Assessment of Bird-management Strategies to Protect Sunflowers

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*Even though avian damage to sunflower (*Helianthus annuus *L.) is a worldwide economic issue, several of the current methods used to reduce sunflower damage were developed and tested in the Prairie Pothole Region of the United States. An intensive research program was conducted in that area because of the regionalized concentration of sunflower production and the severe incidences of blackbird (Icteridae) depredation. During the past 40 years, federal and university scientists tested chemical and physical frightening agents, aversive repellents, bird-resistant sunflowers, decoy crops, habitat management, population management, and cultural modifications in cropping. Some of these techniques have broad applicability and may be useful in depredation scenarios involving other bird species and crops. Population suppression is intuitively appealing, but it typically fails beyond local scales because of avian mobility, population dynamics, and public antipathy. Scare devices, repellents, habitat management, and decoy crops are more likely to meet the test of predictable efficacy and practicality.*

Keywords: avian pests, blackbirds, damage reduction, Prairie Pothole Region, sunflower

The sunflower (*Helianthus annuus* L.) is a globally important oilseed crop. About 24 million hectares are planted annually (National Sunflower Association 2011). Damage to sunflowers caused by foraging flocks of granivorous birds occurs in every major sunflower-growing region of the world, including Australia, China, Europe, India, North America, Pakistan, Russia, South America, and Ukraine (Linz and Hanzel 1997). Foraging flocks, which can number from a few birds to over 100,000, can cause serious economic harm, because growers have few efficacious and environmentally safe means to reduce damage. Regional surveys of bird damage to sunflowers conducted outside the United States are practically nonexistent, but localized damage of up to 25% of a field has been reported in various countries (Bomford 1992, Linz and Hanzel 1997, Khaleghizadeh 2011). In South America, members of the parakeet (Psittacidae) and dove (Columbidae) families can form roosts numbering in the millions and cause significant damage to nearby sunflowers (De Grazio 1989, Bucher 1992, Rodgriguez et al. 1995). In Australia, cockatoos (Cacatuidae) and parrots (Psittacidae) are the main culprits (Bomford 1992). Sparrows (Emberizidae, Passeridae), doves, and crows (Corvidae) cause most of the damage in Europe, whereas parakeets and parrots do so on the Indian subcontinent (De Grazio 1989). In Africa, doves and sparrows are largely responsible for sunflower damage (van Niekerk 2009).

In the United States, members of the family Icteridae (blackbirds) cause nearly all of the damage to sunflowers (figure 1). Sunflower production occurs predominantly in the central regions of the United States. The vast majority of production occurs in the Prairie Pothole Region (PPR) in South Dakota and North Dakota, where 72% (550,000 hectares [ha]) of the total US sunflower crop was harvested in 2010 (National Sunflower Association 2011). The PPR has ideal soils and climatic conditions, which help produce yields surpassing 1800 kilograms (kg)/ha. Unfortunately for sunflower growers in this region, the PPR is renowned for its high density of cattail-dominated (*Typha* L.) wetlands, and concomitantly, its large populations of blackbirds, which use these wetlands for reproduction and roosting. Listed in descending order of postbreeding population size in the PPR, the three major blackbird species that depredate the sunflower are red-winged blackbird (*Agelaius phoeniceus littoralis*, population: 39 million), common grackle (*Quiscalus quiscula* L., population: 19 million), and yellow-headed blackbird (*Xanthocephalus xanthocephalus*, population: 17 million) (Peer et al. 2003). Annually, the three species combined eat about 19,000 metric tons of sunflower ($7.0 million, at $0.37/kg; National Sunflower Association 2010), a figure based on bioenergetic estimates (Peer et al. 2003). Field surveys of blackbird damage have produced results similar to this value, which represents 2% regional damage (Hothem et al. 1988, Klosterman et al. 2011). However, the local density of blackbirds is dictated by habitat features within the PPR landscape, and where birds are concentrated, damage levels of more than 20% can occur (Klosterman et al. 2011). Damage of about 5% is generally considered an economically important threshold and is considered tolerable by sunflower growers (Linz and Homan 2010).

Blackbird damage begins after the ray petals drop from the ripening sunflower heads in late August and the peripheral

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Figure 1. Large flocks of blackbirds of mixed species feed in sunflower fields. Photograph: H. Jeffrey Homan.

Figure 2. Birds can easily access sunflower achenes by perching on the head. Photograph: H. Jeffrey Homan.

rows of achenes begin to develop (figure 2). The damage season lasts until harvest in October; however, 75% of it occurs within two and a half weeks of petal drop (Cummings et al. 1989). Levels of damage are locally variable, both within and among years, because of varying cropping patterns and the intermittent suitability of wetlands for roosting. Damage by blackbirds is one of the major reasons that sunflower growers in the PPR have decreased their plantings by 44% from a peak of 1 million ha (National Sunflower Association 2010). It is unlikely that sunflower plantings will increase without an effective management strategy that reliably reduces blackbird damage.

In the early 1970s, US scientists launched an intensive research program in the PPR with the goal of reducing blackbird losses with effective and environmentally safe methods. Since then, researchers have studied the ecology and life histories of red-winged blackbirds (RWBL), common grackles (COGR), and yellow-headed blackbirds and have tested a myriad of methods, including chemical and physical frightening agents, aversive repellents, bird-resistant sunflowers, decoy crops, habitat management, population management, and cultural modifications in cropping. In the present article, we discuss (a) the efficacy and economic viability of the strategies now in use, (b) the methods that were tested in the field and later abandoned for a lack of efficacy or safety, (c) the management strategies that failed scientific scrutiny prior to their implementation, and finally, (d) the future directions of bird-damage research, particularly those based on nonlethal methods.

Propane cannons

Propane cannons are the most popular of numerous mechanical, visual, and auditory methods used for scaring birds away from crop fields (Bomford and O'Brien 1990). Cummings and colleagues (1986) tested a combined propane exploder and carbon dioxide pop-up scarecrow in sunflower fields and found that it was effective, particularly if it was used before an ingrained feeding pattern had developed. The effectiveness of propane cannons, however, was shown to be limited to relatively small areas (table 1). For example, Cummings and colleagues (1986) suggested that to be effective, at least one cannon should be used for each 2–3 ha area of sunflower crop. In the PPR, field sizes are often 65 ha or larger; therefore, for propane cannons to be economically effective, the expected field damage should exceed 18%—a high level of bird damage for the PPR (Linz and Hanzel 1997). We recommend that cannons be moved often, that devices be installed that will vary the direction and timing of the explosions, and that the cannons be augmented with pyrotechnics or live ammunition.

In 2010, North Dakota Wildlife Services distributed 465 propane cannons to 224 sunflower growers who had reported blackbird damage. In addition, eight field personnel were deployed to reinforce these devices with the use of a combination of pyrotechnics and shotguns (Phil Mastrangelo, US Department of Agriculture Wildlife Services [USDA-WS], Bismarck, ND, personal communication, 16 February 2011). The program is ongoing, and no analysis of its effectiveness has yet been conducted.

Repellents

Sunflower growers and wildlife managers recognize that integrated pest-management plans would benefit from an effective chemical repellent. For more than 60 years, the USDA-WS's National Wildlife Research Center (NWRC) has screened thousands of candidate compounds (Schafer et al. 1983). Relatively few of those compounds, however, showed evidence of repellency and so underwent further testing through replicated cage tests or field trials (Avery 2002, Avery and Cummings 2003).

Recent research on candidate blackbird repellents has been focused on naturally occurring compounds and pesticides registered by the US Environmental Protection Agency (USEPA). Testing for bird repellency is generally done in

Table 1. Methods that are commercially available to sunflower producers to help reduce sunflower damage caused by blackbirds in the Prairie Pothole Region of the United States.

Method	Cost[a] (dollars per hectare)	Threshold[b]	Comments
Propane cannons	110	120[c]	1 unit for 3 hectares
Repellents			
Flock Buster	50	–	Questionable efficacy
Bird Shield	42	–	Questionable efficacy
Decoy crops	375	800[d]	Situational efficacy
Desiccation	24	1000[e]	Saflufenacil + glyphosate
Roost-site destruction	95	238[f]	Aquatic glyphosate

Note: The costs and economic thresholds for use are estimates.
[a]When applicable, these figures include the estimated cost of aerial application ($12 per hectare).
[b]The number of birds per hectare at the break-even point of application costs.
[c]Amortized over a 10-year life expectancy for the propane cannon.
[d]This figure is based on the opportunity cost of agricultural production. Costs are less for lands not in agricultural production (e.g., Conservation Reserve Program crops). Also, the threshold estimate includes the assumption of decoy crops' protecting crops of confectionary sunflowers (Hagy et al. 2008).
[e]Based on an advancement of the harvest of seven days and 0.009 kilogram of sunflower eaten per day per bird at $0.37 per kilogram sunflower (Peer et al. 2003). This figure does not include the savings related to a faster dry down which helps avoid plant lodging due to insect and disease damage.
[f]Amortized over the four-year life expectancy of the treatment.

two steps; first, cage tests of individuals or small groups are conducted, and if these tests show promise, they are followed by field trials. A reduction of feeding rates of more than 80% is generally needed before a candidate repellent is allowed to advance to field-trial status. In the present article, we restrict our discussion to only those bird repellents showing strong potential for use as foliar applications; repellents used to protect planted seeds are rarely usable in crops nearing maturity because of chemical persistency.

Registered repellents for the sunflower

Flock Buster (West Fargo, North Dakota) and Bird Shield (Bird Shield Repellent Corporation, Pullman, Washington) are the only repellents registered for use on ripening sunflowers. The active ingredients in both products have been designated by the US Food and Drug Administration as compounds "generally recognized as safe." They can be found in foods produced for human consumption. Werner and colleagues (2010) conducted a concentration response test and discovered that Flock Buster (i.e., lemongrass oil, garlic oil, clove oil, peppermint oil, rosemary oil, thyme oil, and white pepper) showed less than 50% repellency—far too low to be effective in fields. The active ingredient of Bird Shield—methyl anthranilate—is a chemical known to repel birds if it is used in sufficient quantities (Avery 2002). However, Werner and colleagues (2005) aerially applied Bird Shield at the label-recommended rate of 1.2 liters (l)/ha on fields of ripening rice and sunflowers and found no difference in damage between the treated and untreated fields. A few sunflower growers reported to the senior author during extension meetings that they still use the products in North Dakota, albeit with inconsistent results.

The bird repellency of registered pesticides

Expanding currently registered pesticides to allow for their additional use as avian repellents is the most economical approach, because of the high cost of developing new products. For example, Eisemann and colleagues (2011) estimated that it costs about $8 million to register a new agricultural pesticide compared with about $1 million to supplement a registered pesticide for an additional use (e.g., bird repellency). Two fungicides (i.e., boscalid and propiconazole) were evaluated as bird repellents for rice and sunflower crops. They both reduced the birds' feeding rates, but they were judged unsuitable candidates because they reduced feeding by less than 80% (Linz et al. 2006, Werner et al. 2008). Propiconazole was the most promising of the two; in cage tests, it reduced the feeding rates of RWBL on rice by 69% at 200% of the label-recommended application rate. During field evaluation, however, no difference was detected in the average mass of rice harvested between propiconazole-treated and -untreated rice plots.

Linz and colleagues (2006) and Werner and colleagues (2010) tested seven active ingredients found in various insecticide products, including chlorpyrifos, cyfluthrin, cyhalothrin, esfenvalerate, tralomethrin, and zeta-cypermethrin. Of these, only chlorpyrifos showed potential, with a more-than-80% reduction in feeding rates relative to untreated sunflower achenes (Linz et al. 2006, Werner et al. 2010). Chlorpyrifos is sprayed on a number of crops, including ripening sunflowers, but the manufacturer of chlorpyrifos has shown no inclination to expand the label to include its use as a bird repellent.

Bird repellency of biopesticides

Biopesticides are derived from natural compounds present in animals, plants, and bacteria and from certain minerals. Avery and Cummings (2003) suggested that, among the numerous biopesticides tested for avian repellency, 9,10-anthraquinone (Arkion Life Sciences, New Castle, Delaware) might be an effective blackbird repellent. Anthraquinone (AQ) is an effective seed treatment for repelling granivorous birds from newly planted fields of canola, rice, corn, and sunflowers (Avery and Cummings 2003, Werner et al. 2009, 2011). Cage studies have consistently shown that the feeding rates of blackbirds are reduced by 80% or more with AQ treatments (Avery and Cummings 2003). However, the results from field trials on ripening rice were equivocal; AQ protected the field plots of ripening rice in Louisiana for seven days following aerial application, but similar tests on wild rice in California yielded no treatment effect (Avery and Cummings 2003). The lack of effectiveness was attributed to an influx of new blackbirds at the study site and to the use of the treated field as a night roost and daytime loafing site. Werner and colleagues (2011) reported that AQ repels COGR and RWBL confined within enclosures in fields of standing sunflowers. Initial studies to determine the AQ concentration needed to repel free-ranging blackbirds from ripening sunflowers are slated to begin in 2011 in both the United States and Uruguay. The latter country already has AQ-based repellents registered for several crops, including sunflowers (Rodriguez et al. 2004).

We are aware of the slow progress in the development of effective foliar repellents for reducing crop damage, as are many resource managers working with bird–agriculture conflicts. The testing of foliar repellents on sunflowers is still relatively new, and we have yet to assess whether this approach will ultimately provide an effective product. Certainly, the inconsistent results from repellent research on foliar rice indicate that the expectations for the sunflowers should be restrained. The sunflower, compared with rice, presents at least two major obstacles that will have to be overcome. First, bird damage in sunflowers can occur up to the harvesting date, so the repellent must be effective for up to six weeks, but the chemical residues must be gone by harvest in October. Second, the downward-facing heads of sunflower plants prevent a repellent from reaching the achenes through aerial application, the preferred method of crop treatment.

Our future research on repellents includes studies on the use of high-clearance ground sprayers that can apply high volumes of liquids with nozzles pointed upward toward the face of the heads. This equipment should enable pesticide applicators to achieve better coverage of the achenes than is possible with low-volume aerial applications (Mullally 2010). In addition, we will test whether a persistent compound, such as AQ, sprayed on the back of sunflower heads might provide sufficient repellency to move birds to an alternate food source. Both of these studies will provide strong indications of the potential for efficacy of repellents on sunflowers. Finally, if AQ fulfills its potential as a cost-effective feeding deterrent for ripening sunflowers, the ecological and environmental effects on nontarget bird species will likely need to be investigated. Sunflower producers, researchers, and resource managers, alike, expect significant progress in the use of repellents on sunflowers within the next few years. If expectations cannot be met in a reasonable amount of time, support for developing a foliar repellent will likely diminish.

Decoy crops

The concept of reducing blackbird damage to sunflower crops by offering supplemental feeding plots (i.e., decoy crops) was first tested in the early 1980s with 10 plots of oilseed sunflowers planted near commercial sunflower fields (Cummings et al. 1987). Exploitation of the decoy fields by blackbirds indicated that the commercial fields had attained a positive cost:benefit ratio of 1:4 (i.e., 1 unit of cost provided 4 units of benefit), with a range of 1:2–1:5. Although the results were promising, no government entities were willing to formally implement a decoy crop program.

The use of supplemental feeding plots as a bird-management tool was revisited in 2004 and 2005 (figure 3). The USDA-WS offered candidate sunflower producers $375.00/ha to plant 35 8-ha Wildlife Conservation Sunflower Plots (WCSPs) near cattail-dominated wetlands with histories of elevated levels of blackbird damage (Hagy et al. 2008, 2010). The blackbird damage in the WCSPs was highly variable, ranging from 0% to 100%. During both years of the study, the WCSPs produced an average of 1290 kg/ha, and birds removed 435 kg/ha, valued at $160.95/ha (at $0.37/kg). We assumed, as did Cummings and colleagues (1987), that birds feeding in the WCSPs would have caused the same amount of damage to commercial sunflower fields. In comparison with the research by Cummings and colleagues (1987), the cost:benefit ratio was 2:1, indicating a negative economic return. However, the cost:benefit ratio did not include the intrinsic values of the WCSPs, such as the use of the plots as wildlife habitat by sizable numbers of nontarget bird species, some of which are grassland bird species of conservation concern (Hagy et al. 2010).

Given the expense of planting decoy plots, WCSPs are best used to protect high-value oil and confectionery sunflower varieties planted either near roosts or under the flight lines of blackbirds emanating from roosts. The planting of oilseed

Figure 3. Wildlife Sunflower Conservation Plot located near a blackbird roost in North Dakota. Photograph: Heath M. Hagy.

sunflowers near confectionary sunflowers—the latter being much more valuable—could offset WCSP planting costs if blackbird damage in the WCSP were 12% or more, a level of damage found in 74% of the WCSPs (Hagy et al. 2008).

Sunflower producers in areas with high densities of blackbird roosting sites and low densities of sunflower fields may be able to offset both the planting and the opportunity costs of WCSPs, provided that they follow the placement, planting chronology, and landscape-structure recommendations of Cummings and colleagues (1987) and Hagy and colleagues (2008, 2010). Decoy plots should be (a) planted near cattail-dominated wetlands that have historically served as night roosts; (b) placed near stands of trees a short distance from, but not adjacent to, commercial fields needing protection; (c) planted earlier than commercial fields to habituate birds to the use of the plots; and (d) planted with a varietal mix of sunflowers with differing periods to maturity, which would thereby provide blackbirds access to ripening sunflowers throughout late summer and fall.

An initial release of a perennial sunflower variety is anticipated in 2012, which would make WCSPs more cost effective (Kantar et al. 2010). Perennial sunflowers would substantially reduce planting costs, stabilize highly erodible lands near wetlands, and provide year-round habitat for wildlife, adding more to WCSPs' economic contributions. If WCSPs were to become a viable tool in an integrated pest-management strategy for sunflowers, it would provide synergy with other management tools being developed, especially repellents. When an alternative food source is available, repellents potentially become more effective (Avery 2002). That is, if starvation is the only alternative for birds, they will withstand greater levels of discomfort from repellents or, for that matter, other means of harassment.

Sunflower growers often argue that, in addition to planting costs, WCSPs take valuable agricultural land out of production. Cummings and colleagues (1987) suggested, however, that in some situations, planting decoy crops on federal wildlife refuges and waterfowl production areas was a viable alternative to planting on private lands. Landowners also can plant decoy food plots on Conservation Reserve Program lands to attract blackbirds and other wildlife away from commercial fields (NRCS 2010).

Cultural practices

Some growers in the PPR have simply abandoned sunflowers and have substituted other crops (e.g., soybeans, corn) that are less likely to sustain blackbird damage (Klosterman et al. 2011). Other growers, recognizing the value of sunflowers in their crop rotation, have opted to use cultural practices. Such practices include (a) planting fewer bird-attractive crops (e.g., beans) or decoy crops in strategic locations near traditional roosts; (b) synchronizing the planting time of sunflowers with those in neighboring fields to eliminate the availability of early-maturing and late-maturing crops in the same locality; (c) planting large fields to spread the damage over greater areas; (d) delaying the plowing of harvested grain fields to provide an alternate food source; (e) controlling weeds and insects that may habituate birds to feeding in sunflower fields prior to achene development; (f) leaving unplanted pathways within fields so that growers have access to interior portions to scare blackbirds; and (g) planting less valuable crops where they can aggregate undisturbed (Linz and Hanzel 1997).

Finally, sunflower growers can reduce the plants' exposure time to foraging blackbirds by using a chemical desiccant to allow earlier harvesting. Advancing the harvest date reduces the chances of large flocks of late-migrating RWBL and COGR causing severe damage. Desiccation can advance the harvest date by a week or more without affecting the sunflowers' yield or oil content. In addition to avoiding late-season bird damage, growers can reduce losses due to weather events that can cause the lodging of stalks compromised by insects and diseases. Paraquat and sodium chloride were the only desiccants available for many years. They are both very effective at advancing the harvest date (up to three weeks earlier), but they have serious disadvantages. For example, if precipitation occurs after a paraquat application, the stems may fail under the strain of moisture-laden heads, which may reduce harvesting efficiency in addition to causing an increased risk of disease. Sodium chloride is expensive for use in desiccation and is now rarely used, because it must be applied at high volumes (187–280 per ha) with a ground sprayer.

In 2007, the USEPA allowed modifications to the glyphosate herbicide label to include late-season weed control in sunflower plots. This provided the added benefit of killing the sunflower plants and shortening the date to harvest by an average of 10 days (Howatt et al. 2008). Glyphosate applications on sunflowers that have achieved physiological maturity (achenes at less than 35% moisture content) do not reduce the plants' yield or oil content, and the plants do not absorb moisture from precipitation.

In 2010, a saflufenacil-based herbicide became available for desiccating sunflowers and controlling broad-leafed weeds. Furthermore, it can be tank mixed with a glyphosate-based herbicide to control grasses. Howatt and colleagues (2008) tested a tank mix of 25 grams (g)/ha of saflufenacil and 842 g/ha of glyphosate on physiologically mature sunflowers (30% moisture) and found that it dried the sunflowers faster than a glyphosate-only application. Using approximate 2011 prices, this tank mix would cost about $12/ha plus application costs. We believe that desiccation can be used to reduce late-season blackbird damage, but research on the costs and benefits will be needed in order to determine its efficacy.

Cattail management

In 1989, scientists in the United States initiated a multifaceted series of studies to assess the efficacy, cost–benefits, and environmental effects of using an aquatic herbicide to eliminate blackbird roosting habitat by fragmenting cattail-dominated wetlands (Linz and Homan 2010). In 1991, the USDA-WS initiated a demonstration cattail-management program in North Dakota and South Dakota. Through 2010, the USDA-WS has annually sprayed less than 1% (1500 ha) of cattail-dominated wetlands in the Dakotas using aerial applications of the herbicide glyphosate (Linz and Homan 2010). This limited spray coverage, combined with the findings of numerous field studies on ecological and environmental effects, led Linz and Homan (2010) to conclude that glyphosate has a minimal impact on wetland fauna. Indeed, numerous wetland species benefited from the treatments. The cattail in the PPR is an invasive species that can completely overgrow wetlands. Glyphosate returns the wetlands to their natural state of open water interspersed with sparse stands of emergents (Linz and Homan 2010).

Since its inception in 1991, the cattail program has undergone several changes. Initially, the program used fixed-wing aircraft that applied glyphosate at the highest label-recommended rate and volume. Several studies indicated that both the rate and the volume could be lowered substantially (Linz and Homan 2010). On the basis of these studies, the program switched from fixed-wing aircraft to rotary-wing aircraft (i.e., helicopters) in 2000. This also allowed the minimum size of candidate wetlands to be reduced from 10 ha to 4 ha and eliminated complaints about chemical drift onto shoreline vegetation. Currently, wetlands are treated with an aqueous solution containing 2.2 kg/ha glyphosate and 1% volume:volume of surfactant. In 2010, $95 covered the chemical and application costs for each treated hectare, a decrease of about 30% from the cost in 1995 (Linz et al. 1995a, Leitch et al. 1997). Assuming that the daily sunflower consumption by one blackbird is 0.009 kg/day (Peer et al. 2003), each bird will damage 0.27 kg over a 30-day damage period. With the sunflower's 5-year (2004–2009) market price valued at $0.37/kg (National Sunflower Association 2010), a single blackbird (combining sexes and species) damages about $0.10 of sunflower crop each year. Therefore, growers must anticipate an average of 950 blackbirds/ha ([$95/ha]/[$0.10/year]) of cattails to justify the treatment costs. The regrowth of cattails following treatment is contingent on water levels; however, if water depths remain stable at less than 30 centimeters (cm), treatments should last from four to six years (Linz and Homan 2010). A treatment that is effective for at least four years requires only 238 blackbirds/day/ha of cattails to justify the costs, provided that the sunflower crop is planted every year on lands somewhere near the treated wetland. Cattail-dominated wetlands harboring fewer than 238 blackbirds/ha are common in North Dakota, and roosts containing fewer than 1000 blackbirds/ha are located each year in sunflower-growing areas (Linz and Homan 2010).

Presumably, dispersing dense concentrations of blackbirds from their roost sites spreads bird damage over a larger area, which would thereby reduce the severity of localized damage. Statistical evidence to support this hypothesis, however, is indirect (Linz et al. 1995a). We recommend a systematic monitoring program to assess the regrowth of cattails and to track temporal changes in blackbird damage patterns near glyphosate-treated wetlands.

Avicides and surfactants

In the 1960s, in response to producer concerns about large populations of pest-bird species using dairies and feedlots, the US Fish and Wildlife Service developed the avicide DRC-1339 (3-chloro-p-toluidine hydrochloride, also known as 3-chloro-4-methylbenzenamine hydrochloride). It has broad utility for population management because it is highly toxic to several bird species that are agricultural pests, including European starlings (*Sturnus vulgaris* L., Sturnidae), blackbirds, and corvids. Rice grains and cracked corn are two of the more commonly used delivery substrates because of blackbird feeding preferences (Glahn and Wilson 1992, Linz et al. 1995b). DRC-1339 is considered environmentally safe when it is applied according to the label instructions, which include applying the avicide away from all nontarget birds. If nontarget birds are found on the bait site, the bait must be removed immediately.

Compound PA-14 Avian Lethal Agent was developed in the 1960s for reducing blackbird and European starling numbers at winter roosts (Heisterberg et al. 1987). It is a nonionic surfactant with excellent wetting characteristics. When applied to birds at low temperatures (less than 7°C) and with more than 1.3 cm of rainfall, PA-14 destroys the insulative properties of the feathers so that the birds die from hypothermia. In 1992, the product was withdrawn from use because of the costs associated with providing additional data to the USEPA. Dolbeer and colleagues (1997) recommended that a surfactant be maintained as a population-management tool, and in the mid-2000s, sodium lauryl sulfate (SLS), which works similarly to PA-14, was proposed as a replacement (Byrd et al. 2009). Sodium lauryl sulfate is a surfactant found in many commercially available soap products. The USEPA has included SLS on a list of chemicals exempt from registration under the Federal Insecticide, Fungicide, and Rodenticide Act. SLS might be an effective environmentally safe replacement for PA-14, but there has been large variability in the number of mortalities per wetting attempt (0–15,000), which is attributed to mechanical problems with pumps and poor water quality (Byrd et al. 2009). Additional testing will be needed in order to fully develop this product for widespread use.

Population reduction at winter roosts

In the southern United States, operational DRC-1339 baitings to reduce blackbird populations that damage newly planted rice may help lessen the impacts of bird depredation on sprouting rice. Glahn and Wilson (1992) reported that a survey of rice growers following a two-year DRC-1339-baiting program indicted a more-than-80% reduction in economic damage. In the 1990s, sunflower growers requested NWRC scientists to evaluate the effects that management operations with DRC-1339 at wintering areas had on the rates of sunflower damage. The notion that reducing blackbird numbers at winter roosts would protect sunflowers in the PPR was quickly abandoned, because RWBL and COGR that reproduce in the PPR disperse throughout the southern United States during the winter. Therefore, selecting and targeting specific roosts that harbored blackbirds that damaged sunflower crops was not possible. In addition, Dolbeer and colleagues (1997) analyzed the results of an 18-year blackbird-management program in the southern United States with PA-14 and found that, despite an annual kill of two million blackbirds known to breed in Michigan, Ohio, and Indiana, they could not detect any changes in the breeding populations in those states.

DRC-1339 baiting at spring-migratory roosts

In the mid-1990s, a multiyear assessment was conducted on the feasibility of an operational DRC-1339 program for reducing the number of spring-migrating blackbirds in eastern South Dakota (Knittle et al. 1987, Linz et al. 2003, Homan et al. 2004). This area is a major stopover site used by millions of blackbirds migrating toward their breeding territories in sunflower production areas approximately 350 km to the northwest (Knittle et al. 1987, Homan et al. 2004). Linz and colleagues (2003) demonstrated that thousands of blackbirds could be attracted to small field plots in cornfields during the spring. Even though an operational DRC-1339 program was logistically feasible in South Dakota, the program was not implemented. Blackwell and colleagues (2003) modeled the population impact of removing two million RWBL in the PPR each year under a five-year program and found that the associated costs of the management action, relative to potential losses in the sunflower crop, produced inefficient cost:benefit ratios of approximately 2:1–4:1, depending on population assumptions. Furthermore, we contend that other factors occurring at larger scales in the PPR, including wetland drainage and massive losses of expiring parcels in the Conservation Reserve Program (lands used by blackbirds for reproduction) will continue to have a much greater effect on blackbird populations than a spring baiting program. After careful consideration of the potential negative ramifications from the public and the inverse cost:benefit ratios, spring baiting in eastern South Dakota was not pursued.

DRC-1339 baiting in ripening sunflowers

Sunflower producers in the PPR remain supportive of DRC-1339 as a management tool, reasoning that using DRC-1339 directly in sunflower fields might be the solution. To test this concept, Linz and Bergman (1996) placed DRC-1339 baits on the ground in ripening sunflower fields near blackbird roosting sites. They did not detect a statistical difference in the amount of bird damage between baited and unbaited fields. Despite fewer blackbirds' using the treated fields during the posttreatment period than during the pretreatment period and despite the presence of poisoned blackbirds in nearby wetlands, Linz and Bergman (1996) believed that the mortality was inconsequential relative to the number of blackbirds present in the study area.

In the late 1990s, Linz and colleagues (2000) again attempted to bait blackbirds in ripening sunflower fields. Observations of the DRC-1339 plots indicated that the blackbirds fed infrequently on the ground; concomitantly, the blackbird damage did not differ between the treated and the reference fields. Enticing blackbirds away from the heads of ripening sunflowers is a challenge that must be met for the effective use of DRC-1339 plots in sunflower fields. Moreover, the risks of poisoning nontarget bird species in late summer and early fall are substantial. Sunflower fields are an attractive habitat for many migrating granivorous bird species that use the fields for food and cover (Hagy et al. 2010). In fact, Hagy and colleagues (2010) observed 44 bird species using sunflower fields during the migratory period, with some granivorous species (e.g., ring-necked pheasants, *Phasianus colchicus*; western meadowlarks, *Sturnella neglecta*; mourning doves, *Zenaida macroura*) being particularly susceptible to low DRC-1339 dosages (Eisemann et al. 2003).

In 2007 and 2008, Winter (2010) made what was presumably a final attempt at baiting blackbirds feeding in ripening sunflower plots. Recognizing that ground-based DRC-1339 would not work in sunflower plots, elevated feeding trays containing DRC-1339 baits were attached to cages of live decoy blackbirds adjacent to ripening sunflower fields. Winter and colleagues (2009) hypothesized that the live decoy blackbirds would attract conspecifics to the bait trays while decreasing the risks of nontarget poisonings. Their field observations demonstrated that the risks to nontarget species were minimal, but the decoy blackbirds failed to attract sufficient numbers of blackbirds to the trays to make this management strategy cost effective.

Trapping

Decoy traps allow wildlife managers and growers to reduce the numbers of a depredating target species while greatly reducing the risks of taking nontarget species. Cage traps stocked with decoy birds have been used successfully to remove European starlings at fruit orchards (Conover and Dolbeer 2007), blackbirds in rice-growing areas (Meanley 1971), and house sparrows feeding on small experimental sunflower plots (Montplaisir et al. 2006). Nevertheless, defending large-scale agriculture by trapping has been proven to be ineffective. For example, Weatherhead and colleagues (1980) concluded that decoy traps removed less than 2% of the trappable number of blackbirds foraging in ripening cornfields. Linz and colleagues (2010) evaluated two large-sized, mobile decoy traps (11 × 2.5 × 2.5 meters) for capturing blackbirds actively feeding on ripening sunflowers during late summer and early fall. They captured 154 blackbirds among the thousands using the fields. Moreover, the captures occurred after the crop had reached physiological maturity and after the achenes had become less palatable, and so the risk for substantial damage had subsided. Linz and colleagues (2010) deemed this method economically inefficient for protecting sunflower crops because of the labor and travel costs associated with maintaining the decoy birds.

Bird-resistant sunflowers

In the 1980s, plant geneticists developed sunflower lines with certain traits believed to thwart foraging by blackbirds while maintaining their palatability, yield, and oil content. The bird-resistant features included a concave head shape, thick fibrous hulls, hulls with high levels of anthocynanins, a long chaff, long bracts, a head-to-stem distance of more than 15 cm, and ground-facing flowers (Gross and Hanzel 1991). Field tests and cage experiments showed that blackbirds preferred standard oilseed hybrids to bird-resistant varieties; however, the bird-resistant varieties had low oil content and agronomic yield, which are unfortunately characteristics avoided both by blackbirds and by sunflower producers.

In the early 1990s, the bird-resistant sunflower-breeding program was abandoned because of the prohibitive technical challenges involved in developing a commercially competitive hybrid that would have the combination of bird-resistant traits and high oil content and yield. In August 2010, North Dakota State University and the USDA Agricultural Research Service announced a collaborative research project to develop the use of double-haploid technology to rapidly develop and evaluate new cultivars from completely homozygous inbred sunflower lines (Jan et al. 2011). This technology could be used to rapidly develop new bird-resistant varieties in the future.

Aerial hazing

The unyielding nature and scale of the sunflower-damage problem led growers to seek special funding to support the use of aircraft to scare blackbirds. From 1986 to 1994, the US Congress provided funding for a blackbird-hazing program in North Dakota that used fixed-wing aircraft flying at low altitudes to harass blackbirds away from sunflower fields and roosting sites. Although a backseat gunner would sometimes kill the blackbirds, the goal was to disperse them and to reduce localized damage. Aerially harassed blackbirds would often take refuge in row crops, shelterbelts, or dense cattail stands until the pursuit ended. Anecdotal evidence indicated that aerial hazing was more effective later in the damage period, which indicates that the annual molt early in the damage period was affecting the birds' abilities to leave the areas in which the operations were being conducted (Linz et al. 1983). The federal program ended when safety issues associated with low-flying aircraft, combined with the high costs of hiring an aircraft, a pilot, and a gunner, seemed to outweigh the benefits. Currently, a few growers hire private fixed-wing aircraft and helicopters to chase birds away.

Avitrol FC Corn Chops-99

Avitrol (i.e., 4-aminopyridine; Avitrol Corporation, Tulsa, OK) is a chemical highly toxic to all bird species, but it is categorized as a chemical frightening agent when it is used on corn and sunflower plots. Ingestion of a single treated particle causes a bird to make alarm calls and to fly erratically, which, in theory, frightens other birds from the baited area. Avitrol-treated corn particles are diluted (99:1) with untreated particles and are spread on the ground in fields with bird damage. Early assessments showed that Avitrol was effective at protecting sunflowers from blackbirds, but subsequent studies cast doubt on its efficacy and cost effectiveness (Jaeger et al. 1983, Besser et al. 1984). Similarly, Avitrol did not protect sunflowers from damage caused by parakeets in Uruguay. Mott (1973) found that the parakeets preferred to feed only on the standing sunflower heads and would not feed on the ground. In 2010, the manufacturer withdrew Avitrol from the market in the United States because of the costs associated with providing additional registration data required by the USEPA.

A vexing problem and imperfect solutions

Bird damage to agriculture is a global phenomenon that has probably existed since the advent of crop agriculture. Most of the methods and concepts discussed in the present article either have been used or can be used in nearly all agricultural ecosystems facing problems with flocking granivorous birds. For example, decoy crops were used in an attempt to lure cockatoos (*Cacatua* spp.) from ripening sunflowers in Australia (Bomford 1992), and habitat manipulation was used in Africa to move quelea (*Quelea* spp.) away from roosting habitats near cereal crops (McWilliam and Cheke 2004). The methods fall into three board categories: frightening, evading, and population suppression. The frightening category includes not only auditory and visual stimuli but also repellents (i.e., gustatory stimuli). The tools involved in evasion methods include decoy crops, habitat management, crop phenology, and crop placement. Population suppression (e.g., shooting, poisoning, nest destruction) seems to be the method that most agricultural producers and resource managers gravitate toward (Conover 2002). According to our experience and that of others, it is also the category with the least chance for long-term success at controlling damage. Lethal control of the red-billed quelea (*Quelea quelea*) in Africa and the wood pigeon (*Columba livia* G.) in England are two prime examples of the ineffectiveness of lethal control (Dyer and Ward 1977). However, we cannot reject lethal control completely, because its success can depend on the circumstances under which the conflict occurs. Where the pest population is highly localized and closed to immigration, lethal control may be the best solution. For example, Bucher (1992) and Basili and Temple (1999) suggested that nest poisoning of colonial nesting monk parakeets (*Myiopsitta monachus*) and illegal broadcasting of grain poisons for wintering flocks of dickcissels (*Spiza americana*) in South America could severely affect those populations.

The great mobility of foraging bird flocks poses the greatest challenge to developing and deploying an effective program of bird-damage management. For this reason, we believe that methods in the evasion category have the most potential for long-term effectiveness. Generally, evasion methods are not focused on the pest bird itself, but are instead intended to manipulate the environment that surrounds the crops that are vulnerable to damage. This approach bypasses the often-insurmountable obstacles encountered when damage-management programs based on techniques that frighten (e.g., habituation) or kill (e.g., fecundity, population size) are implemented. Therefore, decoy crops, habitat management, and harvest advancement through desiccation (i.e., crop phenology) should probably form the base of an integrated pest-management strategy.

It is an indication of the intractable nature of the bird–agriculture conflict in the PPR that we are still attempting to develop effective methods to reduce bird damage to sunflowers after more than 40 years of research. The methods we have tested have been used in many areas of the United States and with several crop types. We have learned as much from our failures as from our successes. We suggest, on the basis of our experience, the following methods in descending order of their ease of use and potential efficacy: habitat management of roosting sites, plant desiccants to accelerate harvest time, and decoy crops. A damage-management strategy combining these three techniques is most likely to meet the test of predictable efficacy, economic viability, and practicality. In the next decade, it is possible that an effective bird repellent will be registered for use on ripening sunflowers (and other grain crops) and that a perennial sunflower variety will be developed that could be used as an alternative food source for birds. Alternative sources of foods, possibly in combination with repellents, should help us make significant advances in the management of blackbird damage to sunflower crops (Avery 2002). We caution, however, that there are no perfect solutions to bird-damage conflicts.

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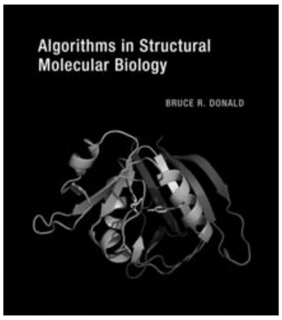

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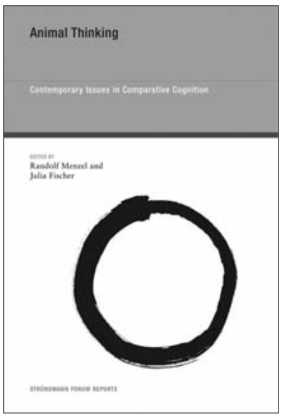

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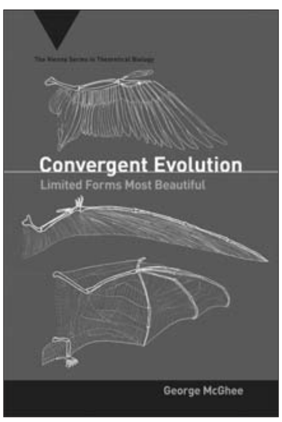

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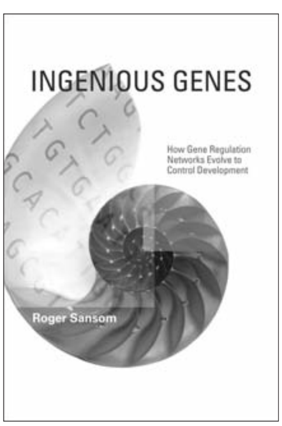

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