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PEER-REVIEWED ARTICLE

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Deterring Wild Birds during Fruit and Vegetable Production

ABSTRACT

Wild birds can be serious pests on farms by damaging produce and introducing food safety hazards to production fields and packinghouses. The most serious crop damage is usually caused by fruit- or seed-eating species such as blackbirds, cardinals, robins, or crows, whereas other species such as sparrows, finches, and starlings can take up residence in farm buildings and quickly become a nuisance. Creating an effective management plan to deter wild birds from fields and buildings begins with correctly identifying bird species and the damage that they are likely to cause. Just as different kinds of pest insects target different plants at different times of the year, not all birds feed in the same way, nor at the same time. Targeting deterrence strategies toward specific species is more cost-effective than a "catch-all" approach and reduces the likelihood that nontarget species are affected. The most effective management plan will be targeted toward specific problem species at specific times of year and may involve mixing and matching different deterrence strategies.

INTRODUCTION

Wild birds can cause significant damage to fresh produce, and the extent of damage can vary greatly depending on geographic location and commodity type *(16, 49)*. Estimates of damage based on grower surveys from five states ranged from US$42/acre for Oregon tart cherry growers to US$2,941/acre for growers of Honeycrisp apples in Washington state *(1)*. Beyond product consumed by birds, losses occur from pecking damage, produce knocked off the plant, and increased susceptibility to plant disease due to bird-inflicted damage. American robins and cedar waxwings have been identified as significant fruit consumers across multiple regions *(24)*. Losses because of food safety concerns include unharvestable produce due to fecal deposition because bird feces can contain bacterial pathogens such as *Salmonella enterica* and *Campylobacter jejuni (28, 44)*. European starlings have been identified as vectors of bacterial pathogens of concern for public health from livestock operations *(45)*.

Growers have options regarding mitigation strategies to reduce bird damage, although a survey by Keller et al. *(28)*

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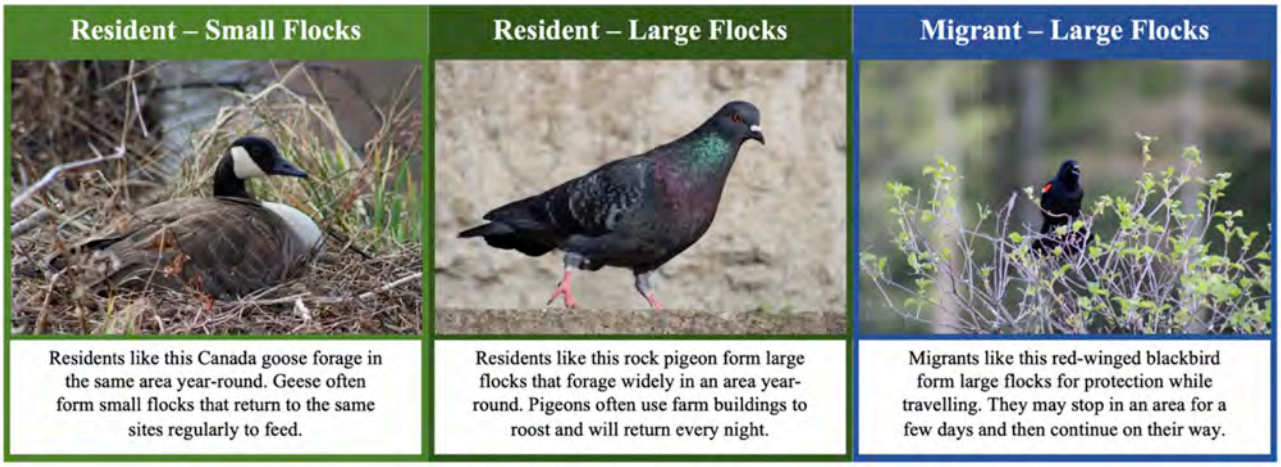

FIGURE 1. Examples of different foraging and residency behaviors: 1) resident and small flocks, 2) resident and large flocks, and 3) migrant and large flocks. These three types of birds may require different management strategies. ***Photo credit: Julia Berliner.***

indicated that most growers use management tools only when bird damage results in significant economic loss. Some deterrents have been reported by growers or researchers to be more effective than others *(45)*. However, labor, expense, overall efficacy, geospatial and temporal factors, target bird species *(Fig. 1)*, crop characteristics, and consumer perceptions should all be considerations for growers selecting deterrents intended to protect produce crops.

This review provides an overview of deterrents commonly used in fruit and vegetable production areas as well as advantages and disadvantages to their implementation in a production environment. It is not intended to serve as an endorsement for any strategy or technology, and growers are advised to conduct their own assessments to determine whether methods are appropriate for their own operations.

Site cleanliness

Managing waste and leftover produce should be the first priority for any operation trying to manage pest populations, including wild birds. In a packing facility, especially one that is open to the environment, emptying cull bins frequently, keeping material swept off of floors and surfaces, and ensuring food waste does not accumulate within the facility will reduce the likelihood of birds entering in search of food. Likewise, dumpsters and other trash collection areas likely to attract birds should be closed off, when possible, emptied regularly, and managed to reduce bird access. Reducing access to readily available food sources will greatly increase the effectiveness of other implemented deterrent or control measures *(19)*.

Scaring deterrents

The most common types of bird deterrents use "scaring" strategies that startle and drive birds away from fields. Tools such as scarecrows, predator decoys, and loud noises can be effective in the short term, but over time and with repeated exposure, birds will become accustomed to and learn to ignore most of these devices. Pairing visual stimuli such as decoys with auditory cues such as predator noises or distress calls can increase the effectiveness of scaring deterrents *(48)*. Changing the types and locations of stimuli can also prevent bids from becoming habituated to any one technique.

It should be noted that using scaring techniques may increase crop damage, especially if they are used after birds have already formed the habit of foraging at a particular location. Birds may be temporarily startled but then return, resuming feeding activities in a different part of the field and spreading damage across a wider area. Species such as crows and starlings that pluck fruit may be startled into dropping already picked fruit but then return once the stimuli is gone to pluck more. Therefore, it is important to think carefully about the intended effect and timing when using scaring deterrents.

Timing of scaring deterrents

The effectiveness of scaring deterrents largely depends on the kind of bird being targeted and when scaring deterrents are deployed. Scaring techniques are most effective when birds encounter them before they have formed a habit of visiting a field to forage, usually before crops have reached peak ripeness. However, because birds may habituate to scaring techniques over time, these tools should not be deployed too early or they will be ineffective when it matters. Waiting until just before crops ripen or as soon as birds begin to show interest in a field can help ensure scaring techniques work as intended. Regularly scouting fields for signs of birds or bird intrusion will help determine when deterrents need to be implemented.

TABLE 1. Common problematic bird species and their residency status and foraging and nesting behavior

Species	Residency	Dates in Georgia	Foraging behavior	Nesting behavior[a]
Canada goose	Resident	Year-round	Pairs or small flocks	Colonial cavity nester
Rock pigeon	Resident	Year-round	Large flocks	
American crow	Resident	Year-round	Small, nomadic flocks	
Barn swallow	Summer migrant	March–September	Large flocks	Colonial cavity nester
European starling	Resident	Year-round	Large, nomadic flocks	Colonial cavity nester
Brown thrasher	Resident	Year-round	Individually or in pairs within territory	
Northern mockingbird	Resident	Year-round	Individually or in pairs within territory	
American robin	Resident	Year-round; large flocks October and March	Small flocks year-round, but large, nomadic flocks often pass through areas in mid fall and early spring as individuals migrate to and from more northern states	
Cedar waxwing	Fall migrant	September–May	Large, nomadic flocks	
House sparrow	Resident	Year-round	Small or large flocks	Cavity nester
House finch	Resident	Year-round	Small or large flocks	Occasional cavity nester
Red-winged blackbird	Resident	Year-round; large flocks September–May	Small flocks during spring and summer; large, nomadic flocks during fall and winter as individuals from more northern states take up winter residence	Nest parasite
Common grackle	Resident			
Brown-headed cowbird	Resident			
northern cardinal	Resident	Year-round	Individually or in pairs within territory	

[a]Nesting behavior can guide management plans; for example, cavity nesters can be dissuaded from nesting in buildings by physical barriers. This is not intended as an endorsement of any manufacturer or product type, and effectiveness may vary based on geographic location, climate, weather, crop type, production practices, and other factors.

The migratory and foraging behavior of the targeted species can also greatly affect the effectiveness of scaring deterrents. Birds can be divided into two main categories: resident species that live in a region or specific location year-round, and migratory species that are only in a specific region or location for part of the year *(Table 1)*. Many resident species have small territories that they actively defend, so only one or a few individuals occupy the space at a time. However, some residents such as starlings are more nomadic, forming large flocks that move among different feeding locations across a wider landscape. Some migratory species hold small territories for part of the year, whereas others may forage in large flocks at a specific location for a few days or weeks. Scaring techniques are more likely to be effective when used against nomadic residents that forage at different sites, or migrants that are passing through an unfamiliar area.

TABLE 2. Common scaring and physical deterrents and their price ($USD), advantages, and disadvantages

Deterrent	Price (US$)	Advantages	Disadvantages
Scaring Deterrents			
Reflective surfaces (e.g., mirrors, tape)	5–30	• Relatively inexpensive • Easy to install	• Not effective for some species • Potential to be caught in farm equipment
Decoys (e.g., hawk kites, statues)	10–200	• Relatively inexpensive • Easy to install	• Effects may be short term • Only effective at short distances
Lasers	200–400	• Can be targeted toward specific species or individuals	• Expensive • May require user training • Effects may be short term • Light nuisance • Effects may be short term • Noise nuisance
Predator/ distress sounds	10–20 CDs 150–300 machine	• Can be targeted toward specific species • Can be broadcast over large areas	
Ultrasonic devices	250–650	• Little maintenance	• Expensive • Limited evidence these work
Sonic nets	2,500	• Little maintenance	• Expensive
Drones	500–5,000	• Can be targeted toward specific species or individuals	• Expensive • Requires user training • Effects may be short term
Nest boxes	50–100	• Little maintenance • Support bird conservation	• Effectiveness may vary with time of year
Trained falcons	1,000–6,000	• Very effective • Can be targeted toward specific species	• Expensive • Requires trained handler to supervise
Physical Deterrents			
Netting	50–500/ft	• Very effective	• Can be expensive and timely to install • Can interfere with farm operations • Risk of physical contamination
Spikes/wires	20–30/10 ft	• Prevents roosting and perching	• Can be expensive and timely to instal • Risk of physical contamination

Many resident species that hold territories have nowhere else to go once they are established at a specific location and are thus less likely to be scared off entirely. Identifying when migratory or nomadic species are likely to threaten crops can ensure scaring devices are in place in time to deter birds. Several types of scaring deterrents are described below, and a list of advantages, disadvantages, and cost estimates for the described methods is provided in *Table 2*.

Types of scaring deterrents

In the following text, we present several potential scaring deterrents: reflective surfaces, decoys, lasers, predators sounds, ultrasonic devices and sonic nets, drones, next boxes, and trained falcons.

Reflective surfaces such as mirrors, reflective tape, or CDs can be used directly in crop fields as well as in raptor and martin nest boxes to keep out unwanted species. Tape can be tied directly to trellises, stakes, or trees to protect crops by flapping and reflecting light, although care should be taken that trailing tape does not interfere with farm equipment or harvesting procedures. The density at which tape is positioned in the field is important; if gaps are left between taped areas, birds may simply reposition from taped rows or trees to nontaped rows or trees *(14, 20)*. Although tape has been used to deter geese, doves, crows, blackbirds, and black-capped chickadees *(9, 17)*, not all birds are repelled by tape *(15)* and those that are may quickly habituate *(46)*. Likewise, although mirrors in nest boxes may deter some species, they are ineffective at keeping out others, such as starlings *(41)*. In fact, some birds, particularly those that are highly territorial, may confuse reflections of themselves with competitors and become aggressive toward mirrors instead of being repelled.

Decoys include tools such as predator statues, scarecrows, hawk and falcon kites, and scare-eye balloons. Similar to reflective surfaces, decoys may be useful at repelling some species, but not others. Predator decoys, for example, may actually attract blackbirds and crows because these species frequently engage in "mobbing" behavior toward hawks. Predator models can be placed on top of buildings or mounted to posts in fields. Some models are available that can move in the wind, which might be more effective than stationary models *(12)*. Although scarecrows and predator decoys have been found to repel birds in the short-term, birds typically habituate after a few days *(10)*, so these must be moved regularly to remain effective. Hawk and falcon kites are kites printed or colored to look like predatory birds. They can either be tethered directly to a stake on a long line or flown underneath a helium balloon. Kites tethered beneath balloons may be more effective than those tethered to the ground; balloon-tethered kites were successful in reducing crop damage in both grapes and corn *(11, 27)*. Scare-eye balloons, or more generally, scare-eye spots, mimic the reflective eyes of owls or other predators to deter birds. Balloons, similar to reflective tape, can be hung directly in crops and moved around as needed. Scare-eye balloons are only effective at short distances of 15–20 m *(18)*, and birds may habituate after 1–2 weeks *(25)*. The most effective decoys are those that are lifelike, involve movement (e.g., flapping, flying), change locations frequently, are paired with auditory cues, and are installed before birds have habituated to agricultural fields *(48)*.

Lasers include light-emitting devices such as pointers and guns that can be flashed in fields or fired at perched or roosting birds. Lasers are most effective at dusk and dawn when ambient light levels are low. Repeated targeting of roosting cormorants and crows by lasers has been reported to successfully clear roosts and buildings for a few hours or days *(5)*. Some species seem to be more sensitive to laser light than others: in one study, lasers were used to drive off geese, herons, cormorants, pelicans, and diving ducks, but were ineffective when fired at gulls, shorebirds, grebes, coots, or dabbling ducks *(21)*. Stationary devices that emit moving lasers in fields can drive birds away from fields, especially if alternative food sources are nearby *(7)*. Although stationary devices may be more time- and cost-effective than using guns or pointers, which often require user training, indiscriminate laser use can also drive away nontarget birds.

Predator sounds such as hawk screams and distress sounds of target birds can be used alone or in conjunction with visual scaring deterrents to increase their effectiveness *(3)*. Bird vocalizations, just like human language, vary by situation and region. Birds have a wide range of sounds and calls that they use to defend territory, communicate their location, warn of predators, and attract mates. Many devices preloaded with predator and distress noises are available and can be connected to speaker systems or mounted in-field and set to play at random intervals. Other recordings, including CDs and digital audio files, can also be used.

Alarm calls are used by birds to warn of nearby danger and are usually species specific. Species that are gregarious and forage together, such as blackbirds and grackles or titmice and chickadees, may respond to each other's alarm calls. Using alarm calls of a specific targeted species might be more effective than distress or alarm calls of unrelated species because some birds ignore the vocalizations of others, especially if they are not known to forage or interact with each other regularly. Distress sounds are made by caught birds and are used to startle predators to try and escape rather than to warn of danger. Rather than being repelled by distress sounds, some birds are attracted by distress noises to try and gather information about what types of danger are in the area *(13)*. Using alarm calls or distress sounds alone may not be very effective, because behavioral trials indicate birds may need to both hear an auditory cue and observe a threat visually to be deterred from a particular location *(22)*.

Predatory birds such as hawks and eagles also vocalize for much the same reasons other birds do. Predators do not tend to vocalize while hunting, so using predator sounds

alone, may not be very effective at repelling birds because the sound alone may not indicate an immediate threat. Like predator decoys, birds more quickly to habituate to predator and distress noises if they are repetitive and sound frequently from the same location. Before implementing bird vocalizations as a deterrent strategy, growers should consider the bird species that they need to target, the quality of the sound recording that they are using, and the placement and orientation of broadcasting equipment. In addition, pairing visual deterrents such as predator decoys with audio deterrents may increase efficacy of both deterrents.

Ultrasonic devices and sonic nets both use nonbiological noise to deter birds. Ultrasonic devices use sounds at high frequencies to drive birds away, although there is limited evidence that ultrasonic devices work as intended. Although bird calls are often high pitched, birds cannot actually hear at the ultrasonic range (>20 kHz; 2). Sonic net devices emit white noise that makes it harder for birds to hear each other and disrupts their communication. Because birds are unable to communicate, they may feel that they are in more danger from predation and leave the area. Sonic nets have been used to successfully deter starlings and blackbirds from fields *(33, 50)* and grain storage *(51)*, although some of these effects diminished after a few days. Both sonic net and ultrasonic devices can be mounted in-field on posts; commercially available devices are usually solar panel compatible.

Drones, either remote controlled boats or unmanned aerial vehicles (UAVs), can be used to harass and drive off birds from fields, buildings, or bodies of water. Drones, especially when paired with auditory cues such as predator noises or distress calls, can present a more realistic threat to birds than other scaring devices, but, as with other kinds of predator decoys, they may be more effective at deterring some bird species than others. Crows or birds of prey may attack UAVs that they perceive as threats or prey. Remote control boats were used in combination with dogs to successfully remove geese from waterways, although geese often returned when boats and dogs were no longer present *(26)*. UAVs were successfully used to clear rock pigeons from buildings for short periods of time *(40)* and reduced damage in vineyards from crows when paired with sounds and a crow effigy *(49)*. Most drones require user training before use, although some systems have been designed with set flight paths to reduce the amount of user training required *(23)*.

Nest boxes can be placed in fields to attract local falcons and other raptors whose presence will deter smaller birds from fields. Kestrels, which breed in Georgia and readily take up take up residence in cavities, are common nest box species. Nest boxes are available commercially and can be mounted in fields on tall posts. The presence of falcons using nest boxes greatly reduced crop damage in vineyards and crop damage and fecal droppings in cherry orchards *(32, 42)*, although depending on the season, falcon impact on other bird species may vary. In studies evaluating the use of falcon nest boxes in agricultural fields, kestrel presence in nest boxes successfully reduced crop damage in sweet cherry orchards, but not in blueberries *(43)*. This may be because during the study, sweet cherries, but not blueberries, were ripening during the kestrel fledgling period *(Fig. 2)*. During this time, adult birds have to feed both themselves and their growing offspring and may therefore be more actively hunting in the immediate vicinity. Therefore, the timing of crops and falcon fledgling period should be considered before relying entirely on nest boxes to manage birds. Nest boxes may be more effective for summer or year-round crops than those grown in other seasons. Nest boxes require at least annual cleaning and some year-round maintenance to keep out unwanted species such as starlings and squirrels.

Trained falcons can be deployed periodically to chase and scare birds away from fields. Falconry as a deterrence method involves an expert handler letting a trained bird fly or hunt in a specific area. Falconry has been used to successfully deter birds from agricultural fields for several days during and after treatment *(37)*. Although effective, this method is expensive and may be less practical for regular use in an agricultural environment.

Alternative resources and sacrificial/lure crops

Alternative resources for birds, such as nearby fields, bird feeders, or buildings can reduce the efficacy of scaring deterrents because birds may simply move to a nearby location and then return when they perceive the threat has passed. If the goal of deterrence is short-term management of a particular field or building, alternative resources may not be a concern, but if long-term or farm-wide management is desired, identification and management of alternative resources should be considered. Early ripening crops, for example, may attract birds to an area before other crops start to produce. Delaying planting or harvesting early may help deter crop damage from birds.

Using lure or sacrificial crops, in contrast, can enhance the effect of scaring deterrents because birds will move from the "scary" field to the safer and less threatening field *(31)*. Lure and sacrificial crops may be costly and labor intensive to use, but can potentially save money in the long term *(30)*. Lure crops can be made more appealing to birds by reducing disturbances, selecting areas closer to roosts, and choosing crops that ripen slightly before or at the same time as nonlure produce *(39)*.

Physical deterrents

Physical deterrents include tools such as nets and spikes that prevent birds from roosting or foraging effectively. In most studies that compared the efficacy of various scaring deterrents with physical deterrents, physical deterrents were as good or better than scaring deterrents in preventing crop damage *(49)*. The main considerations when using physical deterrents such as netting and spikes are the

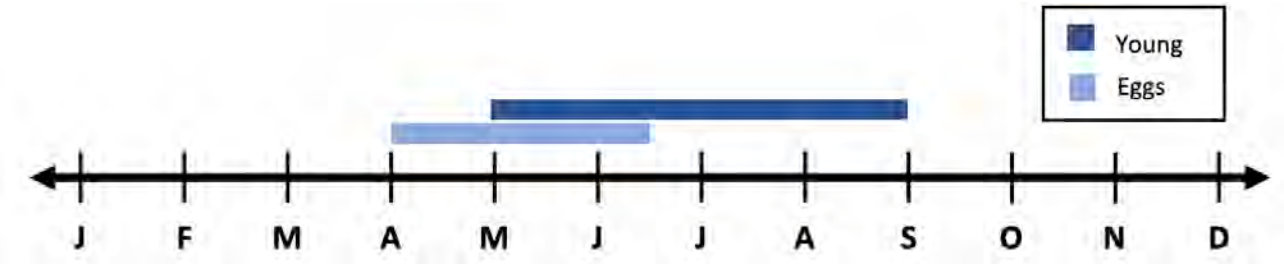

FIGURE 2. Egg-laying and fledgling period (month) for kestrels *(4)*.

price, installation time, and risk of physical contamination. Installing netting to protect grapes may be possible for a small vineyard, for example, but might become prohibitively expensive or time consuming for larger fields. Physical contamination is also a serious concern, particularly if devices are installed in packinghouses or above produce processing or packing areas. Regular inspection and maintenance are important to ensure both continued effectiveness of and reduce the risk of contamination of produce or equipment from physical deterrence devices. Additional information regarding advantages, disadvantages, and cost estimates for physical deterrents is provided in *Table 2*.

Physical deterrents in agricultural structures and packinghouses

Many of the bird species that frequently forage in agricultural fields commonly or exclusively roost in buildings. Starlings, rock pigeons, house sparrows, and house finches often take up residence in rafters, ledges, or lofts of farm buildings and forage in nearby fields. Preventing birds from roosting or nesting in buildings can reduce damage to adjacent crops *(29)*. Birds nesting in buildings can also be problematic because of food safety and property damage concerns. Birds perching or roosting in packinghouses or above food processing areas represent a significant food safety concern because feces and detritus from nests can drop down onto produce processing surfaces, equipment, and produce. Bird feces can contain harmful bacteria such as *Salmonella* and *Campylobacter* that can contaminate produce and potentially cause illness in workers and consumers *(28, 47)*.

Types of physical deterrents

Netting can be placed around and over bushes, trees, trellises, and stakes to prevent birds from damaging crops. Netting or screens can also be installed in rafters and over grates and openings to prevent birds from roosting in or entering buildings and other farm structures. Netting is generally very effective at reducing crop damage by birds in fields *(8, 49)* and bales *(35)*. Birds will take advantage of any tears or rips that develop in netting during storms or strong winds, so frequent inspection and maintenance are required. Netting in fields also has the potential to interfere with farm equipment and may be cumbersome to remove before harvest. Netting is also useful for keeping birds such as starlings from roosting in rafters *(36)*, although sometimes birds will tear and remove netting or screens, so regular inspection and maintenance are also required for netting used in buildings. Netting with larger holes is ineffective at deterring smaller species, so carefully consider bird size before purchasing. Materials such as chicken wire or plastic might be appropriate for buildings, but may damage plants or fall apart due to exposure when used in the field.

Spikes and wires can be installed on or near ledges or rafters to keep birds from perching. Blunt metal or plastic spikes are available in different sizes and configurations and can be installed directly onto ledges. Larger sized spikes are ineffective at keeping smaller birds from roosting, so consider bird size when purchasing. Thin wires can also be installed parallel to ledges or beams to keep birds from perching, although, again, smaller birds may be able to perch between wires if they are spaced too far apart. Birds can sometimes pry off or break spikes, so regular inspection and maintenance are required, particularly if spikes are installed in packinghouses or above food processing areas.

Habitat modification or habitat removal can deprive birds of resources and make an area more inhospitable. Some birds such as geese and starlings prefer to forage in short grass, so allowing grass to grow longer may deter them from foraging near crops *(6, 34)*. Birds are more likely to forage on the edges of fields than in the center, so reconfiguring fields to increase the area to perimeter ratio could help reduce crop damage. Removing natural habitat around fields can actually increase crop damage and food safety concerns *(38, 44)*, because birds have less access to alternative food sources, perches, and roosts. Therefore, large-scale habitat modification or habitat removal is not generally a recommended bird management strategy in agroecosystems.

CONCLUSIONS

Managing wild birds on produce can be difficult and expensive, but by focusing management on particular pest species, growers can reduce the financial and labor costs. Management plans should be informed by the species and its timing and behavior. Growers may have to spend time initially monitoring their fields and making observations. When the time comes to use deterrence, growers may have to test several different strategies to find what works best for them. In the long term, however, this informed, species-specific approach will save growers time and money.

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In Memory

IAFP was notified of the passing of member **Kendra Nightingale.** The Association extends our deepest sympathy to her family and colleagues. IAFP has sincere gratitude for her contribution to food safety.