CHEMICAL REPELLENTS FOR REDUCING CROP DAMAGE BY BLACKBIRDS

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Abstract: Chemical repellents are intended to prevent birds from feeding on a particular food (the crop) at a given location. To be considered effective, a chemical repellent must produce 1 of 2 responses: (1) depredating birds remain but feed on an alternative, noncrop food item; or (2) depredating birds leave and go elsewhere to feed. The search for a safe, cost-effective chemical repellent has spanned decades. During the 1950s, 1960s, and 1990s, repellent screening programs, using captive red-winged blackbirds (*Agelaius phoeniceus*), brown-headed cowbirds (*Molothrus ater*), and European starlings (*Sturnus vulgaris*), identified numerous potentially useful compounds. Despite promising results from trials with captive birds and verification in subsequent field trials, formal registration of bird repellent chemicals for crop protection has remained elusive. In this paper, we present recent results from cage and field trials of various candidate compounds and discuss the potential utility of chemical repellents within integrated blackbird management strategies.

Key words: blackbirds, chemical repellents, crop depredation, feedlots, foraging theory.

Collectively, blackbirds dominate much of the agricultural landscape in North America. The red-winged blackbird (*Agelaius phoniceus*) is considered the most abundant avian species in North America (Yasukawa and Searcy 1995). This contention is supported by results from the Breeding Bird Survey that show the red-winged blackbird to be the most frequently detected species during 1990-2001 (K. L. Pardieck, U. S. Geological Survey, Patuxent Wildlife Research Center, unpublished data). During this same period, the European starling (*Sturnus vulgaris*) and the common grackle (*Quiscalus quiscula*) were the second and fourth most detected species, respectively. These 3 species represented 15.5% of all detections on Breeding Bird Surveys during 1990-2001.

The opportunistic nature of blackbirds enables them to exploit feeding opportunities created by numerous agricultural crops. Blackbirds are gregarious, especially during the nonbreeding season, and when they descend on a crop field, the results are often devastating for the grower. Field crops, including rice, sunflower and sweet corn, are particularly affected by blackbirds. These crops are often grown in or near blackbird breeding habitat. The crops generally mature by mid-summer, coincident with the addition of millions of juvenile blackbirds to the population. Conflicts inevitably arise as farmers attempt to discourage flocks of depredating blackbirds attempting to fatten up in preparation for migration and swollen in size by the year's breeding activities.

Chemical repellents represent 1 category of crop protection methods to reduce impacts of blackbirds. The search for an effective blackbird repellent is decades old. In the 1950s biologists in Arkansas, Louisiana and Colorado initiated a systematic screening program to evaluate candidate bird-repellent compounds (Neff and Meanley 1957). The most promising compounds identified during this process were thiram (tetramethylthiuram disulfide) and 9,10-anthraquinone (Neff et al. 1957). Repellent screening continued throughout the 1960s and 1970s at the Denver Wildlife Research Center (which became the National Wildlife Research Center when it moved to Fort Collins, Colorado, in 1995) according to standard procedures using male red-winged blackbirds as test subjects (Schafer and Brunton 1971). Promising compounds identified in this screening program included methiocarb (3,5-dimethyl-4-[methylthio]phenyl methylcarbamate), anthraquinone, and caffeine (Schafer et al. 1983).

The effort to identify new and potentially useful repellent materials has not abated. Much of the screening in recent years has employed the European starling as the test species. Systematic evaluation of families of related compounds using structure-activity models greatly expanded understanding of the nature and mechanisms of chemical irritation in birds (Clark and Shah 1991, Clark et al. 1991). As a practical bird repellent, methyl anthranilate (MA) is principal among the irritant compounds evaluated (Mason et al. 1989, 1991).

Repellents are intended to move birds from one place to another place. Successful application of a bird repellent might not reduce the overall amount of damage but instead should redistribute the damage. Often, bird damage is highly skewed among sites. Most producers incur little damage but a few suffer high, economically important losses. A realistic goal of blackbird damage management is not to eliminate losses, but to reduce them to an acceptable level. If a repellent can help redistribute the economic impact of blackbirds and provide some relief at high-damage sites, then it will be a useful component of an integrated blackbird damage management plan.

In this paper we discuss in general the use of repellents for management of blackbird damage to crops. We review relevant information on the use of methiocarb, anthraquinone and MA as blackbird repellents. We discuss the advantages and limitations of using repellents and point out the constraints to their development and effective use. We present current status of relevant compounds and future directions for research in this area.

FORAGING THEORY AND CHEMICAL REPELLENTS

Crop fields provide blackbirds with easily accessible sources of food obtainable with relatively little effort. This is especially important to recently fledged birds that are inexperienced foragers. In the late summer and fall, juvenile blackbirds dominate most depredating flocks. Because of the availability of large quantities of food, crop fields, vineyards and orchards provide ideal feeding situations for young birds learning to fend for themselves. Thus, agricultural crops are powerful attractions to blackbirds and depredating flocks are not easily dissuaded. With the potential benefits of feeding on the crop so great, there must be a commensurately high potential cost in order to discourage blackbird use of the crop.

An effective chemical repellent will alter the blackbird's perception of the crop. Generally, the benefits of feeding on the crop far outweigh the costs. The repellent must affect the balance so that either benefits are greatly reduced or costs are greatly increased. The bird is under pressure to feed efficiently. The longer it takes to acquire the requisite nutritional resources, the less time it can spend on other essential activities such as territorial defense, mate acquisition, feather maintenance, predator vigilance, etc. In optimal foraging theory, it is often assumed that the animal is maximizing its rate of energy intake (Pyke et al. 1977). Caloric gain is not the blackbird's only nutritional requirement, but it is pervasive. When it becomes difficult for the blackbird to maintain a satisfactory rate of energy intake by feeding on the crop, then optimal foraging theory predicts the bird will look for other sources of food. A chemical repellent should reduce the blackbird's rate of energy intake below a critical threshold, thereby forcing it to give up and feed elsewhere.

RESEARCH FINDINGS

In our research program, potential repellents are evaluated in a hierarchical testing process. Initially, birds are tested individually in small cages to document responses to a potential repellent across a range of treatment levels. Tests can be conducted either with alternate food offered (2-cup test) or with only the test food available (1-cup test). Cage tests are followed by trials in 3.1 x 9.3-m enclosures and a 0.2-ha flight pen. These larger scale tests involve groups of blackbirds that are exposed to rice or other seeds with repellent levels judged to be effective in the cage tests. Treatments that hold up throughout testing with captive birds are then evaluated under field conditions. Literally dozens of potential repellent compounds have been tested in controlled cage conditions, but relatively few have proceeded beyond cage testing. Here, we review information on repellents that have been field-tested.

Clay-Coated Rice Seed

Consistent with optimal foraging theory, one approach to making the preferred food item less appealing is to make that food item difficult to handle. The goal is to extend the handling time sufficiently so that the bird no longer finds it profitable to eat that type of food. Red-winged blackbirds consume newly planted rice seed at a rate of 6-8 seeds/min. One technique that proved successful in making rice seeds difficult to handle was to coat seeds with a nontoxic clay-based treatment that greatly increased the time interval between seeds taken (Daneke and Decker 1988). The coating was formulated to be hard on the dry seed so that the seed would flow freely during planting. When the coated seed was sown into a flooded rice field, water turned the coating sticky. The wet clay-coated seed caused bird to spend time bill-wiping and cleaning which greatly reduced feeding rates. As a consequence, birds tended to avoid plots where the coated rice was planted (Decker et al. 1990). Rates of feeding in field trials were similar to those recorded during pen trials. These studies demonstrated that in principle it is possible to increase handling time to the point where birds will feed elsewhere, but practical application of these findings to commercial rice operations has not materialized.

Registered Agricultural Pesticides

The myriad of agricultural chemicals already registered for various crop uses provides a source for potentially useful bird repellents. There are major economic advantages to expanding the use of an already-registered compound compared to starting the registration process from scratch with a new chemical. For this reason, we evaluated a number of fungicides in cage and pen trials and determined that a copper-based product, Kocide® SD, had the best prospects to be an effective bird-deterrent rice-seed treatment (Avery and Decker 1991). It is not known why copper treatments reduce blackbird feeding on rice seed. One possibility is that birds perceive physiological effects of copper toxicity and learn to avoid it thereafter. Field evaluations of Kocide SD in Texas rice fields confirmed a reduction in blackbird feeding rates on treated seed previously documented in pen trials, but statistically significant reduction in seed loss occurred in only 2 of 7 study sites (Avery et al. 1994). Copper-based fungicides are relatively inexpensive and are already approved as rice seed treatments, so they could be a potentially useful component of an integrated blackbird management strategy.

The application of the insecticide Sevin® (carbaryl) has been associated with decreased blackbird activity and damage in sweet corn (Woronecki et al. 1981). The observed reductions in blackbird activity were attributed to reductions in insect populations by this broad-spectrum insecticide rather than direct avian repellent activity. Sevin is registered for use on ripening rice to control certain insect pests. A trial was conducted in Louisiana to evaluate whether aerial application of Sevin for insect control would also reduce blackbird use of the rice fields (Fig. 1). Bird activity in treated plots declined immediately after application of the insecticide, but yields from the treated plots did not differ from those in untreated control plots. Sevin acts quickly and does not persist. Test plots were harvested 4 weeks after application, ample time for the chemical to dissipate, so it is not surprising that short-term effects on bird activity were not reflected in plot yields.

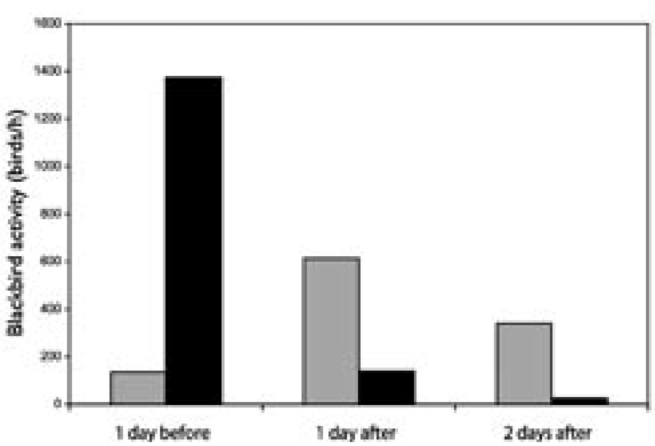

Fig. 1. Blackbird activity in a 3.2-ha test plot declined immediately after application of Sevin XLR insecticide (dark bars). Birds in an adjacent unsprayed plot (open bars) increased after the application.

Primary Repellents

Some compounds require no learning to be effective. These chemicals are inherently aversive and the bird responds reflexively without needing to acquire an avoidance response. Such compounds are called primary repellents, or chemical irritants (Clark 1998). The most useful of the primary repellents is methyl anthranilate (MA), a naturally occurring compound used extensively to impart grape or fruity flavor to candy, gum, soft drinks, and other consumables. It is one of a number of compounds generally regarded as safe (GRAS-listed) by the U. S. Food and Drug Administration. Even though MA is palatable to humans, it is irritating to all avian species tested so far. MA produces pain by stimulating the bird's trigeminal nerve, and is not a taste repellent (Mason et al. 1989). Birds have to contact MA with their eyes, nostrils, or mouths in order to feel the effects of the compound because the strong grape-like odor of the chemical is not aversive to birds (Clark 1996).

In the United States, MA is the active ingredient in formulated products marketed under the trade names Bird Shield® and Rejex-it®. These products are registered as bird repellents for use on turf, soft fruits, and field crops. Controlled field evaluations of the efficacy of MA are few, however. In New York, bird damage to MA-treated blueberry plots did not differ from that in untreated plots although there was some damage reduction in test plots of grapes and cherries (Curtis et al. 1994). A field trial involving several sites in Michigan, Oregon, and Washington found no reduction in bird use of MA-treated blueberry plots (Avery et al. 1996). In some field trials, aerial application of MA to corn and sunflower discouraged depredations by flocks of blackbirds (Askham 2000). Recent evaluations in North Dakota sunflower fields, however, detected no effect from applications of Bird Shield® blackbird repellent (G. M. Linz, personal communication).

MA has been evaluated as a rice-seed treatment to deter blackbirds (Avery et al. 1995*a*). Cage trials demonstrated that with a relatively unappealing alternate food, red-winged blackbirds tolerated MA-treated rice up to a treatment level of 1% (g/g). With untreated rice as the alternate food, however, blackbirds rejected MA-treated rice at the 1% treatment level. Pen trials conducted in Texas and Louisiana confirmed the repellency of MA on rice seed at a treatment rate of 1.7% (g/g), but also documented rapid degradation of the repellent under field conditions. Potentially, MA might be useful as a rice seed treatment, particularly if sufficiently high MA residues can be maintained on the rice seeds throughout the duration of the susceptible period.

A closely related compound, dimethyl anthranilate (DMA), was investigated as a potential repellent for blackbirds at feedlots (Mason et al. 1985). Despite generally favorable results in field trials, there has never been a registration for use of DMA in feedlots.

Secondary Repellents

Unlike primary repellents, or contact irritants, secondary repellents are not immediately aversive. Instead, the bird experiences illness or discomfort sometime after ingestion of the treated food item. The effectiveness of secondary repellents is grounded in the concept of conditioned food avoidance (Garcia and Koelling 1966). Birds associate vomiting, nausea, or other adverse post-ingestional consequences with the food or with a sensory attribute of the food, such as color or taste, and quickly learn to avoid it. The avoidance response produced by a secondary repellent is likely to be more robust than that produced by a primary repellent (Alcock 1970, Rogers 1974).

One secondary repellent, 9,10-anthraquinone, has recently been registered under the brand name Flight Control® as a treatment to repel birds from turf and grass (Blackwell et al. 1999). Ingestion of anthraquinone-treated food can produce vomiting (Avery et al. 1997). Presumably, the emetic response is produced through irritation of the gut lining, but the actual mechanism is unknown. Anthraquinone is not a taste repellent or contact irritant. Birds do not hesitate to eat treated food and exhibit no sign that treated food is unpalatable.

Recent research has expanded on earlier findings of the effectiveness of anthraquinone against rice-eating blackbirds (Neff et al. 1957). In cage and pen trials, both the technical grade unformulated chemical and formulated products reduced blackbird consumption of rice seed at anthraquinone treatment rates of 0.5% and 1.0% (Avery et al. 1997, 1998*a,b*). The findings from feeding trials with captive birds were confirmed and extended in small-plot field trials conducted in Louisiana (Avery et al. 1998*b*, Cummings et al. 2002*a,b*). So far, all results support the potential usefulness of anthraquinone as a blackbird-repellent rice seed treatment.

Damage by blackbirds also occurs when the rice crop is maturing, and anthraquinone has been tested as an aerial application to ripening rice. Results from these trials indicated that blackbirds reduced their use of areas sprayed with Flight Control® (Fig. 2). Evaluations in ripening rice have been conducted only on small plots (2-4 ha), however. Furthermore, in these trials, only one Flight Control® application rate, 18.3 l/ha, was tested. Additional research should be performed to document blackbird responses when large areas of ripening rice are treated with the repellent, and to determine the most cost-effective application strategy for this product.

Crops other than rice will also potentially benefit from the application of anthraquinone as a blackbird repellent. For example, groups of 3 captive red-winged blackbirds were allowed to feed on 1 unprotected sunflower head and 1 sunflower head sprayed with Flight Control® (Fig. 3). Across 3 treatments levels, damage to unprotected heads exceeded ($P < 0.001$; $F_{1,9} = 29.77$) that to repellent-treated heads. At the highest Flight Control® treatment rate, damage was reduced 84% relative to untreated heads.

Conversely, when Flight Control® was applied to a test plot of cultivated wild rice in northern California, no decrease in blackbird activity was observed (Avery et al. 2000). The apparent lack of effectiveness was attributed to the birds' using the wild rice not solely for feeding, but also as a night roost and daytime loafing site. Furthermore, if there had been frequent turnover in blackbird flocks at the study site, then a steady supply of birds previously unexposed to the repellent would have contributed to the ineffectiveness of the treatment.

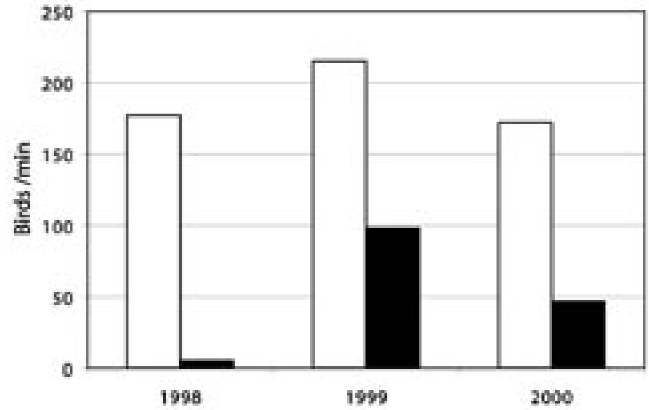

Fig. 2. Blackbird activity in test plots of ripening rice decreased following aerial application of Flight Control bird repellent at a rate of 18.3 l/ha. Open bars represent mean numbers of birds prior to treatment; shaded bars represent mean levels of bird activity during 5 days post-treatment.

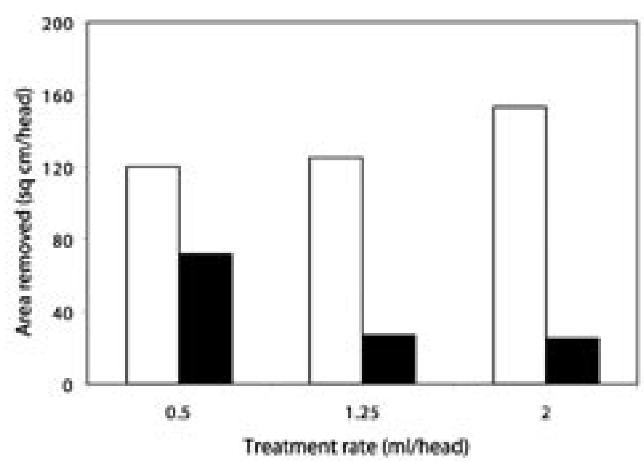

Fig. 3. Damage to sunflower heads by 3-bird groups of captive male red-winged blackbird was reduced by the application of Flight Control bird repellent to the heads. Open bars represent damage to untreated heads; shaded bars show the losses on treated heads.

At this time, Flight Control® is not registered in the United States as a bird repellent on sunflower, rice, or on any other food crop.

Methiocarb (3,5-dimethyl-4-[methylthio]phenyl methylcarbamate) was originally developed as an insecticide. The potential bird-repellent uses of the compound were soon recognized, however, and a number of applications for bird damage management were developed (Hermann and Kolbe 1971). Methiocarb inhibits acetylcholinesterase at synapses in the nervous system, but the effects produced by methiocarb are rapidly reversible, and the animal experiences only transitory nervous system disruption. Affected birds exhibit a range of symptoms, including retching, vomiting, and temporary paralysis. The severity of symptoms depends on the dose received. Typically, vomiting begins within 10 minutes of ingestion of treated food. An affected bird can become immobilized within 30 minutes of ingesting an appropriate dose and will recover fully in another 30 minutes. Birds that feed on methiocarb-treated food exhibit no sign that the chemical tastes bad. Treated food is readily accepted at first, and feeding slows only when the bird begins to detect physiological effects of the chemical.

Methiocarb is a secondary repellent, and repellency occurs when birds feed on treated food, become sick, and associate either the food itself or characteristics of the food with the discomfort (Rogers 1974). Affected birds rapidly learn to avoid that food item. As with anthraquinone, the avoidance response can be affected by factors such as the bird's prior experience with the food item, the strength of the post-ingestional discomfort, and the availability of alternative food. Applied properly, methiocarb is very safe with regard to target and nontarget species (Dolbeer et al. 1994). Free-feeding birds acquire a repellent dose and stop feeding before a lethal dose is ingested.

In North America, methiocarb was tested extensively in many agricultural applications. It has been used to protect newly seeded and sprouted crops, ripening grain crops, and soft fruits. It was commercially sold as Mesurol® and until 1989 was registered in the United States as a bird repellent on cherries, grapes, and blueberries and as a treatment for corn seed. Field trials conducted in Louisiana established methiocarb as an effective blackbird-repellent rice seed treatment (Holler et al. 1982). Methiocarb is no longer registered as a bird repellent for use on food crops. In the United States, methiocarb is used primarily as a molluscicide on ornamental plants. Methiocarb is also labeled with the U. S. Environmental Protection Agency (USEPA) as a repellent to reduce predation by corvids on eggs of endangered species (Avery et al. 1995*b*).

FUTURE CONSIDERATIONS

The process of identifying and producing an effective, registered bird-repellent chemical can be lengthy, uncertain, and expensive (Mason and Clark 1992). The likelihood that a chemical will be registered for bird repellent uses might be increased if the chemical is already approved for human consumption and if it is already approved by the USEPA for other uses. An example of a potentially promising compound that meets those criteria and that merits further investigation is caffeine. This compound is a naturally occurring nervous system stimulant commonly found in many foods and drinks and is "generally regarded as safe" by the U. S. Food and Drug Administration. An emergency use permit was recently granted by the USEPA for application of caffeine as a toxicant to manage populations of non-native tree frogs in Hawaii. Additional pest control applications are possible (Hollingsworth et al. 2002).

In a standard series of behavioral trials with male red-winged blackbirds, Schafer et al. (1983) identified caffeine as having low toxicity and high repellency. Based on that information, a series of feeding trials were conducted at the NWRC's Florida field station to obtain an initial assessment of the potential effectiveness of caffeine as a blackbird repellent applied to rice seed. In these 1-cup trials, individually caged male red-winged blackbirds were offered untreated rice for 4 sessions and then given caffeine-treated rice for 4 additional mornings. Caffeine treatment rates were 0.1%, 0.15%, and 0.25% (g/g). The highest rate produced a 76% reduction in consumption of rice seed, similar to that obtained with anthraquinone (Fig. 4). We recommend that caffeine be evaluated in additional pen and field trials to investigate more completely its potential for management of blackbird damage to seeded rice and other crops.

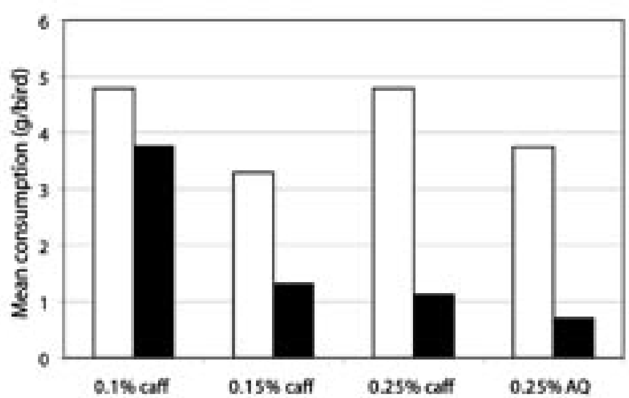

Fig. 4. In 3-h, 1-cup feeding trials conducted on 4 successive mornings, consumption of caffeine- and anthraquinone-treated rice seed (shaded bars) by individually caged male red-winged blackbirds was reduced relative to consumption of untreated rice by control groups (open bars).

Others have pointed out various limitations and constraints to the use of repellents for management of bird damage to crops (e.g., Rogers 1980, Bruggers 1989). It is instructive to revisit these guidelines as they apply to blackbird management.

Taste.—None of the compounds discussed in this paper are taste repellents. For birds, primary repellency is mediated through the trigeminal nerve. The bird senses pain and irritation, not a bad taste.

Timing.—Repellent applications should be timed to prevent birds from establishing a behavior pattern that includes feeding in the crop. Once birds become established, they are much more difficult to dissuade. Crops such as rice and sunflower ripen over 3-4 weeks so multiple applications of a repellent will likely be needed. When alternate sources of food become scarce, it will be more difficult to prevent birds from feeding on the crop.

Efficacy.—It is unreasonable to expect total crop protection. This is especially true for secondary repellents such as anthraquinone that require a period of learning before individual birds acquire an avoidance response. If the flocks of depredating blackbirds are transient and characterized by frequent turnover, then a primary repellent that produces an immediate response might be more effective than a secondary repellent that requires a period of learning.

Variation.—Considerable variation exists among crops and among birds that damage crops. A strategy that works in one situation might not be applicable in another setting. A repellent application that succeeds against red-winged blackbirds (60 g) might not be effective against a much larger bird such as a boat-tailed grackle (200 g). A strategy to manage damage in rice fields where blackbirds feed and roost will likely differ from that employed in sunflower fields which are used by blackbirds as feeding sites only.

Integration.—A blackbird repellent should be viewed as a component of an integrated damage management strategy, not as the sole answer to a damage problem. Weeds and insect infestations have been associated with increased blackbird numbers, so an integrated strategy could include suppression of insect and weed populations. Habitat management aimed at reducing the attractiveness of nearby roost sites could also be an important component. Repellents should not be viewed in isolation but rather as part of a whole strategy.

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