2017

The Future of Blackbird Management Research

Page E. Klug
USDA/APHIS/WS National Wildlife Research Center, pklug@usgs.gov

In: G.M. Linz, M.L. Avery, and R.A. Dolbeer, editors. Ecology and management of blackbirds (Icteridae) in North America. 2017. CRC Press, Boca Raton, FL. Pgs. 217-234.

CHAPTER 13

The Future of Blackbird Management Research

Page E. Klug
National Wildlife Research Center
Bismarck, North Dakota

CONTENTS

Human society values birds for their intrinsic and aesthetic value as well as the ecosystem services they provide as pollinators, consumers of pests, and distributors of nutrients and seeds (Wenny et al. 2011). At the same time, conflict between birds and humans is an age-old phenomenon that has persisted as society has transformed and the scale of agriculture has expanded (Conover 2002). Managing conflict between birds and agriculture is challenging for many reasons. Foremost, the need to consider both human welfare and conservation of protected bird species is paramount, with nonlethal management methods preferred to lethal measures from societal, economical, and ecological standpoints (Miller 2007; Linz et al. 2015). Second, methods must be effective, practical, and economical for agricultural implementation. Finally, management methods must overcome characteristics that make birds difficult to manage including uncertainty in population estimates, fecundity, mobility, and adaptive behaviors. All challenges are compounded when attempting to establish management methods that fit within modern agricultural practices, while simultaneously supporting conservation efforts to protect wildlife.

Labor-saving devices and methodologies resulting from agricultural advances in mechanical, chemical, genetic, and information technologies have facilitated a shift to larger crop fields, a broader range of suitable habitat for a variety of crops, and consolidated farms in North America (MacDonald et al. 2013). This shift to large, less labor-intensive farms has supported the ability to feed an ever-increasing human population but has complicated the relationship between humans and wildlife. Modern agriculture directly impacts wildlife by altering natural habitat, resulting in the increase of species able to thrive in agricultural landscapes and the decline of species unable to adapt. Thus, agriculture often provides increased carrying capacity for species responsible for agricultural damage (Van Vuren and Smallwood 1996). However, changes in harvest efficiency have resulted in less crop waste and reduced availability of high-energy foods available to birds postharvest, potentially placing common farmland birds at risk of decline (Krapu et al. 2004; Galle et al. 2009). Nevertheless, vertebrate species able to adapt to the agricultural landscape often reach pest levels, resulting in producers seeking tools to reduce damage, tools that have not necessarily advanced in concert with modern agriculture.

Red-winged blackbirds (150 million; *Agelaius phoeniceus*), brown-headed cowbirds (120 million; *Molothrus ater*), common grackles (69 million; *Quiscalus quiscula*), and yellow-headed blackbirds (15 million; *Xanthocephalus xanthocephalus*) are among the most numerous birds in North America (Rosenberg et al. 2016). This book has identified conflicts between blackbirds and agricultural commodity groups including livestock, rice, corn, sunflower, and numerous specialty crops (Dolbeer 1990; Cummings et al. 2005; Anderson et al. 2013; Klosterman et al. 2013; Figure 13.1). Continued progress in development of blackbird management methods and acquisition of baseline knowledge as to its impacts on blackbird populations are needed at local, regional, and national scales.

In this chapter, I evaluate gaps in knowledge and potential research directions. I address the following topics: (1) blackbird biology at the species, population, and community levels; (2) the influence of changing landscapes on blackbirds and agricultural damage in terms of agricultural practices, habitat, and climate change; (3) the limitations of lethal and nonlethal management tools (i.e., repellents, frightening devices, and evading strategies) and how research can optimize techniques or facilitate new tool discovery; and (4) economic evaluation of management and human dimensions.

Figure 13.1 Evidence of blackbird damage to sunflower in which expelled shells are left on the back of the downward-facing sunflower head. (Courtesy of Conor Egan/USDA Wildlife Services.)

13.1 BLACKBIRD ECOLOGY

Although the red-winged blackbird is one of the most studied wildlife species, much is left to understand about its biology and the biology of other blackbird species. The majority of blackbird literature focuses on mating systems, sexual selection, and breeding behavior (Searcy and Yasukawa 1995; Beletsky 1996; Beletsky and Orians 1996), with additional focus on avian communication and social bonds of species with both territorial and colonial behaviors (Beletsky 1996). Beyond the breeding season, most research has been conducted in the context of blackbirds as pests when large roosts or flocks come into conflict with human society (Conover 2002). Searcy and Yasukawa (1995) listed gaps in our knowledge of red-winged blackbirds, including several that influence management in relation to agriculture. I concur that little is known about blackbird physiology in relation to migration, behavior of independent young birds, and overall effect of species and subsets of populations on agriculture and human health and safety. Brown-headed cowbirds have been the focus of much research due to their unique nest parasitism behavior, potential influence on birds of conservation concern, and agricultural crop damage, but many data gaps exist for cowbirds as well as other less studied blackbirds.

The impact of yellow-headed blackbirds, common grackles, and brown-headed cowbirds on agriculture are thought to be substantially less than red-winged blackbirds due to factors such as smaller population sizes, habitat use, feeding habits, or earlier molt and migration (Besser 1985; Twedt et al. 1991; Homan et al. 1994; Peer et al. 2003; Twedt and Linz 2015). Research has mainly focused on management tools to address damage from red-winged blackbirds (e.g., Dolbeer 1990; Linz et al. 2011; U.S. Department of Agriculture 2015), but the impact of other species holds potential to change as avian populations respond to habitat and climate change (Homan et al. 1994). Additionally, tools aimed at red-winged blackbirds may negatively impact species with small or declining populations (e.g., Brewer's blackbirds [*Euphagus cyanocephalus*] and rusty blackbirds [*Euphagus carolinus*]) or may impact the continental population of red-winged blackbirds (Greenberg et al. 2011; Sauer et al. 2014). Understanding the importance of the southern United States as overwintering habitat and the Prairie Pothole Region (Bird Conservation Region [BCR] 11) as a stronghold for breeding blackbirds experiencing continental declines is necessary to assure protection of a native species and to maintain a balance between human and wildlife well-being (Weatherhead 2005; Strassburg et al. 2015; Chapter 7, this volume). Monitoring changes in both winter roost and breeding numbers is essential, and evaluating possible factors influencing abundance and distribution should be a research focus. Updated take models using accurate demographic information are necessary, given declining blackbird populations, specifically brown-headed cowbirds, where aggressive population reduction may not be warranted (Peer et al. 2003; Chapter 5, this volume). Thus, the status of blackbird populations must be addressed at multiple scales and the influence of management on demography explored throughout their annual cycle, especially considering the impact of habitat and climate change (e.g., Blackwell and Dolbeer 2001).

Agricultural stakeholders have voiced concerns about limitations for effective bird damage management and identified three critical research needs: (1) development of national management plans for each blackbird species; (2) development of management tools, including species-specific lethal methods and chemical, auditory, and visual repellents; and (3) research on blackbird biology in relation to damage and avian-borne diseases (U.S. Department of Agriculture 2008). Any program to manage wildlife must be in compliance with the National Environmental Protection Act and the Endangered Species Act, which require research-based information on ecosystem impacts. Thus, to justify management actions, baseline biological information is needed for all blackbirds, with attention also given to nontarget animals.

Research is needed to understand blackbird population dynamics, optimal deployment of management tools, and relationship to crop damage. Studies evaluating blackbird response to climate, habitat, and management at finer scales than publicly available data (e.g., North American Breeding

Bird Survey) would give a better understanding of population trends and impact of management within regions of concern (e.g., overwintering, migration, and breeding grounds; Chapter 6, this volume). For instance, birds may alter migration timing or location of overwintering sites with a warming climate (Van Buskirk et al. 2009). At the same time the proliferation of concentrated animal feedlots (i.e., concentrated, high-energy food) and changes in crop varieties (i.e., genetically modified crops that reduce waste and weed seeds) have altered food distribution and availability, creating complex situations with unknown impact on bird populations and behavior (Gibbons et al. 2006). Regional monitoring programs could elucidate how blackbird populations are changing in concert with land cover or how climate change may be impacting migration timing and onset of breeding and the ultimate impact on crop damage (Nelms et al. 1994).

Information about how molt patterns influence the timing of migration and how that may be affected by climate change is important, especially for yellow-headed blackbirds, where cold sensitivity is a factor in early emigration (Chapter 3, this volume). Additionally, the molt pattern of common grackles has yet to be described in relation to impact on agriculture (Chapter 4, this volume). Although diet and molt pattern in relation to agricultural damage have been evaluated for red-winged and yellow-headed blackbirds, updated data would elucidate changes occurring with changing habitat, climate, and agricultural practices (Linz et al. 1983; Twedt et al. 1991; Twedt and Linz 2015; Chapter 2, this volume). Further investigations into migration, molt patterns, and food habits can be evaluated using stable isotope markers to understand the full annual cycle of blackbirds at a continental scale (Werner et al. 2016). An understanding of species' biology, such as molt, migration, habitat use, diet, dispersal, survival, and reproductive success, could link different periods in the annual cycle and lead to new approaches for managing conflict with blackbirds.

A changing climate will impact not only the phenology of avian populations and natural habitat but also crop phenology and crop variety. Thus, the synergy among climate, land use, and avian populations should be explored (Forcey et al. 2015; Chapter 6, this volume). Changes in the type, amount, and distribution of woody vegetation could impact blackbird populations, especially grackles and brown-headed cowbirds (Rothstein 1994; Peer and Bollinger 1997; Wehtje 2003). Increased abundance of grackles in North Dakota has been linked to warmer temperatures (Forcey et al. 2015), but the reasons behind their range expansion in the West deserves further attention (Marzluff et al. 1994). While blackbirds may respond to loss of forested habitat at their overwintering sites in the southeastern United States, red-winged blackbirds and yellow-headed blackbirds may respond more to oscillations between wet and dry years at their breeding sites (BCR 11) due to their dependence on wetlands. Thus, regional climate projection models in conjunction with land-use data could forecast the impact of climate on blackbirds and help assess future needs and allocation of management (Forcey et al. 2015).

Although the relationship of blackbirds to local and regional habitat is imperative, response to habitat along continental migration pathways should also be emphasized. As technology for tracking individual birds becomes more sophisticated (Bridge et al. 2011), dispersal and migration patterns for each blackbird species and subsets of their populations (i.e., age class and sex) can be evaluated to complement previous estimates (Dolbeer 1978, 1982; Moore and Dolbeer 1989; Homan et al. 2004). With the exception of brown-headed cowbirds (Dufty 1982; Rothstein et al. 1984; Goguen and Mathews 2001), few tracking studies have been conducted to evaluate sociality, habitat use, survival, and migration in blackbirds (Homan et al. 2004). Foremost, the importance of various habitats used during the annual cycle and its impact on physical condition, migration timing, and reproductive success has not been addressed but could elucidate how management during winter (i.e., rice), migration (i.e., concentrated animal feedlots), and postbreeding (i.e., corn, rice, sunflower) seasons are interconnected (e.g., Marra et al. 2015). Movement ecology throughout the annual cycle is also fundamental to understanding population status and the impact of management targeting a specific region, species, sex, or age class.

Understanding the survival of blackbirds by species, age class, and sex is crucial to determining impacts of management in relation to other sources of mortality and natural regulation of populations (Fankhauser 1971; Bray et al. 1979; Stehn 1989). Hatch-year blackbirds hold potential to inflict damage to crops, given that fledglings are the driver behind the annual population numbers of red-winged blackbirds increasing from an estimated 170 million at the start of nesting to 328 million postbreeding (Chapter 8, this volume). As chemosterilant technologies advance, the feasibility of species-specific reproductive inhibition techniques for regionally managing blackbird populations should be explored under the limits of biological and economic feasibility as well as environmental regulations (Fagerstone et al. 2010). Assessing postfledging ecology would also improve management tool distribution, management tool effectiveness, and demographic models for this age class (Chapter 11, this volume). Research projects focused on migration and dispersal of population subsets could improve bioenergetic and economic models for estimating species-specific, region-wide crop damage and impact of management (Peer et al. 2003).

13.2 MANAGEMENT TOOLS

Many management tools, in some form, have been in existence for millennia (Benson 1937; Warnes 2016). Traps, poisons, and scarecrows have been used since prehistoric times, continue to be used today, and hold potential for the future (Conover 2002). Historically, farmers were able to protect resources within a given distance of their domicile and could dedicate significant time to the task. Today, the limited range of most tools is dwarfed by the size of the field to be protected, thus reducing their efficacy. Regardless, agricultural producers still use various techniques to disperse blackbirds, including repellents, decoy crops, firearms, propane cannons, pyrotechnics, and habitat management (Linz et al. 2011). In addition to inconsistent results, methods are often labor intensive and cost prohibitive, especially at the broad scales seen in current agriculture. Integrated pest management is often touted to optimize management, but few studies evaluate the combined effectiveness of methods (Avery 2002).

13.2.1 Lethal Control

Major challenges exist in attempts to benefit agriculture by lethal control of blackbirds, including large continental population sizes, magnitude of natural annual turnover, compensatory factors of increased survival and reproductive success, and migration dynamics (Chapter 7, this volume). Numerous programs have been implemented to reduce blackbird numbers, with limited reduction in crop damage (Linz 2013). First, blackbirds inflicting or about to inflict crop damage may be taken legally in the United States without a permit under an existing depredation order for blackbirds, cowbirds, grackles, crows, and magpies (50 CFR 21.43), but this small-scale control only functions to temporarily scare birds from a localized area. On a broader scale, Blackwell et al. (2003) showed that the cost of annually removing up to 2 million red-winged blackbirds during spring migration would not result in substantial damage reduction during the late-summer sunflower maturity. Additionally, the estimated sustainable allowed take of female red-winged blackbirds should range between 392,000 and 783,000 for BCR 11 (Chapter 11, this volume). Given evidence that the number of birds allowed for a sustainable take is considerably less than the estimated number needed to reduce crop damage, the U.S. Fish and Wildlife Service and public sentiment will likely not support broad-scale lethal control. The need to develop methods for culling large numbers of blackbirds is limited in both feasibility and cost-effectiveness; therefore nonlethal methods should be emphasized (Linz et al. 2015; Chapter 7, this volume).

13.2.2 Chemical Repellents

Chemical repellents have the potential to be a cost-effective method to protect large, commercial fields if used in conjunction with other tools to disperse birds, such as frightening devices, evading strategies, and habitat management (Avery 2002; Hagy et al. 2008; Linz and Homan 2011). Although a variety of chemicals have been tested for repellency (Chapter 8, this volume), registered repellents are restricted to nonlethal formulations shown to be safe for the environment and food consumption. Thus, one avenue of research is the continued evaluation of naturally occurring compounds and formulations, including mixtures of repellents and visual deterrents (Avery 2002). For instance, Werner et al. (2014a) found that the addition of nontoxic visual cues added to anthraquinone (AQ) formulations may enhance avian repellency at lower repellent concentrations. Although this is promising in that EPA registrations of repellents are more likely at lower chemical concentrations, execution of this approach in the field needs to be explored for each crop to maximize efficacy and minimize cost.

AQ-based repellents have shown >80% repellency in the lab (Avery et al. 1997; Werner et al. 2009), but translating efficacy from the lab to field is a challenge at the scale of commercial agriculture (Dolbeer et al. 1998; Kandel et al. 2009; Werner et al. 2011, 2014b; Niner et al. 2015). Issues arise when applying any repellent to all major food crops impacted by blackbirds including rice, corn, and sunflower (Werner et al. 2005; Carlson et al. 2013; Werner et al. 2014b). For example, one obstacle to using AQ in ripening sunflower is applying sufficient repellent directly on the face of the sunflower to repel birds while simultaneously minimizing AQ residues on harvested seed. As sunflower matures, the head faces down, making the preferred aerial application problematic given that blackbirds must ingest the repellent to be effective (Avery et al. 1997). Therefore, research should focus on developing application strategies such as ground rigs equipped with drop nozzles to apply chemicals directly to the sunflower face (Mullally 2010; Wunsch et al. 2016; Figure 13.2). Even with effective application technology, achenes will only be partially treated because most of each achene is concealed within the sunflower head or protected by disk flowers (Figure 13.3). However, reduced achene coverage may be sufficient given that birds must remove the adulterated disk flowers or manipulate exposed seed during consumption. Corn and rice have similar application issues, with the target seed being protected by vegetative components of the plant. Understanding avian feeding behavior on crops with varying repellent coverages will provide application details for improved effectiveness, given that repellent coverage is variable and often <100% at the plant scale (Avery 1985).

Researchers should explore crop-specific feeding behavior of blackbirds at various scales ranging from the individual plant and field to the diverse agricultural landscape. Identifying the behavior of each blackbird species and population subsets responsible for damage will inform repellent application and increase cost-effectiveness through precision agriculture. For example, research on blackbird

Figure 13.2 Small-plot ground rig equipped with 360 Undercover® drop nozzles (360 Yield Center, LLC; Morton, IL) to apply avian repellent under the crop canopy and increase application to targeted area (e.g., sunflower face or corn husk). Use of trade names does not imply endorsement by the U.S. government. (Courtesy of Page Klug/USDA Wildlife Services; and 360 Yield Center, https://360yieldcenter.com/products/360-undercover/.)

Figure 13.3 Agricultural crops are often difficult to protect with avian repellents due to the growth form of the plant acting to decrease the amount of repellent on the ingested seed. For example, corn is protected by a husk, rice is protected by awls, and, as pictured here, sunflower is protected by disk flowers and seed husks. (Courtesy of Page Klug/USDA Wildlife Services.)

foraging, habitat use, and flocking behavior could inform the temporal and spatial distribution of repellent at the field scale (Avery 1989). A repellent with a visual cue could be applied with a drop-nozzle–equipped ground rig in areas where birds are likely to learn the negative effects of the repellent-treated crop, and the remainder of the field could be treated aerially, reducing cost. It is important to understand how repellent should be distributed on the landscape as a function of realized damage and the level of partial repellent treatment needed to maintain repellent cost-effectiveness. The use of chemical repellents involves considerable expense in production and application; thus cost–benefit studies must be done to ensure application only in favorable situations (Dolbeer 1981).

In addition to evaluating spatial distribution of damage and repellent application, timing during the growing season must be considered (Bridgeland 1979). The functional cue to which blackbirds respond for onset of damage and food selection in varying crops (i.e., rice, corn, and sunflower) needs to be further addressed. The presence of insects and weeds in fields has been thought to influence the establishment of feeding areas, and this has not been evaluated in relation to cues derived from the crops themselves (Linz et al. 2011). Although vision is a large part of how birds sense their environment, the role of gustatory, olfactory, and chemesthetic senses must also be addressed and may be differentially important or work in concert at varying scales from selection of roosts and crop fields to selection of seeds (Mah and Nuechterlein 1991; Mason et al. 1991; Avery and Mason 1997).

13.2.3 Frightening Devices

Frightening devices have a long history in the management of human–wildlife conflict and hold the possibility for effective hazing of blackbirds in agricultural fields (Bomford and O'Brien 1990; Gilsdorf et al. 2002; Chapter 9, this volume). Factors limiting the success of frightening devices include bird behaviors such as limited mobility during feather molt, strong fidelity to established feeding areas, and habituation to nonrandom noise (Washburn et al. 2006). The limitations of the devices themselves include extent of effectiveness in space and time, immobility, and labor intensity (Linz and Hanzel 2015). Research is needed to develop frightening devices that can respond to the needs of broad-scale agriculture.

Well-designed studies focused on blackbirds are needed; there are few published reports of frightening devices that include testing against blackbirds under field conditions. Modifications to current frightening devices such as propane cannons and pyrotechnics are necessary to increase efficacy and include variation in directionality and timing. Lethal reinforcement is often referenced to limit habituation; however, limited scientific evidence is available to support this contention and differences may exist depending on species (Washburn et al. 2006; Baxter and Allan 2008; Seamans et al. 2013; Chapter 9, this volume). Evaluation of cost-effectiveness is scant in relation to the sheer number of frightening devices on the market, and resources for objective testing of products are limited. Therefore, a strong understanding of the biology of the animal and environmental conditions in which the frightening device would be deployed are necessary for thoughtful selection of devices to be evaluated.

Species-specific frightening devices may be beneficial, especially for the few species that cause the majority of damage (Swaddle et al. 2016). Introduced noise at frequencies interrupting avian communication holds the potential to deter birds from areas of concern. The technology has been shown to be successful in reducing feeding rate in captivity and in reducing bird activity in airfields (Mahjoub et al. 2015; Swaddle et al. 2016) but has yet to be evaluated in agricultural settings. Swaddle et al. (2016) suggested that if birds are not displaced from agricultural areas, the "sonic net" may influence antipredator behavior by masking alarm and predator calls, causing increased vigilance and decreased feeding (Lima and Bednekoff 1999). These sonic nets are appealing in that habituation is decreased, but limitations in spatial extent are evident along with power source restrictions. The effectiveness of disruptive sound for deterring birds is species-specific and may vary with environment but is worth pursuing.

Another promising technology in wildlife damage management is unmanned aircraft systems (UAS), which have already been deployed by producers to protect agricultural fields (BBC 2014; Kerzman 2015) and are being evaluated for use in wildlife and agricultural monitoring (Christie et al. 2016; Figure 13.4). A main benefit to UAS is the ability to overcome mobility limitations of stationary devices and to create a dynamic object. Research is needed to evaluate the feasibility of UAS to mitigate bird damage by evaluating avian physiological and behavioral responses and potential habituation or tolerance (e.g., Ditmer et al. 2015). Researchers also need to establish best practices (i.e., color, size, shape, approach, altitude, and speed) for entities looking to buy and incorporate UAS in blackbird hazing. The potential efficacy of UAS as hazing tools will depend on bird

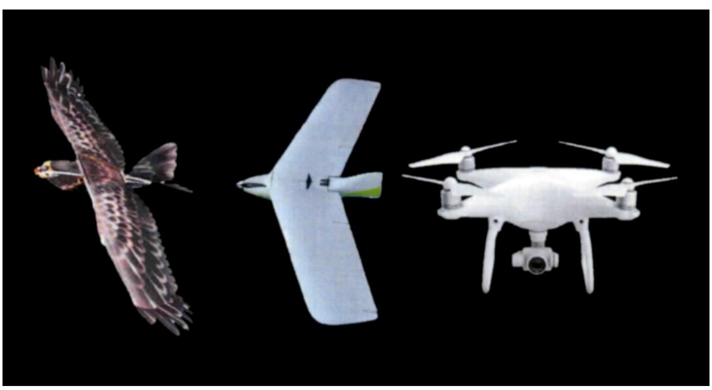

Figure 13.4 Unmanned aircraft systems (UAS) hold potential for use in wildlife and agricultural monitoring as well as frightening devices to reduce the impact of pest species. The potential efficacy of UAS as hazing tools will likely depend on bird detection and response to the flight dynamics. Research is needed to understand avian response to UAS platforms, such as multirotor quadcopters, traditional fixed-wing models or fixed-wing models shaped like a predator. Use of trade names does not imply endorsement by the U.S. government. (Courtesy of Page Klug/USDA Wildlife Services, HobbyKing.com®, https://hobbyking.com/en_us/eagle-epp-slow-flyer-1430mm-w-motor-kit.html; and DJI Technology Co., Ltd.®, http://www.dji.com/products/drones#consumer-nav.)

detection and response to UAS design and flight dynamics. Avoidance responses might be enhanced by designing vehicles based on a perceptual model of red-winged blackbird visual capabilities, so as to enhance detection under varying ambient conditions and responses to UAS during hazing (Blackwell et al. 2012). As technology continues to advance, UAS is a rich area for research with the potential for completely autonomous flight, which would act to substantially decrease labor by removing the need for a human operator and allow the aircraft to deploy when necessary in time and space (Grimm et al. 2012).

Current limitations of UAS as hazing devices include FAA regulations as well as a lack of onboard bird detection systems (Ampatzidis et al. 2015). Thus, signal processing research is needed to improve technology for identifying animal presence or abundance through real-time audio or visual monitoring (Pijanowski et al. 2011; Pérez-García 2012). Labor-saving approaches in wildlife monitoring would allow for measures of blackbird activity and, along with the distribution of crop damage, would allow a better understanding of factors that influence regional dynamics and rigorous testing of methods at the landscape scale. Another benefit of identifying birds in real time would be the ability to develop a detector for initiating scare devices or deploying an autonomous UAS when a nuisance species enters a protected area (Gilsdorf et al. 2002; Ampatzidis et al. 2015). Combining UAS technology with a primary repellent (e.g., methyl anthranilate) may also function to reduce habituation and increase negative connotation with the UAS, if the system released a primary repellent only when a pest scenario arose (Ampatzidis et al. 2015). Difficulty arises in deploying networks that can identify the presence of pest animals at broad landscape scales and is further complicated by topographically complex landscapes and fast-moving, small-bodied organisms. Until research in signal processing advances, use of automated UAS would include predetermined paths to patrol areas harboring the majority of damage (Grimm et al. 2012). Predetermined paths run the risk of habitation, but paths could be designed to vary in space and time and focus on areas of high risk.

13.2.4 Evading Strategies

Habitat management plays a fundamental role in reducing carrying capacity of blackbirds (Linz and Homan 2011; Chapter 10, this volume). The availability of nesting or roosting habitat as a function of water availability (hence cattail stands [*Typha* spp.]) is a likely factor limiting blackbird populations, given that seed-based food is abundant preharvest on agricultural landscapes such as in the Prairie Pothole Region. Management strategies for reducing damage should consider weather effects in addition to broad-scale landscape, given that such factors have been shown to contribute to blackbird relative abundance by impacting wetland habitat (Forcey et al. 2015). Cost-effective and environmentally safe methods to restore wetlands and reduce the dominance of invasive cattails and its impact on avian abundance need to be explored further and include traditional management such as burning, grazing, disking, and herbicides as well as studies exploring the utility of biological control (Linz et al. 2003; Kostecke et al. 2004). Distributing birds across the landscape by managing cattail stands has been shown to be a valuable approach to reducing damage experienced by producers while conserving valued wildlife and thus should be promoted (Linz and Homan 2011).

The use of crop varieties resistant to damage by blackbirds has also shown promise and is worthy of future development, especially in the era of genetic engineering. For example, Dolbeer et al. (1986, 1995) showed for both sweet and field corn that varieties with thicker, longer husks that extend beyond the ear tip have less damage than ears with lesser husks. Research in rice has also shown that modifications to plant morphology (e.g., awns and long, erect flag leaves) could increase resistance to bird depredation (Avery 1979; Abifarin 1984; Bullard 1988). Classical sunflower breeding techniques have been used to develop bird-resistant hybrids with limited utility, given that traits thought to be resistant to birds such as thick, white, fibrous hulls and increased chlorogenic acid and anthocyanin in the hull are related to unacceptable oil content and agronomic yield (Dolbeer et al. 1986; Parfitt and Fox 1986;

Mah et al. 1990; Mason et al. 1991). Although genetic engineering holds potential for corn and rice, regulations for genetically modified sunflower seed are strict due to potential for gene flow between cultivated and wild sunflower (*Helianthus annuus*) in North America (Burke et al. 2002; Cantamutto and Poverene 2007). Thus, sunflower breeders interested in developing bird-resistant hybrids may instead focus on double-haploid technology in which desired cultivars can be developed much faster compared to conventional breeding methods (Jan et al. 2011; Linz et al. 2011). In addition to this, a new frontier in genome engineering with CRISPR-Cas9 technology provides opportunities for incorporating bird-resistance into various crops without the presence of foreign DNA (Doudna and Charpentier 2014).

When implementing management tools to disperse or discourage blackbirds from feeding on a crop, alternative sources of foods are necessary to improve efficacy (Avery 2002). Wildlife conservation food plots (WCFP; also known as *diversionary feeding*, *decoy plots*, and *supplemental*, *lure*, or *trap crops*) are used to entice animals away from situations in which they are viewed as pests and have the potential to be a socially acceptable conservation action to avoid pest scenarios while providing wildlife habitat (Kubasiewicz et al. 2016; Chapter 10, this volume). The few studies that have assessed efficacy of WCFP for blackbirds indicate juxtaposition of WCFP and other less valuable crops is an important factor (Hagy et al. 2008; Linz et al. 2011; Klosterman et al. 2013). Limitations to implementing WCFP include finding an alternative food that blackbirds would prefer over an abundant and calorically dense agricultural crop, siting of WCFP, and cost-effectiveness for producers. A perennial sunflower variety may be developed that could be used as an alternative food source for birds and reduce the cost of WCFP (Kantar et al. 2014; Linz et al. 2014). Planting diversity, crop varieties, plant spacing, planting times, field size, and plot locations are research avenues that can be explored to increase the cost-effectiveness of WCFP (Cummings et al. 1987; Hagy et al. 2008).

Risk factors at the landscape and farm scale need to be evaluated with the potential of habitat manipulation to minimize risk or to identify where not to grow a susceptible crop (Lindell et al. 2016). Bird damage to agricultural crops has been shown to be greater on the edge (Fleming et al. 2002), near tall trees on an otherwise open habitat (Schäckermann et al. 2014), and near cattail marshes (Dolbeer 1980; Otis and Kilburn 1988; Figure 13.5). Additionally, research on how to use a less valuable crop (e.g., corn) as an alternate food source to protect a more valuable crop (e.g., sunflower) might be useful in some situations. To effectively manage bird damage, information is needed as to the influence of habitat composition and cover (e.g., target crop, alternate crops, wetlands, grassland,

Figure 13.5 In the Prairie Pothole Region of North America, blackbirds roost in cattail marshes with flight lines emanating from roosting to feeding areas. Bird damage to agricultural crops has been shown to be greater on habitat edges, near tall trees on an otherwise open habitat, and near roosting habitat such as cattail marshes, all of which are evident in this picture. (Courtesy of USDA Wildlife Services.)

and woodlots; Hagy et al. 2008; Linz et al. 2011; Forcey et al. 2015), timing and synchronization of planting and harvest (Wilson et al. 1989; Samanci 1995; Killi et al. 2004; Alizadeh 2009), and within-field characteristics such as weed and insect abundance, field size and shape, crop density, and short-stature sunflower (Otis and Kilburn 1988; Linz et al. 2011; Trostle et al. 2013). Studies evaluating bird abundance and distribution of crop damage as a function of landscape can inform cropping strategies, location of WCFP, and habitat management implementation (Cummings et al. 1987; Hagy et al. 2008).

In addition to understanding the spatial distribution of damage across the landscape, we must also consider the timing of management tool deployment. Understanding the growth stage at which visual cues of sunflower, rice, and corn indicate palatability to a blackbird would inform the growth stage to apply a tool (Cummings et al. 1989; Wilson et al. 1989; Dolbeer 1990). Understanding how blackbirds perceive their environment and select habitat is vital to being able to influence birds to avoid valued agricultural crops and instead use alternative forage (e.g., Hagy et al. 2008). Future research aimed at understanding the characteristics of a plant or field that make it susceptible to damage will help direct the spatial distribution of management tools, identify high risk areas, and help develop or optimize management tools (Cummings et al. 1989; Dolbeer 1990; Okurut-Akol et al. 1990; Somers and Morris 2002).

13.3 ECONOMICS AND HUMAN DIMENSIONS

A better understanding of economic damage from each blackbird species and the cost of control are needed in all impacted commodities (i.e., livestock, rice, corn, sunflower; Chapter 12, this volume). Estimates of crop damage are the baseline value upon which the cost-effectiveness of a management program can be evaluated (e.g., Dolbeer 1981); therefore, accurate estimates of damage are necessary for making sound decisions on management strategies. Damage estimates at regional scales could be enhanced by using remotely sensed data or using UAS to monitor crop damage (Anderson and Gaston 2013). For example, a normalized difference water index may be able to signal areas with high bird damage in sunflower. Near sunflower harvest, the vegetative parts of the plants are desiccated but the sunflower seeds still contain water. Consequently, heads with reduced seeds would have lower water content, thus signaling damage (Figure 13.6). Alternatively, bioenergetics and economic models along with population estimates of blackbird species are a labor-saving method to estimate damage and should be routinely updated and integrated into management strategies for impacted commodities such as rice, which has not yet been evaluated using this tool (Weatherhead et al. 1982; Peer et al. 2003).

Research is also needed to survey producers about blackbird abundance, crop damage, management tools, and socioeconomic standing to provide a better understanding of varying attitudes and factors influencing producer tolerance and response to damage (Conover 1998; Jacobson et al. 2003). Small-scale farmers or those attempting to initiate a new crop may be hit the hardest economically and thus may be more ardent about finding solutions to reduce bird damage. Conversely, a percentage of producers see no need to control birds or use management tools, and understanding the characteristics of individuals with this viewpoint would inform how to best reach out to concerned producers (Conover 2002). Likewise, producers implementing organic methods are increasing (U.S. Department of Agriculture 2016) and require a different suite of bird management tools than traditional farmers, which may provide opportunity for developing nontraditional approaches to human–wildlife conflict.

Multidisciplinary approaches to understanding conflict between blackbirds and agricultural producers could be developed by combining ecological, socioeconomic, and consumer marketing approaches. For example, consumer interest in food production practices such as eco-labels has shown to increase the market value of fruit crops (Oh et al. 2015). Although connections between producer and consumer are less direct in commodities such as rice, corn, and sunflower compared to fruits and vegetables, small-scale or organic producers may find marketing "bird-friendly" practices beneficial

Figure 13.6 Severely damaged sunflower head close to harvest. Vegetative parts of the sunflower plant are dry near harvest, but the sunflower seeds still contain water. Thus, a normalized difference water index collected through remotely sensed imagery may be able to signal areas of high sunflower damage. (Courtesy of Conor Egan/USDA Wildlife Services.)

(Jacobson et al. 2003). Discovery and testing of nonlethal management tools (e.g., WCFP) could first be tested on small-scale production areas such as organic farms and scaled up to traditional broad-scale agriculture. For example, marketing of bird-friendly products by commercial birdseed companies and avian conservation groups could subsidize producers participating in a WCFP program. Diverse WCFP in terms of crop and hybrid variety (e.g., sunflower, millet, and safflower) could be planted and harvested for sale as bird-friendly birdseed mixes or kept as overwintering habitat for nontarget animals. Such nontraditional approaches could stimulate discussion among producers, government agencies, and conservationists to develop positive attitudes and mechanisms for coexistence (Conover 2002).

13.4 CONCLUSIONS

Strategies to allow humans and wildlife to coexist will remain vital as habitat loss and fragmentation increase in concert with challenges from climate change and human population growth. As human society and the culture of agriculture evolve, so too will approaches to managing conflict between humans and wildlife. Today, local problems are shaped by global phenomena and potential solutions to local problems have far-reaching implications. Thus, optimizing current tools and developing new methods are necessary for effectively managing conflicts between blackbirds and agricultural producers.

REFERENCES

Abifarin, A. O. 1984. The importance of rice awns in the reduction of bird damage. *West African Rice Development Association Technical Newsletter* 5:27–28.

Alizadeh, E. 2009. Effects of sunflower cultivars and different sowing dates on the damage rate caused by birds, in particular house sparrow *Passer domesticus. Podoces* 4:108–114.

Ampatzidis, Y., J. Ward, and O. Samara. 2015. *Autonomous system for pest bird control in specialty crops using unmanned aerial vehicles.* ASABE Annual International Meeting. ASABE, New Orleans, LA.

Anderson, A., C. A. Lindell, K. M. Moxcey, W. F. Siemer, G. M. Linz, P. D. Curtis, J. E. Carroll, et al. 2013. Bird damage to select fruit crops: The cost of damage and benefits of control in five states. *Crop Protection* 52:103–109.

Anderson, K., and K. J. Gaston. 2013. Lightweight unmanned aerial vehicles will revolutionize spatial ecology. *Frontiers in Ecology and the Environment* 11:138–146.

Avery, M. L. 1979. Food preferences and damage levels of some avian rice field pests in Malaysia. *Bird Control Seminar* 8:161–166.

Avery, M. L. 1985. Application of mimicry theory to bird damage control. *Journal of Wildlife Management* 49:1116–1121.

Avery, M. L. 1989. Experimental evaluation of partial repellent treatment for reducing bird damage to crops. *Journal of Applied Ecology* 26:433–439.

Avery, M. L. 2002. Avian repellents. *Encyclopedia of Agrochemicals*, eds. J. R. Plimmer, D. W. Gammon, and N. N. Ragsdale, 1–8. Wiley, New York, NY.

Avery, M. L., J. S. Humphrey, and D. G. Decker. 1997. Feeding deterrence of anthraquinone, anthracene, and anthrone to rice-eating birds. *Journal of Wildlife Management* 61:1359–1365.

Avery, M. L., and J. R. Mason. 1997. Feeding responses of red-winged blackbirds to multisensory repellents. *Crop Protection* 16:159–164.

Baxter, A. T., and J. R. Allan. 2008. Use of lethal control to reduce habituation to blank rounds by scavenging birds. *Journal of Wildlife Management* 72:1653–1657.

BBC. 2014. *Suffolk farm uses drone to scare pigeons off rape crop.* http://www.bbc.com/news/uk-england-suffolk-27069825 (accessed September 1, 2016).

Beletsky, L. D. 1996. *The red-winged blackbird: The biology of a strongly polygynous songbird.* Academic Press, San Diego, CA.

Beletsky, L. D., and G. H. Orians. 1996. *Red-winged blackbirds: Decision making and reproductive success.* University of Chicago Press, Chicago, IL.

Benson, A. B. (ed.) 1937. *Peter Kalm's travels in North America.* Dover Publications Inc., New York, NY.

Besser, J. F. 1985. *A grower's guide to reducing bird damage to US agriculture crops.* Bird Damage Research Report 340. U.S. Fish and Wildlife Service Denver Wildlife Research Center, Denver, CO.

Blackwell, B. F., T. L. DeVault, T. W. Seamans, S. L. Lima, P. Baumhardt, and E. Fernández-Juricic. 2012. Exploiting avian vision with aircraft lighting to reduce bird strikes. *Journal of Applied Ecology* 49:758–766.

Blackwell, B. F., and R. A. Dolbeer. 2001. Decline of the red-winged blackbird population in Ohio correlated to changes in agriculture (1965–1996). *Journal of Wildlife Management* 65:661–667.

Blackwell, B. F., E. Huszar, G. M. Linz, and R. A. Dolbeer. 2003. Lethal control of red-winged blackbirds to manage damage to sunflower: An economic evaluation. *Journal of Wildlife Management* 67:818–828.

Bomford, M., and P. H. O'Brien. 1990. Sonic deterrents in animal damage control: A review of device tests and effectiveness. *Wildlife Society Bulletin* 18:411–422.

Bray, O. E., A. M. Gammell, and D. R. Anderson. 1979. Survival of yellow-headed blackbirds banded in North Dakota. *Bird-Banding* 50:252–255.

Bridge, E. S., K. Thorup, M. S. Bowlin, P. B. Chilson, R. H. Diehl, R. W. Fleron, P. Hartl, et al. 2011. Technology on the move: Recent and forthcoming innovations for tracking migratory birds. *BioScience* 61:689–698.

Bridgeland, W. 1979. Timing bird control applications in ripening corn. *Bird Control Seminar* 8:222–228.

Bullard, R. W. 1988. Characteristics of bird-resistance in agricultural crops. *Vertebrate Pest Conference* 13:305–309.

Burke, J. M., K. A. Gardner, and L. H. Rieseberg. 2002. The potential for gene flow between cultivated and wild sunflower (*Helianthus annuus*) in the United States. *American Journal of Botany* 89:1550–1552.

Cantamutto, M., and M. Poverene. 2007. Genetically modified sunflower release: Opportunities and risks. *Field Crops Research* 101:133–144.

Carlson, J. C., S. K. Tupper, S. J. Werner, S. E. Pettit, M. M. Santer, and G. M. Linz. 2013. Laboratory efficacy of an anthraquinone-based repellent for reducing bird damage to ripening corn. *Applied Animal Behaviour Science* 145:26–31.

Christie, K. S., S. L. Gilbert, C. L. Brown, M. Hatfield, and L. Hanson. 2016. Unmanned aircraft systems in wildlife research: Current and future applications of a transformative technology. *Frontiers in Ecology and the Environment* 14:241–251.

Conover, M. R. 1998. Perceptions of American agricultural producers about wildlife on their farms and ranches. *Wildlife Society Bulletin* 26:597–604.

Conover, M. R. 2002. *Resolving human-wildlife conflicts: The science of wildlife damage management.* CRC Press/Taylor & Francis, Boca Raton, FL.

Cummings, J. L., J. L. Guarino, C. E. Knittle, and W. C. Royall. 1987. Decoy plantings for reducing blackbird damage to nearby commercial sunflower fields. *Crop Protection* 6:56–60.

Cummings, J. L., J. L. Guarino, C. E. Knittle, and W. C. Royall. 1989. Chronology of blackbird damage to sunflowers. *Wildlife Society Bulletin* 17:50–52.

Cummings, J. L., Shwiff, S., and S. Tupper. 2005. Economic impacts of blackbird damage to the rice industry. *Wildlife Damage Management Conference* 11:317–322.

Ditmer, M. A., J. B. Vincent, L. K. Werden, J. C. Tanner, T. G. Laske, P. A. Iaizzo, D. L. Garshelis, et al. 2015. Bears show a physiological but limited behavioral response to unmanned aerial vehicles. *Current Biology* 25:2278–2283.

Dolbeer, R. A. 1978. Movement and migration patterns of red-winged blackbirds: A continental overview. *Bird-Banding* 49:17–34.

Dolbeer, R. A. 1980. *Blackbirds and corn in Ohio.* Resource Publication 136. U.S. Department of the Interior Fish and Wildlife Service, Washington, DC.

Dolbeer, R. A. 1981. Cost-benefit determination of blackbird damage control for cornfields. *Wildlife Society Bulletin* 9:44–51.

Dolbeer, R. A. 1982. Migration patterns for sex and age classes of blackbirds and starlings. *Journal of Field Ornithology* 53:28–46.

Dolbeer, R. A. 1990. Ornithology and integrated pest management: Red-winged blackbirds *Agelaius phoeniceus* and corn. *Ibis* 132:309–322.

Dolbeer, R. A., T. W. Seamans, B. F. Blackwell, and J. L. Belant. 1998. Anthraquinone formulation (Flight Control) shows promise as avian feeding repellent. *Journal of Wildlife Management* 62:1558–1564.

Dolbeer, R. A., P. P. Woronecki, and T. W. Seamans. 1995. Ranking and evaluation of field corn hybrids for resistance to blackbird damage. *Crop Protection* 14:399–403.

Dolbeer, R. A., P. P. Woronecki, and R. A. Stehn. 1986. Resistance of sweet corn to damage by blackbirds and starlings. *Journal of American Society of Horticultural Science* 111:306–311.

Doudna, J. A, and E. Charpentier. 2014. The new frontier of genome engineering with CRISPR-Cas9. *Science* 346:1258096.

Dufty, A. M. 1982. Movements and activities of radio-tracked brown-headed cowbirds. *Auk* 99:316–327.

Fagerstone, K. A., L. A. Miller, G. Killian, and C. A. Yoder. 2010. Review of issues concerning the use of reproductive inhibitors, with particular emphasis on resolving human-wildlife conflicts in North America. *Integrative Zoology* 5:15–30.

Fankhauser, D. P. 1971. Annual adult survival rates of blackbirds and starlings. *Bird-Banding* 42:36–42.

Fleming, P. J. S., A. Gilmour, and J. A. Thompson. 2002. Chronology and spatial distribution of cockatoo damage to two sunflower hybrids in south-eastern Australia, and the influence of plant morphology on damage. *Agriculture, Ecosystems and Environment* 91:127–137.

Forcey, G. M., W. E. Thogmartin, G. M. Linz, P. C. McKann, and S. C. Crimmins. 2015. Spatially explicit modeling of blackbird abundance in the Prairie Pothole Region. *Journal of Wildlife Management* 79:1022–1033.

Galle, A. M., G. M. Linz, H. J. Homan, and W. J. Bleier. 2009. Avian use of harvested crop fields in North Dakota during spring migration. *Western North American Naturalist* 69:491–500.

Gibbons, D. W., D. A. Bohan, P. Rothery, R. C. Stuart, A. J. Haughton, R. J. Scott, J. D. Wilson, et al. 2006. Weed seed resources for birds in fields with contrasting conventional and genetically modified herbicide-tolerant crops. *Proceedings of the Royal Society of London B: Biological Sciences* 273:1921–1928.

Gilsdorf, J. M., S. E. Hygnstrom, and K. C. VerCauteren. 2002. Use of frightening devices in wildlife damage management. *Integrated Pest Management Reviews* 7:29–45.

Goguen, C. B., and N. E. Mathews. 2001. Brown-headed cowbird behavior and movements in relation to livestock grazing. *Ecological Applications* 11:1533–1544.

Greenberg, R., D. W. Demarest, S. M. Matsuoka, C. Mettke-Hofmann, D. Evers, P. B. Hamel, and K. A. Hobson. 2011. Understanding declines in rusty blackbirds. *Studies in Avian Biology* 41:107–125.

Grimm, B. A., B. A. Lahneman, P. B. Cathcart, R. C. Elgin, G. L. Meshnik, and J. P. Parmigiani. 2012. Autonomous unmanned aerial vehicle system for controlling pest bird population in vineyards. *ASME 2012 International Mechanical Engineering Congress and Exposition* 4:499–505.

Hagy, H. M., G. M. Linz, and W. J. Bleier. 2008. Optimizing the use of decoy plots for blackbird control in commercial sunflower. *Crop Protection* 27:1442–1447.

Homan, H. J., G. M. Linz, and W. J. Bleier. 1994. Effect of crop phenology and habitat on the diet of common grackles (*Quiscalus quiscula*). *American Midland Naturalist* 131:381–385.

Homan, H. J., G. M. Linz, R. M. Engeman, and L. B. Penry. 2004. Spring dispersal patterns of red-winged blackbirds, *Agelaius phoeniceus*, staging in eastern South Dakota. *Canadian Field-Naturalist* 118:201–209.

Jacobson, S. K., K. E. Sieving, G. A. Jones, and A. Van Doorn. 2003. Assessment of farmer attitudes and behavioral intentions toward bird conservation on organic and conventional Florida farms. *Conservation Biology* 17:595–606.

Jan, C. C., L. Qi, B. Hulke, X. Fu. 2011. *Present and future plans of the sunflower "Doubled Haploid" project.* National Sunflower Association Research Forum, Fargo, ND. http://www.sunflowernsa.com/research/searchable-database-of-forum-papers/ (accessed September 1, 2016).

Kandel, H., B. Johnson, C. Deplazes, G. M. Linz, and M. M. Santer. 2009. *Sunflower treated with Avipel (Anthraquinone) bird repellent.* National Sunflower Association Research Forum, Fargo, ND. http://www.sunflowernsa.com/research/searchable-database-of-forum-papers/ (accessed September 1, 2016).

Kantar, M. B., K. Betts, J.-M. S. Michno, J. J. Luby, P. L. Morrell, B. S. Hulke, R. M. Stupar, et al. 2014. Evaluating an interspecific *Helianthus annuus* × *Helianthus tuberosus* population for use in a perennial sunflower breeding program. *Field Crops Research* 155:254–264.

Kerzman, J. 2015. Drones & sunflower. *The Sunflower Magazine* 41(5):20–22.

Killi, F., B. Kilic, and K Goner. 2004. The effect of different planting dates on the extent of bird damage in confection and oilseed sunflowers. *Journal of Agronomy* 3:36–39.

Klosterman, M. E., G. M. Linz, A. A. Slowik, and H. J. Homan. 2013. Comparisons between blackbird damage to corn and sunflower in North Dakota. *Crop Protection* 53:1–5.

Kostecke, R. M., L. M. Smith, and H. M. Hands. 2004. Vegetation response to cattail management at Cheyenne Bottoms, Kansas. *Journal of Aquatic Plant Management* 42:39–45.

Krapu, G. L., D. A. Brandt, and R. R. Cox Jr. 2004. Less waste corn, more land in soybeans, and the switch to genetically modified crops: Trends with important implications for wildlife management. *Wildlife Society Bulletin* 32:127–136.

Kubasiewicz, L. M., N. Bunnefeld, A. I. T. Tulloch, C. P. Quine, and K. J. Park. 2016. Diversionary feeding: An effective management strategy for conservation conflict? *Biodiversity and Conservation* 25:1–22.

Lima, S. L., and P. A. Bednekoff. 1999. Back to the basics of antipredatory vigilance: Can nonvigilant animals detect attack? *Animal Behaviour* 58:537–543.

Lindell, C. A., K. M. M. Steensma, P. D. Curtis, J. R. Boulanger, J. E. Carroll, C. Burrows, D. P. Lusch, et al. 2016. Proportions of bird damage in tree fruits are higher in low-fruit-abundance contexts. *Crop Protection* 90:40–48.

Linz, G. M. 2013. *Blackbird population management to protect sunflower: A history.* National Sunflower Association Research Forum, Fargo, ND. http://www.sunflowernsa.com/research/searchable-database-of-forum-papers/ (accessed September 1, 2016).

Linz, G. M., S. B. Bolin, and F. J. Cassel. 1983. Postnuptial and postjuvenal molts of red-winged blackbirds in Cass County, North Dakota. *Auk* 100:206–209.

Linz, G. M., E. H. Bucher, S. B. Canavelli, E. Rodriguez, and M. L. Avery. 2015. Limitations of population suppression for protecting crops from bird depredation: A review. *Crop Protection* 76:46–52.

Linz, G. M., and J. J. Hanzel. 2015. Sunflower and bird pests. In *Sunflower: Chemistry, production, processing, and utilization*, eds. E. M. Force, N. T. Dunford, and J. J. Salas, 175–186. AOCS Press, Urbana, IL.

Linz, G. M., and H. J. Homan. 2011. Use of glyphosate for managing invasive cattail (*Typha* spp.) to protect crops near blackbird (Icteridae) roosts. *Crop Protection* 30:98–104.

Linz, G. M., H. J. Homan, L. B. Penry, and P. Mastrangelo. 2003. Reducing blackbird-human conflicts in agriculture and feedlots: New methods for an integrated management approach. In *Management of North American blackbirds: Special symposium of the wildlife society ninth annual conference*, ed. G. M. Linz, 21–24. National Wildlife Research Center, Fort Collins, CO.

Linz, G. M., H. J. Homan, S. J. Werner, H. M. Hagy, and W. J. Bleier. 2011. Assessment of blackbird management strategies to protect sunflower. *BioScience* 61:960–970.

Linz, G. M., B. S. Hulke, M. B. Kantar, H. J. Homan, R. M. Stupar, and D. L. Wyse. 2014. Potential use of perennial sunflower to reduce blackbird damage to sunflower. *Vertebrate Pest Conference* 26:356–359.

MacDonald, J. M., P. Korb, and R. A. Hoppe. 2013. *Farm size and the organization of U.S. crop farming, ERR-152*. U.S. Department of Agriculture, Economic Research Service, Washington, DC. http://www.ers.usda.gov/publications/pub-details/?pubid=45110 (accessed November 17, 2016).

Mah, J., G. M. Linz, and J. J. Hanzel. 1990. Relative effectiveness of individual sunflower traits for reducing red-winged blackbird depredation. *Crop Protection* 9:359–362.

Mah, J., and G. L. Nuechterlein. 1991. Feeding behavior of red-winged blackbirds on bird-resistant sunflowers. *Wildlife Society Bulletin* 19:39–46.

Mahjoub, G., M. K. Hinders, and J. P. Swaddle. 2015. Using a "sonic net" to deter pest bird species: Excluding European starlings from food sources by disrupting their acoustic communication. *Wildlife Society Bulletin* 39:326–333.

Marra, P. P., E. B. Cohen, S. R. Loss, J. E. Rutter, and C. M. Tonra. 2015. A call for full annual cycle research in animal ecology. *Biology Letters* 11:20150552.

Marzluff, J. M., R. B. Boone, and G. W. Cox. 1994. Historical changes in populations and perceptions of native pest bird species in the west. *Studies in Avian Biology* 15:202–220.

Mason, J. R., G. Nuechterlein, G. Linz, R. A. Dolbeer, and D. L. Otis. 1991. Oil concentration differences among sunflower achenes and feeding preferences of red-winged blackbirds. *Crop Protection* 10:299–304.

Miller, J. E. 2007. Evolution of the field of wildlife damage management in the United States and future challenges. *Human-Wildlife Conflict* 1:13–20.

Moore, W. S., and R. A. Dolbeer. 1989. The use of banding recovery data to estimate dispersal rates and gene flow in avian species: Case studies in the red-winged blackbird and common grackle. *Condor* 91:242–253.

Mullally, S. 2010. 'High Boys' in sunflower: Another look. *The Sunflower Magazine* 36(5):24–25.

Nelms, C. O., W. J. Bleier, D. L. Otis, and G. M. Linz. 1994. Population estimates of breeding blackbirds in North Dakota, 1967, 1981–1982 and 1990. *American Midland Naturalist* 132:256–263.

Niner, M. D., G. M. Linz, and M. E. Clark. 2015. Evaluation of 9,10 anthraquinone application to pre-seed set sunflowers for repelling blackbirds. *Human-Wildlife Interactions* 9:4–13.

Oh, C., Z. Herrnstadt, and P. H. Howard. 2015. Consumer willingness to pay for bird management practices in fruit crops. *Agroecology and Sustainable Food Systems* 39:782–797.

Okurut-Akol, F. H., R. A. Dolbeer, and P. P. Woronecki. 1990. Red-winged blackbird and starling feeding responses on corn earworm-infested corn. *Vertebrate Pest Conference* 14:296–301.

Otis, D. L., and C. M. Kilburn. 1988. *Influence of environmental factors on blackbird damage to sunflower.* Technical Report No. 16. U.S. Fish and Wildlife Service, Washington, DC.

Parfitt, D. E., and G. J. Fox. 1986. Genetic sources of resistance to blackbird predation in sunflower. *Canadian Journal of Plant Science* 66:19–23.

Peer, B. D., and E. K. Bollinger. 1997. Common grackle (*Quiscalus quiscula*). No. 271. *The birds of North America*, ed. P. G. Rodewald. Cornell Lab of Ornithology, Ithaca, NY. https://birdsna.org/Species-Account/bna/species/rewbla (accessed September 25, 2016).

Peer, B. D., H. J. Homan, G. M. Linz, and W. J. Bleier. 2003. Impact of blackbird damage to sunflower: Bioenergetic and economic models. *Ecological Applications* 13:248–256.

Pérez-García, J. M. 2012. The use of digital photography in censuses of large concentrations of passerines: The case of a winter starling roost-site. *Revista Catalana d'Ornitologia* 28:28–33.

Pijanowski, B. C., L. J. Villanueva-Rivera, S. L. Dumyahn, A. Farina, B. L. Krause, B. M. Napoletano, S. H. Gage, et al. 2011. Soundscape ecology: The science of sound in the landscape. *BioScience* 61:203–216.

Rosenberg, K. V., J. A. Kennedy, R. Dettmers, R. P. Ford, D. Reynolds, C. J. Beardmore, P. J. Blancher, et al. 2016. *Partners in Flight Landbird Conservation Plan: 2016 Revision for Canada and Continental United States*. Partners in Flight Science Committee. http://www.partnersinflight.org/ (accessed September 25, 2016).

Rothstein, S. I. 1994. The cowbird's invasion of the far west: History, causes and consequences experienced by host species. *Studies in Avian Biology* 15:301–315.

Rothstein, S. I., J. Verner, and E. Steven. 1984. Radio-tracking confirms a unique diurnal pattern of spatial occurrence in the parasitic brown-headed cowbird. *Ecology* 65:77–88.

Samanci, B. 1995. The effect of different planting dates on the extent of bird damage in sunflower. *Turkish Journal of Agriculture and Forestry* 19:207–211.

Sauer, J. R., J. E. Hines, J. E. Fallon, K. L. Pardieck, D. J. Ziolkowski, Jr., and W. A. Link. 2014. *The North American Breeding Bird Survey, Results and Analysis 1966–2013. Version 01.30.2015*. U.S. Geological Survey, Patuxent Wildlife Research Center, Laurel, MD.

Schäckermann, J., N. Weiss, H. von Wehrden, and A. M. Klein. 2014. High trees increase sunflower seed predation by birds in an agricultural landscape of Israel. *Frontiers in Ecology and Evolution* 2:1–35.

Seamans, T. W., B. F. Blackwell, and T. L. DeVault. 2013. Brown-headed cowbird (*Molothrus ater*) response to pyrotechnics and lethal removal in a controlled setting. *Wildlife Damage Management Conference* 15:56–62.

Searcy, W. A., and K. Yasukawa. 1995. *Polygyny and sexual selection in red-winged blackbirds*. Princeton University Press, Princeton, NJ.

Somers, C. M., and R. D. Morris. 2002. Birds and wine grapes: Foraging activity causes small-scale damage patterns in single vineyards. *Journal of Applied Ecology* 39:511–523.

Stehn, R. A. 1989. *Adult survival rate of red-winged blackbirds*. Bird Damage Research Report 371. U.S. Fish and Wildlife Service, Denver Wildlife Research Center, Denver, CO.

Strassburg, M., S. M. Crimmins, G. M. Linz, P. C. McKann, W. E. Thogmartin. 2015. Winter habitat associations of blackbirds and starlings wintering in the south-central United States. *Human-Wildlife Interactions* 9:171–179.

Swaddle, J., D. Moseley, M. Hinders, and E. P. Smith. 2016. A sonic net excludes birds from an airfield: Implications for reducing bird strike and crop losses. *Ecological Applications* 26:339–345.

Trostle, C., D. Pietsch, A. Schlegel, and P. Evans. 2013. *Height, yield, and oil content of short-stature sunflower (Helianthus annuus) vs. conventional height sunflower in the Southern Great High Plains*. National Sunflower Association Research Forum, Fargo, ND. https://www.sunflowernsa.com/Research/Research-Forum-PowerPoint-Presentations-Since-2008/2013/ (accessed September 1, 2016).

Twedt, D. J., W. J. Bleier, and G. M. Linz. 1991. Geographic and temporal variation in the diet of yellow-headed blackbirds. *Condor* 93:975–986.

Twedt, D. J., and G. M. Linz. 2015. Flight feather molt in yellow-headed blackbirds (*Xanthocephalus xanthocephalus*) in North Dakota. *Wilson Journal of Ornithology* 127:622–629.

U.S. Department of Agriculture. 2008. *Recommendations of conferees for management of blackbird, starling, and corvid impacts on municipalities, airports, crops and livestock*. Management of Blackbird, Starling, and Corvid Conference, Nashville, Tennessee, USA. Animal and Plant Health Inspection Service, Wildlife Services, Washington, DC. https://www.aphis.usda.gov/wildlife_damage/nwrc/publications/Linz_Management%20of%20blackbird%20starling%20and%20corvid%20conference.pdf (accessed November 28, 2016).

U.S. Department of Agriculture. 2015. *Managing blackbird damage to sprouting rice in southwestern Louisiana. Environmental Assessment*. Animal and Plant Health Inspection Service, Wildlife Services, Washington, DC.

U.S. Department of Agriculture. 2016. *Organic market overview*. Economic Research Service, Washington DC. http://www.ers.usda.gov/topics/natural-resources-environment/organic-agriculture/organic-market-overview/ (accessed November 15, 2016).

Van Buskirk, J., R. S. Mulvihill, and R. C. Leberman. 2009. Variable shifts in spring and autumn migration phenology in North American songbirds associated with climate change. *Global Change Biology* 15:760–771.

Van Vuren, D., and K. S. Smallwood. 1996. Ecological management of vertebrate pests in agricultural systems. *Biological Agriculture and Horticulture* 12:39–62.

Warnes, K. 2016. Scarecrows historically speaking. http://historybecauseitshere.weebly.com/scarecrows-historically-speaking.html (accessed September 1, 2016).

Washburn, B. E., R. B. Chipman, and L. C. Francoeur. 2006. Evaluation of bird response to propane exploders in an airport environment. *Vertebrate Pest Conference* 22:212–215.

Weatherhead, P. J. 2005. Long-term decline in a red-winged blackbird population: Ecological causes and sexual selection consequences. *Proceedings of the Royal Society of London B: Biological Sciences* 272:2313–2317.

Weatherhead, P. J., S. Tinker, and H. Greenwood. 1982. Indirect assessment of avian damage to agriculture. *Journal of Applied Ecology* 19:773–782.

Wehtje, W. 2003. The range expansion of the great-tailed grackle (*Quiscalus mexicanus* Gmelin) in North America since 1880. *Journal of Biogeography* 30:1593–1607.

Wenny, D. G., T. L. DeVault, M. D. Johnson, D. Kelly, C. H. Sekercioglu, D. F. Tomback, and C. J. Whelan. 2011. The need to quantify ecosystem services provided by birds. *Auk* 128:1–14.

Werner, S. J., J. C. Carlson, S. T. Tupper, M. S. Santer, and G. M. Linz. 2009. Threshold concentrations of an anthraquinone-based repellent for Canada geese, red-winged blackbirds, and ring-necked pheasants. *Applied Animal Behaviour Science* 121:190–196.

Werner, S. J., S. T. DeLiberto, S. E. Pettit, and A. M. Mangan. 2014a. Synergistic effect of an ultraviolet feeding cue for an avian repellent and protection of agricultural crops. *Applied Animal Behaviour Science* 159:107–113.

Werner, S. J., K. A. Hobson, S. L. Van Wilgenberg, and J. W. Fischer. 2016. Multi-Isotopic (δ^2H, $\delta^{13}C$, $\delta^{15}N$) tracing of molt origin for red-winged blackbirds associated with agro-ecosystems. *PLoS One* 11:e0165996.

Werner, S. J., H. J. Homan, M. L. Avery, G. M. Linz, E. A. Tillman, A. A. Slowik, R. J. Byrd, et al. 2005. Evaluation of Bird Shield™ as a blackbird repellent in ripening rice and sunflower fields. *Wildlife Society Bulletin* 33:251–257.

Werner, S. J., G. M. Linz, J. C. Carlson, S. E. Pettit, S. T. Tupper, and M. M. Santer. 2011. Anthraquinone-based bird repellent for sunflower crops. *Applied Animal Behaviour Science* 129:162–169.

Werner, S. J., S. K. Tupper, S. E. Pettit, J. W. Ellis, J. C. Carlson, D. A. Goldade, N. M. Hofmann, et al. 2014b. Application strategies for an anthraquinone-based repellent to protect oilseed sunflower crops from pest blackbirds. *Crop Protection* 59:63–70.

Wilson, E. A., E. A. LeBoeuf, K. M. Weaver, and D. J. LeBlanc. 1989. Delayed seeding for reducing blackbird damage to sprouting rice in southwestern Louisiana. *Wildlife Society Bulletin* 17:165–171.

Wunsch, M. J., M. Schaefer, B. Kraft, J. Hafner, and J. Kallis. 2016. Prospects for using drop nozzles to improve fungicide coverage and control of Sclerotinia head rot. *National Sunflower Association Research Forum*, Fargo, ND. http://www.sunflowernsa.com/research/searchable-database-of-forum-papers/ (accessed September 1, 2016).