Title
Managing mouse plagues in rural Australia

Journal
Proceedings of the Vertebrate Pest Conference, 18(18)

ISSN
0507-6773

Authors
Caughley, Judy
Donkin, Christine
Strong, Kevin

Publication Date
1998

DOI
10.5070/V418110167

MANAGING MOUSE PLAGUES IN RURAL AUSTRALIA

JUDY CAUGHLEY, and **CHRISTINE DONKIN**, Robert Wicks Research Centre, Queensland Department of Natural Resources, P.O. Box 318, Toowoomba, Qld, Australia 4350.

KEVIN STRONG, Robert Wicks Research Centre, Queensland Department of Natural Resources, P.O. Box 178, Inglewood, Qld, Australia 4387.

ABSTRACT: The frequency of mouse plagues in grain-growing areas of Australia has increased since the advent of conservation farming practices. The increase has been particularly marked on the Darling Downs in Queensland where the frequency has trebled. Broadscale monitoring is undertaken by the government to provide a general forewarning of plague. However, the authors found, from a questionnaire to farmers, that the incidence and timing of plagues is highly variable across the Downs. It is apparent that farmers need to monitor the numbers of mice on their properties at regular intervals if they are to undertake preventive management. Bait cards (pieces of paper soaked in canola oil) were tested as a method for on-farm monitoring. The average amount of each card eaten was significantly correlated with the density of mice, but because of the scatter of the data the authors recommend that the cards be used in conjunction with other signs of mice such as evidence of crop damage or of active holes and runways in stubble. Zinc phosphide bait was found to be a highly effective rodenticide if used at a time when food was scarce. If the bait receives registration, it would be a valuable tool to control mice in crops, especially prior to flowering. On the basis of these results, it was concluded that effective management of mice could best be achieved by minimizing food supply in stubble by efficient harvesting, regular monitoring, and by strategic baiting and stubble management when necessary.

KEY WORDS: bait card, monitoring, mouse plague, mice, *Mus domesticus*, zinc phosphide

Proc. 18th Vertebr. Pest Conf. (R.O. Baker & A.C. Crabb, Eds.) Published at Univ. of Calif., Davis. 1998.

INTRODUCTION

The house mouse (*Mus domesticus*) was introduced to Australia around the time of European settlement and has since spread across the whole of the continent. Most of the time its numbers are low but, when conditions are favorable, populations can irrupt to "plague proportions"—that is, high enough numbers to be a pest. When these irruptions occur in agricultural areas, they cause serious economic, environmental and social stress (Caughley et al. 1994).

Over most of this century, plagues have been relatively rare events occurring on average about once every 8 to 10 years in a particular district. Until recently, they have tended to follow droughts, and drought-breaking rain was considered the primary trigger for an irruption (Saunders and Giles 1977; Singleton 1989). However, the frequency of plagues has increased since the 1980s (Singleton and Brown 1998). The increase is attributed to the advent and progressive adoption of conservation agriculture, particularly stubble retention which provides continuous shelter and protection for mice between cropping phases.

The increase has been particularly marked on the Darling Downs in Queensland where a plague has occurred on average every three years since 1980 (Singleton and Brown 1989). The Darling Downs is a premier grain-growing region. Farming is intensive and a farm may have three plantings per year (winter, spring and summer) depending on rainfall and soil moisture profiles. The winter crop is typically wheat or barley; spring and summer plantings are principally sorghum and cotton, but corn, sunflower, and legumes are also grown.

Mouse numbers have been monitored on a 32 km transect, across the Central Downs since 1976 and used to provide an early warning of outbreaks. However, the authors have noticed that the monitoring does not predict all outbreaks on the Downs. In some areas, particularly to the east of the transect, plagues may occur in different years. It has also been noticed that not all farmers in an area in a given year are affected. In an attempt to quantify this variability, a questionnaire was sent to farmers asking them when they had experienced mouse problems in crops in the last five years (Donkin and Caughley 1998).

At the same time, the apparent variability in plague occurrence and severity across the Downs led the authors to question how farmers could best manage mouse outbreaks. If the broadscale monitoring and prediction of plagues is only partially satisfactory in warning farmers of the likelihood of a plague, on-farm monitoring by farmers themselves will be necessary.

At present, farmers use a number of methods to track mouse abundance over time. The most common method is general surveillance. By noticing the number of mice seen when harvesting and working paddocks, in sheds and around silos, and when driving at night, farmers are aware of the trends in numbers on their property. When numbers increase to such a level that mice begin to be a problem around the house and sheds, farmers lay traps and/or bait. Both trapping and baiting provide them with a quantitative estimate of density if numbers caught or amount of bait used are recorded.

For tracking numbers in fields, the most common technique being promoted is "bait cards" which are squares of paper soaked in canola oil and pegged out overnight in crops or other habitat. The extent of nibbling on the papers provides an indication of mouse abundance (Ryan and Jones). Bait cards were widely used by farmers during broadscale baiting campaigns in recent plagues in Victoria, South Australia, and Queensland. In Victoria and South Australia, baiting was recommended by government agencies if, on average, 20% of each bait card was eaten. In Queensland, the threshold was set at 10%. However, these threshold figures have not been equated to mouse densities.

The use of bait cards for regular monitoring in fields is as yet not widely adopted. The authors believe that farmers are more likely to use the method if it can be related to mouse densities, and for that reason they have endeavored to establish this relationship.

The next problem that needed to be addressed was how farmers can control mice if their monitoring indicates numbers are increasing. To date, farmers have had limited options to control mice by baiting. No rodenticide is registered for broadacre application in cereal crops in Australia. During the plagues in 1993 and 1995, strychnine was given temporary approval. However, no maximum residue level (MRL) has been assigned for strychnine by Australian authorities or by the International Codex Committees on Pesticide Residues and Residues of Veterinary Drugs in Food. When no MRL is assigned, it is by default set at zero. Since it is impossible to prove zero contamination because all assay techniques have a lower limit of detection, the use of strychnine is no longer permitted.

In 1997, temporary approval was given by the National Registration Authority for Agricultural and Veterinary Chemicals (NRA) for field trials and for broadscale use of zinc phosphide bait during irruptions in several areas of Australia. Because an MRL exists for the bait's breakdown product, phosphine, it would be possible to register the product if it were found to be successful in controlling mice and have no untoward environmental or occupational health impact.

To evaluate zinc phosphide bait, field trials were conducted with the bait in different crop stages. On the basis of these results, the authors make recommendations on how strategic baiting could be incorporated into mouse control if the product receives registration. At the time of writing, the NRA has received an application from the manufacturer for the registration of the bait for broadacre application in cereal, oil and legume crops. If the bait is registered, farmers will then have the option of strategic baiting when their monitoring indicates mouse numbers are high.

This paper reports on the results of the three-pronged approach into the management of mouse plagues on the Darling Downs. First, the authors evaluate the pattern of mouse plague irruptions on the Darling Downs in Queensland; second, they evaluate the use of bait cards for monitoring mouse numbers; and third, they evaluate the efficacy of zinc phosphide as a broadacre rodenticide. The findings are then incorporated into recommendations for on-farm management.

METHODS

Evaluating the Pattern of Recent Mouse Plague Irruptions on the Darling Downs

Downs Monitoring—Mouse numbers have been monitored at 47 sites along a 32 km transect on the Darling Downs since 1976. The monitoring was undertaken approximately monthly between 1976 and 1986 by Cantrill (1992). In 1989, the Department of Lands (now Department of Natural Resources) re-instigated the monitoring and has trapped at varying time intervals since. The sites encompass the range of soil types used for cropping on the Downs. Eighteen of the 47 sites are within roadside verges; 28 sites are on farms and have varied in crop type and stage over seasons; and one site is in pasture. On each trapping occasion, 20 break-back mouse traps baited with bacon are laid at each site in a line at 8 to 10 meter intervals in the late afternoon and collected early the next morning. Traps that have fired, but have not caught a mouse are subtracted from the total number of traps set (940) to give an adjusted number of traps; % trap success is then calculated as:

$$\% \text{ trap success} = \frac{\text{No. mice caught} \times 100}{\text{Adjusted no. traps}}$$

Questionnaire—To evaluate the spatial and temporal heterogeneity of mouse plagues across the Downs at the farm level, a questionnaire was mailed to members of the Queensland Grain Growers Association on the Downs. They were asked whether they had experienced mouse problems in crops in the last five years (1992 to 1996 inclusive), and to rate the problem in each of the seasons as minor, moderate, or severe. Full details of the questionnaire are given in Donkin and Caughley (1998).

Evaluating Bait Cards as a Monitoring Technique

Bait cards are 10 cm x 10 cm squares of white paper which are soaked in canola oil and pegged out overnight in a line of 10 cards at a spacing of 10 meters. The cards are placed within crops, stubbles, and any other area where mice may be harboring. For each site, the number of squares eaten on each card is counted and the average number for all the cards is calculated to give "% bait card eaten" for that site (Figure 1).

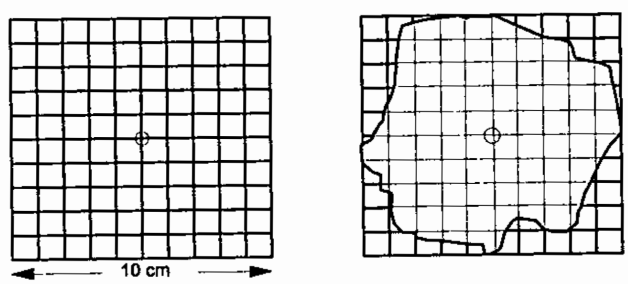

Figure 1. Diagram of bait cards. To estimate amount eaten, the number of squares remaining are counted or the nibbled bait card is superimposed on an unused card as shown on the right, and the number of squares visible on the lower card are counted and subtracted from 100. The card here is about 27% eaten.

Bait cards were used in combination with three other methods of estimating mouse numbers on different occasions over the past year. The three other methods were: population estimation by mark-recapture; % trap success with live capture traps; and % trap success with break-back traps. The live traps used were Elliott Type E traps which were baited with rolled oats and peanut butter, and usually set in a grid of 6 by 8 traps at 10 meter intervals. Traps were set for one or two nights, depending on whether the aim was an index of density (i.e., % trap success) or a population estimate. Break-back traps were used as described above under Downs monitoring.

Evaluating Zinc Phosphide as a Broadacre Rodenticide

The bait used was manufactured by Animal Control Technologies Ltd. and contained 2.5% active ingredient mixed with sesame oil and applied to irradiated wheat grains. The maximum permissible application rate under the field trial permit was 1 kg per hectare. Five trials were run using ground application, four in sorghum stubble and one in soybean stubble, using a granular applicator mounted on a fertilizer spreader. One trial was run in a wheat crop (pre-flowering) using aerial application.

The effectiveness of the bait was measured by determining the number of mice by mark recapture immediately before baiting and then three nights after baiting. In the soybean stubble, an indication of the amount of alternative food was obtained by counting the number of soybeans within ten 1 m^2 quadrants.

RESULTS

The Pattern of Recent Mouse Plague Irruptions on the Darling Downs

In the 10 years between 1977 and 1986, the trap success exceeded 20% between March and July in six of the years, and 30% in two of these six years (Cantrill 1992) (Table 1). In the nine years of government monitoring since then (1989 to 1997), the trap success has exceeded 20% in four of the years, and exceeded 30% in three (Figure 2). The number of plagues (n = 6) between 1980 and 1997 is the same as that reported by Singleton and Brown (1998), but there is a slight difference in the years in which these plagues occurred [Singleton and Brown (pers. comm.) included an outbreak in 1991 that was not apparent in the results from the monitoring; conversely, the monitoring detected an outbreak in the Central Downs in 1997 that they did not include].

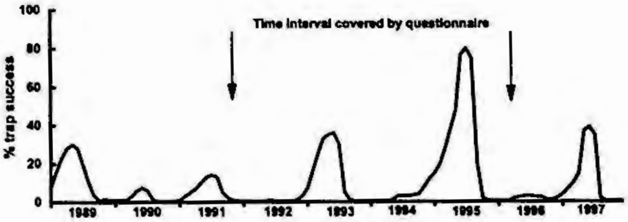

Figure 2. Trend in % trap success recorded on the Downs transect between 1989 and 1997. The time interval covered by the questionnaire encompasses two peaks in density—one moderate in 1993 and one extremely high in 1995.

Table 1. Maximum % trap success (gs) recorded each year between 1977 and 1986 by Cantrill (1992) and between 1989 and 1997 by government monitoring on the Darling Downs transect.

Year	Maximum %ts
1977	11.1
1978	22.9
1979	14.6
1980	**33.6**
1981	4.1
1982	23.2
1983	20.4
1984	25.1
1985	**35.4**
1986	12.6
1987	n.d
1988	n.d
1989	**28.4**
1990	7.1
1991	**11.7**
1992	0.8
1993	**33.8**
1994	2.6
1995	**77.4**
1996	3.0
1997	36.3

The bold figures denote the plague years in Singleton's and Brown's calculation of plague frequency between 1980 and 1997 (Singleton and Brown, pers. comm.). n.d. = no data.

The differences in plague occurrence in Table 1 is indicative of the spatial and temporal heterogeneity of irruptions of mice across the Downs, and is further evidenced in the results of the questionnaire. From the Downs monitoring, the authors were expecting that the questionnaire would show that farmers experienced crop damage from two plagues—1993 and 1995. Instead they found, first that 22% of the respondents had had no problem with mice over the five years (Table 2). Second, half of the farmers had experienced only one plague. Third, when one specific outbreak was looked at, namely the major plague that occurred on the Downs in 1995, only 43% of respondents were affected. While half of these ranked the damage they suffered as severe, the other half ranked it as moderate. Even more surprising was the result that some farmers reported a problem when the Downs monitoring indicated mouse numbers were low (particularly in 1996).

It is clearly evident that farmers need to monitor mice on their own properties if they are to implement control measures to limit mouse damage.

Table 2. Number of plagues experienced over the last five years by Darling Downs respondents to the questionnaire (n=204).

No. of Plagues Experienced	% of Respondents
0	22
1	53
2	23
3	2

Note: broadscale monitoring has indicated there were two outbreaks of mice in that time (see Figure 2.)

<u>Evaluation of Bait Cards</u>

As yet the authors have insufficient data matching % bait card eaten and population estimate, since bait cards have been laid on only three occasions when mark-recapture was undertaken. More data (n=21) are available comparing % bait card taken and % trap success with Elliott traps. Therefore, to obtain a relationship between % bait card eaten and population size, a relationship was first derived (Figure 3) between % trap success with Elliott traps and population size from mark recapture, namely:

$$\ln(\text{mice per ha}) = 1.34 \ln(\text{trap success}) - 0.22$$

that is, $\text{mice per ha} = 0.8 \text{ trap success}^{1.34}$

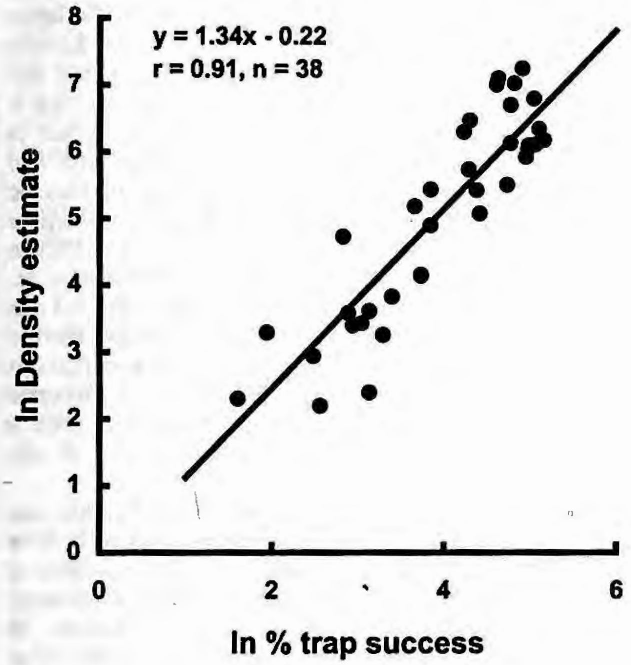

Figure 3. Relationship between % trap success with Elliott traps and density (mice per ha) estimated from mark-recapture.

Using this relationship, the authors calculated the estimated density of mice from % trap success with Elliott traps at the 21 sites, where they had both % trap success with Elliotts and % bait card eaten. The following relationship was then derived between % bait card eaten and estimated density ($r^2 = 0.64$):

$$\text{estimated density (mice per ha)} = 8.0 (\% \text{ bait card eaten}) + 69$$

At the previously recommended threshold for baiting, namely 10% bait card eaten, the equation indicates the number of mice would be around 150 per hectare. While this density is possibly an appropriate threshold (as yet there is no relationship between density and crop damage), the variation in the data around this value is high. The authors are concerned that farmers could be misled by a low bait card take. For instance, on two occasions a low % bait card eaten was recorded when the % trap success with Elliott traps was high (Figure 4). The high variability when the bait card take is below 10% is even more obvious in the data obtained on bait card take and % trap success with breakback traps (Figure 5).

The reason for the low bait card take at high mouse densities is unknown. It may simply be that the amount of card eaten is a combination of mouse numbers and the amount of other food available, but to date the authors have not been able to establish a significant relationship between crop type and stage and % bait card eaten. Much more data are needed on factors influencing the amount of bait card eaten before this index can be used reliably as a means of monitoring mouse numbers or as a threshold for strategic baiting.

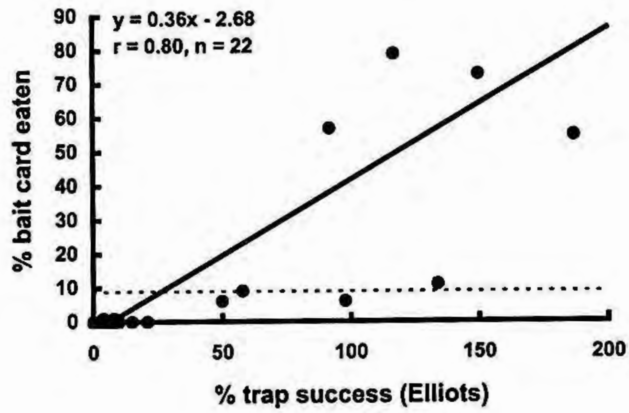

Figure 4. Relationship between % bait card eaten and % trap success with Elliott traps.

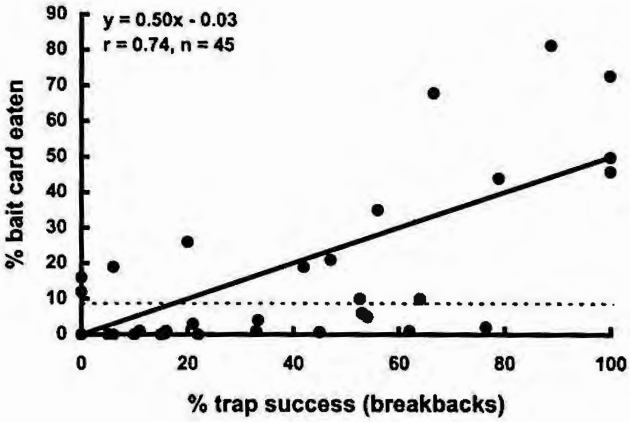

Figure 5. Relationship between % bait card eaten and % trap success with breakback traps.

Evaluation of Zinc Phosphide Bait as a Broadacre Rodenticide

The effectiveness of the zinc phosphide bait varied markedly between trials (Table 3). The worst result was achieved when the bait was applied immediately after harvest. There could be two explanations for this failure. First, the pre-baiting estimate may have been an underestimate if the mice were disturbed by the harvester. However the % trap successes on the two nights of pre-baiting were respectively 98% and 103%—mice were definitely active above ground. The second reason is that too much alternative food was available. The crop was badly affected by sorghum ergot which produces a sugary exudate on the seed heads. It is likely that the mice were feeding on the exudate as well as the sorghum grain. The ergot exudate was still present on secondary stalks left behind after harvesting and there was cracked grain in the trash; both would have competed with the bait as a food source.

At the other end of the spectrum, the reduction achieved was highly satisfactory. In both the pre-flowering wheat crop and one of the old sorghum stubbles, the number of mice remaining after baiting was low enough to curtail impact for several months. At the remaining two sites, the availability of alternative food was reasonably high. The sorghum crop had been severely lodged and the farmer had not used crop lifters when harvesting. Heads on the ground still contained seed four months later, and the number of mice was high. Even though a 64% reduction was achieved, the number of mice remaining was still high enough to cause significant damage if they dispersed into adjacent crops when the seed supply in the sorghum was spent. In the soybean stubble, the result was similar.

DISCUSSION

The results highlight a number of problems for managing mouse irruptions. First, the evaluation of the pattern of mouse plagues across the Downs in recent years indicates the high level of spatial and temporal variation in irruptions and how important it is that farmers undertake monitoring on their own properties at regular intervals. This spatial and temporal heterogeneity in plagues has been reported in all plague-affected areas in Australia (Mutze 1991; Singleton and Redhead 1989; Chambers et al. 1996), and an effective means of on-farm monitoring is needed in all the grain-growing areas.

On the Downs, the most important times to monitor mice are in summer and autumn. Mice begin breeding in spring and, if conditions are favorable, numbers will continue to rise through summer. The peak density usually occurs between March (late autumn) and July (mid winter). For this reason damage is usually most severe in maturing summer crops and in early plantings of winter crops.

Bait cards are a simple means of monitoring and it was found the % eaten was significantly correlated with estimated density of mice and with % trap success. However, while a high % bait card eaten indicated high mouse numbers, the converse was not necessarily so. Setting 10% bait card eaten as a recommended threshold for baiting may prevent farmers from taking action when mouse numbers are in fact at a level that will lead to extensive crop damage. Further research may improve the accuracy of the bait card technique, but in the meantime the authors suggest that a low bait card take is confirmed by other signs of mouse activity, such as number of holes and runways in stubble, and evidence of damage in crops. If farmers are uncertain, it is recommended that they use traps such as breakback traps to determine the density of mice.

In addition to monitoring, farmers need to employ management practices that will limit the build up of mice. Brown et al. (1998) found that good farm hygiene, particularly reduction of weeds and grasses along fencelines to reduce seed set and harbor for mice, reduced the severity of an outbreak. Generally the farms on the Downs are well managed; the majority of farmers mow grassy verges and keep areas around buildings and grain storages relatively clean. Also, because land use is intensive on the Downs, the extent of grassy areas is small. The major habitat for mice is within crops and stubble. To control the numbers of mice in stubble, the best routine management practice available to farmers is to harvest efficiently. At present, there is insufficient attention paid to minimizing grain left behind at harvest. For example, crops that are badly drought affected are not always harvested. Crop lifters are not always used to harvest crops with significant lodging. Diseased crops (e.g., with sorghum ergot) are not dried off and harvested quickly. In each situation, mice are provided with a source of food which prolongs the suitability of the habitat.

There will be times, despite good farm hygiene and efficient harvesting, that mouse numbers will be high in stubble. Farmers can then work or slash the stubble to reduce the amount of cover for mice without necessarily losing the advantage of erosion control through its retention. If zinc phosphide bait receives registration as a broadacre rodenticide, strategic baiting may also be an option. But strategic baiting will principally be a tool for controlling mice in crops since there are no alternative management options (except grazing off the crop or cutting it for hay). Because these field trials showed that

Table 3. The results of the field trials on the effect of zinc phosphide bait on mouse numbers per hectare.

Crop Type and Stage	Food Availability	Pre-baiting Density	Post-baiting Density	Reduction	Comments
Wheat —booting	very low	573	31	95%	Mice feeding on embryo heads in tillers
Sorghum —stubble	very low	442	41	91%	4 months post harvest
Sorghum —stubble	moderate	1,317	478	64%	4 months post harvest, but crop severely lodged
Soybean —stubble	high	896	544	39%	3 weeks post harvest; soybeans 8 g m^2
Sorghum —stubble	very high	1,106	1,134	-3%	2 days post harvest; crop badly affected by ergot

the best results are achieved when alternative food is scarce, farmers need to check for mice in their crops and undertake baiting (if necessary) before flowering commences. If mice are not detected before seed fill, baiting is still an option, but warn that if numbers are very high there may still be enough mice remaining to cause damage to the crop. If this is the case, the best option is to harvest the crop as early as possible.

At present, the authors are advocating baiting as a strategic control measure in crops, but it is hoped that in the long term there may be a form of biological control. Research is underway at the Vertebrate Biocontrol Centre on controlling mice through virally-vectored immunocontraception (Chambers et al. 1997). These experiments are proceeding well and may be at the field testing stage within the decade. In the meantime, the authors believe that an integrated approach of good farm hygiene, especially clean harvest, on-farm monitoring, and strategic baiting when mouse numbers are high will reduce the burden of mice for Australian grain-growers.

LITERATURE CITED

BROWN, P. R., G. R. SINGLETON, C. DUNN, and D. A. JONES. 1998. The management of house mice in agricultural landscapes using farm management practices: an Australian perspective. Proceedings of 18th Vertebrate Pest Conference, Costa Mesa, California, March 1998.

CANTRILL, S. 1992. The population dynamics of the House Mouse (*Mus domesticus*) in a dual crop agricultural ecosystem. Ph.D. thesis, Queensland University of Technology.

CAUGHLEY, J., V. MONAMY, and K. HEIDEN. 1994. Impact of the 1993 mouse plague. Occasional Paper Series No. 7. Grains Research and Development Corporation, Canberra.

CHAMBERS, L. K., G. R. SINGLETON, and M. VAN WENSVEEN. 1996. Spatial heterogeneity in wild populations of house mice (*Mus domesticus*) on the Darling Downs, south-eastern Queensland. Wildlife Research 23:23-38.

CHAMBERS, L. K., G. R. SINGLETON, and G. M. HOOD. 1997. Immunocontraception as a potential control method of wild rodent populations. Belgian Journal of Zoology 127 (Suppl. 1):145-156.

DONKIN, C., and J. CAUGHLEY. 1998. Are mouse plagues increasing in frequency in Queensland? Proceedings of the 11th Australian Vertebrate Pest Conference, Bunbury, May 1998.

MUTZE, G. J. 1991. Mouse plagues in south Australian cereal-growing areas. III. Changes in mouse abundance during plague and non-plague years, and the role of refugia. Wildlife Research 18:593-604.

RYAN, G. E., and E. L. JONES. 1972. A report on the mouse plague in the Murrumbidgee and Coleambally irrigation areas. 1970. NSW Agriculture, Orange.

SAUNDERS, G. R., and J. R. GILES. 1977. A relationship between plagues of the house mouse, *Mus musculus* (Rodentia:Muridae) and prolonged periods of dry weather in south-eastern Australia. Australian Wildlife Research 4:241-247.

SINGLETON, G. R. 1989. Population dynamics of an outbreak of house mice (*Mus domesticus*) in the mallee wheatlands of Australia—hypothesis of plague formation. Journal of Zoology, London 219:495-515.

SINGLETON, G. R., and P. R. BROWN. 1998. Management of mouse plagues in Australia: integration of population ecology, bio-control and best farm practice. Advances in Vertebrate Pest Management, D.P. Cowan and C.J. Feare, eds. Zoological Library Vol. 7 (in press).

SINGLETON, G. R., and T. REDHEAD. 1989. House mouse plagues. Ch. 30 *in* Mediterranean Landscapes in Australia: Mallee Ecosystems and their Management, J. C. Noble and R. A. Bradstock, eds. CSIRO, Melbourne.