THE IMPACT OF THE INSECTICIDE CARBOFURAN (FURADAN 480F) ON THE BURROWING OWL IN CANADA

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PREFACE

As a result of the advice given Agriculture Canada based on the data presented in this report, Agriculture Canada has instituted a restiction for the use of carbofuran formulated as Furadan 480F. This action, implemented as a supplementary label, prohibits the use of Furadan 480F within a minimum of 250 m of an occupied Burrowing Owl burrow. This regulatory decision represents a negotiated position in which several mitigating options were considered. These options ranged from instituting various setback distances ranging from 50 m where effects on Burrowing Owls were seen, to 400 m, the active foraging range of the owl, to Environment Canada's recommendation for extensive geographic restrictions in use.

In addition to this restriction, effective June 1989, Agriculture Canada is announcing the re-evaluation of all uses of flowable and granular formulations of carbofuran because of Environment Canada's concerns about its potential impact on birds.

SUMMARY

The Burrowing Owl is officially listed as a threatened species in Canada. Because of its limited range and specialized life habits, concerns were raised with respect to its vulnerability to insecticides used to control grasshopper infestations. In 1986 and 1987, the Canadian Wildlife Service commissioned field studies to look at the impacts of operational grasshopper spraying on this species. The results of this work indicate that there is an urgent need to reduce the exposure of the Burrowing Owl to one of the insecticides in use; carbofuran (Furadan 480F).

Evidence of an impact of carbofuran on Burrowing Owls

Our data show that in 1986 and 1987 carbofuran had a significant impact on the survival and reproductive success of Burrowing Owls when sprayed over nest burrows. Of the 12 oversprayed pairs we observed on four sites in 1986 and 1987, eight (75%) failed completely and a minimum of 12 (50%) of the adults disappeared after the overspray and were not seen again on any follow-up visits for the remainder of the breeding season. Excluded from the 12 adults which disappeared are three females with large brood patches and in heavy moult that were found in burrows that were excavated 17 to 29 days after the overspray at one site. These failed breeders may or may not have been members of the resident pairs which disappeared. The impact on reproductive success decreased with decreasing proximity of the exposure. Although the 27% decrease in reproductive success in those nests sprayed within 50 m but not oversprayed was not statistically significant, the significant trend with proximity of application is suggestive of an impact beyond 50 m. Our relatively small sample size and *a posteriori* design which depended upon operational spraying greatly reduced our ability to detect an impact. We therefore consider these results to be indicative of a serious problem.

A further indication of the widespread impact resulting from the use of carbofuran is available from a survey of landowners we conducted on our study areas. Landowners with Burrowing Owls nesting on their lands who had sprayed for grasshoppers in 1985 or 1986 and who had used carbofuran in the past were found to have significantly smaller numbers of active nests in 1987 than landowners who had sprayed for grasshoppers in 1985 or 1986 but had never used carbofuran. This is consistent with our own data which showed that colonies were smaller in 1987 following the use in 1986 of carbofuran than after the use of another insecticide. Haug (1985) similarly recorded a dramatic decline in site reoccupancy and colony size following a year of heavy grasshopper spraying.

Our data suggest that the impact of carbofuran was a result of its toxicity rather than food removal. The other insecticides applied did not cause a similar impact although we caution that there were probably too few data to be sure about the safety of any insecticide other than carbaryl (Sevin). Burrowing Owls are extremely opportunistic in their food habits and it is unlikely that any insecticide application would result in a temporary food shortage severe enough to result in nestling mortality or abanonment of territories.

If the impact results from poisoning via the ingestion of contaminated prey, or dermal or other routes, it is predictable that the risk will decrease with increasing distance from the site of application because the proportion of the owls' activity decreases with increasing distance from the burrow. It is, however, difficult to establish a safe limit. The foraging range of adult owls in Saskatchewan exceeded 400 m and flights of up to 2.75 km were recorded.

Carbofuran use and the potential for exposure of Burrowing Owls

Based on current knowledge of the distributions of various crops, pest infestations and breeding Burrowing Owls, we were able to divide registered uses of carbofuran into three groups, relative to their likely hazard to the owls:

1. Highest likelihood of impact: the registration for grasshopper control in alfalfa, barley, flax, headlands, mustard, oats, pastures, rape (canola), roadsides, sweet clover and wheat as well as the registration for alfalfa weevil in alfalfa.

   The distribution of agronomically significant grasshopper infestations is so similar to the nesting distribution of Burrowing Owls that no grasshopper insecticide can be used without potentially exposing most of the owls. For example, 99% of all known nesting sites in Saskatchewan occur in crop districts in which grasshopper infestations in 1985-86 potentially needed control. Forage crops, including alfalfa, roadsides and pastures are favored habitats of this species.

2. Lower likelihood of impact: all registrations on sunflower as well as registrations for flea beetles and red turnip beetles in canola and mustard.

3. Little likelihood of impact: registration for control of wheat midge in wheat, providing rhe range of this pest does not expand greatly.

Options for risk mitigation

A major effort is currently underway to rehabilitate the Burrowing Owl in Canada. The Canadian Wildlife Service, the provincial governments of Saskatchewan, Manitoba Alberta and British Columbia, World Wildlife Fund Canada and the natural history societies of the three Prairie Provinces are all expending considerable resources toward this goal. Carbofuran is undoubtedly not the only man-made factor that has an impact on this species but we believe that unless exposure of Burrowing Owls to carbofuran is significantly reduced, other remedial actions underway may be less effective and the survival of this population further jeopardized. The rapid disappearance of this species from parts of its current Canadian range is indicative of the urgency with which this problem needs to be addressed.

The results of the study presented here on Burrowing Owls as well as the numerous bird kills that have resulted from the operational use of carbofuran (Appendix 1), emphasize the need for an immediate regulatory evaluation of this insecticide. As the Burrowing Owls is already a threatened species, protective action must be taken immediately to prevent further declines. Thus, waiting for the lengthy process of re-evaluation is undesirable.

There are several options for mitigating the risk to Burrowing Owls. The first, and most conservative, is suspension of the use of carbofuran in the breeding range of the Burrowing Owl. A second, less drastic, option is to make changes to the label to direct users not to use carbofuran in areas frequented by Burrowing Owls. This option could include buffer zones around Burrowing Owl nesting sites or restict use in regional municipalities or counties where Burrowing Owls are present. Obviously the prefered option, from the point of view of maximum mitigation of risk to Burrowing Owls, is the first.

NOTE: It is the responsibility of Agriculture Canada to weigh the risks and benefits of pesticides in making regulatory decisions. The options presented above are specific to Burrowing Owls and do not take into consideration the benefits of carbofuran, only the risks.

Conclusion

In view of the impact of carbofuran on this species and that several alternative registered products exist (of assumed equal efficacy) for control of grasshoppers and alfalfa pests in the Prairie Provinces, we believe that the use of Furadan 480F poses an unacceptable and unnecessary risk to the continued survival of the Burrowing Owl.

The impact of grasshopper insecticides on other species of prairie wildlife should be assessed, particularly those species which are threatened, endangered, or where populations are declining. The apparent sensitivity of waterfowl to carbofuran and the large number of dabbling ducks directly exposed to this insecticide is of immediate concern.

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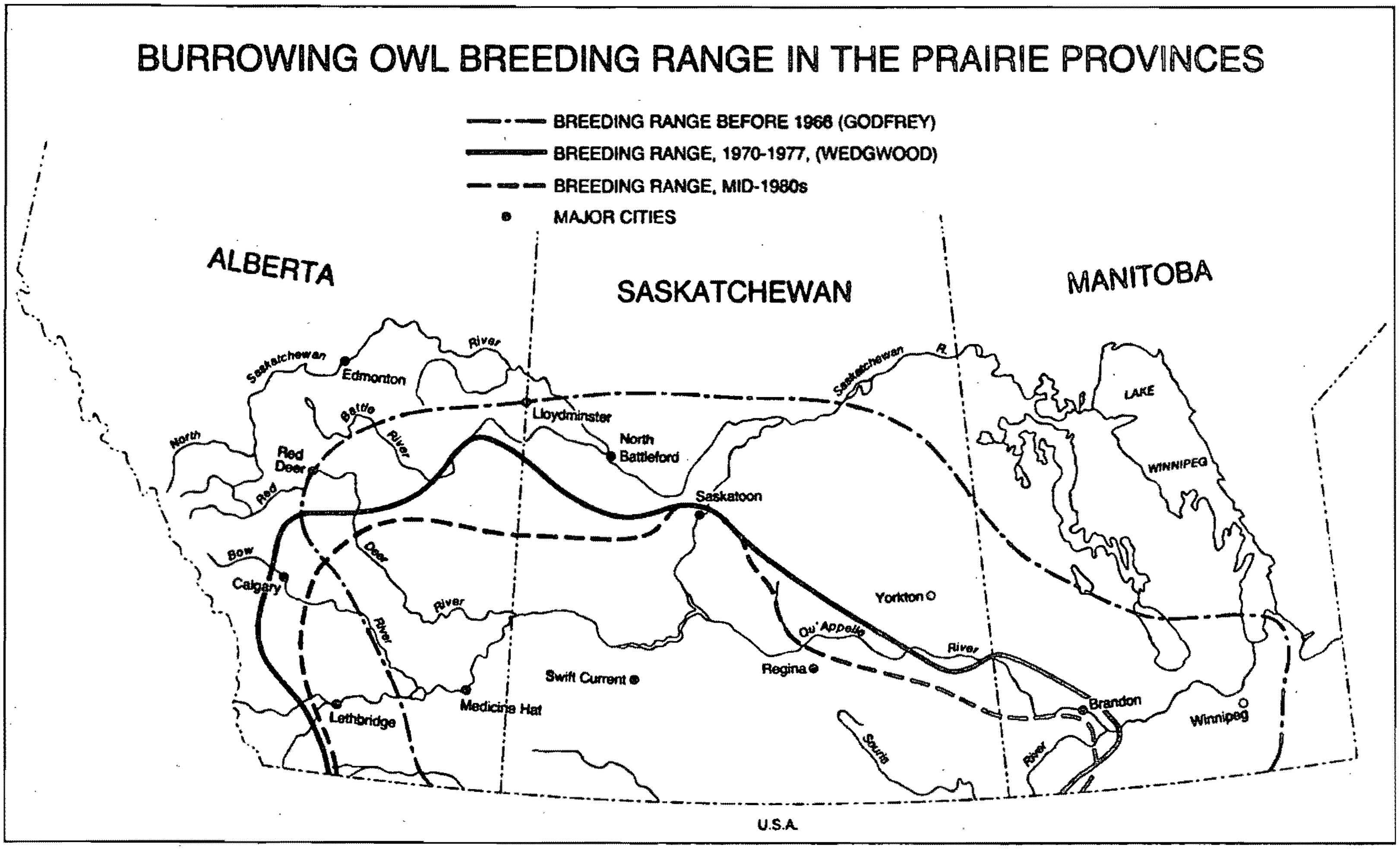

Figure 1. Burrowing Owl breeding range in the Prairie Provinces, past and present.

1. INTRODUCTION

In 1979, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) designated the Burrowing Owl (*Athene cunicularia*) a threatened species in Canada; ie. one which is likely to be endangered with immediate extinction owing to the actions of man if the factors affecting its vulnerability are not reduced. This small owl nests on the prairies in abandoned mammal burrows, feeds extensively on small mammals, grasshoppers and other insects, and is frequently associated with areas where cereal and forage crops are now grown (Figure 1). On the basis of our observations in Saskatchewan, densities of nesting Burrowing Owls are currently much higher on farmland than on rangeland. Also, the component of the population which nests in farmland is very important since colonies in this habitat appear to be larger than those in rangeland and therefore have the greatest potential recruitment to the population. Two-thirds of the Canadian breeding population is thought to reside in Saskatchewan (Wedgwood 1978). There is evidence that the current population is below the carrying capacity of the present habitat on the prairies and has declined sharply in recent years. The overall magnitude of this decline is unknown, but Wedgwood (pers. comm.) reports that between 1976 and 1987 in South-central Saskatchewan, breeding numbers have declined by 50%. The most dramatic documentation of this decline has been in Manitoba where the population has declined from 76 pairs in 1982 to 35 in 1984 (Ratcliff 1986) to 15 pairs in 1987 (E.A. Haug, pers. comm.).

This report assess the impact of carbofuran flowable insecticide (Furadan 480F) on the Burrowing Owl. The report is in two parts: the first (Section 2.0) specifically addresses the impact on Burrowing Owls associated with the use of carbofuran to control grasshopper infestations, the second (section 3.0) examines the potential impact associated with other uses of carbofuran. In both cases these impacts are compared to those associated with other insecticides registered for the same use. Conclusions are presented at the end of each part. In appendix 1, the extreme toxicity of carbofuran to birds and the history of bird kills associated with the use of this insecticide are documented.

2. FIELD INVESTIGATIONS OF THE IMPACT OF GRASSHOPPER CONTROL ON BURROWING OWLS

2.1 INTRODUCTION

The Canadian prairies are frequently the site of agronomically significant grasshopper infestations which have typically been controlled by insecticides. According to Wedgwood, respondants to his survey from three different districts in Alberta noted that owls had not been seen since most farms were sprayed with insecticides to control severe grasshopper infestations in 1974 and 1975. He recommended that data on the effects of grasshopper control practices be collected. Zarn (1974) also noted that there were no studies on the effects of agricultural chemicals on Burrowing Owl populations, nor on whether the insect population remaining after a grasshopper control program was adequate for the owls. One of the most severe grasshopper outbreaks ever recorded on the prairies began in 1981. This outbreak peaked in 1985 and 1986. It was estimated that over 3 million hectares were sprayed in Saskatchewan alone to control grasshoppers in 1985, and carbofuran was used on 40% of this area (Sheehan et al. 1987). In the same year in Alberta, an estimated 700,000 hectares were sprayed to control grasshoppers and carbofuran was used on 60% of this area (D. Johnson and L. Kok, pers. comm.)

Where chemical agents are used for grasshopper control there is potential for Burrowing Owls and other wildlife to be exposed. The hazard has not been assessed for many species of wildlife. However, the recent CWS assessment of the hazard posed by grasshopper insecticides to waterfowl on the Canadian prairies (Sheehan et al. 1987) suggests that chemical control of grasshoppers in this ecosystem is an agricultural practice with considerable adverse potential.

2.2 STUDY AREA AND METHODS

In 1986 and 1987 we undertook research to investigate the impact of operational grasshopper control on Burrowing Owls nesting in Saskatchewan. Funds provided by Environment Canada's Pestfund were used to contract Dr. Paul C. James, Curator of Ornithology at the Saskatchewan Museum of Natural History, Regina, as principal field investigator. He was assisted by Tom Ethier, Paul Chytyk and Merv Hey.

Three study areas were selected using the predicted severity of grasshopper infestation and known burrowing owl density. These areas were expected to have moderate to severe grasshopper infestations, based on the 1986 "Grasshopper Forecast in Saskatchewan" (Sask. Agriculture, Regina):

1. An area of predominantly rangeland near Val Marie (35 pairs on 13 sites in 1986);

2. The heavily cultivated area surrounding Regina (64 pairs on 17 sites in 1986 and 107 pairs on 35 sites in 1987); and

3. The heavily cultivated area surrounding Moose Jaw (114 pairs on 34 sites in 1987).

Active Burrowing Owl sites were located in May and early June. Repeated observations were made at the occupied burrows by the same observer, usually in the early morning or late afternoon, from a distance, using binoculars and/or telescope. The proportion of occupied burrows in which at least one young was successfully raised (nest success) and the maximum number of young to appear above ground (brood size) were determined. Twenty-nine of 30 sites studied in 1986 were revisited in 1987 to determine the number of pairs present. At most burrows the young were captured, banded, weighed and measured.

Landowners, land managers and rural municipalities provided details of their grasshopper control measures, including the date, location, and the agent applied. In a recent Saskatchewan study using radiotelemetry (Haug 1985), 60% of flights from the nest burrow were within 50 m and 90% within 400 m. We therefore regarded any insecticide spraying event which occured within 400 m of an active nest burrow as a potential exposure. Exposures were divided into four proximity categories based upon the distance from the burrow at which exposure occured: (i) no exposure within 400 m (code = 0), (ii) at least one exposure between 50 and 400 m of the burrow but no exposure closer than 50 m from the burrow (code = 1), (iii) at least one exposure within 50 m of a burrow but no overspray of the burrow (code = 2), and (iv) at least one overspray of the burrow (code = 3). The six male owls monitored by Haug (1985) were never located farther than 250 m from the nest burrow during daylight; peak foraging occurred between 2000 and 0630 hours and flights as distant as 2750 m were recorded during this period. Haug estimated the mean home range of her telemetered owls to be 2.41 km^2 (0.14 to 4.81) with a major axis of 2.43 km (0.67 to 3.41). These figures are very similar to those reported by Butts (1973) for Burrowing Owls nesting in Oklahoma. *Our use of a 400m radius from the burrow as the effective area for estimates of insecticide exposure represents only 20% of the mean home range and is therefore conservative.* The preferred foraging habitat of the adult males was grass/forbs, which included roadsides, rights-of-way, hayland, ungrazed pastures, and uncultivated land, most of which are potential or favoured targets of insecticide applications for grasshopper control. These habitats were present near most nesting sites.

Treatment groups were chosen *a posteriori* based upon the relative number of burrows exposed to the various insecticides in use. The statistical trend analysis was done separately for each pesticide. The variables considered were: (a) number of exposures to the insecticide, (b) number of additional exposures to other insecticides, (c) total number of insecticide exposures, (d) nest success, and (e) brood size. Since the insecticide being analysed was not applied to burrows in category 0, variables a and c were analysed for proximity categories 1 - 3 while other variables were analysed for categories 0 - 3. As nest burrows were clustered on a number of different farms, outcomes on a particular farm might be expected to be correlated. A "farm effect" was allowed for in all analyses by using the totals for each farm within in proximity category as the basis of analysis. In the case of carbofuran, the analyses were also conducted assuming no "farm effect", treating each burrow as an independent observation.

A simple regression of the mean reproductive measure per burrow against proximity score was calculated and the significance of the trend with proximity was assesed using a re-randomization test (Edgington 1986, Sokal and Rohlf 1981). All possible outcomes that could be obtained where randomly rearranged 1000 times and the proportion of times the randomly rearranged data gave an outcome as extreme as the observed outcome provided a measure of probability. For the numbers of applications of various insecticides (variables a, b, and c) a two-sided test for change was used, whereas a one-sided test for decline with increasing proximity was applied to nest success and brood size. Whenever a significant trend with proximity was detected for nest success and brood size, the trend was retested after discarding the highest proximity category. This statistical methodology, although not routine, was carefully chosen to provide adequate power given the study design. The detailed statistical analysis and raw data are provided in Appendix 2.

Although a well-planned *a priori* design is often easier to interpret, two factors mitigated against the use of such an experimental design in this case:

1. the threatened status of this species, its continued and rapid decline, and the difficulty in locating a large enough study population; and

2. the difficulty of establishing true controls in the field situation due to the clumped distribution of this species, overlapping home ranges, and large foraging distances.

Our choice of an *a posteriori* design allowed us to examine the results of operational pesticide use by the prairie farming community, as opposed to a contrived situation, and provided information on pesticide combinations and multiple applications that accurately reflect the way insecticides are currently used by two farming communities. The greatest weakness of an *a posteriori* design is its conservative nature.

Regurgitated pellets were collected at each site in June and July 1986, and over a more restricted period in 1987. Individual pellets were crushed and the presence of remains of grasshoppers (Acrididae), beetles (Coleoptera) and vertebrates recorded.

In August 1987, the farmers and owners of all land on which owls were studied in 1986 and 1987 were surveyed by telephone to obtain better information, both current and historic, on the nesting habitat and agricultural practices on land where owls currently nest in Saskatchewan. In all, 66 farmers were contacted. A one-sided re-randomization test was used to assess the difference in the mean number of owls on farms where carbofuran was used and farms where this chemical was never used.

Spearman rank correlations were used to test the association between regional differences in intensity of grasshopper spraying and the breeding distribution of Burrowing Owls.

2.3 RESULTS

2.3.1 Exposure to Grasshopper Insecticides

Only 23 of the 99 nesting pairs we located on the two study areas in 1986 were not subjected to at least one spray event within 400 m of their nest burrow. Ninety-seven percent of the 64 burrows studied near Regina were exposed at least once, in marked contrast to only 40% of the 35 burrows studied in the Val Marie area. Thirty-nine percent of exposed burrows were subjected to three to eight events, and 70% of the exposures were within 50 m of the nest burrow. Three roadside applications by municipalities in the Regina area exposed a total of 48 burrows (77% of those exposed) on 15 farms. Similarly, two roadside applications by municipalities in the Val Marie area exposed 12 burrows (86% of those exposed) on four properties.

Of the 61 exposed burrows at which young were later observed above ground on one or more visits, 50 (82%) were only exposed before the young were observed (Figure 2). The majority of insecticide exposures occured between June 10 and 30, while female owls were incubating eggs (approx. 60 %) or brooding small young, and the males were responsible for all the provisioning.

In 1986, a total of six insecticides were applied within 400 m of one or more nest burrows under study. Carbofuran (Furadan), carbaryl (Sevin), chlorpyrifos (Lorsban), and deltamethrin (Decis) accounted for 35%, 35%, 15% and 10% of the applications, respectively. The other insecticides used were malathion and methamidophos. All but deltamethrin are cholinesterase inhibitors.

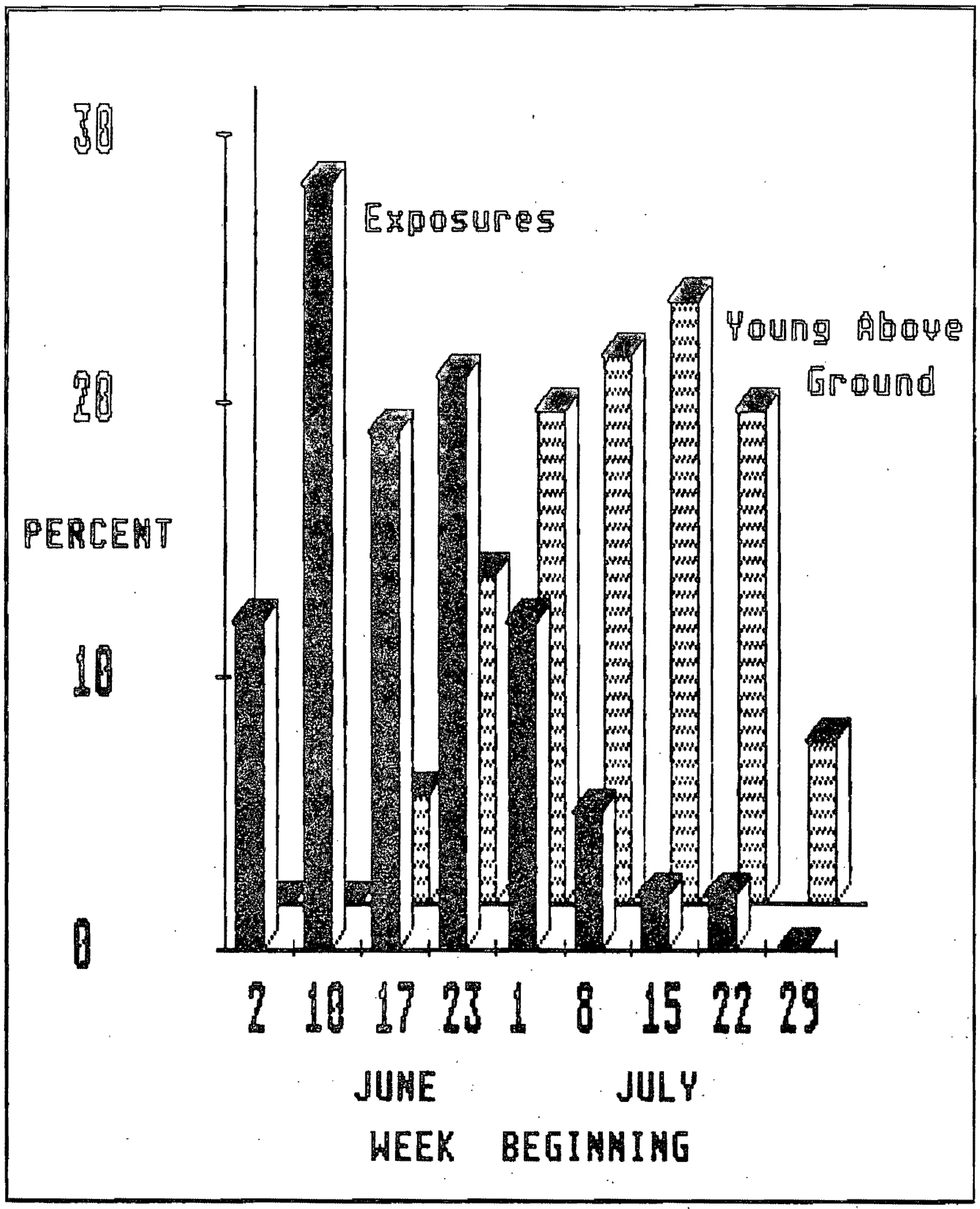

Figure 2. Chronology of exposure of burrows to insecticides and emergence of young Burrowing Owls on both study areas in 1986.

In 1987, cold, wet weather in April and May combined with a record low wheat price resulted in a marked reduction in the amount of insecticides applied to control grasshoppers in Saskatchewan. A single application of an insecticide (carbofuran) was made on one of 69 farms, exposing five (2%) of the 221 burrows under study.

2.3.2 Impact of Exposure to Grasshopper Insecticides, 1986 and 1987

The brood size and nesting success in relation to the chemicals applied at various proximities to the nest burrow are summarized in table 1.

For the trend analysis of each pesticide treatment, the number of burrows in each proximity category with no exposure to any other insecticide within 400 m was determined. Examination of the data revealed that only the carbaryl treatment group had sufficient observations to allow an analysis of its impact in the absence of all other insecticides. It was therefore necessary to incorporate other exposures in our analyses for specific chemicals, assuming a simple additive model (ie. carbaryl alone, carbaryl + chlorpyrifos, carbaryl + chlorpyrifos + deltamethrin, and carbaryl + chlorpyrifos + deltamethrin + carbofuran) after first showing that the number of burrows in each proximity category was approximately equal by the absence of a significant trend. We address the question of additive and/or synergistic effects in section 2.3.4.

Carbaryl, Chlorpyrifos and Deltamethrin

There was no significant ($P = 0.46$) trend in the number of carbaryl exposures across the proximity categories (1 - 3), nor was there a significant trend in either nest success ($P = 0.43$) or brood size ($P = 0.36$) over the proximity categories (0 - 3).

An analysis of the observations for chlorpyrifos treatments (including burrows exposed to carbaryl but excluding exposure to any other insecticide) revealed no significant ($P = 0.95$) trend in the number of exposures to carbaryl with proximity (0 - 2) to the burrow. The number of exposures to chlorpyrifos was too small to allow testing for a trend in number of sprays of chlorpyrifos or total sprays over proximity categories 1 to 3. No significant trend in nest success ($P = 0.92$) or brood size ($P = 0.40$) was detected with proximity (0 - 2) of chlorpyrifos exposure to the nest burrow.

An analysis of the results for the deltamethrin treatments (including burrows exposed to carbaryl and chlorpyrifos but excluding exposure to any other insecticide) revealed no significant ($P = 0.85$) trend in the number of exposures to these chemicals with proximity (0 - 3) to the burrow. The number of

Table 1. Variation in Burrowing Owl reproductive success with proximity of various insecticide applications to control grasshoppers in Saskatchewan in 1986.

Treatment and Proximity	Number of sites	Active burrows	Nest Success	Young per Nest
None within 400m with any agent	8	23	74%	3.8
Any agent other than carbofuran within 400m	18	42	79%	3.5
Carbaryl within 400m no other agents	12	30	77%	3.6
Carbofuran within 400m and any carbaryl, chlorpyrifos or deltamethrin sprays	12	32	59%	2.7
Chlorpyrifos within 400m and any carbaryl spray	3	6	100%	3.5
Deltamethrin within 400m and any carbaryl or chlorpyrifos sprays	3	6	67%	3.0
Carbaryl overspray	4	13	69%	2.9
Carbofuran overspray	3	7	14%	0.6
Carbaryl within 50m but not oversprayed	4	9	78%	4.4
Carbofuran within 50m but not oversprayed	4	9	56%	3.0
Carbaryl between 50 and 400m	4	8	88%	3.6
Carbofuran between 50 and 400 m	5	16	81%	3.6

exposures to deltamethrin was too small to allow tests for a trend in number of sprays of deltamethrin or total sprays over proximity categories 1 to 3 to be run. No significant trend in nest success rate (P = 0.53) or brood size (P = 0.40) was detected with proximity (0 - 3) of deltamethrin exposure to the burrow.

Having shown that exposure to carbaryl, chlorpyrifos and deltamethrin did not significantly alter nest success or brood size, either singly or in combination, we have incorporated burrows also exposed to these agents into our analysis of burrows exposed to carbofuran. This was necessary to increase our sample size.

Carbofuran

Although there was a trend in total insecticide exposures (Carbaryl + chlorpyrifos + deltamethrin + carbofuran) over proximity categories 1 - 3, there was no significant trend in the number of exposures to insecticides other than carbofuran over proximity categories 0 to 3 (P = 0.94) nor in total carbofuran exposures (P = 0.80) over categories 1 to 3. Thus, there were no confounding trends resulting from our *a posteriori* selection of treatment groups.

There were significant declines in nesting success (P = 0.002) and brood size (P = 0.006) with increasing proximity (0 to 3) to the nest burrow. These trends were also evident (P = 0.13 and P = 0.26) when direct oversprays were excluded although the probability of the trend being spurious increased. Based upon the lack of evidence of confounding sampling bias, and the fact that these trends persist when potential "farm effects" are ignored, these trends can be ascribed to carbofuran.

Exposure to carbofuran within 50 m of the nest burrow but without the burrow having been oversprayed resulted in a 17% reduction in brood size and a 27% reduction in nesting success relative to all burrows exposed to an insecticide other than carbofuran. Direct overspraying of the burrow resulted in a 83% reduction in brood size and a 82% reduction in nest success.

Tables 2 and 2a give case histories for 23 burrows on six farms which were directly oversprayed with carbofuran in 1985, 1986, or 1987 based on our observations or unsolicited reports from landowners. The latter are included here for the sake of completeness. Because of the biased nature of reporting by landowners, the observations at sites FD and FA can not be combined with the other observations of oversprays for analysis. Of the 12 pairs we observed on four sites, eight (75%) failed completely and a minimum of 12 (50%) of the adults disappeared after spraying and were not seen again on any follow-up visits over the remainder of the breeding seasons. Only one pair (14%) was present in 1987 on the sites where seven pairs were

Table 2. Histories of all cases where carbofuran was applied directly to the burrow on our study areas in 1986 & '87.

Site	date, method of application, distance and insecticide	Number of pairs	Observations
D	1 June 1986 aerial o.s. carbofuran	1	Failed. One adult but no young seen on repeated visits after spraying. No owls present in 1987.
C	14 June 1986 ground 50-400m carbaryl 17 June 1986 ground o.s. carbofuran	5	All nests failed. No owls observed on July 23 and 27. A single adult was observed on July 4,9,16,23 & 31 which did not give an alarm call when flushed & was not associated with a burrow. An owl with large brood patch and in heavy molt was trapped at one burrow 9 July. All burrows were excavated on July 9,15 or 16. Two more owls in similar condition were found in two of the burrows when excavated. In one there were eggshells and remains of chicks, the the other nothing. Another burrow contained an egg. * No owls present in 1987.
U	8 & 17 June 1986 ground o.s. carbofuran 14 June 1986 aerial o.s., carbaryl	1	Adults did not disappear. Four young first observed on July 21. One pair present in 1987.
ZD	14 June 1987 aerial o.s. carbofuran	5	Two pairs disappeared after spraying and were not seen again. Remaining 3 pairs raised 5, 5, and 2 young which emerged on the 5, 5, and 15 July.

* Therefore, at the most, 3 or 4 owls were associated with this pasture after the overspray and may not have been members of the original 5 nesting pairs. However, they did appear to be females whose breeding attempt had failed.

Table 2a. History of two cases where carbofuran was applied directly to the burrow as volunteered by farmers during our studies.

Site	Year, method of application, insecticide	Number of pairs	Observations
FD	1985 aerial carbofuran	3	Farmer reported all owls disappeared after spraying and were not seen again in 1985. No owls seen in 1986. One pair present in 1987.
FA	1986 aerial carbofuran	8	Farmer reported that all owls disappeared after spraying and were not seen again in 1986. Two pairs present in 1987.

oversprayed in 1986. Two farmers reported additional cases where colonies of three and eight pairs had been oversprayed with carbofuran in 1985 or 1986 and the adults disappeared. Only two pairs (18%) were present where there had been 11 the previous year. In contrast, only two of 14 burrows (14%) oversprayed with carbaryl in 1986 failed completely and nine pairs (64%) were present in 1987 where 14 were present in 1986. These reoccupancy rates may be compared to the overall reoccupancy rate between 1986 and 1987 of 71% at the seven unexposed sites on the Regina and Val Marie study areas.

The disappearence of adults after their nest burrow was oversprayed with carbofuran is markedly different from what was observed in cases were nests failed due to predators, cave-ins etc.. In those situations the adults remained in the vicinity of the nest burrow for several weeks following the event. We believe the disappearance of the adults and disproportionately low site reoccupancy in the following year suggest that they were poisoned following exposure to carbofuran.

Nest success increases with increasing distance of the carbofuran spray events from the burrow. Exposure through ingestion of contaminated prey, dermal and other routes, will decrease with increasing distance from the burrow as a function of the documented decrease in owl activity with increasing distance from the nest burrow. Our inability to detect impacts at increasing distances from the burrow may simply reflect a lower probability of exposure of the birds under observation. It is reasonable to assume that, to document impacts further from the burrow, would require study of a greater number of pairs than was necessary to detect impacts in close proximity to the burrow.

An independent confirmation of the impact of carbofuran on nesting Burrowing Owls was obtained in 1987. At every nesting site in the Regina and Moose Jaw study areas the landowners were approached and asked about their previous spraying activities (1982 to 1986). Thirty-nine landowners were identified who had sprayed for grasshoppers in 1985 and/or 1986. These landowners were asked whether they had ever used carbofuran (although not necessarily in 1985 or 1986). The 39 landowners were then divided on the basis of past carbofuran use. The frequency distributions of the number of active burrows per site for the two groups in 1987 differed markedly (Table 3). Farms where carbofuran had been used had smaller numbers of active burrows in 1987 than those where carbofuran had never been used. The difference in the mean number of active burrows per site was significant ($P = 0.005$) using a randomization test. To avoid any bias introduced by the fact that the four largest colonies (9,11,12 and 14 pairs) all occured in the no-carbofuran group, the analysis was repeated by incorporating these observations into a single group with five pairs or more and the randomization test repeated. The difference was still significant ($P= 0.01$).

Table 3. Comparison of the frequency distributions of the number of breeding pairs of Burrowing Owls present in 1987 relative to previous carbofuran use by the landowners. All sites included were occupied in 1986 and/or 1987 and all sites were treated with a grasshopper insecticide by the landowner in 1985 and/or 1986 as determined by interviews conducted in 1987.

Number of pairs on farm in 1987	Farms where carbofuran was used	Farms where carbofuran not used
0	1	0
1	9	3
2	9	2
3	2	3
4	3	0
5	1	2
9	0	1
11	0	1
12	0	1
14	0	1
Mean	2.0	5.1

2.3.3 Diet of Burrowing Owls

The 1454 regurgitated pellets collected from the vicinity of burrows on the three study areas in 1986 and 1987 indicate the temporal and spatial variation in the owls'consumption of rodents, grasshoppers (Orthoptera) and beetles (Coleoptera) in the diet in a year (1986) when grasshopper populations were agronomically significant and a year (1987) when their populations were generally below that necessitating chemical control (Table 4). In both years there was a decrease in the occurrence of rodents and a concomitant increase in the occurrence of grasshoppers as the summer progressed, leveling off by 15 July. The 1987 data for Moose Jaw and Regina more closely resemble the 1986 data for Val Marie than for Regina in 1986 and reflect the similarity in the relative severity of the grasshopper infestations. Our data are very similar to those reported by Haug (1985) for a minimum of 10 pairs of owls on her study areas near Saskatoon in 1982 when there was a severe grasshopper infestation in that area. The temporal trends she reports are very similar to those we observed (Figure 3).

A review of 22 studies conducted in 13 states and provinces revealed that the diet of Burrowing Owls in North America includes representatives of 2 phyla, 7 classes, 24 orders and over 69 families of animals (Table 5). Though this species is capable of capturing a wide variety of vertebrate and arthropod prey and is not dependent upon any single taxonomic group, rodents and insects (families Orthoptera and Coleoptera) were utilized in 90% or more of the locations and must be regarded as dietary staples. The considerable geographic and temporal variation in the reported diets suggests that this species is an opportunistic rather than a specialized predator. Although insects are numerically the most important prey taken in all areas, they represent a small fraction (6 to 32%) of the dietary biomass and may well be consumed in proportion to their relative availability (Marti 1974, Green 1983, Gleason and Johnson 1985). Vertebrates, particularly rodents, contribute the bulk of the biomass.

Are the Carbofuran-associated Impacts a Result of Food Removal?

In their studies of owls nesting in artifical burrows in Oregon, Henny and Blus (1981) identified 29 prey items *inside* the nest chamber *before* the young had emerged from the burrow; 28 were mammals representing eight genera and one was a young pheasant. Walker (1952) observed one brood in the nest chamber in Colorado. In a period of 100 minutes the young were supplied with 22 grasshoppers, 17 beetles, two lizards, a frog and a jumping mouse. During another hour, a small snake, a ground squirrel, grasshoppers and beetles were provided by the parents. These observations suggest that the young are fed some insects before they emerge from the burrow but that insects are a very small component of their dietary biomass. On the Regina study

Table 4. Variation in the occurrence of grasshoppers, beetles, and rodents in 1454 Burrowing Owl pellets collected at burrows in the Regina (R), Val Marie (VM), and Moose Jaw (MJ) study areas in 1986 and 1987.

		Totals represented			Percent Occurrence		
Week	Area	Farms	Burrows	Pellets	Hoppers	Beetles	Rodents
June 23	R-86	4	15	77	54	43	87
July 8	R-86	4	11	79	65	32	47
	VM86	7	12	95	47	41	74
July 15	R-86	1	5	50	94	32	26
	VM86	1	6	38	66	34	50
	R-87	23	?	230	50	43	55
	MJ87	9	?	99	35	49	77
July 22	R-86	13	49	459	89	38	26
July 29	R-86	4	7	41	85	78	19
	VM86	2	2	20	95	50	30
	R-87	1	?	4	100	50	0
	MJ87	4	?	56	75	39	39

Table 5. Occurrence of arthropod and vertebrate components of the diet of Burrowing Owls in two provinces and 12 states based on 23 studies (*). Those Orders and Families/Subfamilies most frequently identified are listed.

Class	Orders	Families	Genera	Percent Occurrence	
Crustacea	1	1	1	21	
Arachnida	2	2+	2+	50	
Insecta	9	39+		100	
	Coleoptera	18			100
	Orthoptera	6			93
	Hymenoptera	7			71
	Diptera	?			29
	Homoptera	1			21
	Lepidoptera	?			21
Arthropods 3	12	42+			
Amphibia	2	4	4	50	
Reptilia	2	4	7	43	
Aves	4	10	18	71	
		Alaudidae			50
		Eberizinae			43
		Icterinae			29
Mammalia	4	9	20	100	
		Soricidae			36
		Leporidae			50
		Sciuridae			50
		Heteromyidae			79
		Geomyidae			50
		Cricetidae			86
		Muridae			43
Vertebrates 4	12	27	49		

* Sources of data for Table 5.

Saskatchewan: Haug (1985), Fox (unpubl), this study

British Columbia: Canning et al. (1987)

Colorado: Longhurst (1942), Walker (1952), Hamilton (1941) Kelso (1938), and Marti (1974).

Oregon: Maser et al. (1971), Henny and Blus (1981), and Green (1983).

Idaho: Gleason (1978), Gleason and Craig (1979)

Iowa: Errington and Bennet (1935), Scott (1940)

California: Neff (1941), Thomsen (1971)

Oklahoma: Butts (1973)

New Mexico: Best (1969)

Utah: Smith and Murphy (1973)

Nevada: Bond (1942)

Arizona: Glover (1953)

Dakotas: Grant (1965), James and Seabloom (1968)

Minnesota: Grant (1965)

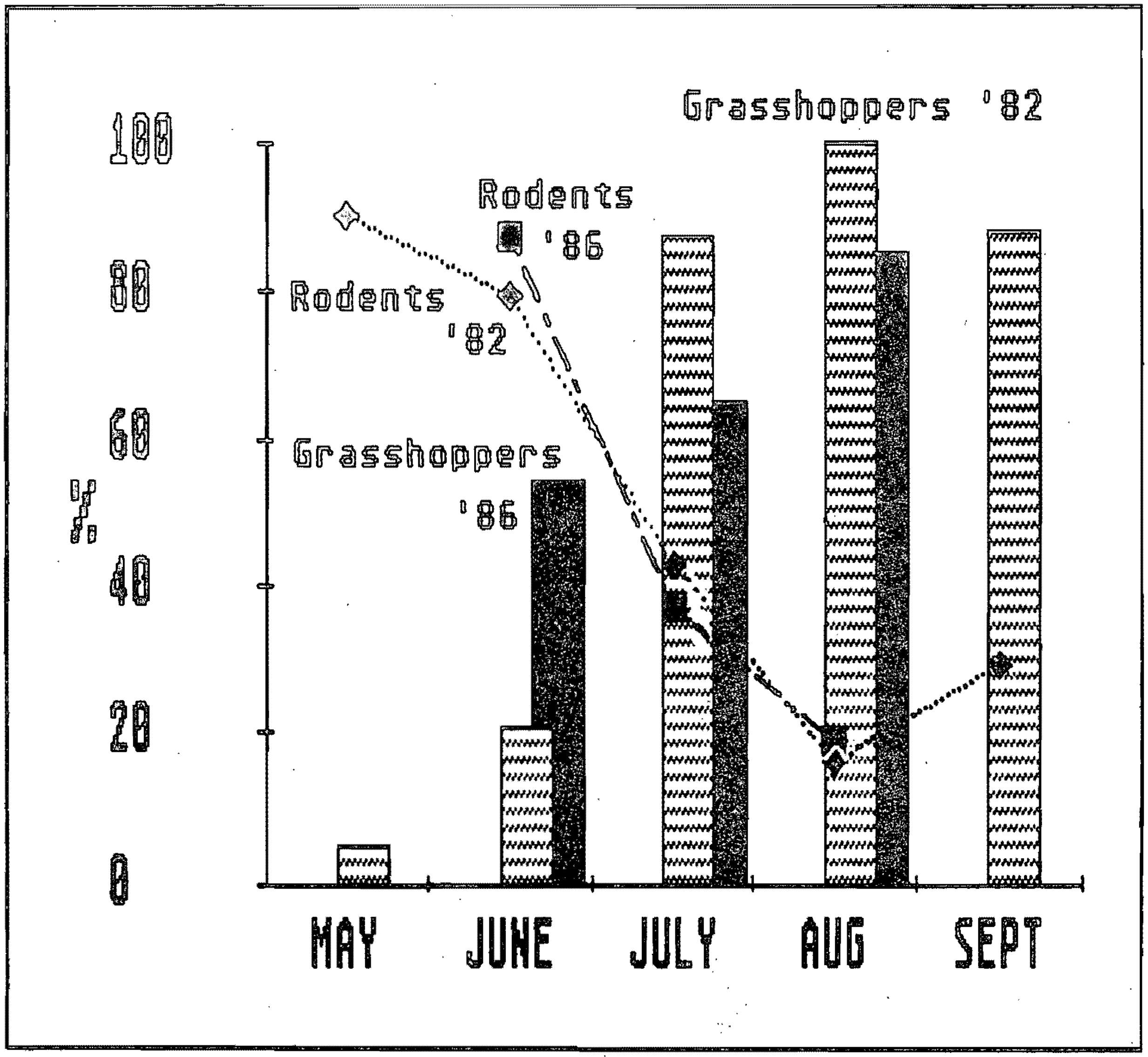

Figure 3. A comparison of the temporal variation in the occurrence of grasshoppers and rodents in owl pellets collected in 1986 on the Regina study area with pellets collected in 1982 by Haug on her study area west of Saskatoon. The data for all samples in any month are pooled.

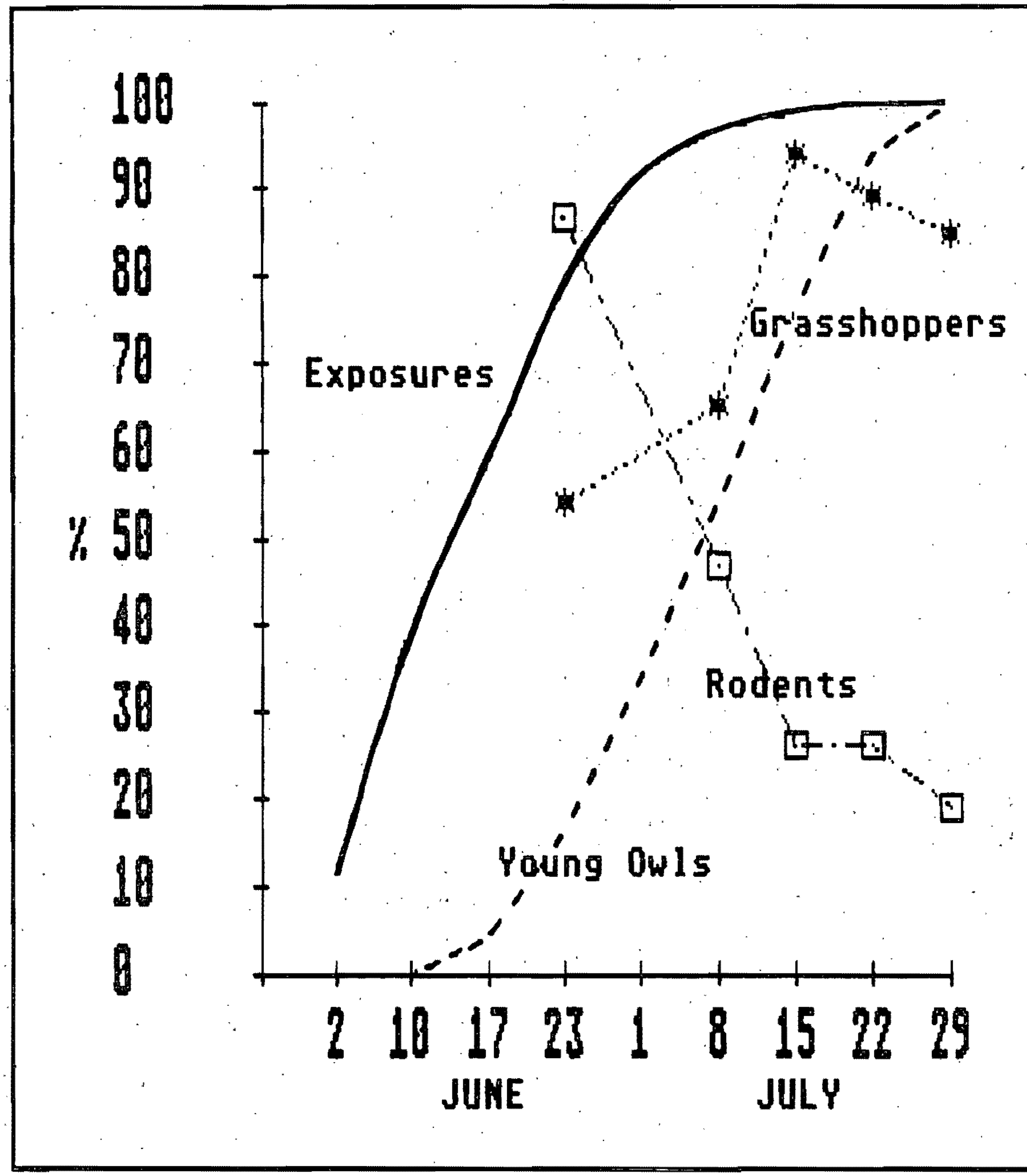

Figure 4. Variation in the occurrence of rodents and grasshoppers in the pellets of Burrowing Owls on the Regina study area in 1986 in relation to the timing of insecticide exposures and emergence of young owls both of which are plotted cummulatively.

area, 80% of the insecticide exposures had occurred by 30 June 1986 but only 16% of the broods had emerged although approx. 50% had hatched (Figure 4). At this time, rodents occurred in 87% of the pellets and grasshoppers in only 54%. The majority of spraying occurred before the young emerged, at a time when their diet is entirely provided by the parents. The occurrence of grasshoppers increases in the diet in parallel to the emergence of young owls, suggesting that the young owls are fed and prey upon grasshoppers and other insects in the vicinity of the burrow. Insects provide an abundant, easily caught protein source.

Brusnyk and Westworth (1987) studied the effects of a controlled application of carbofuran on unconfined cricetid rodent populations during the grasshopper infestation of 1986 on the grasslands near Youngstown, Alberta. They retrapped disproportionately fewer of their tagged *Peromyscus maniculatus* and *Microtus pennsylvanicus* in the 72 hours immediately following spraying and a month later than on their unsprayed control sites, suggesting a carbofuran-induced population response. However, the populations of both species remained relatively stable with young animals comprising the majority of the unmarked animals captured post-spray, suggesting that immigration from adjacent habitats was rapid. Moreover, 2.0 ppm of carbofuran was detected in the pooled gastro-intestinal tracts of the *Peromyscus* collected on the experimental site. These findings suggest that carbofuran contamination of rodents within the home ranges of Burrowing Owls is more likely to affect the owls through secondary poisoning than via food removal.

On the Regina and Moose Jaw study areas, 99% of the broods had emerged by 21 July 1987. At this time grasshoppers occurred in only 45% of the pellets and rodents in 69%. Grasshopper numbers were much lower and peaked later in 1987 than in 1986 and the owls relied less heavily upon them. However, in the Regina area broods were larger (4.0 *vs* 3.2) and overall nest success equivalent (70% *vs* 71%) in 1987. Similarly, Green (1983) in his studies of Burrowing Owls nesting in the Columbia basin of Oregon, reported that grasshoppers were present in "epidemic" numbers (40 per m^2 on some sites) in 1980 but numbers were much lower in 1981. In 1980 grasshoppers accounted for 31% of the insects present in pellets. This proportion dropped to 3% in 1981, however owl nest success was similar in both years.

Two phyla, 5 classes, 9 orders and at least 18 families of animals have been identified in the diet of Burrowing Owls in studies in Saskatchewan (Table 5) suggesting that their diet is diverse. It is therefore highly unlikely that the temporary elimination, by any insecticide, of the rodents and insects within the home range of a pair of breeding owls would result in a food shortage which would lead to nestling mortality or territorial abandonment. Although they may differ in their initial rate of knockdown, the various insecticides applied to control grasshoppers in Saskatchewan are of roughly equivalent efficacy although their toxicity to wild rodents differs.

2.3.4 Additive/Synergistic Effects of Multiple Exposures

In 1986, 76 pairs were exposed to insecticidal sprays within 400 m of their burrow. The median number of exposures per pair was two (range 1 to 8) and the median interval between exposures was eight days (range 2 to 19). Thirty-two of the 36 applications involved cholinesterase inhibitors. We therefore recognise the need to address the question of impacts resulting from additive and/or synergistic cholinesterase inhibition as well as cumulative food removal.

The relatively long median interspray interval and relatively short environmental half-life of the cholinesterase-inhibiting insecticides applied on our study areas mitigate against additive/cumulative cholinesterase inhibition. The greatest impact was noted with carbofuran when it was applied directly over the burrow. A minimum of 12 of the 24 adults (50%) from the 12 pairs so exposed disappeared after the carbofuran overspray; at 11 of these burrows there was only one carbofuran application and carbofuran was the only agent oversprayed. We therefore do not believe that synergism was a significant contributor to the impacts documented. However, to completely eliminate possible synergistic or additive effects from multiple spray exposures, much more fundamental research would be required to elucidate the potential interactions resulting from multiple chemical exposures involving carbofuran and carbaryl, chlorpyrifos, and deltamethrin as well as the large number of herbicides used in prairie agriculture today.

2.4 CONCLUSIONS

1. Exposure to carbofuran (Furadan 480F) within 50 m of the nest burrow without direct overspray, resulted in statistically nonsignificant reductions of 17% in brood size and of 27% in nesting success relative to all burrows exposed to an insecticide other than carbofuran. If the impact results from exposure to carbofuran via ingestion of contaminated prey, dermal and othe routes, larger sample sizes would be required to adequately define a minimum distance from the burrow at which carbofuran could be applied safely. Owl foraging movements greater than 2.7 km have been recorded and it is therefore conceivable that exposure through contaminated food could occur at such distances.

2. Direct overspraying of the burrow with carbofuran resulted in an 83% reduction in brood size and an 82% reduction in nesting success. Adults disappeared from the majority of oversprayed nest burrows shortly after spraying occured, resulting in total nest failure.

3. Overspraying nesting sites with carbofuran reduces both the chances that the site will be reoccupied and the number of pairs present in the following year.

4. The other insecticides applied did not have a similar impact although we caution that there were probably too few data to be sure about the safety of any insecticide other than carbaryl (Sevin).

5. Efficacy testing is a prerequisite for registration of pesticides in Canada and insecticides other than carbofuran hold a significant share of the grasshopper control market. Therefore, although they may differ in their initial rate of knockdown, it is reasonable to assume that the various insecticides applied during our study are of roughly equivalent efficacy. We would therefore not expect a greater degree or duration of insect removal with carbofuran than with the other agents used. Small mammal mortality may be significant in the case of carbofuran, but a recent Alberta study indicated that replacement rates, via immigration are very rapid. Carbofuran was the only insecticide with a detectable impact, therefore ruling out food removal as the mechanism of action. Burrowing Owls are extremely opportunistic in their food habits and it is unlikely that application of any insecticide would result in a temporary food shortage severe enough to result in nestling mortality or abandonment of territories. We therefore hypothesize that carbofuran's impacts on this species are the result of its toxicity to the owls.

6. Carbofuran is known to be extremely toxic to a number of bird species and there is a long history of bird kills associated with this insecticide (Appendix 1).

7. The impact of grasshopper insecticides on other species of prairie wildlife should be assessed, particularly those species which are threatened, endangered, or whose populations are declining. The apparent sensitivity of waterfowl to carbofuran and the large number of dabbling ducks directly exposed to this chemical is of immediate concern.

3. POTENTIAL HAZARD TO BURROWING OWLS RESULTING FROM REGISTERED USES OF CARBOFURAN FLOWABLE AND ALTERNATIVE INSECTICIDES.

3.1 INTRODUCTION

Hazard is a function of toxicity and exposure. Like many cholinesterase-inhibiting insecticides, carbofuran has been registered for control of a wide variety of insect pests. In the previous section we have documented carbofuran's high toxicity to Burrowing Owls. In this section we assess the potential for exposure, based upon current knowledge of the distributions of breeding Burrowing Owls and the pest-crop combinations for which Furadan 480F is currently registered.

3.2 GRASSHOPPER CONTROL IN ALFALFA, BARLEY, FLAX, HEADLANDS, MUSTARD, OATS, PASTURES, RAPE, ROADSIDES, SWEET CLOVER AND WHEAT

The use of insecticidal sprays to control agronomically significant grasshopper outbreaks has the potential to expose more Burrowing Owls than any other pest-control program in the Prairie Provinces. All of the owl data reported herein were obtained during such an outbreak which began in 1981 (in Saskatchewan at least - A.Ewen pers. comm.) and peaked in 1985 and 1986. The use of insecticides was most extensive during those two years. Sheehan et al. (1987) estimated that, in 1985, 2.7 - 3.6 million hectares were sprayed at least once in Saskatchewan. Madder and Stemeroff (1986) estimated *sprayed wheat areas only* for the years 1980-1985 (Table 6). If their estimate is correct, the 1985 estimate of Sheehan et al. for total spray area is low, as a large proportion of grasshopper spraying takes place in non-crop areas. An estimated 700,000 hectares of land were sprayed in Alberta in 1985 (D.Johnson and L.Kok, pers. comm.).

Our studies demonstrate that exposure of Burrowing Owls to grasshopper insecticides is likely if infestations occur where owls are nesting. The full extent of overlap has not been documented. We tested for the broad spatial association between Burrowing Owls and grasshopper distribution to see whether carbofuran could still be used as a grasshopper control agent in some parts of the Prairies with little likelihood of exposure of Burrowing Owls. This analysis was most detailed for Saskatchewan and Alberta where most of the grasshopper spraying takes place. Wedgwood (1978) estimated that 1,280 pairs of the estimated 2,000 pairs of owls in Canada nest in Saskatchewan.

Saskatchewan

Locations of sites of Burrowing Owl colonies in Saskatchewan were obtained from Didiuk (1986) and W. Harris (pers. comm.). Most sites were identified during the period 1970-1985. There has not been a concurrent comprehensive survey of all these sites. Approximately 70% of these sites were occupied during the period

Table 6. Number of hectares of wheat treated at least once for grasshopper control in the Prairie Provinces; 1980 to 1985.

PROVINCE	YEAR					
	1980	1981	1982	1983	1984	1985
Manitoba	0	0	0	6,305	21,804	97,634
Saskatchewan	49,854	10,179	610,687	175,917	622,183	2,098,362
Alberta	0	5,422	0	18,690	21,0221	551,649
TOTAL	49,854	15,601	610,687	200,912	854,208	2,747,645

From: Madder and Stemeroff (1986).

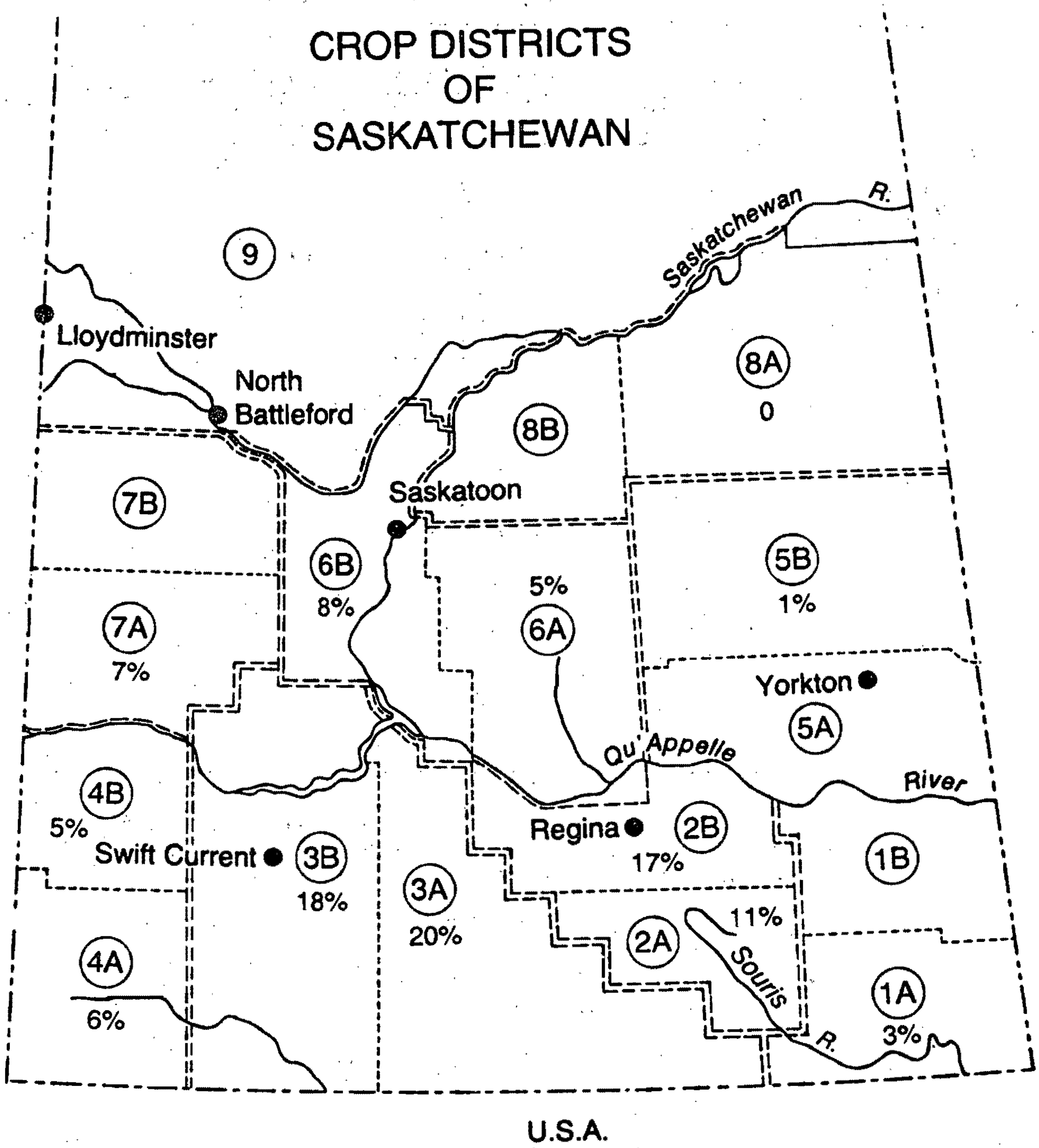

Figure 5. Crop districts and rural municipalities of Saskatchewan and proportion of Burrowing owl nesting sites recorded in the 1980s located in each.

Table 7. Mean grasshopper infestation score for 1985-86, number of Burrowing Owl nesting sites and Percentage of wheat crop sprayed in 1985 by crop district in Saskatchewan.

	CROP DISTRICT	85-86 MEAN INFESTATION SCORE [a]	NESTING SITES	% OF WHEAT AREA SPRAYED IN 1985. [b]
Control measures not usually required	5B	0.00	0	0.0
	8A	0.00	0	0.0
	8B	0.32	1	0.0
	9A	0.39	0	0.0
	9B	1.24	2	5.0
	7B	1.37	2	12.0
	5A	1.38	1	0.1
	1B	1.79	5	30.0
Control measures may be required	6A	2.11	49	10.0
	6B	2.50	83	49.0
	7A	2.58	67	85.0
	1A	2.63	30	30.0
	2B	2.79	164	25.0
	3A-S	3.00	143	7.0 [c]
	3B-N	3.11	110	79.0 [c]
	4A	3.17	57	13.0
	2A	3.27	108	30.0
	3B-S	3.33	65	79.0 [c]
	3A-N	3.58	51	7.0 [c]
	4B	3.70	54	13.0

a. Calculated by giving each rural municipality-year combination equal weight. 0=unsurveyed and normal, 1=light, 2=moderate, 3=severe and 4=very severe.

b. From Madder and Stemeroff (1986).

c. Madder and Stemeroff did not distinguish between 3A-N and 3A-S and between 3B-N and 3B-S.

1980 - 1988 (W. Harris, pers. comm.). The number of pairs present at each site is not known. Wedgwood (1978) concluded, on the basis of historical records, that the overall range of the species had not changed in Saskatchewan, despite a reduction in population size. Therefore, the data used here represent the best possible estimate of the range of the Burrowing Owl in Saskatchewan. The colony sites were partitioned by crop district (Figure 5) and their distribution compared to two separate measures of grasshopper infestations:

1. Infestation forecasts for 1985 and 1986. Although infestation forecasts are poor predictors of future insecticide use (Sheehan et al. 1987), they are useful in providing a relative measure of infestation severity once we know that the infestation has indeed materialized and that spraying has taken place.

2. Estimates of the proportion of wheat treated for grasshopper by Madder and Stemeroff (1986). The main drawback of these estimates are that their confidence intervals are unknown and that they do not take into account the large proportion of spraying that takes place on crops other than wheat or on non-crop land.

The results of this comparison are given in table 7. Saskatchewan Agriculture suggests that, in areas of moderate infestation forecast and higher (2 or more on our numerical scale), control measures may be required. Ninety-nine percent of all Burrowing Owl nesting sites in Saskatchewan occur in crop districts in which grasshopper infestations in 1985-86 potentially needed control. A Spearman rank correlation between the number of nest sites and mean infestation score was calculated to be +0.762 ($P<0.001$). The Spearman rank correlation between the number of owl nesting sites and the spray estimates of Madder and Stemeroff was +0.657 ($P<0.001$).

Alberta

In Alberta, nesting is broadly distributed with a concentration in the southeast area of the province corresponding to crop districts 1, 2, and 3 (Figure 6). Spraying of wheat was most extensive in crop districts 1 and 2 (Table 8). Ninety-eight percent of the total hectarage treated in 1984-85 was in the crop districts known to be of importance to breeding Burrowing Owls. Researchers at the Agriculture Canada Research Station in Lethbridge have mapped the intensity of grasshopper insecticide use by county in Alberta in 1985 and 1986 and have superimposed the locations of the known Burrowing Owl breeding sites on these maps for us (D. Johnson and L. Kok, pers. comm.). The 289 nesting sites were distributed among 18 counties. The Spearman rank correlation between the total hectares sprayed and the number of owl nesting sites, on a county basis, was +0.691 ($P<0.001$) in 1985 and +0.504 ($P<0.05$) in 1986. In 1986,

Table 8. Number of hectares of wheat treated for grasshoppers in Alberta by crop district, 1984-1985, in relation to Burrowing Owl nesting distribution.

DISTRICT	1984	1985	IMPORTANCE TO BURROWING OWLS
1	82,200	124,108	39%
2	126,500	396,868	52%
3	272	14,220	7%
4	734	762	2%
5	92	5,270	-
6	88	10,036	-
7	335	385	-

From: Madder and Stemeroff (1986).
G.L. Erickson, (pers. comm.)

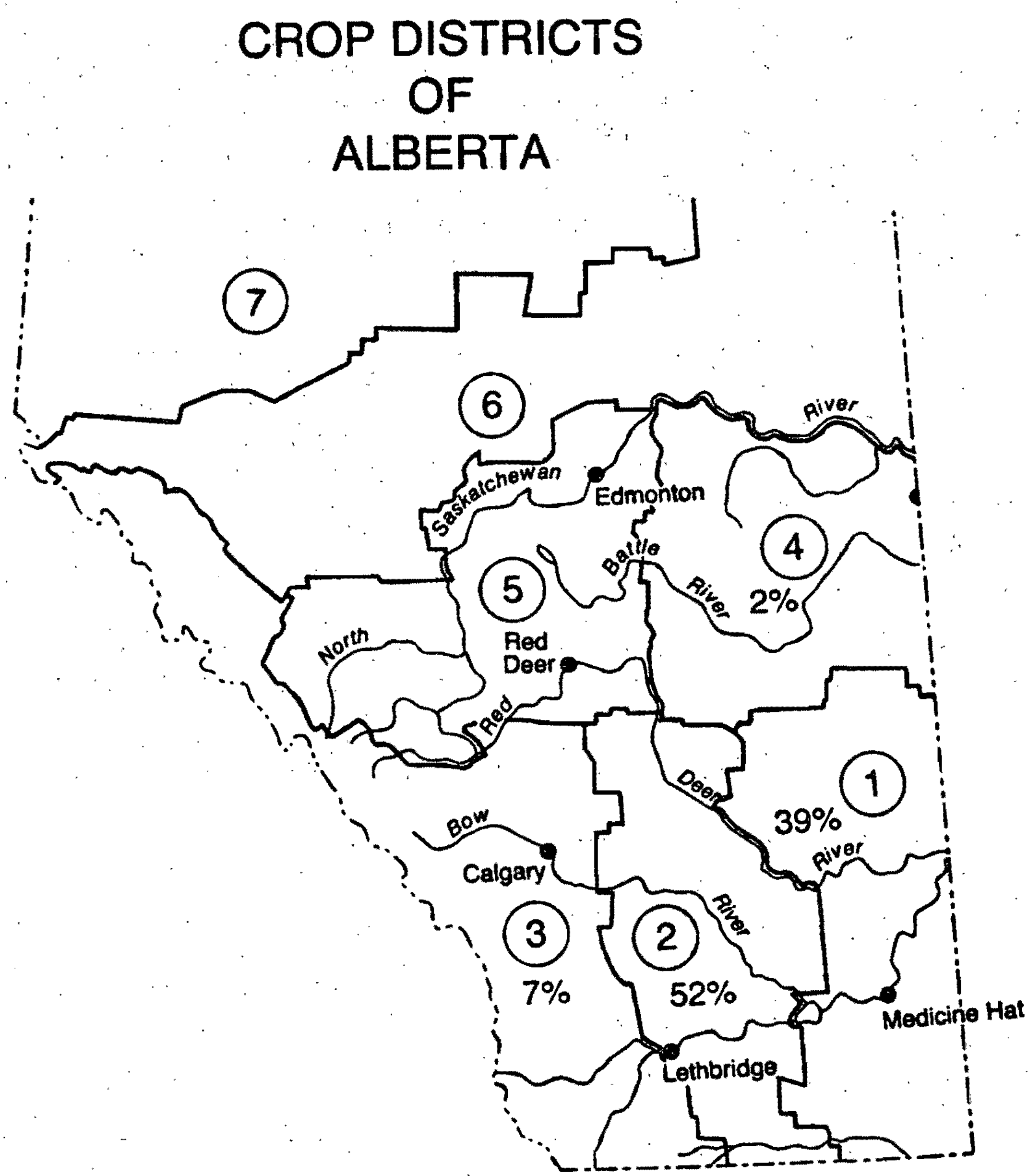

Figure 6. Crop districts of Alberta and approximate proportion of recent Burrowing Owl nesting sites located in each.

Carbofuran accounted for 67% of the area sprayed, deltamethrin for 15%, dimethoate for 7%, chlorpyrifos for 5%, carbaryl for 4% and malathion the remainder.

Manitoba

In Manitoba, most of the Burrowing Owls were concentrated in the southwest corner of the province (Ratcliff 1986, E.A. Haug, pers. comm.) in crop districts 1 and 2 and to a lesser extent, districts 3, 7 and 8 (Fig. 7). According to Madder and Stemeroff, most of the spraying of wheat crops during the last grasshopper infestation took place in districts 1,2,7 and 8 (Table 9). Ninety-five percent of the area sprayed to control grasshoppers in Manitoba in 1985 was in the crop districts where Burrowing Owls nest.

Based on the above and our own exposure data generated in 1986, we conclude that, in the three Prairie Provinces, the distribution of agronomically significant grasshopper infestations is so similar to the nesting distribution of Burrowing Owls that no grasshopper insecticide (including carbofuran) can be used without potentially exposing a large proportion of the Burrowing Owl population.

Alternatives to carbofuran

Alternative insecticides registered by Agriculture Canada for grasshopper control are as follows (Agriculture Canada 1987):

Wheat: Azinphos-methyl, carbaryl, chlorpyrifos, cypermethrin, deltamethrin, dimethoate, malathion.

Barley: Azinphos-methyl, carbaryl, chlorpyrifos, cypermethrin, deltamethrin, dimethoate, malathion.

Flax: Deltamethrin, malathion.

Oats: Azinphos-methyl, carbaryl, chlorpyrifos, deltamethrin, dimethoate, malathion.

Mustard: Malathion.

Alfalfa: Azinphos-methyl, carbaryl, dimethoate, malathion, methoxychlor, parathion.

Sweet Clover: Carbaryl, dimethoate.

Pastures: Carbaryl, diazinon, dimethoate, malathion, naled, parathion.

'Headlands' or 'roadsides' are not currently listed as sites of use by Agriculture Canada. A number of the above products are used along roadsides and field edges and perhaps some label

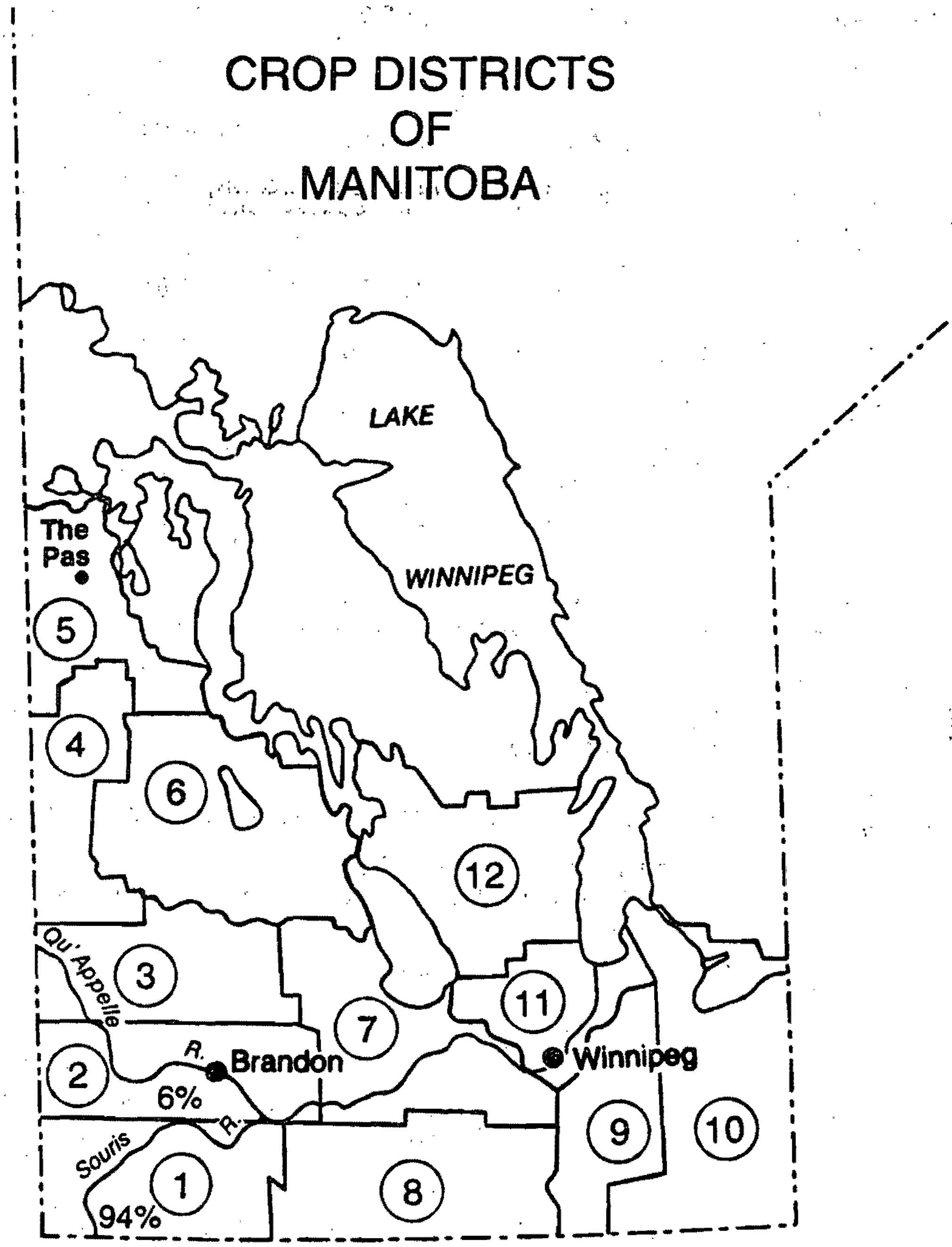

Figure 7. Crop districts of Manitoba and proportion of Burrowing Owl nesting sites occupied in 1987 located in each.

Table 9. Number of hectares of wheat treated for grasshoppers in Manitoba by crop district, 1983-1985, in relation to Burrowing Owl nesting distribution.

DISTRICT	1983	1984	1985	IMPORTANCE TO BURROWING OWLS
1	1,260	1,560	30,816	***
2	1,940	11,088	33,242	***
3	1,035	2,020	1,366	*
4	440	470	4,880	
5,6	0	0	0	
7	0	0	12,140	*
8	1,630	6,666	15,190	*
9,10	0	0	0	

*** Very important

* Somewhat important

From: Madder and Stemeroff (1986).
Ratcliff (1986), E.A. Haug (pers. comm.)

clarifications would be useful. Indeed, this is one aspect of grasshopper spraying that ensures a high degree of exposure of Burrowing Owls. Much of the spray is not applied to the crop proper but rather on the egg beds near the crops. Furthermore, a number of pesticide-crop combinations do not presently appear as alternatives probably more by omission than for any scientific reason. One reason for the attractiveness of carbofuran may be its straighforward marketing in that only one formulation is registered for a large number of use sites, and, with the exception of one pest (alfalfa weevil), always at the same rate of application. In contrast, many of the alternatives show a confusing array of products, rates and recommendations. Also, carbofuran is undoubtedly a popular choice by virtue of its competitive price (L. Harris and A. B. Ewen, pers. comm.)

Not all of the alternatives listed above are likely to be used. Some of them (.eg. parathion, diazinon) are also known to be very toxic to a number of wildlife species. However, on the basis of information in Sheehan et al. (1987) and Madder and Stemeroff (1986), as well as information received through our contacts and surveys of farmers on whose lands Burrowing Owls nested, we would expect carbaryl, deltamethrin and to a lesser extent chlorpyrifos and dimethoate to divide up the current market share held by carbofuran should the use of the latter for grasshopper control be curtailed.

Not all of the alternative insecticides were recommended by the provincial departments of agriculture in 1986 (Manitoba Agriculture 1986, Saskatchewan Agriculture 1986, Alberta Agriculture 1986). In tables 10 and 11, the relative toxicity of those insecticides recommended by at least one provincial agriculture department are given for two 'indicator species': the Mallard and Ring-necked Pheasant. For the Mallard, there is a marked difference between the risk factor for carbofuran and that of the next-most toxic insecticide. With the pheasant, the difference is not as marked although carbofuran is still the most toxic. Some concerns have been expressed with respect to the high aquatic invertebrate toxicity of the synthetic pyrethroids (deltamethrin and cypermethrin) and chlorpyrifos which may mitigate against aerial delivery of these products in some parts of the prairies. This issue is currently under discussion between Agriculture Canada and the Canadian Wildlife Service. Current estimates place the extent of aerial application for grasshopper control at 13% or less (Sheehan 1987).

The data of Madder and Stemeroff (1986) suggest a gradual shift away from carbofuran toward the four alternative insecticides mentioned above for grasshopper control in wheat. This suggests that users are satisfied with the efficacy and cost-effectiveness of these alternatives. Also, it has been suggested that users may not be comfortable with the high mammalian toxicity of carbofuran (L. Harris, pers. comm.) However, as recently as 1986, carbofuran accounted for 67% of the

Table 10. Relative risk factor for the 3-4 month old pheasant in the form of LD_{50} - equivalent doses applied per m^2 based on 1986 recommendations for the three Prairie Provinces.

Insecticide[a].	LD_{50}[b]. (mg/kg)	No. of LD_{50} - equivalents per m^2 for 1 kg. pheasant [c].							
		grasshoppers on cereals	grasshoppers on forage	grasshoppers on oilseeds	grasshoppers on pastures	alfalfa weevil	fleabeetle in Canola	Red turnip beetle in Canola	Sunflower beetle
carbofuran	2.4-7.2	1.9-5.6[d].	1.9-5.6	1.9-5.6	1.9-5.6	3.7-11	1.9-5.6	1.9-5.8	1.9-5.8
chlorpyrifos	12-25	1.9-4.0		1.9-4.0					
dimethoate	16-25	2.0-3.1	1.9-3.0	1.7-2.7	1.9-3.0	1.9-3.0			
methidathion	17-64			0.49-1.8		0.83-3.1	0.28-1.0	0.41-1.5	0.83-3.1
azinphos methyl	59-94	0.45-0.71	0.45-0.71			0.88-1.4	0.14-0.23	0.22-0.35	0.28-0.45
endosulfan	80-263								0.24-0.70
malathion	120-230	0.38-0.72	0.59-1.1	0.38-0.72	0.38-0.72	0.59-1.1	0.38-0.72		
carbaryl	500- 2000	0.084-0.34	0.056-0.22	0.030-0.12	0.084-0.34	0.090-0.36	0.030-0.12		

a. Excluding synthetic pyrethroids. Their direct toxicity is assumed to be negligible. Also, comparable toxicity data are lacking for methamidophos and methoxychlor.

b. Comparable data from Hudson et. al. (1984), 95% conf. interval for both sexes and 3-4mo. old birds only (technical a.i.).

c. Based on the highest rate of application recommended in either Alberta Agriculture (1986), Saskatchewan Agriculture (1986), or Manitoba Agriculture (1986).

d. Meaning that each m^2 receives 1.9-5.6 median lethal doses for a 1 kg. pheasant. A median lethal dose is the quantity of chemical necessary to kill half of the test population.

Table 11. Relative risk factor for the 3-4 month old Mallard in the form of LD_{50} - equivalent doses applied per m^2 based on 1986 recommendations for the three Prairie Provinces.

Insecticide[a].	LD_{50}[b]. (mg/kg)	No. of LD_{50} - equivalents per m^2 for 1 kg. mallard [c].							
		grasshoppers on cereals	grasshoppers on forage	grasshoppers on oilseeds	grasshoppers on pastures	alfalfa weevil	fleabeetle in Canola	Red turnip beetle in Canola	Sunflower beetle
carbofuran	0.31-0.50	27-44[d].	27-44	27-44	27-44	53-86	27-44	28-45	28-45
methamidophos	6.7-11			5.4-8.9					
methidathion	16-34			0.92-2.0		1.6-3.3	0.52-1.1	0.76-1.6	1.6-3.3
endosulfan	24-46								1.2-2.3
dimethoate	30-88	0.56-1.6	0.54-1.6	0.49-1.4	0.54-1.6	0.54-1.6			
chlorpyrifos	35-160	0.30-1.4		0.30-1.4					
azinphos-methyl	98-190	0.22-0.43	0.22-0.43			0.44-0.85	0.071-0.14	0.11-0.21	0.14-0.27
malathion	1000-2100	0.041-0.087	0.065-0.14	0.041-0.087	0.041-0.087	0.065-0.14	0.041-0.087		
methoxychlor	2000		0.077			0.077			
carbaryl	2600	0.065	0.043	0.023	0.065	0.069	0.023		

a. Excluding synthetic pyrethroids. Their direct toxicity is assumed to be negligible.

b. Comparable data from Hudson et. al. (1984), 95% conf. interval for both sexes and 3-4 month old birds only (technical a.i.).

c. Based on the highest rate of application recommended in either Alberta Agriculture (1986), Saskatchewan Agriculture (1986) or Manitoba Agriculture (1986).

d. Meaning that each m^2 receives 27-44 median lethal doses for a 1 kg. mallard. A median lethal dose is the quantity of chemical necessary to kill half of the test population.

area sprayed in Alberta (D. Johnson and L. Kok, pers. comm.).

3.3 CONTROL OF THE ORANGE WHEAT BLOSSOM MIDGE IN WHEAT

The wheat midge has recently been elevated to the status of major pest following wheat yield losses in 1982 and 1983 in the Nipawin-Tisdale-Hudson Bay-Carrot River area of Saskatchewan (Saskatchewan Agriculture undated). In 1984, the Canadian Wildlife Service, in its advisory role in the pesticide registration process, agreed to the emergency registration of dimethoate, chlorpyrifos, methoxychlor, permethrin and deltamethrin, the latter two by ground application only. CWS was not consulted regarding the registration of carbofuran for this pest. Currently, carbofuran, dimethoate and chlorpyrifos are registered for this pest (Agriculture Canada 1987, R. Lidstone pers. comm.)

The area treated for the wheat midge in Saskatchewan and Manitoba was estimated by Madder and Stemeroff (1986) and is summarized in table 12. In Saskatchewan, treatment was confined to crop districts 5A, 5B, 8A and 8B. In Manitoba, crop districts 5 and 9 received treatment. From tables 7 and 9, it appears that the overlap between treatment for wheat midge and Burrowing Owls will be minimal unless there is a dramatic expansion of the range of this pest. For this reason, alternative insecticides were not investigated any further. Currently, chlorpyrifos is the product most frequently used (L. Harris, pers. comm.).

3.4 CONTROL OF THE ALFALFA WEEVIL IN ALFALFA

The Alfalfa Weevil is probably not a major pest on the Canadian prairies. Only one infestation (1,214 ha in Alberta in 1979) was described between 1970 and 1983 in the Canadian Agricultural Insect Pest Review (Sheehan et al. 1987) although this source cannot be relied upon as an exhaustive list of the number of treated hectares for these 'minor' pests. Alfalfa is grown for hay or seeded in tame pasture, usually in conjunction with grasses. Farmers in Saskatchewan (at least) are currently being encouraged to increase the number of hectares seeded to alfalfa (Saskatchewan Agricultural Services Co-ordinating Committee 1984).

The distribution of alfalfa in Alberta was examined on the basis of the 1986 Census of Agriculture (Table 13). This distribution was compared to the Burrowing Owl nest distribution discussed previously. It appears that alfalfa is broadly distributed and extensively overlaps the range of the owl. Fifty-eight percent of the total hectarage seeded to alfalfa in 1986 was in crop districts important to breeding Burrowing Owls. We have no information on the relative likelihood of treatment for alfalfa weevil but two factors are cause for concern:

Table 12. Number of wheat hectares treated for wheat midge by treated district in Saskatchewan and Manitoba; 1984-85

PROVINCE	DISTRICT	1984	1985
Saskatchewan	5A	19,430	3,952
Saskatchewan	5B	43,140	13,855
Saskatchewan	8A	35,878	13,020
Saskatchewan	8B	17,994	9,440
Manitoba	5	28,017	14,736
Manitoba	9	750	2,202

From: Madder and Stemeroff (1986).

Table 13. Number of hectares seeded to alfalfa and alfalfa mixtures by crop district in Alberta (198)* and relative importance of these crop districts to Burrowing Owls based on nesting distribution.

CROP DISTRICT	ha	IMPORTANCE TO BURROWING OWLS
1	58,711	39%
2	101,708	52%
3	119,791	7%
4	112,477	2%
5	194,872	-
6	159,305	-
7	63,789	-

From: Statistics Canada (1982 and 1987), G.L. Erickson (pers. comm.)

* Calculated on the basis of "all tame hay" multiplied by the proportion of "all tame hay" that was "alfalfa mixtures" in each crop district in 1981

1. *The rates of application of all insecticides used for the control of alfalfa weevils are substantially higher than the rates registered for the same chemicals to control grasshoppers. According to the calculations presented in table 11, the recommended rate for carbofuran is such that approximately 53-86 "Mallard lethal dose-equivalents" are applied for each meter square of crop. This represents an unprecedented risk factor for the Mallard or any other species with a similar sensitivity to this chemical.*

2. Adult male Burrowing Owls in Saskatchewan showed a distinct preference for 'hayland' in their foraging activities (Haug 1985). This habitat category included alfalfa and other forage crops. Ratcliff (pers. comm.) working in Manitoba has observed owls foraging in alfalfa fields when burrows were located nearby. Gleason and Craig (1979) working in Idaho, documented several burrows on the edge of alfalfa fields. They speculated that the owls were attracted to this crop because of the large populations of rodents inhabiting it. Scott (1940) in Iowa, documented a burrow within a field of alfalfa.

It should also be kept in mind that the use of carbofuran in alfalfa has given rise to several instances of wildlife mortality, notably of waterfowl (see Appendix 1).

Alternatives to carbofuran

The registered alternatives for this specific use pattern are azinphos-methyl, carbaryl, deltamethrin, dimethoate, malathion, methidathion, methoxyclor and phosmet (Agriculture Canada 1987). As seen in tables 10 and 11, all alternatives are much less toxic to the Mallard and the Ring-necked Pheasant. All but phosmet were recommended by at least one provincial department of agriculture in 1986 (Manitoba Agriculture 1986, Saskatchewan Agriculture 1986, Alberta Agriculture 1986).

3.5 CONTROL OF FLEA BEETLES AND RED TURNIP BEETLES IN RAPE (CANOLA) AND MUSTARD

Information on insecticide use on canola is available from Madder and Stemeroff (1986). We did not find the equivalent figures for mustard. However, the latter is a minor crop when compared to canola (88,000 ha vs. 1.4 million ha in 1981 and 169,000 ha vs. 2.2 million ha in 1988 - Statistics Canada 1982 and 1987). Eighty-three percent of the mustard seeded in 1986 was seeded in Saskatchewan.

Flea beetles (*Phyllotreta* and *Psylliodes* spp.) are a regular pest of canola and, in most crop districts, greater than 80% of the seeded area is treated for this pest every year. However, an estimated 94-97% of the treatment is accomplished by means of treated seed or insecticide granules which are soil-incorporated at seeding. These methods of treatment pose their own hazards to some species of birds, notably small songbirds (Canadian Wildlife Service unpublished and Appendix 1) but this is outside the scope of the present discussion. The hazards of secondary poisoning of Burrowing Owls as a result of their vertebrate prey eating treated seed or granular insecticides have not been investigated. In table 14, the number of hectares of canola subjected to an insecticide spray are given by census district for 1985 (Madder and Stemeroff 1986). Given the stable nature of this pest, we do not expect dramatic changes from one year to the next. The total number of hectares planted to canola in the prairies seems to have peaked and has now stabilized (Sheehan et al. 1987). We estimate that approximately 31,000 ha of canola would be treated with foliar insecticides in those crop districts of importance to Burrowing Owls (35% of the total hectarage treated). Of the available foliar insecticides, the market share of carbofuran in the period 1980-1985 has been estimated to be 34-100% for Alberta, 63-100% for Saskatchewan and 45-94% for Manitoba (Madder and Stemeroff 1986).

However, no data are available to assess the desirability of this crop as a foraging site for the owls. A certain amount of exposure through drift would seem inevitable in those cases where nesting takes place in close proximity to canola fields. Spraying normally would take place from May to late June.

Carbofuran is also registered for the control of red turnip beetle (*Entomoscelis americana*) in canola. This appears to be a minor pest and does not even appear in Madder and Stemeroff's survey of canola insecticides. No infestations were reported in the Canadian Agricultural Insect Pest Review between 1970 and 1983 (Sheehan et al. 1987) although, as outlined earlier, this is not a reliable indicator because pests are not systematically inventoried. Spraying for this pest would take place between mid-May to mid-June (Sheehan et al. 1987). The 1986 Manitoba Insect Control Guide (Manitoba Agriculture 1986) recommends that control include spraying of the field margins which may increase the chance that Burrowing Owls will be exposed.

Alternatives to carbofuran

The following alternatives are registered for the foliar control of flea beetles in canola and/or mustard: azinphos-methyl, carbaryl, cypermethrin, deltamethrin, malathion and methidathion (Agriculture Canada 1987). Alternatives for the control of the red turnip beetle are azinphos-methyl and methidathion (Agriculture Canada op.cit.). The relative toxicities of non-pyrethroid, provincially-recommended alternatives to the Mallard and Ring-necked Pheasant are given in tables 10 and 11. The risk factors for carbofuran are higher and do not overlap with those calculated for alternatives for which comparable toxicity data are available.

Table 14. Number of hectares of Canola estimated to have been treated with foliar insecticides by crop district in the three Prairie Provinces (1985) and probable importance of each crop district to Burrowing Owls based on nest site distribution.

PROVINCE	CROP DISTRICT	NUMBER OF HECTARES	IMPORTANCE TO BURROWING OWLS
Alberta	1	348	39%
	2	4,532	52%
	3	3,424	7%
	4	7,505	2%
	5	9,899	-
	6	7,144	-
	7	5,066	-
Saskatchewan	1-4	398	79%
	5A	1,604	-
	5B	3,214	-
	6A	2,675	5%
	6B	1,415	8%
	7A	36	7%
	7B	1,144	-
	8A	4,846	-
	8B	2,999	-
	9A	6,255	-
	9B	5,388	-
Manitoba	1	2,631	***
	2	1,836	***
	3	2,418	*
	4	1,263	
	5	1,054	
	6	3,046	
	7	3,107	*
	8	3,163	*
	9	580	
	10	311	
	11	819	
	12	1,328	

*** Very important
* Somewhat important

From: Madder and Stemeroff (1986)
G.L. Erickson (pers. comm.), W. Harris (pers.comm.)
Ratcliff (1986), E.A. Haug (pers. comm.)

3.6 CONTROL OF GRASSHOPPERS AND SUNFLOWER BEETLE IN SUNFLOWER

Manitoba is the province of concern with respect to sunflowers. In 1981, 109,000 ha were sown with this crop compared to 7,000 in Saskatchewan and less than 1,000 in Alberta (Statistics Canada 1982). In 1986 the hectarage was decreased to 22,758 in Manitoba, 2,963 in Saskatchewan, and 1,794 in Alberta (Statistics Canada 1987). The distribution of this crop in Manitoba is given in table 15. The approximate nesting distribution of the Burrowing Owl is also indicated. In 1981, 29% of the total hectarage sown was in crop districts of importance to breeding Burrowin Owls. In 1986, this percentage increased to 82%.

Grasshoppers probably seldom need chemical control in sunflowers. The 1986 Manitoba Insect Control Guide (Manitoba Agriculture 1986) does not list grasshoppers as one of the usual sunflower pests and carbofuran is the only insecticide currently registered for this purpose (Agriculture Canada 1987). We have no data on the extent to which sunflower beetles (*Zygrogranna exclantionis*) require chemical control. The rate registered for this pest is the same as that used for grasshopper control and spraying could occur from May to when heads begin to form. (Sheehan et al. 1987 and Manitoba Agriculture 1986).

We have no information regarding the likelihood that Burrowing Owls will utilize growing sunflower fields for foraging. Based on the habitat preferences of the bird, it is unlikely that much use of these fields would occur other than when the crop is very young.

Alternatives to carbofuran

The following alternative insecticides are registered for sunflower beetles in sunflower: Azinphos-methyl, cypermethrin, deltamethrin, endosulfan and methidathion. The relative toxicity of the non-pyrethroids (all of which are recommended in Manitoba - Manitoba Agriculture 1986) to the Mallard and Ring-necked Pheasant are given in tables 10 and 11. Again, carbofuran has the highest risk factor, especially for the Mallard.

3.7 CONCLUSION

On the basis of information currently available to us, we conclude that registrations of carbofuran for control of grasshoppers in all sites, and for control of alfalfa weevils in alfalfa, would result in the greatest potential exposure of Burrowing Owls to that chemical. The potential for exposure would appear to be less during the control of flea beetles and red turnip beetles in canola and mustard, and sunflower beetles in sunflower but more work is needed to ascertain this. In particular, we lack kmowledge of pest control practiced by

Table 15. Number of hectares sown to sunflowers in Manitoba by crop district (1986) and importance of each crop district to Burrowing Owls based on nesting distribution.

CROP DISTRICT	NO. HECTARES	IMPORTANCE TO BURROWING OWLS
1	6,135	***
2	3,500	***
3	386	*
4	0	
5	0	
6	0	
7	4,755	*
8	3,735	*
9	3,829	
10	0	
11	295	
12	0	

*** Very important

* Somewhat important

From: Statistics Canada (1982 and 1987)
Ratcliff (1986), E.A. Haug (pers. comm.)

mustard growers; this crop is becoming much more popular in Saskatchewan where Burrowing Owls are the most widely distributed. Little exposure is likely to result from the treatment of wheat for the wheat midge given the current range of this pest. *In all cases, alternative insecticides of lower toxicity to at least some wildlife species are available.*

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APPENDIX 1

The toxicity of carbofuran to birds.

Carbofuran is extremely toxic to birds and mammals and its use has long been associated with cases of wildlife mortality. The following is a brief synopsis of the data available on its toxicity to laboratory bird test species as well as a repertory of avian kills that have been brought to the attention of the Canadian Wildlife Service.

Acute toxicity to birds

Laboratory evidence

The acute oral toxicity of carbofuran (technical) to some avian species is one of the highest recorded for any insecticide. The laboratory-determined LD_{50} for technical carbofuran is below 1 mg/kg for the two waterfowl species tested as well as some songbird species (Table 1). The 480F (flowable) formulation (marketed as 4F in the U.S.A.) is approximately twice as toxic to quail as the technical material (E.F. Hill, pers. comm.).

Toxic dietary levels (LC_{50}) of technical carbofuran administered in dry mash are given in table 2. The mallard again is shown to be more sensitive than the galliform species tested with an LC_{50} value ranging from 21 ppm to 190 ppm depending on the laboratory and test conditions. [Note: Some of the the values in this table were taken from an EPA summary of data submitted by the manufacturer, FMC Corporation, for purposes of registration in the U.S. These data were not submitted to Canadian registration authorities and therefore were not critically reviewed. The lower value of 21 ppm for the Mallard as well as the value of 158 ppm for the Bobwhite Quail are not readily comparable with the other values since the exposure time deviated from the usual 5 days advocated by the U.S. EPA.] Dietary toxicities in the three galliform species tested, ranged from 158 ppm to 681 ppm.

Unfortunately, the large variation in the sensitivity of the species tested to date has not been explained. Without data specific to the burrowing owl, the toxicity of carbofuran to that species cannot be determined.

The most significant route of exposure for birds is expected to be through feeding on contaminated vegetation or prey although it has also been postulated that toxicologically significant quantities of the insecticide could be ingested through preening (National Research Council of Canada [NRCC] 1979). According to the data of Schafer et al. (1973) on the dermal toxicity of carbofuran to the Red-billed Quelea and House Sparrow (100 mg/kg in both cases), carbofuran does not appear to present as great a risk through the dermal route than it does through the oral route.

Field incidents associated with the use of carbofuran flowable

Between 1973 and 1986, we are aware of at least fifteen incidents of bird kills which have been attributed to the use of carbofuran flowable in North America excluding the information reported above for the burrowing owl (Flickinger et al. 1980, Hill and Fleming 1982, NRCC 1979, Leighton and Wobeser 1987, United States Environmental Protection Agency [EPA] 1979, California Department of Fish and Game [CFG] 1973, 1974a, 1974b, 1976, 1977, 1978, 1986b and undated, Virginia Polytechnic Institute 1986a, Oklahoma Department of Agriculture 1985, U.S. Fish and Wildlife Service [USFWS] 1976, and J.Bascietto (EPA), pers. comm.). Cases where carbofuran flowable was used to deliberately poison wildlife (eg. Flickinger et al. 1986) or cases where the circumstances of the incident do not allow us to determine which use pattern or formulation of carbofuran was involved (eg. Newfoundland gull kill reported by Leighton and Wobeser 1987) are excluded from this tally. Over 6000 birds were reported to have died in the 15 incidents. In all but three instances, waterfowl were the primary non-target casualties. Other casualties have included California gulls (1 incident in Saskatchewan), small passerines and coots (1 incident in Virginia and Kansas, respectively).

Eleven of the twelve waterfowl kills were related to alfalfa spraying. The four worst incidents reported involved 2500, 1100+, 750-1000 and 500 adult ducks and geese. Under California State Law, it is illegal to use carbofuran without first ensuring that waterfowl are not present in the fields or nearby. This usually means overflying the fields before any application takes place (Littrell, California Department of Fish and Game [CFG], pers. comm.). In a 1974 press release from the California Department of Fish and Game, mention is made of an FMC Corporation bulletin which recommends that Furadan not be used within one mile of nesting sites of geese or in any field where geese or other waterfowl are known to be feeding (CFG 1974a).

In a few of the cases reported above, alfalfa residue levels were measured in the field where the kill had taken place. Two kills occurred at levels of 42 and 44 ppm on a fresh weight basis measured the day following application (CFG 1977, 1986b) and a third at a level of 15 ppm measured 60 hours after application (CFG 1973). Safe re-entry intervals for waterfowl in alfalfa fields have been estimated to be 7 days by the California Department of Fish and Game (Littrel, undated).

Insect residue levels from any crop treated with carbofuran are not available to us at this time. However, three samples of grasshoppers retrieved from the upper gastrointestinal tract of California Gulls poisoned in Saskatchewan following roadside spraying for grasshoppers ranged from 4.2 to 7.2 ppm (Leighton and Wobeser 1986). These values probably underestimate post-spray insect contamination levels since some residue absorption by the gulls had already occured.

Only the impact on songbirds has been systematically studied and this, with limited success. Jorgensen et al. (1983) working on behalf of the manufacturer, FMC, claimed that no impacts were seen on a population of resident Savannah Sparrows in a treated alfalfa field. However, this claim could not be substantiated following review of this report and further information was requested from the company (Mineau unpublished).

Horstman (1985) looked primarily at nesting Brewer's blackbirds sprayed in the course of roadside treatments for grasshoppers in Alberta. Her results were equivocal. Higher mortality rates in treated sites could have been habitat-related and nestling mortalities in the treated area were not proven to be caused by carbofuran. The study was repeated in 1986 with better sample sizes (Horstman 1987). No impact was detected following oversprays of nestlings but two factors limited the usefulness of that study: 1) there was no grasshopper infestation during this study and birds were therefore not exposed to large numbers of contaminated prey. Parents were seen foraging away from treated areas and 2) the effectiveness of the spray was compromised by having the tank mixture sit overnight before being used (Horstman pers. comm.). Also, the relative sensitivity of Brewer's blackbirds to carbofuran was not ascertained. However, this study provided some confirmation that direct dermal contact may not be a significant factor when considering carbofuran toxicity because nestlings were in theory exposed to some degree of direct spray deposit.

<u>Incidents associated with the use of carbofuran granular</u>

We are aware of more than 50 incidents of primary poisoning of birds that have been attributed to the use of granular carbofuran. Excluded from this total are cases of gross misuse as well as the field tests carried out by FMC Corporation or the U.S. EPA specifically to look at avian mortality in corn fields. These will be discussed separately.

At least 24 incidents have been reported following the use of the 3G and 5G formulations for rice planting in the Spring (Flickinger 1980, California Department of Fish and Game [CFG] 1984a, 1984b, 1985a, 1986c and undated, J. Bascietto (U.S. EPA) pers.comm.). Three more cases were reported in the Fall and it is unclear whether this represents misuse or a carryover of the granules over the summer (CFG 1986a). This use is not registered in Canada but these kills underscore the high hazard of this chemical to waterfowl. Various species of ducks were involved in all but two of these incidents. Shorebirds and Red-winged blackbirds were the other species affected.

We are aware of 5 reports of kills associated with the use of the 10G granules in pine plantations (Overgaard et al. 1983, U.S. EPA 1979). In this use pattern, granules are either incorporated by hand into the hole made for the seedling or by means of a deep-injection mechanism which is reported to achieve better than 99% incorporation of the granules. A total of 96 dead birds were reported from 4 plantations where the granules were used (Overgaard et al. op. cit.). In Canada, there has recently been some research on the use of carbofuran granules to reduce insect dammage to cones and seeds of white spruce (Cerezke and Holmes 1986) but there are no such registered uses as yet.

We are also aware of at least 14 reports of kills associated with the use of either the 10G or 15G formulation in corn (Kleinert 1974, New York Department of Environmental Conservation 1981, J. Bascietto (U.S. EPA) pers. comm., Stone and Gradoni 1985, Indiana Department of Natural Resources 1986). One kill may have involved diazinon as a contributing factor. Although the 15G (15% a.i.) formulation is not registered in Canada, differences between the impact of the two formulations are expected to be negligible in most cases since a single 10% granule may exceed a lethal dose for small bird species (Balcomb et al. 1984a). The available documentation varies enormously between incidents. Not included above are a number of monitoring studies designed specifically to monitor bird kills resulting from the use of carbofuran granules in corn at planting. Three of these studies were made under contract to the manufacturer (Booth et al. 1983, 1986 a and b) as requirements for the special review presently being conducted in the U.S. A fourth was carried out by the U.S. EPA and subsequently published by Balcomb (1984 b). What these studies demonstrated is that granular carbofuran cannot be used without an attendant loss of resident breeding passerines which forage in the treated fields. In cases where the fields are near habitats suitable to birds, the kill may involve more than the resident breeders. On one study site (Booth et al. 1983), a total of 912 bird carcasses were recovered after 145 ha were treated with the 10 and 15 G granules. Of these, 831 were of the same species - Horned larks - and most were young of the year.

It appears that problems are not restricted to North America. Mortality of birds in corn fields following the use of incorporated granules has also been reported in South Africa (Ledger 1987).

Extensive waterfowl mortality involving a total of approximately 2400 birds of several species was documented on five separate occasions in flooded turnip and potato fields following the use of granular carbofuran in British Columbia between 1973 and 1977 (NRCC 1979). One of those incidents was linked to improper use of the product. As a result of the kills, granular carbofuran was voluntarily withdrawn from B.C. for several years. Its use was resumed in 1986. That same year, an incident was reported involving the mortality of 500-1000 Savannah Sparrows in turnip and radish fields (Agriculture Canada 1986). At least three bird kills following the use of the granules in turnip fields have also been documented in the United Kingdom (Ministry of Agriculture Fisheries and Food [MAFF] 1982, 1984) and a kill has recently been reported in a potato field in New York State (J. Bascietto (U.S. EPA pers. comm.).

The most extensive bird kill resulting from the use of granular carbofuran was probably one reported following the prophylactic use of the granules in Canola. In 1984, a Saskatchewan farmer reported that a quarter section (160 acres or 65 ha) of canola treated with the CR-10 carbofuran granules was covered with dead birds. Thirty carcasses of Lapland Longspurs were collected but, based on the pathologist's report and further communication with the farmer, it is estimated that 2,000 birds were still visible in the field three days later even though the field had been harrowed twice and half of the carcasses were reported to have been scavenged (Canadian Wildlife Service 1987). The true magnitude of this kill will never be known.

Incidence of Secondary Poisoning

Smaller animals killed or incapacitated by primary acute poisoning become easy prey for avian predators and scavengers. The risk comes from ingesting carbofuran or its active metabolites in postabsorptive tissues of the prey, or unassimilated, either on the surface or in the gut of the prey.

Over a dozen incidents (excluding 2 intentional kills) of secondary poisoning of birds from consumption of prey contaminated by granular carbofuran have been reported (Balcomb 1983, Booth et al. 1983, Overgard et al. 1983, U.S. Fish & Wildlife Service 1986a, 1986b, New York Department of Environmental Conservation 1985, Stone and Gradoni 1987, Canadian Wildlife Service 1975, J. Bascietto (U.S. EPA) pers. comm.). Kills involved Bald Eagles (4 incidents, 6 birds), Red-Shouldered Hawks (1 incident, 2 birds), Red-tailed Hawks (2 incidents, 2 birds), Loggerhead Shrikes (1 incident, 2 birds), Northern Harriers (2 incidents, 2 birds), unidentified owls (2 incidents, 2 birds) and hawk (1 incident, 1 bird) as well as Ravens (2 incidents, 3 birds).

As reviewed earlier, approximately 45 California Gulls died following ingestion of sprayed grasshoppers near Moose jaw, Saskatchewan (Leighton and Wobeser 1987).

The difficulty of detecting impacts

We believe that the number of reported kills greatly underestimates the magnitude of the problem. First, kills are expected to occur primarily in areas that are not generally visited or adequately monitored. Second, even if the areas are visited, the probability of detecting carcasses is low, especially for smaller birds or where scavenging could be occurring (Balcomb 1986).

Also, it is common for kills to be insufficiently investigated or documented so that the causative agent cannot be identified (eg. National Wildlife Health Centre 1987). Chemicals such as carbofuran that are readily metabolized also pose difficulties of analysis. On a relative scale, carbofuran accounts for a large proportion of documented wildlife kills in North America.

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Updated December 1987.

Table 1. Acute oral toxicity of carbofuran to birds ordered from the most sensitive to the least sensitive species tested.

SPECIES	SEX	AGE	LD50(mg/kg)	95% CONF.	SOURCE
Fulvous whistling-duck	F	3-6 mo.	0.238	0.200-0.283	1
Mallard Duck	U	33-39h.	0.370	0.283-0.484	2
Mallard Duck	U	6-8d.	0.628	0.530-0.744	2
Mallard Duck	U	27-33d.	0.510	0.410-0.635	2
Mallard Duck	F	3-4 mo.	0.397	0.315-0.500	1
Mallard Duck	M/F	6 mo.	0.415	0.333-0.516	2
Mallard Duck	M*	12 mo.	0.480	0.381-0.604	1
Mallard Duck	F*	12 mo.	0.510	0.410-0.635	1
Red-winged Blackbird	U	adult	0.422		3
Red-billed Quelea	U	adult	0.422-0.562		3
House Finch	U	adult	0.750		3
House Sparrow	U	adult	1.33		3
Rock Dove	U	adult	1.33		3
Brown-headed Cowbird	U	adult	1.33		3
Common Grackle	U	adult	1.33-3.16		3
Japanese Quail	M	14d.	1.9	1.7-2.1	4
Japanese Quail	F	14d.	1.7	1.3-1.9	4
Ring-necked Pheasant	F	3 mo.	4.15	2.38-7.22	1
Northern Bobwhite	F	3 mo.	5.04	3.64-6.99	1
Northern Bobwhite	M/F	16-20 wks.	12	7.0-19	5
European Starling	U	adult	5.62		3

M= male
F= female
U= sex unknown
*= in breeding condition

1. Hudson et al. 1984
2. Hudson et al. 1972
3. Schafer et al. 1983 (rangefinding values only)
4. Sherman and Ross in NRCC 1979
5. Hill and Camardese, 1984

Table 2. Dietary toxicity of carbofuran to birds ordered from the most sensitive to the least sensitive species tested.

SPECIES*	AGE	DURATION OF EXPOSURE	LC50(ppm)	95% CONF.	SOURCE
Mallard Duck	5-7d	14d	21	16-27	1.
Mallard Duck	14d	5d	79	55-114	2.
Mallard Duck	10d	5d	190	156-230	3.
Bobwhite Quail	5-7d	14d	158	125-200	1.
Bobwhite Quail	14d	5d	681	509-1104	4.
Japanese Quail	14d	5d	438	356-529	3.
Japanese Quail	14d	5d	746	549-1014	5.
Ring-necked Pheasant	10d	5d	573	492-666	3.

* Sexes unknown in all cases

1. U.S. EPA 1983a
2. U.S. EPA 1983b
3. Hill et al. 1975
4. U.S. EPA 1983c
5. Hill and Camardese 1986

to G. Fox
P. Mineau
Toxic Substances and
Monitoring Division
CWS, Hull, Quebec

December 22, 1987

from Senior Biostatistician
CWS, Hull, Quebec

subject: ANALYSIS OF BURROWING OWL DATA

As you have requested, I have analyzed the data on the effect of grasshopper spraying on burrowing owls. For this analysis the treatments applied to each burrow were classified by distance from the burrow and number of applications for each pesticide. The distance from the burrow was coded into 3 categories: i) overspray of the burrow ii) spray within 50 m of burrow but no overspray and iii) spray between 50 and 400 m of burrow. For each burrow, the number of sprays for each pesticide within each of these categories was recorded as was whether the burrow was successful in producing young and the maximum number of young seen at the burrow.

The distance data were re-coded to a proximity score for each pesticide as follows. The proximity score had 4 levels: 0 no exposure within 400 m, 1 at least one exposure between 50 and 400 m of nest but no exposure closer to burrow, 2 at least one exposure within 50 m of burrow but no overspray of burrow and 3 at least one overspray of burrow.

An additional set of data was collected from a survey of farmers who had burrowing owls present on their property. The farmers were asked how many burrows were on their farm and whether they had used carbofuran in 1985 or 1986.

STATISTICAL ANALYSIS

The analysis was done separately for each pesticide. The variables analyzed were: i) number of sprays with the pesticide, ii) number of sprays with any other pesticides, iii) total number of sprays, iv) burrow success rate and v) maximum number of young per burrow. Variables i) and iii) were analyzed for proximity categories 1-3 while the other variables were analyzed for categories 0-3. This is because the pesticide being analyzed was not applied to category 0 and hence trends including category 0 would be meaningless for variables i) and iii).

Since it is possible that burrows in the same farm may be correlated, the total for each farmer within each proximity category was used in the analysis. A simple regression of the mean per burrow against proximity score was calculated. The significance of the trend with proximity score was assessed using a re-randomization test. For variables i), ii) and iii) a two-sided test for change was done while for variables iv) and v) a one sided test for decline with increasing proximity was made.

Whenever a significant trend with proximity was detected for variables iv) and v), a search for the no significant detectable trend level was done by sequentially discarding the highest proximity score and rerunning the test for trend.

For carbofuran the above tests were also run assuming no farmer effect. In this test each burrow was treated as an independent observation.

For the survey data, the mean number of burrows per farm was compared within farms which had been sprayed for grasshoppers in 1985 or 1986, between farms where carbofuran had been used in the past and farms where carbofuran had never been used. The comparison was done using a one-sided re-randomization test.

RESULTS

For each pesticide, the number of observations in each proximity category when all other pesticides had a proximity score of zero, was calculated. Examination of the data revealed that only carbaryl had a sufficient amount of data to allow an analysis of it's effect in the absence of all other pesticides.

For carbaryl, an analysis of the data excluding exposure to any other pesticide was done. No significant ($p>0.05$) trend in the number of sprays for the 3 sprayed proximity categories was detected and no significant ($p>0.05$) trend in either burrow success or maximum number of young over the 4 proximity categories was detected, Table 1.

Since no detectable effect of carbaryl was detected, the analysis of the other pesticides was done ignoring the carbaryl exposure.

For chlorpyrifos, an analysis of the data allowing exposure to carbaryl but excluding exposure to any other pesticide was done. No significant ($p>0.05$) trend in the number of sprays of other chemicals (carbaryl) over the 4 proximity categories was found. The number of exposures to chlorpyrifos was too small to allow tests for a trend in number of sprays of chlorpyrifos or total sprays over proximity categories 1-3 to be run. No significant ($p>0.05$) trend in the burrow success rate or the maximum number of young per burrow was detected, Table 2.

Since no detectable effect of chlorpyrifos was found, the analysis of all other pesticides was done ignoring chlorpyrifos and carbaryl exposure.

For deltamethrin, an analysis of the data allowing exposure to carbaryl and chlorpyrifos but excluding exposure to any other chemical was done. No significant ($p>0.05$) trend in the number of sprays with other chemicals was found . The number of exposures to deltamethrin was too small to allow tests for a trend in number of sprays of deltamethrin or total sprays over proximity categories 1-3 to be run. No significant ($p>0.05$) trend in the burrow success rate or the maximum number of young per burrow was detected, Table 3.

Since no detectable effect of deltamethrin was found, the analysis of all other pesticides was done ignoring deltamethrin, chlorpyrifos and carbaryl exposure.

For carbofuran, an analysis of the data allowing exposure to carbaryl, chlorpyrifos and deltamethrin but excluding exposure to any other pesticide was done (Table 4). No significant (p>0.05) trend in the number of sprays of other chemicals over the 4 proximity categories was found. Similarly, no significant (p>0.05) trend in the number of sprays of carbofuran or the total sprays over proximity categories 1-3 was found. A significant (p<0.05) decline in the burrow success rate and the maximum number of young per nest with increasing proximity (0-3) to the nest was found. When the test was repeated discarding the overspray category the decline with proximity was no longer significant (p>0.05).

The analysis for carbofuran was repeated ignoring farmer effects (Table 5). There was a significant (p<0.05) decline in the total number of sprays with proximity categories 1-3. All other tests gave similar conclusions to the tests including farmer effects.

The results of the analysis of the survey are shown in Table 6. The mean number of burrows per farm was significantly (p<0.05) smaller for farms in which carbofuran was sprayed then for farms where other pesticides were used.

Brian Collins

TABLE 1: Carbaryl (Sevin) with no other pesticide spraying

PROXIMITY	FARM	NO. OF BURROWS	NO. OF SPRAYS	NO. OF SUCCESSFUL NESTS	MAXIMUM NO. OF YOUNG
0	A	2	0	2	10
0	B	1	0	0	8
0	C	3	0	1	11
0	D	2	0	2	9
0	E	6	0	6	29
0	F	5	0	4	17
0	G	2	0	2	3
0	H	2	0	0	0
1	I	2	2	1	4
1	J	4	8	4	17
1	K	1	1	1	3
1	L	1	1	1	5
2	M	1	3	0	3
2	J	5	10	5	24
2	K	1	1	0	0
2	H	2	2	2	13
3	N	1	1	1	2
3	O	1	2	1	6
3	P	1	1	0	0
3	Q	10	10	7	30

TOTAL NUMBER OF SPRAYS

GROUP	PROX.	NO. FARMS	RATIO	AVERAGE
1	1.0	4	12/ 8	1.500
2	2.0	4	16/ 9	1.778
3	3.0	4	14/ 13	1.077

OBSERVED TREND WITH PROXIMITY (1-3) -.212

ESTIMATED PROBABILITY TREND<0 .2230
ESTIMATED PROBABILITY TREND>0 .7790
ESTIMATED PROBABILITY FOR A TWO SIDED TEST .4630
BASED ON 1000 ITERATIONS

TABLE 1 cont.

NEST SUCCESS

GROUP	PROX.	NO. FARMS	RATIO	AVERAGE
1	.0	8	17/ 23	.739
2	1.0	4	7/ 8	.875
3	2.0	4	7/ 9	.778
4	3.0	4	9/ 13	.692

OBSERVED TREND WITH PROXIMITY (0-3) -.012

ESTIMATED PROBABILITY TREND<0 .4270
ESTIMATED PROBABILITY TREND>0 .5730
ESTIMATED PROBABILITY FOR A TWO SIDED TEST .8510
BASED ON 1000 ITERATIONS

MAXIMUM NUMBER OF YOUNG SEEN PER NEST

GROUP	PROX	NO. FARMS	RATIO	AVERAGE
1	.0	8	87/ 23	3.783
2	1.0	4	29/ 8	3.625
3	2.0	4	40/ 9	4.444
4	3.0	4	38/ 13	2.923

OBSERVED TREND WITH PROXIMITY (0-3) -.145

ESTIMATED PROBABILITY TREND<0 .3600
ESTIMATED PROBABILITY TREND>0 .6400
ESTIMATED PROBABILITY FOR A TWO SIDED TEST .6740
BASED ON 1000 ITERATIONS

TABLE 2 Chlorpyrifos (Lorsban) with any level of carbaryl spraying but no other pesticide

PROXIMITY	FARM	NO. OF BURROWS	TOTAL SPRAYS	LORSBAN SPRAYS	OTHER SPRAYS	NEST SUCCESS	MAXIMUM NO. OF YOUNG
0	A	2	2	0	2	1	4
0	B	2	0	0	0	2	10
0	C	1	0	0	0	0	8
0	D	3	0	0	0	1	11
0	E	1	1	0	1	1	2
0	F	1	3	0	3	0	3
0	G	9	18	0	18	9	41
0	H	2	0	0	0	2	9
0	I	6	0	0	0	6	29
0	J	1	2	0	2	1	6
0	K	2	2	0	2	1	3
0	L	5	0	0	0	4	17
0	M	1	1	0	1	1	5
0	N	2	0	0	0	2	3
0	O	1	1	0	1	0	0
0	P	4	2	0	2	2	13
0	Q	10	10	0	10	7	30
1	R	2	10	10	0	2	8
2	F	1	5	1	4	1	4
2	R	3	15	15	0	3	9

SPRAYS WITH OTHER CHEMICALS

GROUP	PROX.	NO. FARMS	RATIO	AVERAGE
1	.0	17	42/ 53	.792
2	1.0	1	0/ 2	.000
3	2.0	2	4/ 4	1.000

OBSERVED TREND WITH PROXIMITY (0-2) .017

ESTIMATED PROBABILITY TREND<0 .6110
ESTIMATED PROBABILITY TREND>0 .3900
ESTIMATED PROBABILITY FOR A TWO SIDED TEST .9510
BASED ON 1000 ITERATIONS

TABLE 2 cont.

NEST SUCCESS

GROUP	PROX.	NO. FARMS	RATIO	AVERAGE
1	.0	17	40/ 53	.755
2	1.0	1	2/ 2	1.000
3	2.0	2	4/ 4	1.000

OBSERVED TREND WITH PROXIMITY (0-2) .135

ESTIMATED PROBABILITY TREND<0 .9190
ESTIMATED PROBABILITY TREND>0 .0990
ESTIMATED PROBABILITY FOR A TWO SIDED TEST .2720
BASED ON 1000 ITERATIONS

MAXIMUM NUMBER OF YOUNG SEEN PER NEST

GROUP	PROX.	NO. FARMS	RATIO	AVERAGE
1	.0	17	194/ 53	3.660
2	1.0	1	8/ 2	4.000
3	2.0	2	13/ 4	3.250

OBSERVED TREND WITH PROXIMITY (0-2) -.152

ESTIMATED PROBABILITY TREND<0 .3970
ESTIMATED PROBABILITY TREND>0 .6040
ESTIMATED PROBABILITY FOR A TWO SIDED TEST .7780
BASED ON 1000 ITERATIONS

TABLE 3 Deltamethrin (Decis) with any level of carbaryl or chlorpyrifos spraying but no other pesticide

PROXIMITY	FARM	NO. OF BURROWS	TOTAL SPRAYS	DECIS SPRAYS	OTHER SPRAYS	NEST SUCCESS	MAXIMUM NO. OF YOUNG
0	A	2	2	0	2	1	4
0	B	2	0	0	0	2	10
0	C	1	0	0	0	0	8
0	D	3	0	0	0	1	11
0	E	1	1	0	1	1	2
0	F	2	8	0	8	1	7
0	G	9	18	0	18	9	41
0	H	2	0	0	0	2	9
0	I	6	0	0	0	6	29
0	J	1	2	0	2	1	6
0	K	2	2	0	2	1	3
0	L	5	0	0	0	4	17
0	M	1	1	0	1	1	5
0	N	2	0	0	0	2	3
0	O	1	1	0	1	0	0
0	P	4	2	0	2	2	13
0	Q	5	25	0	25	5	17
0	R	10	10	0	10	7	30
2	S	2	10	4	6	1	1
2	T	3	6	3	3	2	13
3	T	1	2	1	1	1	4

SPRAYS WITH OTHER CHEMICALS

GROUP	PROX.	NO. OBS.	RATIO	AVERAGE
1	.0	18	72/ 59	1.220
2	2.0	2	9/ 5	1.800
3	3.0	1	1/ 1	1.000

OBSERVED TREND WITH PROXIMITY (0-3) .092

ESTIMATED PROBABILITY TREND<0 .6760
ESTIMATED PROBABILITY TREND>0 .3240
ESTIMATED PROBABILITY FOR A TWO SIDED TEST .8520
BASED ON 1000 ITERATIONS

TABLE 3 cont.

NEST SUCCESS

GROUP	PROX.	NO. OBS.	RATIO	AVERAGE
1	.0	18	46/ 59	.780
2	2.0	2	3/ 5	.600
3	3.0	1	1/ 1	1.000

OBSERVED TREND WITH PROXIMITY (0-3) -.000

ESTIMATED PROBABILITY TREND<0 .5340
ESTIMATED PROBABILITY TREND>0 .4740
ESTIMATED PROBABILITY FOR A TWO SIDED TEST .9960
BASED ON 1000 ITERATIONS

MAXIMUM NUMBER OF YOUNG SEEN PER NEST

GROUP	PROX.	NO. OBS.	RATIO	AVERAGE
1	.0	18	215/ 59	3.644
2	2.0	2	14/ 5	2.800
3	3.0	1	4/ 1	4.000

OBSERVED TREND WITH PROXIMITY (0-3) -.127

ESTIMATED PROBABILITY TREND<0 .4010
ESTIMATED PROBABILITY TREND>0 .5990
ESTIMATED PROBABILITY FOR A TWO SIDED TEST .7510
BASED ON 1000 ITERATIONS

TABLE 4 Carbofuran (Furadan) with any level of carbaryl, chlorpyrifos an deltamethrin spraying but no other pesticide.

PROXIMITY	FARM	NO.OF BURROWS	TOTAL SPRAYS	FURIDAN SPRAYS	OTHER SPRAYS	NEST SUCCESS	MAXIMUM NO. OF YOUNG
0	A	2	2	0	2	1	4
0	B	2	0	0	0	2	10
0	C	1	0	0	0	0	8
0	D	3	0	0	0	1	11
0	E	1	1	0	1	1	2
0	F	2	8	0	8	1	7
0	G	9	18	0	18	9	41
0	H	2	0	0	0	2	9
0	I	6	0	0	0	6	29
0	J	1	2	0	2	1	6
0	K	2	2	0	2	1	3
0	L	2	10	0	10	1	1
0	M	5	0	0	0	4	17
0	N	4	8	0	8	3	17
0	O	1	1	0	1	1	5
0	P	2	0	0	0	2	3
0	Q	1	1	0	1	0	0
0	R	4	2	0	2	2	13
0	S	5	25	0	25	5	17
0	T	10	10	0	10	7	30
1	G	5	26	5	21	4	19
1	U	1	3	2	1	1	3
1	L	2	16	6	10	2	8
1	V	6	12	6	6	4	20
1	W	2	14	4	10	2	7
2	X	4	16	8	8	2	10
2	Y	2	8	6	2	2	9
2	U	2	6	4	2	1	4
2	V	1	2	1	1	0	4
3	Z	5	10	5	5	0	0
3	AA	1	1	1	0	0	0
3	BB	1	3	2	1	1	4

Table 4 cont.

TOTAL SPRAYS

GROUP	PROX.	NO. OBS.	RATIO	AVERAGE
1	1.0	5	71/ 16	4.438
2	2.0	4	32/ 9	3.556
3	3.0	3	14/ 7	2.000

OBSERVED TREND WITH PROXIMITY (1-3) -1.189

ESTIMATED PROBABILITY TREND<0 .0530
ESTIMATED PROBABILITY TREND>0 .9470
ESTIMATED PROBABILITY FOR A TWO SIDED TEST .1500
BASED ON 1000 ITERATIONS

TOTAL SPRAYS WITH CARBOFURAN

GROUP	PROX.	NO. OBS.	RATIO	AVERAGE
1	1.0	5	23/ 16	1.438
2	2.0	4	19/ 9	2.111
3	3.0	3	8/ 7	1.143

OBSERVED TREND WITH PROXIMITY (1-3) -.076

ESTIMATED PROBABILITY TREND<0 .3680
ESTIMATED PROBABILITY TREND>0 .6320
ESTIMATED PROBABILITY FOR A TWO SIDED TEST .7990
BASED ON 1000 ITERATIONS

TABLE 4 cont.

SPRAYS WITH OTHER CHEMICALS

GROUP	PROX.	NO. OBS.	RATIO	AVERAGE
1	.0	20	90/ 65	1.385
2	1.0	5	48/ 16	3.000
3	2.0	4	13/ 9	1.444
4	3.0	3	6/ 7	.857

OBSERVED TREND WITH PROXIMITY (0-3) -.025

ESTIMATED PROBABILITY TREND<0 .4900
ESTIMATED PROBABILITY TREND>0 .5100
ESTIMATED PROBABILITY FOR A TWO SIDED TEST .9400
BASED ON 1000 ITERATIONS

NEST SUCCESS

GROUP	PROX.	NO. OBS.	RATIO	AVERAGE
1	.0	20	50/ 65	.769
2	1.0	5	13/ 16	.813
3	2.0	4	5/ 9	.556
4	3.0	3	1/ 7	.143

OBSERVED TREND WITH PROXIMITY (0-3) -.164

ESTIMATED PROBABILITY TREND<0 .0020
ESTIMATED PROBABILITY TREND>0 .9980
ESTIMATED PROBABILITY FOR A TWO SIDED TEST .0020
BASED ON 1000 ITERATIONS

OBSERVED TREND WITH PROXIMITY (0-2) -.080

ESTIMATED PROBABILITY TREND<0 .1310
ESTIMATED PROBABILITY TREND>0 .8690
ESTIMATED PROBABILITY FOR A TWO SIDED TEST .2290
BASED ON 1000 ITERATIONS

TABLE 4 cont.

MAXIMUM NUMBER OF YOUNG

GROUP	PROX.	NO. OBS.	RATIO	AVERAGE
1	.0	20	233/ 65	3.585
2	1.0	5	57/ 16	3.563
3	2.0	4	27/ 9	3.000
4	3.0	3	4/ 7	.571

OBSERVED TREND WITH PROXIMITY (0-3) -.730

ESTIMATED PROBABILITY TREND<0 .0060
ESTIMATED PROBABILITY TREND>0 .9940
ESTIMATED PROBABILITY FOR A TWO SIDED TEST .0070
BASED ON 1000 ITERATIONS

OBSERVED TREND WITH PROXIMITY (0-2) -.243

ESTIMATED PROBABILITY TREND<0 .2620
ESTIMATED PROBABILITY TREND>0 .7380
ESTIMATED PROBABILITY FOR A TWO SIDED TEST .4650
BASED ON 1000 ITERATIONS

TABLE 5 Carbofuran (Furadan) with any level of carbaryl, chlorpyrifos and deltamethrin spraying but no other pesticide. Analysis assuming no farmer effect.

TOTAL SPRAYS

GROUP	PROX.	NO. OBS.	RATIO	AVERAGE
1	1.0	16	71/ 16	4.438
2	2.0	9	32/ 9	3.556
3	3.0	7	14/ 7	2.000

OBSERVED TREND WITH PROXIMITY (1-3) -1.177

ESTIMATED PROBABILITY TREND<0 .0000
ESTIMATED PROBABILITY TREND>0 1.0000
ESTIMATED PROBABILITY FOR A TWO SIDED TEST .0030
BASED ON 1000 ITERATIONS

TOTAL SPRAYS WITH CARBOFURAN

GROUP	PROX.	NO. OBS.	RATIO	AVERAGE
1	1.0	16	23/ 16	1.438
2	2.0	9	19/ 9	2.111
3	3.0	7	8/ 7	1.143

OBSERVED TREND WITH PROXIMITY (1-3) -.046

ESTIMATED PROBABILITY TREND<0 .4480
ESTIMATED PROBABILITY TREND>0 .5520
ESTIMATED PROBABILITY FOR A TWO SIDED TEST .8840
BASED ON 1000 ITERATIONS

TABLE 5 cont.

SPRAYS WITH OTHER CHEMICALS

GROUP	PROX.	NO. OBS.	RATIO	AVERAGE
1	.0	65	90/ 65	1.385
2	1.0	16	48/ 16	3.000
3	2.0	9	13/ 9	1.444
4	3.0	7	6/ 7	.857

OBSERVED TREND WITH PROXIMITY (0-3) .036

ESTIMATED PROBABILITY TREND<0 .5920
ESTIMATED PROBABILITY TREND>0 .4080
ESTIMATED PROBABILITY FOR A TWO SIDED TEST .8620
BASED ON 1000 ITERATIONS

NEST SUCCESS

GROUP	PROX.	NO. OBS.	RATIO	AVERAGE
1	.0	65	50/ 65	.769
2	1.0	16	13/ 16	.813
3	2.0	9	5/ 9	.556
4	3.0	7	1/ 7	.143

OBSERVED TREND WITH PROXIMITY (0-3) -.157

ESTIMATED PROBABILITY TREND<0 .0010
ESTIMATED PROBABILITY TREND>0 .9990
ESTIMATED PROBABILITY FOR A TWO SIDED TEST .0010
BASED ON 1000 ITERATIONS

OBSERVED TREND WITH PROXIMITY (0-2) -.069

ESTIMATED PROBABILITY TREND<0 .1630
ESTIMATED PROBABILITY TREND>0 .8840
ESTIMATED PROBABILITY FOR A TWO SIDED TEST .3240
BASED ON 1000 ITERATIONS

TABLE 5 cont.

MAXIMUM NUMBER OF YOUNG

GROUP	PROX.	NO. OBS.	RATIO	AVERAGE
1	.0	65	233/ 65	3.585
2	1.0	16	57/ 16	3.563
3	2.0	9	27/ 9	3.000
4	3.0	7	4/ 7	.571

OBSERVED TREND WITH PROXIMITY (0-3) -.704

ESTIMATED PROBABILITY TREND<0 .0010
ESTIMATED PROBABILITY TREND>0 .9990
ESTIMATED PROBABILITY FOR A TWO SIDED TEST .0010
BASED ON 1000 ITERATIONS

OBSERVED TREND WITH PROXIMITY (0-2) -.224

ESTIMATED PROBABILITY TREND<0 .2660
ESTIMATED PROBABILITY TREND>0 .7360
ESTIMATED PROBABILITY FOR A TWO SIDED TEST .5270
BASED ON 1000 ITERATIONS

TABLE 6 Comparison of number of burrows per farm treated in 1985 or 1986 between farmers who prefer or have used carbofuran and those who claim to never have used carbofuran.

GROUP	NO. OF OBS.	AVERAGE NO. OF BURROWS
Carbofuran	25	2.000
Other Insecticides	14	5.143

OBSERVED DIFFERENCE 3.143

ESTIMATED PROBABILITY THAT CARBOFURAN GROUP HAS A LOWER MEAN NUMBER OF BURROW THAN THE OTHER INSECTICIDE GROUP = .0050 BASED ON 1000 ITERATIONS