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Wildlife in Airport Environments: Chapter 10 Managing Turfgrass to Reduce Wildlife Hazards at Airports

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Managing Turfgrass to Reduce Wildlife Hazards at Airports

Multiple factors—including safety regulations, economic considerations, location, and attractiveness to wildlife recognized as hazardous to aviation—influence the choice of land cover at airports. The principal land cover at airports within North America has historically been turfgrass, usually cool-season perennial grass species native to Europe. However, recent research has determined that, from a wildlife perspective, not all turfgrasses are alike. Some grasses are more palatable to herbivorous hazardous wildlife (e.g., Canada geese [*Branta canadensis*]) than others, and thus are more likely to increase the potential for wildlife–aircraft collisions when planted near critical airport operating areas. How turfgrasses are managed (e.g., by mowing or herbicide use) can also influence the degree of use by wildlife. In this chapter we (1) review the role of vegetation in the airport environment, (2) review traditional and current methods of vegetation management on airfields, (3) discuss selection criteria for plant materials in reseeding efforts, and (4) provide recommendations for future research.

Vegetation in the Airport Environment

Airports are large, complex, anthropogenically influenced environments that contain buildings and structures, impervious surfaces (e.g., pavement), and vegetated areas. Vegetation can typically be found at airports in landside areas (e.g., manicured lawns near terminal buildings and roadways), within the air operations area along taxiways and runways, in larger safety areas (e.g., runway protection zones), and on airport property in outlying areas (i.e., adjacent to the airfield). Within the USA alone, airport properties include >330,000 ha of grassland, primarily composed of areas mown at least once annually, and representing ~39–50% of airport property (DeVault et al. 2012).

Green, well-managed turfgrass represents a highly valued landscape within most societies (Ulrich 1986, Casler and Duncan 2003, Casler 2006). Turfgrass areas on the airfield and landside areas of airports add to the aesthetic—and ultimately the economic—value of the airport environment. This is particularly true when the airfield is the first part of an area seen by air travelers arriving in a new destination. An airport in a predominantly dry, desert environment might appear as an "oasis" with areas of green, growing vegetation. Managed turfgrass areas deter the amount of damage to aircraft associated with jet blast and foreign object debris, allow for the passage of aircraft straying from paved areas, and do not inhibit emergency vehicles from responding to aircraft safety incidents and accidents (Federal Aviation Administration 2011). Additionally, airfield vegetation should be relatively inflammable, tolerant to vehicle traffic and to drought, require minimal maintenance for stand persistence, prevent soil erosion, and reduce stormwater runoff. Airfield vegetation, especially near runways and taxiways, should provide limited food resources for hazardous birds (e.g., seeds, insects), provide minimal hid-

Fig. 10.1. Westover Air Reserve Base, Chicopee, Massachusetts, USA. Airfields often contain large expanses of vegetation, typically composed of turfgrasses and herbaceous vegetation. Photo credit: Brian E. Washburn

ing cover for hazardous wildlife (DeVault et al. 2011), and resist invasion by other plants that provide food and cover for wildlife (Austin-Smith and Lewis 1969, Washburn and Seamans 2004, Linnell et al. 2009; Fig. 10.1).

Numerous wildlife species (both birds and mammals) hazardous to aviation are associated with turfgrass areas at airports. In highly urbanized environments, airfields typically represent some of the largest areas of grassland habitats within those ecosystems (Kutschbach-Brohl et al. 2010, DeVault et al. 2012) and thus can be particularly attractive to hazardous birds that forage in or otherwise use open grassland habitats. Wildlife that pose a hazard to aviation use turfgrass plants and seeds directly as a food source (e.g., Canada geese, European starlings [*Sturnus vulgaris*]), or indirectly by searching for prey items such as insects and small mammals that are often found in abundance within airfield grassland habitats (e.g., raptors, coyotes [*Canis latrans*]). Other hazardous species use the open, grassland areas at airfields because the habitat conditions are similar to what these species naturally prefer (e.g., eastern meadowlarks [*Sturnella magna*], killdeer [*Charadrius vociferus*]). Wildlife use of airfield grasslands can be seasonal (e.g., during migration periods) or throughout the year, depending on the hazardous wildlife species involved, the composition of the airfield vegetation, the geographic location of the airport, and other factors.

Traditional and Current Turfgrass Management at Airfields

Traditional methods of managing wildlife habitat in grassland ecosystems, such as discing, prescribed burning, and planting food plots, benefit wildlife by providing food, cover, water, loafing areas, or other resources (Bolen and Robinson 2002). In contrast, the focus of habitat management efforts at airfields should be to develop and maintain areas that are unattractive to wildlife, particularly those species that pose a hazard to aviation (DeVault et al. 2011).

Government agencies responsible for airfield management around the world have recognized the need to manage habitat and to establish guidelines for vegetation management at airfields. Some organizations or authorities are specific in their recommendations, whereas others are vague and leave on-field management decisions to the local airport authority. The International Civil Aviation Organization (1991) recommends that grass be maintained at a height of ≥20 cm (8 inches). The Civil Aviation Authority (CAA) in the United Kingdom has a policy to maintain grass from 15 to 20 cm (6 to 8 inches) and describes a detailed program of mowing, thatch removal, weed control, and fertilization (CAA 2008). In the Netherlands, vegetation management involves mowing once or twice each year, followed by thatch removal within 24 hr of mowing and no fertilization of the grassland areas (Royal Netherlands Air Force 2008). This "poor grass" system reduces food for wildlife, maintains turf for erosion control, and lowers maintenance costs (Dekker and van der Zee 1996). Transport Canada does not recommend a single grass height but leaves the decision to each airport based upon the bird species that pose the greatest hazards to that airport (Transport Canada 2002). In the USA, the Federal Aviation Administration does not have a direct policy on grass height but advises airport authorities to develop vegetation management plans based on the airport's geographic location and the types of hazardous wildlife found nearby (Federal Aviation Administration 2007). The U.S. Air Force maintains a policy on grass height (U.S. Air Force Instruction 91-202, 7.11.2.3) that states, "mow airfield to maintain a uniform grass height between 7 and 14 inches [18–36 cm]." The U.S. Air Force recognizes that exceptions to this policy should occur, and a waiver procedure is available to allow for varying management practices.

The aforementioned vegetation management policies are primarily based on studies conducted in the United Kingdom in the 1970s (Brough 1971, Mead and Carter 1973, Brough and Bridgman 1980). Studies conducted at airports in the USA to determine whether tallgrass management regimens reduce bird activity have produced conflicting results (Buckley and McCarthy 1994, Seamans et al. 1999, Barras et al. 2000). These conflicting results might be due to variation in the ways studies were designed, species-specific responses of birds to vegetation height management, or variation in the density or structure of vegetation within various study locations. Seamans et al. (2007) and Washburn and Seamans (2007) found that birds exhibited species-specific responses to management practices of maintaining a set vegetation height in grasslands areas. Further, some species of birds using vegetation ≥10 cm (4 inches) tall have decreased foraging success (Baker and Brooks 1981, Whitehead et al. 1995, Atkinson et al. 2004, Devereux et al. 2004) and reduced response times to predators due to the visual obstruction of the vegetation (Bednekoff and Lima 1998, Whittingham et al. 2004, Devereux et al. 2006, Whittingham and Devereux 2008). However, flock size might be positively correlated with bird use of habitat potentially hazardous to their survival (Bednekoff and Lima 1998, Lima and Bednekoff 1999, Fernández-Juricic et al. 2004). For a given species, vegetation height and density affect escape timing and flight behavior (Devereux et al. 2008), as well as the perception of vegetation as protective cover or potential habitat for predators (Lazarus and Symonds 1992, Lima 1993). European starlings might prefer shorter vegetation but use taller vegetation when that is all that is available (Devereux et al. 2004, Seamans et al. 2007). Studies examining vegetation height seldom consider vegetation density, but when density has been presented, some bird species and numbers have decreased as vegetation density increased (Bollinger 1995, Norment et al. 1999, Scott et al. 2002, Davis 2005). Likewise, information on use of food resources (e.g. insects, seeds) in airport grasslands by birds recognized as hazardous to aviation is also limited (Bernhardt et al. 2010, Kutschbach-Brohl et al. 2010, Washburn et al. 2011). There is no published work quantifying bird response to airport grassland management that exploits visual obstruction and management of food resources to elevate perceived predation risk and reduce foraging success (Blackwell et al. 2013).

With the exception of the CAA, no organizations provide instruction in airfield vegetation height management that results in dense, uniform areas of vegetation. The CAA instructions include the use of mowing with fertilizers, which are suggested as additional limiting factors for grassland bird populations (Vickery et al. 2001). In our experience, grasslands at most North American airports present a mosaic of bare earth and plants of varying species and height, with some plants going to seed. This is the type of habitat suggested to improve conditions for survival of grassland birds in the United Kingdom (Perkins et al. 2000, Barnett et al. 2004). Also, airfields in North America as well as Europe occur within multiple ecosystems, resulting in a wide range of vegetative conditions (i.e., plant communities) and wildlife issues unique to each area. More research is needed to fully understand how vegetation height, combined with other plant community characteristics (e.g., plant species composition, vegetation density), influences the use of airfield habitats by hazardous birds (Washburn and Seamans 2007; Blackwell et al. 2009, 2013). When developing a vegetation management plan for a specific airport, airfield managers and wildlife biologists should consider the species of hazardous wildlife that typically use the airfield and manage vegetation height to minimize use by those particular species (DeVault et al. 2011).

Other tools, such as herbicides and plant growth regulators, might also be applied to control or manage airfield vegetation (Blackwell et al. 1999, Washburn and Seamans 2007, Washburn et al. 2011). Depending on the vegetation management objectives desired, herbicides allow managers to alter vegetative composition of the airfield by removing (e.g., killing) or favoring (e.g., by removing competition) certain types of plants. Broadleaf-selective herbicides, such as 2,4-D or dicamba, could be used to remove broad-leaved forbs and legumes (e.g., clovers [*Trifolium* spp.]) that are an attractive food resource for certain wildlife species, including herbivorous birds (e.g., Canada geese) and cervids (e.g., white-tailed deer [*Odocoileus virginianus*]).

In addition, grassland plant communities with lower structural and botanical diversity support insect populations with less abundance and diversity (Tscharntke and Greiler 1995, Morris 2000), reducing potential food sources for insectivorous birds. Selective herbicide applications on airfields represent a management option for creating a near monoculture of a desired plant (e.g., seeded turfgrasses) and reducing foraging opportunities for wildlife hazardous to aviation (Washburn and Seamans 2007, Washburn et al. 2011).

Plant growth regulators are commonly used in traditional turfgrass management to reduce growth of vegetation and maintain vegetation at a desired height (Christians 2011). In situations where plant growth regulators might control the growth of vegetation (e.g., turfgrass) as an alternative to mowing, the use of such chemicals may not be cost-effective when compared to mowing only (Washburn and Seamans 2007). Some airports are limited to the number and type of pesticide (chemicals) that can be applied to the airfield; this is especially true of U.S. Department of Defense airfields and installations. Specialized equipment and application licenses also may be required before chemicals can be stored on site or applied to airfield vegetation.

Airfield grassland habitats often contain diverse insect communities that represent a potential attractant to hazardous birds (Kutschbach-Brohl et al. 2010). Laughing gulls (*Larus atricilla*) use airfield habitats for foraging and prey upon Japanese beetles (*Popillia japonica*) and other insects as a seasonal food source (Buckley and McCarthy 1994, Caccamise et al. 1994, Bernhardt et al. 2010). Garland et al. (2009) and Washburn et al. (2011) documented that American kestrels (*Falco sparverious*) struck by aircraft or collected during wildlife control operations at North American airports had eaten grasshoppers. Management of insect pest populations at airports (i.e., turf-damaging true bugs [Hemiptera], grasshoppers [Orthoptera], and beetles [Coleoptera]) identified as a food source (and therefore an attractant to hazardous wildlife) provides an opportunity to reduce the risk of wildlife–aircraft collisions (Washburn et al. 2011). Dietary information from hazardous species using airports (Chapter 8) could be particularly useful in developing effective management options. A variety of insecticides, commonly used to control turf pests, are commercially available for use on airfield grasslands and turfgrass areas (Christians 2011).

Populations of small mammals inhabiting airfield grassland habitats can represent an important attractant (as prey items) for hazardous birds (e.g., hawks and owls) and mammals (e.g., coyotes). Large or dense populations of small mammals at airports can result in increased risk of wildlife–aircraft collisions by bird and mammal predators (see Chapter 8 for a discussion of the confounding issue of abundance versus availability of small mammals to predators). Small mammals can be managed most effectively through an integrated pest management approach, which might involve vegetation management (e.g., mowing), applying toxic rodenticide baits (e.g., zinc phosphide), altering plant communities, or combining various methods (Witmer and Fantinato 2003, Witmer 2011). Numerous studies demonstrate that mowing vegetation reduces small-mammal use of grassland habitats (Grimm and Yahner 1988, Edge et al. 1995, Seamans et al. 2007, Washburn and Seamans 2007).

Prescribed fire (i.e., burning) is one of the most widely used and effective tools for managing grassland habitats (Packard and Mutel 1997, Washburn et al. 2000). Benefits from prescribed fire used within grasslands include removal of encroaching woody vegetation, release of nutrients, and enhancement of native plant populations. Given safety issues related to reduced visibility from smoke and other hazards associated with prescribed burning, this technique has not been frequently used within airport environments. However, burning has potential for assisting with airfield vegetation management goals in situations where the related safety issues could be managed effectively.

Airfield grasslands represent a potential location for biosolids application and a possible source of revenue for airports. Application of municipal biosolids (i.e., treated and stabilized sewage sludge) provides plant nutrition and organic matter inputs to receiving grassland systems. At one military airfield in North Carolina, Washburn and Begier (2011) found that although long-term biosolids applications altered plant communities, the relative hazards posed by wildlife using treated and untreated areas were similar.

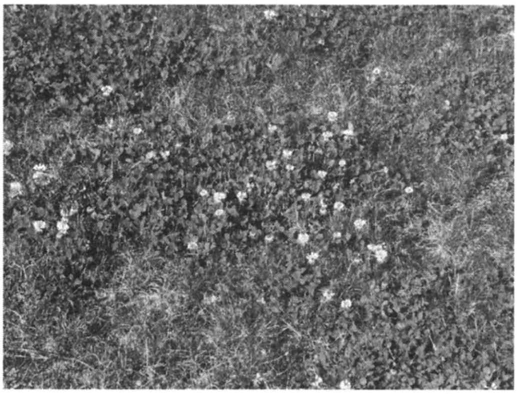

Fig. 10.2. Grass and clover (*Trifolium* spp.). Plant communities on airfields are often diverse and contain plants, such as these, which are selected by hazardous wildlife species. Photo credit: Brian E. Washburn

Selecting Plant Material for Renovation and Initial Seeding Efforts

Species composition of plant communities (the types of plants) in airfield areas also has the potential to impact the degree of attractiveness of airfields to hazardous wildlife and other bird attractants (e.g., insects, small mammals; Austin-Smith and Lewis 1969, Dekker and van der Zee 1996, Washburn and Seamans 2007). Selecting plant materials (e.g., turfgrasses) that are minimally attractive to hazardous wildlife and avoiding those that are commonly utilized by hazardous birds and mammals are important decisions, and present an important management opportunity for revegetation projects at airports (Fig. 10.2).

Abiotic factors (e.g., climatic conditions, soil nutrient levels) and biotic factors (e.g., weed competition) have strong influence on the rate of establishment of turfgrasses and other plants seeded as part of an airfield renovation or revegetation project. These abiotic and biotic factors can vary greatly among airports, depending on the airport's geographic location, local geology and soils, and regional climatic conditions. Some factors, such as weather, cannot be controlled or predicted and are not under control of airfield managers. In contrast, other factors can be monitored and amended when establishing turfgrasses on airfields by using methods such as soil testing and fertilization, planting good-quality turfgrass seed, and applying appropriate chemical control (e.g., herbicides) to reduce weed competition (Willis et al. 2006). Washburn et al. (2007*b*) found that tall fescue (*Schedonorus phoenix*) establishment on airfields was enhanced by the application of mulch during seeding efforts. Specific guidelines for seeding and sodding turfgrasses at airports are available (see Federal Aviation Administration 2009). In addition, many airports and state aviation departments have developed their own airport- and region-specific specifications for seeding and sodding areas within airport environments.

Cover crops are commonly used in seeding efforts following construction projects because they quickly establish vegetative cover to prevent erosion. Use of cover crops, which typically consist of cereal grains (e.g., browntop millet [*Panicum ramosum*], wheat [*Triticum* spp.], and cereal rye [*Secale cereale*]), should not be used for reseeding efforts in airport environments, as they provide food for granivorous birds (e.g., mourning doves [*Zenaida macroura*] and rock pigeons [*Columba livia*]) and other birds recognized as hazardous to aviation (Castellano 1998).

Tall fescue is a cool-season, perennial sod-forming grass that grows well in temperate regions. In recent years, this traditionally agronomic forage grass has been developed as a turfgrass and has become very popular for use in parks, lawns, golf courses, sports fields, and other areas (Casler 2006). Tall fescue is frequently infested with a fungal endophyte (*Neotyphodium coenophialum*) that forms a mutualistic, symbiotic relationship with the grass. Grasses containing endophytic fungi derive several benefits, such as resistance to both grazing and insect herbivory, increased heat and drought stress tolerance, and increased vigor (Clay et al. 1985, Vicari and Bazely 1993, Malinowski and Belesky 2000). Tall fescue is also extremely competitive and develops into solid stands, crowding out other grasses, legumes, and annual weeds (Barnes et al. 1995, Richmond et al. 2006, Washburn et al. 2007*a*). Tall fescue grasslands are generally unattractive as a foraging resource to grassland wildlife (Barnes et al. 1995, Washburn et al. 2000), making it a potentially useful ground cover for airfields in some regions of the USA.

The turfgrass industry has recently developed a large number of "turf-type" cultivars of the most common varieties (e.g., tall fescue, perennial ryegrass [*Lo-*

lium perenne], bermudagrass [*Cynodon dactylon*]) for lawns, golf courses, parks, and other traditional uses. Turf-type cultivars are bred for horticultural characteristics important to the turfgrass industry, namely deep green color, drought and disease resistance, and shorter growth habits than traditional agronomic tall fescue cultivars. In addition, many of the new tall fescue cultivars have high levels of *Neotyphonium* endophyte infection (Mohr et al. 2002). Consequently, a diverse variety of plant materials are commercially available for use in airfield and landside seeding and revegetation projects within airport environments. Washburn et al. (2007*b*) found that high-endophyte turf-type tall fescue cultivars did establish on areas within airports.

The various species of commercially available turfgrass commonly used in North America differ in their attractiveness and utility as food for wildlife hazardous to aviation. Washburn and Seamans (2012) found that Canada geese exhibited clear preferences among commercially available turfgrasses when foraging. Their findings suggest that selected commercial turfgrasses (e.g., zoysiagrass [*Zoysia japonica*], centipedegrass [*Eremochloa ophiuroides*], and St. Augustinegrass [*Stenotaphrum secundatum*]) might be preferable in reseeding and vegetation renovation projects within areas where Canada geese are unwanted (e.g., airfields, parks, athletic fields, and golf courses). In contrast, creeping bentgrass (*Agrostis stolonifera*), Kentucky bluegrass (*Poa pratensis*), and fine fescues (*Festuca* spp.) were favored by foraging geese and thus should be avoided when formulating seed mixtures for reseeding areas at airfields and other places where human–goose conflicts might occur (Fig. 10.3).

Fig. 10.3. Canada geese in study plot. Research examining the foraging preferences of Canada geese provides information about the selection of plant materials for reseeding projects at airports. Photo credit: Brian E. Washburn

Grazing Anatidae (including various species of geese) apparently make foraging choices based on the nutritional content and chemical composition of plants (Gauthier and Bedard 1991, McKay et al. 2001, Durant et al. 2004). The concentration of protein within forage plants is an important component in the foraging preferences for a variety of goose species, including barnacle geese (*B. leucopsis*; Prins and Ydenberg 1985), dark-bellied brent geese (*B. bernicla bernicla*; McKay et al. 2001), white-fronted geese (*Anser albifrons albifrons*; Owen 1976), graylag geese (*A. anser*; Van Liere et al. 2009), and Canada geese (Sedinger and Raveling 1984, Washburn and Seamans 2012). In addition, secondary plant defense compounds, such as alkaloids and tannins, can cause geese to avoid certain plants. Physical characteristics of plants (e.g., leaf tensile strength, hairy leaves) also might influence whether geese (or other wildlife) forage on specific plants (Lieff et al. 1970, Williams and Forbes 1980, Buchsbaum et al. 1984, Conover 1991, Gauthier and Hughes 1995).

In addition to the commercially available turfgrasses, other plants could be appropriate for use on airfields. Linnell et al. (2009) found that wedelia (*Wedelia trilobata*), a mat-forming composite plant, showed promise for use as a vegetative cover on tropical airfields. Pochop et al. (1999) found several grasses that were locally adapted to Alaska and not favored by Canada geese in captive situations. These studies are limited to specific ecotypes and locations but demonstrate the availability of regionally specific plants that are not desired by wildlife hazardous to aviation. Some caution is warranted when establishing nonnative plant species: doing so can result in the escape of exotic species from the airfield environment (Austin-Smith and Lewis 1969). We recommend consulting state departments of agriculture or natural resources Web sites for lists of invasive plants that are illegal to plant because of their noxious or nonnative status. Native plants that are aesthetically pleasing, legal to plant, and unattractive to hazardous wildlife are the best choices for airfield vegetation, assuming seed is available in sufficient quantities and at reasonable cost.

Summary

Although some research has been conducted on the use of airfield grasslands by wildlife hazardous to aviation, much is still unknown. Field research within active airport environments to determine the most effective tools and techniques to reduce insect resources and small mammal populations, and consequently hazardous wildlife use of airfields, is needed. Research examining the use of prescribed fire, herbicides, growth regulators, and other airfield vegetation management methods should also be a priority. As with other aspects of managing human–wildlife conflicts in the airport environment, we suggest that future studies focus on those species that are most hazardous to aircraft (Dolbeer et al. 2000, 2010; DeVault et al. 2011). With regard to airfield grasslands, species that use these habitats for foraging and to meet other life history needs should be of a high priority. Information about the influence of unique land uses (such as biosolids disposal and biofuel production; Chapter 11) on the attractiveness of airfields to hazardous wildlife represents an important area for future research, making it beneficial in the formulation and evaluation of effective management practices for airport environments.

LITERATURE CITED

Atkinson, P. W., D. Buckingham, and A. J. Morris. 2004. What factors determine where invertebrate-feeding birds forage in dry agricultural grasslands? Ibis 146:99–107.

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.

Baker, J. A., and R. J. Brooks. 1981. Raptor and vole populations at an airport. Journal of Wildlife Management 45:390–396.

Barnes, T. G., L. A. Madison, J. D. Sole, and M. J. Lacki. 1995. An assessment of habitat quality for northern bobwhite in tall fescue–dominated fields. Wildlife Society Bulletin 23:231–237.

Barnett, P. R., M. J. Whittingham, R. B. Bradbury, and J. D. Wilson. 2004. Use of unimproved and improved lowland grassland by wintering birds in the UK. Agriculture, Ecosystems, and Environment 102:49–60.

Barras, S. C., R. A. Dolbeer, R. B. Chipman, G. E. Bernhardt, and M. S. Carrara. 2000. Bird and small mammal use of mowed and unmowed vegetation at John F. Kennedy International Airport, 1998–1999. Proceedings of the Vertebrate Pest Conference 19:31–36.

Bednekoff, P. A., and S. L. Lima. 1998. Re-examining safety in numbers: interactions between risk dilution and collective detection depend upon predator targeting behaviour. Proceedings of the Royal Society B 265:2021–2026.

Bernhardt, G. E., L. Kutschbach-Brohl, B. E. Washburn, R. B. Chipman, and L. C. Francoeur. 2010. Temporal variation in terrestrial invertebrate consumption by laughing gulls in New York. American Midland Naturalist 163:442–454.

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 on and near airports? Landscape and Urban Planning 93:1–9.

Blackwell, B. F., T. W. Seamans, and R. A. Dolbeer. 1999. Plant growth regulator (Stronghold™) enhances repellency of anthraquinone formulation (Flight Control™) to Canada geese. Journal of Wildlife Management 63:1336–1343.

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.

Bolen, E. G., and W. L. Robinson. 2002. Wildlife ecology and management. Fifth edition. Prentice Hall, New York, New York, USA.

Bollinger, E. K. 1995. Successional changes and habitat selection in hayfield bird communities. Auk 112:720–730.

Brough, T. 1971. Experimental use of long-grass in the U.K. Proceedings of the Bird Strike Committee Europe 6.

Brough, T., and C. J. Bridgman. 1980. An evaluation of long grass as a bird deterrent on British airfields. Journal of Applied Ecology 17:243–253.

Buchsbaum, R., I. Valiela, and T. Swain. 1984. The role of phenolic compounds and other plant constituents in feeding by Canada geese in a coastal marsh. Oecologia 63:343–349.

Buckley, P. A., and M. G. McCarthy. 1994. Insects, vegetation, and the control of laughing gulls (*Larus atricilla*) at Kennedy International Airport, New York City. Journal of Applied Ecology 31:291–302.

CAA. Civil Aviation Authority. 2008. CAP 772: birdstrike risk management for aerodromes. Safety Regulation Group, Gatwick Airport South, West Sussex, United Kingdom.

Caccamise, D. F., J. J. Dosch, K. Bennett, L. M. Reed, and L. DeLay. 1994. Management of bird strike hazards at airports: a habitat approach. Proceedings of the Bird Strike Committee Europe 22:285–306.

Casler, M. D. 2006. Perennial grasses for turf, sport, and amenity uses: evolution of form, function, and fitness for human benefit. Journal of Agricultural Science 144:189–203.

Casler, M. D., and R. R. Duncan. 2003. Turfgrass biology, genetics, and breeding. John Wiley and Sons, New York, New York, USA.

Castellano, B. 1998. Grasses attractive to hazardous wildlife. CertAlert 98-05. Federal Aviation Administration, Airports Safety and Operations Division, Washington, D.C., USA.

Christians, N. 2011. Fundamentals of turfgrass management. Fourth edition. John Wiley and Sons, New York, New York, USA.

Clay, K., T. N. Hardy, and A. M. Hammond Jr. 1985. Fungal endophytes of grasses and their effects on an insect herbivore. Oecologia 66:1–5.

Conover, M. R. 1991. Herbivory by Canada geese: diet selection and effect on lawns. Ecological Applications 1:231–236.

Davis, S. K. 2005. Nest-site selection patterns and the influence of vegetation on nest survival of mixed-grass prairie passerines. Condor 107:605–616.

Dekker, A., and F. F. van der Zee. 1996. Birds and grasslands on airports. Proceedings of the International Bird Strike Committee 23:291–305.

DeVault, T. L., J. L. Belant, B. F. Blackwell, J. A. Martin, J. A. Schmidt, and L. W. Burger Jr. 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.

Devereux, C. L., E. Fernández-Juricic, J. R. Krebs, and M. J. Whittingham. 2008. Habitat affects escape behaviour and alarm calling in Common Starlings *Sturnus vulgaris*. Ibis 150:191–198.

Devereux, C. L., C. U. McKeever, T. G. Benton, and M. J. Whittingham. 2004. The effect of sward height and drainage on Common Starlings *Sturnus vulgaris* and Northern Lapwings *Vanellus vanellus* foraging in grassland habitats. Ibis 146:115–122.

Devereux, C. L., M. J. Whittingham, E. Fernández-Juricic, J. A. Vickery, and J. R. Krebs. 2006. Predator detection and avoidance by starlings under differing scenarios of predation risk. Behavioural Ecology 17:303–309.

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.

Dolbeer, R. A., S. E. Wright, J. Weller, and M. J. Begier. 2010. Wildlife strikes to civil aircraft in the United States 1990–2009. Serial Report 16. U.S. Department of Transportation, Federal Aviation Administration, Office of Airport Safety and Standards, Washington, D.C., USA.

Durant, D., H. Fritz, and P. Duncan. 2004. Feeding patch selection by herbivorous Anatidae: the influence of body size, and of plant quantity and quality. Journal of Avian Biology 25:144–152.

Edge, W. D., J. O. Wolff, and R. L. Carey. 1995. Density-dependent responses of gray-tailed voles to mowing. Journal of Wildlife Management 59:245–251.

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.

Federal Aviation Administration. 2009. Standards for specifying construction of airports. Advisory Circular 150/5370-10E. U.S. Department of Transportation, Washington, D.C., USA.

Federal Aviation Administration. 2011. Airport planning. Advisory Circular 150/5300-13. U.S. Department of Transportation, Washington, D.C., USA.

Fernández-Juricic, E., S. Siller, and A. Kacelnik. 2004. Flock density, social foraging, and scanning: an experiment with starlings. Behavioural Ecology 15:371–379.

Garland, H., A. D. Peral, D. M. Bird, and M. A. Fortin. 2009. High frequency of American kestrel strikes at the Montreal–Trudeau International Airport: a case study. Journal of Raptor Research 43:382–383.

Gauthier, G., and J. Bedard. 1991. Experimental tests of the palatability of forage plants in greater snow geese. Journal of Applied Ecology 28:491–500.

Gauthier, G., and R. J. Hughes. 1995. The palatability of Arctic willow for greater snow geese: the role of nutrients and deterring factors. Oecologia 103:390–392.

Grimm, J. W., and R. H. Yahner. 1988. Small mammal response to roadside habitat management in central Minnesota. Journal of the Minnesota Academy of Science 53:16–21.

International Civil Aviation Organization. 1991. Bird control and reduction. Airport Services Manual, Document 9137 -AN/898, Part 3. Montreal, Quebec, Canada.

Kutschbach-Brohl, L., B. E. Washburn, G. E. Bernhardt, R. B. Chipman, and L. C. Francoeur. 2010. Arthropods of a seminatural grassland in an urban environment: the John F. Kennedy International Airport, New York. Journal of Insect Conservation 14:347–358.

Lazarus, J., and M. Symonds. 1992. Contrasting effects of protective and obstructive cover on avian vigilance. Animal Behaviour 43:519–521.

Lieff, B. C., C. D. MacInnes, and R. K. Kistra. 1970. Food selection experiments with young geese. Journal of Wildlife Management 34:321–327.

Lima, S. L. 1993. Ecological and evolutionary perspectives on escape from predatory attack: a survey of North American birds. Wilson Bulletin 105:1–47.

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.

Linnell, M. A., M. R. Conover, and T. J. Ohashi. 2009. Using wedelia as ground cover on tropical airports to reduce bird activity. Human–Wildlife Conflicts 3:226–236.

Malinowski, D. P., and D. P. Belesky. 2000. Adaptations of endophyte-infected cool-season grasses to environmental stresses: mechanisms of drought and mineral stress tolerance. Crop Science 40:923–940.

McKay, H. V., T. P. Milsom, C. J. Feare, D. C. Ennis, D. P. O'Connell, and D. J. Haskell. 2001. Selection of forage species and the creation of alternative feeding areas for dark-bellied brent geese (*Branta bernicla bernicla*) in southern UK coastal areas. Agriculture, Ecosystems, and Environment 84:99–113.

Mead, H., and A. W. Carter. 1973. The management of long grass as a bird repellent on airfields. Journal of the British Grassland Society 28:219–221.

Mohr, M. M., W. A. Meyer, and C. Mansue. 2002. Incidence of *Neotyphodium* endophyte in seed lots of cultivars and selections of the 2001 national tall fescue test. Rutgers Turfgrass Proceedings 34:196–201.

Morris, M. G. 2000. The effects of structure and its dynamics on the ecology and conservation of arthropods in British grasslands. Biological Conservation 95:129–142.

Norment, C. J., C. D. Ardizzone, and K. Hartman. 1999. Habitat relations and breeding biology of grassland birds in New York. Studies in Avian Biology 19:112–121.

Owen, M. 1976. The selection of winter food by white-fronted geese. Journal of Applied Ecology 13:715–729.

Packard, S., and C. F. Mutel. 1997. The tallgrass restoration handbook for prairies, savannas, and woodlands. Island Press, Washington, D.C., USA.

Perkins, A. J., M. J. Whittingham, R. B. Bradbury, J. D. Wilson, A. J. Morris, and P. R. Barnett. 2000. Habitat characteristics affecting use of lowland agricultural grassland by birds in winter. Biological Conservation 95:279–294.

Pochop, P. A., J. L. Cummings, K. L. Wedemeyer, R. M. Engeman, and J. E. Davis Jr. 1999. Vegetation preferences of captive Canada geese at Elmendorf Air Force Base, Alaska. Wildlife Society Bulletin 27:734–740.

Prins, H. H. T., and R. C. Ydenberg. 1985. Vegetation growth and a seasonal habitat shift of the barnacle goose (*Branta leucopsis*). Oecologia 66:122–125.

Richmond, D. S., J. Cardina, and P. S. Grewal. 2006. Influence of grass species and endophyte infection on weed populations during establishment of low maintenance lawns. Agriculture, Ecosystems, and Environment 115:27–33.

Royal Netherlands Air Force. 2008. Voorschrift Vogelaanvaringspreventie (1^{E} Uitgave). Behandelende Instantie: CLSK/DO/HAMO. Publication No. 063178. Breda, Netherlands.

Scott, P. E., T. L. DeVault, R. A. Bajema, and S. L. Lima. 2002. Grassland vegetation and bird abundances on reclaimed Midwestern coal mines. Wildlife Society Bulletin 30:1006–1014.

Seamans, T. W., S. C. Barras, G. E. Bernhardt, B. F. Blackwell, and J. D. Cepek. 2007. Comparison of 2 vegetation-height management practices for wildlife control at airports. Human–Wildlife Conflicts 1:97–105.

Seamans, T. W., R. A. Dolbeer, M. S. Carrara, and R. B. Chipman. 1999. Does tall grass reduce bird numbers on airports? Results of pen test with Canada geese and field trials at two airports, 1998. Pages 160–170 *in* Proceedings of the first joint annual meeting. Bird Strike Committee–USA/Canada. Vancouver, British Columbia, Canada.

Sedinger, J. S., and D. G. Raveling. 1984. Dietary selectivity in relation to availability and quality of food for goslings of cackling geese. Auk 101:295–306.

Transport Canada. 2002. Wildlife control procedures manual. TP 11500 E. Third edition. Transport Canada, Safety and Security, Aerodrome Safety Branch, Ottawa, Ontario, Canada.

Tscharntke, T., and H. J. Greiler. 1995. Insect communities, grasses, and grasslands. Annual Review of Entomology 40:535–558.

Ulrich, R. S. 1986. Human response to vegetation and landscapes. Landscape and Urban Planning 13:29–44.

Van Liere, D. W., N. J. M. Van Eekeren, and M. J. J. E. Loonen. 2009. Feeding preferences of greylag geese and the effect of activated charcoal. Journal of Wildlife Management 73:924–931.

Vicari, M., and D. R. Bazely. 1993. Do grasses fight back? The case for antiherbivore defenses. Trends in Ecology and Evolution 8:137–141.

Vickery, J. A., J. R. Tallowin, R. E. Feber, E. J. Asteraki, P. W. Atkinson, R. J. Fuller, and V. K. Brown. 2001. The management of lowland neutral grasslands in Britain: effects of agricultural practices on birds and their food resources. Journal of Applied Ecology 38:647–664.

Washburn, B. E., T. G. Barnes, and J. D. Sole. 2000. Improving northern bobwhite habitat by converting tall fescue fields to native warm-season grasses. Wildlife Society Bulletin 28:97–104.

Washburn, B. E., S. C. Barras, and T. W. Seamans. 2007*a*. Foraging preferences of captive Canada geese related to turfgrass mixtures. Human–Wildlife Conflicts 1:214–223.

Washburn, B. E., and M. J. Begier. 2011. Wildlife responses to long-term application of biosolids to grasslands in North Carolina. Rangeland Ecology and Management 64:131–138.

Washburn, B. E., G. E. Bernhardt, and L. A. Kutschbach-Brohl. 2011. Using dietary analyses to reduce the risk of wildlife–aircraft collisions. Human–Wildlife Interactions 5:204–209.

Washburn, B. E., J. S. Loven, M. J. Begier, D. P. Sullivan, and H. A. Woods. 2007*b*. Evaluating commercially available tall fescue varieties for airfields. Pages 1–12 *in* Proceedings of the FAA worldwide airport technology transfer conference. Federal Aviation Administration, Washington, D.C., USA.

Washburn, B. E., and T. W. Seamans. 2004. Management of vegetation to reduce wildlife hazards at airports. Pages 1–7 *in* Proceedings of the FAA worldwide airport technology transfer conference. Federal Aviation Administration, Washington, D.C., USA.

Washburn, B. E., and T. W. Seamans. 2007. Wildlife responses to vegetation height management in cool-season grasslands. Rangeland Ecology and Management 60:319–323.

Washburn, B. E., and T. W. Seamans. 2012. Foraging preferences of Canada geese: implications for reducing human–goose conflicts. Journal of Wildlife Management 76:600–607.

Whitehead, S. C., J. Wright, and P. A. Cotton. 1995. Winter field use by the European starling *Sturnus vulgaris*: habitat preferences and the availability of prey. Journal of Avian Biology 26:193–202.

Whittingham, M. J., S. J. Butler, J. L. Quinn, and W. Cresswell. 2004. The effect of limited visibility on vigilance behaviour and speed of predator detection: implications for the conservation of granivorous passerines. Oikos 106:377–385.

Whittingham, M. J., and C. L. Devereux. 2008. Changing grass height alters foraging site selection by wintering farmland birds. Basic and Applied Ecology 9:779–788.

Williams, G., and J. E. Forbes. 1980. The habitat and dietary preferences of dark-bellied brent geese and wigeon in relation to agricultural management. Wildfowl 31:151–157.

Willis, J. B., J. B. Beam, W. L. Barker, and S. D. Askew. 2006. Weed control options in spring-seeded tall fescue (*Festuca arundinacea*). Weed Technology 20:1040–1046.

Witmer, G. W. 2011. Rodent population management at Kansas City International Airport. Human–Wildlife Interactions 5:269–275.

Witmer, G. W., and J. W. Fantinato. 2003. Management of rodent populations at airports. Proceedings of the Wildlife Damage Management Conference 10:350–357.