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INTRODUCTION

Wildlife-aircraft collisions (wildlife strikes) pose a serious safety risk to aircraft. Wildlife strikes cost civil and military aviation at least $490 million annually in the United States (Cleary et al. [1]). Over 46,500 wildlife strikes with civil aircraft were reported to the U.S. Federal Aviation Administration (FAA) during 1990-2002 (Cleary et al. [1]). Aircraft collisions with birds accounted for 97% of the reported strikes, whereas strikes with mammals and reptiles were 3% and <1%, respectively (Wright and Dolbeer [2]). Gulls (*Larus* spp.), waterfowl such as Canada geese (*Branta canadensis*), raptors (hawks and owls), and blackbirds (Icterinae)/starlings (*Sturnus vulgaris*) are the species presently of most concern at airports (Dolbeer et al. [3], Cleary et al. [1]). Sound management techniques that reduce bird numbers in and around airports are therefore critical for safe airport operations.

Large-scale lethal control efforts to solve wildlife-aviation conflicts are often undesirable or impractical (Dolbeer [4], Dolbeer [5]). Nonlethal frightening techniques to keep birds and other hazardous wildlife away from airports (e.g., pyrotechnics, propane cannon exploders, acoustical devices) are available (Marsh et al. [6], Cleary [7]), but may be untested, only temporarily effective, or cost-prohibitive (Dolbeer et al. [8]). Modifying and managing habitats within airport environments is the most important long-term component of an integrated wildlife damage management approach to reduce the use of airfields by birds and mammals that pose hazards to aviation.

Traditional grassland habitat management practices, such as disking, prescribed burning, and planting food plots, are conducted to benefit wildlife by providing food, cover, water, loafing areas, or other necessities (Bolen and Robinson [9]). In contrast, the focus of habitat management efforts on airfields should be to develop and maintain habitats that are unattractive to wildlife species hazardous to aviation.

MANAGING THE HEIGHT OF AIRFIELD VEGETATION

Managing the height of vegetation on airfields is one method that might reduce bird numbers on airports. Tall vegetation (e.g., 15-25 cm) is thought to interfere with visibility and ground movements of flocking birds, such as European starlings and gulls (Blockpoel [10], U. S. Federal Aviation Administration [11], Dekker and van der Zee [12]). Traditionally, the basis for tall vegetation height management recommendations has come from studies conducted in Great Britain (Mead and Carter [13], and Brough and Bridgman [14]). However, bird species of concern in the United States were not present during those studies and thus the response of bird species that pose significant risk to aviation in the U.S. (e.g., Canada geese) is unknown. In addition, tall grass management in Great Britain involves a rigorous mowing regimen, thatch and weed removal, and the use of fertilizers to maintain an erect, dense stand of grass (Civil Aviation Authority [15]). This type of vegetation management is not generally practiced on North American airfields.

Preliminary studies conducted at airports in the U.S. to determine if tall grass management regimens reduce bird activity have produced conflicting results (Buckley and McCarthy [16], Seamans et al. [17], Barras et al. [18]). One reason for conflicting results is due to variation in the ways studies were designed, species-specific responses of birds to vegetation management, and density or structure of vegetation within the study areas. Vegetation height, when coupled with dense vegetation that restricts ground movements of birds, might reduce the attraction of airfield areas for certain bird species by making it too difficult for birds to forage (Norment et al. [19], Sheffield et al. [20]). Older vegetative stands that have open space at ground level may be attractive for some avian species (Norment et al. [19]). Barras et al. [18] found higher bird and mammal use of airfield areas that contained older, unmowed vegetation. Cleary et al. [21] noted more small mammals were present in areas containing vegetation that had not been managed compared to areas of mowed vegetation. In each case, areas of airfields not subjected to some form of vegetative management contained more wildlife than areas that had been managed.

Although mechanical mowing is the most widely used tool for vegetation management on airfields, other tools, such herbicides and plant growth regulators, might also be applied to control vegetation. The use of herbicides might allow managers to alter the vegetative composition of the airfield by removing (e.g., killing) or favoring (e.g., by removing competition) certain types of plants. For example, broadleaf-selective herbicides, such as 2,4-D, could be used to remove forb and clovers that might be an attractive food resource for certain wildlife species. Use of such chemicals would have to be cost effective when compared to mowing while ultimately acting as a bird deterrent. Further, some airfields are limited to the number and type of chemicals that they may apply. Specialized equipment and application licenses may also be required before chemicals may be stored on-site or applied to airfield vegetation.

These findings suggest that to be most effective, the vegetation height management regimen for an individual airport should be selected based on the specific bird species that pose the most risk to aviation at that airport (e.g., raptors, blackbirds). In addition, the composition of the plant communities that are present on that airfield should be examined and carefully considered. Consultation with certified wildlife biologists familiar with the area and airfield operations should be part of any airfield vegetation management planning.

SPECIES COMPOSITION OF AIRFIELD VEGETATION

Species composition of plant communities (the types of plants) on airfield areas might also impact the degree of attractiveness of airfields to hazardous birds and other bird attractants (e.g., insects, small mammals) (Austin-Smith and Lewis [22], Brooks et al. [23], Dekker and van der Zee [12]). Ideally, airfield vegetation should possess a variety of desirable qualities. Vegetation used on airfields should be aesthetically pleasing to the public, relatively inflammable, tolerant to vehicle traffic, drought tolerant, and require minimal maintenance for stand persistence. In addition, airfield vegetation that provides limited food resources for hazardous birds (e.g., seeds, insects), provides little cover for small mammals (an attractant to raptors and owls), and resists invasion by other plants that provide food and cover for wildlife (Austin-Smith and Lewis [22], Linnell et al. [24]).

Caution is warranted when plant species not currently present in an area are being established due to the potential of invasive exotic species that might escape from the airfield environment and become pests (Austin-Smith and Lewis [22]). Many states maintain lists of invasive plants that are illegal to plant because of their noxious or non-native status. Native plants that are esthetically pleasing, legal to plant, and not attractive to wildlife would be the most favorable choices for airfield vegetation.

Many plants produce a variety of compounds (e.g., secondary metabolites) that offer protection from grazing animals, including alkaloids, tannins, and caffeine (Alcock, J. [25]). These plant defense compounds make these plant species unattractive to foraging birds and mammals; thus, these plants might be appropriate for airfield vegetation.

Tall fescue (*Festuca arundinacea*) is a cool-season perennial sod-forming grass that grows well in the U.S. in areas of temperate climate and may also be unattractive to wildlife (Mead and Carter [13], Barnes et al. [26]). Tall fescue is extremely competitive and develops into solid stands, crowding out other grasses, legumes, and annual weeds (Barnes et al. [26], Washburn et al. [27]). Tall fescue is a poor forage for livestock due to the fungal endophyte *Neotyphodium coenophialum* that forms a mutualistic symbiotic relationship with tall fescue. Alkaloids produced by the tall fescue endophyte have been shown to cause weight loss, reproductive problems, and a variety of diseases in livestock and laboratory small mammals (Schmidt and Osborn [28], Bacon and Hill [29]). Total livestock-related economic losses due to the tall fescue endophyte have been estimated to be between $500 million and $1 billion annually in the United States (Ball et al. [30]).

Recent studies suggest wild mammals and birds may be affected by consumption of endophyte-infected tall fescue. Fewer small mammals, an attractant to raptors and owls, were found in endophyte-infected tall fescue fields compared to endophyte-free tall fescue fields (Pelton et al. [31], Coley et al. [32]). Washburn [33] found that wild Eastern cottontail rabbits (*Sylvilagus floridanus*) selectively avoided foraging on tall fescue in grasslands dominated by this grass. Furthermore, consumption of endophtye-infected tall fescue causes decreased forage intake, weight loss, and other nutritional problems in a variety of birds, including Canada geese, dark-eyed juncos (*Junco hyemalis*), and northern bobwhite (Madej and Clay [34], Lane [35], Conover and Messmer [36]).

Recently, a large number of "turf-type" tall fescue varieties have been developed for the turfgrass industry. Turf-type tall fescues are bred to maintain deep green color, drought and disease resistance, and grow to shorter heights than traditional tall fescues. In addition, many of these new varieties have high levels of endophyte-infection (Mohr et al. [37]).

A study was conducted at the USDA, Wildlife Services, National Wildlife Research Center in Sandusky, Ohio with one of these new tall fescue varieties (Crossfire II™) to determine if Canada geese exhibited a feeding preference between tall fescue and a perennial ryegrass (*Lolium perenne*) mixture. The behavioral responses of captive geese to the two vegetation types were observed during July and August of the first (2001) and third (2003) growing seasons following seeding of grass mixtures in spring of 2000. During 2001, Canada geese showed no preference between the tall fescue and perennial ryegrass mixture plots when loafing, resting, or foraging. However, after two additional growing seasons, the tall fescue became the dominant plant in the fescue treatment plots (>90% coverage) and formed a dense monoculture. During behavioral observations conducted in 2003, Canada geese fed almost exclusively in the perennial ryegrass mixture plots and avoided foraging in the tall fescue plots. The findings from this study suggest tall fescue might be a favorable species to be used in reseeding and vegetation renovation projects on airfields and other areas where Canada geese are unwanted. We recommend that field trials be conducted on airports in various parts of the United States.

Other plants besides tall fescue have shown promise as desirable airport vegetation that is unattractive to wildlife. On tropical airfields, *Wedelia* sp. was found to be unattractive to birds and small mammals (Linnell et al. [24]). Pochop et al. [38], in a study of feeding preferences of captive Canada geese to various native plants in Alaska, found 3 species that were not preferred by Canada geese and that could feasibly be planted on airfields. Many questions remain unanswered regarding what specific vegetation types and species are most appropriate, as well as specifically where on airfields they should be planted, to minimize the attractiveness of airports to hazardous wildlife. Much future research will be required to find those plants that will meet the needs of ground cover without attracting wildlife hazardous to aviation in all of the various ecotypes found across the United States.

LANDSCAPING AND VEGETATION RENOVATION

Landscaping at airports needs to consist of plants that are aesthetically pleasing to the public. However, plant species used in landscaping projects should be carefully selected to avoid creating attractants to hazardous wildlife. For example, trees and shrubs that produce fruits and berries, such as crab apple trees (*Malus* spp.), holly (*Ilex* spp.), blueberry (*Vaccinium* spp.) and dogwood (*Cornus* spp.), should not be included in new airport landscaping projects and should be removed from existing areas. In addition, evergreen trees, such as spruces (*Picea* spp.), pines (*Pinus* spp.), and junipers (*Juniperus* spp.) should not be planted in dense stands as they provide desired roosting habitat for many flocking species of birds. The cost of later removal, remediation for damage caused by birds, and the inconvenience of re-doing a project provide suitable reasons for considering wildlife during the initial planning stages of landscaping work. Professional wildlife biologists, working in conjunction with landscape architects, will be able to create landscaped areas that are pleasing to people and concurrently are not attractive to damage causing wildlife.

FUTURE RESEARCH NEEDS

A variety of plant species are currently available for testing as potential plants for use on airfields. Great care must be taken when evaluating potential plant species. These plants must not be attractive to wildlife hazardous to aviation and must not be noxious plant species that will invade the region around the airfield, forcing out desired native plants. Current information is available to help airport managers and landscapers to avoid planting certain varieties of plants that are known to be attractive to wildlife. However, many questions need to be answered before recommendations can be made as to what is the best plant or group of plants to manage for on airfields in the various ecotypes found in North America. Future research is needed to provide regionally specific recommendations for desirable airfield vegetation types and management regimens that minimize or eliminate the attractiveness of airports to hazardous wildlife.

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