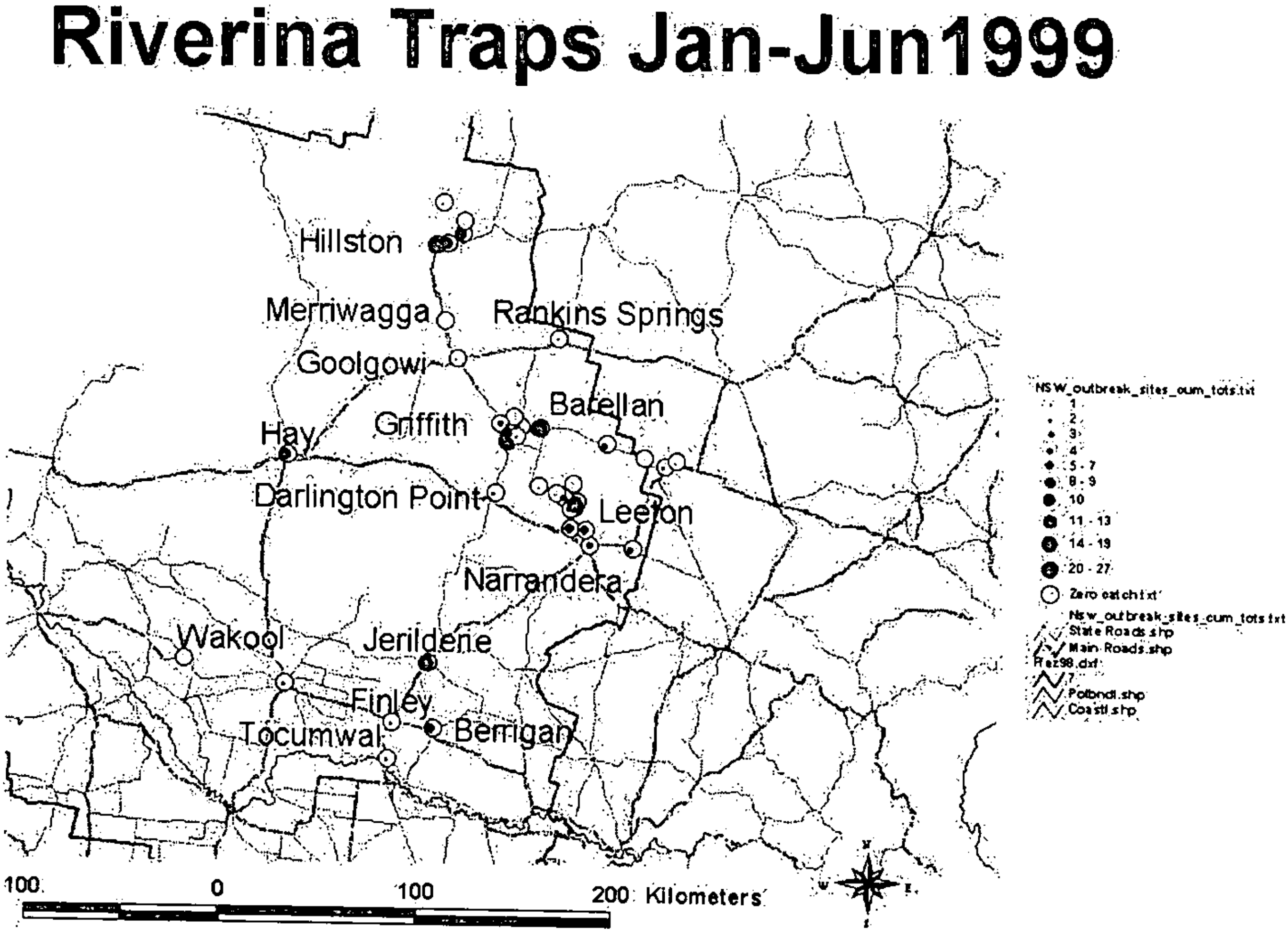

Riverina Traps Jan-Jun1999
Hillston
Merriwagga
Rankins Springs
Goolgowi
Barellan
Hay
Griffith
Darlington Point
Leeton
Narrandera
Wakool
Jerilderie
Finley
Tocumwal
Berrigan
100
0
100
200 Kilometers
NSW_outbreak_sites_cum_tots.txt
1
2
3
4
5 - 7
8 - 9
10
11 - 13
14 - 19
20 - 27
Zero catch.txt
Nsw_outbreak_sites_cum_tots.txt
State Roads.shp
Main Roads.shp
Rez98.dxf
7
Polbndl.shp
Coastl.shp

Figure A7

Riverina Traps Jul-Dec 1999

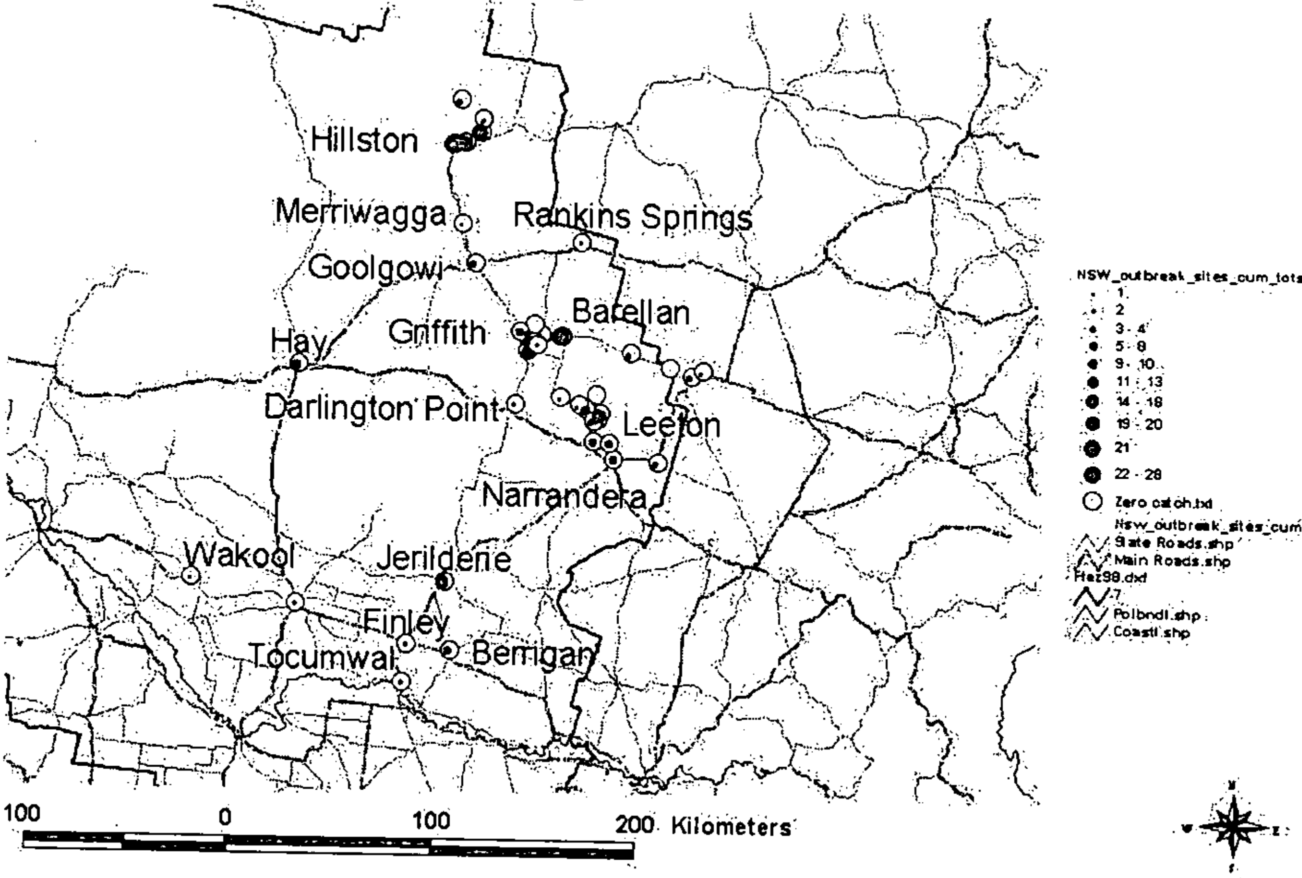


Figure A8

Riverina Traps Jan-Jun 2000

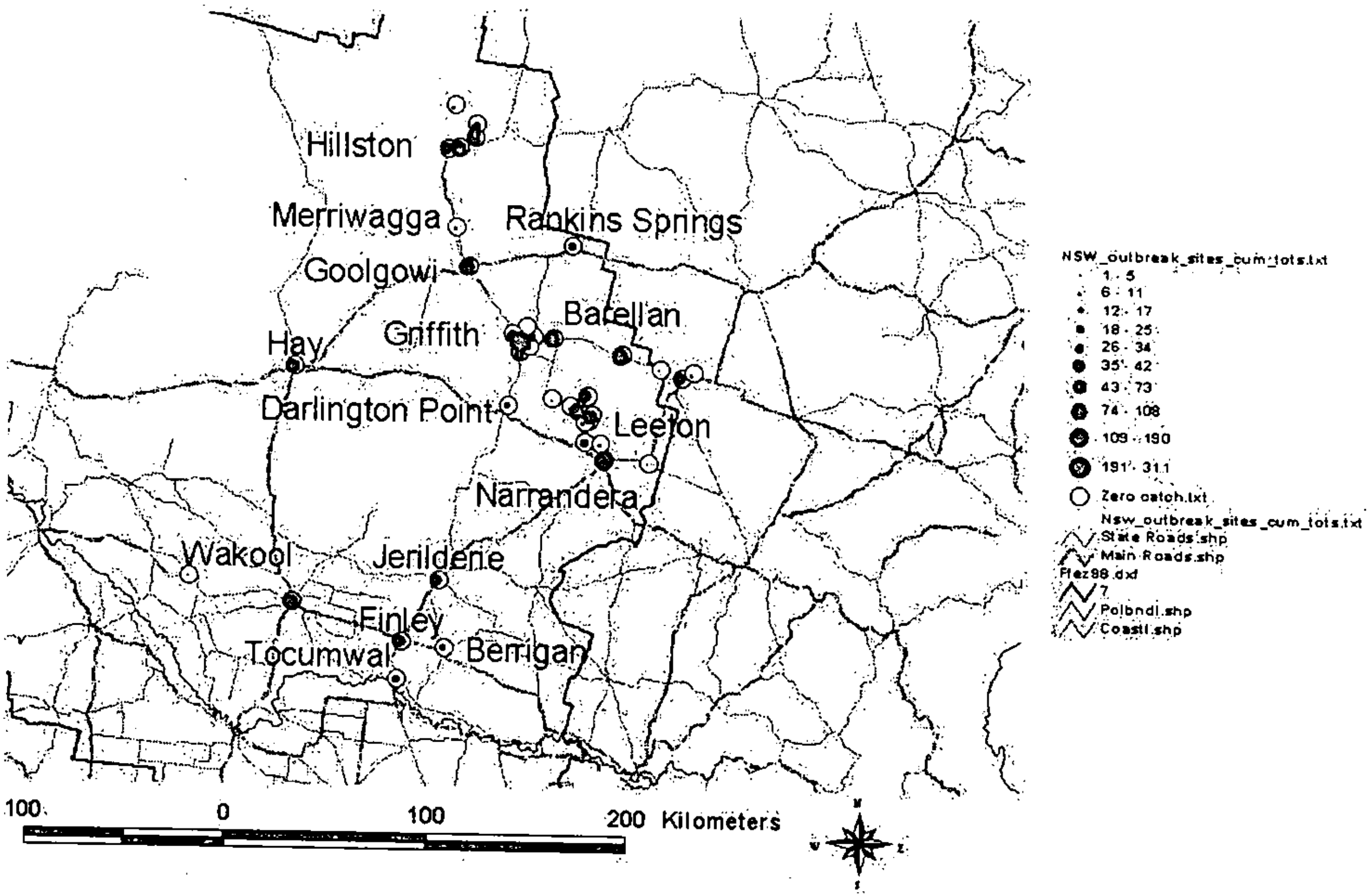


Figure A9

Accumulated trap catches of wild flies at Griffith

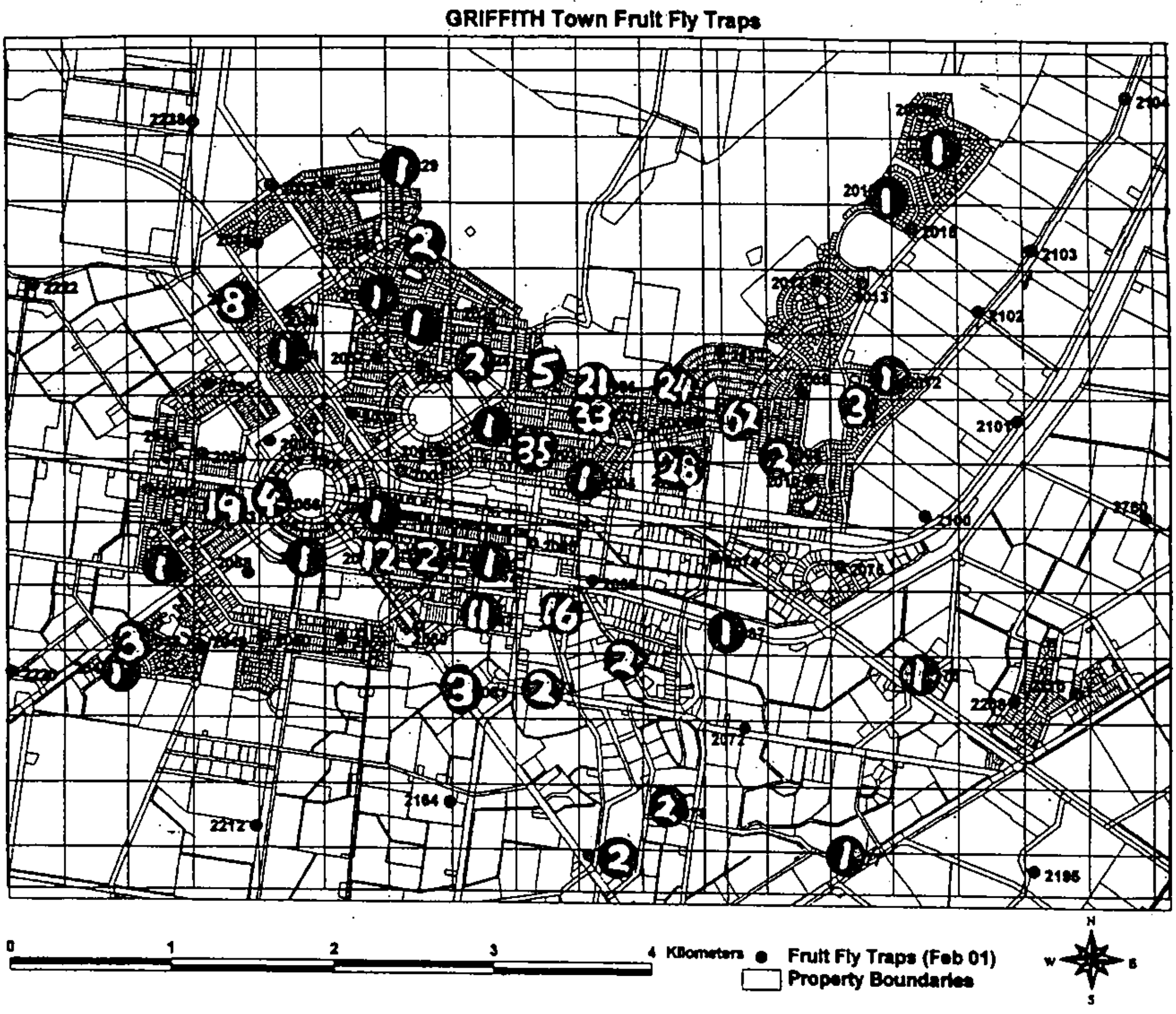


Figure A10

Accumulated trap catches of wild flies at Narrandera

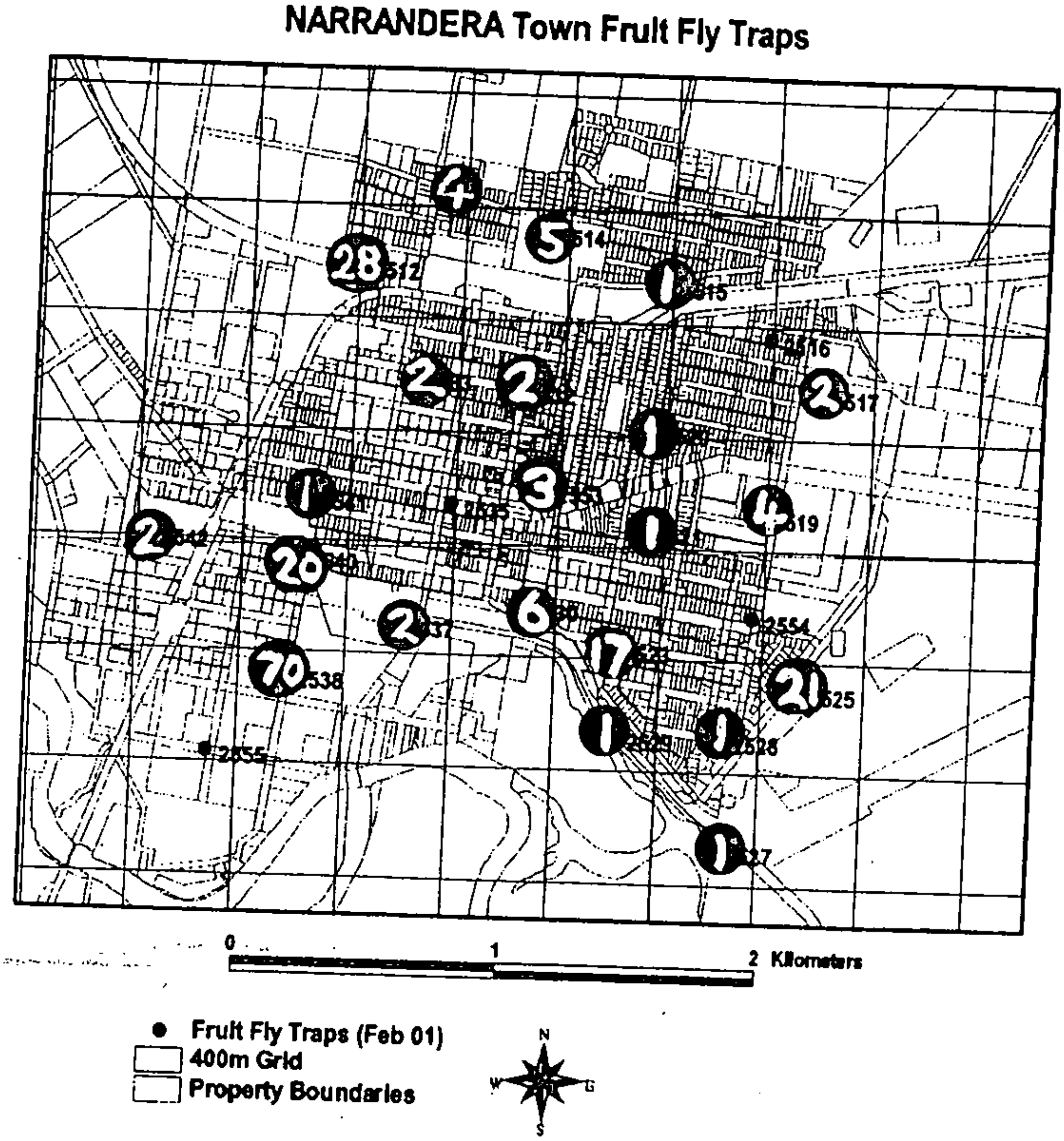
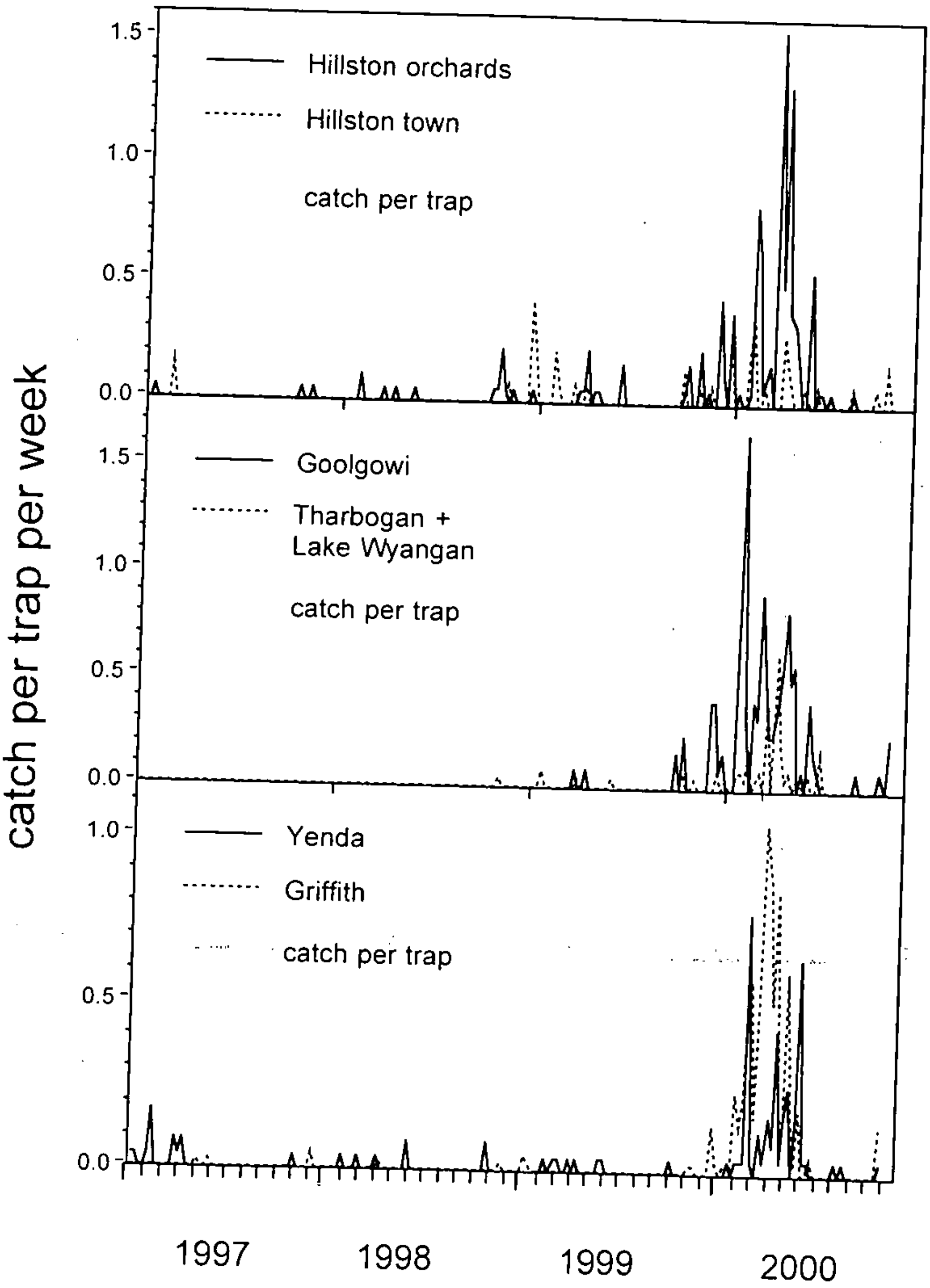


Figure A 11



Hillston orchards
Hillston town
catch per trap
Goolgowi
Tharbogan +
Lake Wyangan
catch per trap
Yenda
Griffith
catch per trap
catch per trap per week
1.5
1.0
0.5
0.0
1.5
1.0
0.5
0.0
1.0
0.5
0.0
1997
1998
1999
2000

Figure A12

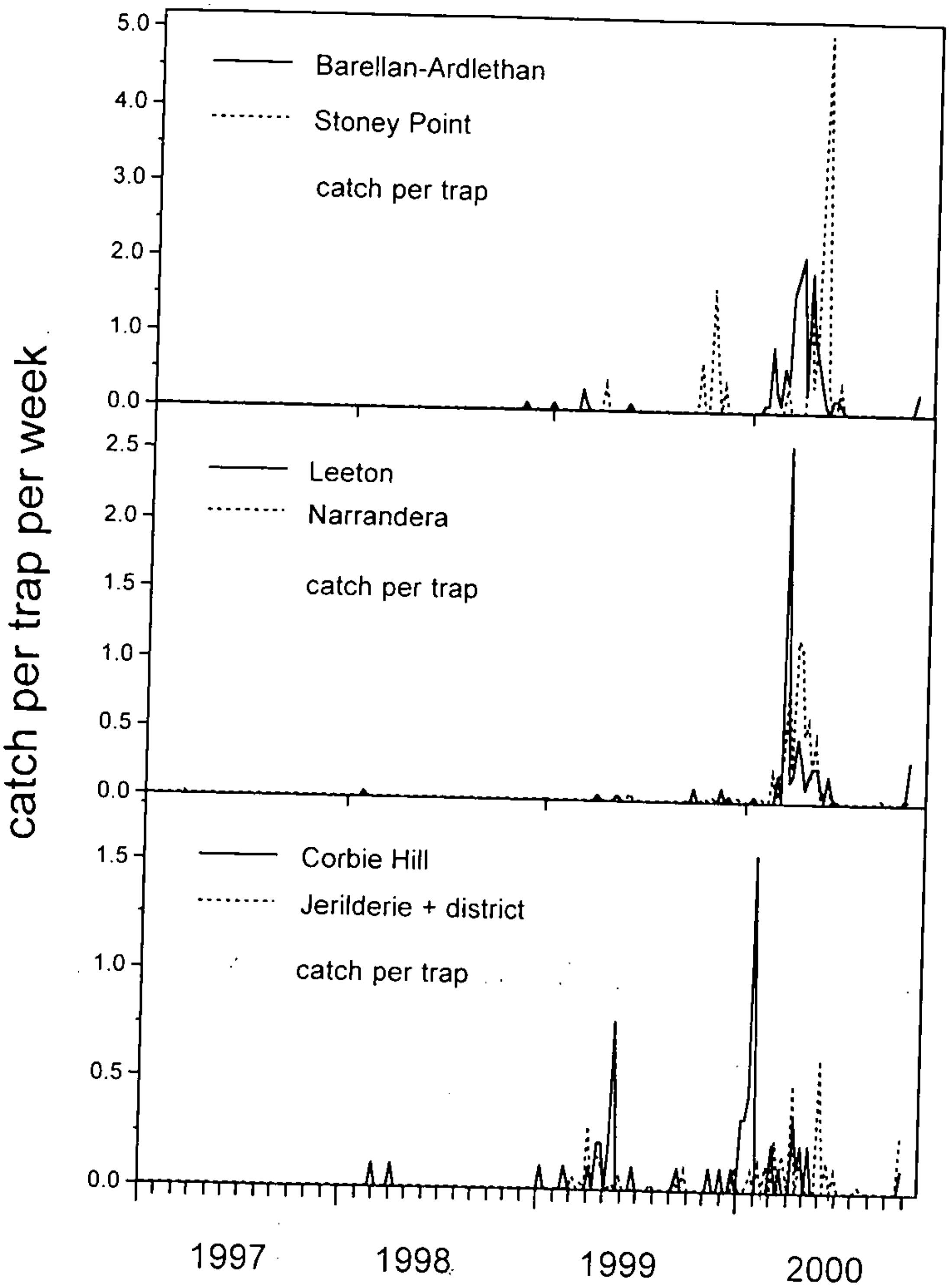
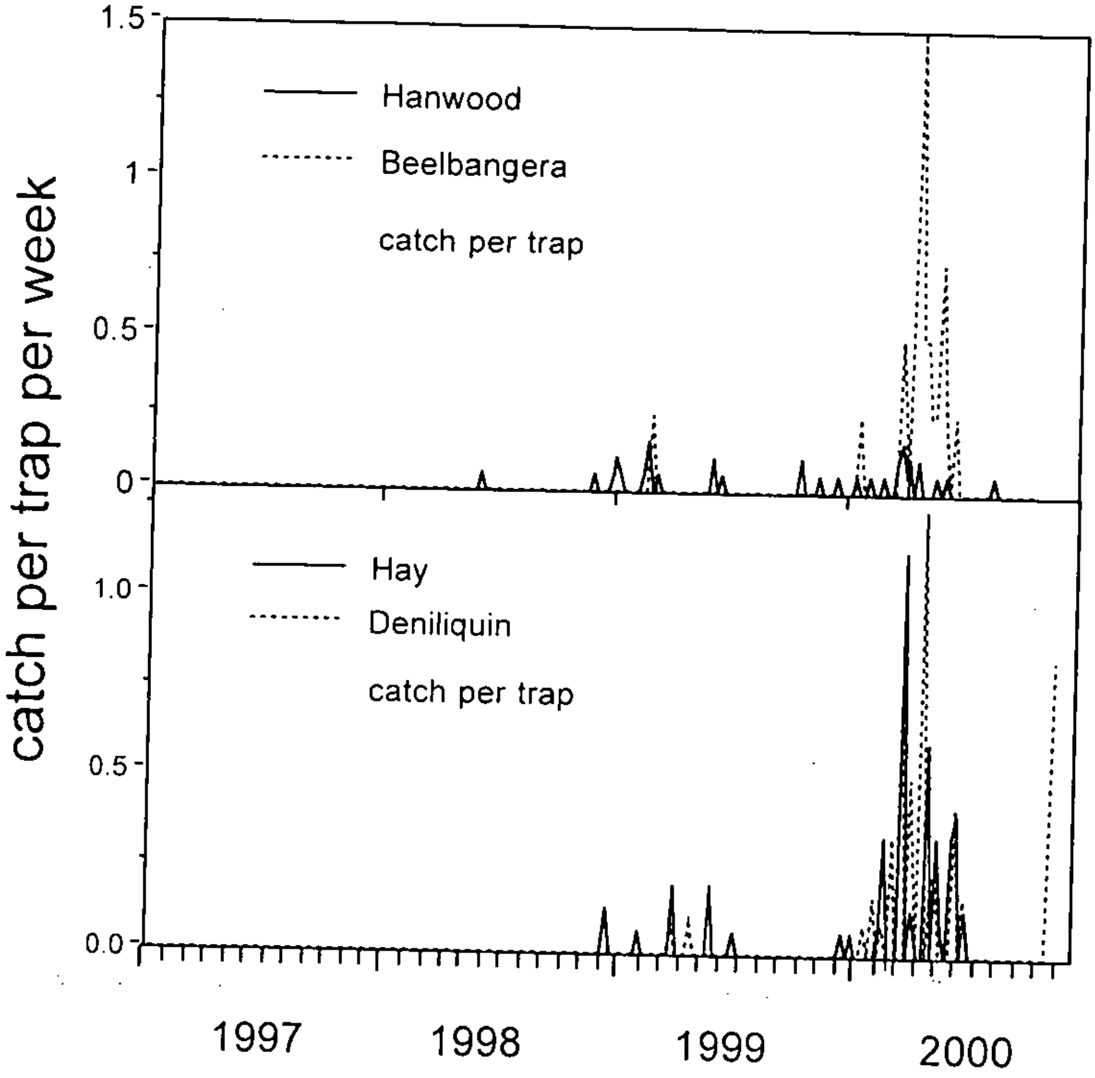

5.0
4.0
3.0
2.0
1.0
0.0
Barellan-Ardlethan
Stoney Point
catch per trap
2.5
2.0
1.5
1.0
0.5
0.0
Leeton
Narrandera
catch per trap
1.5
1.0
0.5
0.0
Corbie Hill
Jerilderie + district
catch per trap
catch per trap per week
1997
1998
1999
2000

Figure A13



1.5
1
0.5
0
Hanwood
Beelbangera
catch per trap
1.0
0.5
0.0
Hay
Deniliquin
catch per trap
catch per trap per week
1997
1998
1999
2000

APPENDIX B

Wild (W) and sterile (S) catches by traps at selected locations. Traps identified by four digit code.

Note: trapping after mid-late April is unlikely due to low temperatures.

Table B 1

Corbie hill (1 Km spacing)

DATE	2475		2476		2477		2478		2480	
	W	S	W	S	W	S	W	S	W	S
27/09/1999										
4/10/1999										
11/10/1999										
18/10/1999										
25/10/1999										
1/11/1999										
8/11/1999										
15/11/1999										
22/11/1999			1							1
29/11/1999	1					1		1		1
6/12/1999			1			7				
13/12/1999						5		4		8
20/12/1999		2		3			3	2		
27/12/1999								1		1
3/01/2000							4	1		
10/01/2000			2				12	8		24
17/01/2000				5		1		25		1
24/01/2000										
31/01/2000										
7/02/2000										
14/02/2000			1				1	4		
21/02/2000										
28/02/2000							1			
6/03/2000										
13/03/2000										
20/03/2000					1		2			
27/03/2000							1			
3/04/2000							2			
10/04/2000										
17/04/2000							1			
24/04/2000										
1/05/2000										
8/05/2000										
15/05/2000										
22/05/2000										
29/05/2000										
5/06/2000										
12/06/2000										
19/06/2000										

Table B 2

Corbie hill (1 km spacing)

DATE	2481		2482		2483		2484		2485	
	W	S	W	S	W	S	W	S	W	S
27/09/1999				2112						
4/10/1999										
11/10/1999										
18/10/1999										
25/10/1999				29						
1/11/1999										
8/11/1999				88						
15/11/1999			1							
22/11/1999				9						
29/11/1999		1		2		152		11		
6/12/1999		4				163		12		11
13/12/1999		9				35		1		
20/12/1999		1		24		16				
27/12/1999		2		7693		11				
3/01/2000				4		5				
10/01/2000										
17/01/2000				136		5				
24/01/2000				25						
31/01/2000										
7/02/2000										
14/02/2000										
21/02/2000										
28/02/2000										
6/03/2000										
13/03/2000										
20/03/2000										
27/03/2000										
3/04/2000										
10/04/2000										
17/04/2000					1					
24/04/2000										
1/05/2000										
8/05/2000										
15/05/2000										
22/05/2000										
29/05/2000										
5/06/2000										
12/06/2000										
19/06/2000										

Table B 3

(400 m spacing)

DATE	Leeton 2373 W	Leeton 2373 S	Leeton 2374 W	Leeton 2374 S	Leeton 2376 W	Leeton 2376 S	Leeton 2377 W	Leeton 2377 S	Leeton 2380 W	Leeton 2380 S	Leeton 2382 W	Leeton 2382 S	Leeton 2384 W	Leeton 2384 S	Leeton 2385 W	Leeton 2385 S
27/09/1999																
4/10/1999																
11/10/1999																
18/10/1999																
25/10/1999		5		1		331										
1/11/1999	2	207		3		420		2						5		1
8/11/1999		110		4		18		2						12		1
15/11/1999		151		5		82		19		1				15		13
22/11/1999		1143		7		248				4		1		13		15
29/11/1999		593		12		283		11		28				25		41
6/12/1999		518				319						3		14		108
13/12/1999		128				121						4		15		5
20/12/1999		1652				119		43		2		4		28		49
27/12/1999		4		4		549		65						76		273
3/01/2000																
10/01/2000																
17/01/2000																
24/01/2000																
31/01/2000																
7/2/2000																
14/02/2000																
21/02/2000																
28/02/2000																
6/03/2000			2													
13/03/2000	1		1													
20/03/2000											1					
27/03/2000			1													
3/04/2000									1							
10/04/2000			1										1			
17/04/2000																
24/04/2000																
1/05/2000																
8/05/2000																
15/05/2000																
22/05/2000																
29/05/2000																
5/06/2000																
12/06/2000																
19/06/2000																

Table B 4

(400 m spacing)

DATE	Leeton 2386 W	Leeton 2386 S	Leeton 2387 W	Leeton 2387 S	Leeton 2388 W	Leeton 2388 S	Leeton 2389 W	Leeton 2389 S	Leeton 2392 W	Leeton 2392 S	Leeton 2393 W	Leeton 2393 S	Leeton 2394 W	Leeton 2394 S	Leeton 2395 W	Leeton 2395 S
27/09/1999																
4/10/1999																
11/10/1999																
18/10/1999																
25/10/1999																
1/11/1999						48				2						
8/11/1999		1				125				2						
15/11/1999		3		22		110		3				11	1	4		4
22/11/1999		1		235		138		6		1		23		32		1
29/11/1999		13		79		25		5		8		26		38		5
6/12/1999		22		29				3		10		99		48		50
13/12/1999		2		7				3				62		5		15
20/12/1999				11						5		91		38		
27/12/1999				95		18		15		33				26		3
3/01/2000																
10/01/2000																
17/01/2000																
24/01/2000																
31/01/2000																
7/2/2000																
14/02/2000																
21/02/2000																
28/02/2000																
6/03/2000																
13/03/2000	1		1												1	
20/03/2000											1					
27/03/2000			1													
3/04/2000																
10/04/2000					1											
17/04/2000																
24/04/2000																
1/05/2000							1									
8/05/2000	1				1											
15/05/2000																
22/05/2000																
29/05/2000																
5/06/2000																
12/06/2000																
19/06/2000																

Table B 5.

*1 km spacing

DATE	Leeton 2398		Leeton 2400		Leeton* 2454		Leeton* 2455		Leeton* 2456		Leeton* 2457		Leeton* 2458	
	W	S	W	S	W	S	W	S	W	S	W	S	W	S
27/09/1999														
4/10/1999														
11/10/1999														
18/10/1999														
25/10/1999														
1/11/1999		2		12										
8/11/1999		2		18										
15/11/1999		2		80										
22/11/1999		1		47										1
29/11/1999		4		58						2				
6/12/1999		1		89										
13/12/1999		2		9		4	3	3		16				
20/12/1999				29		15		6		7				1
27/12/1999				106										
3/01/2000														
10/01/2000														
17/01/2000														
24/01/2000												1		
31/01/2000														
7/2/2000														
14/02/2000														
21/02/2000														
28/02/2000														
6/03/2000														
13/03/2000					1				1				1	
20/03/2000							1				2		1	
27/03/2000														
3/04/2000											1		1	
10/04/2000							2							
17/04/2000					3		2							
24/04/2000							1							
1/05/2000														
8/05/2000									1				1	
15/05/2000							1							
22/05/2000														
29/05/2000														
5/06/2000														
12/06/2000														
19/06/2000														

Table B 6

Stoney point and Wamoon (with 1 km spacing)

DATE	Stoney Point 2449 W	Stoney Point 2450 W	Stoney Point 2451 W	Stoney Point 2451 S	Stny Pt 2452 W	Wamoon 2422 W	Wamoon 2422 S	Wamoon 2433 W	Wamoon 2433 S	Wamoon 2425 W	Wamoon 2425 S	Wamoon 2426 W	Wamoon 2426 S
27/09/1999				10									
4/10/1999			5	1984									
11/10/1999			2	6349									
18/10/1999				15751									
25/10/1999			1	7			1						
1/11/1999				11									
8/11/1999				1									
15/11/1999				3									
22/11/1999													
29/11/1999													
6/12/1999													
13/12/1999													
20/12/1999													
27/12/1999					1								
3/01/2000													
10/01/2000									1		1		
17/01/2000							4		1				
24/01/2000													1
31/01/2000													
7/2/2000					4							2	
14/02/2000			1	1									
21/02/2000					49								
28/02/2000					3								
6/03/2000					2								
13/03/2000					1								
20/03/2000		1	4										
27/03/2000			1			1				1		2	
3/04/2000	2		1		1			1		1			
10/04/2000	8		2			1				1		1	
17/04/2000	14		1			1				1		1	
24/04/2000			1		1			1					
1/05/2000													
8/05/2000								2				1	
15/05/2000			1										
22/05/2000													
29/05/2000													
5/06/2000													
12/06/2000													
19/06/2000													

Table B 8

Yanco (1 km spacing)

DATE	2466		2467		3493		2494		2495		2496	
	W	S	W	S	W	S	W	S	W	S	W	S
27/09/1999												
4/10/1999												
11/10/1999												
18/10/1999												
25/10/1999		55										
1/11/1999		62								4		2
8/11/1999										2		1
15/11/1999		61										
22/11/1999		125										
29/11/1999		775		13		1				5		1
6/12/1999										15		
13/12/1999										31		
20/12/1999		145										
27/12/1999		33		3						43		1
3/01/2000										66		1
10/01/2000												
17/01/2000		15								67		
24/01/2000		2								171		
31/01/2000								4				
7/2/02000								4				
14/02/2000												
21/02/2000								2				
28/02/2000										5		
6/03/2000												
13/03/2000												
20/03/2000												
27/03/2000									1			
3/04/2000												
10/04/2000												
17/04/2000												
24/04/2000												
1/05/2000												
8/05/2000												
15/05/2000												
22/05/2000												
29/05/2000												
5/06/2000												
12/06/2000												
19/06/2000												

Table B 9

(400 m spacing)

DATE	Narrandera 2512		Narrandera 2513		Narrandera 2514		Narrandera 2515		Narrandera 2516		Narrandera 2517		Narrandera 2518		Narrandera 2519	
	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S
27/09/1999																
4/10/1999																
11/10/1999																
18/10/1999																
25/10/1999																
1/11/1999						2										
8/11/1999																
15/11/1999				9		332		2		1				6		1
22/11/1999				1		268								2		
29/11/1999	1	9		15		24		12		4		8		12		9
6/12/1999		4		9				1		4				10		2
13/12/1999		8		11		2		8		12				10		8
20/12/1999		2				2										
27/12/1999		2		10		14		3		9				2		
3/01/2000																2
10/01/2000		1		4		36		1			1	2				1
17/01/2000		13		8		35		5		34		28				11
24/01/2000		2				7				8		1				
31/01/2000	6	1		3		2						2				1
7/2/2000	1	4		1		8		1		1						2
14/02/2000	1	1										1	1		1	
21/02/2000																
28/02/2000	5														1	
6/03/2000		1	1													
13/03/2000	7						1								2	
20/03/2000	5				1											
27/03/2000	1															
3/04/2000			1		1											
10/04/2000											1					
17/04/2000					3											
24/04/2000																
1/05/2000																
8/05/2000			1													
15/05/2000																
22/05/2000			1													
29/05/2000																
5/06/2000																
12/06/2000																
19/06/2000																

(Table B 10

400 m spacing)

DATE	Narrandera 2520		Narrandera 2521		Narrandera 2522		Narrandera 2523		Narrandera 2524		Narrandera 2525		Narrandera 2526		Narrandera 2527	
	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S
27/09/1999																
4/10/1999																
11/10/1999																
18/10/1999																
25/10/1999																
1/11/1999		3		1				3						2		
8/11/1999								11		1		2		1		
15/11/1999		29		15		1		41				6		2		
22/11/1999		51		6				21				54		21		
29/11/1999		24		66				47		4		19		94		24
6/12/1999		40		65				9		8		1		667		23
13/12/1999		54		67		15		21		28				301		57
20/12/1999		11		5		3		2		1		3		16		1
27/12/1999		115		46												
3/01/2000					1			29		39		14		85		14
10/01/2000		14				3		16		3		8		17		7
17/01/2000		705		231		13		612		7		10		76		10
24/01/2000		15		29				18		48		1		4		1
31/01/2000		2		4				12		3				9		2
7/2/2000		3		3				8		4				4		
14/02/2000						3		1								
21/02/2000			1				1			1						
28/02/2000							3									
6/03/2000							1	1								
13/03/2000							7	2					1			
20/03/2000							2	1								
27/03/2000																
3/04/2000							1									
10/04/2000							2				1					
17/04/2000															1	
24/04/2000																
1/05/2000																
8/05/2000	1										1					
15/05/2000																
22/05/2000																
29/05/2000																
5/06/2000																
12/06/2000																
19/06/2000																

Table B 11

(400 m spacing)

DATE	Narrandera 2528 W	Narrandera 2528 S	Narrandera 2529 W	Narrandera 2529 S	Narrandera 2530 W	Narrandera 2530 S	Narrandera 2531 W	Narrandera 2531 S	Narrandera 2532 W	Narrandera 2532 S	Narrandera 2533 W	Narrandera 2533 S	Narrandera 2534 W	Narrandera 2534 S	Narrandera 2535 W	Narrandera 2535 S
27/09/1999																
4/10/1999																
11/10/1999																
18/10/1999																
25/10/1999																
1/11/1999				1				2				99		1		5
8/11/1999				1												
15/11/1999				8		1		5		1		214		6		74
22/11/1999				4		4				1		143		2		32
29/11/1999		2		22		10		49		62		664		31		306
6/12/1999		11		24		11		36		19		729		8		112
13/12/1999				4		4				29		561		32		79
20/12/1999		1						1				85				
27/12/1999								15		34		301		11		46
3/01/2000						5										
10/01/2000				1		2		15		21		20		2		22
17/01/2000		10		2		33		78		72		117		20		
24/01/2000						4		12		7		50		5		
31/01/2000		3				2				8		10		2		
7/2/2000				2		1		3				14		2		5
14/02/2000				1								2				2
21/02/2000			1		1							2	1			
28/02/2000																
6/03/2000							1									
13/03/2000				1	1		1		1							
20/03/2000					1		1									
27/03/2000					1						1					
3/04/2000																
10/04/2000									1							
17/04/2000					1						1					
24/04/2000	1															
1/05/2000																
8/05/2000					1								1			
15/05/2000																
22/05/2000																
29/05/2000																
5/06/2000																
12/06/2000																
19/06/2000																

Table B 12

(400 m spacing)

DATE	Narrandera 2536		Narrandera 2537		Narrandera 2538		Narrandera 2539		Narrandera 2540		Narrandera 2541		Narrandera 2542	
	W	S	W	S	W	S	W	S	W	S	W	S	W	S
27/09/1999														
4/10/1999														
11/10/1999														
18/10/1999														
25/10/1999														
1/11/1999		3		2		2				2				
8/11/1999						2								
15/11/1999		531		7		2		1		5		13		
22/11/1999		300		7		4						4		
29/11/1999		619		115		1				15		32		4
6/12/1999		208		42				31		15		18		3
13/12/1999		137		25		3		10		14		20		
20/12/1999		9						2				1		
27/12/1999		78		20				6		5		5		2
3/01/2000														
10/01/2000		10		2						2		4		1
17/01/2000		77		38				11		44		67		9
24/01/2000		2		9		1		39		8				1
31/01/2000		3		2		6						18		1
7/2/2000		1				6		2				4		
14/02/2000	1	1		1	1	3	1	1				2		1
21/02/2000	1				3		1							
28/02/2000					13		2							
6/03/2000					4									
13/03/2000					5		8							
20/03/2000					19		2				1		1	
27/03/2000			1		8		2							
3/04/2000			1		9		4							
10/04/2000					2									
17/04/2000					6									
24/04/2000														
1/05/2000														
8/05/2000														
15/05/2000														
22/05/2000														
29/05/2000														
5/06/2000														
12/06/2000														
19/06/2000														

Table B 13

Paynters Siding (1 km spacing)

DATE	2543		2547		2546		2549		2550	
	W	S	W	S	W	S	W	S	W	S
27/09/1999										
4/10/1999	1									
11/10/1999						101		52		77
18/10/1999		1	1							
25/10/1999						49		554		310
1/11/1999		8				3		148		78
8/11/1999								28		14
15/11/1999		11						7		6
22/11/1999						3		147		3
29/11/1999		97				13		2003		37
6/12/1999		77						1553		85
13/12/1999		75				6		1889		77
20/12/1999		11				24		141		1
27/12/1999		39			4			1099		257
3/01/2000										
10/01/2000		8				66		402		64
17/01/2000		82		2				285		41
24/01/2000		4								3
31/01/2000		5						9		
7/02/2000		1						2		
14/02/2000								1		
21/02/2000										1
28/02/2000	1									
6/03/2000										
13/03/2000										
20/03/2000										
27/03/2000										
3/04/2000										
10/04/2000										
17/04/2000			1							
24/04/2000			1							
1/05/2000										
8/05/2000					1				1	
15/05/2000									1	
22/05/2000										
29/05/2000										
5/06/2000										
12/06/2000										
19/06/2000										

APPENDIX C

C (1) Destinations of sterile fly shipments 1999/2000 from Factory Annual report

2.11 DISTRIBUTATION OF FLIES

Table 4. Distribution of flies — Date, Destination and Quantity (in millions)*

Date Irradiated	South Australia	Mildura	Wagga Wagga	Griffith	Narrandera	Gosford	QA	Replacement	Total
07/09/99					3.20	1.20	0.32	0.20	5.20
14/09/99					1.28	1.12	0.32	0.40	3.20
21/09/99					4.32	1.04	0.32	0.40	6.30
28/09/99					2.40	1.76	0.32	0.40	5.10
05/10/99				0.10	1.04	1.12	0.32	0.60	4.14
12/10/99				0.12	1.44		0.32	0.40	3.17
19/10/99				1.12	1.12		0.32	0.60	2.96
26/10/99				1.12	1.36		0.32	0.60	3.52
02/11/99				1.12	1.36		0.32	0.60	3.60
09/11/99	0.14			2.66	2.39		0.32	0.60	7.00
16/11/99				2.50	2.66		0.32	0.40	7.80
23/11/99				2.40	2.85		0.32	0.40	5.90
30/11/99				2.80	2.66		0.32	0.40	7.20
07/12/99				2.80	2.66		0.32	0.40	6.98
14/12/99				2.80	2.66		0.32	0.40	7.03
21/12/99				1.20	1.20		0.32	0.40	3.55
28/12/99					1.05		0.32	0.40	.032
05/01/00				1.05		0.56	0.32	0.40	3.78
11/01/00						2.40	0.32	0.40	3.10
18/01/00						2.64	0.32	0.40	3.10
25/01/00						1.44	0.22	0.40	3.30
01/02/00			3.20				0.32	0.40	5.33
08/02/00			2.96				0.32	0.40	3.65
15/02/00			3.68				0.32	0.40	4.40
22/02/00		1.60	2.32				0.32	0.40	4.75
29/02/00		1.60	2.24				0.32	0.40	4.49
07/03/00		2.00	4.00				0.32	0.40	6.77
14/03/00		2.00	3.04				0.32	0.80	5.96
21/03/00	1.04	1.04	1.92				0.32	0.60	4.85
28/03/00	2.00	1.04	3.92				0.32	0.60	7.86
04/04/00	2.00	2.00	2.64				0.32	0.60	7.13
11/04/00	4.00	2.00	3.40			1.04	0.32	0.20	10.08
18/04/00	4.00	2.56				1.44	0.32	0.40	8.56
25/04/00	4.00	2.00				0.16	0.32	0.40	8.63
02/05/00	3.40					1.04	0.32	0.60	8.34
09/05/00	4.00	2.00		0.08		0.88	0.32	0.40	6.84
16/05/00	4.00	2.00				1.84	0.32	0.40	7.80
23/05/00	4.00					0.72	0.32	0.40	6.12
30/05/00	2.00					3.84	0.32	0.40	4.54
06/06/00	2.00						0.32	0.20	3.47
13/06/00							0.32	0.20	4.57
Total	36.58	21.84	33.32	22.17	35.85	24.24		17.80	220.39

* The difference between the total flies produced column and the total flies distributed column is the amount destroyed.

Tri-State Fruit Fly Production Facility Annual Report 1999/2000 10

C (2) Sample page from PestMon data base

IdentifiedDate	(All)
TrapType	(All)
Species	SterileBactrocera tryoni (SQF)
TrapCode	(All)
SiteTown	Hillston
RunDescription	(All)
CollectionCentreName	(All)
CollectionRegionName	Fruit Fly Exclusion Zone

Sum of FlyNumbers		
ClearedDate	SiteNo	Total
5/01/00	2292	8
	2298	3
	2303	3
	2304	24
	2305	5
	2306	2
	2319	1
	2322	1
5/01/00 Total		47
7/01/00	2298	2
7/01/00 Total		2
11/01/00	2298	4
11/01/00 Total		4
13/01/00	2292	5
	2303	1
	2304	2
	2305	1
	2324	1
13/01/00 Total		10
18/01/00	2297	1
	2298	1
18/01/00 Total		2
20/01/00	2292	5
	2303	1
	2304	1
20/01/00 Total		7
28/01/00	2292	2
	2298	2
	2315	18
	2320	1
28/01/00 Total		23
2/02/00	2292	2
	2317	1
2/02/00 Total		3
9/02/00	2292	2
	2298	5
9/02/00 Total		7
1/03/00	2320	1
1/03/00 Total		1
2/03/00	2298	1

APPENDIX D

Maps showing towns and locations mentioned in text

D (1) and D (2) on following pages

Figure D1

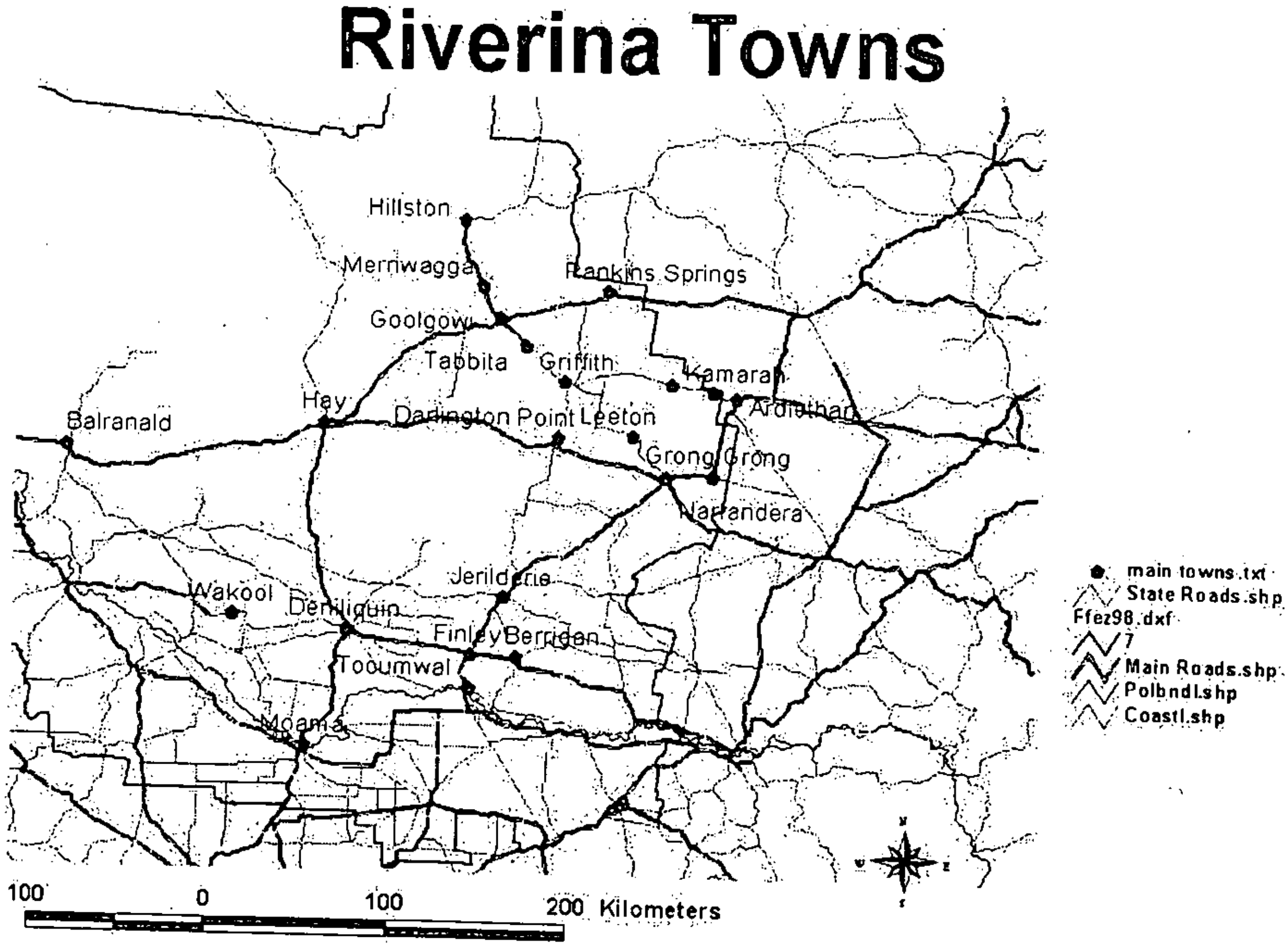
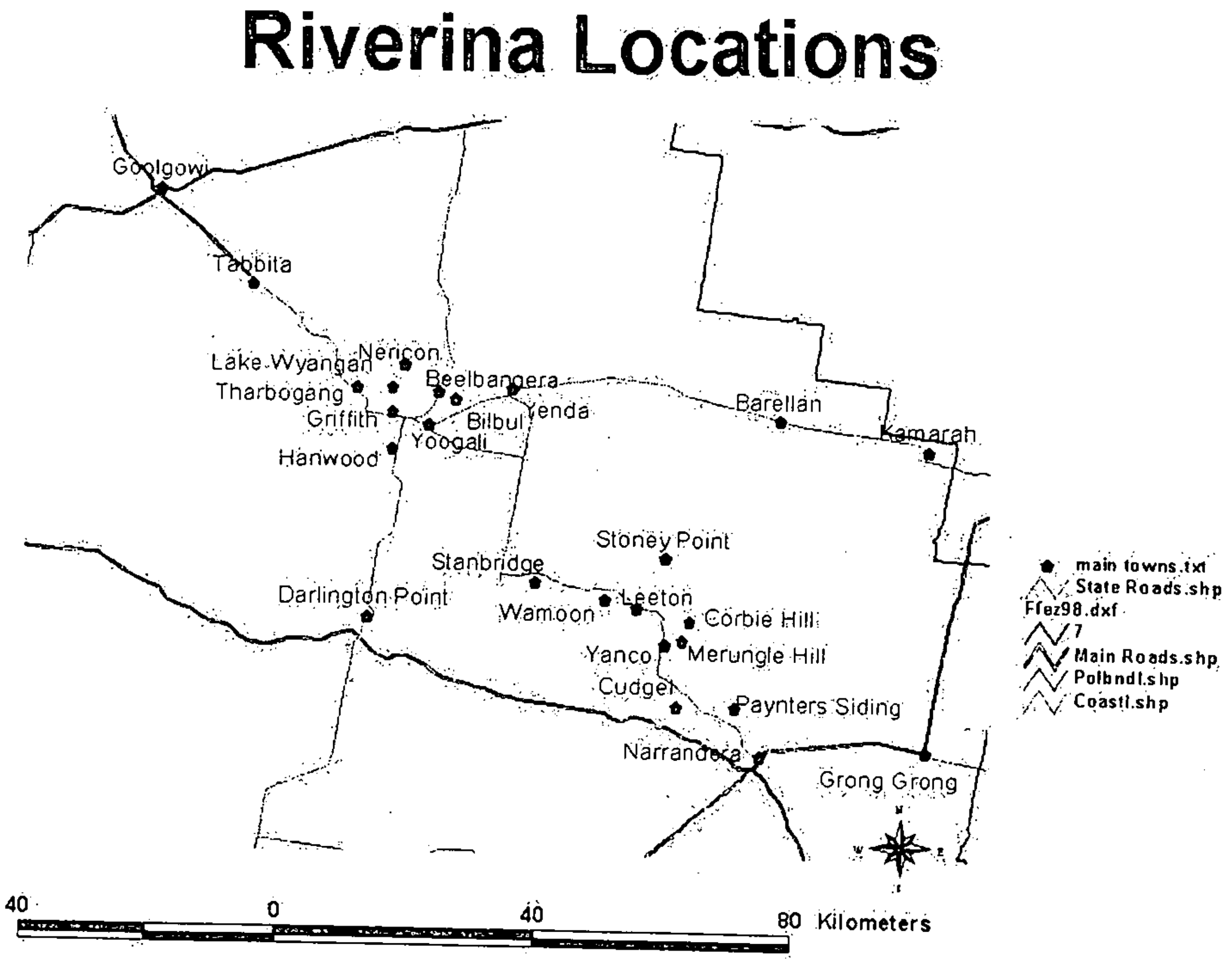

Riverina Towns
Hillston
Merriwagga
Rankins Springs
Goolgowi
Tabbita
Griffith
Kamarah
Ardlethan
Hay
Balranald
Darlington Point
Leeton
Grong Grong
Narrandera
Jerilderie
Wakool
Deniliquin
Finley
Berrigan
Tocumwal
Moama
100
0
100
200 Kilometers
main towns.txt
State Roads.shp
Ffez98.dxf
7
Main Roads.shp
Polbndl.shp
Coastl.shp

Figure D2


Riverina Locations
Goolgowi
Tabbita
Lake Wyangan
Nericon
Tharbogang
Beelbangera
Griffith
Bilbul
Yenda
Yoogali
Hanwood
Barellan
Kamarah
Stoney Point
Stanbridge
Darlington Point
Wamoon
Leeton
Corbie Hill
Yanco
Merungle Hill
Cudgel
Paynters Siding
Narrandera
Grong Grong
main towns.txt
State Roads.shp
Ffez98.dxf
7
Main Roads.shp
Polbndl.shp
Coastl.shp
40
0
40
80 Kilometers