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Wildlife in Airport Environments: Chapter 11 Wildlife Conservation and Alternative Land Uses at Airports

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11 Wildlife Conservation and Alternative Land Uses at Airports

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Given all the attention paid throughout this book to minimizing the risk of wildlife–aircraft strikes, the title of this chapter may seem like an oxymoron. This book has emphasized management as related to the hazardous (to aircraft) sector of biodiversity. In this chapter we focus on the issue of protection and management of less hazardous taxa, and how altering land use at airports might, in limited circumstances, contribute to this objective.

The term "conservation" often leads to confusion and perceived conflicting goals of management. In fact, many of the direct management techniques used at airports (e.g., deterrents, translocation, etc.) could be considered conservation measures, because they remove birds from harm's way. None of these techniques are designed to extirpate a species from the environment; they are employed to reduce or remove risk to aviation, as well as the birds themselves (Blokpoel 1976, Conover 2002). Even in cases where lethal population control is used, the species involved are typically common and not threatened with extinction. In the context of this chapter we define conservation as the "protection and management of biodiversity" (Groom et al. 2006).

Conservation biologists and other scientists have debated whether wildlife conservation, such as promoting grassland birds, is an appropriate objective for airports (Kelly and Allan 2006, Blackwell et al. 2013). However, there is a lack of scientific literature on this topic to provide the necessary guidance. The ambiguity of promoting conservation at airports exists because of numerous factors, including imperfect information about wildlife response to habitat management or altering land use, variation in human values for certain wildlife taxa, and spatial variations in wildlife resource needs. Research based on ecological and animal behavior principles is necessary to achieve a safe airport environment while having any hope for wildlife conservation (Blackwell et al. 2013). Nevertheless, wildlife management at airports must continue in the face of uncertainty. Our goal is to provide background information necessary to reduce ambiguity on this issue as well as a roadmap for consideration of future conservation and applied research efforts.

Current Land Use and Implications for Wildlife

The connections between land use, land cover, and wildlife habitat are at the forefront of conserving wildlife at airports (Blackwell et al. 2009). Land use can be defined as how and why humans employ the land and its resources (Meyer 1995, Turner et al. 2001). Land cover refers to the "vegetation type present such as forest, agriculture, and grassland" (Turner et al. 2001). We use Hall et al.'s (1997) definition of habitat as "the resources and conditions present in an area that produce occupancy—including survival and reproduction—by a given organism." In the context of the airport environment, most species' habitat requirements will not be met solely on airport property, requiring movements to and from the airport (which, incidentally, could

increase strike risk; Chapter 12). The airport proper may be used for specific resource needs, such as food (Chapter 8). For some grassland species, however, seasonal habitat may exist only on airport property (Kershner and Bollinger 1996). Eastern meadowlarks (*Sturnella magna*) are grassland-obligate birds that forage and nest in grass-dominated areas (e.g., hayfields or mowed airport fields; Roseberry and Klimstra 1970), whereas European starlings (*Sturnus vulgaris*) are a facultative-grassland species that forage in grasslands but nest in cavities (Kessel 1957). Meadowlarks require only a single land use or cover type; starlings minimally require two land-use/cover types to fulfill their life history requirements. Not only does this simple example demonstrate the importance of terminology usage, but it has important implications for management. Control or conservation of meadowlarks could conceivably be achieved in a single grassland patch within the airport boundary. However, management of starlings to reduce use at the airport may require alterations of two land-use types—mowed fields and structures offering cavities—making the task more difficult.

Wildlife occupancy of various land-use/cover types can markedly influence the risk of wildlife collisions with aircraft. The International Civil Aviation Organization (2002) provides this summary of the effects of certain land uses on wildlife hazards:

> Land uses considered as contributing to wildlife hazards on or near [i.e., within 13 km] airports are fish-processing operations; agriculture; livestock feed lots; refuse dumps and landfills; factory roofs; parking lots; theaters and food outlets; wildlife refuges; artificial and natural lakes; golf and polo courses, etc.; animal farms; and slaughter houses.

In addition, the International Civil Aviation Organization grades land uses as to whether they are acceptable within radii from the airport center of 3 and 8 km (1.9 and 5 miles). The Federal Aviation Administration (2007) also provides guidance for hazardous attractants at or near airports. Other chapters in this book discuss land-use/cover types, including water resources (Chapter 9), turfgrass (a form of grassland; Chapter 10), and trash facilities (included in Chapter 8). These land-use/cover types can represent a substantial portion of the area surrounding airports; other land uses may include agriculture as well as alternative energy crops and sources (DeVault et al. 2009, 2012). In this chapter we briefly discuss agriculture, including alternative energy crops, and its value for avian conservation and hazardous species reduction, as well as habitat needs of grassland birds.

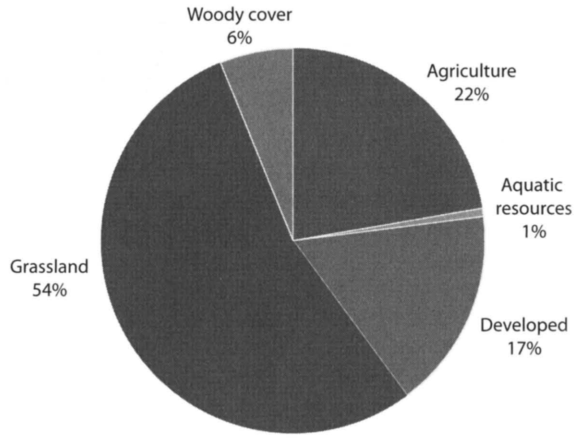

Fig. 11.1. Percentage of land cover or habitat type for 10 small airports in Indiana, USA. Adapted from DeVault et al. (2009)

Agriculture as a Land Use, Cover Type, and Habitat Component

As noted above, airports consist of a wide range of land cover and potential habitat types (Fahrig 2003, DeVault et al. 2009; Fig. 11.1). The degree to which habitat contributes to wildlife–aircraft strike risk at airports should not be based on the overall number of wildlife species that use the cover, however, but on the relative hazards those species pose to aircraft (DeVault et al. 2011). A land cover with greater wildlife abundance and diversity may actually represent a lower hazard to aircraft and might be more suitable for use at airports. Robertson et al. (2011) compared bird communities in three different land covers, including corn (*Zea mays*), switchgrass (*Panicum virgatum*), and prairie. The higher avian species richness in the prairie system (45 species; Fig. 11.2) might imply that prairies present a greater hazard to aircraft. However, when considering the relative hazard of the species found in the cover (Dolbeer et al. 2000, Dolbeer and Wright 2009, DeVault et al. 2011), corn had the greatest overall hazard to aviation (Fig. 11.2).

Federal Aviation Administration regulations dis-

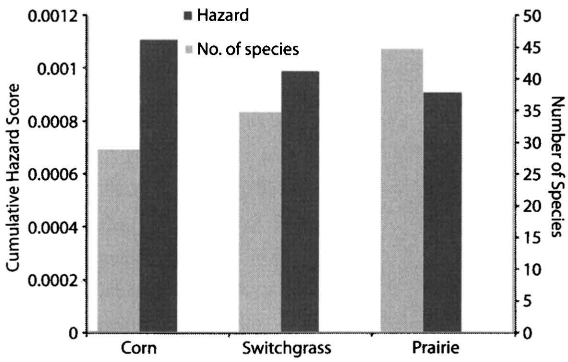

Fig. 11.2. Cumulative hazard and diversity of bird communities for three habitat types. Cumulative hazard scores were derived from relative hazard scores (Dolbeer and Wright 2009), were summed for each habitat type, and then scaled for interpretation. Lower values indicate less hazardous bird communities. Data adapted from Robertson et al. (2011)

courage the presence of "hazardous wildlife attractants," including all types of agriculture, at and near certificated U.S. airports (Federal Aviation Administration 2007, Blackwell et al. 2009). Even so, many U.S. airports lease portions of their land for agricultural production (Blackwell et al. 2009, DeVault et al. 2009), in part to reduce the economic burden of mowing turfgrass (Thomson 2007). These leased portions typically contain crops such as corn, wheat (*Triticum* spp.), and soybeans (*Glycine* spp.), which are wildlife attractants (Dolbeer et al. 1986, DeVault et al. 2007, Cerkal et al. 2009) even though they are notoriously depauperate, simplistic systems (Matson et al. 1997, Butler et al. 2007). If these systems lack diversity, then why are they not suited for airport use? These systems offer an important resource (i.e., food) for species that tend to be larger in size (e.g., white-tailed deer [*Odocoileus virginianus*]; Hein et al. 2012) and are most hazardous to aircraft (DeVault et al. 2011). But not all agriculture crops should be discounted categorically as a potential land cover for airports. Crops that lack palatable forage or abundant seed resources, such as some biofuel crops, may not attract hazardous wildlife, could potentially promote/protect some wildlife species of conservation concern, and provide some economic return. Empirical evidence is needed to determine which crops might fulfill these criteria at airports.

Herbaceous Cellulosic Feedstocks as a Potential Land Use at Airports

Crops under consideration for planting at airports include those that can be used to produce biofuel. Candidate crops for biofuel production range widely, from monocultures of exotic plants (e.g., *Miscanthus giganteus*; Heaton et al. 2008) to diverse native warm-season grass mixtures (Tilman et al. 2006, 2009; Somerville et al. 2010), although the use of nonherbaceous feedstocks may not be feasible within air operations areas (AOAs) because of safety concerns related to visibility (Austin-Smith and Lewis 1969). Existing grasslands at airports could potentially be managed for biofuel production if converted to appropriate herbaceous cellulosic feedstocks (Blackwell et al. 2009, DeVault et al. 2012). Switchgrass, for example, can yield 8.7–12.9 Mg/ha (19,180–28,440 lb/ha) of biomass depending on ecotype and management (McLaughlin and Kszos 2005, Adler et al. 2006, Mooney et al. 2008, Borsuk et al. 2010). Low-input, diverse native warm-season grass mixtures may produce even higher ethanol yields with greater greenhouse gas benefits than switchgrass monocultures (Tilman et al. 2006). The amount of grassland available at airports is much less than the area necessary to sustain a biofuel energy plant (Kocoloski et al. 2011), but airports could be integrated into an overall production and transportation strategy for biofuel production and thus could potentially contribute to this area of alternative energy production (DeVault et al. 2012).

Species composition of wildlife communities varies widely across different biofuel crops (Fargione et al. 2009, Meehan et al. 2010, Robertson et al. 2011). Field research is lacking on biofuel crops that, from an aviation perspective, would be compatible with safe airport operations, although research is ongoing (Blackwell et al. 2009, Martin et al. 2011, DeVault et al. 2012). We consider three possible land covers or grassland communities that might be feasible for the airport environment: switchgrass, *Miscanthus*, and a native prairie community (bluestems [*Andropogon* spp. and *Schizachyrium* spp.], Indiangrass [*Sorghastrum* spp.], and associated forbs).

Most research on herbaceous perennial grasslands for biofuels has been conducted on switchgrass (Murray and Best 2003, Murray et al. 2003, Roth et al. 2005;

Fig. 11.3. Switchgrass (*Panicum virgatum*) field planted for biomass production near West Point, Mississippi, USA. Photo credit: Tara Conkling

Fig. 11.3). But many of these studies were conducted on Conservation Reserve Program fields, which limit applicability to biofuel production at airports. Recent studies examining impacts of cellulosic biofuel crops on wildlife indicate that both *Miscanthus* and native grasses, including switchgrass and native warm-season grasses (as mentioned earlier), may provide benefits to some birds during winter and breeding seasons (Murray et al. 2003, Bellamy et al. 2009, Sage et al. 2010). The benefits of *Miscanthus* are temporary, however, without continuous wildlife management practices necessary to maintain the features of established plots that are attractive to birds (Bellamy et al. 2009). These features may be lost if plots are managed primarily to maximize biofuel production (Bellamy et al. 2009). There are additional questions regarding wildlife response to large plots of *Miscanthus* in the USA, as the vegetation structure is different from native grasslands, and it is unknown if avian species would perceive the bamboo-like vegetation as suitable habitat (Fargione et al. 2009).

Switchgrass and other native warm-season grasses may provide less ethanol output per unit area than *Miscanthus* (Heaton et al. 2008), but as native grass species, they might also be preferable as noninvasive wildlife habitat. Using switchgrass to convert existing row crop fields to biomass production provides new habitat for grassland birds (Murray et al. 2003), which could also reduce the presence of species typically attracted to crop fields (Dolbeer et al. 1986, DeVault et al. 2007). Roth et al. (2005) found that variation in the timing of switchgrass biofuel harvests and the resulting vegetation structure favored different grassland bird species, and a mosaic of harvest timings may increase local avian diversity. Recent research indicates that mixed-species grasslands with more diverse vegetation structures may provide even greater avian species richness and abundances than switchgrass (Robertson et al. 2011). T. J. Conkling et al. (unpublished data) have found prairie to be productive for breeding grassland birds such as dickcissels (*Spiza americana*), whereas switchgrass monoculture has demonstrated conservation value during winter months for species such as Le Conte's sparrow (*Ammodramus leconteii*). Preliminary results of studies in Mississippi investigating the hazard level of birds occupying switchgrass and prairie suggest these land covers may be suitable for airport grasslands in certain situations (T. J. Conkling et al., unpublished data).

Conservation of Birds

There are >3,300 km^2 (1,274 miles^2) of airport grasslands in the contiguous USA (DeVault et al. 2012).

Due to the amount of airport grasslands and because populations of grassland birds in North America are declining from habitat loss and degradation (Peterjohn and Sauer 1999, Askins et al. 2007), it has been suggested that airports may provide needed grassland habitat. However, airport grasslands pose challenges with respect to potential conservation efforts that must be recognized. We outline issues with habitat fragmentation, the role of airports as part of the general landscape, potential population losses of birds using airport grasslands, and the attraction of hazardous species to grasslands. Much of this section parallels the work of Blackwell et al. (2013).

Although the average airport in the contiguous USA contains 113 ha of turfgrass and other associated grassland cover types (DeVault et al. 2012), at many of these airports much of the grassland is scattered (i.e., fragmented) across a much larger area. Furthermore, some smaller airports do not contain grassland that extends appreciably beyond the AOA. The lack of large, unfragmented grassland tracts at some airports limits their value for grassland bird conservation. It is well established that habitat fragmentation negatively impacts abundance, distribution, and reproductive success of many grassland bird species, with declines more pronounced in area-sensitive species (Coppedge et al. 2001, Riffell et al. 2001, Chalfoun et al. 2002, Koper and Schmiegelow 2006, Ribic et al. 2009). Habitat fragmentation and the resulting loss of landscape connectivity is a major contributor to avian species declines and extinctions globally (Fischer and Lindenmayer 2007), yet patches as small as 50 ha may maximize bird species richness in a fragmented landscape (Helzer and Jelinski 1999), and small grassland patches with minimal edge habitat may also benefit grassland bird breeding and conservation (Davis and Brittingham 2004, Walk et al. 2010). Even so, research indicates that small grassland fragments cannot provide suitable habitat for bird species requiring large habitat patches (Johnson and Temple 1986, Vickery et al. 1995, Johnson and Igl 2001). Additionally, the shape of the habitat fragment and the distribution of fragments throughout the landscape can affect the settlement patterns of bird species (Laurance and Yensen 1991, Herkert 1994) or nest predation rates during the breeding season (Burger et al. 1994, Bergin et al. 2000, Grant et al. 2006). Therefore the habitat needs of the species of interest must be compared to the available size and shape of grassland areas at each airport.

Local- and landscape-scale influences ultimately drive grassland bird use for most species (Cunningham and Johnson 2006, Blackwell et al. 2009, Martin et al. 2011). When considering the potential for airports as suitable habitat for grassland birds, airports must be viewed in association with the surrounding habitat matrix. In areas with substantial grassland surrounding patches, for example, nest success may increase (Berman 2007). Keyel et al. (2011) found that species believed to be area-sensitive may also respond to habitat openness, rather than patch size. If airports can provide additional grassland habitat to supplement the existing matrix, avian species—especially those with less stringent area requirements—may increase their use of these patches.

Despite the best intentions of biologists, conservation practices created specifically for wildlife on or off airport properties could result in sink habitats for grassland birds (McCoy et al. 1999, Murphy 2001). Ecological traps (Schlaepfer et al. 2002, Battin 2004) are also possible if infrequently managed grassland areas are mown during the breeding season (Kershner and Bollinger 1996), or if area-sensitive species are attracted to habitat patches with a high edge-to-area ratio (Winter and Faaborg 1999, Johnson and Igl 2001, Davis and Brittingham 2004, Renfrew et al. 2005). Some researchers argue that impacts to grassland species of conservation concern can be limited by adjusting timing of mowing relative to a species' breeding season (Brennan and Kuvlesky 2005). Kershner and Bollinger (1996) noted that nest predation accounted for only 23% of nest failures at airports in Illinois, relative to 44% of nest failures resulting from mowing. By altering mowing and providing some nest predator control, it may be possible to reduce the sink potential of airport grasslands for birds. Still, Blackwell et al. (2013) note that, regardless of whether airport grasslands function as sink habitats (Murphy 2001) or provide connectivity between grassland patches, issues associated with the attraction of species known to pose strike hazards to aviation remain (see also Martin et al. 2011).

Most grassland bird species require mature grasslands at some point in their life cycle (Askins et al. 2007); such habitats generally harbor greater invertebrate and vertebrate species diversity and richness

(Gardiner et al. 2002), which could also enhance resources for species hazardous to aviation (Sodhi 2002). Because safety should be the first priority of all airports, any grassland management approach that attracts hazardous species (DeVault et al. 2011) should be altered to reduce the attraction of the area to these species. If that alteration results in the loss of habitat for grassland bird species of concern, alternative management plans should be explored.

Grassland areas within the AOA may be minimally useful for grassland birds due to habitat fragmentation, small patch size, losses from mowing, and because providing permanent habitat for obligate grassland species will likely conflict with management techniques needed to remove food resources or roosting sites for hazardous species (Blackwell et al. 2013). One scenario that could possibly enhance grassland bird conservation, however, would be for grassland conservation management to occur beyond the AOA and other airport-specific siting criteria (Blackwell et al. 2009, 2013). Such placement might allow specific management of nonhazardous species on and near airport lands without compromising air safety.

Conservation of Mammals

Mammals are often overlooked as a source of risk for aviation, which has direct implications for conservation management of most mammalian species at airports. Dolbeer and Wright (2009) reported that, since 1990, U.S civil aircraft struck 36 mammal species, including eight species of bats. Of these 36 species, 21 (including two bat species; Dolbeer and Wright 2009) caused damage to aircraft. Mammal species considered high to extremely high hazards to aircraft included mule deer (*O. hemionus*), white-tailed deer, domestic dog (*Canis familiaris*), and coyote (*C. latrans*; Biondi et al. 2011, DeVault et al. 2011). Other mammal species struck by aircraft include eastern cottontail (*Sylvilgaris floridanus*), raccoon (*Procyon lotor*), black-tailed jackrabbit (*Lepus californicus*), woodchuck (*Marmota monax*), opossum (*Didelphus virginianus*), striped skunk (*Mephitis mephitis*), and red fox (*Vulpes vulpes*; K. M. Biondi, unpublished data; Dolbeer and Wright 2009). In addition to their high hazard ranking, the most frequently struck mammals are deer and coyotes (Dolbeer and Wright 2009, Biondi et al. 2011, DeVault et al. 2011). Any management or land-use modifications should avoid promoting use by deer and canids.

Mammal species of conservation concern are typically associated with unmanaged systems and are mostly ill adapted to human-altered environments (Ceballos et al. 2005), making mammal conservation at airports unlikely overall. Small mammals adapted for grasslands such as shrews (Soridae), *Peromyscus* spp., and other Muridae species—including cotton rats (*Sigmodon hispidus*) and jumping mice (*Zapus* spp.; Hall and Willig 1994, Kaufman et al. 1997)—may be attracted to airport grasslands. However, increased populations of these species at airports should generally be avoided, as both avian and mammalian predators of small mammals are typically large in size and hazardous to aircraft. Under simplistic models and assumptions, increased small-mammal diversity and biomass might cause functional and abundance shifts in predators (Holling 1965, Korpimäki and Norrdahl 1991, Korpimäki and Krebs 1996). Direct management of these predators may be possible, but the tradeoff in conservation value, increased risk to aviation, and management cost would likely preclude targeted mammalian conservation at airports.

Summary

Conservation of wildlife species on airports, although problematic, may be best achieved through altering current land covers from traditional turfgrass management. Possible alternatives include prairie grass and switchgrass systems managed for forage or biofuels (DeVault et al. 2012). These options could, in some circumstances, conserve wildlife directly by providing in situ habitat for grassland birds (away from the AOA) or, perhaps more feasibly, indirectly by reducing the global carbon footprint (Tilman et al. 2009). Regardless, all alternative habitats at airports should be considered in the context of landscape fragmentation, metapopulation dynamics, and edge effects as they relate to grassland birds. Mammal conservation is not likely feasible at airports on any measurable scale. Most importantly, we encourage managers interested in wildlife conservation at airports to consider carefully how management of various grasslands systems might promote occupancy by hazardous species. Wildlife conservation

will likely occur only past airport-specific siting criteria (Federal Aviation Administration 2007) to minimize risk to aviation (Blackwell et al. 2009, 2013). Potential economic benefits of alternative energy sources may contribute to adoption of biofuel grasslands on airports, but more research is needed.

LITERATURE CITED

Adler, P. R., M. A. Sanderson, A. A. Boateng, P. J. Weimer, and H. J. G. Jung. 2006. Biomass yield and biofuel quality of switchgrass harvested in fall or spring. Agronomy Journal 98:15–18.

Askins, R. A., F. Chavez-Ramirez, B. C. Dale, C. A. Haas, J. R. Herkert, F. L. Knopf, and P. D. Vickery. 2007. Conservation of grassland birds in North America: understanding ecological processes in different regions. Report of the AOU Committee on Conservation. Ornithological Monographs 64:1–46.

Austin-Smith, P. J., and H. F. Lewis. 1969. Alternative vegetative ground cover. Pages 153–160 *in* Proceedings of the world conference on bird hazards to aircraft, 2–5 September 1969. National Research Council of Canada, Kingston, Ontario, Canada.

Battin, J. 2004. When good animals love bad habitats: ecological traps and the conservation of animal populations. Conservation Biology 18:1482–1491.

Bellamy, P. E., P. J. Croxton, M. S. Heard, S. A. Hinsley, L. Hulmes, S. Hulmes, P. Nuttall, R. F. Pywell, and P. Rothery. 2009. The impact of growing *Miscanthus* for biomass on farmland bird populations. Biomass and Bioenergy 33:191–199.

Bergin, T. M., L. B. Best, K. E. Freemark, and K. J. Koehler. 2000. Effects of landscape structure on nest predation in roadsides of a midwestern agroecosystem: a multiscale analysis. Landscape Ecology 15:131–143.

Berman, G. M. 2007. Nesting success of grassland birds in fragmented and unfragmented landscapes of north central South Dakota. Thesis, South Dakota State University, Brookings, USA.

Biondi, K. M., J. L. Belant, J. A. Martin, T. L. DeVault, and G. Wang. 2011. White-tailed deer incidents with U.S. civil aircraft. Wildlife Society Bulletin 35:303–309.

Blackwell, B. F., T. L. DeVault, E. Fernández-Juricic, and R. A. Dolbeer. 2009. Wildlife collisions with aircraft: a missing component of land-use planning for airports. Landscape and Urban Planning 93:1–9.

Blackwell, B. F., T. W. Seamans, P. M. Schmidt, T. L. DeVault, J. L. Belant, M. J. Whittingham, J. A. Martin, and E. Fernández-Juricic. 2013. A framework for managing airport grasslands and birds amidst conflicting priorities. Ibis 155:199–203.

Blokpoel, H. 1976. Bird hazards to aircraft: problems and prevention of bird/aircraft collisions. Clarke, Irwin, Ottawa, Ontario, Canada.

Borsuk, M. E., S. D. Wullschleger, E. B. Davis, L. R. Lynd, and C. A. Gunderson. 2010. Biomass production in switchgrass across the United States: database description and determinants of yield. Agronomy Journal 102:1158–1168.

Brennan, L. A., and W. P. Kuvlesky. 2005. North American grassland birds: an unfolding conservation crisis? Journal of Wildlife Management 69:1–13.

Burger, L. D., J. Burger, and J. Faaborg. 1994. Effects of prairie fragmentation on predation on artificial nests. Journal of Wildlife Management 58:249–254.

Butler, S. J., J. A. Vickery, and K. Norris. 2007. Farmland biodiversity and the footprint of agriculture. Science 315:381–384.

Ceballos, G., P. R. Ehrlich, J. Soberón, I. Salazar, and J. P. Fay. 2005. Global mammal conservation: what must we manage? Science 309:603–607.

Cerkal, R., K. Vejrazka, J. Kamler, and J. Dvorak. 2009. Game browse and its impact on selected grain crops. Plant Soil Environment 55:181–186.

Chalfoun, A. D., F. R. Thompson III, and M. J. Ratnaswamy. 2002. Nest predators and fragmentation: a review and meta-analysis. Conservation Biology 16:306–318.

Conover, M. R. 2002. Resolving human–wildlife conflicts: the science of wildlife damage management. CRC Press, Boca Raton, Florida, USA.

Coppedge, B. R., D. M. Engle, R. E. Masters, and M. S. Gregory. 2001. Avian response to landscape change in fragmented southern Great Plains grasslands. Ecological Applications 11:47–59.

Cunningham, M. A., and D. H. Johnson. 2006. Proximate and landscape factors influence grassland bird distributions. Ecological Applications 16:1062–1075.

Davis, S. K., and M. Brittingham. 2004. Area sensitivity in grassland passerines: effects of patch size, patch shape, and vegetation structure on bird abundance and occurrence in southern Saskatchewan. Auk 121:1130–1145.

DeVault, T. L., J. C. Beasley, L. A. Humberg, B. J. MacGowan, M. I. Retamosa, and O. E. Rhodes Jr. 2007. Intrafield patterns of wildlife damage to corn and soybeans in northern Indiana. Human–Wildlife Conflicts 1:205–213.

DeVault, T. L., J. L. Belant, B. F. Blackwell, J. A. Martin, J. A. Schmidt, L. W. Burger, and J. W. Patterson. 2012. Airports offer unrealized potential for alternative energy production. Environmental Management 49:517–522.

DeVault, T. L., J. L. Belant, B. F. Blackwell, and T. W. Seamans. 2011. Interspecific variation in wildlife hazards to aircraft: implications for airport wildlife management. Wildlife Society Bulletin 35:394–402.

DeVault, T. L., J. E. Kubel, O. E. Rhodes Jr., and R. A. Dolbeer 2009. Habitat and bird communities at small airports in the midwestern USA. Proceedings of the Wildlife Damage Management Conference 13:137–145.

Dolbeer, R. A., P. P. Woronecki, and R. L. Bruggers. 1986. Reflecting tapes repel blackbirds from millet, sunflowers, and sweet corn. Wildlife Society Bulletin 14:418–425.

Dolbeer, R. A., and S. E. Wright. 2009. Safety management systems: how useful will the FAA National Wildlife Strike Database be? Human–Wildlife Conflicts 3:167–178.

Dolbeer, R. A., S. E. Wright, and E. C. Cleary. 2000. Ranking the hazard level of wildlife species to aviation. Wildlife Society Bulletin 28:372–378.

Fahrig, L. 2003. Effects of habitat fragmentation on biodiversity. Annual Review of Ecology, Evolution, and Systematics 34:487–515.

Fargione, J. E., T. R. Cooper, D. J. Flaspohler, J. Hill, C. Lehman, T. McCoy, S. McLeod, E. J. Nelson, K. S. Oberhauser, and D. Tilman. 2009. Bioenergy and wildlife: threats and opportunities for grassland conservation. Bioscience 59:767–777.

Federal Aviation Administration. 2007. Hazardous wildlife attractants on or near airports. Advisory Circular 150/5200-33B. U.S. Department of Transportation, Washington, D.C., USA.

Fischer, J., and D. B. Lindenmayer. 2007. Landscape modification and habitat fragmentation: a synthesis. Global Ecology and Biogeography 16:265–280.

Gardiner, T., M. Pye, R. Field, and J. Hill. 2002. The influence of sward height and vegetation composition in determining the habitat preferences of three Chorthippus species (Orthoptera: Acrididae) in Chelmsford, Essex, UK. Journal of Orthoptera Research 11:207–213.

Grant, T. A., E. M. Madden, T. L. Shaffer, P. J. Pietz, G. B. Berkey, and N. J. Kadrmas. 2006. Nest survival of clay-colored and vesper sparrows in relation to woodland edge in mixed-grass prairies. Journal of Wildlife Management 70:691–701.

Groom, M. J., G. K. Meffe, and C. R. Carroll. 2006. Principles of conservation biology. Sinauer, Sunderland, Massachusetts, USA.

Hall, D. L., and M. R. Willig. 1994. Mammalian species composition, diversity, and succession in conservation reserve program grasslands. Southwestern Naturalist 39:1–10.

Hall, L. S., P. R. Krausman, and M. L. Morrison. 1997. The habitat concept and a plea for standard terminology. Wildlife Society Bulletin 25:173–182.

Heaton, E. A., F. G. Dohleman, and S. P. Long. 2008. Meeting US biofuel goals with less land: the potential of *Miscanthus*. Global Change Biology 14:2000–2014.

Hein, A. M., C. Hou, and J. F. Gillooly. 2012. Energetic and biomechanical constraints on animal migration distance. Ecology Letters 15:104–110.

Helzer, C. J., and D. E. Jelinski. 1999. The relative importance of patch area and perimeter-area ratio to grassland breeding birds. Ecological Applications 9:1448–1458.

Herkert, J. R. 1994. The effects of habitat fragmentation on midwestern grassland bird communities. Ecological Applications 4:461–471.

Holling, C. S. 1965. The functional response of predators to prey density and its role in mimicry and population regulation. Memoirs of the Entomological Society of Canada 97:1–60.

International Civil Aviation Organization. 2002. Land use and environmental control. Airport Planning Manual 9184 AN/902, Part 2. Montreal, Quebec, Canada.

Johnson, D. H., and L. D. Igl. 2001. Area requirements for grasslands birds: a regional perspective. Auk 118:24–34.

Johnson, R. G., and S. A. Temple. 1986. Assessing habitat quality for birds nesting in fragmented tallgrass prairies. Pages 245–249 *in* J. Verner, M. L. Morrison, and C. J. Ralph, editors. Wildlife 2000: modeling habitat relationships of terrestrial vertebrates. University of Wisconsin Press, Madison, USA.

Kaufman, G. A., D. W. Kaufman, F. L. Knopf, and F. B. Samson. 1997. Ecology of small mammals in prairie landscapes. Pages 207–243 *in* F. L. Knopf and F. B. Samson, editors. Ecology and conservation of Great Plains vertebrates. Springer, New York, New York, USA.

Kelly, T., and J. Allan. 2006. Ecological effects of aviation. The ecology of transportation: managing mobility for the environment. Environmental Pollution 10:5–24.

Kershner, E. L., and E. K. Bollinger. 1996. Reproductive success of grassland birds at east-central Illinois airports. American Midland Naturalist 136:358–366.

Kessel, B. 1957. A study of the breeding biology of the European starling (*Sturnus vulgaris* L.) in North America. American Midland Naturalist 58:257–331.

Keyel, A. C., C. M. Bauer, C. R. Lattin, L. M. Romero, and J. M. Reed. 2011. Testing the role of patch openness as a causal mechanism for apparent area sensitivity in a grassland specialist. Oecologia 169:1–12.

Kocoloski, M., W. M. Griffin, and H. S. Matthews. 2011. Impacts of facility size and location decisions on ethanol production cost. Energy Policy 39:47–56.

Koper, N., and F. K. K. Schmiegelow. 2006. A multi-scaled analysis of avian response to habitat amount and fragmentation in the Canadian dry mixed-grass prairie. Landscape Ecology 21:1045–1059.

Korpimäki, E., and C. J. Krebs. 1996. Predation and population cycles of small mammals. BioScience 46:754–764.

Korpimäki, E., and K. Norrdahl. 1991. Numerical and functional responses of kestrels, short-eared owls, and long-eared owls to vole densities. Ecology 72:814–826.

Laurance, W. F., and E. Yensen. 1991. Predicting the impacts of edge effects in fragmented habitats. Biological Conservation 55:77–92.

Martin, J. A., J. L. Belant, T. L. DeVault, B. F. Blackwell, L. W. Burger Jr., S. K. Riffell, and G. Wang. 2011. Wildlife risk to aviation: a multi-scale issue requires a multi-scale solution. Human–Wildlife Interactions 5:198–203.

Matson, P. A., W. J. Parton, A. G. Power, and M. J. Swift. 1997. Agricultural intensification and ecosystem properties. Science 277:504–509.

McCoy, T. D., M. R. Ryan, E. W. Kurzejeski, and L. W. Burger Jr. 1999. Conservation Reserve Program: source or sink habitat for grassland birds in Missouri? Journal of Wildlife Management 63:530–538.

McLaughlin, S. B., and L. A. Kszos. 2005. Development of switchgrass (*Panicum virgatum*) as a bioenergy feedstock in the United States. Biomass and Bioenergy 28:515–535.

Meehan, T. D., A. H. Hurlbert, and C. Gratton. 2010. Bird communities in future bioenergy landscapes of the Upper Midwest. Proceedings of the National Academy of Sciences of the United States of America 107:18,533–18,538.

Meyer, W. B. 1995. Past and present land use and land cover in the USA. Consequences 1:25–33.

Mooney, D. F., R. K. Roberts, B. C. English, D. D. Tyler, and J. A. Larson. 2008. Switchgrass production in marginal environments: a comparative economic analysis across four west Tennessee landscapes. Proceedings of the 2008 annual meeting. Agricultural and Applied Economics Association, 27–29 July 2008, Orlando, Florida, USA.

Murphy, M. T. 2001. Source–sink dynamics of a declining eastern kingbird population and the value of sink habitats. Conservation Biology 15:737–748.

Murray, L. D., and L. B. Best. 2003. Short-term bird response to harvesting switchgrass for biomass in Iowa. Journal of Wildlife Management 67:611–621.

Murray, L. D., L. B. Best, T. J. Jacobsen, and M. L. Braster. 2003. Potential effects on grassland birds of converting marginal cropland to switchgrass biomass production. Biomass and Bioenergy 25:167–175.

Peterjohn, B. G., and J. R. Sauer. 1999. Population status of North American grassland birds from the North American breeding bird survey, 1966–1996. Studies in Avian Biology 19:27–44.

Renfrew, R. B., C. A. Ribic, and J. L. Nack. 2005. Edge avoidance by nesting grassland birds: a futile strategy in a fragmented landscape. Auk 122:618–636.

Ribic, C. A., R. R. Koford, J. R. Herkert, D. H. Johnson, N. D. Niemuth, D. E. Naugle, K. K. Bakker, D. W. Sample, and R. B. Renfrew. 2009. Area sensitivity in North American grassland birds: patterns and processes. Auk 126:233–244.

Riffell, S. K., B. E. Keas, and T. M. Burton. 2001. Area and habitat relationships of birds in Great Lakes coastal wet meadows. Wetlands 21:492–507.

Robertson, B. A., P. J. Doran, L. R. Loomis, J. R. Robertson, and D. W. Schemske. 2011. Perennial biomass feedstocks enhance avian diversity. GCB Bioenergy 3:235–246.

Roseberry, J. L., and W. D. Klimstra. 1970. The nesting ecology and reproductive performance of the Eastern Meadowlark. Wilson Bulletin 82:243–267.

Roth, A. M., D. W. Sample, C. A. Ribic, L. Paine, D. J. Undersander, and G. A. Bartelt. 2005. Grassland bird response to harvesting switchgrass as a biomass energy crop. Biomass and Bioenergy 28:490–498.

Sage, R., M. Cunningham, A. J. Haughton, M. D. Mallot, D. A. Bohan, A. Riche, and A. Karp. 2010. The environmental impacts of biomass crops: use by birds of *Miscanthus* in summer and winter in southwestern England. Ibis 152:487–499.

Schlaepfer, M. A., M. C. Runge, and P. W. Sherman. 2002. Ecological and evolutionary traps. Trends in Ecology and Evolution 17:474–480.

Sodhi, N. S. 2002. Competition in the air: birds versus aircraft. Auk 119:587–595.

Somerville, C., H. Youngs, C. Taylor, S. C. Davis, and S. P. Long. 2010. Feedstocks for lignocellulosic biofuels. Science 329:790–792.

Thomson, B. 2007. A cost effective grassland management strategy to reduce the number of bird strikes at the Brisbane airport. Thesis, Queensland University of Technology, Brisbane, Australia.

Tilman, D., J. Hill, and C. Lehman. 2006. Carbon-negative biofuels from low-input high-diversity grassland biomass. Science 314:1598–1600.

Tilman, D., R. Socolow, J. A. Foley, J. Hill, E. Larson, L. Lynd, S. Pacala, J. Reilly, T. Searchinger, C. Somerville, and R. Williams. 2009. Beneficial biofuels—the food, energy, and environment trilemma. Science 325:270–271.

Turner, M. G., R. H. Gardner, and R. V. O'Neill. 2001. Landscape ecology in theory and practice: pattern and process. Springer-Verlag, New York, New York, USA.

Vickery, P. C., M. L. Hunter, and S. M. Melvin. 1995. Effects of habitat area on the distribution of grassland birds in Maine. Conservation Biology 8:1087–1097.

Walk, J. W., E. L. Kershner, T. J. Benson, and R. E. Warner. 2010. Nesting success of grassland birds in small patches in an agricultural landscape. Auk 127:328–334.

Winter, M., and J. Faaborg. 1999. Patterns of area sensitivity in grassland-nesting birds. Conservation Biology 13:1424–1436.