Direct Losses of Birds to Pesticides – Beginnings of a Quantification[1]

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Abstract

Recent analyses and modeling of avian pesticide field studies have led to the conclusion that bird kills are regular and frequent in insecticide-treated fields. Unfortunately, data are seldom adequate to quantify this mortality. Also, mortality is expected to be highly variable in response to varying bird presence in and around treated fields. Studies reporting kills of birds in cornfields treated with granular formulations of carbofuran provide a good example of the types of calculations that are needed to estimate direct bird losses in farm fields. Several studies provide the means to correct carcass counts for search efficiency and scavenging. Based on typical Midwest cornfields, use of granular carbofuran resulted in an estimated annual mortality rate of 3.0 to 16 songbirds per ha of treated field, the higher number corresponding to better field edge habitat. Much larger kills also occurred where fields bordered non-crop habitat more suitable for birds. At the peak of its popularity in the United States, this single product was conservatively giving rise to an estimated annual loss of 17-91 million birds in cornfields alone. Granular carbofuran formulations continue to be sold and used in most Latin American countries on a wide variety of crops.

Key words: agriculture, bird kills, carcass counts, cornfields, *Eremophila alpestris,* Horned Lark, pesticides, scavenging.

Introduction

Birds are extremely mobile, and it is therefore difficult to exclude them from areas that have been treated with pesticides. Also, birds are opportunistic foragers and several species respond to agricultural pests by entering treated areas to gorge themselves on the pest species (Kirk et al, 1996). As reviewed by Brown (1978), birds were amongst the first casualties recorded in the course of our earliest attempts to control pests on a broad scale with chemicals. For example, application of calcium arsenate dust to German forests in the mid 1920s resulted in extensive mortality of Woodlarks (*Lullula arborea*) and Whitethroats (*Sylvia communis*). The first comprehensive institutional review of agrochemical use in the US – otherwise known as the Mrak Commission – concluded that "Much of the significant evidence on the worldwide effects of insecticides have been provided by birds." (Mrak 1969) The main 'effects' the authors of this report had in mind was undoubtedly such impacts as eggshell thinning from the persistent organochlorine insecticide DDT as well as the extensive contamination and kills of seed eaters and their predators by cyclodiene insecticides such as aldrin and dieldrin. The use of persistent and bioaccumulating pesticides such as the organochlorines has now been greatly reduced in most of the world but the replacements are not without their impact on birds also.

Two groups of neurotoxic pesticides, the organophosphorous and carbamate compounds tend to be very acutely toxic to birds and cases of mortality are frequently reported (e.g. Mineau et al. 1999). Ongoing cases of mass mortality and the apparent indifference to such mortality has been roundly denounced in the popular press (e.g. Williams 1997). However, it has been difficult to quantify the full extent of this mortality. Pimentel (1992) advanced a figure of a direct pesticide (poisoning) kill of birds in the US of 67 million per year based on the estimate that 10 percent of exposed birds would be killed. Unfortunately, whether high or low, this figure is not easily defensible. Recent analyses and modeling of avian pesticide field studies (Mineau 2002) have led to the conclusion that bird kills are regular and frequent in insecticide-treated fields; to arrive at a scientifically defensible estimate of the actual number of bodies will be much more difficult. One reason is the difficulty of finding carcasses because of the high scavenging rates that are the norm in farmland (Mineau and Collins 1988). For example, Balcomb (1986) found overnight disappearance rates of songbirds as high as 92 percent in Maryland cornfields.

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Also, it is exceedingly difficult to define an average agricultural field and quantify the bird presence (and hence, possible impact) in such a field at the time of pesticide application. In some cases, the extent of bird mortality is defined not so much by the pesticide as it is by the number of birds present to be killed. This will be apparent in the example provided below – that of granular formulations of carbofuran, specifically the silica-based formulations formerly used at planting in corn, potatoes and a number of other crops. The use in corn specifically has been thoroughly studied and, because it became part of a US special review, the information is in the public domain and available from the US EPA (Environmental Protection Agency) docket office, or obtainable through the provisions of the Freedom of Information Act. These studies were reviewed in earlier publications (e.g. Mineau 1988, 1993, US EPA 1989) but this is the first attempt to make them fully quantitative by correcting the figures for scavenging losses and search efficiency.

Case Study: Estimating Numbers of Birds Killed by Granular Carbofuran at Seeding in Corn

The following case study is used to highlight a ‘worst-case’ impact of pesticides on birds in an agricultural setting. Carbofuran is especially toxic to birds, and its formulation on silica particles (ideal grit material) ensured ample exposure to birds (Mineau 1993). Fortunately, most uses of granular carbofuran formulations have now been discontinued in the US and no granular formulations of this pesticide are permitted in Canada. However, they remain registered on a large variety of crops in most of Latin America where they continue to place our migratory birds at risk. A recent (June 2002) emergency exemption for 10,000 acres of rice in Louisiana and subsequent revocation about a month later shows that the pros and cons of this chemical continue to be the subject of debate. In addition, there are other granular pesticides, although perhaps slightly less toxic, which have similar albeit slower acting effects on birds in agricultural settings.

Available Studies

There are few pesticide use patterns whose effects on birds have been characterized as thoroughly as granular carbofuran in corn. Studies were carried out in Utah (Booth et al. 1983) as well as in Iowa and Illinois (Booth et al. 1986). Other studies (e.g. Balcomb et al. 1984, Stinson 1991) provide additional supporting evidence but the studies by Booth and colleagues were done on a scale and intensity that allow for a better quantification of the mortality. Because mortality from carbofuran is reasonably quick, it is probably easier to detect mortality with this product than with some of its competitors. *table 1* provides details of the study designs and carcass searching protocols. Searching for carcasses pre- and post-treatment is the traditional method used to quantify mortality. In the studies presented, virtually all the documented mortality could be ascribed to treatment, as deduced from the following lines of evidence:

1. a virtual absence of carcasses pre-treatment despite very intensive searches of the fields;
2. very low levels of mortality on 'control' plots and indications that virtually all of this 'control' mortality consisted of birds moving in from treated plots before dying;
3. chemical and/or biochemical diagnosis of a number of carcasses still suitable for analysis; and
4. obvious signs of intoxication in several birds.

The three studies as a group are probably a fair representation of typical spring corn planting in the US and of the hazards this type of pesticide treatment poses to birds. One possible exception is the Iowa study where granule spills at row ends and throughout the field area were covered manually by observers on foot in an effort to reduce exposure to birds. Although this is not standard agricultural practice, it probably had minimal effect on the study outcome. Regardless of the rate and exact method of application, there is always a surplus of granules left on the soil surface available to kill birds (Mineau 1993) and a single carbofuran granule is generally lethal to a songbird (Balcomb et al, 1984). The different study designs provide us with different measures that can be used to estimate true mortality rates for both the field centers and field perimeters (*table 2*). The latter typically receive much more bird visitation than field centers (Best et al, 1990). For most species inhabiting farmland, visits into the field are generally from one of the field edges. It is therefore most logical to quantify the kill rates of some species on the basis of field edge rather than field area. This is in sharp contrast to a few species such as the Horned Lark (*Eremophila alpestris*) which shuns edges and is found at similar density throughout the field. This species was therefore quantified on the basis of field area. Other edge-aversive species such as the Killdeer (*Charadrius vociferus*) or Eastern Meadowlark (*Sturnella magna*) were not found in sufficient numbers to warrant separate treatment, as was the case for the Horned Lark.

Table 1— *Carcass search protocol.*

State	Risk of exposure[a]	Average field size	Search effort	Search method	Duration of search post-application	Number of searches
Iowa[b]	lower than average	20.7 ha	high	lines of searchers – entire crop area	45 days	18-20 per field
Illinois[c]	average	11.5 ha	high	same	45 days	18-20-field
Utah[d]	higher than average	17.1 ha	very high	same	69 days	daily

[a]Risk of exposure based on application rate and method.
[b]Granule spills at row ends and throughout field area were manually covered by observers on foot in an effort to reduce exposure to birds. This is not standard agricultural practice. Surrounding area was primarily grassy and agricultural.
[c]Surrounding habitat was considered superior for birds than in Iowa. More trees and cover available.
[d]Surrounding habitat: grass and pastures with high weed content. These were plots rather than separate fields, some of the plots being contiguous.

Table 2— *Mortality by species group.*

		Raw carcass counts (primary poisoning in searched treated area only)[a]			Uncorrected carcass counts standardized for area or length of field edge	
State	Species	Field center	Field perimeter	Total	Total carcasses per 100 ha of field	Total carcasses per km of field edge
Iowa	all birds	8	20	28	22.5	2.2
	HOLA[b]			9	7.2	-
	non-HOLA			19	-	1.5
Illinois	all birds	20	70	90	130.4	9.9
	HOLA			11	15.9	-
	non-HOLA			79	-	8.7
Utah	all birds			873	849.2	N/A[c]
	HOLA			799	777.2	-
	non-HOLA			74	-	N/A[c]

[a]Primary kills only. Kills of raptors and other scavenger species excluded. Secondary poisoning with carbofuran is frequent (Mineau et al 1999) but difficult to quantify because most individuals expected to die offsite.
[b]HOLA - Horned lark
[c]Several 'fields' are actually plots bordered by other corn plots which precludes a measurement of the amount of field edge available.

None of the studies searched the habitat adjacent to the field for carcasses despite evidence that birds were flying between fields and therefore ran a high risk of dying away from the immediate area of the crop. Working with a similar product (a granular formulation of diazinon insecticide used in corn at planting in south-central Iowa), Johnson (1990) documented an additional 1.4 bird carcasses per unit of transect in the habitat adjacent to the field for each carcass actually found in the perimeter of the corn field. This suggests a correction factor of 2.4 to be applied to perimeter counts of carcasses where the search did not extend beyond the crop area. This is probably a very conservative correction because Johnson did not search the entire habitat adjacent to the field but merely a single transect of approximately 6 m in width.

Correcting for Search Efficiency and Scavenging

So far, none of the estimates presented in *table 2* has been corrected for search efficiency or for scavenging. As reviewed elsewhere (Mineau and Collins 1988), these factors can result in most of the carcasses not being located by the search teams. Unfortunately, scavenging rates measured by Booth and colleagues in the carbofuran studies only documented the loss of older carcasses and 'feather spots' and not that of fresh ones (they were taken for residue analysis). For this reason, the study by Johnson (1990) was used again. Under similar conditions of intensive search (12 systematic transect searches including 5 daily searches immediately post application), and in similar agricultural settings, they determined that 15 percent of carcasses (in a range of sizes) 'seeded' on the search transects over the first three days post application were recovered by the search teams. This correction factor, which accounts for both searcher efficiency and scavenging, appears to be a reasonable all-around factor for studies in freshly-seeded cornfields. Balcomb (1986) found that scavenging alone resulted in an average 24-hour loss of 75 percent of songbird carcasses from bare cornfields in Maryland. The average search efficiency reported by Booth and colleagues (1983, 1986) in the Iowa and Illinois studies for 'dummy carcasses' was about 60 percent for any one search. Combining these two independent values places the likely success rate of finding a carcass at 15 percent also ((1-0.75) x 0.60 = 0.15). This assumes that subsequent searches do not improve very much the probability of finding fresh carcasses, a reasonable assumption given the high scavenging rates documented by most observers. A 15 percent recovery rate was therefore applied to all studies, although it is possible that, in the case of the Utah study, scavenging rate was less because of a 'swamping' effect of so many carcasses in such a small area.

Focus on the Horned Lark

It is difficult to find estimates of densities of Horned Lark or of other species inhabiting cornfields in order to estimate what proportion of birds may have been killed by treatment. Beason and Franks (1974) reported 13 Horned Lark territories in a 35.6 ha corn and hayfield plot in Illinois. This equals a breeding bird density of 73 birds per 100 ha, or a total lark density of 100 birds per 100 ha, assuming the simultaneous presence of all fledged young (average fledging rate calculated to be 0.75 young per clutch by Beason and Franks). Territory size in their study ranged from 0.6 to 3.1 ha with a mean of 1.6 ha. Using their average territory size would place the maximum number of breeding larks at 125 birds per 100 ha (or 172 per 100 ha with fledglings) given perfect 'packing' of territories. Graber and Graber (1963) in Illinois gave Horned Lark densities (based on strip counts of field centers) averaging between 7.4 larks per 100 ha to 106 larks per 100 ha depending on the year and location within the State. The carbofuran kill rates of 48 and 106 larks per 100 ha estimated from the Iowa and Illinois studies (*table 3*) would therefore represent the majority of the larks on site if densities were in line with the estimates given above. Yet, based on transect counts obtained during the carbofuran impact studies in Iowa and Illinois, Best and colleagues (Best et al 1990) reported that carbofuran use did not result in significant differences in transect counts between treated and untreated fields. They estimated Horned Lark densities of 0.5 per 100 ha (sd = 1.1) in the middle of Iowa cornfields and 6.8 per 100 ha (sd = 9.6) in Illinois. These clearly are very low density estimates compared to the estimated kills in those same fields. This suggests that their transect counts were not very sensitive to on-going mortality and/or that floaters were coming in from adjacent areas to fill the vacancies or simply to forage in the fields regardless of the field-specific kill rate. Movement of birds from off-site areas was clearly happening in the Utah field study. A total of 799 Horned Lark carcasses were actually recovered in that study (*table 1*). Most were young of the year birds hatched in surrounding fields. After correcting for search efficiency and scavenging, it can be estimated that over 50 birds were drawn in from surrounding habitat and poisoned for each treated hectare (*table 3*). It is noteworthy that, despite this very large kill rate, these authors also were unable to show any decrease in bird activity based on transect counts, thus clearly pointing out the limitations of that technique.

Table 3— *Uncorrected and corrected estimates of mortality.*

	Horned Lark per 100 ha		Non-Horned Larks per km field edge			
Study	Uncorrected	Corrected[a]	Uncorrected	Corrected[a]	Including habitat adjacent to the fields[b]	Total average primary poisoning per ha cornfield[c]
Iowa	7.2	48	1.5	10	24	3.05
Illinois	15.9	106	8.7	58	139	15.9
Utah	777.0	5180	-	-	-	-

[a]Corrected by estimates of searcher efficiency and scavenging rates.
[b]This correction deemed necessary for 'edge species' likely to leave fields to die. Edge-aversive species such as Horned larks are less likely to leave the fields to die. A correction factor of 2.4 was used after Johnson (see text).
[c]Total for all species (Horned Lark and non-Horned Lark). This estimate is based on a hypothetical field constructed from the sample of fields studied in Iowa and Illinois: The sample of cornfields in the two States combined had a median area of 15 ha and an aspect ratio of 1.7. This corresponds to a 297 m x 505 m field with a perimeter of 1604 m.

Extrapolating to the US as a Whole

Kill rates for Horned Larks and other species were corrected separately as described earlier. Assuming a hypothetical corn field 'constructed' from the median size and aspect ratio of the fields used in the Iowa and Illinois studies, an average rate of kill can be estimated to be between 3.05 and 15.9 songbirds per hectare of corn (*table 3*). If birds are drawn to a treated field from surrounding areas, then clearly the 'ecological footprint' of the treatment is much larger that the field itself. However, in calculating the overall loss of birds from the use of a chemical, there is bound to be a certain degree of 'double accounting' in the case of adjoining fields where both are treated: The same birds cannot be killed twice. This aspect will be ignored in the following extrapolation although it may result in kill estimates being slightly inflated. A countervailing bias is that we know the number of birds dying off-site to be grossly underestimated (see below). Assuming that the Illinois and Iowa fields were more typical of the main US Corn Belt than the Utah field sites, we can estimate the overall loss of birds resulting from the use of granular carbofuran. According to the US EPA, the US use of carbofuran granular to seed corn declined from a high of 5.7 million ha in 1978 to about 1.8 million ha in 1985 for a cumulative total of about 26 million ha for this 8-year period (USEPA 1989). At its peak, therefore, this single chemical formulation was killing an estimated 17 to 91 million songbirds annually in the US Corn Belt (depending on whether the estimate is based on the Iowa or on the Illinois numbers – *table 3*). This does not include kills in other crops in which the product was registered and applied under similar conditions (e.g. at planting to relatively bare ground) such as soybean, sorghum, peanuts, tobacco, cotton or sunflowers. It also does not include the occasional large scale kill as seen in the Utah study where the surrounding habitat was conducive to a large movement of birds into the treated field. Finally, this estimate also excludes the secondary kills of predators and scavengers.

Conclusions

Under normal circumstances, mortality of birds in fields is not likely to be detected unless the birds in question are large and highly visible, and they happen to die in large groups in areas of high public visibility (e.g. the case of waterfowl killed by diazinon (Stone and Gradoni 1980)). Even then, cases rarely come to the attention of regulatory authorities. Conversely, we can predict that most of the ongoing pesticide-induced avian mortality in North American agriculture is likely to be of small, highly cryptic, and widely dispersed species. Little of that mortality is likely to come to light without the benefit of large-scale expensive field surveillance exercises. Even then, efforts to detect carcasses are likely to be unsuccessful if time to death is increased (the case with some newer products), search intensity inadequate or scavenging excessive (Mineau and Collins 1988). As mentioned above, the use of the granular formulations of carbofuran has been greatly reduced in the US, and, after a 15-year struggle, all granular formulations were completely withdrawn from Canada. However, our information is that these granular formulations are widely registered in Latin America where our neotropical migrants and many local resident species are most certainly exposed to lethal doses. On wintering or staging grounds where certain species might be concentrated, the activities of a few individual farmers or pesticide applicators can have enormous impacts relative to those calculated for the breeding grounds. For example, an estimated 20,000 Swainson's Hawks (*Buteo swainsoni*) were killed in a small area of the Argentine pampas by applications of the organophosphate monocrotophos (Hooper et al. 1999); the same chemical had killed an estimated 10,000 American Robins (*Turdus migratorius*) in two small Florida potato fields (Lee 1972) and several thousand migrants of 37 species were killed by a single mosquito control application of the insecticide fenthion (Seabloom et al. 1973). Recent analysis of the entire corpus of avian field studies (studies such as the ones described here – Mineau 2002) indicates that these publicized kills are not isolated events but rather the 'tip of the iceberg.' Given the usual application rates at which current use insecticides are sprayed, direct mortality of exposed birds is both inevitable and relatively frequent with a large number of insecticides currently registered. The absence of bird carcasses is not a good indication that any given pesticide use pattern is safe for birds. Before the US EPA mandated field testing with granular carbofuran (based on an acute toxicity trigger), only a handful of very small kills had come to light.

It is also clear, however, that the full extent of avian pesticide-induced mortality will be very difficult to calculate. Very few pesticides have received sufficient scrutiny to allow for the type of calculations that were done here for granular carbofuran in corn. Finally, even when the direct kill can be estimated, it ignores the less obvious chronic or sub-acute behavioral or physiological effects that some pesticides have on birds, such as compromised escape behaviors or breeding success (Grue et al 1997) or the indirect food-mediated effects (Potts 1986) that might also negatively affect bird populations.

Literature cited

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

Balcomb, R., C. A. Bowen, D. Wright, and M. Law. 1984. **Effects on wildlife of at-planting corn applications of**

granular carbofuran. Journal of Wildlife Management 48(4): 1353-1359.

Balcomb, R., R. Stevens, and C. A. Bowen, II. 1984. **Toxicity of 16 granular insecticides to wild-caught songbirds.** Bulletin of Environmental Contamination and Toxicology 33: 302-307.

Beason, R. C. and E. C. Franks. 1974. **Breeding behavior of the Horned Lark.** Auk 91: 65-74.

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.** American Midland Naturalist 123: 84-99.

Booth, G. M., M. W. Carter, D. L. Fischer, C. D. Jorgenson, L. B. Best, and R. W. Whitmore. 1986. **Effects of Furadan formulations 10G and 15G birds associated with Iowa and Illinois cornfields.** FMC Corporation, Unpublished report, 22 December 1986, 354 p.

Booth, G. M., M. W. Carter, C. D. Jorgensen, C. M. White, and R. C. Whitmore. 1983. **Effects of Furadan formulations 10G and 15G on avian populations associated with corn fields.** FMC Corporation, Unpublished report, July 1993, 106 p.

Brown, A. W. A. 1978. **Ecology of pesticides.** New York, NY: John Wiley and Sons.

Graber, R. R. and J. W. Graber. 1963. **A comparative study of bird populations in Illinois, 1906-1909 and 1956-1958.** Illinois Natural History Survey Bulletin 28: 383-538.

Grue, C. E., P. L. Gibert, and M. E. Seeley. 1997. **Neuro-physiological and behavioral changes in non-target wildlife exposed to organophosphate and carbamate pesticides: Thermoregulation, food consumption, and reproduction.** American Zoologist 37: 369-388.

Hooper, M. J., P. Mineau, M. E. Zaccagnini, G. W. Winegrad, and B. Woodbridge. 1999. **Monocrotophos and the Swainson's Hawk.** Pesticide Outlook 10(3): 97-102.

Johnson, G. 1990. **Diazinon 14G: an evaluation of its effects on wildlife associated with corn fields in southern Iowa.** Ciba Geigy Corporation, Unpublished; 440 p. (EPA MRID 415147-01).

Kirk, D. A., M. D. Evenden, and P. Mineau. 1996. **Past and current attempts to evaluate the role of birds as predators of insect pests in temperate agriculture.** Current Ornithology (5): 175-269.

Lee, C. 1972. **Death in the Potato Fields.** The Florida Naturalist 45: 60-61.

Mineau, P. 1988. **Avian mortality in agro-ecosystems. 1. The case against granular insecticides in Canada.** In: M. P. Greaves, B. D. Smith, and P. W. Greig-Smith, editors. Field Methods for the Study of Environmental Effects of Pesticides. Croydon, UK: British Crop Protection Council Monograph No. 40.

Mineau, P. 1993. **The hazard of carbofuran to birds and other vertebrate wildlife.** Canadian Wildlife Service Technical Report No. 177. Ottawa, Canada: Headquarters, Canadian Wildlife Service, Environment Canada; 96 p.

Mineau, P. 2002. **Estimating the probability of bird mortality from pesticide sprays on the basis of the field study record.** Environmental Toxicology and Chemistry 21(7): 1497-1506.

Mineau, P. and B. T. Collins. 1988 . **Avian mortality in agro-ecosystems. 2. Methods of detection.** In: M. P. Greaves, B. D. Smith, and P. W. Greig-Smith, editors. Field methods for the study of environmental effects of pesticides. Croydon, UK: British Crop Protection Council.

Mineau, P., M. R. Fletcher, L. C. Glaser, N. J. Thomas, C. Brassard, L. K. Wilson, J. E. Elliott, L. Lyon, C. J. Henny, T. Bollinger, and S. L. Porter. 1999. **Poisoning of raptors with organophosphorus and carbamate pesticides with emphasis on Canada, US, and U.K.** Journal of Raptor Research 33(1): 1-37.

Mrak, E. M. 1969. **Report of the Secretary's Commission on Pesticides and their Relationship to Environmental Health.** Washington, DC: US Department of Health, Education and Welfare.

Pimentel, D., H. Acquay, M. Biltonen, P. Rice, M. Silva, J. Nelson, V. Lipner, S. Giordano, A. Horowitz, and M. D'Amore. 1992. **Environmental and economic costs of pesticide use.** BioScience 42(10): 750-760.

Potts, G. R. 1986. **The Partridge: Pesticides, predation and conservation.** London, UK: William Collins Sons and Co.

Seabloom, R. W., G. L. Pearson, L. W. Oring, and J. R. Reilly. 1973. **An incident of fenthion mosquito control and subsequent avian mortality.** Journal of Wildlife Diseases 9: 18-20.

Stinson, E. R. 1991. **Wildlife mortality associated with furadan 15G use on Virgina corn fields during the 1991 growing season.** Virginia Department of Game and Inland Fisheries. Final report to the Virginia Pesticide Control Board; 26p.

Stone, W. B. and P. B. Gradoni. 1980. **Wildlife mortality related to use of the pesticide diazinon.** New York State Department of Environmental Conservation; 27p.

U.S. Environmental Protection Agency (US EPA). 1989. **Carbo-furan.** Special review technical support document. Washington, DC: US Environmental Protection Agency.

Williams, T. 1997. **Silent Scourge.** Audubon 99(1): 28-35.