A Review of Bird Deterrents Used in Agriculture

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ABSTRACT: Animal intrusion causes significant agricultural losses each year. Wild and domestic animals destroy crops by eating and trampling them, and can pose food safety risks due to the deposition of feces on or near the crops. Birds are one of the most challenging animals to keep out of agricultural fields. Growers try countless methods to deter them, including visual, auditory, tactile, and olfactory means. While some of these methods work some of the time, none provide stand-alone protection all the time. Recently there has been interest in developing technology-based solutions to deter nuisance birds in agricultural settings, while others are exploring more natural methods, including falconry. We provide a general overview of bird deterrent methods that are currently in use in agricultural settings, and explore options for novel methods. We found that very few independent scientific studies have been conducted to assess the efficacy of most bird deterrent methods. Ultimately, a multi-tiered approach using integrated pest management techniques will likely be most useful as it can be tailored to meet the needs of individual farmers.

KEY WORDS: animal intrusion, birds, bird deterrent, falconry, integrated pest management, nuisance bird

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INTRODUCTION

Fragmentation of natural habitats during conversion of wild lands to agriculture and the subsequent increase in agrochemicals has resulted in a loss of biodiversity and a deterioration of ecosystem function, including natural pest control. Non-crop habitats (hedgerows, field margins, fallows) harbor natural enemies to crop pests (Bianchi et al. 2006). Such habitats also harbor beneficial songbirds that consume insect pests (Jedlicka et al. 2011, Garfinkel and Johnson 2015, Kross et al. 2016), and provide perching sites for raptors that deter avian and rodent pests (Kay et al. 1994). Balancing the role of agricultural lands in providing habitat for biodiversity while simultaneously avoiding bird damage and reducing food safety risks is the primary goal behind the concept of co-management, which is recommended by the Food Safety Modernization Act (USFDA 2015).

Animal intrusion into fresh produce fields causes significant agricultural losses each year. Wild and domestic animals destroy crops by eating and trampling them, and can pose food safety risks due to the deposition of potentially contaminated feces on or near the crops (Jay-Russell 2013). Birds are one of the most challenging animals to keep out of agricultural fields, and they may harbor foodborne pathogens. For example, European starlings are a source of *Salmonella enterica* at concentrated animal feeding operations (CAFOs), posing a greater risk of pathogen transfer than other variables like cattle density, facility management operations, and environmental variables (Carlson et al. 2011b). They also may be a significant source of other *Salmonella* spp, *Escherichia coli* O157, and other shiga toxin–producing *E. coli* (Gaukler et al. 2009). During a study at a CAFO in southern Arizona, 103 birds were tested for foodborne

Table 1. Bird deterrents commonly used to protect fresh produce fields from nuisance birds.

Category	Specific Type
Visual	Lasers, Dogs, Humans, Scarecrows, Predator models, Corpses or effigies, Balloons with eyespots, Kites, Kite hawks, Falconry, Drones, Lights (flashing, rotating, strobe, searchlights), Mirrors, Reflectors, Reflective tapes, Flags, Rags, Streamers, Dyes or colorants, Air dancers
Auditory	Propane sound cannons, Bangers, Screamers, Squawkers, Whistlers, Gunfire, Distress calls, Ultrasonic sounds, High intensity sounds, Sonic net
Tactile	Spikes, Sticky substances
Habitat modification	Bait stations, Lure crops, Sacrificial crops, Removal of roost structures, food, and shelter
Exclusion	Nets, Electric fencing, Overhead wires, Anti-perching devices
Chemical	Methyl anthranilate, Anthraquinone, DRC-1339, Keyplex-350, Measurol
Reproductive	Chemo-sterilants, Contraceptives, Immune contraceptive vaccines
Lethal	Avicide, Shooting, Egg destruction, Nest destruction
Multi-faceted	Pyrotechnics, Optical gel, Falconry, Drones

pathogens. Two (1.9%) tested positive for *Salmonella*, and five (4.9%) tested positive for non-O157 Shiga toxin-producing *E. coli* (STEC) (Rivadeneira et al. 2016). Other studies have shown similar results as documented in a review by Langholz and Jay-Russell (2013) where they listed 23 studies on foodborne pathogen prevalence in birds, including positive results for ducks, gulls, starlings, and pigeons. A more recent review listed foodborne pathogens specifically transmitted by wild birds (Sanchez et al. 2016). All reviews discuss a 2008 outbreak of *Campylobacter* related to pea consumption because it was one of few outbreaks directly linking the pathogen to a wildlife source, in this case, sandhill cranes (Gardner et al. 2011). This highlights the potential risks to food safety associated with migratory birds.

Damage and food safety risks from wildlife activities remain significant economic problems despite the use of a variety of methods to control bird and rodent pests (Gebhardt et al. 2011). Yield loss and economic impacts vary by crop and region, but can be a substantial burden on growers (Anderson et al. 2013). Growers of fresh produce try countless methods to deter birds. These deterrents fall into nine general categories (Table 1). This paper is not intended to be an exhaustive review of bird deterrents, but instead we present an overview of the ones most used in the field, as well as methods that utilize multiple techniques in an effort to develop integrated pest management for nuisance bird control.

OVERVIEW OF BIRD DETERRENTS

The array of visual bird deterrents is expansive, and includes lights that are flashing or rotating, searchlights, mirrors and reflectors, reflective tape, flags, rags, streamers, lasers, dogs, humans, scarecrows, raptor models, corpses, balloons with eyespots, kites, kite hawks, mobile predator models, and water dyes or colorants (Bishop et al. 2003). All of these methods work to some degree for a short period of time until habituation. Lasers that were used to disperse crows, for example, resulted in an initial dispersion, but crows reoccupied their roosts the same night that the lasers were used, and none of the roosts were abandoned (Gorenzel et al. 2002). Kite balloons were shown to be effective in the short term, but birds quickly become habituated, reducing the effectiveness over time (Hothem and DeHaven 1982, Santilli et al. 2012). Similarly, balloons with eye spots have been used in an attempt to reduce damage to vineyard grapes in New Zealand, but growers reported no economically significant effect (Fukuda et al. 2008). Generally, balloons, scarecrows, hawk kites, and reflective tape work best with sound cannons or netting, described below (Oregon Winegrowers Association; OWA 2010).

Noise deterrents are generally effective, but much like visual deterrents, birds easily become habituated to them, decreasing their efficacy over time. They have the added issue that growers who use them are subject to complaints of nuisance noise from neighbors (Bishop et al. 2003). Propane sound cannons are the most commonly used noise deterrent, but they need to be repositioned weekly and set to go off randomly every 7-20 minutes during daylight hours for the greatest effect. Since sound cannons usually make a hissing noise before sounding off, they give birds a warning to leave the area, and then they return after the explosive noise. Some of the other common noise deterrents include bangers, screamers, squawkers, whistlers, scare cartridges, and noise bombs (OWA 2010). Even human presence can be used as a noise deterrent if they rattle cans, crack whips, yell, honk horns, or shoot guns (OWA 2010, Ainsley and Kosoy 2015). Human activity can be very effective at keeping nuisance birds out of fields when fields are small enough to drive or walk around, but it can be expensive to maintain a human guard on duty. Instead, some growers use synthetic sounds that offer unambiguous messages that elicit interspecific responses, like distress calls (Ribot et al. 2016). They prevent habituation by varying the rhythm and number of signals emitted (Aubin 1990). In a study of alarm calls from crimson rosellas in orchards, researchers found that these birds were effectively deterred in the short- to medium-term (Ribot et al. 2016). However, distress calls offer another challenge since they may be an invitation to nearby predators indicating that their next meal is ready. Broadcast units are a less expensive, more technologically advanced noise deterrent that reproduce accurate and effective birds calls that significantly reduce damage in vineyards (Berge et al. 2007). Another moderately effective noise deterrent is the sonic net, which overlaps with the frequency range of bird vocalizations, making communication among a flock ineffective. When used at an airfield, researchers demonstrated an 82% reduction in birds in the sonic net area, and it remained effective after four weeks of exposure (Swaddle et al. 2016).

Fencing is an effective non-lethal, long-term method used as a standard technique to minimize wildlife intrusion into agricultural lands (Franklin and VerCauteren 2016). While fencing cannot be used to deter birds, netting can be. While noise deterrents used against juvenile starlings in a cherry orchard were shown to be ineffective, research suggests that the netting-in of an orchard would be more effective (Summers 1985). However, while netting is the most effective method, it is also has some drawbacks. It is one of the most expensive methods for deterring birds due to the massive areas of crops that need to be covered (OWA 2010). It can also be easily damaged, and it can be a hazard to wildlife. Other exclusions that are used with birds are electric fencing, overhead wires, and anti-perching devices, such as spikes, some of which are also considered tactile deterrents and forms of habitat modification described below.

The concept of habitat modification to deter nuisance birds includes a wide array of activities, from providing better quality forage or shelter in alternate locations through lure crops or sacrificial crops to simply removing roost structures, food, and shelter, forcing birds to go elsewhere. In many cases, deterring nuisance birds from one field causes them to negatively impact neighboring farms. For that reason, Ainsley and Kosoy (2015) propose collective action on the part of neighboring farmers in which communal feeding plots are constructed to protect the fields of all farmers in a single area, thereby evenly distributing crop losses and maintaining stable bird populations in the ecosystem (Ainsley and Kosoy 2015). The USDA's Wildlife Services attempted this method when they began to cost share eight hectare Wildlife

Conservation Sunflower Plots (WCSP) with sunflower growers to lure migrating blackbirds away from commercial sunflower fields. The targeted blackbirds ended up removing 10 times more sunflower seeds from the WCSP than from commercial fields, making this strategy an important part of an integrated pest management plan for commercial sunflower growers (Hagy et al. 2008).

Monk parakeets tend to damage corn and sunflower fields that are closest to man-made structures and adjacent trees, areas with tree patches around the crop fields, and areas with high availability of pasture and weedy and fallow fields (Canavelli et al. 2014). The removal of these landscape features that attract birds, like areas with structures for perching, breeding, and shelter, can cause birds to move out of an area (Sinclair 2005). A recent study indicated that hedgerows harbor higher biodiversity of rodents, but that biodiversity does not spill over into wildlife intrusion into fields (Sellers et al. 2018). While rodents differ from birds, the concept of wildlife utilizing adjacent habitat without affecting agricultural crops or impacting food safety is similar.

Physiological methods of bird control include such things as chemo-sterilants, contraceptives, and immune-contraceptive vaccines (Franklin and VerCauteren 2016). These are rarely, if ever, used by growers in agricultural areas because they require extensive permitting and veterinary oversight, often times making their use unfeasible. Linz, Bucher, et. al. (2015) identified four limiting factors hindering the use of contraceptive methods and lethal control of birds (described below) in agriculture, including: 1) the high cost of implementation combined with challenges related to maintaining long-term control of birds, 2) determining the population level in an area that would be considered acceptable and therefore serves as a level of success, 3) ensuring that the treatment would be directed only at the birds actually causing crop damage, and 4) managing immigration of non-treated birds.

Chemical bird deterrents, such as taste and behavioral repellants, are expensive, difficult to apply, not as effective in the field as they are in the lab, need to be licensed, and some overlap with lethal deterrents. Despite this, some chemical treatments have been effective. For example, methyl anthranilate, a common food additive, is used as a biodegradable non-toxic bird repellant for grapes and berries. One study showed a decrease in crop loss by 88% to 99% when crops were treated with methyl anthranilate (Askham 1992). However, in another study, methyl anthranilate was not effective against frugivorous bird species in the northeastern US (Curtis et al. 1994).

Anthraquinone is another commonly used chemical used to deter birds. There was up to a 93% decrease in rice consumption by blackbirds and grackles when seeds were treated with anthraquinone before planting (Avery et al. 1998). Horned larks are also affected by anthraquinone, damaging 60% of treated lettuce seedlings but 100% of untreated seedlings (York et al. 2000). Other chemicals, including 3-chloro-4-methylaniline hydrochloride, 3-chloro ptoluidine hydrochloride, and 3-chloro-4-methylaniline all were able to control starlings at a concentrated animal feeding operation (CAFO), thereby eliminating *Salmonella enterica* from feedbunks and causing a substantial decline of the pathogen in the water troughs (Carlson et al. 2011a). In developing a multi-national plan for bird control, there were two important recommendations: 1) Collect better data about bird pest damage and 2) develop alternative approaches to toxicants or develop environmentally safe toxicants. (Bruggers et al. 1998).

Lethal measures used to control birds include avicides, shooting, egg destruction, and nest destruction. Not only are these measures expensive and time consuming, they are generally frowned upon by the public since they are in direct contrast to the concepts of wildlife protection and environmental stewardship. Linz, Bucher, et. al. (2015) assert that lethal control of birds is not an effective or appropriate method to prevent crop damage, especially when used in isolation, due to environmental risks, including to non-target birds, and a lack of efficacy in the long-term. Other researchers agree, citing that avicide is costly, unstable, and unsustainable for a community since birds are a necessary component of agricultural ecosystems (Ainsley and Kosoy 2015). In fact, when researchers modeled an idea that was proposed to lethally remove 2 million red winged blackbirds per year for five years with 3-chloro-4-methylalanine-treated rice, a cost:benefit analysis found that the results of culling these birds, even in combination with other non-lethal efforts, would be negligible (Blackwell et al. 2003). In a study conducted in the United Kingdom, nine bird deterrent techniques were implemented at six landfill sites. While distress calls, lethal falconry, and lethal and non-lethal ammunition worked best for initial deterrence, birds quickly became habituated to non-lethal measures. Despite this, public perception often prevents the use of lethal techniques (Cook et al. 2008).

Drones and unmanned aerial vehicles are being used with increasing frequency in agriculture to conduct stand counts of crops, to identify areas with potential disease or insect presence, and to survey land prior to planting. They are also being used to protect crops from nuisance birds right now in Yuma, Arizona. Unlike other methods, birds cannot anticipate when and where a drone will appear, and since most have not been exposed to drones previously, birds see them as potential predators. Some drones must be operated in person by a pilot, while others are designed to launch, deploy to specific waypoints, and then land completely under autonomous control. In general, they employ visual, auditory, and predator mimicry to discourage habituation (Grimm et al. 2012). Studies are currently underway to determine how effective drones will be when used in isolation, as well as in combination with other bird deterrent techniques.

Falconry is an age-old hobby and sport dating back to 722 BC. As far back as 1893, people acknowledged that hawks and owls could be beneficial to agriculture (Fisher and Merriam 1893). However, it wasn't until the past 10 years that falconry has come into its own as a means of nuisance bird abatement in the United States. Trained falcons were first introduced as working birds in vineyards to protect the grapes. Their presence was associated with a significant decrease in the number of nuisance birds present, and a 95% reduction in crop loss relative to vineyards without falcons (Kross et al. 2012). In the

United Kingdom, falconry was used at landfills to hunt (not deter) scavenging gulls and corvids. Falcons were effective against corvids and black headed gulls, but not against larger gulls (Baxter and Allan 2006). Since the trained birds were flown seven days per week for up to 12 weeks, it became impractical to maintain the falconers on site. In fact, that is one of several reasons that falconry is not used more regularly in agriculture; It requires licensed falconers that train for years, assistants, multiple species of trained birds that require specialized care, radio communication, and field vehicles. In addition, trained birds cannot be flown at night or during some weather conditions, and nuisance birds often return after falcons are removed. Due to these limitations, some view falconry as impractical for use in large scale agriculture (Kenward 1978). Others, however, cite positive outcomes associated with falconry in agriculture, including increasing predation pressure, decreasing the cost of biological controls applied to agricultural land (Machar et al. 2017), and minimizing the use of fields by nuisance birds during peak activity (Navarro-Gonzalez and Jay-Russell 2016).

A survey conducted of the public's perception of bird control showed the methods that are most positively received are falconry and the installation of owl nest boxes, which were both typically described as more natural techniques. Conversely, the methods that were reported as most negative were live ammunition and methyl anthranilate, both viewed as less natural (Herrnstadt et al. 2015).

SUMMARY

There are no bird deterrents that provide 100% protection. Many deterrents focus on explosive noises, reducing attractiveness of potentially affected crops, making other crops more attractive, habitat manipulation, and exclusion netting, but the general consensus is that bird scaring and population reduction is ineffective (Bomford and Sinclair 2002). All successful deterrents require multiple techniques, and sometimes year round efforts (Sinclair 2005). Gebhardt, Anderson, et al. (2011) examined published studies, surveys, and unpublished reports about bird damage in 19 crops. They found that bird damage remains significant despite the use of a wide variety of bird control methods, including avicides, trapping, exclusion, and chemical aversion. When three bird deterrent systems were tested, including visual, acoustic, and falconry, the most effective was visual scaring, indicating that an effective deterrent must immediately respond to the presence of birds to reduce the probability of landing. However, even with the best visual deterrents, habituation arises rapidly (Soldatini et al. 2008).

Since there are no bird deterrents that work all the time in every situation with lasting effects, our recommendation is to utilize a variety of techniques that together provide the best results while keeping public perception in mind. Birds are a critical part of every ecosystem, offering ecosystem services that are not always acknowledged, including pest control in agricultural fields. The coexistence of birds with agriculture is not a new concept, but it has become one of the most challenging endeavors for growers as they strive to protect nature, serve as good stewards of our land, and maintain the highest levels of food safety in the world.

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