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Commentary

Supporting farmer adoption of sustainable bird management strategies

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Abstract: Pest birds cause substantial and costly damage to crops. Managing birds is complex because (1) they are highly mobile, (2) they habituate quickly to many deterrents, (3) some species provide benefits to farmers by deterring and consuming pest insects, rodents, and other birds, and (4) birds are highly valued by many people. Thus, farmers have many issues to consider when developing bird management strategies. Here I discuss recent work indicating that farmer adoption of sustainable agricultural practices is more likely when practices are effective, clear guidelines for implementation are available, implementation is relatively easy, and when practices are linked, in farmers' minds and logistically, with other farm management practices. This manuscript draws together information about these factors for common bird management tactics to aid in the development of sustainable bird management strategies by farmers and the development of education programs for farmers by extension personnel and researchers. Such strategies will necessarily involve combinations of tactics, following the framework of Integrated Pest Management.

Key words: agricultural conservation practices, barriers to adoption, bird management, farmer adoption, integrated pest management, pest birds, sustainability

Bird management is costly to farmers and local economies (Anderson et al. 2013) and poses many challenges. First, pest bird management is difficult because birds are highly mobile and persistent once a food source has been discovered. Second, management strategies must be consistent with maintaining the quality of soil, water, air, and biodiversity that is critical to the production of crops (Millennium Ecosystem Assessment 2005). Third, while numerous bird species eat crops (e.g., Hannay et al. 2019) and potentially pose food safety hazards (Smith et al. 2020), other bird species consume and deter pest birds (e.g., Kross et al. 2012, Shave et al. 2018). Thus, ideally, bird management strategies would discourage pest birds and encourage beneficial birds (Garcia et al. 2020). Finally, farmers must be motivated to implement effective, sustainable strategies (i.e., barriers to adoption must be low). Here I discuss recent work investigating factors that influence farmer adoption of management practices and suggest that these factors be considered by extension personnel and researchers to enhance the adoption of sustainable bird management strategies.

Factors influencing adoption of management practices

Farmer adoption of sustainable pest management strategies is a critical piece of the goal of improving agricultural productivity while protecting the environment. However, while assessing farmer knowledge and educating farmers about wildlife is important (e.g., Shapiro et al. 2020), simply providing farmers with information does not necessarily lead to adoption of particular strategies; being more informed does not consistently lead to changes in behavior (McKenzie-Mohr et al. 2012). This begs the question of how to increase farmer adoption of pest bird management strategies that are environmentally sustainable.

A recent review investigated factors that positively influence the likelihood of farmers adopting conservation practices related to issues like nutrient, soil, and pest management (Prokopy et al. 2019). The researchers searched the literature for studies based in the United States and published between 1982 and 2017. From 93 quantitative studies, the researchers found that farmers who self-identified as being stewards, leaders,

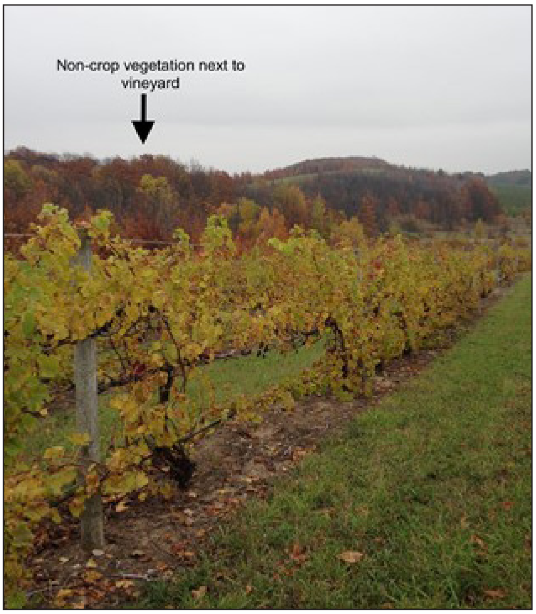

Figure 1. Non-crop vegetation near a vineyard in Michigan, USA. Non-crop vegetation can provide habitat for beneficial birds that eat insects but also pest birds that eat fruit (*photo courtesy of S. Wieferich*).

and innovative were most likely to adopt conservation practices, as were farmers with positive environmental attitudes and who had previously adopted conservation practices. Higher incomes and education, an expectation that a practice would lead to higher yield, and engaging in marketing to increase revenue were also positively associated with adopting conservation practices (Prokopy et al. 2019).

Agricultural conservation practices include those designed to increase "functional biodiversity," which can be useful in providing pest regulation through natural predators. A survey of European apple (*Malus* spp.) farmers (Penvern et al. 2019) found that they employed a number of techniques in support of functional biodiversity, from installing bird nest boxes to maintaining hedgerows. Hedgerows and other non-crop vegetation in agricultural landscapes can support beneficial birds that prey on insect crop pests (Garfinkel and Johnson 2015, Kross et al. 2016, Garfinkel et al. 2020; Figure 1), although the vegetation may also be used by fruit-eating birds (Lindell et al. 2016). Farmers often implement multiple functional biodiversity techniques simultaneously, and thus it is challenging for them to evaluate whether single tactics reduce pest damage. Thus, farmers need specific advice and training to meet their needs (Penvern et al. 2019). This conclusion was similar to those in other recent studies. When apple growers in New York and Pennsylvania, USA were asked about factors that would influence their likelihood of making land management changes to attract native pollinator species (Park et al. 2020), they stated that the effectiveness of the changes in attracting pollinators and clear recommendations as to how to make the changes would be critical. In another study, blueberry (*Vaccinium* spp.) and cherry (*Prunus* spp.) growers strongly agreed that they would be more likely to adopt a conservation practice if extension or industry provided explicit information about the practice and how to implement it (Bardenhagen et al. 2020*a*).

Interviews of blueberry and cherry growers in Michigan, USA were used to create mental models of farmers' decision-making about pest management and inform processes to encourage farmers to adopt conservation practices (Bardenhagen et al. 2020*b*). The study showed that cost, fruit quality, pest management effectiveness, pest pressure, and timing (how tasks necessary to implement a practice fit into the existing farm schedule) were central factors in the models (Bardenhagen et al. 2020*b*). In addition, farmers that thought about the interactions among factors in their management systems, like those between natural predators and yield, were more likely to adopt conservation practices (Bardenhagen et al. 2020*b*).

I am unaware of any studies that have explicitly investigated whether the cost-benefit ratio of a particular bird management technique influences grower adoption. However, in a survey of blueberry and cherry growers from 5 states, a majority of growers believed bird damage reduced profits (Anderson et al. 2013). Bardenhagen et al. (2020*a*) demonstrated that 83% of blueberry and cherry farmers surveyed expected farm income to increase if natural predators of birds increased on their farms. Farmers also perceived that over half of consumers would be very interested in fruit produced with conservation practices like predator nest boxes, indicating the potential for increased income by letting consumers know about these production practices (Bardenhagen et al. 2020*a*). Shave et al. (2018) showed that nest boxes for predatory birds have a very favor-

Figure 2. Two inflatable tube men in a vineyard in Michigan, USA (*photo courtesy of S. Wieferich*).

Figure 3. A hawk-kite in a sweet cherry (*Prunus avium*) orchard in Michigan, USA (*photo courtesy of S. Wieferich*).

able cost-benefit ratio with regard to pest bird management in sweet cherry (*Prunus avium*) orchards. Thus, fruit farmers have some awareness of the potential financial benefits of managing bird damage with natural predators, which should enhance adoption in some of the contexts described in the next paragraph.

In short, these recent studies suggest that to increase adoption of sustainable bird management strategies, farmers need information about the effectiveness of a practice and clear guidelines as to how and when to implement a practice. In addition, practices that are relatively simple to implement and can be done within the established schedule of farm management are more likely to be adopted. Finally, demonstrating to farmers the links between farm inputs and outcomes and sustainable practices may improve adoption of practices. For example, if practices can be linked to marketing and/or costs and/or yields, it is more likely they will be adopted than if they are presented as simply another task farmers should take on. Future areas of research should include cost-benefit analyses of sustainable bird management strategies, the potential for social influences on farmer adoption of strategies (e.g., Lewis et al. 2011, Noy and Jabbour 2020), and the potential for cost-share arrangements to enhance adoption of strategies that are somewhat complex, like management of field-edge vegetation (e.g., Brodt et al. 2009).

Current state of bird management tactics

Particular pest management tactics may deter birds only in some contexts (e.g., Linz et al. 2011, Lindell et al. 2018*a*, Werner et al. 2019). For this reason, and to reduce reliance on pesticides, integrated pest management programs (IPM) bundle several pest management tactics (Osteen and Fernandez-Cornejo 2013). Therefore, IPM can be seen as an environmentally sustainable framework of pest management with each of the following tactics having its own set of environmental costs and benefits.

Visual deterrents like inflatable tube men (Figure 2) and hawk-kites (Figure 3) are relatively easy to deploy, but previous tests do not provide strong evidence that they reduce crop damage (Steensma et al. 2016, Lindell et al. 2018*a*). Environmental costs include the materials and energy such deterrents require. Overall, such costs are likely to be low, similar to some of the other deterrents below, including lasers. Acoustic devices like propane cannons, explosives that scare birds but do not harm them, and broadcasts of bird distress calls can be effective in reducing damage (e.g., Berge et al. 2007). One downside of these devices is that the noise they generate can disturb neighbors and farmworkers. Some chemical deterrents reduce bird damage in some crops at some stages. For example, anthraquinone deters Canada geese (*Branta canadensis*; geese) and sandhill cranes (*Antigone canadensis)* from eating young plants and seeds (Werner et al. 2019, Barzen et al. 2020), but this chemical cannot be applied to all crops; it is not labeled for use in fruit. Tests of sprays containing methyl anthranilate did not show clear differences in bird damage between treated and control groups (e.g., Avery et al. 1996, Lindell et al. 2018*a*). Netting reduces bird

Figure 4. A fixed-wing drone used in experiments in sweet cherry (*Prunus avium*) orchards, Michigan, USA, in 2018 (*photo courtesy of C. Lindell*).

damage (Berge et al. 2007, Wang et al. 2020) and is viewed as an effective management strategy by many farmers (Anderson et al. 2013). However, it has substantial costs in labor and materials and is not generally an option for tree crops. Falconry is more expensive than other management techniques. Although it reduced blueberry damage in the Pacific Northwest of North America (Steensma et al. 2016), it did not reduce damage to rice by local swamphens (*Porphyrio porphyria*) in Spain (Moreno-Opo and Piqué 2018). Handheld lasers reduced geese abundance and increased sward height in treatment plots compared to control plots in Danish pastures (Clausen et al. 2019). More up-to-date laser devices that provide a constant, moving beam of laser light over fields are currently being tested (Brown et al. 2019). Large-scale population suppression (e.g., through trapping) is not likely to be effective beyond local scales (Linz et al. 2011).

Newer bird management tactics include drones and "sonic nets." We are beginning to understand features of drones (Figure 4) that improve bird deterrence. For example, in a test arena, red-winged blackbirds (*Agelaius phoeniceus*) avoided food longer and increased time alert in response to more realistic predator-like drones compared to simple fixed-wing or multirotor drones (Egan et al. 2020). Also, drones carrying crow (*Corvus* spp.) effigies were able to deter large and small birds from vineyards in Australia for varying periods of time (Wang et al. 2019). At this point, drones still demand substantial human involvement and cannot be deployed in certain conditions, such as strong winds. Environmental costs because of material and energy requirements for drones should be relatively low. Sonic "nets," which are devices that produce sounds in the frequencies birds hear and make it difficult for them to communicate and detect predators, reduced bird abundance at airfields and have been suggested for use in crops (Swaddle et al. 2016). These types of devices cause some noise pollution.

Careful crop and habitat management may be effective in reducing bird damage in crops like sunflowers (*Helianthus annuus*) and fruit. For example, decoy crops may attract birds accustomed to feeding in commercial sunflower fields if they are planted near night roost sites, earlier in the season than commercial fields, and with a variety of sunflower types that ripen at different times (Linz et al. 2011). Planting large blocks of particular crops with ripening periods that overlap with the majority of other blocks in an area will dilute bird damage (Linz et al. 2011, Eaton et al. 2016, Lindell et al. 2016). These types of management require detailed knowledge of pest bird biology, including their use of habitats within the landscape.

Although birds can cause significant crop damage, they also consume crop pests including insects, mammals, and birds. Much research in the last 2 decades has focused on the potential of natural predators to reduce crop pests and damage (e.g., Jedlicka et al. 2011; Maas et al. 2013; reviewed in Lindell et al. 2018*b*; Garfinkel et al. 2020; Garcia et al. 2020; Olimpi et al. 2020; Castañeda et al., in press). Birds that prey on and/or are aggressive toward crop-eating birds can be useful in deterring birds that damage crops. Re-introducing a native raptor that preyed on birds into a New Zealand winegrape-growing area reduced bird damage (Kross et al. 2012). American kestrels (*Falco sparverius;* Figure 5), small falcons, reduced fruit-eating bird abundance in sweet cherry orchards, with potentially large economic gains for the region (Shave et al. 2018). Nest boxes and perches are tools that can be used to attract predatory and aggressive birds to particular places on the landscape (Peisley et al. 2017, Shave and Lindell 2017). The likelihood that boxes and perches will be used by predatory birds varies from place to place, so studies to ascertain the likelihood of use are important.

Figure 5. An American kestrel (*Falco sparverius*), which deters pest birds, in a sweet cherry (*Prunus avium*) orchard in Michigan, USA. Kestrels can be attracted to orchards by installing next boxes on poles (*photo courtesy of C. Lindell*).

Figure 6. Netting in a blueberry (*Vaccinium* spp.) field in Michigan, USA (*photo courtesy of C. Lindell*).

Environmental impacts of bird management techniques

Sustainable agriculture requires social, economic, and environmental sustainability. Here I focus on the potential environmental impacts of bird management practices. Some negative environmental impacts stem from the resources used in construction and deployment of materials. These impacts can be reduced by using the minimal number of devices necessary for effective bird management and by using solar panels for power, when possible. Netting (Figure 6), particularly large areas, necessarily involves a large amount of materials and would have a larger environmental impact than many of the other techniques mentioned above.

Negative environmental impacts could also stem from contamination of soil, water, and/or air. Avian repellents containing the active ingredients methyl anthranilate and anthraquinone are considered safe in many contexts and, if used correctly, should not pose risks of environmental contamination. In contrast, fenthion, an avicide used against the red-billed quelea (*Quelea quelea*) in grain crops in parts of Africa, is highly toxic to non-target organisms (Cheke and El Hady Sidatt 2019). Further, although the noise associated with some bird management techniques has long been recognized as annoying to neighbors, any effects on farmworkers and non-target wildlife of this type of noise pollution are not clear and should be investigated.

Positive environmental impacts could stem from the addition of resources like nest boxes and perches that could benefit natural predator species with declining populations (Lindell et al. 2018*b*). In addition, nest boxes, perches, and falconry also potentially provide marketing opportunities. Farmers perceived that using next boxes in fruit production would be viewed positively by consumers (Bardenhagen et al. 2020*a*); other work showed consumers were willing to pay more for fruit produced with raptor nest boxes or falconry as pest bird management tactics compared to fruit produced with a chemical spray to deter birds (Herrnstadt et al. 2016). I provide a summary of bird management tactics and considerations with regard to some of the critical factors shown to influence adoption by farmers, along with their potential environmental impact (Table 1).

Conclusion

Much of the recent work on farmer adoption backs up the proposition that changes in behavior are more likely to occur if messages focus on specific actions that are feasible to implement (Schultz 2011). For example, the knowledge, planning, and time necessary to implement a habitat management scheme to deter birds (e.g., Linz et al. 2011), which may be environmentally sustainable, would likely be daunting to most farmers. Work with farmers in California, USA indicated that potential barriers to the adoption of hedgerows or other types of managed vegetated edges, which could provide habitat for natural enemies and pollinators, were anticipated high establishment and maintenance costs and time commitments to manage the edge (Brodt et al. 2009). In contrast, the addition

Table 1. Bird management tactics and 3 factors that potentially impact likelihood of adoption (effectiveness, level of knowledge and guidelines required for implementation, and ease of implementation). Also included are sustainability considerations and potential links to other components of the production/distribution/consumer system.

Tactic	Effective?[a]	Substantial level of specific knowledge/ guidelines important?	Ease of implementation[b]	Sustainability	Other points
Acoustic deterrents	M	No	+++	Noise pollution	Relationships with neighbors
Chemical repellents: methyl anthranilate and anthraquinone	M	Yes	++	Materials and energy required to apply	Potentially detrimental to marketing
Drones	M	No	++	Likely small impact	Local, state, federal regulations
Falconry	M	No	++	Likely small impact	Potentially useful in marketing
Habitat management	M	Yes	+	Variable	Multi-stakeholder coordination likely needed
Lasers	M	No	+++	Likely small impact	
Lethal control	M	Yes	+	Potentially large negative impact	Unpopular with many people
Nest boxes/ perches for predatory birds	M	Yes	+++	Encouraging natural predators; potentially positive impact on native declining species	Potentially useful in marketing
Netting	H	No	+	Large amount of materials needed	
Visual deterrents	L	No	+++	Likely small impact	

[a]High (H) means literature shows and >50% of farmers surveyed consider the tactic to be moderately or very effective in deterring birds; Moderate (M) means literature shows mixed results and/or 30–49% of farmers surveyed think the tactic is moderately or very effective in deterring birds; Low (L) means literature tends to show the tactic does not deter birds consistently and that <30% of farmers surveyed think the tactic is moderately or very effective in deterring birds. For some tactics, like drones and falconry, the number of studies is small. Farmer survey data from Anderson et al. (2013).
[b]+++ is relatively easy to implement; ++ requires a greater investment of materials and equipment and labor or the need to hire a professional (falconry); + requires the most investment of materials, labor, and/or planning.

of a few acoustic bird deterrents may be more achievable, despite questions about long-term effectiveness and the resulting noise pollution. Providing clear guidelines about effectiveness and implementation as well as making the links between bird management and other facets of a farming operation, like marketing, explicit will be helpful in improving farmer adoption. In addition, several studies suggest that many farmers bundle conservation practices and are more likely to adopt a conservation practice if they are employing others. Therefore, presenting conservation practices as packages, from both training and implementation perspectives, may be useful. Two final caveats are important. Most previous work on farmer adoption patterns has focused on factors that are positively associated with adoption rather than investigating factors that create barriers to adoption (Prokopy et al. 2019). Second, most research about farmer adoption of agricultural conservation practices has focused on individual and farm characteristics rather than on structural factors. However, structural factors like market characteristics, government policies, and industry and research priorities could play large roles in encouraging adoption or in creating barriers to adoption of particular practices (Prokopy et al. 2019). Much work remains to be done to generate environmentally sustainable bird management strategies and get them into practice.

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