THE HAZARD OF CARBOFURAN TO BIRDS AND OTHER VERTEBRATE WILDLIFE

Pierre Mineau, Ph.D.
National Wildlife Research Centre
Canadian Wildlife Service
Environment Canada
Ottawa, K1A 0H3

Technical Report Series No. 177

ISBN 0-662-20823-4

Cat. # CW69-5/177E

PREFACE

This document was written and submitted to Agriculture Canada in the fall of 1991 as the contribution of the Canadian Wildlife Service to the Special Review of the insecticide carbofuran (Agriculture Canada 1990). It consists of a detailed review of the information available to assess the lethal hazard of carbofuran to wildlife. It has not hitherto been made public other than through formal Access to Information channels because, in part, it reviews information that is the property of FMC Corporation, the manufacturer of carbofuran. The document is now being published with the approval of FMC Corporation as a supporting document to Agriculture Canada's Discussion Document D93-02 entitled: 'Special review of carbofuran insecticide: Effects on avian fauna and benefits to agriculture'. The latter can be obtained from Agriculture Canada, Plant Industry Directorate, Information Division, Ottawa K1A 0C5 (1 800 267 6315). The 'Highlights and Conclusions' section of the Canadian Wildlife Service document is reproduced in the Agriculture Canada document. Public input is being sollicited for a period of 90 days following publication of the Discussion Document.

Unless specifically noted, the scientific information contained in the document has *not* been updated. For example, no carbofuran kills documented after September 1990 (the original cutoff date in the 1991 document) have been included here. Information updates have been incorporated in the text only where recent scientific information was felt to offer significant new insights. These updates are italicized and clearly identified. Citations to specific studies, however, *have* been updated where possible and a few clarifications added to the text. Otherwise, this document is as originally submitted in 1991.

Highlights and conclusions of the risk assessment are provided on page ii.

Les faits saillants et les conclusions de cette analyse de risque se trouvent à la page x.

ACKNOWLEDGEMENTS

This document and its preceding drafts benefited immensely from the exchanges I was able to have with a large number of individuals. I would like to acknowledge especially J. Bascietto and L. Lyon, both formerly with the U.S. Environmental Protection Agency, and B. Stinson with the State of Virginia, for sharing with me their knowledge of this insecticide, as well as enduring my frequent phone requests and the marathon late-night discussions. Comments on previous drafts were received from many colleagues too numerous to mention, and these have without a doubt led to major improvements to the final production. The text further benefited from the sharp editorial pen of Marla Sheffer.

Pierre Mineau
July 1993

HIGHLIGHTS AND CONCLUSIONS

This summary as well as the full risk assessment document published by the Canadian Wildlife Service review only the risks that carbofuran use poses directly to vertebrate wildlife through acute toxicity. This is the area of greatest concern associated with this insecticide. Any potential concerns relating to sublethal effects of the pesticide or secondary effects on vertebrate wildlife mediated through removal of invertebrate or vertebrate food supply are not covered here.

Carbofuran is a carbamate insecticide that inhibits cholinesterase enzymes and disrupts nervous transmission in vertebrate and invertebrate species alike. Carbofuran is classified as extremely hazardous to humans based on acute oral rat LD_{50} values in the 8–14 mg/kg range.[1] For the flowable formulation, this means that just a few drops are potentially lethal. By comparison, this is the approximate LD_{50} for the *least* sensitive bird species. The toxicity of carbofuran to a number of bird species is given in Table 1.

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

Species	Sex	Age	LD_{50} (mg/kg)	95% confidence interval
Fulvous Whistling-Duck (*Dendrocygna bicolor*)	F	3–6 mo.	0.238	0.200–0.283
Mallard (*Anas platyrhynchos*)	U	33–39 h	0.370	0.283–0.484
	U	6–8 d	0.628	0.530–0.744
	U	27–33 d	0.510	0.410–0.635
	F	3–4 mo.	0.397	0.315–0.500
	M/F	6 mo.	0.415	0.333–0.516
	M*	12 mo.	0.480	0.381–0.604
	F*	12 mo.	0.510	0.410–0.635
Red-winged Blackbird (*Agelaius phoeniceus*)	U	adult	0.422	
Red-billed Quelea (*Quelea quelea*)	U	adult	0.422–0.562	
American Kestrel (*Falco sparverius*)	M/F	1–4 yr.	0.6	0.5–1.0
House Finch (*Carpodacus mexicanus*)	U	adult	0.750	
House Sparrow (*Passer domesticus*)	U	adult	1.33	
Rock Dove (*Columba livia*)	U	adult	1.33	
Brown-headed Cowbird (*Molothrus ater*)	U	adult	1.33	
Common Grackle (*Quiscalus quiscula*)	U	adult	1.33–3.16	
Japanese Quail (*Coturnix coturnix*)	M	14 d	1.9	1.7–2.1
	F	14 d	1.7	1.3–1.9
Eastern Screech-Owl (*Otus asio*)	M/F	2–5 yr.	1.9	1.4–2.7

[1] This is the acute dose calculated to kill half of the test population to which it is given. It is expressed in milligrams of technical carbofuran per kilogram of body weight.

Species	Sex	Age	LD_{50} (mg/kg)	95% confidence interval
Ring-necked Pheasant (*Phasianus colchicus*)	F	3 mo.	4.15	2.38–7.22
Northern Bobwhite (*Colinus virginianus*)	F	3 mo.	5.04	3.64–6.99
	M/F	16–20 wk.	12	7.0–19
	M/F	1–2 yr.	8.0	6.0–10
European Starling (*Sturnus vulgaris*)	U	adult	5.62	

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

It is not unusual for birds to be more susceptible than mammals to cholinesterase-inhibiting insecticides. However, the LD_{50} values given in Table 1, which are below 1 mg/kg for the two species of waterfowl tested, half of the songbirds, and one of the two birds of prey, mean that carbofuran has one of the highest recorded toxicities to birds of any insecticide registered for use in Canada.

Carbofuran is available both as liquid (flowable) and as granular formulations. Because of different exposure potentials of the granular versus liquid formulations of carbofuran, their hazards to birds and other terrestrial wildlife will be considered separately.

GRANULAR CARBOFURAN

All existing granular formulations of carbofuran are especially hazardous to birds. Registered rates of application range from 0.225 to 5.5 kg a.i./ha, but this difference in rate is probably of less consequence than the fact that a surplus of granules always seems to be available to birds under normal agricultural conditions. On the strength of the evidence to date, it does not appear that adequate mitigation of the hazard is possible. The impact on birds from the use of the registered granular formulations will continue to be extensive if those formulations are allowed to remain on the market. The main findings of this assessment with regard to the granular formulations of carbofuran are summarized below.

Routes of exposure

- Birds actively seek and consume carbofuran granules. The granules are approximately the same size as dietary grit, which consists of small pebbles or large grains of sand that are swallowed and retained in the gizzards of birds to aid in breaking down foodstuffs. Kills of birds resulting from the normal agricultural uses of granular carbofuran have shown conclusively that both the Furadan 10G and Furadan CR-10 formulations (two of the currently registered formulations sold in Canada) are consumed by birds. There is no reason to believe that the 5G is any less attractive to birds. The CR-10 and 5G granules, which are formulated on a corncob base, may also be attractive because of their value as food. FMC Corporation (the manufacturer of carbofuran) has documented kills of at least 45 bird species in the course of its own supervised field trials in corn (maize) fields alone.

- It has been demonstrated under laboratory conditions that a single granule of carbofuran can be lethal to a small songbird. Therefore, exposure need only be minimal to cause an impact. In a sample of 479 Horned Larks (*Eremophila alpestris*) found dead in a group of Utah cornfields treated with granular carbofuran, the median number of granules found in the birds' gizzards was two.

- The consumption of invertebrates, notably earthworms, is an additional route of exposure to granular carbofuran, because the granules can adhere to the invertebrates and contaminate their tissues. Based on residue levels found in earthworms from a cornfield, a realistic hazard assessment indicates that, at the lowest carbofuran application rate in corn, a single earthworm can be lethal to the songbird consuming it. Field studies have reported dead American Robins (*Turdus migratorius*), which feed primarily on earthworms. The contamination of nestlings of other songbirds in proximity to a treated cornfield has also been documented, indicating that contaminated invertebrates were being brought to the nest.

- Flooding or puddling of fields is another way in which several bird species have been killed by carbofuran granules. Problems have been especially severe in the heavy acidic soils of the lower mainland of British Columbia but have also been reported elsewhere. Exposure can be through the sifting of contaminated soil slurries and direct ingestion of granules, primarily by waterfowl, or through drinking contaminated water.

- Secondary poisoning of eagles, hawks, vultures, and other birds of prey by granular carbofuran has been repeatedly documented under operational use conditions as well as in at least one supervised field trial. Here, we restrict the use of the term "secondary poisoning" to refer to the poisoning of a flesh eater feeding on the contaminated tissues of a vertebrate. As of September 1990, there were upwards of 30 documented incidents on record in the United States, excluding incidents involving intentional misuse of carbofuran products (cases in which carbofuran was shown to have been used in order to intentionally poison birds of prey). Large-scale secondary poisoning of vultures in South African cornfields has also been reported to the Canadian Wildlife Service. Secondary poisonings of a Red-tailed Hawk (*Buteo jamaicensis*) and of at least two Bald Eagles (*Haliaeetus leucocephalus*) have recently been confirmed in British Columbia, and several more birds are suspected of having been similarly poisoned. It appears that most or all had been scavenging poisoned waterfowl in fields.

Engineering aspects

- Current planters and planting machinery used in row crops leave large numbers of exposed granules on the soil surface. For example, it is estimated that, under prevailing conditions in Ontario cornfields, between 515 and 1065 Furadan 10G granules are left on the soil surface per metre of furrow. The best possible incorporation of granulars, an in-furrow application in a laboratory setting, still leaves between 17 and 27 granules exposed per metre of furrow. Several studies and reports have shown that even in-furrow applications will not reduce bird mortality with a granular product as toxic as carbofuran, because a surplus of surface granules will always be available to foraging birds. Furthermore, birds habitually scratch the soil surface and probe the soil with their beaks while foraging and could obtain incorporated granules that way. Mortality has been reported even when no granules were found on the surface.

- Similarly, the prevailing type of seed drill used for canola (00 oilseed rape) in western Canada leaves, on average, between six and 17 of the larger Furadan CR-10 granules on the soil surface per square metre of field, with "hot spots" as high as 33 granules per square metre.

Magnitude and frequency of kills

- On the basis of kill rates reported in company studies conducted in corn fields, it can be concluded that the use of granular carbofuran will result in the deaths of a large proportion of the songbirds breeding in and around treated fields. This does not take into account the fact that the reported kill rates do not include birds that leave the field before dying or those that are scavenged or not found. There is also more limited evidence that small mammals are poisoned as well.

- Studies performed by the manufacturer of carbofuran in five different U.S. states, but under conditions typical of Canadian farming, have shown conclusively that the kill rate on carbofuran-treated corn fields is less a function of granule application technique than of the presence of birds in and around the fields. Even attempts to patrol freshly planted fields on foot and to manually cover granules did not succeed in reducing the hazard to birds. In-furrow applications of granular carbofuran (the method giving the best possible granule incorporation) under ideal conditions of calibration and supervision still gave rise to bird kills.

- Kill reports available from the operational use of granular carbofuran confirm the hazard already established by the available field studies. In addition, kill reports from granular carbofuran use on crops such as canola, potatoes, turnips, sugar beets and green peppers indicate that the problem with granular carbofuran extends to most, and probably all, crops for which granulars are currently registered.

- The use of Furadan CR-10 on canola is probably the most serious problem currently because of the potential for mass mortality of very large flocks of arctic migrants that traverse the northern prairies at canola seeding time. A large kill of Lapland Longspurs (*Calcarius lapponicus*) that occurred on a carbofuran-treated field in 1984 is thought to have taken place under conditions of granule incorporation that were better than those achieved with the most popular seeding implement. The number of birds in that incident was estimated at more than 2,000. This is thought to be an underestimate because this species travels north in very large flocks and carcasses were said to have been distributed over an entire quarter section (64 ha). Surveys have shown freshly seeded canola fields to be very attractive to a large number of bird species.

- Waterfowl and other water birds have repeatedly been poisoned when they have foraged in treated fields that were flooded or that developed puddles *months* after the pesticide application. In acidic soils, the granules can be particularly persistent and have remained lethal for upwards of 7 months in a few well-documented instances, both in Canada and in the United States.

North American status

- The U.S. Environmental Protection Agency (EPA) has recently announced a negotiated settlement with FMC Corporation to withdraw all but five minor uses of granular carbofuran in the United States. As stated by the EPA, "none of [the] risk reduction measures [evaluated by the EPA] were adequate to reduce the risk to birds, given the high toxicity of carbofuran granules."

- The State of Virginia recently conducted an extensive survey that showed that bird kills were found in 33 of 44 treated cornfields despite such drastic risk reduction measures as wide buffer zones on the edges of fields, devices to shut off granule flow in turn areas, and extensive training programs for the applicators. A complete ban on granular carbofuran is now in effect in that state.

- The American Ornithologists' Union, one of the world's largest association of professional ornithologists, passed a resolution in 1990 calling for the cancellation and immediate suspension of all carbofuran granular products and urging the U.S. government to also ban the liquid formulation of the insecticide.

FLOWABLE CARBOFURAN

Exposure of wildlife species to the liquid (flowable) formulation of carbofuran is much more context-dependent and the likely hazard to wildlife species more variable than with the granular formulations. Rates of application of the liquid formulation range from 0.072 to 2.5 kg a.i./ha, or by a factor of 35, depending on the crop. Application may be by ground equipment or by air. A review of the evidence available to date helps to identify the main risk factors associated with carbofuran spray applications. An understanding of those risk factors allows for extrapolation to crops for which direct knowledge of the wildlife impact is unavailable. Knowledge of the principal risk factors also allows an assessment of the likelihood that mitigation of the risks associated with the liquid formulation could be successfully implemented.

However, the evidence indicates that it is very unlikely that the hazard of liquid carbofuran to wildlife could ever be eliminated completely. The toxicity of this insecticide is simply too high. Kills of birds recorded at the second lowest registered spray rate (132 g a.i./ha) leave little doubt that absolute safety is unattainable with this product. Studies carried out by the manufacturer at either 550 or 1100 g a.i./ha applied by ground rig, by air, or through centre-pivot irrigation systems suggest that kills of songbirds and also small mammals, reptiles, and amphibians are common and unavoidable. The extent of the kills is likely to be site-specific and may depend on the extent of field edge contamination and on the quality of the habitat surrounding the fields.

The main findings of this assessment with regard to the liquid formulation of carbofuran are summarized below.

Routes of exposure

- Laboratory studies indicate that a substantial fraction of an LD_{50} can be attained by songbirds feeding on contaminated grasshoppers and other invertebrates at one of the lowest registered spray rates (132 g a.i./ha). Measurements of brain cholinesterase inhibition in songbirds collected in a sprayed pasture confirm that the safety margin is limited or nonexistent at that rate.[2] Kills of gulls (*Larus sp.*) feeding on freshly sprayed grasshoppers have been recorded. This route of exposure is also the likely explanation for the impact of carbofuran on the Burrowing Owl (*Speotyto cunicularia*),[3] which is discussed in greater detail below. It must therefore be assumed that the potential for lethal intoxication of consumers of grasshoppers is always present following a grasshopper control program. This lack of safety margin is of the greatest concerns given that the rate of carbofuran registered for grasshopper control is one of the lowest registered rates of application in Canada.

- A number of experimental studies indicate that dermal exposure of birds through overspray or contact with treated vegetation does not pose a significant hazard. This also appears to be the case for waterfowl, despite their apparent susceptibility to this insecticide. Mallard ducklings traversing areas where carbofuran had been applied at either 132 or 264 g a.i./ha were shown to be relatively safe provided they did not attempt to feed. There is evidence that overland movements by duck broods are rapid and that feeding is unlikely. However, concerns remain that any amount of feeding or pecking at the vegetation by the ducklings will almost certainly lead to incapacitation of the birds. Should some of the ducklings become incapacitated, the delay may result in the rest of the brood also being poisoned.

- A large number of kills of waterfowl have been reported in U.S. alfalfa fields when the birds have entered the fields to graze on the crop. Simple calculations show that alfalfa and other forage crops sprayed with carbofuran at the registered Canadian spray rates (0.132–2.5 kg a.i./ha) contain sufficient residues to kill grazing waterfowl. Data are lacking to indicate to what extent waterfowl and other species (e.g., grouse, pheasant, large mammals) are likely to graze on treated forage crops or in the margins of treated fields in Canada. At least one Canadian field study showed a significant impact of the grasshopper spray rate on small-mammal populations. Herbivorous species such as voles (*Microtus pennsylvanicus*) appeared to be the most affected, suggesting that exposure was primarily through grazing on contaminated vegetation.

---

[2] Because carbofuran inhibits cholinesterase enzymes, the measurement of cholinesterase activity in brain tissue is a direct measure of the exposure of one of the key target sites to the insecticide. The extent of cholinesterase depression can be related approximately to the likelihood of fatal intoxication.

[3] This species was formerly in the genus *Athene*. The species name remains the same.

- In Canada, there is at least one incident on record of waterfowl mortality resulting from exposure to contaminated puddles following liquid carbofuran treatment of a turnip field in British Columbia. Bird kills resulting from the use of carbofuran in drip water in U.S. vineyards are a well-documented problem, but this use pattern is not registered in Canada.

- Secondary poisoning of a bird of prey was also seen in one of the company's field studies. The extent to which secondary poisoning occurs with the flowable formulation is not known.

Burrowing Owls

- One of the most serious hazard of carbofuran flowable remains its demonstrated impact on the threatened Burrowing Owl. Research has shown conclusively that carbofuran applied at the grasshopper spray rate (132 g a.i./ha) has a significant impact on the survival and reproductive success of Burrowing Owls. Significant declines in nesting success and brood size were seen with increasing proximity of carbofuran spraying to the nest burrow. There was no such trend of lowered reproductive indices with increasing proximity of spray for some of the main alternative insecticides to carbofuran (carbaryl, deltamethrin). Information available on likely routes of exposure (see above) strongly suggests that the hazard to Burrowing Owls is in direct proportion to the availability of contaminated prey items, either invertebrates or rodent species.

- Reports of owl colony abandonment following exposure to carbofuran were also provided by landowners. Analysis by the Canadian Wildlife Service also suggests that carbofuran use may have affected burrow reoccupancy in subsequent years.

- Removal of the product from the nesting range of the owl was initially proposed by the Canadian Wildlife Service following the field research that demonstrated the impact. In 1989, an interim regulatory decision was taken to label the product so as to prevent its use within 250 m of owl burrows. Unfortunately, despite an aggressive publicity campaign conducted by both the Canadian Wildlife Service and the manufacturer, knowledge of the new label requirement amongst users of the product is still not sufficient to achieve adequate protection of the species.

Evidence of an impact on songbirds and other vertebrates

- Studies on the effects of spraying flowable carbofuran at the registered grasshopper rate (132 g a.i./ha) on populations of roadside-nesting songbirds did not demonstrate any consistent impact. However, birds were found to forage away from the spray sites, and a number of deficiencies in the studies precluded definitive interpretation. A large pasture treated at the same low rate was also assessed postspray. Population surveys did not indicate major impacts on any of the common bird species. No conclusions could be reached regarding effects on the small-mammal populations with the information presented to date (full analysis of these data is not yet available). Birds in the spray block experienced very poor nesting success, but this is not thought to have been a treatment effect. Brain cholinesterase measurements indicated that a segment of the bird and small-mammal populations sustained life-threatening exposures, indicating little or no margin of safety.

- Studies involving the spraying of alfalfa fields at either 550 or 1100 g a.i./ha by ground and air were carried out by the manufacturer in the United States. (The lower rate of 550 g a.i./ha is close to the rate registered in Canada for corn, potato, peppers, and strawberries in eastern Canada. The applications to corn for the control of the European corn borer, *Ostrinia nubilalis*, are almost entirely aerial.) Spray deposits in the crop proper were low (e.g., averaging 23% only for the ground applications at the 550 g a.i./ha rate), but contamination of field edges was substantial. Songbird mortality was recorded at both application rates, whether the insecticide was applied by air or by ground. Most of the dead birds were associated with field edges. The level of field edge contamination did not differ substantially between the fields treated by ground or by air: six of 16 fields treated by ground application had maximum field edge deposits (presumably the downwind edge) higher than average in-field deposits; nine of 16 fields treated by air had higher edge deposits than in-field deposits. Secondary poisoning was also documented in the form of a paralyzed Northern Harrier (*Circus cyaneus*) feeding on a dead rabbit (*Sylvilagus floridanus*). Dead mammals, reptiles, and amphibians were also found. In Canada, a paralyzed bird was found on the edge of a strawberry field treated at 528 g a.i./ha.

- Further studies by the company involved the aerial application of carbofuran to cornfields at rates of 1100 g a.i./ha for the control of the European corn borer. This is approximately twice the rate registered for corn borers in Canada, although only two applications were made, whereas four are permissible in Canada. This rate of application is still lower than the rates registered in Canada for sugar beets, raspberries, strawberries in British Columbia, and cole crops. Application coverage was again very poor, with average deposits of 22% of applied and contamination of field edges again documented. Despite the low measured rates of application, the spray again killed a number of songbirds. Others were found paralyzed. Other vertebrates were also killed, including four southern leopard frogs (*Rana sphenocephala*) found between 2 and 6 hours postspray along one of the field edges. A potential impact of carbofuran on amphibians is significant given the current concerns over their diminishing populations.

  It should be noted that some of the dead or paralyzed birds were found in the edges of control fields. However, residue analyses from those control field edges showed that they had received carbofuran contamination because neighbouring fields had been treated with the insecticide.

- Residue levels of 2 ppm carbofuran were measured in the gastrointestinal tracts of deer mice captured on treated sites. Similar levels were found in songbirds. The paralyzed Northern Harrier mentioned above was feeding on a rabbit carcass containing 0.1 ppm carbofuran. This raises the possibility that secondary poisoning is a widespread occurrence following the use of flowable carbofuran. However, the data do not currently allow us to make this determination, because residues in the gastrointestinal tracts of small mammals or birds are not readily comparable to the total body burden measured in the rabbit carcass.

North American Status

- The flowable formulation of carbofuran has not yet been formally the subject of a special review in the U.S. although, informally, review activities have been taking place within the U.S. EPA and draft documents have been prepared in the anticipation of a review. As mentioned earlier, groups such as the American Ornithologists Union have been pressuring the U.S. EPA to take action on the flowable formulation.

- Some States have taken unilateral action to control the use of the flowable formulation within their jurisdiction. In California, the product is labelled so that it cannot be used within 1 mile (1.6 km) of any nesting waterfowl or on areas where grazing waterfowl may be expected to feed. Similar labelling in Canada would mean a virtual elimination of the product from the Canadian prairies. California has also imposed recent restrictions on the use of the product in vineyards.

- In Canada, a recommendation to eliminate the use of carbofuran from the entire (current and historical) range of the Burrowing Owl has now been put forth by the Canadian Burrowing Owl Recovery Team, a federal-provincial initiative to rehabilitate the species.

FAITS SAILLANTS ET CONCLUSIONS

Le présent résumé ainsi que l'évaluation complète des risques publiée par le Service canadien de la faune ne passent en revue que les risques que le carbofuran pose directement pour la faune vertébrée en raison de sa toxicité aiguë. C'est là la plus grande crainte liée à l'utilisation de cet insecticide. Le présent document n'aborde pas les préoccupations relatives à ses effets sublétaux ou à ses effets secondaires sur les espèces fauniques vertébrées par suite de la disparition d'espèces invertébrées ou vertébrées.

Le carbofuran est un insecticide du groupe des carbamates qui inhibe les enzymes cholinestérasiques et perturbe le transfert de l'influx nerveux chez les espèces tant vertébrées qu'invertébrées. D'après les valeurs de la DL_{50} orale aiguë, qui se situent entre 8 et 14 mg/kg chez le rat, le carbofuran est classé comme extrêmement dangereux pour les humains[4]. Dans le cas de la formulation fluidifiable, quelques gouttes à peine peuvent être fatales, ce qui correspond à la DL_{50} approximative pour les espèces d'oiseaux *les moins* sensibles. Le tableau 1 présente la toxicité du carbofuran pour un certain nombre d'espèces d'oiseaux.

Tableau 1.
Toxicité orale aiguë du carbofuran de qualité technique pour les oiseaux, de l'espèce la plus sensible à l'espèce la moins sensible.

Espèce	Sexe	Âge	DL_{50} (mg/kg)	Intervalle de confiance de 95 %
Dendrocygne fauve (*Dendrocygna bicolor*)	F	3-6 mois	0,238	0,200–0,283
Canard colvert (*Anas platyrhynchos*)	U	33-39 h	0,370	0,283–0,484
	U	6-8 j	0,628	0,530–0,744
	U	27-33 j	0,510	0,410–0,635
	F	3-4 mois	0,397	0,315–0,500
	M/F	6 mois	0,415	0,333–0,516
	M	12 mois	0,480	0,381–0,604
	F	12 mois	0,510	0,410–0,635
Carouge à épaulettes (*Agelaius phoeniceus*)	U	adulte	0,422	
Queléa (*Quelea quelea*)	U	adulte	0,422–0,562	
Crécerelle d'Amérique (*Falco sparverius*)	M/F	1-4 ans	0,6	0,5-1,0
Roselin familier (*Carpodacus mexicanus*)	U	adulte	0,750	
Moineau domestique (*Passer domesticus*)	U	adulte	1,33	
Pigeon biset (*Columba livia*)	U	adulte	1,33	

---

1 C'est la dose aiguë calculée comme létale pour la moitié d'une population expérimentale qui lui est exposée. Elle est exprimée en milligrammes de carbofuran de qualité technique par kilogramme de poids corporel.

Espèce	Sexe	Âge	DL_{50} (mg/kg)	Intervalle de confiance de 95 %
Vacher à tête brune (*Molothrus ater*)	U	adulte	1,33	
Quiscale bronzé (*Quiscalus quiscula*)	U	adulte	1,33-3,16	
Caille du Japon (*Coturnix coturnix*)	M F	14 j 14 j	1,9 1,7	1,7-2,1 1,3-1,9
Petit-duc maculé (*Ottus asio*)	M/F	2-5 ans	1,9	1,4-2,7
Faisan de chasse (*Phasianus colchicus*)	F	3 mois	4,15	2,38-7,22
Colin de Virginie (*Colinus virginianus*)	F M/F M/F	3 mois 16-20 semaines 1-2 ans	5,04 12 8,0	3,64-6,99 7,0-19 6,0-10
Étourneau sansonnet (*Sturnus vulgaris*)	U	adulte	5,62	

M = mâle U = sexe indéterminé
F = femelle * = en période de reproduction

Il arrive souvent que les oiseaux soient plus sensibles à des insecticides inhibiteurs de la cholinestérase que les mammifères. Toutefois, les DL_{50} présentées au tableau 1 sont inférieures à 1 mg/kg dans le cas des deux espèces d'oiseaux aquatiques étudiées, de la moitié des espèces d'oiseaux chanteurs et d'une des deux espèces d'oiseaux de proie; le carbofuran est par conséquent l'un des insecticides les plus toxiques pour les oiseaux parmi tous les insecticides homologués au Canada.

Le carbofuran est vendu sous forme liquide (fluidifiable) et en granulés. Les possibilités d'exposition aux formulations granulées et liquides étant différentes, les risques pour les oiseaux et d'autres espèces fauniques terrestres seront examinés séparément.

CARBOFURAN EN GRANULÉS

Toutes les formulations granulées existantes de carbofuran sont particulièrement dangereuses pour les oiseaux. Les doses d'emploi homologuées varient de 0,225 à 5,5 kg m.a./ha, mais cet écart est probablement de moindre importance que le fait qu'il semble toujours y avoir un surplus de granulés accessibles aux oiseaux dans les champs. Compte tenu des données accumulées jusqu'ici, il ne semble pas qu'il soit possible de prendre des mesures adéquates pour atténuer le risque. L'impact sur les oiseaux de l'utilisation de formulations homologuées de granulés continuera d'être important si ces formulations restent sur le marché. Voici un résumé des principales conclusions de l'évaluation des formulations de carbofuran en granulés.

<u>Voies d'exposition</u>

- Les oiseaux cherchent activement et consomment des granulés de carbofuran. Ces granulés sont à peu près de la même grosseur que les petits cailloux et les gros grains de sable que les oiseaux avalent et gardent dans leur gésier pour triturer leur nourriture. Une étude de la mortalité des oiseaux causée par l'épandage habituel dans les champs de carbofuran en granulés a démontré de façon concluante que les oiseaux mangent des granulés de Furadan 10G et CR-10 (deux des formulations actuellement homologuées au Canada). Rien ne porte à croire que le 5G soit moins attirant pour les oiseaux. Les granulés de CR-10 et de 5G sont préparés avec une base de rafle de maïs et peuvent également attirer les oiseaux en raison de leur valeur alimentaire. La FMC Corporation (fabricant du carbofuran) a recensé des oiseaux morts appartenant à au moins 45 espèces lors de ses propres essais sur le terrain uniquement dans des champs de maïs.

- Il a été démontré en laboratoire qu'un seul granulé de carbofuran peut entraîner la mort d'un petit oiseau chanteur. Par conséquent, même une exposition minime aura un impact. Dans un échantillon de 479 alouettes cornues (*Eremophila alpestris*) trouvées mortes dans un groupe de champs de maïs de l'Utah traités au carbofuran en granulés, le nombre médian de granulés découverts dans le gésier des oiseaux était de deux.

- La consommation d'invertébrés, plus précisément des vers de terre, est une autre voie d'exposition au carbofuran en granulés, puisque ces derniers peuvent adhérer aux invertébrés et contaminer leurs tissus. D'après les concentrations de résidus découvertes dans des vers de terre provenant d'un champ de maïs, une évaluation réaliste des risques révèle qu'un seul ver de terre, à la dose d'emploi la plus faible du carbofuran, peut entraîner la mort d'un oiseau chanteur qui le consomme. Des études sur le terrain ont fait état de morts chez le merle d'Amérique (*Turdus migratorus*), une espèce friande des vers de terre, et ont présenté des données sur la contamination des oisillons d'autres oiseaux chanteurs vivant à proximité d'un champ de maïs traité, révélant que des invertébrés contaminés étaient ramenés au nid.

- Il a été démontré que plusieurs autres espèces d'oiseaux sont tuées par les granulés de carbofuran lorsque les champs sont inondés ou parsemés de flaques d'eau. De tels problèmes ont été particulièrement graves dans les sols acides lourds des basses terres du Fraser en Colombie-Britannique, mais ont également été signalés ailleurs. Les oiseaux, principalement des espèces de sauvagine, peuvent être exposés au produit lorsqu'ils sondent la boue contaminée et ingèrent directement les granulés, ou lorsqu'ils boivent de l'eau contaminée.

- L'empoisonnement secondaire par des granulés de carbofuran d'aigles, de faucons, de vautours et d'autres rapaces a été maintes fois établi lors d'opérations d'épandage ainsi que pendant au moins un essai au champ. Nous restreignons ici le sens de l'expression «empoisonnement secondaire» à l'empoisonnement de carnivores consommant les tissus contaminés d'un vertébré. Au 30 septembre 1990, plus de 30 cas avaient été signalés aux États-Unis, exception faite des incidents où l'on avait fait un mauvais usage intentionnel des produits de carbofuran (cas où il était établi que le carbofuran avait été utilisé à dessein pour empoisonner des oiseaux de proie). Des cas d'empoisonnement secondaire à grande échelle de vautours dans des champs de maïs de l'Afrique du Sud ont également été signalés au Service canadien de la faune. Des empoisonnements secondaires de buses à queue rousse (*Buteo jamaicensis*) et d'au moins deux pygargues à tête blanche (*Haliaeetus* *leucocephalus*) ont récemment été confirmés en Colombie-Britannique, et on soupçonne que plusieurs autres oiseaux ont été ainsi empoisonnés. Il semble que la plupart de ces oiseaux, sinon tous, se nourrissaient des cadavres d'espèces de sauvagine empoisonnées dans les champs.

Aspects techniques

- Les semoirs et le matériel de plantation actuellement utilisés pour les cultures en lignes laissent beaucoup de granulés sur la surface du sol. Ainsi, on estime que de 515 à 1 065 granulés de Furadan 10G restent à la surface du sol par mètre de sillon dans un champ de maïs typique de l'Ontario. La meilleure méthode d'incorporation des granulés, soit leur dépôt dans la raie de semis dans un cadre expérimental, laisse toujours de 17 à 27 granulés exposés par mètre de sillon. Plusieurs études et rapports ont montré que même cette méthode ne réduira pas la mortalité des oiseaux causée par un produit granulé aussi toxique que le carbofuran, car les oiseaux en quête de nourriture auront toujours accès à un surplus de granulés en surface. De plus, les oiseaux grattent généralement la surface du sol et le fouillent avec leur bec à la recherche de nourriture, et ils pourraient ainsi avaler des granulés incorporés au sol. Des cas de mortalité ont été signalés même lorsque aucun granulé n'avait été découvert en surface.

- De la même façon, le type de semoir en ligne le plus utilisé pour le canola (colza 00) dans l'ouest du Canada laisse en moyenne de 6 à 17 des plus gros granulés de Furadan CR-10 à la surface du sol par mètre carré de champ, avec des «zones d'accumulation» pouvant atteindre jusqu'à 33 granulés par mètre carré.

Ampleur et fréquence de la mortalité

- À partir des taux de mortalité signalés dans les études du fabricant effectuées dans des champs de maïs, on peut conclure que l'utilisation de carbofuran en granulés entraînera la mort d'un pourcentage important des oiseaux chanteurs se reproduisant dans les champs traités et aux alentours. On ne tient pas compte du fait que les taux de mortalité signalés n'incluent pas les oiseaux qui quittent le champ avant de mourir, ni ceux qui sont dévorés par des oiseaux de proie ou qui ne sont jamais découverts. Certaines constatations portent également à croire que de petits mammifères sont aussi empoisonnés.

- Des études effectuées par le fabricant du carbofuran dans cinq États américains différents, mais dans des conditions caractéristiques du milieu agricole canadien, ont montré de façon concluante que le taux de mortalité dans les champs de maïs traités au carbofuran est moins fonction de la méthode d'application des granulés que de la présence d'oiseaux dans les champs et aux alentours. Même lorsqu'on parcourait à pied les champs qui venaient d'être plantés afin d'enfouir à la main les granulés qui y restaient, on n'est pas parvenu à réduire les risques pour les oiseaux. Dans des conditions idéales d'étalonnage et de surveillance, l'application dans la raie de semis des granulés de carbofuran (méthode procurant la meilleure incorporation possible) a quand même entraîné de la mortalité chez les oiseaux.

- Le nombre de morts signalées à la suite de l'épandage à grande échelle de granulés de carbofuran confirme les risques établis préalablement par les études sur le terrain. De plus, les cas connus de mortalité causée par l'utilisation de carbofuran en granulés pour protéger des cultures comme le canola, la pomme de terre, le navet, la betterave à sucre et le poivron vert indiquent que le problème du carbofuran en granulés s'étend à la plupart des cultures pour lesquelles ce produit est homologué, sinon à toutes.

- L'utilisation du Furadan CR-10 pour protéger le canola est probablement le plus grave problème à l'heure actuelle en raison des possibilités de mortalité massive chez les très grandes volées d'oiseaux migrateurs arctiques qui traversent le nord des prairies à l'époque des semailles. Un grand nombre de bruants lapons (*Calcarius lapponicus*) sont morts en 1984 dans un champ traité au carbofuran; on pense que l'incorporation des granulés était pourtant supérieure à la norme obtenue avec le matériel d'ensemencement le plus populaire. Lors de cet incident, le nombre de mortalités a été estimé à plus de 2 000 oiseaux. Le nombre réel etait probablement beaucoup plus élevé car cette espèce migre vers l'arctique en très grandes volées et les carcasses étaient, selon les rapports, réparties sur tout un quart de section (64 hectares). Des relevés ont démontré que les champs de canola fraîchement ensemencés sont très attrayants pour un grand nombre d'espèces d'oiseaux.

- Des espèces de sauvagine et d'autres espèces d'oiseaux aquatiques ont été empoisonnées à maintes reprises après s'être alimentées dans des champs inondés ou parsemés de flaques d'eau *plusieurs mois* après l'application du pesticide. Dans des sols acides, les granulés peuvent être particulièrement persistants et, dans quelques cas bien connus, sont restés létaux jusqu'à 7 mois après leur application, tant au Canada qu'aux États-Unis.

<u>Situation en Amérique du Nord</u>

- L'Environmental Protection Agency des États-Unis (EPA) a annoncé récemment qu'elle avait négocié avec la FMC Corporation le retrait aux États-Unis du carbofuran en granulés, exception faite de cinq types d'usage mineur. Comme l'a déclaré l'EPA, «aucune des mesures de réduction des risques [évaluées par l'EPA] n'était suffisante pour réduire les dangers pour les oiseaux, compte tenu de la forte toxicité des granulés de carbofuran».

- L'État de Virginie a récemment effectué un relevé à grande échelle qui a révélé la présence d'oiseaux morts dans 33 de 44 champs de maïs traités, malgré les mesures énergiques de réduction des risques qui avaient été prises, comme l'établissement de larges zones tampons en bordure des champs, l'installation de dispositifs interrompant l'épandage des granulés lors des virages et l'élaboration de programmes de formation approfondie destinés aux responsables de l'application de l'insecticide. L'utilisation de granulés de carbofuran est maintenant complètement interdite dans cet État.

- En 1990, l'American Ornithologists' Union, l'une des plus grandes associations d'ornithologues professionnels au monde, a adopté une résolution exigeant l'annulation et le retrait immédiat de tous les produits de carbofuran sous forme de granulés et pressant le gouvernement américain d'interdire également la formulation liquide de cet insecticide.

CARBOFURAN FLUIDIFIABLE

L'exposition des espèces fauniques à la formulation liquide (fluidifiable) de carbofuran est davantage fonction de la situation et les risques éventuels sont plus variables que dans le cas des formulations en granulés. Les doses d'emploi de la formulation liquide varient de 0,072 à 2,5 kg m.a./ha, soit d'un facteur de 35, selon le type de culture. L'application peut être terrestre ou aérienne. Un examen des données disponibles jusqu'à maintenant aide à déterminer les principaux facteurs de risque liés à des pulvérisations de carbofuran. Ces facteurs de risque, une fois bien compris, peuvent être extrapolés à des cultures pour lesquelles il n'existe pas de données directes relatives aux incidences sur la faune. La connaissance des risques principaux permet également d'évaluer les possibilités que des mesures d'atténuation des risques causés par la pulvérisation de formulations liquides puissent être mises en oeuvre avec succès.

Toutefois, les faits révèlent qu'il est très peu probable que les risques du carbofuran liquide pour la faune puissent jamais être éliminés complètement. Cet insecticide est tout simplement trop toxique — le nombre d'oiseaux morts recensés avec la deuxième plus faible dose d'emploi homologuée (132 g m.a./ha) ne laisse guère de doute quant à l'impossibilité de rendre ce produit tout à fait sûr. Des études effectuées par le fabricant et comportant des épandages terrestres, aériens ou par des systèmes d'irrigation à arroseurs géants de doses de 550 ou de 1 100 g m.a./ha laissent supposer que la mortalité d'oiseaux chanteurs ainsi que de petits mammifères, de reptiles et d'amphibiens est répandue et inévitable. L'ampleur de la mortalité varie probablement selon le site et peut dépendre de l'étendue de la contamination en bordure des champs et de la qualité des habitats entourant ces champs.

Voici un résumé des principales conclusions de l'évaluation de la formulation liquide de carbofuran.

Voies d'exposition

- Des études en laboratoire montrent que des oiseaux chanteurs se nourrissant de sauterelles et d'autres invertébrés contaminés peuvent ingérer, à l'une des plus faibles doses de pulvérisation homologuées (132 g m.a./ha), une fraction importante de la DL_{50}. Des mesures du degré d'inhibition de la cholinestérase du cerveau chez des oiseaux chanteurs recueillis dans un pâturage traité confirment que la marge de sécurité est limitée ou inexistante à cette dose d'emploi[5]. Des morts de goélands (*Larus* sp.) se nourrissant de sauterelles dans des champs récemment traités ont été signalées. Cette voie d'exposition est également l'explication vraisemblable de l'impact du carbofuran sur la chouette des terriers (*Speotyto cunicularia*)[6], qui est examiné plus en détail ci-dessous. Il faut donc

---

2 Le carbofuran inhibant la cholinestérase, la mesure de l'activité de la cholinestérase dans les tissus du cerveau est une mesure directe de l'exposition à l'insecticide dans l'un des principaux sites visés. Le degré d'inhibition de la cholinestérase peut être corrélé de façon approximative aux possibilités d'intoxication fatale.

3 Cette espèce appartenait autrefois au genre *Athene*. Le nom de l'espèce reste le même.

supposer que le potentiel d'intoxication létale des prédateurs des sauterelles est toujours présent à la suite d'un programme de lutte contre les sauterelles. L'absence de marge de sécurité est des plus préoccupantes, car la dose d'emploi homologuée du carbofuran pour lutter contre les sauterelles est l'une des plus faibles au Canada.

- Un certain nombre d'études expérimentales révèlent que l'exposition cutanée des oiseaux par suite d'une exposition directe aux pulvérisations ou par contact avec la végétation traitée ne constituent pas un risque important. Il semble également en être de même pour les espèces de sauvagine, malgré leur sensibilité apparente à cet insecticide. Il a été démontré que des canetons colverts traversant des régions traitées au carbofuran à raison de 132 ou 264 g m.a./ha étaient relativement en sécurité pourvu qu'ils ne tentent pas de se nourrir. Certains faits indiquent que les déplacements terrestres des nichées de canards sont rapides et qu'il est peu probable qu'elles s'alimentent. Toutefois, il n'en reste pas moins que des oisillons, pour peu qu'ils s'alimentent ou qu'ils picorent la végétation, risquent presque à coup sûr de devenir impotents, causant un retard qui peut entraîner l'empoisonnement du reste de la couvée.

- De grands nombres d'oiseaux aquatiques morts ont été signalés aux États-Unis dans des champs de luzerne où ils étaient allés se nourrir. Un simple calcul montre que les champs de luzerne et d'autres cultures fourragères ayant reçu la dose de carbofuran homologuée au Canada (0,132-2,5 kg m.a./ha) contiennent suffisamment de résidus pour tuer les espèces de sauvagine qui s'y alimentent. On ne sait pas dans quelle mesure les espèces de sauvagine et autres (p. ex., tétras, gélinottes, faisans, grands mammifères) se nourrissent dans les champs traités ou en bordure de ceux-ci au Canada. Au moins une étude canadienne effectuée sur le terrain a montré un impact significatif sur les populations de petits mammifères des doses pulvérisées pour lutter contre les sauterelles. Des espèces herbivores, comme le campagnol des champs (*Microtus pennsylvanicus*), semblent être les plus touchées, ce qui laisse supposer que l'exposition provient principalement de la consommation de végétation contaminée.

- Au Canada, on a signalé au moins un cas de mortalité d'espèces de sauvagine à la suite d'une exposition à des flaques d'eau contaminées par le traitement au carbofuran liquide d'un champ de navets de la Colombie-Britannique. La mortalité d'oiseaux provoquée par la présence de carbofuran dans les eaux d'irrigation goutte à goutte des vignobles américains est un problème bien connu, mais ce type d'utilisation n'est pas homologué au Canada.

- L'empoisonnement secondaire d'un oiseau de proie a également été observé lors d'une des études sur le terrain du fabricant. On ne sait si la formulation fluidifiable est souvent cause d'empoisonnement secondaire.

Chouette des terriers

- L'impact irréfutable du carbofuran fluidifiable sur la chouette des terriers, une espèce menacée de disparition, est encore l'un des dangers les plus graves de ce produit. Des recherches ont montré de façon concluante que le carbofuran, appliqué à une dose permettant de lutter contre les sauterelles (132 g m.a./ha), a un impact significatif sur le taux de survie et de reproduction de la chouette des terriers. On a observé une diminution significative du taux de succès de la nidification et du nombre d'oisillons en fonction de l'augmentation de la proximité des terriers de nidification par rapport aux champs traités au carbofuran. Aucune tendance à la baisse des indices de reproduction avec l'accroissement de la proximité des champs traités n'a été observée pour les principaux insecticides substituts du carbofuran (carbaryl, deltaméthrine). Les données disponibles sur les voies probables d'exposition (voir ci-dessus) laissent fortement supposer que les risques auxquels sont exposées les chouettes des terriers sont directement proportionnels à la disponibilité d'espèces de proie contaminées, soit des invertébrés ou des rongeurs.

- Des agriculteurs ont également signalé des colonies de chouettes des terriers abandonnées à la suite d'une exposition au carbofuran. Les analyses effectuées par le Service canadien de la faune permettent également de supposer que l'utilisation du carbofuran peut avoir influé sur l'occupation des terriers au cours des années ultérieures.

- L'élimination de ce produit dans l'aire de nidification de la chouette a tout d'abord été proposée par le Service canadien de la faune à la suite de recherches sur le terrain ayant démontré l'impact de ce pesticide. En 1989, une décision réglementaire provisoire a été prise : elle prévoyait l'étiquetage du produit de façon à interdire son utilisation à moins de 250 m de terriers de chouettes. Malheureusement, malgré une campagne de publicité énergique menée par le Service canadien de la faune et le fabricant, les utilisateurs du produit ne connaissent pas encore assez bien la nouvelle exigence pour que l'espèce soit suffisamment protégée.

<u>Preuves d'un impact sur des oiseaux chanteurs et d'autres vertébrés</u>

- Des études sur les effets de pulvérisations de carbofuran fluidifiable à la dose homologuée pour lutter contre les sauterelles (132 g m.a./ha) sur les populations d'oiseaux chanteurs nichant en bordure des routes n'ont révélé aucun impact systématique. Toutefois, on a découvert que les oiseaux s'alimentaient loin des sites traités, et certaines lacunes des études ont empêché toute interprétation définitive des résultats. Un vaste pâturage ayant reçu cette même dose faible a également été évalué après le traitement. Des relevés des populations n'ont indiqué aucun effet majeur sur les espèces courantes d'oiseaux. Les données compilées jusqu'à maintenant (leur analyse complète n'est pas encore disponible) n'ont pu permettre d'arriver à des conclusions à l'égard des effets sur les populations des petits mammifères. Le succès de nidification des oiseaux nichant dans le bloc traité a été très faible, mais on ne pense pas que cela puisse être dû au traitement. Des mesures de la cholinestérase dans les tissus du cerveau révèlent qu'un segment des populations d'oiseaux et de petits mammifères a été exposé de façon aiguë au produit, ce qui révèle une marge de sécurité faible, voire inexistante.

- Le fabricant a effectué aux États-Unis des études consistant à traiter des champs de luzerne à raison de 550 ou 1 100 g m.a./ha, pulvérisés par voie terrestre et aérienne. (La plus faible dose de 550 g m.a./ha se rapproche de la dose homologuée au Canada pour les champs de maïs, de pommes de terre, de poivrons et de fraises de l'est du Canada. Les applications dans les champs de maïs pour lutter contre la pyrale du maïs (*Ostrinia nubilalis*) sont presque uniquement aériennes.) Le dépôt du produit pulvérisé dans les champs mêmes était faible (seulement 23 % en moyenne dans le cas des applications terrestres à une dose de 500 g m.a./ha), mais la contamination en bordure des champs était importante. Des cas de mortalité d'oiseaux chanteurs ont été observés avec les deux doses d'emploi, que la pulvérisation ait été aérienne ou terrestre. La plupart des oiseaux morts se trouvaient en bordure des champs. Le degré de contamination en périphérie ne différait pas beaucoup entre les champs traités au sol ou par avion : 6 des 16 champs traités au sol avaient un dépôt maximal en périphérie (probablement du côté sous le vent) supérieur au dépôt moyen dans le champ, et 9 de 16 champs traités par avion présentaient des dépôts plus élevés en bordure que dans le champ même. Un cas d'empoisonnement secondaire a également été signalé, soit un busard Saint-Martin (*Circus cyaneus*) paralysé qui se nourrissait d'une carcasse de lapin à queue blanche (*Sylvilagus floridanus*). Des mammifères, des reptiles et des amphibiens morts ont également été découverts. Au Canada, un oiseau paralysé a été trouvé en bordure d'un champ de fraises traité à raison de 528 g m.a./ha.

- D'autres études effectuées par le fabricant portaient sur des applications aériennes de carbofuran sur des champs de maïs à raison de 1 100 g m.a./ha afin de lutter contre la pyrale du maïs. Cette dose est environ le double de celle homologuée pour lutter contre ces ravageurs au Canada, bien que seulement deux applications aient été effectuées (le maximum admissible au Canada est de quatre). Cette dose d'emploi est tout de même plus faible que celle homologuée au Canada pour la betterave à sucre, les framboisiers et les fraisiers en Colombie-Britannique, ainsi que pour les choux. Ici encore, les superficies traitées ont été mal couvertes, avec un dépôt moyen du produit de 22 %, et on a observé une contamination en bordure des champs. Malgré les faibles taux d'application mesurés, le traitement a encore entraîné la mort d'un certain nombre d'oiseaux chanteurs, et des oiseaux paralysés ont été découverts. D'autres vertébrés ont également été tués, y compris quatre grenouilles léopard (*Rana sphenocephala*) trouvées en bordure d'un champ de 2 à 6 heures après le traitement. L'impact potentiel du carbofuran sur les amphibiens est important, compte tenu des préoccupations actuelles sur la diminution de leurs populations.

  Il convient de noter que certains des oiseaux morts ou paralysés ont été découverts en bordure de champs témoins. Toutefois, des analyses des résidus prélevés en bordure de ces champs ont montré qu'ils avaient été contaminés par le carbofuran puisque des champs avoisinants avaient été traités avec cet insecticide.

- Des concentrations de résidus de carbofuran de 2 ppm ont été mesurées dans le tube digestif de souris sylvestres capturées dans les endroits traités. Des concentrations similaires ont été découvertes chez des oiseaux chanteurs. Le busard Saint-Martin paralysé dont nous avons fait état précédemment se nourrissait d'une carcasse de lapin contenant 0,1 ppm de carbofuran. Cela soulève la possibilité que l'empoisonnement d'autres animaux soit un phénomène répandu causé par l'utilisation de carbofuran fluidifiable; les données actuelles ne nous permettent toutefois pas de l'affirmer, car les résidus trouvés dans les tubes digestifs des petits mammifères ou des oiseaux ne sont pas aisément comparables à la charge corporelle totale mesurée dans la carcasse de lapin.

Situation en Amérique du Nord

- La formulation fluidifiable n'a pas encore fait l'objet d'une réévaluation formelle aux États-Unis; toutefois, de façon non officielle, une révision est en cours au sein de l'EPA et des documents ont été préparés en prévision d'une réévaluation. Comme on l'a déjà mentionné, certains groupes, comme l'American Ornithologists' Union, font pression sur l'EPA des États-Unis pour qu'elle prenne des mesures concernant la formulation fluidifiable.

- Certains États ont agi de façon unilatérale pour restreindre l'utilisation de la formulation fluidifiable sur leur territoire. En Californie, le produit est étiqueté de façon à ne pouvoir être utilisé à moins d'un mille (1,6 km) de toute espèce de sauvagine nicheuse ainsi que de tout endroit où des espèces de sauvagine brouteuses pourraient s'alimenter. Au Canada, un tel étiquetage équivaudrait pratiquement à éliminer le produit dans les Prairies canadiennes. La Californie a aussi imposé récemment des restrictions à l'utilisation du produit dans les vignobles.

- Au Canada, l'équipe fédérale-provinciale de rétablissement de la chouette des terriers a recommandé l'interdiction du carbofuran dans toute l'aire d'extension (actuelle et historique) de la chouette.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

1. INTRODUCTION

Carbofuran (2,3-dihydro-2,2-dimethyl-7-benzo-furanyl methyl carbamate) is a carbamate insecticide sold under the trade name "Furadan." It is a potent and direct cholinesterase inhibitor that does not need metabolic alteration before becoming toxic. It is available either as a liquid suspension (the flowable formulation) or as a granular product.

The environmental fate of carbofuran and its toxicity to nontarget organisms, especially terrestrial invertebrates, have been extensively reviewed (NRCC 1979; Eisler 1985; Berisford *et al.* 1985; Trotter *et al.* 1989; Bharadia 1990). This document reviews only the risks that carbofuran use poses directly to vertebrate wildlife through acute toxicity. This is where lies the greatest concern associated with this insecticide. Any potential concerns relating to sublethal effects of the pesticide or effects on vertebrate wildlife mediated through removal of invertebrate or vertebrate food supply are not covered here. The review relies in large part on unpublished information, either submitted by the manufacturer in support of its product or obtained from various government agencies, especially the U.S. Environmental Protection Agency (EPA) through access to the public docket on the Special Review of granular carbofuran. Not all the relevant information is reviewed here. For example, a number of studies and much relevant information have been submitted by the registrant in the United States but not in Canada, despite official requests by Agriculture Canada and the Canadian Wildlife Service.

Because of the very different exposure potentials of the granular and liquid formulations of carbofuran, their risks to birds and other wildlife will be considered separately in this report. Also, studies pertaining to the flowable formulation are reviewed in somewhat more detail than studies on the granular formulation. The reason for this is that the flowable formulation has not yet been the subject of a U.S. special review and much of the information has not yet publically been reviewed.

2. ACUTE TOXICITY TO BIRDS

Carbofuran is classified as extremely hazardous to humans based on acute oral rat LD_{50} values in the 8–14 mg/kg range (Health and Welfare Canada 1987).[7] This means that even a few drops are potentially lethal. By comparison, this is the approximate LD_{50} for the *least* sensitive bird species. The toxicity of carbofuran to a number of bird species is given in Table 1.

It is not unusual for birds to be more susceptible than mammals to cholinesterase-inhibiting insecticides. However, the LD_{50} values given in Table 1, which are below 1 mg/kg for the two species of waterfowl tested, half of the songbirds, and one of the two birds of prey, mean that carbofuran has one of the highest recorded toxicities to birds of any insecticide registered for use in Canada.

Hill and Camardese (1984) found no significant differences in the toxicities of technical carbofuran and the 10% sand core granules (Furadan 10G) to Northern Bobwhite. On the other hand, the flowable formulation (Furadan 480F or Furadan 4F in the United States) is approximately 1.7 times as toxic as the technical active ingredient to the same species (E.F. Hill, U.S. Fish and Wildlife Service, pers. comm.).

---

[7] This is the acute dose calculated to kill half of the test population to which it is given. It is expressed in milligrams of technical carbofuran per kilogram of body weight.

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

Species	Sex	Age	LD_{50} (mg/kg)	95% confidence interval	Source
Fulvous Whistling-Duck (*Dendrocygna bicolor*)	F	3-6 mo.	0.238	0.200-0.283	1
Mallard (*Anas platyrhynchos*)	U	33-39 h	0.370	0.283-0.484	2
	U	6-8 d	0.628	0.530-0.744	2
	U	27-33 d	0.510	0.410-0.635	2
	F	3-4 mo.	0.397	0.315-0.500	1
	M/F	6 mo.	0.415	0.333-0.516	2
	M*	12 mo.	0.480	0.381-0.604	1
	F*	12 mo.	0.510	0.410-0.635	1
Red-winged Blackbird (*Agelaius phoeniceus*)	U	adult	0.422		3
Red-billed Quelea (*Quelea quelea*)	U	adult	0.422-0.562		3
American Kestrel (*Falco sparverius*)	M/F	1-4 yr.	0.6	0.5-1.0	6
House Finch (*Carpodacus mexicanus*)	U	adult	0.750		3
House Sparrow (*Passer domesticus*)	U	adult	1.33		3
Rock Dove (*Columba livia*)	U	adult	1.33		3
Brown-headed Cowbird (*Molothrus ater*)	U	adult	1.33		3
Common Grackle (*Quiscalus quiscula*)	U	adult	1.33-3.16		3
Japanese Quail (*Coturnix coturnix*)	M	14 d	1.9	1.7-2.1	4
	F	14 d	1.7	1.3-1.9	4
Eastern Screech-Owl (*Otus asio*)	M/F	2-5 yr.	1.9	1.4-2.7	6
Ring-necked Pheasant (*Phasianus colchicus*)	F	3 mo.	4.15	2.38-7.22	1
Northern Bobwhite (*Colinus virginianus*)	F	3 mo.	5.04	3.64-6.99	1
	M/F	16-20 wk.	12	7.0-19	5
	M/F	1-2 yr.	8.0	6.0-10	6
European Starling (*Sturnus vulgaris*)	U	adult	5.62		3

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

1. Hudson *et al.* 1984
2. Hudson *et al.* 1972
3. Schafer *et al.* 1983 (range-finding values only)
4. Sherman and Ross in NRCC 1979
5. Hill and Camardese 1984
6. Wiemeyer and Sparling 1991

Consumption of as few as one to five granules of Furadan 10G can be fatal to small birds (Balcomb *et al.* 1984a). An average 10G granule (based on a mean weight of 0.320 mg; Hill and Camardese 1984) contains 0.032 mg of active carbofuran, which represents the approximate LD_{50} for a small songbird. A corncob-based granule also marketed in Canada (Furadan CR-10) is larger (2.25 mg; Maze *et al.* 1991) and contains an average of 0.22 mg of active carbofuran (or 70 times the amount on a 10G granule). A single CR-10 granule is therefore capable of killing even large-bodied birds or some of the least sensitive songbirds.

The toxicity of carbofuran can also be expressed as the calculated concentration in the feed that kills half of the test organisms, usually in a standardized 5-day feeding period (LC_{50}). The LC_{50} ranges between 21 and 746 ppm (FMC 1972, 1976a; Hill *et al.* 1975), depending on the species and the age of the test birds. The Mallard in these tests proved more sensitive than the Ring-necked Pheasant or the Northern Bobwhite. However, these data are of limited usefulness. Laboratory short-term feeding tests with the more acutely toxic carbamate and organophosphate insecticides appear to generally underestimate hazard (Mineau 1991a).

3. EXPOSURE OF WILDLIFE TO THE GRANULAR FORMULATION

3.1 REGISTERED USE PATTERNS IN CANADA

Three formulations of granular carbofuran are currently registered in Canada. Their identity and use patterns are given in Table 2. Application rates are given per 100 m of row for row crops and per hectare for field crops. This distinction is important in order to calculate the distribution of surface-visible granules in the two types of culture.

In the United States, a 15G formulation is also registered. According to the manufacturer (FMC 1990), the 15G formulation is comparable to the 10G formulation with the exception that it consists of 15% carbofuran by weight rather than 10%.

3.2 ROUTES OF EXPOSURE

3.2.1 Direct ingestion

Birds have no teeth and therefore must regularly consume large quantities of grit (coarse sand, small pebbles) in order to aid the grinding of food in their muscular gizzards. This need is particularly acute in birds that consume vegetation (either foliage or seeds). It is thought that this is primarily why birds actively seek and consume pesticide granules, although they may also mistake some for seed. This grit is retained in the gizzard even when the bird is fasting or once food has passed down the alimentary canal (British Ornithologists' Union 1985). The manufacturer of carbofuran reports that at least 45 species of birds from 17 different families have been killed in the course of their supervised field trials[8] (FMC 1986a). Although some of this mortality might have been attributable to puddling or to contaminated insects, most was probably attributable to direct uptake by birds, thus showing the widespread attractiveness of the granules.

---

[8] A "supervised" trial or field study in this document refers to a situation in which the application of the product was under the direct control of the experimenters. This is in contrast to an "operational" study, in which the experimenters did not have any influence over calibration, technique, or the equipment used to apply the pesticide.

Table 2.
Formulations of granular carbofuran and registered use patterns in Canada.

Crop	Rate of application of the granular formulation (maximum registered)	Usual row spacing (cm)	Equivalent rate of application (kg a.i./ha)
10G formulation			
Corn (field, sweet, silage)	110 g/100 m	75	1.47
Onion (dry from seed)	70 g/100 m	40	1.75
Potato	300 g/100 m	90	3.33
Rutabaga, turnip	175 g/100 m	70	2.50
Sugar beet	50 g/100 m	60	0.83
5G formulation[a]			
Rutabaga, turnip	500 g/100 m	70	3.57
Potato - furrow treatment - broadcast treatment	 600 g/100 m 100 kg/ha	 90 N/A	 3.33 5.00
Canola, mustard	5.5 kg/ha	N/A	0.28
CR-10 formulation			
Canola, mustard	2.8 kg/ha	N/A	0.28

[a] This formulation was not marketed for several years in favour of the CR-10 granule. It has recently been reintroduced in the marketplace.

In a laboratory setting, Kenaga (1974) reported that Northern Bobwhite given *ad libitum* access to blank (carrier only) clay granules or granules containing 10% chlorpyrifos consumed up to 4.9 g/week or 0.70 g/day. If the weight of a chlorpyrifos granule is assumed to be 0.064 mg (Hill and Camardese 1984), this would correspond to approximately 11 000 granules per day. The same weight of granular material would represent approximately 2200 Furadan 10G granules or just over 300 of the larger Furadan CR-10 granules.

The ingestion of granules and dietary grit by birds in the field is only now being investigated in a systematic fashion (Best 1990; Fischer and Best 1990). However, some useful information is already available in the case of carbofuran. In one study conducted by the registrant in Utah cornfields, 831 Horned Larks (*Eremophila alpestris*) as well as 81 individuals of other species were found dead following the ingestion of either the 10G or 15G formulation (FMC 1983). The number of granules ingested was counted from all carcasses with intact gastrointestinal tracts. The resulting frequency distribution of granules per bird is given in Table 3 for the Horned Lark as well as for the other two most common casualties, Brown-headed Cowbirds (*Molothrus ater*) and Yellow-headed Blackbirds (*Xanthocephalus xanthocephalus*). This sample is known to be biased towards a smaller number of granules because it does not include those granules that passed through the birds. Also, this is not equivalent to an *ad libitum* ingestion, because birds are known to die rapidly from carbofuran intoxication. This frequency distribution uses a more complete data set and therefore supersedes the one reported in Mineau (1988) for a subsample of individuals from the same kill.

Table 3.
Frequency distribution of carbofuran granules in the gastrointestinal tracts of 555 birds poisoned in Utah cornfields.

Species	% frequency of granules in gastrointestinal tract						Sample size
	0	1	2	3–5	6–10	>10	
Horned Lark	18.0	20.3	15.4	23.8	12.8	9.70	479
Brown-headed Cowbird	64.5	16.1	6.5	6.5	6.4	0	31
Yellow-headed Blackbird	50.0	10.0	15.0	15.0	10.0	0	20
All birds	**22.2**	**18.9**	**14.4**	**22.7**	**12.3**	**9.50**	**555**

The maximum number of granules found was 53 in one Horned Lark. The median number of granules in the Horned Lark was two, and 22.5% of the birds had ingested more than five granules.

The relative attractiveness of different granule bases has already been examined in a laboratory setting. Kenaga (1974) reported that both clay and corncob granules were readily accepted by Northern Bobwhite when mixed into the feed. On the basis of the field kills reported (see Section 3.3.2), we can conclude that the two granular formulations of carbofuran in common use in Canada are both readily accepted as sources of dietary grit by a broad range of bird species.

***Update:** Much more information is now available on the question of the direct uptake of insecticide granules as grit by songbirds (Best and Gionfriddo 1991a, 1991b; Best 1992; Best and Fischer 1992; L.B. Best, University of Iowa, pers. comm.). It is now apparent that silica-based granules (such as the carbofuran 10G) are very attractive to birds. Silica, quartz, and feldspar are the most sought after as grit material in the wild. The fact that carbofuran 10G or 15G granules tend to be much more spherical than "typical" grit material does not seem to deter birds. Corncob granules (such as the carbofuran CR-10) also tend to resist breakdown in the gizzard and therefore may be retained as grit. The very high clay granule consumption rate obtained by Kenaga (1974) and reported above may not be typical of other grit types less prone to rapid breakdown. Given the choice, birds should select harder grit and reduce their overall consumption. Both silica and corncob granule types also resist breakdown in the field and are therefore available to birds for relatively long periods of time.*

3.2.1.1 Estimated availability of granules following application

A number of engineering studies and field surveys were reviewed in order to estimate the number of granules left on the soil surface under various cropping situations in Canada. The confidence in these estimates is greatest for corn and canola, the two crops for which incorporation has been scientifically studied. **The following is a summary only. The reader is referred to Appendix 1 for a detailed review (with references) and discussion of these studies.**

A. Row crops

A "typical" seeding operation in corn (based on the method used by 70% of corn farmers surveyed in Ontario: banded[6] application in front of the press wheel without added chains or tines) is estimated to leave on the soil surface a quantity of granules ranging from 15% to 31% of the amount applied. This means that between 515 and 1065 granules of Furadan 10G are left on the soil surface for each metre of furrow. The remaining 30% of farmers surveyed banded the granules behind the press wheel. Most, but not all, then used tines or chains to disturb the band and loosely incorporate the granules. This method results in an estimated 7.4–16% of the insecticide being left on the surface, which corresponds to between 254 and 550 granules of Furadan 10G per metre of furrow. If the prevailing agricultural advice and labels were to be changed so as to make in-furrow applications mandatory, average surface counts could be reduced to between 0.5% and 0.8% of applied, or 17–27 granules of Furadan 10G per metre of furrow.

Any recommendation that has the net effect of reducing the number of surface granules makes good ecological sense. However, in-furrow applications of carbofuran have repeatedly given rise to extensive bird mortality, even where incorporation (verified with fluorescent dyes applied to the granules) was said to be 100% (see Section 3.3.1.5). In-furrow applications might provide an enhanced safety margin for granular products of lower toxicity than carbofuran.

The above estimates are idealized and do not take into account row-to-row variation in planter performance, turn areas or obstructions in the field, or spillage during loading and calibration of the machinery. Given calibration errors and machine tolerances currently in effect, applications of 1.5 × nominal rate along any one seed furrow would not be uncommon. In turn rows or under other situations in which planters rise out of the ground, this could give rise to over 5000 surface granules of Furadan 10G per metre of furrow.

Discrete areas of high concentration of surface granules are expected, and these need to be considered in assessing the likely impact of a granular treatment. If, as seems to be the case, birds actively seek pesticide granules as sources of grit, then the presence of any such "hot spot" or spill will negate the benefit accrued from any other measure in place to reduce the average number of surface granules. Moreover, soil incorporation of granules will not prevent exposure of birds that scratch or probe the soil in their foraging activities.

Applications to row crops other than corn are assumed to give rise to similar counts of surface granules. Because of the way in which the granules are applied in sugar beet (in front of the furrow openers), incorporation of the granules in that crop is thought to be poorer. No information is available for that crop in North America. However, kills resulting from the use of carbofuran in sugar beet have been reported in the U.K. (Greig-Smith *et al.* 1989).

B. Field crops (canola, or rapeseed)

A "typical" seeding operation in canola (based on the drilling equipment used by an

---

[6] Banding means that the granules are applied over the seed furrow in a band about 18 cm wide. An attempt is then made to "incorporate" the granules into the soil, either through the furrow-closing mechanism or through the use of chains or wire tines. See Appendix 1 for more information on banding.

estimated 79% of western Canadian canola farmers) results in average surface counts of granules between 4.7% and 5.3% of the applied amount, or between six and seven of the larger Furadan CR-10 granules per square metre of field. "Hot spots" of up to 33 granules per square metre are expected on the basis of the work to date. This excludes any calibration or machine errors. At field edge, where cross seeding (the drill being run perpendicular to and over the ends of the seed rows) is the norm, the surface counts are expected to be between 3.6% and 7.0% of the applied amount, or between nine and 17 granules of Furadan CR-10 per square metre of field.

3.2.2 Contaminated soil invertebrates

It has been documented that carbofuran granules can adhere to earthworms. Even after granules had been washed from the surface of the worms, whole body residues were found to range between 0.3 and 670 ppm in 11 of 12 worms analyzed following a 1.1 kg a.i./ha in-furrow application to corn (Balcomb *et al.* 1984b). The average residue concentration per worm was 84.7 ppm. At the maximum concentration reported in that study, ingestion of a single large mature worm (*Lumbricus terrestris*: 15 cm, 5 g; Cathey 1982) would result in a dose of 43.5 mg/kg for an average-sized American Robin (*Turdus migratorius*: 77 g; Dunning 1984). At the average residue level reported, a single worm would represent a dose of 5.50 mg/kg. Given that this value is higher than most of the LD_{50} values reported for songbirds (see Section 2), we can conclude that a worm with an average body burden would likely be lethal to an adult robin ingesting that worm. The risk would be even greater if granules were left adhering to the worms. The risk to nestling birds would be higher than the risk to adults. A similar hazard is likewise predicted for foraging American Woodcocks (*Scolopax minor*) (Eisler 1985). In the United Kingdom, a Buzzard (*Buteo buteo*) found dead with earthworms in its beak tested positive for carbofuran (Fletcher *et al.* 1989). No details were given on the pesticide application; it is therefore not clear whether the granular or the flowable formulation was involved. Stinson *et al.* (in press) report the poisoning of American Kestrels following an application of the 15G formulation in furrow (see 3.3.2.1 L.). Stomach contents of two of the birds only contained insect parts.

The acute LD_{50} of technical carbofuran in the mouse is approximately 2.0 mg/kg (NRCC 1979). It is therefore likely that small mammals (such as moles and shrews) that regularly consume earthworms are very much at risk from the use of granular formulations of carbofuran. Observed behavioural changes in exposed worms, such as muscle spasms and coiling, are likely to attract predators (reviewed in NRCC 1979). There is no readily available information on carbofuran residues in or on other soil invertebrates. Any such contamination of the invertebrate fauna would only add to the already high risk of exposure.

3.2.3 Contaminated soil/sediments

Carbofuran granules have given rise to many instances of waterfowl mortality in flooded or partly flooded fields (see Section 3.3.2.2). When fields flood or puddles form, even a long time after application, waterfowl (primarily) are attracted to those fields; they sift waterlogged sediments in search of food and drink contaminated water. The label for Furadan 10G specifies that the granules should not be applied to soils subject to flooding. Problems have arisen primarily in acidic soils, presumably on account of the longer half-life of the granules under those conditions (Getzin 1973). Root crops are often grown on soils subject to high water retention. Clearly, it is difficult for growers to foresee puddling or flooding that will take place after the application of a pesticide.

3.2.4 Secondary poisoning

Many instances of secondary poisoning with granular formulations of carbofuran have been recorded (see Section 3.3.2.3). Although small quantities of carbofuran are readily metabolized in a living warm-blooded organism, undigested granules in the gut of the primary casualties contain sufficient carbofuran to kill large scavengers and birds of prey, such as eagles, buteo hawks, and vultures. Over 30 separate incidents of mortality involving birds of prey have been recorded so far in North America (excluding those cases in which carbofuran has been wilfully used to kill birds).

3.3 EVIDENCE FOR A HAZARD RESULTING FROM USE

The evidence that granular carbofuran causes extensive wildlife mortality comes from two sources: supervised field trials and reported kill incidents. Both lines of evidence are briefly reviewed here.

3.3.1 Supervised field trials

Field trials under experimental control usually offer better evidence than kill reports, because the pesticide applications are usually strictly monitored and because search efforts and other critical parameters are usually reported. The disadvantage of field studies, especially those that rely on finding carcasses, is that they often have a low power of problem detection (Mineau and Collins 1988). However, detecting avian mortality does not seem to have been a problem during the studies on granular carbofuran performed to date. Three of these studies were conducted under contract to the manufacturer (FMC 1983, 1986a, 1986b) to fulfill requirements for the U.S. re-registration of the product. A fourth was carried out and subsequently published by Balcomb *et al.* (1984b). A fifth study (Overgaard *et al.* 1983) deals with a use pattern not registered in Canada but nevertheless offers some useful insight. The amount of information contained in these studies is substantial, and only a brief outline will be given here.

Although most of these studies were conducted in cornfields, results likely are representative of other types of crops. Indeed, because applications of granular formulations are made to bare fields, there is little to distinguish a cornfield from a potato field or any other type of field immediately after planting. Thus, only two variables remain: the number of granules accessible to birds, and the presence of birds in the field. In fact, many of the data reviewed in Appendix 1 as well as the kill record reported below (see Section 3.3.2) support the idea that the exact incorporation rate of the granular formulation may be largely inconsequential. This is because there always appears to be a surplus of surface granules in and around treated fields, regardless of the crop or cropping conditions.

3.3.1.1 FMC 1983: corn, Utah, incorporated band application

Furadan 10G and 15G granules were banded in cornfields at seeding at a rate of 340 g/100 m. The number of granules applied in this study is 3× higher than the Canadian rate of application for corn (see Table 2), but is similar, in terms of granule numbers, to the 300 g/100 m rate registered for potatoes in Canada. This rate in corn, although registered in the United States at the time, was apparently seldom used. The banded granules were then incorporated following label recommendations, and "*care was taken to avoid spillage while loading or exposure of granules at row-ends during turning.*" Depending on the type of incorporation device (chain or tines), one would expect a surface deposit of between 3.7% and 7.9% of the applied amount, which corresponds to between 381 and 815 granules per metre of furrow (Appendix 1). This compares favourably with Ontario seeding conditions, in which the estimated "typical" surface residue is 515–1065 granules per metre (see Section 3.2.1.1). This is because the higher rate of application of the Utah study was offset by band incorporation; incorporation devices are not frequently used in Ontario (see Appendix 1).

Three plots totalling 45 ha were planted with the 10G formulation. In total, 373 dead birds of eight species were picked up over the course of the 60-day monitoring period. A further 504 carcasses were picked up on nearby plots (57 ha) seeded with the 15G formulation, and 35 birds had managed to move to control plots before dying. The overall kill rate was not statistically different between the 10G and 15G plots, but the spatial proximity of the plots meant that kills could not always be associated with any one plot. As reported above (see Table 3), most of the dead birds were Horned Larks, which were fledging from nearby fields. Fourteen species of birds were killed, including two species of raptors: Northern Harrier (*Circus cyaneus*) and Short-eared Owl (*Asio flammeus*).

3.3.1.2 FMC 1986a: corn, Iowa and Illinois, incorporated band application

Investigators monitored three plots seeded with Furadan 10G and three plots seeded with Furadan 15G in Illinois and in Iowa. The granules were banded at the same rate as that currently registered in Canada (see table 2), row spacing was either 75 cm or 95 cm, and the band was incorporated. Again, care was taken to avoid spillage or surface exposure of granules. At the Iowa sites, the company also went to great lengths to reduce the avian hazard, even though these efforts resulted in unrealistic farming practices. In the authors' words, "*FMC personnel witnessed the planting operations and assisted in covering spills of Furadan granules. In general, these efforts consisted of walking along end rows (where the planter was raised and lowered when turning around) and kicking soil over any spills observed.*" This was carried to an extreme at one of the sites in particular, where "*the FMC representative systematically searched all end rows for exposed granules. As instructed by the FMC representative, the farmer disked the end rows after planting the long rows and then planted the end rows. In addition, he was asked to place a plastic flag at locations where he stopped in mid field during planting. These sites were subsequently inspected by the FMC representative.*"

Despite all of these efforts and a number of exposed granules considered to be far smaller than typical for Canadian conditions (see Appendix 1), substantial bird mortality still took place. As in the Utah study, no significant differences were found between the kill rates in the 10G and 15G plots. Carcass counts were 103 individuals of 17 species on the 69 ha in Illinois and 29 individuals of 11 species on the 124.5 ha in Iowa.

There are a number of reasons why these figures are minimum estimates of mortality, even if we discount the fact that granule incorporation was uncharacteristically high as a result of the unrealistic granule incorporation practices. Sites were not chosen to maximize bird populations. Indeed, the Iowa sites were chosen as being typical of the intensively cropped U.S. corn belt, and the nearest woodlot was more than 1.6 km from any of the plots. Nesting habitat was therefore very limited for any tree-nesting species. Furthermore, searches for carcasses took place only every 3 days; in cornfield habitats in Maryland, Balcomb (1986) found a very high disappearance rate of planted carcasses, ranging from 62% to 92% within the first 24 hours. Also, investigators on the Iowa plots searched only the fields proper, whereas it is expected that poisoned birds will reach shelter if they can (Mineau and Collins 1988). There was evidence in this study and in the Utah study that some birds managed to leave the field where they were poisoned before dying. These factors taken together mean that the calculated mortality rate based on finding carcasses alone is a *gross* underestimate of the actual kill rate.

However, as reviewed by Mineau (1988), even the uncorrected kill rates obtained in this study (0.23 carcasses/ha of planted field in Iowa and 1.5 carcasses/ha in Illinois) amount to a large proportion of the breeding birds known to nest in this type of habitat. In other words, carbofuran use may poison a large proportion of the breeding birds nesting in the general vicinity of the fields where it is used. Most of the poisoned species recorded in these studies are birds that frequent agricultural field edges in Canada (Freemark *et al.* 1991; Canadian Wildlife Service, unpublished). For the period 1980–1985, based on the corn acreage planted with carbofuran and the uncorrected kill rates documented by FMC for the Iowa and Illinois sites, Mineau (1988) estimated very conservatively that carbofuran had directly poisoned between 50 000 and 300 000 adult birds in southern Ontario alone. Because the kills took place largely during the breeding season, the impact on the populations was even more extensive, because brood loss would also have occurred in many cases. No evidence has come to light that would cast doubt on the validity of that estimate.

If there is good nesting habitat in the vicinity of fields (as was the case in the Utah study discussed in Section 3.3.1.1), carbofuran-treated fields become lethal traps for birds attracted to them, especially fledglings or migrants. Moreover, the above estimates do not include the scavengers or raptors, which likely perished after consuming some of the primary casualties. Searchers in the Iowa/Illinois studies also found a few carcasses of small mammals.

3.3.1.3 FMC 1986b: corn, Florida and Texas, in-furrow application

This study (and the next by Balcomb and colleagues) is interesting because granules were applied in furrow (at 110 g/100 m of furrow) rather than banded. As discussed in Appendix 1, this is the best possible way to apply granulars so as to leave the least amount on the surface; however, this is not the preferred method of application in Canada. Furthermore, row spacing in Texas was 100 cm, which is substantially wider than the typical Ontario row spacing of 75 cm.

There are indications that the plots chosen were not very attractive to the usual guilds of field edge birds. The Texas plots were rotated from cotton, one of the most insecticide-intensive crops, and the availability of insects for insectivorous bird species was likely very low. The Florida plots had very poor bird habitat and, more importantly, received 30 applications of insecticide (permethrin or methomyl) during the 2 months following planting and carbofuran application. Despite a reportedly high scavenging rate, an uncorrected kill rate of 0.74 birds/ha of planted field was obtained for the Texas site. This value is in the range obtained in the Iowa/Illinois study (see Section 3.3.1.2). A flock of 148 Fish Crows (*Corvus ossifragus*) was found dead on one of the Florida plots, but the birds were thought to have been poisoned by other pesticides, as they had no carbofuran granules in their gastrointestinal tracts. The lack of carcasses in this study was explained by a very low use of the fields by birds (U.S. EPA 1989).

Both this study and the previous one in Iowa and Illinois (see Section 3.3.1.2) also attempted to examine the effects of granular carbofuran on raptor populations because of the numerous reports of secondary kills with carbofuran. However, these portions of the studies were largely discredited on methodological grounds. For more details, the reader is referred to U.S. EPA (1989).

3.3.1.4 Balcomb 1983, Balcomb et al. *1984b: corn, Maryland, in-furrow application*

Balcomb *et al.* (1984b) estimated a kill rate of 0.13–0.2 birds/ha in cornfields in Maryland where carbofuran was being applied in furrow at 1.1 kg a.i./ha. However, the kill rate reported in this study should not be compared with the rates obtained in the FMC studies reviewed above (see Sections 3.3.1.1–3.3.1.3). The total search effort was very low. Furthermore, the rate of carcass removal by scavengers was subsequently reported to be very high at this particular location (Balcomb 1986). Secondary poisoning was also documented in this study (Balcomb 1983).

This study suggests that the best possible method of granule incorporation (in-furrow use; see Appendix 1) does not result in enhanced safety to birds. This point will be further demonstrated by the Virginia State monitoring exercise (3.3.2.1 L.). Again, this is an indication that bird kills in fields seeded with granular carbofuran are less a function of granule incorporation than of the presence of birds to be killed and of the inherent toxicity of this insecticide.

This study provided information to assess the hazard of consuming contaminated earthworms (see Section 3.2.2). It further demonstrated that Common Grackle (*Quiscalus quiscula*) nestlings taken from a nest on the edge of a treated cornfield had carbofuran residues in their gastrointestinal tracts, presumably from having been fed contaminated invertebrates.

3.3.1.5 Overgaard et al. *1983: pine seed orchards*

The use of carbofuran in pine seed orchards is not registered in Canada, although it has been the subject of research by Canadian forestry entomologists (Cerezke and Holmes 1986). This use involves incorporating a very high rate (up to 30 kg a.i./ha) of the granules in the root zone of the trees. Overgaard *et al.* (1983) used a deep-injection mechanism (POWR-TILL™) to incorporate the granules and reported incorporation rates of 99.1%, 99.5%, 99.9%, and 100% on four treated sites. The investigators used a fluorescent tracer dye applied to the granules to estimate incorporation rates. Yet, over a 5-day period posttreatment, Overgaard and colleagues recovered 96 dead and 30 moribund birds from around the treated trees. Many species were killed, including wood warblers. Even on one of the study sites where incorporation was said to be 100%, three moribund birds and 12 carcasses were recovered, including a Loggerhead Shrike (*Lanius ludovicianus*) that likely died of secondary poisoning.

This study confirmed the extent to which the carbofuran granules are attractive to birds. It is possible that, despite claims to the contrary, incorporation of the granules was less than 100% at the Florida site, because at least 15 casualties were noted. Alternatively, the birds may have uncovered granules through their foraging activities, or they may have been poisoned by contaminated invertebrates.

3.3.2 Reported kills

Given the overwhelming volume of field data implicating granular carbofuran in bird kills, only a brief summary of the kill record will be made. Few bird kills are ever reported by growers or bystanders. When kills are reported, the information surrounding the kills is often inadequate. This is exemplified by an entry in the discontinued "Pesticide Incidents Monitoring System" (PIMS) of the U.S. EPA (1979): "*00/00/71 WI [Wisconsin] In an agricultural incident carbofuran was a suspect factor in an undescribed bird kill. No conclusions about pesticide involvement were drawn from the investigation. One owl was suspected of containing residues; laboratory results were not reported.*" This example is given, not to denigrate in any way the efforts of that agency in compiling relevant pesticide information, but rather to point to the real difficulty involved in assembling kill information from a myriad of sources and agencies.

Similarly, a large number of kills reported by the National Wildlife Health Laboratory of the U.S. Fish and Wildlife Service are often described by "*carbamate toxicosis suspected*" leaving the regulator to ponder on the chemical involved as well as on the significance of that particular event. In Canada, there is currently no centralized mechanism for reporting wildlife kills. In a 1988 survey of 351 farmers in Quebec, 5% of the individuals contacted reported having encountered bird mortality in their fields. In nine cases, the farmers volunteered the identity of the chemical responsible: three of those nine cases were carbofuran kills. All cases involved toxic anticholinesterase insecticides or rodenticides (J.L. DesGranges, Canadian Wildlife Service, pers. comm.).

Update: *The Canadian Cooperative Wildlife Health Centre, a coalition of university veterinary* *schools funded by Environment Canada, will be serving as the centralized facility to record incidents of wildlife mortality related to pesticides as well as other toxic or disease agents. The head office is in Saskatoon and can be reached through a toll-free number: 1-800-567-2033.*

Kill reports are especially inadequate to deal with the diffuse mortality of breeding songbirds that is expected from the use of granular carbofuran (Mineau 1988). A further difficulty in the last years of widespread use of granular carbofuran in the United States was that the labels specified that dead birds should be buried (L. Lyon, U.S. Fish and Wildlife Service, pers. comm.). Although this was possibly a positive step from the point of view of reducing secondary poisoning, compliance with the label made it unlikely that kills would be reported. The legality of disposing of migratory birds in this fashion was a further point of contention.

Despite their repetitive nature, some of the documented kill incidents will be reviewed briefly to: 1) confirm the experimental findings under operational conditions; 2) offer evidence for crops and situations not directly tested; and 3) provide useful supplementary data such as residue profiles in carcasses. A more complete list of known kills, especially those that have taken place in the United States, is available from the U.S. EPA Docket Office.

The increasing number of reported kills with time is not an indication of greater carbofuran usage. In fact, the use of the Furadan 10G formulation in corn has dropped considerably over the last decade (U.S. EPA 1989). Rather, the increased number of kill reports is directly linked to the EPA's Special Review of the granular products in that country. It is noteworthy that few reports of kills are available relative to the large area annually treated with carbofuran. However, systematic research by the company and others (see Section 3.3.1) has conclusively demonstrated that bird kills following the use of Furadan granules are largely unavoidable.

As a result of the U.S. Special Review, a number of farmers in that country have come forward with observations of mass mortality (see Appendix 2), despite requests for support by the manufacturer of the product (see Appendix 3). Clearly, the absolute number of incidents involving carbofuran that have come to the attention of the U.S. EPA or the Canadian Wildlife Service is only a crude gauge of the wildlife hazard resulting from the use of this insecticide. Kill reports should therefore be assessed in a qualitative rather than quantitative fashion.

Reports from the United States and from Canada (with one notable exception; see below) are given equal consideration provided the crop and/or route of exposure are typical of Canadian agricultural conditions. Some cases, such as the report of hundreds of birds dying in vineyards after drinking drip irrigation water treated with carbofuran (Anonymous 1992), certainly highlight the toxicity of carbofuran to birds but have less direct relevance to Canadian agriculture, because carbofuran is not registered for use in irrigation water (a procedure known as chemigation) in Canada. However, the exclusion of evidence collected in the United States for use patterns registered in Canada makes little sense scientifically; southern Ontario and Illinois cornfields are closer to each other in terms of crop phenology and bird fauna than either is to a turnip field in Newfoundland. Agricultural practices are generally similar in both countries, and the presence of the same, or ecologically equivalent, species of breeding songbirds at planting has been confirmed (Freemark *et al.* 1991; Canadian Wildlife Service, unpublished; R. Knapton, Long Point Bird Observatory, unpublished). Under U.S. law [FIFRA Section 6(a)(2)], companies have to report to the EPA any kills and other problems that have come to their attention and some kills do come to the attention of the authorities through this process - this is not a current requirement in Canada.

There is one notable exception with respect to the registered use patterns in the two countries: granular carbofuran was registered in the United States for application to standing corn. Granules were dispersed above the canopy with the intent that a sufficient number of granules would fall in the whorls of the corn leaves. The hazard of this practice is obvious from the above data, but kills reported following this use pattern will not be dealt with here. Another difference between the two countries, as reported earlier, is that a 15G sand core formulation was registered in the United States. The equivalency of this formulation to the 10G granules in causing bird kills was demonstrated in the company research reviewed earlier (see Sections 3.3.1.1 and 3.3.1.2).

No effort was made to systematically gather information from outside North America, although some information is available. For example, kills have been reported from the use of the granules in root crops in the United Kingdom (Greig-Smith 1988). "Large numbers" of thrushes, sparrows and two Little Owls (*Athene noctua*) died in an irrigated cauliflower field where spot application of the granules had taken place (Greig-Smith *et al.* 1990). In one Norfolk sugar beet field, about 30 pheasants were poisoned (Greig-Smith *et al.* 1989). This last case is interesting in view of the lack of information on this registration in North America. One report from South Africa mentions hundreds of paralyzed waterfowl and poisoned vultures in fields where granular carbofuran was incorporated at planting (Ledger 1987).

The following reports also exclude wilful misuses of carbofuran, instances in which the evidence points to the chemical being used specifically to kill vertebrate "nuisance" species. Other cases fall into a category that could be referred to as "technical misuses." These are situations in which labels were not followed to the letter, although there was no obvious intent of harm on the part of the grower. For example, a U.S. applicator may not have had a valid permit to handle "Restricted Class" products (a category to which carbofuran belongs in the United States), even though there was no evidence that the material was improperly applied. Alternatively, the planting machinery may have been used incorrectly, or it was not of the recommended type. There is evidence that the ability of pesticide users to adequately follow label instructions, calibrate their machinery, and meter out the proper rates of chemicals is extremely variable (see Appendix 1). Indeed, if one were to take the product labels to the letter, all applications of carbofuran would classify as misuses. For example, the labels for all of the granular products state: "***Keep out of areas inhabited by fish, birds and wildlife as this product is highly toxic to such animals.***" Clearly, there would be no need for this review if users were in compliance with that directive.

The kills are separated into three groups thought to reflect three different modes of granule uptake, as discussed earlier (Section 3.2):

- selective uptake of granules or uptake of granules adhering to earthworms or other invertebrates, usually by small songbirds;
- uptake of granules and drinking of contaminated water from puddles or flooded areas. Waterfowl are often implicated, although any bird is theoretically at risk. The larger body size of waterfowl species makes them more apt to be detected; and
- uptake of granules by raptors and other scavengers consuming dead or moribund birds or mammals in the fields.

3.3.2.1 Kills resulting from selective granule uptake

Most kills have been reported from cornfields. This reflects not a higher inherent risk from carbofuran in corn but rather the total area planted to corn relative to other crops in North America. The rate of application to corn is similar in both the United States and Canada.

A. 1972–1973, corn, Wisconsin

According to Hickey (1976), reports of dead sparrows were received from growers when carbofuran was initially registered for use on corn rootworm. This is significant, in that it may show that growers may be less likely to report kills over time if those kills have become part of standard agricultural practice.

Kleinert (1974) reported results from cursory surveys of 77 cornfields treated with Furadan 10G, either as an incorporated band or in furrow. This type of low-intensity survey generally has a very low power to detect carcasses (Mineau and Collins 1988). Nevertheless, 13 dead songbirds and four dead small mammals were recovered. Mortality was also seen in fields treated with granular fensulfothion, an organophosphate insecticide.

B. 21 May 1979, corn, New York

Ten American Robins were picked up on the edge of a freshly planted cornfield treated with granular carbofuran. Some of the robin tissue (not specified if from a pooled sample or a single individual) showed 10 ppm carbofuran in the gastrointestinal tract and 1 ppm in the liver (Kinsinger and Lusskin 1980; Stone 1981, 1985).

C. April 1980, corn, Ludowici, Georgia

This incident indicates that birds may be poisoned through ingestion of contaminated insects. Four Cattle Egrets (*Bubulcus ibis*) died and another was found moribund in a freshly planted cornfield. The stomach contents of the birds contained mole crickets and a few bottle fly larvae, and a pooled analysis yielded 43.1 ppm carbofuran (Davidson and Steiner 1980a, 1980b; Kirkland 1989).

Because of their large body size, it is unlikely that Cattle Egrets would pick up granules directly. The granules may have been adhering to the insects. Alternatively, the egrets may have been scavenging other carcasses (this would explain the fly larvae). Balcomb *et al.* 1984b (see Section 3.2.2) demonstrated the hazard from earthworms contaminated with carbofuran granules. This may also be the case for other invertebrates.

Kirkland (1989) also mentioned a kill of Chipping Sparrows (*Spizella passerina*) under similar circumstances in 1977, but no further details were given.

D. May 1983, corn, Shelby, New York

Twenty Wood Ducks (*Aix sponsa*), a Mallard, two Killdeer (*Charadrius vociferus*), one Blue Jay (*Cyanocitta cristata*), and one Common Grackle were found in a field treated with Furadan 15G. A complicating factor in this case is that the seed corn had also been treated with diazinon. The birds contained residues of both chemicals, and the relative contribution of each is impossible to determine (Stone and Gradoni 1985a).

E. May 1984, canola (rapeseed), Vonda, Saskatchewan

This is the first of two incidents reported for canola crops in Canada. Details of this incident were obtained from the investigating pathologist at the University of Saskatchewan, as well as from the farmer who had seeded the crop. The relevant correspondence is given in Appendix 4.

In summary, it was estimated that over 2000 Lapland Longspurs (*Calcarius lapponicus*) died in this incident. One notable feature of this kill was that the seed/granule mixture was broadcast with an air seeder and then harrowed. According to the farmer, this is a common practice in his area, a fact that was confirmed independently (R. Atkins, Alberta Farm Machinery Institute, pers. comm.). Air seeders are used either to broadcast the canola seed or, alternatively, to position the seeds at a very shallow depth. In either case, the fields are then harrowed and packed. However, the Furadan CR-10 label recommends the use of a press drill or hoe drill, and harrowing is not usually carried out or recommended following the use of these drills.

In order to test the hypothesis that this kill could have been avoided if the farmer had seeded his crop with the recommended implement, an engineering study was carried out to compare the incorporation of granules following the use of a press drill, hoe drill, or air seeder (Maze *et al.* 1991; see Appendix 1). This study showed conclusively that the press drill (one of the recommended implements and the one most used in western Canada) gave the highest counts of surface granules. The method used by the farmer involved in this kill resulted in fewer granules on the soil surface, which should have resulted in a lesser hazard to the birds than the most prevalent seeding techniques.

Circumstances indicate that this kill is on the record because a flock of birds was unfortunate enough to land in a freshly seeded field and, more importantly, the farmer witnessed the event and reported it. Even kills involving very large numbers of birds are unlikely to be reported: the birds are cryptic, the fields isolated, and the farmers unlikely to return to the fields at least until the crop germinates. If growers do witness kills, they may not be willing to come forward. The incident also establishes the attractiveness of the Furadan CR-10 granules to songbirds.

This incident has serious ramifications. Granular carbofuran is used in canola for the prophylactic control of flea beetles (Lamb and Turnock 1982) over extensive areas of the northern prairies (between 0.37 and 0.54 million hectares yearly from 1981 to 1985; Madder and Stemeroff 1986). Peak canola seeding is in mid-May (Alberta Agriculture 1985), the time when the largest flocks of migrants such as Lapland Longspurs traverse the prairies. Of particular concern are those species that migrate in very large flocks and are known to use open agricultural land for foraging (e.g., Horned Larks, Lapland Longspurs, buntings). There are reports of flocks of Lapland Longspurs covering entire quarter sections (64 ha) of the level open farmland in east-central Saskatchewan (Houston and Street 1959). Flocks of 10 000 or more birds are not uncommon (Nero 1962; Lister 1964; Hatch 1966; Houston 1971, 1972; Renaud 1973; Gollop 1986, 1987). Clearly, a few "incidents" such as the one recorded in 1984 could have serious consequences for the populations of some of these species. Although large flocks of migrants are our main concern, there is also the ever-present risk to the locally breeding birds that frequent agricultural fields.

***Update:** Surveys of canola fields at seeding time were carried out in the spring of 1992 under contract to the Canadian Wildlife Service (P.A. Martin and T.W. Arnold, unpublished). Results from these surveys confirmed fears as to the likelihood of exposure resulting from the use of at-seeding granulars in canola. Numerous species were identified using the fields, including large flocks of Lapland Longspurs, which showed a preference for freshly seeded fields or fields prepared for seeding. Other migrants using these fields in substantial numbers included Horned Larks as well as a number of shorebird species. Several species of resident breeders (such as Savannah Sparrows [*Passerculus sandwichensis*] were found to be foraging extensively in the fields.*

F. September 1986, turnip and Lobok radishes, Richmond, British Columbia

Based on crude carcass searches and uncorrected rates, it was estimated that between 500 and 1178 birds died in this incident (Edwards 1986). Most were Savannah Sparrows, but some

Lincoln's Sparrows (*Melospiza lincolnii*) were also recovered. Birds were found throughout the field area. Furadan is registered for use on turnips but not radishes. The landowners claimed to have used fensulfothion (an organophosphate), but this was later disproved. Two pooled gut contents from the birds tested negative for organophosphates but gave carbofuran levels of 26 ppm and 14 ppm. Carbofuran residues were also detected in the turnips and radishes.

G. July 1987, green peppers, Marlboro, New Jersey

Although the lower acreage of some vegetable crops makes it unlikely that kills will be found and reported, some reports do exist. Seven House Finches were found killed by a side dressing of the 15G granules in peppers. The birds had been feeding on weed seeds on the edge of the field (Stansley 1987).

H. September 1988, canola, Jeanette's Creek, Ontario

Rapeseed premixed with CR-10 granules was seeded as a cover crop for soil conservation purposes. The seed and granules were applied with a clover seeder starting at 09:30 and harrowed between 14:30 and 17:00 of the same day. The bird mortality was reported 6 days later by a neighbour. At that time, it was estimated that approximately 200–300 sparrows and "blackbirds" (mixed flocks of several species) had been killed (Collins 1988). A composite sample of pooled crop contents contained 7 ppm carbofuran (Brash and Barker 1988).

Again, this was a case in which the seed had been broadcast on the surface and then harrowed. As discussed earlier (see E.) and based on available engineering research, this method of granule incorporation may in fact leave fewer granules on the soil surface than some of the recommended seed drills.

I. May 1989, corn, North Garden, Virginia

Twelve songbirds of several species moved away from a field planted with the 15G granule to die in a neighbour's yard. Several were alive but immobilized when first found. Residues were 70.3 ppm in the gizzard of one robin, 16.4 ppm in another, and 19.3 ppm in a Chipping Sparrow. Brain cholinesterase inhibition ranged from nondetectable to 74% inhibition in three birds analyzed (Chudoba 1989; Hayes 1989).

J. March 1990, potatoes, Modest Town, Virginia

Potatoes were seeded with the 15G granules applied in furrow at a rate of 2.5 kg a.i./ha. This is lower than the Canadian rate of 3.25 kg a.i./ha. An individual reported dead birds on his land. Subsequent investigation of the nearby potato field uncovered about 25 dead grackles. The planter was found to have left some potato seeds and granules uncovered at the ends of the rows (Christian 1990a, 1990b). An investigation by the Virginia Department of Agriculture and Consumer Services established that the pesticide had not been misused, although this agency recommended that the farmer be more diligent in covering up poorly placed potatoes and granules (Walls 1990).

K. April 1990, corn, Essex County, Virginia

This kill is highly significant for a number of reasons:

1. Carbofuran 15G granules were applied at less than half of the usual rate (0.5 kg a.i./ha).

2. The granules were applied in furrow, therefore giving the best possible incorporation of the product.

3. The kill was investigated by an EPA biologist well acquainted with the carbofuran situation. She was able to provide insightful information on the distribution of carcasses and other relevant features of the field. Her report is given in Appendix 5.

Notable in the EPA biologist's observations was the fact that there were no obvious spills of granules (the material had been very well applied) and that there were dead birds throughout the entire field area, often as far as 30–50 m from a field edge. The significance of this finding is twofold: first, some birds obviously do make use of the centre-field areas, although field edges are generally recognized as being more important (Best *et al.* 1990); secondly, this demonstrated once again that the problem was not merely spillage of granules at row ends, but rather poor incorporation throughout the length of the furrows. Over 200 dead birds were found in this incident, excluding feather-spots (badly scavenged carcasses) and moribund individuals. The kill was reported by a jogger who happened to be running by the field.

L. Summer 1990, Virginia Monitoring Program

In 1990, the Virginia Department of Game and Inland Fisheries conducted a monitoring exercise to look for bird carcasses in fields following operational use of granular carbofuran when used in furrow (Stinson *et al.* in press). Bird kills were found on 10 of 11 farms monitored, or 33 of 44 fields searched, despite such measures as intensive training of the applicators by FMC personnel, the use of devices to cut off the supply of granules at row ends, and the use of 18-23 m wide no-pesticide zones on the edges of fields. Thirty species (25 birds, 4 mammals and 1 reptile) were found dead or debilitated in the fields. Of the carcasses recovered in the fields proper, 42% were found more than 18 m from the edge of the cultivated area. Fresh carcasses testing positive for residues were recovered up to 15 days post-application despite evidence that scavenging levels were high and that searchers were missing many of the carcasses.

Granular carbofuran was banned in the State of Virginia as of 1 June 1991.

3.3.2.2 Kills associated with puddling of fields following application

This is thought to represent a different type of hazard inherent in carbofuran granules. Typically, the granules are applied at seeding. Over the course of the spring and summer, and even during the following fall and winter, puddles may form in the fields or the fields may even flood completely. At that point, the fields become attractive foraging sites for waterfowl and other birds. It is unlikely that waterfowl selectively pick up single granules from the soil surface. Given their body size and bill morphology, it is more likely that granules are unwittingly ingested as the birds sift through sediments or when contaminated water and crop residues are ingested.

At issue is the length of time that this hazard remains following the use of the granules. This hazard scenario has never been systematically investigated through fieldwork. Nevertheless, numerous reported incidents ascertain that puddling and flooding of fields treated with granular carbofuran present a significant risk to birds.

A number of the reported kills occurred in the Fraser River valley of British Columbia, an area of acidic soils. Base-catalyzed hydrolysis is the most important chemical degradation pathway for carbofuran (reviewed in NRCC 1979). The half-life of carbofuran in water due to hydrolysis alone ranged from 0.2 days at pH 9.5 to 1700 days at pH 5.2. It has been postulated that microbial action also aids in breakdown of granular carbofuran in flooded soil situations, but this may only be the case if the soils are neutral or alkaline (reviewed in Trotter *et al.* 1989).

A pH range of 5.3–5.6 was reported for a soil sample taken from the Fraser River delta at Ladner (see B. below). A series of samples in the lower Fraser delta had pH values ranging from 3.8 to 6.4 (FMC 1976b), but most values were between 5.0 and 5.9. Degradation is expected to be very slow at such low pH values. Williams *et al.* (1976) showed a buildup of residues in Fraser valley soils after 2 years of use. Ahmad *et al.* (1979) gave a half-life of 60–75 days for the Furadan 10G granule and 11–13 days for the technical grade at pH 6.5. Caro *et al.* (1973) gave a 117-day half-life for a 10G granule applied in furrow in silt loam of pH 5.2. In one of the kill incidents reported below (see B.), granules were found to contain almost half of their initial carbofuran concentration 7–8 months after weathering in the fields. FMC (1976b) indicated that granules still contained 6.33% of carbofuran (the nominal concentration of Furadan 10G is 10%) 3 months after exposure to soil from the Reifel Refuge in the Fraser delta. FMC reported nondetectable levels after 6 months but did not provide conditions of pH, moisture, or temperature.

It is therefore not surprising that, in the kill record, a long period of time has often elapsed between application of the granules and the kills.

A. December 1973, turnip,[7] Richmond, British Columbia

Fifty to 60 dead Northern Pintail (*Anas acuta*) and Mallards were found in a partly flooded field along the Fraser River. A water sample from a puddle contained 1.7 ppm and a soil sample 1.96 ppm carbofuran (Whitehead 1975a). Granules were found in the gut contents of one of the birds.

B. November 1974 – January 1975, turnip, Ladner, British Columbia

Heavy rains flooded about a tenth of a field in proximity to the river (Ladner is on the opposite shore of the Fraser from Richmond). Approximately 50 dead ducks were found in and around the flooded area. Four species were involved (Mallard, Northern Pintail, American Wigeon [*Anas americana*], and Green-winged Teal [*Anas crecca*]). A subsequent visit to the same site about a month later uncovered another 15–20 ducks and a Glaucous-winged Gull (*Larus glaucescens*). Ten more ducks were picked up on a third visit, for a total of about 80 birds.

Although the site was a harvested potato field, there was a row of immature cabbage on one side of the field. According to the farmer, the field had been planted to turnips the previous April or May, and carbofuran had been used at that time (the material had been applied in band with a Gandy™ seeder). Unseasonal spring rains had caused crop failure, and the entire field had then been plowed and put in potatoes. The potatoes had been harvested in September and the row of cabbage planted at that time.

The second group of birds was found in and amongst the flooded section of the row of cabbages. Water samples taken from the main puddle contained 0.063 ppm carbofuran. Soil sample pH values ranged from 5.3 to 5.6. Granules were found in the guts of some of the birds. Combined organs (heart, liver, gizzard, and intestines) from one bird were analyzed. One laboratory reported a value of 60.9 ppm carbofuran, whereas another reported 8.2 ppm for the same sample.

---

[7] This and other kills below refer to turnip crops. No distinction is made here between Swedish turnip or rutabaga (*Brassica napo-brassica*) and the real turnip (*Brassica rapa*), the former being more common in North America.

(It is possible that some degradation could have taken place in transit from one laboratory to the other.) A sample of granules taken from the field contained 4.3% carbofuran, or slightly less than half of the nominal 10% concentration, and this following approximately 7–8 months of weathering. According to the company, the release rate was well within the range expected for the Furadan 10G granules.

There was some confusion as to the acreage actually planted to turnips, and some questions remained regarding the rate of application of the pesticide. Also, some jugs of Furadan flowable were found on site that may have been used on the potato crop. However, the presence of carbofuran granules in the ducks and the residue levels left in the granules at the time of the kill make the early summer application of the granular formulation a more likely culprit (Whitehead 1975a; FMC 1975a; Bruns 1975).

C. October–December 1975, turnip, Ladner, British Columbia

This kill occurred in a field adjacent to (and owned by the same grower as) the field in which the kill reported above (see B.) occurred. (However, the application responsible for the previous kill had been made by an applicator and not the owner.) Approximately 60 Green-winged Teal found initially had granules in their gastrointestinal tracts. Propane exploders were installed to keep other birds out of the field. A month after the first birds were found, the propane exploders malfunctioned, and about 1000 teal entered the field and were killed within a few hours. Five teal examined contained between two and 125 granules of carbofuran in their guts.

The owner of the field had applied the granules to transplanted turnips in late May/early June. The granules had been applied around the plants by hand rather than with a calibrated applicator as in other fields farmed by the same individual. The crop was harvested in mid-July, after which part of the field was disked. The field developed puddles in October after heavy rains. Based on the number of granules still present in the field and on residue levels found in the leftover turnips, it was determined that the grower had overapplied the product by a facter of 2–4. The grower had also applied the granules to a nearby cabbage field, where 40 more ducks and a hawk (unspecified) were found. Furadan 10G is not registered for cabbage. The granules had been banded as in a turnip crop.

The grower was fined under the Pest Control Products Act because of the high rate of application and the application to an unregistered crop. Following this incident, FMC withdrew registrations of the 10G granule for shallow uses (i.e., carrots and turnips/rutabagas) from the lower mainland of British Columbia (Whitehead 1975b; FMC 1975b, 1976b). At the request of British Columbia's Department of Agriculture (P. McMullen, Chemagro, pers. comm.), the sale of Furadan 10G resumed in the lower mainland in 1986.

D. 1977, turnip, Fraser valley, British Columbia

Approximately 50 ducks died in this incident (NRCC 1979). Few details are available, except that it followed the usual pattern (P.A. Whitehead, Canadian Wildlife Service, pers. comm.). In view of the voluntary withdrawal in effect on the product, the kill was thought to have resulted from the use of old stock.

E. Fall 1986/winter 1987, turnip, Richmond, British Columbia

Immediately following the reintroduction of Furadan 10G granules to the lower mainland of British Columbia, a large kill of Savannah and Lincoln's sparrows was recorded (see Section 3.3.2.1). Visits to the same field in the late fall/winter following the kill also revealed the presence of badly decayed duck carcasses. No formal survey was attempted (P.A. Whitehead, Canadian Wildlife Service, pers. comm.).

F. Fall 1989/winter 1990, Richmond and area, British Columbia

A number of Bald Eagles (*Haliaeetus leucocephalus*) and Red-tailed Hawks (*Buteo jamaicensis*) were turned in to a raptor rehabilitation centre after having consumed ducks and gulls. At least one bird so far has tested positive for carbofuran. No waterfowl kill was officially reported to authorities that winter, suggesting, again, that only a small proportion of kills is ever reported. (See Section 3.3.2.3 for details of this incident.)

G. April/May 1990, corn, Smyrna, Delaware

It is now documented that water bird mortality following puddling in fields treated with granular carbofuran is not restricted to the acidic organic soils of the lower mainland of British Columbia. A large number of kills have been reported from the use of granular carbofuran in rice (see I. below). Furthermore, some instances of waterfowl mortality resulting from the use of the granules in corn are now coming to light as a result of the U.S. EPA Special Review.

The 15G granules were applied to corn in furrow at a rate of 1.3 kg a.i./ha. The equipment was new and, when inspected, was found to be in good working order and well calibrated. In fact, the farmer who had applied the granules had apparently been featured in a training video by FMC Corp. on the proper application of granular Furadan. Snow Geese (*Chen caerulescens*) were seen foraging in the field on the day of application. On the evening of the day of application, approximately 2.5 cm of rain fell, producing two or three pockets of water in low-lying areas. The next day, some of the geese in the field were observed convulsing, and the authorities were called. In total, 34 Snow Geese, seven ducks, and a Laughing Gull (*Larus atricilla*) were picked up. Dead earthworms and frogs were also found in the furrows. Upon a second visit a few days later, the investigating officer found three more dead ducks and more dead frogs.

This scenario repeated itself in another cornfield a few kilometres away. Again, the application was in furrow. At least four ducks were known to have died in that field. Dead earthworms were found in the furrows. The investigating officer could see no evidence of any granules left on the soil surface (Kuncir 1990).

H. January 1990, corn, Twitchell Island, California

Approximately 155 dead ducks and geese were found in a flooded cornfield as well as one Red-tailed Hawk and four Northern Harriers. One of the harriers had the remains of a songbird in its stomach. The songbird was found to contain 3.9 ppm carbofuran.

The cornfield in question had been treated with the 10G granules the previous May/early June. The field had been flooded in sections in December and January for duck hunting purposes. The planter had been loaded at the opposite end of the field from where most of the kills were found and unloaded back at the farm. There was therefore no evidence of any careless use of the pesticide. The granules were able to kill the birds (and, furthermore, cause secondary poisoning) following 7 months of weathering in the field. Soil pH was not given (Littrell 1990; Otsuji 1990).

I. Rice, California

Although carbofuran is not registered for use on rice in Canada, it is useful to briefly examine the kill record for this use pattern as it relates to the hazard of granular material in flooded soils.

Twenty-two kill incidents, resulting from the use of a 5% carbofuran granule in rice, were documented in California between 1984 and 1988. Approximately 525 birds, mostly waterfowl but also American Coot (*Fulica americana*) and a few raptors (four Red-tailed Hawks and one Northern Harrier), were recovered in those incidents (Littrell 1988). Forty-two analyses of bird crop contents were presented by Littrell (1988). Residue values ranged from below detection to 640 ppm carbofuran in the gastrointestinal tracts. The median residue level was 6.3 ppm.

The granules are applied in the spring by air or ground to prepared fields, after which the fields are flooded and the soaked rice seed applied by air. Most of the mortality has been recorded in the spring in freshly flooded fields. However, there are also a number of fall kills on record. Carbofuran is not registered for fall use. The kills in question are a result of either a long-term persistence of the granules or a misuse of the product. Littrell (1988) favoured misuse as an explanation of the kills, largely on the basis of his belief that granules do not persist. From the evidence reviewed above, however, it appears that fall kills are very possible from spring use of the product.

3.3.2.3 Kills resulting from secondary poisoning

The first widely available report of a predator or scavenger dying from the ingestion of a bird or mammal killed by granular carbofuran was the publication by Balcomb (1983). This particular hazard had hitherto not been considered despite a few earlier indications of such a problem. For example, the deaths of an unidentified hawk and a Glaucous-winged Gull had been documented in the British Columbia waterfowl kills (see Section 3.3.2.2). Balcomb showed that the quantity of carbofuran in the gastrointestinal tracts of songbirds killed by the carbofuran granules (this was following the use of Furadan 10G in furrow for corn) could be sufficient to kill a larger-bodied predator or scavenger. Most at risk are predators or scavengers that consume their prey whole or that consume the viscera of their prey.

Table 4 provides a summary of cases of secondary poisoning reported to the U.S. EPA up to September 1990, as reflected by entries in the carbofuran "docket" (the public record of all information pertinent to the Special Review of carbofuran). This table excludes those cases in which criminal misuse is suspected (e.g., where carbofuran-laced baits were used with the intention of killing raccoons, coyotes, or other vertebrates). A positive determination of carbofuran residues in the gastrointestinal tract of at least one casualty was made in every incident. As with the primary kills, most were associated with corn planting.

A. Fall 1989/winter 1990, British Columbia

Recently, a number of suspicious raptor deaths and/or poisonings were reported from the lower mainland of British Columbia. Although this investigation is still ongoing (Elliott and Wilson 1993), the following is an account of the information available to date, most of which was obtained by the staff of a raptor rehabilitation centre and the attending veterinarian (Mineau 1990, 1991b).

Moribund or dead Bald Eagles and Red-tailed Hawks were found in the immediate Richmond–Ladner area in the lower mainland of British Columbia. This is the area where several waterfowl kills resulting from carbofuran use on root crops have taken place (see Section 3.3.2.2). Moribund birds typically exhibited lethargy, inability to stand, balance problems or incoordination, a fixed "vacant" stare and constricted pupils, as well as a below-normal body temperature. All of these symptoms are consistent with acute poisoning with an anticholinesterase agent such as carbofuran (Hudson *et al.* 1984). The birds had full crops, a noticeable "chemical" odour on the breath and in the crop contents, as well as an oily, reddish-brown exudate in the mouth and crop. Balcomb (1983) reported that a Red-shouldered Hawk (*Buteo lineatus*) secondarily poisoned by Furadan 10G salivated a "brown fluid." All of the hawks and eagles were in good flesh. Also, a number of cases were associated with the presence of waterfowl displaying similar symptoms.

Table 4.
Summary of incidents of secondary poisoning recorded in the United States up to September 1990 (excluding known misuses).

Species	No. of incidents	No. of individuals
Bald Eagle (*Haliaeetus leucocephalus*)	12	15
Red-tailed Hawk (*Buteo jamaicensis*)	10	14
Northern Harrier (*Circus cyaneus*)	2	5
Cooper's Hawk (*Accipiter cooperii*)	2	4
American Crow (*Corvus brachyrhynchos*)	2	2
Great Horned Owl (*Bubo virginianus*)	2	2
Golden Eagle (*Aquila chrysaetos*)	1	3

The arrival of dead or moribund birds appeared to follow periods of rain, conditions documented in Section 3.3.2.2 as being conducive to waterfowl mortality in fields treated with granular carbofuran. Crop contents were either manually removed or surgically excised in most of the birds. Following this procedure, recovery was seen to be very rapid. Again, this is entirely consistent with poisoning with a carbamate insecticide. Crop contents in all cases consisted of duck or gull body parts.

Crop contents from one Red-tailed Hawk were analyzed and found to contain 2 ppm carbofuran. Heavy metal levels in liver and kidney from the same bird were low, and the analysis was also negative for strychnine, nicotine, and barbiturates. (The last analysis was performed because a case of eagle mortality had been reported following scavenging on cattle that had been destroyed by lethal injection.)

Approximately 15–16 Bald Eagles and four Red-tailed Hawks fit the same pattern and are suspected of having died from pesticide poisoning. These are the two species that have been the most frequently reported killed by secondary poisoning from granular carbofuran in the United States (Table 4). Other birds were apparently picked up by other groups and/or agencies and hence do not appear in the above tally.

No waterfowl kills were officially reported to the authorities in the winter of 1989–1990. However, the raptor rehabilitation centre in question handled a number of ducks and geese that were delivered to them over the same period. Their crops were edematous, and some were disgorging a clear fluid, a symptom commonly noted in waterfowl poisoned with anticholinesterase insecticides (e.g., Stone and Gradoni 1985b; Frank *et al.* 1991). A dead gull was also found exhibiting similar symptoms. The waterfowl were mostly buried or disposed of in some other manner. No connection was made between the dead ducks and gulls and the eagles at the time.

Although only one chemical residue analysis is available, carbofuran poisoning appears likely for a high proportion of these birds. In a well-documented Bald Eagle kill related to the use of granular carbofuran in corn, one bird with a 58.6% inhibition of brain cholinesterase (diagnostic of ingestion of a potentially lethal dose) was determined to have crop content residues of 0.64 ppm carbofuran. This bird had been scavenging remains of Rock Doves and blackbirds (Hill and Swineford 1985; Thomas 1985; Patterson 1986). Finally, the presence of duck and gull feathers in all of the birds (fish is the more habitual diet of the Bald Eagles, at least) and the apparent association of the kills with periods of rain suggest that the birds were able to locate kills of waterfowl resulting from carbofuran use.

Update: *Recently released data from Agriculture Canada indicate that crop contents from one of the Bald Eagles contained 200 ppm carbofuran. Carbofuran was not detected in samples from two other eagles. Granular carbofuran has once again been withdrawn from sale in the lower Fraser valley. Based on more recent information, it has been determined that at least one of the other currently registered granular insecticides (phorate) is also causing raptor mortality.*

4. EXPOSURE OF WILDLIFE TO THE FLOWABLE FORMULATION

4.1 REGISTERED USE PATTERNS IN CANADA

Only one formulation of liquid carbofuran (Furadan 480F) is registered in Canada. This formulation is identical to the Furadan 4F formulation registered in the United States (D. Carlson, FMC Corp., pers. comm.). Therefore, studies carried out with either formulation are deemed applicable to the Canadian formulation. Flowable formulations are finely ground wettable powders in a thick suspension. The terms "liquid carbofuran" and "carbofuran flowable" will be used interchangeably here.

Table 5 lists the registered uses and application rates in effect in Canada. In standard evaluation methodology (e.g., Urban and Cook 1986), potential exposure from a liquid formulation of a pesticide, especially through ingestion of contaminated foodstuffs, is assumed to be linearly related to the application rate. For ease of comparison between different studies and different crops, application rates are provided in multiples of the rate for grasshopper control (e.g., 1 × = 0.275 L of the 480F formulation or approximately 132 g a.i./ha), which is one of the lowest registered rates in Canada and certainly the most broadly used.

4.2 ROUTES OF EXPOSURE

Wildlife can be exposed in different ways to Furadan 480F. Oral exposure through contaminated food has been the route of pesticide uptake receiving the most emphasis (e.g., Kenaga 1973; Urban and Cook 1986). Wildlife can also ingest residues directly while preening (grooming) and drinking, dermally through direct spray deposition or contact with contaminated surfaces, or through inhalation of fine droplets or vapour.

Recent work on the organophosphates fenitrothion and methyl parathion (Mineau *et al.* 1990; Driver *et al.* 1991) indicates that dermal uptake and inhalation can be significant routes of pesticide exposure in wild birds. However, the relative importance of these routes of exposure is likely to vary tremendously with the chemical and the particular exposure situation (Mineau 1991a).

Table 5.
Registered use patterns of carbofuran flowable in Canada, ordered by increasing rate of application. Application rates are given as kilograms of carbofuran active ingredient per hectare and in multiples (e.g., 2×) of the grasshopper spray rate.

Crop	Pest	Rate (kg a.i./ha)[a]	No. of sprays registered[a]	Multiple of the grasshopper rate
Field crops, corn, pastures, noncrop areas, sunflowers, alfalfa	Grasshoppers	0.132	2	1×
Wheat	Wheat midge	0.132	2	1×
Sunflower	Sunflower beetle	0.132	2	1×
Canola, mustard	Flea beetle, red turnip beetle	0.132	1[b]	1×
Alfalfa	Alfalfa weevil, blotch leafminer	0.264	1	2×
Corn	European corn borer	0.528	4	4×
Green peppers (Ontario)	European corn borer	0.528	6	4×
Strawberries (eastern Canada)	Several	0.528	1	4×
Potato	Several	0.816	No limit	6×
Sugar beets	Root maggot	1.12	1	8.5×
Raspberries (British Columbia)	Bud or root weevil	1.2	2	9×
Strawberries (British Columbia)	Root weevil, spittlebug	1.2	2	9×
Turnip, rutabaga	Root maggot	2.5	3	19×

[a] Maximum registered for that use pattern.
[b] Applications against flea beetles may also be applied at half of the rate indicated whereupon two applications are allowed. This 0.072 kg a.i./ha rate is the lowest registered in Canada.

4.3 EVIDENCE FOR A HAZARD TO SONGBIRDS AND OTHER INSECTIVOROUS SPECIES

4.3.1 Supervised field trials

The most extensive field studies available for carbofuran flowable are those carried out by the manufacturer for the U.S. EPA. These studies are basically carcass searches conducted in cornfields and alfalfa fields. They are briefly reviewed here.

4.3.1.1 FMC 1989a: corn studies

These studies were carried out in unirrigated agricultural fields in Nebraska as well as in pivot-irrigated fields in Texas and New Mexico. The methodology was similar in both cases, but the studies are discussed separately.

A. Nebraska, standard agricultural fields

Application of the chemical

Carbofuran was applied by air to cornfields at a rate of 1.1 kg a.i/ha (8.5 ×), which corresponds to approximately twice the Canadian corn rate but is equal to the sugar beet rate and lower than the raspberry, B.C. strawberry, and root crop rates currently registered in Canada (Table 5). Two applications were made, whereas four are allowed in Canada.

Although the mixing and application were carefully supervised, the researchers had considerable difficulty with their chemical "accountability." Tank samples taken directly from the spray booms immediately after spraying had recovery rates of the active ingredient that ranged from 66% to 210%, with the exception of one sample that was said to contain 1.9% of expected. The flowable formulation of carbofuran is a suspension that is difficult to keep homogenized.[8] The fact that such a high degree of variability was encountered in a carefully monitored field trial suggests that the amount of carbofuran deposited is likely to fluctuate widely under operational use conditions. This should be borne in mind when considering residue information from field trials or reported kills. The researchers also appeared to experience problems with their analytical capability, because three fresh samples of formulation taken directly from the jugs gave recoveries ranging from 75% to 84%.

Spray cards placed at various levels in the crop reinforced the fact that difficulties had been encountered. Individual readings from cards placed in the crop canopies ranged from 0.18% to 100% of expected in the eight treated fields over the course of the two applications. Average deposits from each application ranged from 6.6% to 44%, with a grand mean of 22% of expected. Application coverage was therefore very poor overall. ('Successful' aerial applications typically result in deposits of 60% or better; Sheehan *et al.* 1987). Peak residues (2 hours postspray) of field edge vegetation (all four edges being pooled for any given field, with samples taken 5 m into the edge) were said to average 53.4 ± 64.3 ppm for the first application and 44.4 ± 90.4 ppm for the second. Drift cards were also positioned approximately 3 m into all four field edges. The field

---

[8] D. Forsyth (Canadian Wildlife Service, pers. comm.) determined that a sample of carbofuran poured off the top of a small spray tank 8 minutes after agitation had a concentration 12% below expected. After 30 minutes, enough of the carbofuran had settled that surface samples contained 30% less than expected. The material remained satisfactorily in suspension for only 4 minutes after the initial mixing.

edge receiving the most drift (presumably the downwind edge, although wind conditions during application were not given) received 16.2–167% of mean deposits obtained at the top of the corn canopy (mean of 82.1%, based on 13 different applications). This extent of edge contamination following aerial application is not surprising, especially in cases in which several spray swathes contribute to the downwind spray deposition (Maybank *et al.* 1978).

<u>Carcass searches</u>

Plots were searched for 7 days before the first Furadan application and for a 7-day period following each of the two applications. The authors of the study erred in using the "pretreatment" mortality as a meaningful covariate of posttreatment mortality. In fact, plots had received applications of toxic insecticides (including ethyl parathion) 2–3 weeks prior to commencement of the study, so that the presence of carcasses prespray was not necessarily indicative of "natural" mortality. Also, there was no allowance made for the fact that "pretreatment" mortality represented carcasses and feather-spots accumulated over an unknown period of time. The statistical analysis of the carcass data, which, among other manipulations, tried to compare pre- and posttreatment mortality, is therefore of dubious validity and relevance. Further numerical manipulations of questionable value include comparing the kill data with surveys of live birds also carried out on the plots. In fact, the authors acknowledged that the surveys were difficult to interpret because the lateness of the season meant that the bird populations were mobile and not "tied" to the fields in question.

However, as the areas searched in treated and control fields were similar and search intensities were held roughly constant, it is still meaningful to look at the overall number of carcasses found in treated versus control fields, assuming that most of the pretreatment carcasses were found over the 7 days of searching. This assumes that, effectively, the areas were swept clean of carcasses before the application of Furadan flowable. For reasons given above, the number of carcasses found in the course of these pretreatment sweeps is not relevant. In other words, this study is potentially useful from a qualitative standpoint only.

<u>Results of the carcass searches</u>

Fourteen dead birds were found in the carbofuran-treated fields and in the edges of those fields over the 14-day period comprising the two applications. By contrast, five dead birds were found in the edges of the control fields. Those fields had been treated with pyrethroid insecticides (of low acute toxicity to birds). The authors speculated that this "control" mortality may have been a result of exposure to pesticides used on adjacent fields not under experimental control. Interestingly, at least one of the five control carcasses was from a field edge where the adjoining cornfield was said to have been treated with carbofuran, at three-quarters of the experimental rate. (An immobilized but live warbler was also associated with the same control plot.) Furthermore, detectable carbofuran residues were found in edge vegetation from <u>all</u> fields where carcasses were found. Therefore, there was not a single carcass found posttreatment that was not associated with some carbofuran use, either experimentally or incidentally.

More complete data on the pesticide treatments in effect in adjoining fields likely would have allowed a clearer interpretation of how many of the "control" carcasses were possibly the result of carbofuran use not under the control of the researchers. Unfortunately, many of those data were said to be "not available." Carcasses found on control plots were not analyzed for the presence of residues. The gastrointestinal tracts and/or brains of 11 birds found dead on carbofuran plots were analyzed for the presence of carbofuran. All but two birds tested positive for residues. However, these two individuals were recovered 5 and 6 days postspray, and the lack of residues in those two carcasses is easily explained by residue degradation (see Fig. 1).

Figure 1.
Carbofuran residues in the gastrointestinal tracts of bird carcasses found at various intervals postspray in a Nebraska cornfield study.

```
Residue (ppm)
2.7 +
    I  *
    I
    I
    I
1.8 +
    I
    I
    I          10 cases plotted
    I
0.9 +
    I     *
    I
    I  *
    I     *         *
0.0 +          *     *    *(2) *
   -+---------+---------+---------+---------+-
   0.0       2.0       4.0       6.0       8.0
           Days postapplication
```

Finding positive evidence of carbofuran residues in any carcass was made even more improbable by poor analytical recovery. The authors looked at the persistence of residues injected into the gastrointestinal tracts of carcasses left to age in the fields and others spiked in the laboratory. Recovery of carbofuran from the gastrointestinal tracts of four birds analyzed immediately (0.5 h) after laboratory spiking ranged from 0.5 to 1.3 ppm (7.3–19% of expected). Birds spiked in the field and then taken to the laboratory rarely had levels that were quantifiable (>0.10 ppm) and usually had levels below the detection limit (<0.05 ppm).

One conclusion to be drawn from these data is that <u>finding carbofuran residues in field-recovered carcasses is a significant event</u>. The authors' attempts to ascribe much of the mortality in this and the following studies to causes other than carbofuran (on the basis of pretreatment mortality in the same plots) are totally unconvincing.

A number of observations of "deficit behaviour" (any behaviour judged to be abnormal) were also made by the researchers. However, there appeared to be some difficulty in judging whether individuals were behaving abnormally, and a number of the reports lacked a good description of the abnormal behaviour in question. Only one type of abnormal behaviour is unequivocal: immobilization of the individual. This effect is typical of cholinesterase-inhibiting insecticides and less likely to be misinterpreted by a field observer. Four birds were found immobilized in Nebraska: one was the aforementioned warbler associated with a "control" edge adjacent to carbofuran use, and the other three were on carbofuran plots.

Carcasses of other animals (mostly mammals and amphibians) were also associated with both treated and control fields but were found primarily in field edges, making the interpretation difficult for reasons mentioned above. Four of seven nonbird carcasses found posttreatment and analyzed had measurable quantities of carbofuran in their gastrointestinal tracts. Temporal association between carbofuran treatment and amphibian mortality was suggested when four southern leopard frogs (*Rana sphenocephala*) were found in the edge of a carbofuran plot between 2 and 6 hours following application.

Approximately 32 ha (divided equally between field and edge) were searched for carcasses in the carbofuran-treated fields. This represents an uncorrected kill rate of 0.43 birds/ha.

B. Texas/New Mexico pivot-irrigated fields

Despite the different outward appearance of these fields (perfect circles of 800 m diameter) and the nature of the field edge habitat (which was concentrated in the uncropped corners of the square fields), the methods utilized in this study were very similar to the methods used in the Nebraska study. Results were also similar and confirmed those obtained previously.

<u>Application of the chemical</u>

Again, serious problems of chemical accountability were reported. Three spray tank samples gave carbofuran recoveries ranging from 22% to 41% of the amount of carbofuran active ingredient expected. Collection cards positioned high in the corn canopy registered mean field deposits ranging from 19% to 70% of nominal rate, with an average of 36%. These applications are somewhat better than those on the Nebraska plots (with a grand mean of 22%) but still poor from an agronomic point of view. A considerable degree of field edge contamination was again reported.

<u>Results of the carcass searches</u>

Seventeen dead birds were found in the carbofuran fields and edges posttreatment, with a roughly equal proportion in both habitats. Most of this mortality was recorded within 2 days of a carbofuran application. This compares with two dead birds found in the control plots (one in a field, the other in a field edge). The control fields in this study were being treated with dimethoate applied in cottonseed oil as well as with the "control application" of a pyrethroid. Again, it is meaningless to look at pretreatment mortality in view of the range of pretreatment sprays in effect in control and treated fields (ethyl parathion again was used on some plots). All bird carcasses analyzed for carbofuran had quantifiable residues in their gastrointestinal tracts (range 0.2–2.4 ppm).

Three immobilized birds were reported found on the Texas/New Mexico plots, including one raptor (Northern Harrier). Two of the birds were on control plots. However, carbofuran residues were once again found in these "control" edges. Residues in the edges of the control field where the immobilized harrier was found were identical to those in the edges of treated fields 4 days postapplication (13.3 ppm).

Nonbird mortality was also interesting. Eight dead amphibians (toads, frog, salamander) and one mouse (genus *Peromyscus*) were found on carbofuran plots posttreatment. All had quantifiable carbofuran residues in their gastrointestinal tracts, ranging from 0.1 to 9.4 ppm. A dead mouse (unspeciated) and a skink (a type of lizard) were found in the edges of control fields.

The finding of dead amphibians with high gut residue levels in these Texas study plots combined with the observation of the four dead leopard frogs associated with a carbofuran spray in the Nebraska study (residue analyses for these specimens were excluded from the tables; no reasons given) indicates that amphibians as well as birds are at risk from carbofuran use. Recent data from the Canadian prairies, an area of extensive carbofuran use, indicate a dramatic decline in the number of amphibians. There is therefore reason to be concerned about the continued use of carbofuran in an area of diminishing amphibian populations.

Given a similar search area in the Texas/New Mexico plots (about 32 ha divided equally between field and edge), an uncorrected mortality rate of 0.53 birds/ha is obtained.

It is difficult to translate these estimates into the real wildlife mortality resulting from the use of carbofuran. The authors reported that the extent of carcass disappearance was much lower than previously reported for bare cornfields at planting time (Balcomb 1986). For example, in the Nebraska plots, the cumulative proportion of planted carcasses (black chicks of domestic fowl) found after 7 days of searching ranged from 31.3% to 100% (mean 74.2%) of total in the fields and from 43.8% to 100% (mean 78.4%) in edge habitat. This measure presumably incorporates both the search efficiency of the investigators and the rate of scavenging.

However, other factors influence one's ability to detect mortality. For example, the behaviour of poisoned individuals may make carcasses difficult to find, as poisoned birds may seek cover or leave the field altogether. In addition, a regular human (and search dog) presence on the fields may affect the presence of both potential casualties and potential scavengers (Mineau and Collins 1988). Indeed, it has been found that carcasses that are merely "planted," as they were in this study, are much more readily found than carcasses that are placed as if the dying bird was trying to conceal itself (Stutzenbaker *et al.* 1984).

Therefore, it is probably safer to treat these studies in a qualitative rather than a quantitative fashion. They indicate that carbofuran flowable applied aerially to corn against the European corn borer (at a nominal rate of twice the Canadian rate but with a reported application success less than half of expected) can and does kill birds and other vertebrates, including amphibians.

4.3.1.2 FMC 1989b: alfalfa studies

Studies utilizing the same basic design as the corn studies reported above were performed in alfalfa fields in Kansas and Oklahoma. Sixteen fields (eight in each study area) were treated twice with carbofuran flowable by ground (Kansas) or by air (Oklahoma), first at a rate of 1.1 kg a.i./ha (8.5×) and then at half that rate (approx. 4×) about 1–2 months later. Both applications are higher than the registered Canadian applications to alfalfa (2×). The second application is equivalent to the corn application registered in Canada.

Unfortunately, the design of these studies was complicated by the fact that both carbofuran and control fields were also treated with carbaryl or methomyl as needed. In addition, control fields were treated with chlorpyrifos. Thus, of the planned eight pairs of treated–control fields in Oklahoma, only two pairs in fact received the same insecticide application. Furthermore, insecticide treatments (including carbofuran use) took place in some fields adjacent to study plot fields, once again confusing the exposure situation. Highlights of these studies will nevertheless be summarized here.

Survey data in the corn studies reviewed earlier were confounded by postbreeding emigration of birds. In the alfalfa studies, arrival of the birds on the plots in the course of the study and mowing of the fields made the census data again difficult to use or interpret.

Because of the lag between the two treatments, there were two periods of pretreatment carcass searches in both the Kansas and Oklahoma fields. Searches were carried out for 10 days before each treatment and for 7 days thereafter.

A. Kansas fields, ground application

Application of the chemical

Samples taken directly from the tank sprayer gave carbofuran recoveries ranging from 46% to 106% (N = 8), again suggesting poor mixing of the active ingredient in the spray solution. Deposits collected on cards just above the crop canopy showed that deposits on individual plots ranged between 23% and 57% of expected following the first application and between 1.0% and 75% of expected for the second. Grand means were 43% and 23% for the first and second sprays, respectively. These deposits are low for ground application equipment. The highest field edge deposits (presumably the downwind samples, although their location was not specified) taken 3 m in from the edge of the field gave deposits ranging from barely detectable to 14 times greater than those obtained in the fields proper. In six of the 16 applications monitored, maximum field edge residues were higher than the average field deposit.

Results of the carcass searches

Only five bird carcasses were found over the 20 days of pretreatment periods in all fields, treated or control. However, 15 dead birds were found in the search areas following the two carbofuran sprays and seven following the two control chlorpyrifos sprays. Eight of the 15 birds found on carbofuran plots posttreatment were found following the second spray; this is very relevant to the Canadian use situation, because this spray rate corresponds to that used on corn. Searchers also found four immobilized individuals, three in carbofuran plots. These included a Northern Harrier that had been feeding on an eastern cottontail (*Sylvilagus floridanus*), which was found to contain 0.1 ppm carbofuran residues. Nonbird carcasses were also found in both carbofuran and chlorpyrifos plots, but only following insecticide application. Of the eight bird carcasses found in either posttreatment period on the carbofuran plots and analyzed, five had detectable carbofuran in the gastrointestinal tract or in the brain. Again, this is very significant in light of the aforementioned difficulty of recovering carbofuran from spiked carcasses. Likewise, two of three carcasses found in either posttreatment period in the control fields contained chlorpyrifos residues. The significance of this finding is more difficult to ascertain, because there was no field spiking of carcasses with chlorpyrifos.

It appears that both the carbofuran and chlorpyrifos treatments gave rise to mortality in this study. Although chlorpyrifos use has seldom been associated with bird mortality, cholinesterase measurements in birds from a small field of cereal sprayed with chlorpyrifos indicated that exposure was significant and that little or no margin of safety was present (McEwen *et al.* 1986). Alternatively, there were carbofuran residues in all of the control field edges, thus raising the possibility that some or all of the mortality on the chlorpyrifos plots was in fact due to carbofuran use in neighbouring fields.

B. Oklahoma fields, aerial application

Application of the chemical

The difficulty of controlling carbofuran applications was reaffirmed. Samples taken from the spray tanks after application gave recoveries ranging from 23% to 189% of expected (N = 6). Deposition cards in the fields gave readings ranging from 8.5% to 56% of the nominal rate during the first application and from 1.2% to 47% of nominal during the second. As in the Kansas ground spraying situation, some of the fields showed extremely low deposits, especially for the second application. In the Kansas plots, different types of spray cards were used for the two sprays; however, this was not the case in Oklahoma. No other reasons were given that might explain the poor results on some of the plots. Grand means for all treated plots were 33% and 21% of nominal for the first and second sprays, respectively. These values are in the same range as the values reported following ground application in Kansas. Card deposits 3 m into the field edge gave maximum (downwind?) values ranging from less than 1% to 583% of field deposits. Maximum edge deposits exceeded average field deposits in nine of 16 fields monitored.

Results of the carcass searches

Searchers found seven bird carcasses in the posttreatment periods in the carbofuran plots compared with one bird in the pretreatment "sweeps" of the search areas. Of the seven, four were found following the second (lighter) spray. Searchers also recovered 17 bird carcasses from the control plots treated with chlorpyrifos (compared with three in the combined pretreatment periods). Two birds were found immobilized, both on chlorpyrifos plots. Other carcasses, including mammals, reptiles, and amphibians, were recovered from both carbofuran and chlorpyrifos plots postspray.

Of nine carcasses found postspray on the chlorpyrifos search plots and subsequently analyzed, eight had chlorpyrifos residues in either the gastrointestinal tract or the brain. Similarly, three of four carcasses found posttreatment on the carbofuran search areas and analyzed were positive for carbofuran residues.

C. Summary

In summary, it appears that carbofuran applied by ground or by air at either 0.55 kg a.i./ha (4×) or 1.1 kg a.i./ha (8.5×) onto alfalfa and adjacent field margins does kill birds and likely other vertebrates. One of the alternatives to carbofuran, chlorpyrifos applied at 1.1 and 0.55 kg a.i./ha, may also cause bird mortality. We caution, however, that the studies were not entirely adequate for looking at impacts resulting from chlorpyrifos use: chlorpyrifos applications were not monitored, and there is the confounding aspect that all of the control fields had measurable carbofuran residues in their field edges, presumably as a result of spraying in neighbouring fields. Unfortunately, carcasses found on chlorpyrifos plots were not analyzed for carbofuran.

4.3.1.3 FMC 1983: alfalfa, Utah

This study was conducted concurrent with the study on corn granulars reported above (see Section 3.3.1.1). The study is difficult to interpret because of key missing information. Also, the total carcass search effort was minimal relative to the effort needed to ascertain whether mortality had occurred.

4.3.1.4 Horstman 1985, Horstman and Code 1987

These studies looked at the effect of carbofuran spraying of roadside verges for grasshoppers (rate = 1×) on nesting Brewer's Blackbirds (*Euphagus cyanocephalus*) and other passerine species. Horstman (1985) made use of operational spraying, 60% of which was aerial. Egg and nestling mortality rates were significantly higher in sprayed nests, principally as a result of single egg or nestling disappearances. Of eight treated nests with such disappearances, five had been sprayed with carbofuran. Total nest abandonment was also higher in treated nests, but sample size was too small for statistical analysis. Some dead nestlings were found, but residues were not detectable. The author concluded that nestlings might be at risk from ingestion of carbofuran-treated insects. However, she also postulated that habitat differences may have resulted in uneven predation rates, with untreated nests being in habitats less prone to predation.

The Horstman and Code (1987) study was designed to verify the 1985 work and to add to the sample size. This was a planned study in which the investigators applied carbofuran themselves by ground rig for a distance of 0.4 km along the roadside on either side of the nests. Some nests were exposed to two sprays 10 days apart. Only Brewer's Blackbirds were monitored. Unlike observations made in the previous study, adult females were found to be foraging principally in the fields adjoining the road verges rather than in the verges proper. The relative importance of these habitats was not quantified, however. Egg survival and hatching rates did not differ between control and treated nests. Nestling mortality was significantly higher in treated nests than in control nests in one of the two site pairs only, but dead nestlings were not recovered. Predation was higher in treated sites, but abandonment was higher in control sites. Residues were detected in a number of nestlings sacrificed for the analysis.

Taken together, these studies did not demonstrate any convincing effect of carbofuran on nesting Brewer's Blackbirds. There were too few data on the other species in Horstman (1985) to reach any conclusions. Unfortunately, some factors limited the usefulness of these studies:

1. There was no grasshopper outbreak during the 1987 study, and birds may therefore not have been exposed to large numbers of contaminated prey. Although the birds were principally foraging in the ditches in the 1985 outbreak year, the birds were foraging mainly in adjoining fields in 1987.

2. In the 1987 study, there was rain soon after spraying, in the case of both nests in the egg stage (1.5–5 hours between spray and rain) as well as nests in the nestling stage (12–16 hours between spray and rain). In the first case in particular, the incorporation of the insecticide into the local insect biomass may have been reduced.

3. Because of unforeseen delays, the spray truck in 1987 was filled on the day before spraying actually took place. Although it appears that the water used in the truck was not alkaline enough to result in a significant degradation of the carbofuran, it is possible that insufficient agitation resulted in uneven application of the insecticide (L. Horstman, Pecan Resources Ltd., pers. comm.; see Section 4.3.1.1). No samples were taken to confirm the concentration of carbofuran in the spray solution.

4.3.1.5 Irvine 1987, 1990, Forsyth et al. *1989*

These three reports summarize the data currently available on a large-scale experimental carbofuran spray that took place in 1987. Unfortunately, a final report is not yet available on the bird and mammal impact portions of the work.

A large native-grazed pasture (259 ha) was sprayed with carbofuran flowable at the recommended grasshopper rate of 140 g a.i./ha (1 ×). A control site was also established for comparison purposes. The impact work consisted of looking at small mammals and birds from the central cores of the two blocks.

<u>Assessment of deposit</u>

A series of 24 randomly positioned transects supplied with deposition cards was used to monitor droplet deposits in one section (corresponding to one aircraft payload) of the sprayed pasture. Average droplet numbers ranged from 1 to 24/cm^2.

Pools of dead grasshoppers collected with forceps from the same area contained average carbofuran residues of 2.1 ppm 1–3 hours postspray and 2.5 ppm 6–9 hours postspray.

Grasshoppers collected in sweep net samples (which included both live and dead grasshoppers) had residues ranging from 0.45 to 6.6 ppm carbofuran on spray day, which declined rapidly on successive days.

Residues on vegetation samples taken from 0.25-m^2 quadrats averaged 13.3 ppm 1–3 hours postspray and 5.9 ppm 10–11 hours postspray. Overall, vegetation samples from the day of spray (18 June) had residues ranging from 1.1 to 21.8 ppm. On the day following the spray, the residues ranged from 1.2 to 21.7 ppm. A light rain (3 mm) fell on 19 and 20 June, and this appears to have reduced the half-life of the residues on the vegetation. Samples taken on 20 June ranged from 0.1 to 1.1 ppm.

Carcass searches

The area was first searched 8–9 hours postspray. Approximately 0.7% of the total spray area (1.9 ha) was searched over a 3-hour period. The search was repeated 32 and >150 hours postspray. Although the search did not uncover any casualties, the small area searched, the minimal amount of time devoted to this activity, and the breeding density (approx. 4 breeding pairs/ha for all of the regular bird species combined) would have made the finding of casualties difficult even if mortality had occurred. Furthermore, it does not appear as if search efficiency or carcass disappearance rates were determined.

Bird censuses

Three pretreatment surveys and three posttreatment surveys were conducted on three centrally located plots of 300 m by 600 m. Efforts were also made to find nests. Some birds were also collected by shooting for cholinesterase measurement.

Two of 11 common breeding species showed a significant decline in the postspray period relative to the prespray period. Although declines in those species were also seen in the control plot, they were not significant. Details of the nest data were not supplied, but the data summary appeared to show a treatment effect. The success rate was 46% (17/37) for treatment nests versus 83% (10/12) for the controls. This difference is statistically significant (χ^2 = 5.12, P = 0.024). Most of the nest losses were thought to have resulted from predation.

Update: *The raw data on which the reproduction data were based were finally made available in the summer of 1992 and analyzed by D. Forsyth of the Canadian Wildlife Service in Saskatoon (D. Forsyth, pers. comm.). Analysis is still tentative, because approximate nestling ages were not provided; it is therefore often difficult to distinguish between fledging and disappearance of the young for other reasons. Furthermore, control nests were found to have been visited too infrequently for those data to be meaningful. Nevertheless, there does not seem to be an indication of a catastrophic impact over the 1- to 3-day period following the spray, which is when a toxic effect on the adults or young would be expected based on the characteristics of carbofuran. The data do not allow for the determination of more subtle effects.*

As far as it is possible to determine from the figures provided, seven songbirds were collected by shooting on spray day (four Horned Larks, two Red-winged Blackbirds, and one Brown-headed Cowbird). Because spraying took place over an extended period of time, it is impossible to determine whether all birds were collected from areas already sprayed. Four of the seven showed a reduction in brain cholinesterase of more than 20%[9] (three of the four Horned Larks and one Red-winged Blackbird). Maximum cholinesterase depression was 61% in the larks, and the blackbird showed a 52% drop in activity relative to control. Of the three birds sampled on the day following the spray (one Red-winged Blackbird, one Vesper Sparrow [*Pooecetes gramineus*], and one Eastern Kingbird [*Tyrannus tyrannus*]), none showed brain depression of more than 20%.

Small-mammal censuses

A live-trap grid was established and run for 10 nights prespray and 7 nights postspray. Snap traps were also placed away from the grids to collect individuals.

Irvine (1987) stated that there did not appear to be any shift in the relative ratios of new to recaptured animals on a day-by-day basis in the postspray period. However, the data presentation does not allow one to look specifically at the survival of animals marked prior to the spray in the postspray period. Also, inconsistencies between the tabular data and a figure preclude meaningful interpretation. The populations studied appear to show a very high rate of turnover in the prespray period as well as the postspray period. Despite 10 consecutive nights of trapping, the number of recaptures remained consistently below the number of new captures for most of the prespray period.

Only one deer mouse (*Peromyscus maniculatus*) was sampled on the night following the spray. It showed a brain cholinesterase inhibition level of about 45% relative to control. Three more small mammals were sampled about 1 week postspray. One sagebrush vole (*Lagurus curtatus*) may have shown a slight degree of depression at that time.

Laboratory studies

Juvenile Clay-colored Sparrows (*Spizella pallida*) and Vesper Sparrows were captured and held captive to test their reaction towards poisoned grasshoppers and to examine their choice of dead or live grasshoppers. The latter were captive-bred third- or fourth-instar nymphs. Grasshoppers sprayed in the laboratory contained an average of 2.5 ppm (range 1.4–5.1 ppm for pooled samples) carbofuran, which was the average residue level for the field-collected grasshoppers.

In choice experiments, the Clay-colored Sparrows showed a preference for dead grasshoppers (these had been killed by freezing). Vesper Sparrows appeared to show a slight preference for live grasshoppers, but the difference was not great overall.

In other feeding trials, Clay-colored Sparrows offered sprayed grasshoppers *ad libitum* on the third day of a grasshopper-only diet showed no noticeable drop in food intake during the course of that day. In fact, birds feeding on treated grasshoppers appeared to show a slight increase

[9] The level of 20% inhibition is considered indicative of exposure to an anticholinesterase agent (Ludke *et al.* 1975). An inhibition level of 50% or more is generally considered life threatening. Although individual birds can survive single acute doses of anticholinesterase agents that depress their brain cholinesterase by more than 50%, mortality as well as sublethal manifestations of toxicity become much more frequent at that level (Grue *et al.* 1991). There is evidence that collected birds tend to underestimate the level of cholinesterase depression sustained by a population (Mineau and Peakall 1987).

relative to controls.

There appeared to be an increase in activity (measured as the number of hops) and in bill-wiping frequency as a result of the consumption of the treated grasshoppers, but none of the changes was statistically significant at the 0.05 probability level (bill wiping was significant at the 0.057 level). If real, those two observations would be consistent with mild cholinergic stimulation (Hart 1993). No mortality or other visible impact resulted from the feeding.

Following the feeding trials, the carbofuran LD_{50} for the Clay-colored Sparrows was found to be approximately 1.5 mg/kg body weight, a value that places this bird with the other relatively sensitive passerine species (D.L. Forsyth, Canadian Wildlife Service, pers. comm.). Forsyth *et al.* (1989) determined that, after a 4-hour fasting period, the highest consumption of grasshoppers over a 15-minute period among a group of 21 captive individuals was 31 grasshoppers, for a total weight of 3.03 g. Given a mean grasshopper residue concentration of 2.5 ppm and an average body size for the bird of 12.7 g, this short-term ingestion was roughly equivalent to 0.6 mg/kg body weight, or slightly less than one-half of the LD_{50}. Actually, a few individuals given a dose of 0.5 mg/kg in a single bolus (the material having been injected into a puffed wheat pellet) collapsed on the cage floor and remained incapacitated for 30–40 minutes (D.L. Forsyth, Canadian Wildlife Service, pers. comm.). Because no such overt toxicity was seen in the feeding trials, it is likely that not all of the insecticide was extracted from the grasshoppers or that the birds obtained a certain amount of protection from the slower absorption in the course of digestion.

These experiments do not rule out the possibility of acute poisoning from the consumption of grasshoppers in the wild. Wild birds, especially in the breeding season, have to increase their food intake because of the higher energetic demands of feeding a brood. For example, Williams (1987) documented 75% and 87% increases in foraging needs for male and female Savannah Sparrows, respectively, during the nestling period relative to incubation needs. Also, because of their smaller body size, nestlings ingest a larger proportion of their body weight in food and may be more sensitive to cholinesterase inhibitors as a result of their low cholinesterase titres (Grue *et al.* 1981). Although average grasshopper contamination was 2.5 ppm in the field, sweep net samples contained pools of grasshoppers with residues ranging as high as 6.6 ppm carbofuran in this particular study.

The surveys tend to indicate that there was no catastrophic impact on the bird populations of the treated pasture. Although surveys are often of limited usefulness because of the problem of population replacement from outside of the treated block, the large area sprayed in this particular study minimized any such problems. The few cholinesterase data points indicate that a segment of the bird and small-mammal populations sustained very severe brain cholinesterase inhibition. The laboratory studies indicate that a substantial fraction of an LD_{50} could be attained by songbirds feeding on contaminated grasshoppers and other invertebrates.

In summary, there does not appear to have been a major lethal impact on the bird and small-mammal communities, but the margin of safety was probably small or nonexistent. This work was carried out at the second lowest registered rate of carbofuran flowable in Canada. The level of exposure documented does raise obvious concerns as to the potential sublethal impacts (Grue *et al.* 1991).

4.3.1.6 Somers et al. *1988a, 1991*

This study looked at direct spray applications of carbofuran (grasshopper spray rate, 1×) to Ring-necked Pheasants and Chukars (*Alectoris chukar*) ranging between 4 and 14 days of age. The birds were confined to wire mesh cages and exposed to one or two (after a 1-week interval) direct applications from a hand-held boom sprayer. Following the spray, the birds were transferred to brooder units and observed. The birds were weighed before spray and 3 days later. Brain cholinesterase inhibition was measured 1 and 72 hours postspray.

There were no reported effects on either survival or weight gain under the test conditions. Brain cholinesterase inhibition was not significantly depressed in any group.

The residues extracted from the feathers were lower (by up to a factor of 3.5) than expected based on the spray rate and the exposed surface areas of the birds. Although the recovery from the body surface was said to be 85% based on laboratory spikes, recovery of carbofuran from the birds that were actually sprayed in the field may have been lower. Also, the authors do not specify whether the mesh cages had a top that may have intercepted some of the spray. Despite these small deficiencies, the conclusions of the study appear to be sound: topical overspray with carbofuran does not result in appreciable exposure and is therefore of no discernible consequence. Similar conclusions were reached with the insecticides carbaryl and dimethoate. Although pheasant and grouse chicks are insectivorous, there was no attempt to look at that particular route of exposure.

4.3.1.7 Somers et al. *1988b*

A hay field known to attract foraging gulls was treated in July 1986 with a ground application of carbofuran at the grasshopper rate (1 ×). A number of gulls seen foraging on the site were shot and collected over the next 2 days. Five birds in total (of two species) had gullets containing insect parts, including grasshoppers. One Ring-billed Gull's (*Larus delawarensis*) gullet sample contained no carbofuran. Two other Ring-billed Gulls had gullet contents containing 2.0 and 5.7 ppm carbofuran, and two California Gulls (*Larus californicus*) had gullet contents with 0.9 and 0.5 ppm carbofuran, respectively. There was no brain cholinesterase inhibition in the two California Gulls, but the cholinesterase activities of the two Ring-billed Gulls were inhibited approximately 60% relative to controls. These gulls had been collected on the second day after spraying. Based on the data given, it is possible to calculate that each gull had consumed about 23 and 28 grasshoppers, respectively. Gulls have been reported to eat as many as 300 grasshoppers at one time (unpublished observation cited in Somers *et al.* 1988b).

The margin of safety afforded to gulls foraging on freshly sprayed grasshoppers appears to be small at best. More fieldwork is needed to determine how frequently intoxication occurs in the course of grasshopper control programs (see Section 4.3.4).

4.3.2 Reported kills

A. April 1986, tomatoes, Virginia

At least eight American Goldfinches (*Carduelis tristis*) were found near a tomato field sprayed with carbofuran. Their gizzard contents contained 0.17 ppm carbofuran (application to this crop is not registered in Canada; the application rate was not specified). The birds were in poor body condition and had probably just returned from migration. The birds may have been feeding on food contaminated by the insecticide. However, nearby cornfields were treated with granular carbofuran, which is another potential source of the insecticide (Roth 1986).

B. June 1986, grasshopper control, Moose Jaw, Saskatchewan

An estimated 45 gulls were found convulsing after feeding on grasshoppers in a field treated a few hours previously with carbofuran. Carbofuran residue levels on grasshoppers retrieved from the esophagi of the birds ranged from 4.2 to 7.2 ppm (Leighton and Wobeser 1987; Leighton 1988).

Residue levels measured in the dead gulls in this incident are on the high end of the range of levels expected from a normal application for the control of grasshoppers. Irvine and colleagues (see Section 4.3.1.5) reported peak grasshopper levels ranging from 0.45 to 6.6 ppm following an aerial application with 132 g a.i./ha. Two samples of grasshoppers collected after an experimental ground application gave a mean level of 2.5 ppm, but a gullet sample from a gull shot and collected from the plot contained 5.7 ppm carbofuran (Section 4.3.1.7).

C. August–September 1985, Alberta

Two other incidents involving gulls and possibly linked to carbofuran use in Alberta are not very well documented. About 70 Ring-billed Gulls died in August 1985 after eating grasshoppers, but samples were not analyzed for residues. Another 11 Ring-billed Gulls died at a different Alberta location in September, and their gut contents contained 2.7 ppm carbofuran. September is unusually late for grasshopper spraying, and the circumstances surrounding the kill remain unclear (Somers *et al.* 1988b). The year 1985 was one of extensive spraying for grasshoppers in the prairies.

4.4 EVIDENCE FOR A HAZARD TO WATERFOWL AND OTHER GRAZING SPECIES RESULTING FROM USE

The toxicity of carbofuran to waterfowl has been documented earlier (see Section 2). Based on the LD_{50} values generated for the Mallard and the application rates registered in Canada, it is instructive to look at the area of crop that may contain a lethal dose. This is a relevant measure, whether the dose is ingested on sprayed vegetation, drunk from a water puddle, or preened from a sprayed bird. Table 6 relates spray area to the dose needed to kill half of the test birds. Two scenarios are given: a 3-day-old Mallard duckling and an adult-sized bird.

Most impressive in the calculations outlined in table 6 is that, at the highest registered rate in Canada, a Mallard duckling's LD_{50} is received by a surface of less than 1 cm^2. The Mallard was also the least sensitive of the two waterfowl species tested by Hudson and colleagues (1972). The toxicity of the product to waterfowl is acknowledged by the manufacturer. For example, the U.S. labels for liquid carbofuran have the following requirements:

- do not apply before or during furrow irrigation;
- do not apply on fields in proximity of waterfowl nesting areas; and
- do not apply on fields where waterfowl are known to repeatedly feed.

The State of California (where a number of waterfowl kills have been reported) treats any deviation from the above as misuses of the product subject to prosecution. Some of the kills reported below are therefore considered by the State of California as technical misuses, putting the responsibility squarely on the growers to be aware of waterfowl feeding patterns in their areas. California defines "in proximity" as 1 mile (1.6 km) (Betts 1975). Such a requirement in Canada would make most applications of carbofuran illegal (see below).

Three separate hazards to waterfowl stemming from three different types of exposure have been identified:

- consumption of treated vegetation;
- puddling in fields; and
- waterfowl nesting in or traversing areas sprayed with the insecticide.

These hazards are obviously not restricted to waterfowl species, but this group deserves close scrutiny on account of its very high toxicological susceptibility.

Table 6.
Toxicity of technical carbofuran to the Mallard, expressed as the number of square centimetres of spray deposit needed to achieve an LD_{50} in the test organisms.

	Application rate		No. of cm^2 per LD_{50}	
Crops/pests[a]	**g a.i./ha**	**×**[a]	**Duckling**[b]	**Adult**[c]
Grasshopper, wheat midge, sunflower beetle	132	1	15.4	339
Alfalfa	264	2	7.69	170
Potatoes, corn, peppers, strawberries	528	4	3.84	84.8
Sugar beets	1123	8.5	1.81	39.9
Raspberries, B.C. strawberries	1200	9	1.69	37.3
Turnip, rutabaga	2520	19	0.81	17.8

[a] See Table 5 for further details. × refers to the spray rate expressed as multiples of the rate registered for grasshopper control in Canada.
[b] Assuming an LD_{50} of 0.397 mg/kg (Hudson *et al.* 1972) and a weight of 51 g (Martin *et al.* 1991a).
[c] Assuming an LD_{50} of 0.415 mg/kg (Hudson *et al.* 1972) and a weight of 1080 g (Dunning 1984).

4.4.1 Supervised field trials

The hazard of waterfowl grazing on treated vegetation and the puddling hazard of the flowable formulation of carbofuran have not been systematically investigated. Some data for those routes of exposure are available from kill reports (see Section 4.4.2). The only systematic fieldwork has been on the impacts on young ducklings, and this was done at the prompting of the Canadian Wildlife Service. It has been estimated that 0.7 million dabbling ducks may breed in areas sprayed with carbofuran in years of grasshopper outbreaks (Sheehan *et al.* 1987). This episodic spraying activity for grasshoppers is above and beyond the regular use of carbofuran on a variety of crop types. The concern was that, on account of their small size and susceptibility to carbofuran and because of the propensity for prairie ducks to nest in areas favoured by grasshoppers (e.g., roadside ditches, slough margins), young ducklings were most at risk from carbofuran use. A relatively large research effort went into trying to assess that risk, as evidenced by the following sections.

4.4.1.1 Martin et al. *1991b*

Ducklings were imprinted on investigators and walked across upland vegetation 60–90 minutes after it had been sprayed with either 132 g a.i./ha (1×) or 264 g a.i./ha (2×) of Furadan

480F. This interval was considered sufficient to allow drying of the vegetation. Following the walk, the ducklings were allowed to swim in a small pool for 5 minutes and returned to brooders in the laboratory. Within 30 minutes of exposure, the approach behaviour of the ducklings was tested. They were exposed to a desirable stimulus (other ducklings and the vocalization used for imprinting), and their ability/willingness to traverse a 184-cm distance in response to that stimulus was tested. Within 15 minutes of testing (approximately 45 minutes after field exposure), the ducklings were killed and samples taken for measurement of residues and cholinesterase depression.

Residues from petri dishes placed at vegetation height for five different spray events gave mean deposits ranging from 69.3% to 139% of nominal. (Only one of the five sprays exceeded the nominal rate.) Vegetation samples collected from the sprayed area gave average carbofuran levels of 9.1 ppm and 11.5 ppm for two 132 g a.i./ha applications and 23.1 ppm, 25.8 ppm, and 29.1 ppm for three 264 g a.i./ha applications. These values appear low but reasonable in light of the mean vegetation level of 13.3 ppm obtained by Irvine and colleagues (see Section 4.3.1.5) after a 132 g a.i./ha aerial application to a grazed pasture.

No ducklings died during their exposure to the contaminated vegetation. However, some of the birds that had to walk 300 m through the area sprayed with 132 g a.i./ha or any distance (50 m, 150 m, or 300 m) through the area sprayed with 264 g a.i./ha showed marked clinical symptoms of cholinergic stimulation, including spasms and convulsions. (Symptoms of lethargy reported in a few ducklings walked for 50 m through the area that received the low dose were discounted by this reviewer, because no such symptoms were observed in the 150-m walk at the same application rate.) At the high spray rate and longest distance, the majority would not have completed the walk unaided. Brood cohesiveness (groups ranged from 15 to 20 birds) was lost by 200 m into the walk at the high spray rate. Both the spray rate and the distance travelled affected the speed at which the birds were able to complete the behavioural approach test. Brain cholinesterase levels were significantly depressed in all groups except those walked for the shortest distance at the low application rate. After 300 m, brain cholinesterase levels were inhibited by an average of 36% and 71% for the low and high spray rates, respectively.

Using the criterion of 50% brain cholinesterase inhibition cited above (see Section 4.3.1.5), a number of birds at the high dose were at risk of dying. In fact, these birds had to be taken out of the plots and would not have been able to keep up with the brood. Fairbrother *et al.* (1988) observed that duck hens were likely to stay with an incapacitated duckling, thus endangering the whole brood and subjecting them to further exposure to the pesticide. Results from this study suggest that duck broods traversing areas sprayed with carbofuran at 264 g a.i./ha are very much at risk.

4.4.1.2 Martin and Forsyth 1993

The object of this study was to look at the consequence of duckling intoxication on the short-term survival of the birds under more realistic conditions than in the previous work. Only one distance (200 m) was used, but both the 132 and 264 g a.i./ha rates were tested as in the previous study. Application was by means of a small boom sprayer. The study was made more "natural" by the use of brood hens rather than by imprinting the ducklings on the experimenters. Also, the ducklings were led to a pond by the hen. The broods (5–8 ducklings per brood) were observed during the walk and during four 2-hour periods over the following 2 days. Some of the ducklings in each trial were subcutaneously implanted with temperature-sensitive radio-transmitters and their temperatures monitored on the day of exposure.

Results of this work are still preliminary. Deposits appeared to be good for the 264 g a.i./ha applications but may have been low for some of the 132 g a.i./ha applications. There were five replicate experiments conducted at the low spray rate and four at the higher one. At the lower application rate, three ducklings in each of the control and treated groups died on the day of exposure (one duckling in each of three control and three treatment replicates). No signs of toxicity were seen in any of the treated ducklings, but the two that died after completing the walk in the treatment groups showed inhibition of brain cholinesterase (15% and 75% inhibition, respectively). At the higher rate, no ducklings died in the control groups, but three died in the treated groups (one duckling from each of three different runs). All three showed massive cholinesterase depression (53%, 73%, and 84% inhibition) and were unable to complete the walk. The two ducklings with the highest level of inhibition showed symptoms of intoxication.

There were behavioural differences seen between control and treated broods but seemingly without any real biological significance. The temperature data were inconclusive because of the small sample size available and a bias noted in the transmitters.

The effect of the insecticide on the ducklings was less in this experiment than in the previous one. A possible explanation for this is that the ducklings were less inclined to peck at the vegetation while following the hens than while following humans on whom they had been imprinted. The ducklings that died at the higher application rate were those that were seen to peck at the vegetation more than the others. It can be concluded from this experiment that ducklings traversing sprayed areas (at either the 1 × or 2 × level) should be relatively safe provided they do not attempt to feed. There is evidence that overland movements by duck broods are rapid and that feeding is therefore not very likely. Should ducklings have any chance to feed, however, the consequences are likely to be severe. The ducklings that died during the high application rate spray trials were abandoned by their brood hens after the hens unsuccessfully tried to coax them along. Any delay in abandoning a sick duckling would likely result in more ducklings becoming incapacitated and in the probable loss of the entire brood.

4.4.1.3 Webster and Shapiro 1990

This 2-year effort paralleled that of Martin *et al.* (1991b) and Martin and Forsyth (1993) reviewed above. However, the results are difficult to interpret owing to a number of serious deficiencies. The ducklings were not imprinted on either experimenters or brood hens, and their movement through the treated area is difficult to assess. Mean deposits on filter paper targets ranged from 510 to 1200 g a.i./ha in year one and from 62 to 360 g a.i./ha in year two. In year one, several ducklings exhibited gross signs of intoxication after a 50-m walk through treated vegetation, but the chosen behavioural test (allowing the ducklings to choose between different-sized broods) showed no differences between control and treated ducklings. Several ducklings died after the 50-m exposure. Ducklings all survived a 10-m exposure and did not show obvious signs of intoxication. Duckling exposure in year one took place on the morning of spray.

In year two, exposure of the ducklings took place in the morning after spray (spray was in the previous evening). One duckling (of 15) died after a 50-m walk and three after 100 m. The same behavioural test was repeated in year two and again showed no differences despite the obvious incapacitation of some birds.

4.4.2 Reported kills

Because of the small size of young waterfowl and the secretive habits of breeding waterfowl, kills of prefledged individuals are not expected to be seen even if they do occur. Most of the documented mortality of waterfowl as a result of carbofuran flowable has occurred when adult birds have fed on treated crops. All but one of these kills have occurred in alfalfa fields. A short summary of the documented incidents recorded between 1972 and 1987 from U.S. EPA docket files is given below along with additional relevant information when available.

A. May 1972, Lassen Co., Susanville, California

Thirteen Canada Geese (*Branta canadensis*) died, and six geese exhibiting signs of poisoning were captured and later recovered. The application rate was not given. Dead geese were found 24 hours after application. Carbofuran residues in one alfalfa sample were 15 ppm 60 hours postapplication. One sample from the proventriculus of a goose contained 15.5 ppm carbofuran (California Department of Fish and Game 1973).

B. March 1974, Riverside Co., California

Carbofuran was applied by ground at a rate of 560 g a.i./ha (4×). The following day, approximately 2450 American Wigeon, one Mallard, and two Canada Geese were found dead. Residues were detected in duck stomach contents (0.62 ppm) and in the alfalfa (3.6 ppm), but there was no indication when these samples were collected relative to the kill. In a press release by the California Department of Fish and Game, it was noted that the grower could not have prevented the kill because wigeon tend to feed at night undetected. The same press release also made reference to company (FMC Corp.) research that demonstrated the hazard of carbofuran to waterfowl in alfalfa fields (Fredrickson 1974; Hillis 1974; Taylor 1974). (These studies have not been submitted by the company for this review.)

C. April 1975, Patterson Lake, Kansas

Carbofuran was applied by ground at 1.1 kg a.i./ha (8×). Carcasses of 79 American Coot (*Fulica americana*), one cottontail rabbit (*Sylvilagus* sp.), and one frog (*Rana* sp.) were found (U.S. EPA 1979).

D. February 1976, Tishomingo National Wildlife Refuge, Oklahoma

Carbofuran was applied by ground at 560 g a.i./ha (4×). Birds landed in the field soon after the pesticide treatment. Approximately 500 Canada Geese were found dead (Jemison 1976).

E. March 1976, San Jacinto Reservoir, California

Sixty-three dead American Wigeon were recovered. Carbofuran residues were present — 11.4 ppm in one gastrointestinal tract sample. The field was not identified, and other details are therefore not available (Bischoff 1976).

F. May 1976, Mt. Hope, Kansas

An estimated 750–1000 American Wigeon died in this incident. The ducks were found 2 days after the field was sprayed, but time of death is not known. Pooled stomach contents of three birds analyzed 5 days after application contained 0.5 ppm carbofuran (U.S. EPA 1979; Flickinger *et al.* 1980).

G. March 1977, Willows, California

Approximately 1100 American Wigeon were found dead in and near a field treated aerially with 560 g a.i./ha (4×). The crop was about 5 cm high when sprayed. Residues of carbofuran in the alfalfa were 42 ppm (time of collection unspecified), and pooled duck proventriculus samples contained 9.8 ppm carbofuran. Brain cholinesterase levels were depressed 54–77% in a sample of dead birds (O'Connell 1977; Bischoff 1977; Hill and Fleming 1982).

This case became a precedent in U.S. law when a judge ruled that the defendants (the applicator, farm owner, dealer, and salesperson) were indictable under the Migratory Birds Treaty Act (referred to as the Migratory Birds Convention Act in Canada) for killing migratory birds with a pesticide, even though there was no intent to kill the birds (Williams 1988).

American Wigeon also died in another California kill the following September, but details, including the number of birds, were not given (Coon 1983). Another poorly reported incident involved 18–19 geese (U.S. EPA 1979).

H. April 1985, Stevens Co., Oklahoma

Furadan 4F was applied by air at 560 g a.i./ha (4×). Approximately 150–160 American Wigeon and 10 Canada Geese died after feeding on treated alfalfa (Chada 1987).

I. February 1986, El Centro, California

Thirty-two Canada Geese were found dead in an alfalfa field. The field had been sprayed on the previous day with Furadan 4F and a formulation of dimethoate. Alfalfa samples contained 44 ppm carbofuran; dimethoate levels were unspecified. Four gastrointestinal samples from individual geese had residue values ranging from 2.0 to 9.9 ppm carbofuran. Based on other kills, this would have been enough carbofuran to kill the birds. Dimethoate may or may not have been a contributing factor in this case (Littrell 1986; FMC 1987).

J. May 1988, West Lake Island, Oregon

Approximately 36 dead Canada Geese were recovered in this incident. Furadan 4F was tank-mixed with a formulation of Di-Syston (Williams 1988).

K. August 1989, turnip, Westminster, British Columbia

Over 40 Canada Geese were found dead or convulsing in a turnip field. It had been raining the previous day, and there were puddles in the field. Carbofuran flowable had been applied the previous evening. Two gut samples sent for analysis contained 0.055 and 0.350 ppm carbofuran. Analysis of soil samples indicated that the insecticide had been applied at the correct rate (B.C. Ministry of Agriculture and Fisheries 1989; Whitehead 1989).

Unlike all of the previous incidents that involved birds grazing in alfalfa fields, this kill resulted from the application of the flowable formulation to bare ground (seedling turnips). The hazard of puddling with the *granular* formulations of carbofuran was documented earlier (see Section 3.3.2.2). It is now apparent that puddling can also be a source of fatal intoxication with the *liquid* formulation of carbofuran. The numerous kills reported from U.S. vineyards, where carbofuran was applied in drip irrigation systems (at least one incident involved more than 1000 songbirds), is further evidence of the hazard of a carbofuran solution as a source of drinking water for wildlife.

4.4.3 Estimating the hazard to waterfowl and other grazing species in Canada

There are no reports of waterfowl being killed in Canada after grazing on alfalfa. In the prairies, most of the alfalfa is grown for animal feed and is seldom sprayed with insecticides (Jackson 1989). Although a large proportion of the alfalfa grown for seed is sprayed with insecticides, carbofuran is not registered for the main alfalfa pests of concern in western Canada (Jackson 1989). In the west, spraying of alfalfa and other forages with carbofuran is more likely in the course of grasshopper control. If kills were happening, it is unlikely that they would be seen and reported, because they would likely involve widely dispersed breeding individuals rather than large flocks. The Canadian Wildlife Service could not assess the hazard of the liquid formulation to grazing birds outside of the Prairie Region because it did not have access to comprehensive use pattern and sales information to help prepare this evaluation.

The spray rates for alfalfa and other potential forage crops are lower in Canada than they are in the United States. The application rate that has killed waterfowl in the United States (4×) is at least four times greater than the rate registered for grasshoppers and twice the rate registered for alfalfa in Canada. Because the hazard of feeding on carbofuran-treated vegetation has not been systematically investigated, one must rely on extrapolation of the laboratory data and of the U.S. field evidence to assess the risk incurred by waterfowl and other herbivorous species exposed to 1× and 2× applications. However, it is known that several hundred permits are let every year in Ontario (and presumably in other provinces as well) for the use of carbofuran by air against the European corn borer. The application rate against this pest (4×) is the same rate that causes extensive mortality in U.S. alfalfa fields. The extent of off-site contamination and the exposure of grazing birds to carbofuran in the course of those applications are difficult to assess.

4.4.3.1 Residues in sprayed alfalfa and other forages

In two separate U.S. trials, initial residue levels of 67–68 ppm and 141–150 ppm were obtained after spraying alfalfa with the 4F (480F) formulation at 0.55 kg a.i./ha and 1.1 kg a.i./ha, respectively (FMC 1973). Following the principle of "residue per unit dose" as described by Hoerger and Kenaga (1972), initial residue levels of 33–37 ppm are expected from the Canadian applications to alfalfa, whereas applications for grasshopper control are expected to leave vegetation residue levels of 16–18 ppm. As described in Section 4.3.1.5, aerial application for grasshopper (1×) gave a mean level in pasture grass of 13.3 ppm and a high of 21.8 ppm, which are in close agreement.

Canadian data generated by the manufacturer (FMC 1976c) gave lower values than the above. Applications to alfalfa in western Canada gave average field values (N = 2 samples per field; four fields) ranging from 4.23 to 10.7 ppm after a grasshopper spray (1×). Residues on brome grass ranged from 4.66 to 15.2 ppm (also four fields). Applications in Ontario at the alfalfa weevil rate (2×) gave peak residue values between 11.6 and 21.7 ppm. The latter are underestimates, because two of the three values were from 24 hours postspray. Also, average analytical recoveries were only 72% on average for green alfalfa.

These estimates do not include the full range of possible residue levels resulting from the inherent variability of spray deposit achieved in the course of operational use. Some of that variation was documented in the company studies reviewed in Sections 4.3.1.1 and 4.3.1.2. Mineau (1991a) presented a review of factors that affect initial residue levels postspray.

4.4.3.2 Toxicity of sprayed alfalfa

Toxic dietary levels (LC_{50}) of technical carbofuran administered in dry mash were found to be 21, 79, or 190 ppm in the Mallard duckling, depending on the laboratory and test conditions (FMC 1972, 1976a; Hill *et al.* 1975). As pointed out in Section 2, these dietary toxicity tests are somewhat artificial and likely underestimate the dietary hazard of carbofuran to wild birds of equivalent age and species. There are several reasons for this. First, food ingested in the wild typically has a higher moisture content than laboratory mash. Using a moisture conversion factor alone, Mallards would only have to consume fresh alfalfa with a residue level of 40 ppm to equal the higher laboratory-determined LC_{50} of 190 ppm because of the difference in moisture content between alfalfa upper vegetative parts and dry mash (approximately 21% vs. 100% dry matter; Harris 1975). The laboratory-determined values of 21 and 79 ppm would similarly correspond to "fresh alfalfa equivalent toxicity" of 4.4 and 17 ppm. On that basis alone, even the low application rate registered for grasshopper control in Canada represents a toxic hazard to waterfowl feeding on treated vegetation.

In fact, other factors mean that the risk is greater yet. Birds in a laboratory environment typically have lower maintenance requirements and therefore lower food intakes than birds in the wild. Laboratory rations are typically very nutritious, and food intake is minimal relative to a wild situation. Diurnal feeding rhythms are also likely more compressed in a wild situation, which increases the risk of fatal intoxication. Free existence in wild birds is usually achieved at a cost of 1.6–2.6 times the standard metabolic rate determined for caged individuals, and breeding activities would give rise to maintenance costs that are higher still (Hails and Bryant 1979). All of these factors tend to underestimate the actual dietary hazard in the wild. Also, the Mallard was actually the less sensitive of the two waterfowl species tested on an acute basis, and formulated carbofuran is approximately 1.7 times as toxic as the technical-grade material when given on an acute basis to the quail (E.F. Hill, U.S. Fish and Wildlife Service, pers. comm.). This may result in a higher dietary toxicity as well.

In an unpublished Pesticide Informational Report of the California Department of Fish and Game, E. Littrell calculated that alfalfa residue levels of 2 ppm could still be potentially lethal to American Wigeon (a species of duck commonly attracted to alfalfa fields). He based this assessment on food consumption habits of waterfowl in alfalfa and on the LC_{50} value of 79 ppm. On that basis, he proposed a "safe re-entry interval" of 7 days for waterfowl in sprayed alfalfa fields. Residue levels in alfalfa associated with instances of mass mortality in California were never higher than 44 ppm.

4.4.3.3 Summarized assessment of risk

Clearly, waterfowl species grazing on treated vegetation are at risk even at the lower registered rates of application. Other grazing species may also be at risk, although galliformes at least appear to be less sensitive than waterfowl on the basis of species tested to date. Although Canadian spray rates are one-half or one-quarter of the U.S. rates known to cause widespread mortality, this safety factor is unlikely to prevent the death of waterfowl feeding on treated vegetation in Canada.

The Canadian Wildlife Service estimated that, in 1985, 9–10% of the total prairie dabbling duck population nested within the area sprayed for grasshoppers and other insect pests. This area is estimated to have been between 6.5 and 7.0 million hectares. Based on estimated market share, half of this area and therefore approximately 0.7 million ducks were potentially exposed to carbofuran sprays (Sheehan *et al.* 1987) and therefore were in a position to consume contaminated vegetation. At present, we lack any data that would indicate to what extent waterfowl or other species such as grouse or pheasant may consume carbofuran-treated vegetation.

4.5 EVIDENCE FOR A HAZARD TO THE BURROWING OWL

Burrowing Owls (*Speotyto cunicularia*) are officially listed as threatened in Canada, and that status is likely to be "upgraded" to endangered, which denotes a higher level of concern (P. James, Saskatchewan Museum of Natural History, pers. comm.). Because of their range and propensity to consume large numbers of grasshoppers, concerns were raised with respect to their vulnerability to insecticides used to combat grasshopper infestations. In 1986 and 1987, the Canadian Wildlife Service commissioned fieldwork to look at the impacts of operational grasshopper spraying on the species. The following is abstracted from the report (Fox *et al.* 1989) that outlined the research and resulting analyses in great detail.

The data of Fox and colleagues showed conclusively that, in 1986, carbofuran had a significant impact on the survival and reproductive success of Burrowing Owls. There were significant declines in nesting success ($P = 0.002$) and brood size ($P = 0.006$) with increasing proximity of carbofuran spraying to the nest burrow. (Nest success was defined as the proportion of burrows that fledged at least one young.) There was no such trend of lowered reproductive indices with increasing proximity of spray for the insecticide carbaryl or for all insecticides other than carbofuran pooled together. Overspraying of the burrows with carbofuran resulted in an 83% reduction in brood size and an 82% reduction in nesting success. Of 12 pairs of birds exposed to an overspray, eight failed completely. In contrast, only two of 14 burrows sprayed with carbaryl exhibited complete nest failure. In a phone interview conducted subsequent to the study, two landowners reported complete disappearance of owls following a carbofuran overspray (three and eight burrows affected, respectively) at colony sites that were outside the study area. Burrow reoccupancy in 1987 was less frequent following the 1986 use of carbofuran than following the use of other insecticides.

The significance of these findings is increased when one considers that the data were collected from an *a posteriori* design (i.e., the researchers did not direct or control any of the spraying); as well, the statistical analysis was very conservative, in that it allowed for possible biases among owl colonies (a farm effect), even though no such biases were documented.

The impact was related to distance of the spraying from the burrow, and there was some indication that spray events occurring even at more than 50 m from the burrow were also detrimental to reproductive success ($0.05 < P < 0.1$). This is consistent with the hypothesis that the impact resulted from ingestion of contaminated prey rather than direct dermal or inhalatory exposure, although a contribution from multiple sources of exposure certainly cannot be excluded.

These data further suggested that the impact of carbofuran was a result of its toxicity and was not due to food removal. Other insecticides, notably carbaryl and chlorpyrifos, were found not to have similar impacts, although there were too few data to be certain about the safety of chlorpyrifos.

On the basis of owl, crop, and pest distribution at the time, Fox *et al.* (1989) were able to divide carbofuran uses in three groups, depending on their likely hazard to the owls:

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

2. *Lower likelihood of impact*: all registrations on sunflower (grasshopper and sunflower beetle), as well as registrations for flea beetles and red turnip beetles in canola and mustard.

3. *No likelihood of impact*: registration for wheat midge control in wheat.

Following the publication of Fox *et al.* (1989), questions were raised by FMC Corp.

regarding the analysis of the data presented. The relevant correspondence is provided in Appendix 6. The criticism was found to be unwarranted, and the conclusions of the research stand unaltered. Further research has since demonstrated that baiting of ground squirrels with strychnine (something that FMC Corp. claimed could have confounded results of the research) does not appear to pose a risk to Burrowing Owls (James *et al.* 1990).

In the spring of 1990, an interim labelling measure was adopted by Agriculture Canada to try to reduce the exposure of the owls to carbofuran. There is now a prohibition on any spraying of this insecticide within 250 m of a known nesting location. There was an attempt to publicize this requirement widely. The Canadian Wildlife Service produced a pamphlet (see Appendix 7) aimed at the users of carbofuran, warning them of the hazard posed by the product. The Canadian distributor of carbofuran (Chemagro Ltd.) arranged for a wide distribution of the pamphlet in the range of the owl. Chemagro Ltd. also produced radio messages advising farmers of the hazard and asking them to follow the new label requirements. However, a number of factors put into question the usefulness of a label directive to solve the problem associated with the Burrowing Owl:

1. Applicators are not necessarily aware that they have owls, especially if the birds are first-year nesters.

2. Labelling is not enforced (or realistically enforceable).

3. Recent publications have argued for much larger buffer zones around nests (Haug and Oliphant 1990).

4. Recent evidence is that, despite the 1990 intensive publicity campaign described above, the level of awareness of this new label among those individuals who have owls or had owls on their land is still quite low (Agriculture Canada, unpublished).

Update: *There are now several reports concerning the awareness of the 250-m carbofuran label restriction in the farming community. Of a sample of 38 carbofuran users in the range of the Burrowing Owl sampled after the 1992 spray season (these individuals were identified through pesticide retail outlets; 18% were actually aware of owls nesting on or adjacent to their property), an estimated 26% were aware of the 250-m restriction around burrows (Maksymetz 1992). At the time of the survey, this labelling requirement had been in force for three spray seasons; in theory, all individuals who had purchased the product should have been aware of the restriction.*

In a separate published survey carried out after the 1991 spray season (Trowsdale Mutafov 1992), a random stratified sample of 100 farmers in the range of the owl was contacted. Sixteen percent of these individuals had used carbofuran in the course of the two spray seasons when the new label restrictions were being publicized through various print and electronic media. In this sample, 18% were aware of owls nesting on or adjacent to their fields, but not one of the 100 individuals surveyed knew the specific labelling restriction to protect the owls. Only 40% of the habitual users of carbofuran were even vaguely aware of its toxicity to Burrowing Owls.

These results indicate that the labelling approach to the Burrowing Owl situation has failed and is not adequate. The option of not allowing the use of carbofuran within the range of the species is still the best option for risk mitigation and one that has now been recommended by the federal–provincial Burrowing Owl Recovery Team. Even though a broad geographical exclusion of carbofuran is, by far, the most practical option, two potential variations are further discussed:

1. In theory, year-to-year areas of heavy overlap between owl nesting and grasshopper spraying could be predicted and the information used to establish "carbofuran exclusion *zones." Following the initial impact studies detailed in Fox* et al. *(1989), the Canadian Wildlife Service explored, under contract, the extent of actual overlap between Burrowing Owl nests and grasshopper insecticide use in Alberta (Usher and Johnson 1992). The overlap was measured by means of a computerized Geographic Information System (GIS). For this approach to be useful in a proactive mode, more work would be needed to relate the actual use of grasshopper insecticides to grasshopper infestation forecasts available ahead of the spray season. Realistically, the knowledge, expertise, and resources needed to make this yearly determination are not currently available.*

2. *Exclusion of carbofuran could be made on a case-by-case basis. The use of this insecticide could be made subject to issuance of a permit by provincial wildlife authorities, thereby ensuring that no owls are present in the vicinity of the intended spray area. The disadvantage of this approach is that yearly updates of burrow locations would be needed, and this would require a costly and time-consuming monitoring effort as well as added resources to handle the necessary permits.*

4.6 EVIDENCE FOR A HAZARD TO SMALL MAMMALS

There is some evidence that small-mammal kills occur with both the granular (e.g., see Section 3.3.2.1) and flowable (see Section 4.3.1) formulations of carbofuran. One study in western Canada (Section 4.3.1.5) purported not to show any impacts on small mammals from a large spray with the Canadian grasshopper rate (1 ×). However, a number of key questions cannot be answered from the preliminary report currently available for that study.

The following section describes another attempt to systematically investigate the impact of a carbofuran application on small-mammal populations.

4.6.1 Brusnyk and Westworth 1987

Two sites were chosen for this work: a dry pasture and another site with high interspersion of wetlands. Two plots (one control and one treated) were established on each site. Treated plots were sprayed by ground with the grasshopper spray rate (1 ×). Unfortunately, the size of the sprayed plots was not given, nor was there any measure of deposit.

Small mammals were live-trapped for 6 consecutive days prespray and 3 consecutive days postspray. A late-season trapping was also carried out approximately 5 weeks postspray. Some individuals were collected between 16 and 20 hours postspray for brain cholinesterase assays.

Numbers of voles (*Microtus pennsylvanicus*) decreased in both habitats following spray, although the decline was considered significant only in the pasture habitat, where numbers fell by about 85%. (These data do not appear to have been analyzed statistically, and the basis for rejecting the vole decline in the wetland habitat is therefore unclear.) In contrast, total numbers of deer mice remained constant postspray.

Turnover rates on both treated and control plots were high, and survival rates were based on small numbers of recaptured individuals. Survival, defined as the proportion of marked animals recaptured, was much lower for young deer mice and for all voles in treated plots. Survival of adult deer mice did not appear to be affected. However, a significantly higher proportion of male deer mice (relative to expected from control plots) were found in nonreproductive status postspray.

Mean brain cholinesterase levels in collected deer mice did not differ significantly between control and treated plots, but there was evidence that some (males especially) were exposed, based on the variances in the mean brain cholinesterase levels reported (F = 18.65, d.f.= 15, P < 0.05). Unfortunately, the individual data were not supplied.

A pool of gastrointestinal tracts from 20 deer mice contained 2 ppm carbofuran. Field spikes were not carried out, nor was laboratory recovery of carbofuran from mouse tissue reported.

Despite several important deficiencies in this study, a number of interesting observations emerge. Given the almost totally herbivorous diet of the voles, this species would be expected to be more at risk from poisoning than the deer mice, although the latter may eat poisoned insects. There was a catastrophic reduction in the vole population on one of the spray sites, and calculated "survival rates" were lower on the treated plots combined for that species. Although overall numbers of deer mice did not change postspray, there was a significantly higher turnover rate of young individuals on treated plots, indicating higher death or emigration from those plots. Insufficient details are available to properly assess the cholinesterase data. In any case, it is likely that these data are highly biased, because severely intoxicated animals (anorexia being a common symptom of intoxication) are less likely to be attracted to traps baited with food.

The relatively high residue level in the deer mice (2 ppm in gastrointestinal tracts) is cause for concern. It was hypothesized in the study on Burrowing Owls reported above (see Section 4.5) that small mammals might be a source of residues for the owls. A number of other raptors feed extensively on these small-mammal populations. Given the results of the research and likely routes of exposure, it is likely that the voles would have shown higher residue values than the deer mice. Furthermore, small mammals may also develop substantial surface residues as they forage in treated crops, but this was not measured. In FMC research documented earlier (see Section 3.3.1.2), a Northern Harrier was found paralyzed after feeding on a rabbit with 0.1 ppm total body residues. The authors of the current study did not provide the information necessary to convert the 2 ppm of residues in the pool of gastrointestinal tracts to whole body burdens.

LITERATURE CITED

Agriculture Canada. 1990. Carbofuran insecticide. Announcement 90-02. 6 pp.

Ahmad, N., D.D. Walgenbach, and G.R. Sutter. 1979. Degradation rates of technical carbofuran and a granular formulation in four soils with known insecticide use history. Bull. Environ. Contam. Toxicol. 23:572–574.

Alberta Agriculture. 1985. Canola production in Alberta. Agdex 149/20-1. 31 pp.

American Ornithologists' Union. 1990. Resolution 1: Ban on carbofuran. Proceedings of the one hundred and seventh stated meeting of the American Ornithologists' Union. Auk 107 (2, Suppl.):16AA.

Anonymous. 1992. Insecticide banned in three counties. Sacramento Bee Final. 25 March 1992.

Balcomb, R. 1983. Secondary poisoning of red-shouldered hawks with carbofuran. J. Wildl. Manage. 47:1129–1132.

Balcomb, R. 1986. Songbird carcasses disappear rapidly from agricultural fields. Auk 103:817–820.

Balcomb, R., R. Stevens, and C.A. Bowen II. 1984a. Toxicity of 16 granular insecticides to wild-caught songbirds. Bull. Environ. Contam. Toxicol. 33:302–307.

Balcomb, R., C.A. Bowen II, D. Wright, and M. Law. 1984b. Effects on wildlife of at-planting corn applications of granular carbofuran. J. Wildl. Manage. 48(4):1353–1359.

B.C. Ministry of Agriculture and Fisheries. 1989. Canadian geese kill in Richmond, August 14, 1989. 3 pp.

Berisford, Y.C., J.L. Hanula, and G.M. Cowie. 1985. Insecticide background statements: carbofuran. U.S. Forest Service Contract No. 53-43-ZP-5-26. Unpublished report. 115 pp.

Best, L.B. 1990. Granular insecticides and grit use by cornfield birds: evaluating potential avian risks. Annual Meeting of the Society of Environmental Toxicology and Chemistry, Abstract No. 325.

Best, L.B. 1992. Characteristics of corn rootworm insecticide granules and the grit used by cornfield birds: evaluating potential avian risks. Am. Midl. Nat. 128:126–138.

Best, L.B. and D.L. Fischer. 1992. Granular insecticides and birds: factors to be considered in understanding exposure and reducing risk. Environ. Toxicol. Chem. 11:1495–1508.

Best, L.B. and J.P. Gionfriddo. 1991a. Characterization of grit use by cornfield birds. Wilson Bull. 103(1):68–82.

Best, L.B. and J.P. Gionfriddo. 1991b. Integrity of five granular insecticide carriers in House Sparrow gizzards. Environ. Toxicol. Chem. 10:1487–1492.

Best, L.B., R.C. Whitmore, and G.M. Booth. 1990. Use of cornfields by birds during the breeding season: the importance of edge habitat. Am. Midl. Nat. 123:84–99.

Betts, W.A. 1975. [California Department of Food and Agriculture] Furadan 4 flowable. Memorandum to County Agricultural Commissioners, dated 14 February 1975. 2 pp. + add.

Bharadia, J. 1990. Summary of the review of environmental information pertaining to the use of carbofuran in Canada. Environmental Protection, Western and Northern Region, Environment Canada. Draft document, dated 23 March 1990. 75 pp.

Bischoff, A.I. 1976. [California Department of Fish and Game] Pesticide Laboratory Report: Lab. No. 1997, E.P. No. P-74 and accompanying computer printout.

Bischoff, A.I. 1977. [California Department of Fish and Game] Letter to P. Whitehead [Canadian Wildlife Service, Environment Canada], dated 15 November 1977. 2 pp.

Brash, M. and I.K. Barker. 1988. [Department of Pathology, University of Guelph] Necropsy Report No. W270-88 (3 October 1988). 2 pp.

British Ornithologists' Union. 1985. A dictionary of birds. B. Campbell and E. Lack (eds.). Buteo Books, Vermillion, U.K. 670 pp.

Bruns, G. 1975. Carbofuran duck kill. *In* Western Pesticide Workshop. Health Protection Branch, Health and Welfare Canada, Vancouver. pp. 123–125.

Brusnyk, L.M. and D.A. Westworth. 1987. Effects of carbofuran on unconfined small mammal populations in southern Alberta. Unpublished report, Alberta Agriculture, Crop Protection Branch. 42 pp.

California Department of Fish and Game. 1973. Pesticide Laboratory Report: Lab. No. 1734, E.P. No. 808, Update of initial report (16 May 1972) of fish and wildlife loss report, Region 1 (19 March 1973). 1 p.

Caro, J.H., H.P. Freeman, D.E. Gloteflety, N.C. Turner, and W.M. Edwards. 1973. Dissipation of soil-incorporated carbofuran in the field. J. Agric. Food Chem. 21:1010–1015.

Cathey, B. 1982. Comparative toxicities of five insecticides to the earthworm *Lumbricus terrestris*. Agric. Environ. 7:73–81.

Cerezke, H.F. and R.E. Holmes. 1986. Control studies with carbofuran on seed and cone insects of white spruce. Canadian Forestry Service Information Report NOR-X-280.

Chada, R.D. 1987. [Oklahoma Department of Agriculture] Letter to Ann Stavola [U.S. Environmental Protection Agency], dated 30 January 1987. 2 pp. + add.

Christian, R.D. 1990a. [Virginia Department of Agriculture and Consumer Services] Inspection memorandum, dated 27 March 1990.

Christian, R.D. 1990b. [Virginia Department of Agriculture and Consumer Services] Inspection memorandum, dated 29 March 1990.

Chudoba, B.W. 1989. [Virginia Department of Agriculture and Consumer Services] Letter to the grower involved in the kill, dated 27 June 1989. 1 p.

Collins, H.E. 1988. [Ontario Ministry of Natural Resources] Occurrence report, dated 4 October 1988.

Coon, N.C. 1983. [U.S. Fish and Wildlife Service] Letter to R. Balcomb [U.S. Environmental Protection Agency], dated 7 January 1983. 1 p. + add.

Davidson, W.R. and J.M. Steiner. 1980a. [Southeastern Cooperative Wildlife Disease Study, University of Georgia, Athens] Clinical Necropsy Record: Case No. 17-80, Laboratory No. PS-3880 (10 April 1980). 1 p.

Davidson, W.R. and J.M. Steiner. 1980b. [Southeastern Cooperative Wildlife Disease Study, University of Georgia, Athens] Clinical Necropsy Record: Case No. 17-80 (17 April 1980). 1 p.

Driver, C.J., M.W. Ligotke, P. Van Voris, B.D. McVeety, B.J. Greenspan, and D.B. Drown. 1991. Routes of uptake and their relative contribution to the toxicologic response of Northern Bobwhite (*Colinus virginianus*) to an organophosphate pesticide. Environ. Toxicol. Chem. 10(1):21–34.

Dunning, J.B., Jr. 1984. Body weights of 686 species of North American birds. Western Bird Banding Association Monograph No. 1. 38 pp.

Edwards, M. 1986. [Agriculture Canada] Memorandum to J. Hollebone [Pesticide Directorate, Agriculture Canada], dated 22 October 1986.

Eisler, R. 1985. Carbofuran hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish Wildl. Serv. Biol. Rep. 85(1.3). 36 pp.

Elliott, J. and L. Wilson. 1993. Pesticide poisonings of birds of prey in British Columbia, 1990–92. Unpublished draft summary report, Canadian Wildlife Service, Environment Canada.

Fairbrother, A., S.M. Meyers, and R.S. Bennett. 1988. Changes in mallard hen and brood behaviors in response to methyl parathion-induced illness of ducklings. Environ. Toxicol. Chem. 7:499–503.

Fischer, D.L. and L.B. Best. 1990. Oral exposure of birds to silica granules applied at-planting to corn fields. Annual Meeting of the Society of Environmental Toxicology and Chemistry, Abstract No. 108.

Fletcher, M.R., K. Hunter, P.W. Greig-Smith, and A.D. Ruthven. 1989. Investigations of suspected poisoning of animals by pesticides in Great Britain October 1985 to December 1986. *In* Investigations of suspected poisoning of animals by pesticides in Great Britain 1985–1987. Report of the Environmental Panel of the Advisory Committee on Pesticides. Ministry of Agriculture, Fisheries and Food, London. 44 pp.

Flickinger, E.L., K. King, W. Stout, and M. Mohn. 1980. Wildlife hazards from Furadan 3G applications to rice in Texas. J. Wildl. Manage. 44:190–197.

FMC (FMC Corporation). 1972. Acute toxicity evaluations of carbofuran with Bobwhite Quail chicks and young adults, and Mallard ducklings. [T.E. Shellenberger] Unpublished report, dated 7 January 1972. 21 pp.

FMC (FMC Corporation). 1973. Carbofuran property summary. June 1973. 87 pp.

FMC (FMC Corporation). 1975a. Internal memorandum from P.A. Jones [FMC], dated 14 March

1975. 9 pp. + add.

FMC (FMC Corporation). 1975b. Waterfowl kill related to Furadan 10G use in British Columbia, 1974–1975. Internal memorandum from P.A. Jones [FMC], dated 28 November 1975. 9 pp. + add.

FMC (FMC Corporation). 1976a. Eight-day dietary LC50 — Mallard Duck. Carbofuran technical. Final report. [Wildlife International Ltd.] Unpublished report, dated 21 July 1976. 9 pp.

FMC (FMC Corporation). 1976b. Waterfowl kill related to Furadan use in British Columbia, 1974–1975. Internal memorandum from P.A. Jones [FMC], dated 25 February 1976. 10 pp. + add.

FMC (FMC Corporation). 1976c. Determination of the carbamate and phenol residues of carbofuran in green and dry Canadian alfalfa and brome grasses. [B.C. Leppert] Unpublished report, dated 17 November 1976. 33 pp.

FMC (FMC Corporation). 1983. Effects of Furadan formulations 10G and 15G on avian populations associated with corn fields. [G. Booth, M. Carter, and C. Jorgensen] Unpublished report, dated July 1983. 106 pp.

FMC (FMC Corporation). 1986a. Effects of Furadan formulations 10G and 15G on birds associated with Iowa and Illinois cornfields. [G.M. Booth, M.W. Carter, D.L. Fischer, C.D. Jorgensen, L.B. Best, and R.W. Whitmore] Unpublished report, dated 22 December 1986. 354 pp.

FMC (FMC Corporation). 1986b. Effects of Furadan formulations 10G and 15G on birds associated with Florida and Texas cornfields. [G.M. Booth, M.W. Carter, D.L. Fischer, C.D. Jorgensen, L.B. Best, and R.W. Whitmore] Unpublished report, dated 22 December 1986. 134 pp.

FMC (FMC Corporation). 1987. Letter from J.J. Lauber [FMC] to F. Davido [U.S. Environmental Protection Agency], dated 5 May 1987. 1 p.

FMC (FMC Corporation). 1989a. Effects of Furadan 4F on birds associated with Nebraska and Texas/New Mexico corn fields. [C.D. Jorgensen, R.C. Whitmore, G.M. Booth, M.W. Carter, and H.D. Smith] Unpublished report. 751 pp.

FMC (FMC Corporation). 1989b. Effects of Furadan 4F on birds associated with Kansas and Oklahoma alfalfa fields. [G.M. Booth, L.B. Best, M.W. Carter, and C.D. Jorgensen] Unpublished report. 810 pp.

FMC (FMC Corporation). 1990a. Letter from D.B. Carlson [FMC] to W.A. Charnetski [Agriculture Canada], dated 24 September 1990.

Forsyth, D.L., L.L. Jackson, N.D. Westcott, and C.F. Hinks. 1989. Field and laboratory studies of carbofuran intake by grasshoppers and songbirds. Unpublished report, Canadian Wildlife Service, Environment Canada. 87 pp.

Fox, G.A., P. Mineau, B. Collins, and P.C. James. 1989. The impact of the insecticide carbofuran (Furadan 480F) on the burrowing owl in Canada. Canadian Wildlife Service Technical Report Series No. 72, Ottawa. 25 pp. + app.

Frank, R., P. Mineau, H.E. Braun, I.K. Barker, S.W. Kennedy, and S. Trudeau. 1991. Deaths of

Canada Geese following spraying of turf with diazinon. Bull. Environ. Contam. Toxicol. 46:852-858.

Fredrickson, A.S. 1974. Request for analysis and report of analysis on materials submitted by collaborating public agencies. Information No. 41658 (18 March 1974, with 25 March 1974 revision). California Department of Food and Agriculture. 1 p. [D-10910]

Freemark, K., H. Dewar, and J. Saltman. 1991. A literature review of bird use of farmland habitats in the Great Lakes - St. Lawrence region. Canadian Wildlife Service Technical Report Series No. 114.

Getzin, L.W. 1973. Persistence and degradation of carbofuran in soil. Environ. Entomol. 2(3):461-467.

Gollop, J.B. 1986. Prairie provinces region (Spring 1986). Am. Birds 40:487-488.

Gollop, J.B. 1987. Prairie provinces region (Spring 1987). Am. Birds 41:448-450.

Greig-Smith, P.W. 1988. Hazards to wildlife from pesticide seed treatments. *In* Application to seeds and soil. T.J. Martin (ed.). British Crop Protection Council Monograph No. 39. pp. 127-134.

Greig-Smith, P.W., M.R. Fletcher, K. Hunter, M.P. Quick, A.D. Ruthven, and I.C. Shaw. 1989. Investigations of suspected poisoning of animals by pesticides in Great Britain in 1987. *In* Investigations of suspected poisoning of animals by pesticides in Great Britain 1985-1987. Report of the Environmental Panel of the Advisory Committee on Pesticides. Ministry of Agriculture, Fisheries and Food, London. 44 pp.

Greig-Smith, P.W., M.R. Fletcher, K. Hunter, M.P. Quick, A.D. Ruthven, and I.C. Shaw. 1990. Pesticide poisoning of animals 1988: Investigations of suspected incidents in Great Britain. A Report of the Environmental Panel of the Advisory Committee on Pesticides. Ministry of Agriculture, Fisheries and Food, London. 20 pp.

Grue, C.E., G.V.N. Powell, and N.L. Gladson. 1981. Brain cholinesterase (ChE) activity in nestling starlings: implications for monitoring exposure of nestling songbirds to ChE inhibitors. Bull. Environ. Contam. Toxicol. 26:544-547.

Grue, C.E., A.D.M. Hart, and P. Mineau. 1991. Biological consequences of depressed brain cholinesterase activity in vertebrates. *In* Cholinesterase inhibiting insecticides — Their impact on wildlife and the environment. P. Mineau (ed.). Elsevier, Amsterdam. pp. 151-209.

Hails, C.J. and D.M. Bryant. 1979. Reproductive energetics of a free-living bird. J. Anim. Ecol. 48:471-482.

Harris, L.E. 1975. Guide for estimating toxic residues in animal feeds or diets. Unpublished report No. EPA-540/9-75-019. U.S. Environmental Protection Agency.

Hart, A.D.M. 1993. Relationships between behavior and the inhibition of acetylcholinesterase in birds exposed to organophosphorus pesticides. Environ. Toxicol. Chem. 12(2):321-336.

Hatch, D.M.R. 1966. Northern Great Plains region. Audubon Field Notes 20:519-522.

Haug, E.A. and L.W. Oliphant. 1990. Movements, activity patterns, and habitat use of Burrowing

Owls in Saskatchewan. J. Wildl. Manage. 54(1):27–35.

Hayes, L. 1989. [Southeastern Cooperative Wildlife Disease Study, University of Georgia, Athens] Clinical Laboratory Record: Case No. 82-89 (27 June 1989). 1 p.

Health and Welfare Canada. 1987. Pesticide handling — a safety handbook. Ottawa. 144 pp.

Hickey, J.J. 1976. [Department of Wildlife Ecology, University of Wisconsin, Madison] Letter to P. Whitehead [Canadian Wildlife Service, Environment Canada], dated 12 January 1976. 2 pp.

Hill, E.F. and M. Camardese. 1984. Toxicity of anticholinesterase insecticides to birds: technical grade versus granular formulations. Ecotoxicol. Environ. Saf. 8:551–563.

Hill, E.F. and J. Fleming. 1982. Anticholinesterase poisoning of birds: field monitoring and diagnosis of acute poisoning. Environ. Toxicol. Chem. 1:27–38.

Hill, E.F. and D.M. Swineford. 1985. [Patuxent Wildlife Research Centre, U.S. Fish and Wildlife Service, Laurel, Md.] Analytical report: bald eagle. PR-3186 (NWHL 5592-001). 1 p.

Hill, E.F., R.G. Heath, J.W. Spann, and J.D. Williams. 1975. Lethal dietary toxicities of environmental pollutants to birds. U.S. Fish Wildl. Serv. Spec. Sci. Rep. No. 191, Washington, D.C.

Hillis, J.C. 1974. [California Department of Food and Agriculture] Procedure to avoid wild life losses from application of the pesticide Furadan 4F. Internal memorandum, dated 10 April 1974. 2 pp.

Hoerger, F.D. and E.E. Kenaga. 1972. Pesticide residues on plants: correlation of representative data as a basis for estimation of their magnitude in the environment. Environ. Qual. Saf. 1:9–23.

Horstman, L.P. 1985. Preliminary investigations into the effects of grasshopper control activities in southern Alberta on roadside nesting birds. Unpublished report submitted to the Crop Protection Branch of Alberta Agriculture, October 1985. 23 pp.

Horstman, L.P. and T.E. Code. 1987. Effects of roadside application of carbofuran on nesting Brewer's Blackbird. Unpublished report submitted to the Crop Protection Branch of Alberta Agriculture, 20 March 1987.

Houston, C.S. 1971. Northern Great Plains region (Spring 1971). Am. Birds 25:759–764.

Houston, C.S. 1972. Northern Great Plains region (Spring 1972). Am. Birds 26:774–777.

Houston, C.S. and M.G. Street. 1959. Birds of the Saskatchewan River. Saskatchewan Natural History Society Special Publication No. 2. 205 pp.

Hudson, R.H., R.K. Tucker, and M.A. Haegele. 1972. Effect of age on sensitivity: acute oral toxicity of 14 pesticides to Mallard ducks of several ages. J. Toxicol. Appl. Pharmacol. 22(4):556–561.

Hudson, R.H., R.K. Tucker, and M.A. Haegele. 1984. Handbook of toxicity of pesticides to wildlife. 2nd ed. U.S. Fish Wildl. Serv. Resour. Publ. 153. 90 pp.

Irvine, D.G. 1987. Effects of grasshopper insecticides upon valuable wildlife. Progress report submitted to the Wildlife Toxicology Fund of the World Wildlife Fund. 42 pp.

Irvine, D.G. 1990. Effects of grasshopper insecticides upon valuable wildlife. Progress report submitted to the Wildlife Toxicology Fund of the World Wildlife Fund. 17 pp.

Jackson, L.L. 1989. Alfalfa in the prairie provinces. Distribution, insect pest control and attractiveness to birds. Unpublished report, Canadian Wildlife Service, Environment Canada. 64 pp.

James, P.C., G.A. Fox, and T.J. Ethier. 1990. Is the operational use of strychnine to control ground squirrels detrimental to Burrowing Owls? J. Raptor Res. 24(4):120–123.

Jemison, E.S. 1976. [U.S. Fish and Wildlife Service] Memorandum to Regional Director [Albuquerque, N.M.], dated 3 March 1976. 4 pp.

Kenaga, E.E. 1973. Factors to be considered in the evaluation of the toxicity of pesticides to birds in their environment. Environ. Qual. Saf. 2:166–181.

Kenaga, E.E. 1974. Evaluation of safety of chlorpyrifos to birds in areas treated for insect control. Residue Rev. 50:1–41.

Kinsinger, J.A. and R.M. Lusskin. 1980. [Raltech Scientific Services, Inc., Madison, Wis.] Identification of blue crystals from soil sample (1 April 1980). 1 p. + add.

Kirkland, L. 1989. [Georgia Department of Natural Resources, Atlanta] Letter to U.S. Environmental Protection Agency concerning OPP-30000/48A, dated 21 March 1989. 1 p.

Kleinert, S. 1974. [Wisconsin Department of Natural Resources] A study of potential hazard of insecticide granules to birds. Paper prepared for the 28th Annual Wisconsin Pest Control Conference (16–17 January 1974), Madison, Wis. 5 pp.

Kuncir, F. 1990. [Division of Law Enforcement, U.S. Fish and Wildlife Service] Written record of phone conversation with I. Sunzenauer [U.S. Environmental Protection Agency], dated 4 May 1990. 3 pp.

Lamb, R.J. and W.J. Turnock. 1982. Economics of insecticidal control of flea beetles (Coleoptera: Chrysomelidae) attacking rape in Canada. Can. Entomol. 114:827–840.

Ledger, J. 1987. [Endangered Wildlife Trust, Transvaal] Letter to P. Mineau [Canadian Wildlife Service, Environment Canada], dated 3 April 1987.

Leighton, F.A. 1988. Some observations of diseases occurring in Saskatchewan wildlife. Blue Jay 46(3):121–125.

Leighton, F.A. and G.A. Wobeser. 1987. Pesticide poisoning in gulls. Can. Vet. J. 28(3):108–109.

Lister, R. 1964. Northern Great Plains region (Spring 1964). Audubon Field Notes 18:460–464.

Littrell, E. 1986. [California Department of Fish and Game] Pesticide Laboratory Report: Lab. No. L-37-86, E.P. No. P-971 (19 February 1986). 1 p.

Littrell, E. 1988. Waterfowl mortality in rice fields treated with the carbamate, carbofuran. Calif. Fish Game 74:226–231.

Littrell, E. 1990. [California Department of Fish and Game] Pesticide Laboratory Report: E.P. No. P-1273 (22 February 1990). 1 p.

Ludke, J.L., E.F. Hill, and M.P. Dieter. 1975. Cholinesterase (ChE) response and related mortality among birds fed ChE inhibitors. Arch. Environ. Contam. Toxicol. 3:1–21.

Madder, D.J. and M. Stemeroff. 1986. The economics of insect control on wheat, corn and canola in Canada, 1980–1985. Entomological Society of Canada. 172 pp.

Maksymetz, B. 1992. [Agriculture Canada] Burrowing Owl/carbofuran audit report. Unpublished report addressed to A. Laflamme, Pesticides Directorate. 2 pp.

Martin, P.A. and D.J. Forsyth. 1993. Survival and behaviour of captive mallard broods exposed to carbofuran-sprayed vegetation: a field experiment. Ecotoxicology 2(2):79-92.

Martin, P.A., K.R. Solomon, and H.J. Boermans. 1991a. Effects of carbofuran ingestion on Mallard ducklings. J. Wildl. Manage. 55(1):103–111.

Martin, P.A., K.R. Solomon, D.J. Forsyth, H.J. Boermans, and N.D. Wescott. 1991b. Effects of exposure to carbofuran-sprayed vegetation on the behavior, cholinesterase activity, and growth of Mallard ducklings. Environ. Toxicol. Chem. 10:901–909.

Maybank, J., K. Yoshida, and R. Grover. 1978. Spray drift from agricultural pesticide application. J. Air Pollut. Control Assoc. 28(10):1009–1014.

Maze, R.C., R.P. Atkins, P. Mineau, and B.T. Collins. 1991. Measurement of pesticide residue in seeding operations. Trans. Am. Soc. Agric. Eng. 34(3):795–799.

McEwen, L.C., L.R. DeWeese, and P. Schladweiler. 1986. Bird predation on cutworms (Lepidoptera: Noctuidae) in wheat fields and chlorpyrifos effects on brain cholinesterase activity. Environ. Entomol. 15(1):147–151.

Mineau, P. 1988. Avian mortality in agro-ecosystems: 1. The case against granular insecticides in agroecosystems. *In* Field methods for the study of environmental effects of pesticides. M.P. Greaves, P.W. Greig-Smith, and B.D. Smith (eds.). British Crop Protection Council Monograph No. 40. pp. 3–12.

Mineau, P. 1990. Recent kills of Bald Eagles and Red-tailed Hawks in B.C. linked to carbofuran. Letter from P. Mineau [Canadian Wildlife Service, Environment Canada] to L. Lyon [U.S. Environmental Protection Agency], dated 19 September 1990. 3 pp.+ add.

Mineau, P. 1991a. Difficulties in the regulatory assessment of cholinesterase-inhibiting insecticides. *In* Cholinesterase inhibiting insecticides – Their impact on wildlife and the environment. P. Mineau (ed.). Elsevier, Amsterdam. pp. 277–299.

Mineau, P. 1991b. Letter from P. Mineau [Canadian Wildlife Service, Environment Canada] to Dr. W. Weber [B.C. Ministry of Agriculture and Fisheries], dated 18 April 1991. 3 pp.+ add.

Mineau, P. and B.T. Collins. 1988. Avian mortality in agro-ecosystems: 2. Methods of detection. *In* Field methods for the study of environmental effects of pesticides. M.P. Greaves, P.W. Greig-Smith, and B.D. Smith (eds.). British Crop Protection Council Monograph No. 40. pp. 13–27.

Mineau, P. and D.B. Peakall. 1987. An evaluation of avian impact assessment techniques following broad-scale forest insecticide sprays. Environ. Toxicol. Chem. 6:781–791.

Mineau, P., K.M.S. Sundaram, A. Sundaram, C. Feng, D.G. Busby, and P.A. Pearce. 1990. An improved method to study the impact of pesticide sprays on small song birds. J. Environ. Sci. Health B25(1):105–135.

Nero, R.W. 1962. Northern Great Plains region (Spring 1962). Audubon Field Notes 16:423–426.

NRCC (National Research Council of Canada). 1979. Carbofuran: criteria for interpreting the effect of its use on environmental quality. NRCC No. 16740. 191 pp.

O'Connell, R.L. 1977. [U.S. Environmental Protection Agency] Letter to A.E. Conroy II [U.S. Environmental Protection Agency]: Misuse case for PMRC review: Frank Harvey Michaud, Jr., Patrick William Feeney, and John Richard Harris (27 April 1977). 4 pp. [D-10982]

Otsuji, R.T. 1990. [California Agricultural Commissioner's Office, Walnut Grove CA] Narrative (23 February 1990). 3 pp.

Overgaard, N.A., D.F. Walsh, G.D. Hertel, L.R. Barber, R.E. Major, and J.E. Gates. 1983. Evaluation of modified POWR-TILL seeder for soil incorporation to provide insect control and minimize bird mortality. U.S. Department of Agriculture Forest Service Technical Publication R8-TP3. 35 pp.

Patterson, D. 1986. [Division of Law Enforcement, U.S. Fish and Wildlife Service] Written record of phone conversation with J. Bascietto [U.S. Environmental Protection Agency]: Eagle poisonings (7 March 1986). 2 pp.

Renaud, W.E. 1973. Northern Great Plains region (Spring 1973). Am. Birds 27:785–788.

Roth, L. 1986. [Virginia–Maryland Regional College of Veterinary Medicine, Virginia Polytechnic Institute and State University, Blacksburg, Va.] Necropsy Report, Histopathology No. 86-1236 (14 May 1986). 2 pp. + attach.

Schafer, E.W., Jr., W.A. Bowles Jr., and J. Hurlburt. 1983. The acute oral toxicity, repellancy and hazard potential of 998 chemicals to one or more species of wild and domesticated birds. Arch. Environ. Contam. Toxicol. 12:355-382.

Sheehan, P.J., A. Baril, P. Mineau, D.K. Smith, A. Harfenist, and W.K. Marshall. 1987. The impact of pesticides on the ecology of prairie nesting ducks. Canadian Wildlife Service Technical Report Series No. 19.

Somers, J.D., Y. Kumar, A. Khan, and A.W.L. Hawley. 1988a. Physiological effects of spraying carbaryl, dimethoate or carbofuran on gamebirds. *In* Effects of the exposure of birds to insecticides used for grasshopper control in Alberta. A.W.L. Hawley and J.D. Somers (eds.). Alberta Environmental Centre Report No. AECV88-R6. pp. 7–32.

Somers, J.D., A. Khan, and A.W.L. Hawley. 1988b. Effects on gulls of spraying carbofuran for grasshopper control. *In* Effects of the exposure of birds to insecticides used for grasshopper control in Alberta. A.W.L. Hawley and J.D. Somers (eds.). Alberta Environmental Centre Report No. AECV88-R6. pp. 47–62.

Somers, J.D., A.A. Khan, Y. Kumar, and M.W. Barrett. 1991. Effects of simulated field spraying of carbofuran, carbaryl and dimethoate on pheasant and partridge chicks. Bull. Environ. Contam. Toxicol. 46:113–119.

Stansley, W. 1987. [State of New Jersey, Department of Environmental Protection] Letter to I. Sunzenauer [U.S. Environmental Protection Agency] dated 10 November 1987, with enclosures.

Stinson, E.R., L.E. Hayes, P.B. Bush and D.H. White. In press. Carbofuran affects wildlife on Virginia cornfields. The Wildlife Society Bulletin.

Stone, W.B. 1981. [New York Department of Environmental Conservation, Delmar, N.Y.] Letter to R. Balcomb [U.S. Environmental Protection Agency], dated 21 April 1981. 1 p.

Stone, W.B. 1985. [New York Department of Environmental Conservation, Delmar, N.Y.] Letter to J. Bascietto [U.S. Environmental Protection Agency], dated 22 November 1985. 1 p. + add.

Stone, W.B. and P.B. Gradoni. 1985a. Recent poisonings of wild birds by diazinon and carbofuran. Northeast. Environ. Sci. 4(3/4):160–164.

Stone, W.B. and P.B. Gradoni. 1985b. Wildlife mortality related to use of the pesticide diazinon. Northeast. Environ. Sci. 4:30–38.

Stutzenbaker, C.D., K. Brown, and D. Lopries. 1984. Special report: assessment of the accuracy of documenting waterfowl die-offs in a Texas coastal marsh. *In* U.S. Fish and Wildlife Service Workshop on Lead Poisoning in Waterfowl, USFWS, Washington D.C. pp. 88–95.

Taylor, P.A. 1974. [California Analytical Laboratory Inc.] Letter to Leon Woods [California Department of Fish and Game], dated 1 April 1974. 2 pp.

Thomas, N.J. 1985. [National Wildlife Health Research Centre, U.S. Fish and Wildlife Service, Madison, Wis.] Necropsy Report, Case No. 5592-001 (22 May 1985). 2 pp.

Trotter, D.M., R.A. Kent, and M.P. Wong. 1989. Canadian water quality guidelines for carbofuran. Inland Waters Directorate Scientific Series No. 169, Environment Canada. 34 pp.

Trowsdale Mutafov, D. 1992. Does the labelling restriction on carbofuran containers help protect Burrowing Owls? Blue Jay 50(4):201–203.

Urban, D.J. and N.J. Cook. 1986. Standard evaluation procedure: ecological risk assessment. EPA 540/9-85-001, U.S. Environmental Protection Agency, Washington, D.C. 95 pp.

U.S. EPA (Environmental Protection Agency). 1979. Summary of reported pesticide incidents involving carbofuran. Pesticide Incidents Monitoring System Report No. 231.

U.S. EPA (Environmental Protection Agency). 1989. Carbofuran. Special Review technical support document. Office of Pesticides and Toxic Substances.

Usher, R.G. and D.L. Johnson. 1992. Geographic intersection between Burrowing Owl habitat and the distribution of carbofuran sprayed for grasshopper control in Alberta. Unpublished draft manuscript submitted to the Canadian Wildlife Service.

Walls, W.E. 1990. [Virginia Department of Agriculture and Consumer Services] Letter to B. Onley

[Hopeland Farms, Inc.], dated 10 May 1990.

Webster, G.R. and L. Shapiro. 1990. Effects of environmental exposure to carbofuran (Furadan) on Mallard ducklings (*Anas platyrhynchos platyrhynchos*). Interim progress report to the Wildlife Toxicology Fund of the World Wildlife Fund. 21 pp. + add.

Whitehead, P. 1975a. [Canadian Wildlife Service, Environment Canada, Vancouver] Report on the Ladner duck kill — Field investigation of Ladner duck kill to January 6, 1975. Unpublished report. 12 pp.

Whitehead, P. 1975b. [Canadian Wildlife Service, Environment Canada, Vancouver] Internal memorandum to Dr. D. Hocking, dated 1 December 1975. 4 pp.

Whitehead, P. 1989. [Canadian Wildlife Service, Environment Canada, Vancouver] Wildlife kill/sample information (5 August 1989). 1 p. + add.

Wiemeyer, S.N. and D.W. Sparling. 1991. Acute toxicity of four anticholinesterase insecticides to American Kestrels, Eastern Screech Owls and Northern Bobwhites. Environ. Toxicol. Chem. 10(9):1139–1148.

Williams, I.H., M.J. Brown, and P. Whitehead. 1976. Persistence of carbofuran residues in some British Columbia soils. Bull. Environ. Contam. Toxicol. 15:242–243.

Williams, J.B. 1987. Field metabolism and food consumption of Savannah Sparrows during the breeding season. Auk 104:277–289.

Williams, M.H. 1988. [U.S. District Court for the District of Idaho] Memorandum decision in the case U.S. vs. Ronald Rollins. Case No. 88-10033. 15 pp.

APPENDIX 1

SOIL INCORPORATION OF GRANULARS

Label directions for the various uses of granular carbofuran recommend that the granules be covered with soil or that they be drilled below the surface. However, it is the opinion of the Canadian Wildlife Service that farm equipment currently in use and the way in which that equipment is used leave exposed granules available to foraging wildlife. The following is a brief summary of the research on which this determination was made.

1. INCORPORATION OF GRANULARS IN ROW CROPS

Seed planters all work on a similar principle. A furrow is opened, and a seed is dropped into it. The furrow is then closed with a "press wheel" rolling immediately over the furrow or a pair of "side-firming disks" (or closure wheels) that apply lateral pressure to the seed furrow, causing soil to cave in on the seed. Optional chains or metal rakes (tines) can then be dragged over the whole furrow area.

Granules can be introduced at a number of different steps. They can be deposited directly into the seed furrow by means of a narrow delivery tube (in-furrow application) or banded (spread by a diffuser) in front of or over the furrow, either in front of or behind the press wheel or seed-firming disks. Depending on how it is applied, different proportions of the granular insecticide are left on the soil surface over the entire length of the furrow, regardless of the care taken by the operator.

For corn, the recommended method of application in Ontario is to put a 15-cm band in front of the press wheels (Ellis 1982). The 10G label recommends an 18-cm band lightly incorporated by a drag chain or similar means. No mention is made of the placement of the granules relative to the press wheel on the existing product label.

For onions and sugar beets, the label recommends that the material be deposited in furrow. Onions can be seeded at a very shallow depth (as little as 0.5 cm below surface) in soils with adequate moisture retention (OMAF undated).

For potatoes, the label states that the granules should be either banded (10 cm) in the furrow or drilled on the sides of the furrows. We have no information as to the preferred method of application.

For turnips and rutabagas, the granules are to be banded (10 cm) in front of the furrow-opening device. One must rely on the opening and closing of the furrow to achieve granule incorporation.

1.1 Engineering studies

To our knowledge, corn is the only row crop for which granule incorporation has been systematically investigated. Erbach and Tollefson (1983) tested banding under various configurations of commonly used commercial planters (Table A-1). Three different planters were tested with either carbofuran (sand) or chlorpyrifos (clay) granules. The authors reported no statistical differences between planters or between insecticides and therefore reported overall means only. Their results undoubtedly overestimate granule incorporation for a number of reasons:

1. Tests were performed under ideal laboratory conditions with slow-moving (3.2 km/h), evenly textured soil bins and perfectly calibrated machinery.

2. Surface granule counts were not adjusted for the proportion of granules that had not incorporated the dye (see Atkins *et al.* 1989).

3. These data account for only the unincorporated granules along the length of the seed furrow. They do not consider spills that occur when the planters are turning or when the planting shoes lift out of the soil.

4. As discussed by Maze *et al.* (1991), it is likely that many more granules are available to foraging birds than those counted from overhead photographs. Foraging birds work close to the soil and vary their angle of view.

Table A-1.
Average number of surface-visible granules expressed as a proportion of the application rate using standard methods of corn seeding.

Placement relative to press wheel	% of application rate using following methods of incorporation:		
	Drag chain	Tines (rake)	None
Front	7.9	5.8	14.7
Rear	16	7.4	40.2

Source: Erbach and Tollefson (1983).

In another study (Hummel 1983), banding was compared with an in-furrow application using two different planters and variable speeds of planting (Table A-2). Again, controlled laboratory conditions optimized equipment performance, and, again, no allowance was made for poor dye incorporation. Carbofuran 10G granules were used for the tests, as were other granule types. No significant differences were obtained between granule types.

The propensity of the granule bander to give poorer incorporation at higher speeds of seeding was reversed when tines were used. However, the authors cautioned that the tines (or rakes) would be less efficient at incorporating granules under field conditions with a certain amount of surface trash.

Table A-2.
Average number of surface-visible granules expressed as a proportion of the application rate using standard methods of corn seeding.

Method of application	% of application rate at following planter speeds (km/h):		
	4.8	6.9	9.0
Banded[a] in front of seed-firming disks	18	24	31
As above, with tines	6.8	4.9	3.7
In furrow with press wheel	0.5	0.4	0.8

[a] 13-cm-wide band with diffuser 23 cm above soil surface.

Source: Hummel (1983).

Supplementary data were provided by the manufacturer of carbofuran (FMC 1987). A 7-inch (17.8-cm) band was applied in front of the press wheel and incorporated with drag chains. Unfortunately, the granules were not dyed with a fluorescent material as in previous studies, but a correction factor (80%) was determined based on the ability of an observer to find a known quantity of granules. The pink-coloured 15G granules were used, which aided detection somewhat. The counts obtained in this study were also minimum counts, because a 7-inch-wide strip only was counted along the seed furrow. This does not provide the total number of surface granules, as displacement of some granules beyond 7 inches is likely. Nevertheless, the visibility-adjusted mean rate of surface-visible granules was 7.3%. The maximum rate obtained in one of the plots was 13%. These estimates are in the same range as those determined above.

The application of granules in a band in front of the planting shoe, as recommended for rutabagas and turnips, was examined by Bevan and Kelly (1975) with dyed granules. They described the majority of granules being pushed away from the furrow and forming two distinct side bands 51–76 mm apart at the nearest point. They unfortunately did not report on the incorporation efficiency of this method, but pest control was reported to be poor. According to Makepeace (1965), the way to achieve better incorporation with this method is to apply as narrow a band of granules as possible. With the currently suggested band width, it is unlikely that good incorporation is achieved.

1.2 Surveys of operational use

The above studies were performed by agricultural engineers with perfectly calibrated equipment and, often, ideal or standardized soil conditions. A few studies attempted to look at real-life on-the-farm variability in granule application.

In a British study of 52 planters and seed drills fitted with the same granule distribution mechanism (Thompson *et al.* 1984), it was found that one-quarter of the machines were delivering between 110% and 200% of the labelled rate. Superimposed on the overall machine-to-machine variation in application rate was an 11–70% variation between granule outlets on the same machine on over half (58%) of the machines tested.

Another on-farm survey in Nebraska and Iowa (Rider and Dickey 1982) reported errors in granule application ranging from 35% underapplication to 90% overapplication.

One study in southwestern Ontario is especially relevant to this review. The author tested the equipment of 38 corn farmers chosen at random (Ellis 1982). Application rates ranged from 45% to 225% of intended rates, with the median at 90% of the intended rate. Overapplication by 20% or more occurred in 14% of fields. Row-to-row variation in application rate was >20% in half of the fields. Eight percent of the planters gave >50% between-row variation.

Of relevance to our specific concerns with regard to unincorporated granules is the fact that 40% of the farmers said they calibrated the individual granule applicators by observing the flow rate coming out of each. This practice means that a substantial amount of granular material is deposited on the soil surface at field edge while the farmer is calibrating his machinery. A granule diffuser boot was used 92% of the time, and it was positioned 6–20 cm away from the soil surface, either in front of (70%) or behind (30%) the press wheel. Those not using spreaders compensated by increasing the height of delivery to 15–28 cm above soil level. Only 11% of the farmers used wind guards; this was considered to be a problem by the author in view of prevailing wind conditions, which would tend to blow granules away from the furrows. Incorporation equipment such as chains or rakes was used by only 24% of farmers (18% chains, 5.4% rakes). Although not stated by the author, it is reasonable to assume that most of the reported use of chains or rakes was for the 30% of farmers who were banding behind the press wheel, this being the only possible method of incorporation. Conversely, this means that few, if any, farmers were using chains or rakes in combination with banding in front of the press wheel.

Balcomb *et al.* (1984) provided anecdotal information following in-furrow applications of carbofuran. Despite the fact that this is by far the best method of incorporation and the fact that some of the applications were actually made on a USDA research farm, they reported surface granules from the entire length of most seed furrows.

2. INCORPORATION OF GRANULARS IN FIELD CROPS

Furadan CR-10 is mixed directly with the seed before seeding. The label recommends the use of a hoe or press drill. The label also states that disk-type seeding equipment should not be used and that harrowing after seeding causes loss of efficacy.

2.1 On-farm surveys

The only information at our disposal is a personal communication from the distributors of carbofuran (Table A-3). It consists of a 1984 survey of western seeding equipment used for canola. Environment Canada was denied access to the survey, and I therefore cannot comment on the methodology. One would expect the seeding machinery to be that which is traditionally used to seed cereal crops. Because of the need to rotate canola crops and the suitability of cereals as a rotational crop (Alberta Agriculture 1985), farmers are unlikely to invest in canola-specific machinery.

Table A-3.
Popularity of canola seeding equipment in western Canada.

Seeding equipment	Popularity (%)
Press drill	79
Hoe drill	8
Disker seeder	7
Air seeder	6[a]
Airflow broadcast	1

[a] Air seeders are often used to broadcast seed on the soil surface. In this case, as well, as with other broadcast techniques, harrows or harrow-packers are used to incorporate the seed and the granules.

Source: P. McMullen (Chemagro, pers. comm., 26 May 1988).

Alberta Agriculture (1985) reported that press drills gave the best results when seeding the species *Brassica campestris* but that air seeders and hoe drills performed just as well or better for the other common species *B. napus*. With air seeders and hoe drills, best results were obtained with harrow-packer operations after the seeding operation.

2.2 Engineering studies

The only published information is from Maze *et al.* (1991), who tested the various types of aforementioned canola seeding equipment for their efficiency of incorporation (Table A-4). Only the disker seeder was not tested, because the label specifically recommends that it not be used. Furthermore, this type of seeder is falling in popularity in the prairies (R.P. Atkins, Alberta Farm Machinery Institute, pers. comm.).

The authors used a granular substitute made up to be of the exact same size and density as the Furadan CR-10 granules. Fluorescent dye was added to the granules, and the plots were examined under a black light. The efficiency of dye incorporation was measured, and the results were adjusted accordingly. Two different soil conditions were tested (summerfallow and stubble), and seeding was carried out either as a single pass or with two passes (criss-cross), as often happens in the turn rows at the edges of the field.

Table A-4.
Proportion of surface-visible granules in field crops.

Seeding implement	Single seeding (%)		Double seeding (%)	
	Fallow	Stubble	Fallow	Stubble
Press drill	5.3	4.7	7.0	3.6
Hoe drill	0.74	0.37	0.58	0.46
Air seeder[a]	0.31	0.92	0.40	0.13
Air seeder[a] (broadcast)	4.2	2.2	2.3	1.7

[a] Followed by a harrow-packing operation.

Source: Maze *et al.* (1991).

The press drill had a significantly poorer incorporation efficiency overall. The air seeder used in broadcast mode was the second worst. The air seeder used in regular mode and the hoe drill were statistically inseparable. The percentages given hide the very great variability encountered, even under these conditions of precise machine calibration. For example, the uncorrected granule count for 30 0.5-m^2 plots selected at random from the area seeded with the press drill under fallow conditions (the most common prairie conditions) ranged from 0 to 17 granules (Atkins and Maze 1988). Using a weight of 0.00225 g for a CR-10 granule (Maze *et al.* 1991), the standard application rate of 2.8 kg formulation/ha should result in a delivery rate of 62 granules/0.5 m^2. Therefore, the extreme proportion of surface-visible granules under the conditions tested was 27%. It is important to consider this variation, because local concentrations of granules in the field may be more relevant to the wildlife hazard than average field conditions.

Data on incorporation of the CR-10 granule in seeding canola were also submitted by the manufacturer of carbofuran (Table A-5) (FMC 1989a). The proportion of granules left on the soil surface was much lower than those obtained in the published study described above.

Table A-5.
Proportion of surface-visible granules in field crops: manufacturer's data.

Implement	Mean % of surface-visible granules[a]
Press drill	0.33–0.51
Hoe drill	0.00–0.02
Air seeder	0.00–0.05

[a] Range results from tests at different implement speeds and soil conditions.

It is interesting to note that, once again, the press drill was outperformed by approximately a factor of 10. There are several reasons for the lower rates of surface residue obtained in the manufacturer's study:

1. There was no fluorescent dye added to the granules. Observers had to rely on the usual dark purple dye of the granules to be able to count them on 1-m^2 plots of soil under daylight conditions. Adding to this difficulty were weather conditions that were described as "inclement."

2. Seeding was made at a depth of 25–38 mm. This was deeper than the seeding depth used by Maze *et al.* (1991). The latter seeded at a depth of 20 mm in keeping with agricultural recommendations that seeding should be between 12 and 25 mm (Alberta Agriculture 1985).

3. None of the seeding implements was calibrated. Actual seeding rates varied by as much as 214% without any indication of how they were actually determined.

The inability of the operators to achieve proper seeding rate and their choice of a wrong seeding depth suggest that the results obtained are less than typical. The ability of observers to see all of the surface granules is, however, the most serious flaw of this study. For those reasons, these data are considered invalid and unusable in an absolute sense. The relative performance of the press drill with respect to the other seeding implements reinforces the results of Maze *et al.* (1991).

3. OTHER PROBLEMS IN THE APPLICATION OF GRANULARS THAT MAY RESULT IN POOR INCORPORATION

Spillage occurs during the loading of machinery, at row ends when lifting planters out of furrows to permit turning, when planter shoes rise out of soils of irregularly contoured fields, and when the machinery has to abruptly change direction to avoid sloughs and other natural obstacles. The practice of calibrating planters by observing granule flow was mentioned earlier.

Also, wind might influence granule placement, especially with granules of lower specific gravity, such as corncob-based CR-10 granules.

The manufacturer has suggested that a device could be installed on planters to shut off the flow of granules at the ends of the rows (FMC 1989b). The Canadian Wildlife Service applauds any improvements in agricultural machinery that reduce waste of agrochemicals. Although there are no data on this, granule spillage at the ends of rows undoubtedly represents a ready source of exposure for wildlife species inhabiting field margins. However, such a device, even if it could be retrofitted on all planter types and made mandatory across Canada, would not solve the problem. As seen above, granules are left in considerable numbers on the soil surface over the whole length of the furrow. The monitoring program of 1990 in Virginia (see Section 3.3.2.1) demonstrated the inability of these devices to prevent bird kills with carbofuran. It may be that such cut-off devices will prove to be useful for granular products of lesser toxicity to birds than carbofuran, and the idea should be pursued by all registrants of granular products.

LITERATURE CITED

Alberta Agriculture. 1985. Canola production in Alberta. Agdex 149/20-1. 31 pp.

Atkins, R.P. and R.C. Maze. 1988. Measuring pesticide residues in seeding operations. Alberta Agriculture Research Report. Project No. RL0288. 46 pp.

Atkins, R.P., R.C. Maze, and P. Mineau. 1989. Measuring surface seed placement using ultraviolet photography. Am. Soc. Agric. Eng. Pap. No. 89-1518.

Balcomb, R., C.A. Bowen II, D. Wright, and M. Law. 1984. Effects on wildlife of at-planting corn applications of granular carbofuran. J. Wildl. Manage. 48(4):1353–1359.

Bevan, W.J. and J.R. Kelly. 1975. Soil placement of insecticide granules for the control of cabbage root fly on transplanted cauliflowers. Plant Pathol. 24:84–92.

Ellis, C.R. 1982. A survey of granular application equipment and insecticide rates used for control of corn rootworms (Coleoptera: Chrysomelidae) in southern Ontario. Proc. Entomol. Soc. Ont. 113:29–34.

Erbach, D. and J. Tollefson. 1983. Granular insecticide application for corn rootworm control. Trans. Am. Soc. Agric. Eng. 26:696–699.

FMC (FMC Corporation). 1987. Furadan 15G insecticide application. [J.F. Wright] Unpublished report, dated 24 November 1987. 34 pp.

FMC (FMC Corporation). 1989a. Measuring seed and pesticide residues after typical seeding operation. [R.K. Harris and D. May] Unpublished report, dated June 1989. 15 pp.

FMC (FMC Corporation). 1989b. Leakage reduction of commonly used granular pesticide carriers during row crop planting operations. [S.F. Tutt] Unpublished report, dated 27 September 1989. 15 pp.

Hummel, J.W. 1983. Incorporation of granular insecticides by corn planters. Am. Soc. Agric. Eng. Pap. No. 83-1017. 14 pp.

Makepeace, R.J. 1965. The application of granular pesticides. *In* Proc. 3rd British Insecticide and Fungicide Conference, Brighton. British Insecticide and Fungicide Council. pp. 389–396.

Maze, R.C., R.P. Atkins, P. Mineau, and B.T. Collins. 1991. Measurement of pesticide residue in seeding operations. Trans. Am. Soc. Agric. Eng. 34(3):795–799.

OMAF [Ontario Ministry of Agriculture and Food]. Undated. Onions. Publication 486. Agdex 258/20.

Rider, A.R. and E.C. Dickey. 1982. Field evaluation of calibration accuracy for pesticide application equipment. Trans. Am. Soc. Agric. Eng. 1982:258–260.

Thompson, A.R., D.P.H. Kempton, and A.L. Percivall. 1984. The use and precision of insecticide granule applications for protecting brassicas against cabbage root fly. *In* British Crop Protection Conference: Pests and diseases 1984. British Crop Protection Council. pp. 1123–1128.

APPENDIX 2

LETTERS FROM U.S. FARMERS SENT TO THE U.S. EPA IN RESPONSE TO THE SPECIAL REVIEW OF GRANULAR CARBOFURAN IN THE UNITED STATES

(These letters were precipitated by letters from the manufacturer — see Appendix 3 — soliciting their support.)

Four letters are included here. The identities of the authors have been removed.

These letters illustrate the level of concern among some carbofuran users and reinforce the idea that only a small proportion of wildlife kills are ever reported.

February 6, 1989

D-10202 CARBOFURAN SR

[redacted]

OPP-30,000/40
Public Docket and Freedom of Information Section (TS-767C)
Office of Pesticide Programs
U. S. EPA
401 M St. SW
Washington, DC 20460

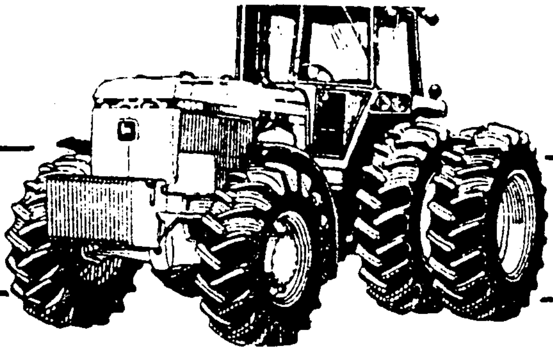
To Whom it may concern:

I am very much aware that Furadan kills game birds. I have found Pheasants and Hungarian Partridge in the spring during corn planting that still had the granuals in their crops. I also found quite a few dead Purple Grackle at the same time. I have never used anything for rootworms. I rotate. My neighbors however do use it and the birds come to my property after they ingest it and die. If I didn't provide the habitat for them I wouldn't find so many. I have to keep my dog tied in the spring. Once I lost a dog after he ate dead Partridges that he found along the fence row and my present dog became very sick after eating a dead Purple Grackle.

Furadan has been used almost 20 years in our area and the decline of birds began at about the same time. FURADAN IS A CHEMICAL WEAPON AND SHOULD BE VERY CLOSELY REGULATED AND BANNED FOR WIDE SPREAD USE. I am a farmer and I am afraid of the damages that carbofuran does.

Sincerely,

postmarked
2/6/89



JAN 28th 1989

Dear sir:

I am a farmer from Michigan and I farm 2007 Acres of Crops today (1989) I was sent a letter from FMC corporation urging me to write to you and my congressman, senator, dep. Ag on behalf of thier companies product Furadan. I use an insecticide on about 800 Acres of my corn ground that is called Counter by Cynamid. I did spray 300 Acres of corn ground for a nieghbor last year and he had used furadan. as labeled with his corn planter Aplicator during planting. On my first pass around the outside of the field near the woods and fence rows I saw many dead birds - mostly blackbirds and Robins. I did not know at that time what had killed so many birds. Later in the next field along the fencerow I saw a mature Red tailed Hawk Dead. I later asked my nieghbor what form of insecticide he had used and he said furadan granular. I have never had a bird kill using Counter. I as a farmer and a friend of nature Agree with the EPA Ruling to ban the use of Furadan s it is not safe too the living enviroment we farm in.

Thank you

Appendices

Public Docket & Freedom of Information Section (TS-767C)
Office of Pesticide Programs
U.S. EPA
401 M Street SW
Washington, DC 20460

D-10230 CARBOFURAN SR

Subj: OPP-30,000/48

From:

Date: February 9th, 1989

I received a letter from the FMC Corporation dated January 6 that their product, Furadan was in jeopardy of being taken off the market by the EPA. They urged me to write to this address in their behalf, but in all reality, I'm not in their defense.

As a farmer, I need a healthy environment for good crops and a successful, healthy life, not only for me, but for my family and the people whom I live with in this world. FMC's main concern has to be the economical growth of their corporation. That product should not have ever been placed on the market.

Back in the early 70's, we purchased liquid Furadan and mixed it with our starter fertilizer for insect control. One of the first things we noticed, was that the planter operator had uncontrollable muscle twitches in his neck. I got on the planter myself and run it the rest of the day. I found myself having muscle problems also, but with my eyelids instead of my neck. We were making an assumption that it may have been the insecticide.

Later, after a good rain, we walked our corn fields, and noticed that we had large numbers of dead earth worms laying on top of the corn rows. Again, we felt that the insecticide was not selective in killing. We had intended to control only cut worms, not kill everything.

Consequently, that was the last time I purchased that product. I felt that it was too dangerous for the pesticide handler, and unsafe to the environment.

I sometimes feel that we may have already eliminated many of natures natural predators that are friendly to us farmers. We may have past the point of recovery. I hope I'm wrong, because if I'm not, we will be chemical dependent on a food supply forever more, else the end of the human race.

RECEIVED 2/14/89

Dear Folks on our side at E.P.A.

I received this letter from my local farmers Co-op.
It's good to see some action taken about this.
I have seen fields that were littered with hundreds
of writhing birds after Furadan was applyed.
Most of these birds were cattle egrets, who generally
pick bugs that are stirred up by field work.
I feel that those birds are benificial and innocent victims.
Please continue your investigations and good work

Thanks

For responsible agriculture,

Letter: 1 page.
Copy of FMC letter to farmers 2 pages

1-27-81

APPENDIX 3

EXAMPLE OF LETTER SENT TO U.S. PESTICIDE DEALERS BY FMC CORPORATION REQUESTING SUPPORT FOR THEIR PRODUCT

Agricultural Chemical Group
2000 Market Street
Philadelphia Pennsylvania 19103
215 299 6000

FMC

January 9, 1989

Dear Dealer:

On January 5, 1989, the United States Environmental Protection Agency (EPA) issued a statement recommending cancellation of registration of granular formulations of Furadan® insecticide-nematicide.

This action represents a direct threat to your business.

It is important for you to get involved now. Following are several facts concerning this statement and the EPA Special Review:

- It has no effect on the availability or use of Furadan for the 1989 growing season and FMC will continue to support the product in every way. In the event of an unanticipated product recall, existing inventories will be managed by FMC at no cost to you.
- The Special Review concerns risk to avian species; it has nothing to do with human toxicity or contamination of the food chain.
- Although Furadan and other granular insecticides can kill birds when accidentally eaten, these products do not interfere with the life cycle of the bird species and have not had an effect on bird populations. Ironically, many of the same species under review have increased their population level to the point where the EPA has approved poisons to control them.

Why should you be concerned?

Perhaps Furadan does not represent a major portion of your crop protection business. In fact, the removal of Furadan from the market may have no adverse effect on your business at all.

.../.

Page Two

But you should know this:

Furadan is only one of several products scheduled for review by the EPA. The EPA has stated that Counter® and Thimet® insecticides will begin their review in 1989 and others will certainly follow.

The future of your business depends on the outcome of these Special Reviews.

We think it's important for every dealer in the U.S. to know about the actions taken by the EPA for three reasons:

1. Many of the products you sell are under widespread and increasing attack.

2. Increasingly, forces outside of the agricultural industry are dictating to dealers what products they will sell. Although you and your growers know how to produce food with minimal environmental disruption, your opinions are rarely solicited.

3. The EPA, quite simply, refuses to play fair. In their crusade, they have criticized Furadan for not meeting standards which they have refused to specify. From their Washington perspective, they have misinterpreted scientific data and have taken positions that are inconsistent with field experience.

What can you do?

Make your voice heard.

Write your congressman, your U.S. senator, the Department of Agriculture and the Environmental Protection Agency. When writing the EPA, this action against Furadan should be identified as OPP-30,000/48 and be submitted to Public Docket and Freedom of Information Section (TS-767C), Office of Pesticide Programs, U.S. EPA, 401 M Street SW, Washington, DC, 20460. Talk to your neighbors and encourage them to write. Let them know that the way they farm is about to change and they will have little to say about it unless they speak up. Now.

Thank you for your time and cooperation.

Sincerely,

A.J. Maro

A.J. Maro

Director of Marketing

APPENDIX 4

CORRESPONDENCE RELEVANT TO THE KILL OF LAPLAND LONGSPURS THAT TOOK PLACE IN 1984 IN VONDA, SASKATCHEWAN

Mineau, P. 1986. Record of phone conversation with the grower, which was then sent to him for correction and returned with comments. The identity of the grower has been removed from the letter.

Mineau, P. 1987. Letter to J. Bascietto [U.S. EPA] setting down details of kill, including the estimated number of casualties.

Environment Canada Environnement Canada

15 October 1986

Your file Votre référence

Our file Notre référence

Vonda, Saskatchewan
S0K 4N0

Dear Mr.

CAF

Thank you for taking the time to talk to me. As discussed on the phone, I have written down the details of the conversation I had with you and your wife and I would be grateful if you could check what I have written and let me know whether it is correct and whether there is anything else that I have missed.

The incident occured in May of 1984 in a 160 acre field that you were seeding with canola.

You estimate that 300+ birds were found in the field. This estimate is based on a count made a few days after you seeded the field by which time the field had been harrowed twice. More importantly, you saw dead birds spread out over the entire 160 acres of the field, usually in little clumps or groups.

This was the first time you had noticed a problem and have not had a similar problem since even though you still use the same equipment and Furadan granules.

You seeded with an air seeder and home-made cultivator. However, the methods you use are normal for your area and your equipment works in the same way as that which is used by your neighbours. I gather that you do not usually harrow the field but that this was done in 1984 in an effort to reduce the number of birds killed. (1) Could you please confirm this ?

From your experience of local practice, most farmers who apply a granular pesticide at seeding would apply it like you in front of the cultivator shovels. The reason for this is to avoid putting the granules in too deep. * 2

(1) - The fields are always harrowed. This is for leveling and incorporating the furadan & Canola.

(2) - Some-seed running the shovels very shallow in the ground and then harrow to level the land

We checked on the the seeding dates. The field was seeded May 22 + 23

The birds had been in our area. We noticed them as they flew in patterns much like the ones we refer to as snow birds.

Please let me know whether this information is correct. this will help us assess the incident. I am including a stamped envelope for your use.

Sincerely,

Pierre Mineau

Pesticide Evaluator
Canadian Wildlife Service
National Wildlife Research Centre
Environment Canada, Conservation
and Protection
Ottawa, Canada
K1A 0E7

It is very possible the incident is as coincidence in timing of the migratory flight and seeding time for the canola that year.

Environment Canada / Environnement Canada
Conservation and Protection / Conservation et Protection

23 January 198

Your file Votre référence

Our file Notre référence

John Bascietto
Ecological Effects Branch
Office of Pesticide Programs
Environmental Protection Agency
TS 769c Washington DC 20460
USA

CAF

Dear John,

As requested, here is my analysis of the carbofuran bi kill that occured in 1984 in Vonda Saskatchewan. The reports y have in hand mention that 60 'Sparrows' were found dead (2 we submitted) and later that 30 Lapland Longspurs were picked up the investigating pathologist. I endeavoured to clarify th situation by contacting both the farmer and the pathologi involved with the case. Here are my conclusions:

1. There is no doubt that carbofuran granules were direct responsible for the kill. This is the CR-10 formulation (corn c base) which is registered for canola (rapeseed) and mustard 2.8 kg of product (280 g a.i.) per ha.

2. Lapland Longspurs only were picked up. The farmer knew th large flocks were present in the area. He mentioned seeing th fly in patterns much like 'snow birds' (Snow Buntings). As y know, at that time of the year, large flocks of Horned Lark buntings and longspurs migrate through the prairies in very lar flocks. Their habit of landing in bare agricultural fields mak them vulnerable to insecticides such as carbofuran. Given so reports of flocks upward of 15,000 birds, I tried to obtain better estimate of the Vonda kill.

3. When pressed for a number, the farmer could only say th there were more than 300 dead birds when he went back to h field to harrow it a second time 2 days after he finished seedi (seeding took place on 22 and 23 May - the farmer was harrowi the field on the evening of 25 May in an effort to stop bir from dying). However, he pointed out that there were dead bir over the entire 160 planted acres in a clumped distribution.

4. The pathologist reported that 2 people found 30 birds in minutes on the evening of May 25. At that time, the farmer h just harrowed the field but had marked some areas of high carca numbers. This marking makes it difficult to judge the tr representativeness of the search pattern carried out by t pathologists. However, if one assumes that the two observers we able to each search a swath width of 30 feet (this is consider

to be wide in view of the difficulty of seeing small cryptic birds such as Longspurs, especially under failing light conditions at 1900 hours) and were travelling at 5 mph (assuming that they did not stop long to pick up the carcasses), then the carcass density is calculated to be 1/3,500 sq. ft. Extrapolating this estimate over the entire field yields a carcass estimate of approximatly 2,000 birds. As mentioned above, the search may have been somewhat better than random in view of the farmer's assistance. However, there are a number of reasons to believe that this scenario is conservative. First of all, the search parameters (both the swath width covered and the walking speed) were generous. More importantly, the search took place 78 hours after the start of seeding and there was evidence of a high scavenging pressure with half of the carcasses showing some marks of scavenging. Gulls and Crows were implicated and it is likely that large numbers of dead longspurs were removed outright from the fields. Finally, the harrowing operation would have also buried a large number of birds before the search was carried out.

I discussed the above with the pathologist who conducted the search and he thought that the figure of 2,000 birds still visible at the time of his visit was not an unreasonable estimate.

In conclusion, I suggest that for purposes of your review, a casualty estimate of 2,000 + is certainly warranted. I personally believe that the kill was much larger but the true magnitude will never be known. This kill is a good example of the hazard posed by toxic granulars such as carbofuran. The farmer seeded his field as he always does. He attributes the kill to a temporal overlap between the migration of the birds and seeding and not to any unusual set of circumstances. The methods he employs are common for his area. I believe that this kill underscores a problem of much greater magnitude. Unfortunately, chances of detecting such an event are slim and this stochastic element also makes any field research difficult if not impossible. Quite simply, one might monitor twenty different fields and not uncover any problems only to find ten thousand dead birds in the twentyfirst.

Sincerely,

Pierre Mineau
Pesticide Evaluator
Wildlife Toxicology and Surveys Branch
Canadian Wildlife Service
National Wildlife Research Centre
Ottawa, K1A 0E7

APPENDIX 5

REPORT OF A SITE VISIT FROM L. LYON (U.S. FISH AND WILDLIFE SERVICE; FORMERLY WITH U.S. ENVIRONMENTAL PROTECTION AGENCY) ON AN APRIL 1990 BIRD KILL IN A VIRGINIA CORNFIELD WHERE GRANULAR CARBOFURAN HAD BEEN APPLIED IN FURROW

Trip Report

SUBJECT: Bird deaths, Essex County, VA, 14 and 19 Apr 1990

FROM: Linda A. Lyon, Wildlife Biologist
Ecological Effects Branch (H7507C) Linda A Lyon 24 April 1990

THRU: Harry Craven, Section Head
Ecological Effects Branch (H7507C) H.T. Craven 4/24/90

TO: Jim Akerman, Chief
Ecological Effects Branch (H7507C)

On Friday, 13 April 1990 Special Agent Don Patterson (Phone: 804-771-2481, FTS-925-2481) of the Division of Law Enforcement, U. S. Fish and Wildlife Service (FWS) called me to report an ongoing bird kill incident in Essex County, VA. Beginning Monday, 9 April a farmer began planting no-till corn (30" row-spacing), using Furadan 15G (carbofuran) applied at the rate of 3 lbs of product (0.45 lbs active ingredient (AI)) per acre. Later on Monday a jogger observed dead and dying birds and reported these to Fairfax Settle (804-443-2481), the Supervisory Game Biologist from the Virginia Department of Game and Inland Fisheries (VDGIF) whose area includes Essex County.

Between Monday and Friday FWS and VDGIF personnel picked up about 200 birds. They did not count feather spots. FWS and VDGIF personnel sent about 100 birds to the Virginia-Maryland Regional College of Veterinary Medicine, Virginia Polytechnic Institute and State University.

On 14 April 1990 Ingrid Sunzenauer and I met Patterson in Virginia to visit the farm. We walked through the fields that had been planted 9 - 14 April. Although our searches were cursory, we found 14 dead birds (2 common grackles, 11 red-winged blackbirds, and 1 blue jay), 12 feather spots, and several birds exhibiting behavior consistent with cholinesterase poisoning. many of the birds had soil adhering the full length of their bills, indicating the birds likely had been probing the soil. The carcasses, especially the female red-winged blackbirds, blended into the no-till substrate. Feather spots were even more difficult to detect than carcasses and sick birds as the feather spots are flush with the surface of the field.

Condition of the carcasses indicated that the birds had died recently. One of the feather spots was adjacent to a small puddle that likely had formed following a light rain on Tuesday in a field that was planted on Monday and Tuesday. This feather spot was about 115 m from the nearest edge that offered cover vegetation. We found carcasses and feather spots in fields that had been treated up to 5 days earlier. In addition, there had been a light rain on 10 April. The rain should have further decreased the amount of carbofuran that the birds could potentially be exposed to. We found carcasses and feather spots in fields that had received rain after the corn had been planted.

Our searches were focused on the areas of the field adjacent to the edge. However, we found carcasses throughout the fields, with many found 30 - 50 m from field edges. Edge vegetation was primarily mixed hardwoods and pines. There was considerable wetland vegetation in proximity to the fields.

We spent considerable time looking for obvious signs of pesticide spillage, particularly in turn rows areas. We also followed the planter as the farmer was treating a field. Again, we looked carefully in turn row areas and along and within furrows. However, we failed to find any obvious concentrations of granules on the soil surface.

On Thursday, 19 April I returned to the farm with Steve Wolfson (Office of General Counsel), and we met Knox Turnbull (804-443-1029), a VDGIF Game Warden in the Essex County area. Turnbull showed us areas where he had recovered large numbers of carcasses. Many of these were 30 - 50 m from edge vegetation. We revisited a field that had numerous feather spots on 14 April, but we could not find feather spots in this field on 19 April.

Bird activity has been ephemeral on this farm. Some days there is notable feeding activity and other days few birds have been observed. Similarly, on some days investigators have found a significant number of carcasses and some days the searchers have not found any carcasses. There have been numerous sightings of bald eagles on the farm since 10 April. This includes a pair of eagles that investigators flushed from a field that had been treated with Furadan 15G.

The laboratory analyses confirm that the birds were exposed to carbofuran. Significant observations include the following.

(1) The application rate (0.45 lb AI/acre) should result in less potential exposure of birds to the pesticide than 1 lb AI. FMC's present risk reduction proposal highlights 1 lb AI as the maximum application rate on corn.

(2) The in-furrow method of application should result in less pesticide on the soil surface and therefore less potential exposure to birds than "conventional" band or "T-band" application. FMC's present risk reduction proposal highlights using the T-band application method. T-band is somewhat of a hybrid between in-furrow and conventional band.

(3) There were fresh carcasses in fields that had been treated with Furadan 15G up to 5 days earlier.

(4) There were carcasses in fields that had received rain since the application of Furadan 15G.

(5) Many carcasses and feather spots were a considerable distance from edge vegetation.

(6) There were no readily apparent spills of Furadan 15G granules visible on the soil surface.

I will submit VDGIF and FWS documentation to the Carbofuran Special Review docket as it is received.

cc: A. Barton
B. Duncan (VDGIF)
S. Houseknecht
K. Turnbull (VDGIF)
K. North
D. Patterson (FWS)
D. Rieder
F. Settle
I. Sunzenauer
D. Urban
S. Wolfson

APPENDIX 6

CORRESPONDENCE RELATING TO THE ANALYSIS OF THE BURROWING OWL DATA IN FOX *ET AL.* 1989

Sheldon, F.R. 1988. Criticism of Fox et al.
Collins, B.T. 1988. Rebuttal of the above.

Note: The issues raised in Sheldon's fourth paragraph were resolved in a meeting between the Canadian Wildlife Service and FMC Corporation on 5 April 1988. The publication draft was confusing, in that it did not assign separate identifiers to farms in different treatment groups (this was corrected in the published version). FMC Corporation was advised of this at the aforementioned meeting. However, they apparently failed to notify Sheldon.

JUN 09 1988
TOXICOLOGY DEPT.
FMC CORP.

To: W.F.Smith

From: F.R.Sheldon 7 Jun 88

Subject: Burrowing Owl Paper - CWS Publication Draft

Subject paper from the Canadian Wildlife Service was reviewed as requested, with special attention to Appendix 2, Analysis of Burrowing Owl Data. Although unfamiliar with customary procedure for the analysis of data from such field studies, I find the approach used in this appendix open to question.

RECEIVED JUN 21 1988 PRODUCT REG. F.M.C.

First, reference is made to the "farm effect" mentioned under Report Section 1.2, Study Area and Methods (Paragraph 2, page 7.). While I agree to the use of farm totals within each proximity score as the basis for analysis, I do not see from Appendix 2 where these totals were used in the analysis. Although the farm totals are listed in this appendix's Tables 1-4, the statistical analyses were carried out on the sums over all farms within each proximity score. There is no justification for eliminating the farm to farm variability in this manner.

Moreover, in the summary statistical tables of Appendix 2 Tables 1-4 there appears a column headed "AVERAGE" which is, in reality, the "RATIO" column expressed as a decimal number, not a true mean or average value. Using the NEST SUCCESS data of Table 1 (Appendix 2, pages 4 and 5) as an example, the true mean or average of the Sucessful Nests to Burrow ratio for Proximity 0 should be calculated from the 8 individual farm ratios of 1.0, 0.0, 0.333, 1.0, 1.0, 0.80 , 1.0 and 0.0. This calculated average is 0.642 with a standard deviation of 0.456 as contrasted with the listed "AVERAGE" on page 5 of 0.739 with no stated measure of variability.

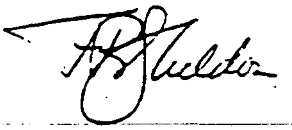
See notes 5 April 88 PM

There appears also to be some anomalous data in the four Table listings of Appendix 2. Taking Table 4 as an example, Farms C and V show 0 Nest Successes but list the Maximum No. of Young as 8 and 4 respectively. With "nest success" defined in the report as "raising at least one young" it is difficult to reconcile the appearance of young with 0 nest success. The same or similar entries in the other tables give rise to questions about the accuracy of the analysis. A question also arises as to why Farm H from Table 1 was not included in the zero proximity category of Tables 2, 3 & 4. In fact, the use of the same capital letters as farm identifiers in each of the tables is so confusing that one might suspect it as delibrate obfuscation.

Another doubtful procedure is that of including the data from pesticides other than carbofuran in the analysis for the effect of this chemical. The report acknowledges a paucity of data and that additional study would be necessary "to completely eliminate possible synergistic or additive effects", but to state that the results of multiple spraying are due to carbofuran borders on the ridiculous; especially when as many as five other sprays were involved (Table 4, Farm Z).

However, using even the flawed data of Table 4, but including the farm to farm variations, a Oneway Analysis of Variance of Nest Success vs Proximity shows no significant difference between the various levels of Proximity (Exhibit A, attached). Although the mean Nest Success values are in the same relative order as those given on page 12 of Appendix 2, the uncertainties associated with these means makes their differences statistically not significant. The same type of analysis for Brood Size produces similar results (Exhibit B).

From the foregoing, I believe the report's comments on carbofuran toxicity to be over-stated and that there is insufficient data presented to warrent the first sentence on page 10 relative to a decline in nesting success and brood size with increasing proximity. The figures under these two categories in Table 1 of the main report are flawed in that they do not include measures of uncertainty.The report's conclusions and recommendations are thus tainted to the extent that these figures were considered.



ROW	C1 (Proximity)	C2 (Burrows)	C3 (Nest Success)	C4 (Max. No. Young)	C5	C6
1	0	2	1	4	0.50000	2.00000
2	0	2	2	10	1.00000	5.00000
3	0	3	1	11	0.33333	3.66667
4	0	1	0	8	0.00000	8.00000
5	0	1	1	2	1.00000	2.00000
6	0	2	1	7	0.50000	3.50000
7	0	9	9	41	1.00000	4.55556
8	0	2	2	9	1.00000	4.50000
9	0	6	6	29	1.00000	4.83333
10	0	1	1	6	1.00000	6.00000
11	0	2	1	3	0.50000	1.50000
12	0	2	1	1	0.50000	0.50000
13	0	5	4	17	0.80000	3.40000
14	0	4	3	17	0.75000	4.25000
15	0	1	1	5	1.00000	5.00000
16	0	2	2	3	1.00000	1.50000
17	0	1	0	0	0.00000	0.00000
18	0	4	2	13	0.50000	3.25000
19	0	5	5	17	1.00000	3.40000
20	0	10	7	30	0.70000	3.00000
21	1	5	4	19	0.80000	3.80000
22	1	1	1	3	1.00000	3.00000
23	1	2	2	8	1.00000	4.00000
24	1	6	4	20	0.66667	3.33333
25	1	2	2	7	1.00000	3.50000
26	2	4	2	10	0.50000	2.50000
27	2	2	2	9	1.00000	4.50000
28	2	2	1	4	0.50000	2.00000
29	2	1	0	4	0.00000	4.00000
30	3	5	0	0	0.00000	0.00000
31	3	1	0	0	0.00000	0.00000
32	3	1	1	4	1.00000	4.00000

EXHIBIT A:

MTB > ONEWAY C5 C1

ANALYSIS OF VARIANCE ON C5 → *NEST SUCCESS*

SOURCE	DF	SS	MS	F
C1	3	0.728	0.243	2.00
ERROR	28	3.397	0.121	
TOTAL	31	4.125		

```
                                        INDIVIDUAL 95 PCT CI'S FOR MEAN
                                        BASED ON POOLED STDEV
LEVEL      N     MEAN     STDEV     --+---------+---------+---------+----
    0     20   0.7042    0.3353                    (---*---)
    1      5   0.8933    0.1535                    (-------*-------)
    2      4   0.5000    0.4082          (--------*-------)
    3      3   0.3333    0.5774     (---------*----------)
                                    --+---------+---------+---------+----
POOLED STDEV =   0.3483            0.00      0.40      0.80      1.20
```

EXHIBIT B:

MTB > ONEWAY C6 C1

ANALYSIS OF VARIANCE ON C6 → *BROOD SIZE*

SOURCE	DF	SS	MS	F
C1	3	12.57	4.19	1.38
ERROR	28	85.09	3.04	
TOTAL	31	97.67		

```
                                        INDIVIDUAL 95 PCT CI'S FOR MEAN
                                        BASED ON POOLED STDEV
LEVEL      N     MEAN     STDEV     -----+---------+---------+---------+-
    0     20    3.493     1.913                          (----*----)
    1      5    3.527     0.392                     (---------*---------)
    2      4    3.250     1.190                  (----------*----------)
    3      3    1.333     2.309     (-----------*-----------)
```

to: G. Fox
P. Mineau
Toxic Substances Evaluation and Monitoring Division

August 23, 1988

from: Senior Biostatistician
Migratory Birds Surveys Division

subject: COMMENTS ON BURROWING OWL PAPER

I have reviewed the comments made by F.R. Sheldon on the statistical methodology used in the burrowing owl paper. It is apparent from paragraphs 2 and 3 of Mr. Sheldon's comments that he has not understood the technique used. I will try to provide a more detailed explanation.

ESTIMATION OF SUCCESS RATE

The variable which we want to study is the proportion of burrows which successfully produce young. There are several formulas for estimating this value. Let

n_j = number of burrows on farm j

x_j = number of successful burrows on farm j

p_j = proportion of successful burrows on farm j

= x_j/n_j

w_j = weighting factor for farm j

The overall average success rate can be estimated as a weighted average of the individual farm success rates

$$p = \frac{\sum_{j=1}^{m} w_j p_j}{\sum_{j=1}^{m} w_j}$$

The estimate of overall success rate proposed by Mr Sheldon giving

$$\hat{p} = \frac{\sum_{j=1}^{m} p_j}{m}$$

The analysis which was performed in the report used weighting by the number of burrows on the farm i.e. setting

$w_j = n_j$.

giving

$$p' = \frac{\sum_{j=1}^{m} n_j p_j}{\sum_{j=1}^{m} n_j}$$

$$= \frac{\sum_{j=1}^{m} x_j}{\sum_{j=1}^{m} n_j}$$

I believe that weighting by number of burrows provides a more valid and easily interpreted measure of the success rate. For example if there were two farms with 1 burrow on one farm which was successful and 9 burrows on another farm none of which were successful. The unweighted estimate of the average success rate would be (1.0 +0.0)/2 =0.5 which is obviously incorrect measure of the success rate. Using the average weighted by the number of burrows on the farm gives (1+0)/(1+9)= 0.1 which is a better measure of the ability of the population to successfully reproduce itself.

ESTIMATES OF VARIABILITY

One of the consequences of using p' as a measure of success rate is there is no simple measure of the variability of the estimate since the weights themselves are a random variable. A measure of variance could be developed based on a jackknife estimate of variance or using the theory of ratio estimates from sample surveys. However, the statistical analysis presented in the next

STATISTICAL TEST

The statistical analysis is based on a randomization test. Consider the hypothetical data shown in Table 1 in which there are 3 farms in each of 2 treatment groups.

TABLE 1 Hypothetical data

GROUP	OBSERVATIONS			p	p'
1	8/8	5/6	2/3	0.833	15/17 = 0.882
2	5/7	2/5	1/4	0.455	8/16 = 0.500

Using p' the observed difference between the two groups is 0.882-0.500=0.332. The objective of the statistical analysis is to determine if a difference of this magnitude is likely to occur when there is no group effect.

If there is no effect due to groups, the assignment of observations to groups is completely at random. Given the observations we can calculate all possible manners in which the observations could have been assigned to the 2 groups. In this example there are 20 possible manners in which the 6 observations could have been assigned to the 2 groups, Table 2 shows all these possible assignments and the observed difference in the p' value between the two groups. The observed values are shown as case 1 in this list. Only case 2 showed a larger value for the difference between the two groups. Using a randomization test one would say that the probability of observing as large a positive difference between group 1 and group 2 would be 2/20 = 0.10. This is a one-sided test of whether group 1 is significantly larger than group 2.

In most realistic problems there are too many possible assignments of the observations to groups for a complete enumeration of all cases to be performed. In these situations a random selection of a reasonably large number of cases is selected and the required probability of the observed event is estimated from these cases.

The randomization test for detecting differences in the proportion surviving between two treatment groups was compared to several other methods (Crump and Howe, 1979) and was shown to provide the correct significance level while attaining the highest power level.
The analysis used in the burrowing owl paper is an extension of this technique to the situation in which there are several ordered treatment groups. A simple linear regression of p' against proximity is used to measure the treatment effect.

TABLE 2 All possible assignments of the observations to the treatment groups for hypothetical data

	GROUP 1		GROUP 2		
CASE	OBSERVATIONS	p'	OBSERVATIONS	p'	DIFFERENCE
1	8/8 5/6 2/3	0.882	5/7 2/5 1/4	0.500	0.332
2	8/8 5/6 5/7	0.857	2/3 2/5 1/4	0.417	0.440
3	8/8 5/6 2/5	0.789	2/3 5/7 1/4	0.571	0.218
4	8/8 5/6 1/4	0.778	2/3 5/7 2/5	0.600	0.178
5	8/8 2/3 5/7	0.833	5/6 2/5 1/4	0.533	0.300
6	8/8 2/3 2/5	0.750	5/6 5/7 1/4	0.647	0.103
7	8/8 2/3 1/4	0.733	5/6 5/7 2/5	0.667	0.067
8	8/8 5/7 2/5	0.750	5/6 2/3 1/4	0.615	0.135
9	8/8 5/7 1/4	0.737	5/6 2/3 2/5	0.643	0.094
10	8/8 2/5 1/4	0.647	5/6 2/3 5/7	0.750	-0.103
11	5/6 2/3 5/7	0.750	8/8 2/5 1/4	0.647	0.103
12	5/6 2/3 2/5	0.643	8/8 5/7 1/4	0.737	-0.094
13	5/6 2/3 1/4	0.615	8/8 5/7 2/5	0.750	-0.135
14	5/6 5/7 2/5	0.667	8/8 2/3 1/4	0.733	-0.067
15	5/6 5/7 1/4	0.647	8/8 2/3 2/5	0.750	-0.103
16	5/6 2/5 1/4	0.533	8/8 2/3 5/7	0.833	-0.300
17	2/3 5/7 2/5	0.600	8/8 5/6 1/4	0.778	-0.178
18	2/3 5/7 1/4	0.571	8/8 5/6 2/5	0.789	-0.218
19	2/3 2/5 1/4	0.417	8/8 5/6 5/7	0.857	-0.440
20	5/7 2/5 1/4	0.500	8/8 5/6 2/3	0.882	-0.382

ALTERNATIVE TEST

Mr Sheldon proposes using an ANOVA based on the observed p_i

values. This analysis uses p as the estimate of overall success rate within the group. His analysis of the data does not reveal any significant differences among the groups but this is because he is not using the most efficient method of analysis. He uses an F-test to detect whether there is any differences among the groups. A more powerful test can be run by searching for differences which are in the direction of interest. In this case we are interested in whether increasing proximity of furadan exposure causes a decline in success rate. Using an omnibus test for differences among the treatment groups has a smaller power to detect this difference than running a test which is specifically designed to search for this type of trend.

I have redone the analysis proposed by Sheldon and separated out the linear contrast for trend across the proximity score and used a one-sided test for a declining rate. (This is similar to running a linear regression of success rate on proximity score except the within group sum of squares is used for the error term in assessing the significance of the regression.) The analysis of the success rate and maximum nestlings per burrow indicated asignificant (p=0.018 and p=0.03 respectively) decline with increasing proximity score. These significance levels are not as extreme as those presented in the original report (p=0.002 and p=0.007) but are significant at the 5% level.

Brian Collins

BRIAN COLLINS

REFERENCE

Crump K.S. and Howe R.B. (1979) A Small Sample Study of Permutation Tests for Detecting Teratogenic Effects, Ebon Research Systems, Washington D.C.

APPENDIX 7

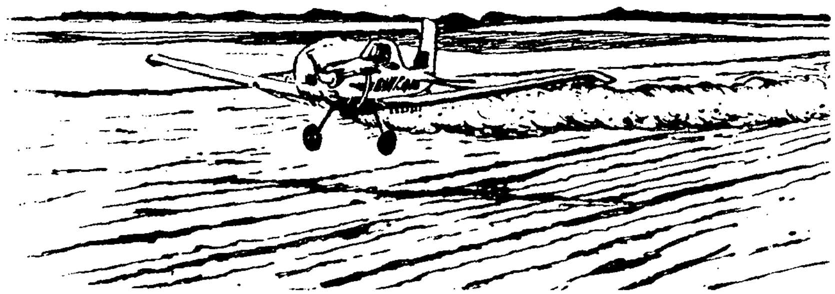
COPY OF THE PAMPHLET PRODUCED BY THE CANADIAN WILDLIFE SERVICE AND DISTRIBUTED BY CHEMAGRO LTD. WARNING OF THE HAZARDS OF CARBOFURAN USE TO THE BURROWING OWL

unicipalities in which urrowing Owls are most bundant:

ASKATCHEWAN	R.M.
l Marie	17
ld Post	43
[illegible]	51
ott	98
aledonia	99
att's Lake	129
edburn	130
aildon	131
herwood	159
ense	160
oose Jaw	161
iverside	168
ictory	226
acadena	228
iry Creek	229
oteau	255
nipe Lake	259
Rosedale	283
Rudy	284
ertile Valley	285
Milden	286
St. Andrews	287
Kindersley	290
Dundurn	314
Montrose	315
Harris	316
Corman Park	344
Vanscoy	345

MANITOBA	R.M.
Argyle	102
Edward	122
Arthur	103
Brenda	109
Winchester	205
Albert	100
Cameron	111
Pipestone	162
Sifton	184
Whitewater	204
Whitehead	202
Cornwallis	116
Morton	153
Glenwood	131
Oakland	157
Riverside	166
Turtle Mountain	196
Strathcona	192
Roblin	167

ALBERTA	
Vulcan	CO 02
Newell	CO 04
Warner	CO 05
Wheatland	CO 16
Cypress	MD 01
Taber	MD 14
Willow Creek	MD 26
Hanna	SA 02



Burrowing Owl Recovery Team contacts

Efforts are currently underway to restore the Burrowing Owl to its former range. For more information on how you may help this species, contact your provincial representative:

Dale Hjertaas
Parks & Renewable Resources
3211 Alberta Street
Regina, Saskatchewan
S4S 5W6
Phone: (306) 787-2892

Ken De Smet
Manitoba Department of Natural Resources
Box 14, 1495 St. James Street
Winnipeg, Manitoba
R3H 0W9
Phone: (204) 945-6301

Steve Brechtel
Alberta Fish and Wildlife Division
9945 - 108 Street
Edmonton, Alberta
T6H 4P2
Phone: (403) 422-9535

The Canadian Wildlife Service provides advice to Agriculture Canada on the impacts of pesticides on wildlife. It does so through review of data submitted by pesticide manufacturers in support of their products as well as through a research program directed at current uses of pesticides.

Users of pesticides are encouraged to be alert to possible risks to wildlife and the environment. Users should read labels carefully, including all advice pertaining to the protection of wildlife and its habitat.

Pesticide registration authorities depend on your cooperation in identifying potential problems to wildlife resulting from pesticide use. If you are aware of impacts on wildlife or desire more information, please contact the Head of Pesticide Evaluation, National Wildlife Research Centre, Canadian Wildlife Service, Environment Canada, Ottawa, Ontario K1A 0H3.

Également disponible en français sous le titre: *Vous pouvez aider une chouette menacée.* Veuillez écrire à: Publications, Service canadien de la faune, Environnement Canada, Ottawa (Ontario) K1A 0H3.

Printed on paper containing recovered waste

Think Recycling!

Pensez à recycler!

Canada

Environment Canada / Environnement Canada
Canadian Wildlife Service / Service canadien de la faune

ATTENTION FURADAN USERS:

You Can Help an Endangered Owl

The new supplemental label for Furadan 480 Flowable now includes precautions regarding the Burrowing Owl.

Users of the insecticide Furadan 480 F (carbofuran) are now required to avoid spraying within 250 m (metres) of any Burrowing Owl nest. This publication has been prepared to alert users of Furadan to this new label requirement. It advises farmers, fieldmen and custom applicators what precautions they must take to protect this endangered species.

The Burrowing Owl, or "Ground Owl," is found in southern Saskatchewan, southern Alberta, and southwestern Manitoba. This small owl lives mostly on the ground and nests in burrows made by badgers and ground squirrels (gophers). Once a common sight on pastures and grassland, the owl has declined to about 2,000 pairs. As a result, the Burrowing Owl has been placed on Canada's endangered species list, and government and private agencies are working to protect the remaining owls.

Why is the Burrowing Owl disappearing?

The plowing of pasture and grassland may be a major reason. Also, many owls are killed by vehicles, late spring snowstorms, and being mistaken for gophers.

Recently, another possible cause for the species' decline has come to light. It has been found that Burrowing Owls are sensitive to Furadan sprayed near their burrow.

In 1986, Environment Canada's Canadian Wildlife Service monitored 99 pairs of nesting owls on farms where spraying for grasshoppers was taking place. Records were kept of the insecticides used, the number of times each was applied, and how close the spray was applied to the nest burrows. Owl pairs were watched and young were counted when they emerged from the burrows.

Why the precaution with Furadan?

Nest burrows sprayed directly with Furadan produced **83 percent fewer young** than nest burrows exposed to other insecticides. In many instances, adult owls were no longer seen after their nest burrows were sprayed with Furadan. Overall, the results showed that as spraying distance from nest burrows increased, effects on the owls decreased.

What to do

Based on these findings, Agriculture Canada and the manufacturer and Canadian distributor of Furadan are requiring users of Furadan 480 F to survey their land and adjacent margins for the owls and to avoid spraying closer than 250 m (273 yd) from occupied nest burrows. In addition to this requirement, the product label suggests that you clearly mark this 250-m set-back margin.

Farmers, fieldmen, and custom applicators

When planning either an aerial or ground application of Furadan, read the product label carefully, follow the directions and remember to:

- Mark a 250-m radius around the nest burrow(s). (Don't place a marker on the burrow itself). If the land belongs to someone else, check with the owner as to the presence of Burrowing Owls. If in doubt, use an alternate method of control.
- Inform the person who will be doing the spray application about the markers.
- Roadsides and rights-of-way: check the right-of-way and adjoining fields in advance. Put markers along the right-of-way to indicate where to stop and start application. If this is not possible, use an alternate method of control.
- Take wind speed and direction into account when spraying.

How to find occupied nest burrows

During the day, the Burrowing Owl stays close to its nest burrow. Starting in late April, look for a small brown owl with large yellow eyes, long legs, and stubby tail standing like a sentinel on the ground. At dawn and dusk, the owl may be off hunting grasshoppers and rodents.

The nest burrow is simply an abandoned gopher or badger hole. Pieces of dried cow manure, used by the owl to line the nest burrow, are sometimes found at the burrow's entrance. Nest burrows are located in areas of sparse, low vegetation such as grazed pastures, rangeland, and roadsides.

Several pairs of Burrowing Owls may nest close together. In late June or early July, when the young owls emerge from the nest and join the adults above ground, family groups can be seen standing together at their nest burrows.