RESEARCH: PROVIDING TECHNIQUES TO REDUCE WILDLIFE RISKS TO AVIATION

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INTRODUCTION

The number of collisions between aircraft and wildlife has increased greatly over the past 50 years. Within the past decade (1992-2002) there has been a 260% increase in the number of reported wildlife strikes (Fig. 1). Currently, it is estimated that wildlife strikes cost the aviation industry almost $500 million per year [1]. The increase in reported wildlife strikes is the result of several factors, including an increase in the percentage of strikes that are reported because of an increase in awareness of the problem. Other factors that have contributed to the increase in reported strikes include increased numbers of aircraft movements and larger populations of hazardous wildlife species [2], resulting in an increase in the actual number of strikes.

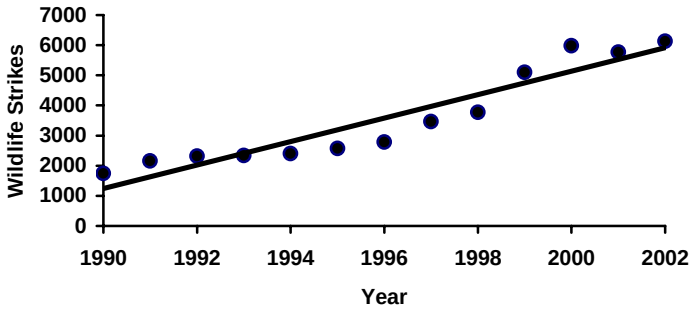

Figure 1. The number of wildlife strikes that have occurred per year from 1990 through 2002. The linear fitted line indicates an almost 30% increase per year in strikes. (Based on [1])

Canada geese (*Branta canadensis*), especially resident geese (Fig. 2), populations have increased dramatically during the recent past. This species is extremely hazardous to aviation because it is a heavy bird (up to 12 lbs for the resident race) and travels in large flocks [2]. Consequently, a strike or ingestion can involve multiple birds. The result might be engine failure and a crash, as illustrated by the aircraft taking off from LaGuardia Airport in September 2003 and the Air Force AWACS crash at Elmendorf AFB, Alaska [3]. The population of white-tailed deer (*Odocoileus virginianus*), the most frequently struck mammal and the mammal causing the greatest amount of damage [1], has shown a geometric growth over the past century. Because they are more active during twilight and at night, they are difficult to see by pilots and tower personnel.

Compounding the problem of wildlife strikes is that newer aircraft have fewer and quieter engines (Fig. 3). This has two potential effects. One, a bird or mammal is less likely to hear the aircraft until it is closer and, perhaps, not have enough time to evade the aircraft. Second, if a 4-engined aircraft takes multiple strikes and looses power on two engines, it still has two engines for power. If a two-engined aircraft loses two engines, it has no power. Clearly, multiple engine ingestion is a greater problem for two-engined aircraft than for four-engined aircraft.

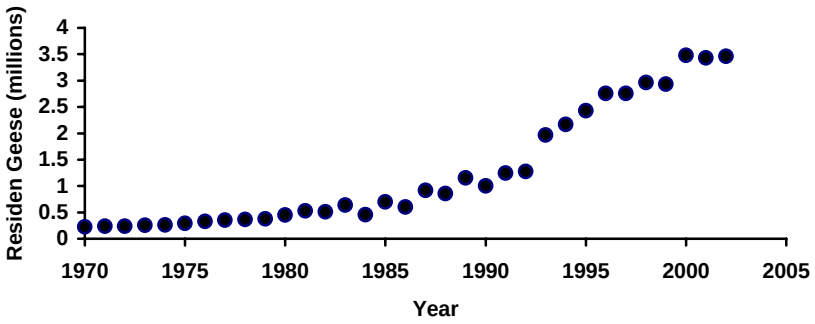

Figure 2. Resident Canada Geese populations have increased more than 10-fold since 1970. (Based on [1])

The most effective means of preventing wildlife strikes is to keep birds and other wildlife out of the Aircraft Movement Areas of the airfield and out of the approach and departure corridors. This can be accomplished most effectively by using an integrated approach combining multiple techniques. There is no "silver bullet" to managing wildlife hazardous to aviation. Wildlife strikes probably will never be eliminated but the probability of a hazardous wildlife strike can be reduced. The mission of the Ohio Field Station of the USDA's National Wildlife Research Center (NWRC) is to develop techniques and products that can be used to manage wildlife and reduce its threat to aviation. In this paper we will present the results of some of our recent research studies and outline our planned research over the next few years. The three broad categories of our research have been habitat management, wildlife deterrents, and wildlife repellents.

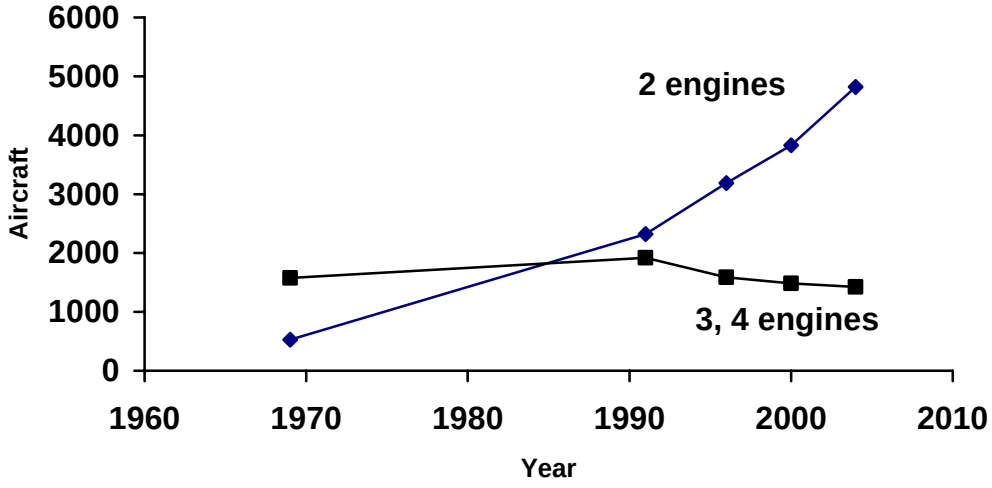

Figure 3. The numbers of aircraft in service for the past 35 years with two engines versus three or four engines has increased. Older aircraft with three or four engines are being replaced by ones with two engines.

HABITAT MANAGEMENT

Perhaps the most effective longterm measure in reducing wildlife strikes is to maintain the habitat of the airfield and the surrounding area such that it does not attract wildlife. Habitat can provide food, shelter from weather, and cover from predators. The fewer benefits a habitat can provide to an animal, the less attractive it will be. In some cases habitat management will be an optimization process because decreasing attractiveness for one species might increase its attractiveness for another (Fig. 4). The simpler a habitat's structure, the fewer species that it will attract [4].

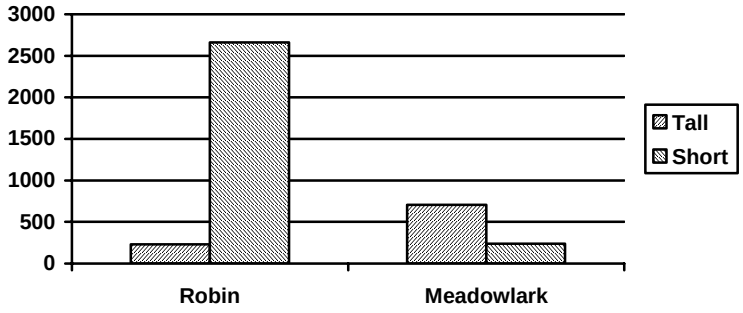

Figure 4. Numbers of American robins (*Turdus migratorius*) and eastern meadowlark (*Sturnella magna*) on the ground in short grass research plots (9-15 cm tall) and tall grass research plots (18-20 cm tall). (Based on Seamans et al. in prep.)

Recent research has been focused on selecting vegetation that target species, such as Canada Geese, find unattractive. Geese graze on grass and other herbaceous plants. Despite being waterbirds geese also spend significant time on land loafing and sleeping. If we can reduce an airport's attractiveness to geese in any of these aspects, we can reduce the number of birds attracted to an airport and the length of time they use it. This reduction, in turn, reduces the risk of geese colliding with an aircraft. Researchers in Alaska have shown that geese preferred Kentucky bluegrass over some native grasses that were more fibrous [5]. Likewise, our research indicates that tall fescue is not preferred by foraging geese [6].

EXCLUSION TECHNIQUES

One approach to keeping nonflying hazardous wildlife from the active areas of the airport is to exclude them with fencing or other barriers. White-tailed deer are the most commonly struck mammal, followed by the coyote (*Canis latrans*) [1]. The present standard for airports is a 10-foot tall chain-link fence, topped by 3 barbed-wire outriggers, and the bottom buried in the ground [7]. If the fence is maintained, it should prevent both deer and coyotes from entering the active area. In situations where a chain-link fence cannot be installed, we have investigated alternate barriers; one such alternative is electric fence. We are currently investigating an electric fence design that is based on a 6 mm polyester rope with copper wires woven into the rope. The fence is marketed under the brand name of ElectroBraid™. In 2002 and 2003 we tested the efficacy of this fence to keep deer away from feed troughs containing 50 -100 lb of whole kernel corn. The fence was 1.3 m tall and composed of 5 strands of fencing spaced 25 cm apart. One strand was grounded and four carried a pulsed 1.5 joule charge of 7 kV. When the fence was

powered, daily mean intrusion rates were reduced 90-99%. When the power was turned off for 2-4 weeks and then back on, intrusions were again significantly reduced but only about 60%. We are currently examining the influence of fencing larger enclosures to test the effect of enclosure size on intrusions.

Thus far, deer intrusions have been limited by this electric fence design. In every test some deer learned to penetrate the fence by going between the strands of fence without touching their ears or nose to it. This behavior was apparently developed when the fence was unpowered. Therefore, it is imperative that power be constantly supplied to the fence to be most effective. Such fencing also must be part of an integrated approach to deer management that includes habitat manipulation, hazing, and lethal control. Because no deer may be tolerated on an airfield, any deer that penetrates the fence must be dispersed from the airfield or killed before it is struck by an aircraft.

DETERRANTS AND DISPERSAL

PERCHING DETERRENTS. Perching deterrents can be used to reduce the attractiveness of specific locations around the airfield to birds. Typically, these are sites such as signs and fences; support beams inside hangers, warehouses, and other buildings; and roofs of terminals and buildings. European starlings (*Sturnus vulgaris*), doves (Columbiformes), and swallows (Hirundinidae) are the most commonly observed species along fences; house sparrows (*Passer domesticus*) and starlings are most commonly observed nesting and roosting inside buildings, and pigeons [rock doves (*Columba livia*)] are frequently observed loitering on and in airport buildings. Although some deterrents might work in more than one type of situation or on more than one species, most deterrents are best suited to specific situations. The Ohio Field Station (NWRC) has tested devices in each of these categories.

One such device is Birdblox™, a plastic device designed to fit over 2" lumber such as inside hangers and warehouses and physically blocks the space or has a row of points so that it is difficult for a bird to perch there. The behavioral responses of individual blackbirds [brown-headed cowbirds (*Molothrus ater*), red-winged blackbirds (*Agelaius phoeniceus*), common grackles (*Quiscalus quiscula*)] and pigeons to Birdblox™ were evaluated in an outdoor aviary. When given a choice of a perch (5 cm X 10 cm X 1.9 m) covered by Birdblox™ and a wire perch (12 gauge) similar to security fencing wire, the birds were recorded perching on the Birdblox™ perch 0.15% of the observations and on the wire perch 14% of the observations. The remainder of the time they perched on the floor or wire sides of the cage. When the wire perch was removed and the only perch available in the cage was guarded by the Birdblox™, birds were recorded perching on the Birdblox™ only 0.16% of the observations. Clearly, the Birdblox™ was effective in deterring these species from utilizing the perches and has potential usefulness inside airport buildings that are frequently left opened.

DISPERSAL. Lasers have been shown to be effective, nonlethal avian repellents [8]. As a result of research at the NWRC Ohio Field Staion, in collaboration with a laser manufacturer (SEA Technology, Inc., Albuquerque, NM), a new device, The Avian Dissuader, was developed and made available to airport and wildlife managers. Since those initial experiments, lasers have been tested against many avian species. The effectiveness of the laser to disperse birds is influenced by factors such as species and ambient illumination. If the light beam is difficult to

distinguish because of poor contrast, birds rarely respond. When used in dark or nearly dark conditions, some birds will immediately try to avoid the light, either by flying or running away. Other species show no response to the light beam. A few species, such as American crows (*Corvus brachyrhychos*) responded at some locations but not at others [9]. We don't know why these inter- and intraspecific differences occur. To address that question we plan to look at the photoreceptors of some of the problem species to determine whether there might be differences in sensitivities among species.

Some pilots believe pulsing landing lights (Pulselite™ manufactured by Precise Flight) reduce the occurrence of bird strikes. We tested the responses of caged cowbirds, pigeons, geese, starlings, doves, and herring gulls (*Larus argentatus*) to an oncoming vehicle equipped with a pair of 250 W landing lights cycled at 0.75 Hz. Although most groups of birds did not show any difference in response to the vehicle with the lights on versus the lights off, brown-headed cowbirds responded sooner to the vehicle with the pulsing lights than to the one without. However, in a subsequent experiment, cowbirds did not respond differently to the light treatment than the other species. Thus, although the results were inconsistent among species, the significant response by cowbirds in one experiment indicates that the technique merits further investigation [10].

USDA-FAA INTERAGENCY AGREEMENT FOR RESEARCH

The USDA Wildlife Services and the FAA Technical Center have entered into a new 5-year Interagency Agreement (FY2004-FY2008). The research task of this agreement delineates three areas of investigation

- Conduct habitat- and land use-studies to minimize the attraction of birds and other wildlife to airport environments as well as waste management facilities, wetlands, and other land uses near airports.
- Develop and evaluate wildlife damage control and monitoring methods and technologies.
- Investigate avian sensory abilities that might be used to develop new control techniques and technologies.

HABITAT STUDIES. Researchers at the NWRC Ohio Field Station have investigated habitat and vegetation use by hazardous wildlife for several years and will continue to do so because habitat modification is an important mechanism to reduce the risk of a wildlife strike on an airfield. One facet of this research is that once the "values" of specific habitat and vegetation types are determined, that information can be incorporated into the GIS system being developed by the Univ. of Illinois, Center of Excellence.

DETERRENTS. The NWRC will continue to evaluate wildlife damage control techniques in captive settings (e.g., aviaries and pens), in simulated airport environments at the Ohio Field Station, or at airports. The techniques and strategies that might be tested include lethal bird control as adjunct to various frightening methods, non-toxic repellent chemicals, various acoustic devices, visual repellents, exclusion devices, and other new devices or techniques that become available and could be used to discourage hazardous wildlife from the vicinity of airports or other facilities near airports that might also attract wildlife.

The most beneficial deterrents are going to be those that are effective at a distance. Such deterrents would keep birds away from airfields and aircraft rather than disperse them after they are present. This is the rationale for extending the research program at the NWRC Ohio Field Station to develop studies on Avian Sensory Perception.

SENSORY PERCEPTION. An area that the Ohio Field Station will be expanding its research in is the investigation of the visual and auditory sensitivities and cognitive capabilities of birds that are hazardous to civilian aviation. Another way of wording the question is: how do birds see, hear, and otherwise sense the world around them? How do they interpret that information? This knowledge will be used to develop techniques and devices to deter birds from aircraft on and away from the airfield. Research will be focused first on the visual capabilities of avian species hazardous to aviation, behavioral responses to visual stimuli, and later on the auditory sensitivities of those same species. Additional studies will be initiated to investigate avian cognition of visual and auditory signals that can be exploited for flight safety.

The first step will be to determine which wavelengths (colors) birds detect. Birds have at least 4 single cones and a double cone, compared to 3 single cones in humans. Avian cones are more complex in structure than human cones and appear to be more narrowly tuned in their spectral sensitivity (Fig. 6). One class of cones in the few species that have been examined is capable of detecting ultraviolet (UV) wavelengths. In Passeriformes this sensitivity is mediated by a UV-sensitive pigment with a peak sensitivity of about 370 nm [11]. The function of the double cone (two cones that share a common membrane along their inner segments) is unknown but might be involved with determining the plane of polarized light [12] or magnetic fields [13]. With a richer set of retinal photoreceptors, birds can probably detect and discriminate colors better than humans but we don't know which wavelengths are the most stimulating to any species.

The pigments and oil droplets of only a few avian species have been examined and none of these are species that present hazards to North American aviation. Similarly, almost nothing is known about what information is sent to the brain from the retina. In humans, there is circuitry within the retina that enhances contrast, discriminates colors, and other color and imaging processing. The avian retina is even thicker than that of humans and other mammals; suggesting that they are capable of even more signal processing than humans. What does this mean for developing new deterrents? We don't know at this time but we need to learn what types of visual processing birds do in order to exploit it and communicate more effectively with the birds. One of the possibilities for helping birds avoid aircraft is for the bird to enhance the visibility of aircraft in the eyes of birds. If we understand the types of processing (flicker detection, edge detection, movement, etc.) that the avian retina and cortex produce, we can engineer devices to exploit those parameters.

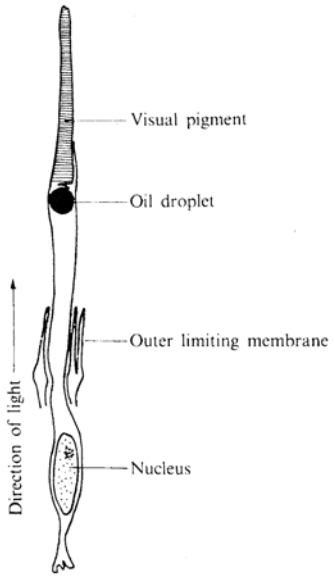

Figure 6. Schematic of an avian retinal cone showing the relationships among the outer segment containing the visual pigment, the oil droplet filter, and the inner segment containing the nucleus.

What we refer to as optical illusions and perceived images are the result of the processing of sensory input by the retina and the brain. Those illusions produced by the retina are "hard-wired" into the nervous system and the result of connections established among neurons during development. They increase the ability of the eye to detect movement and enhance contrast in humans. Presumably, similar connections occur in the avian retina. Interpretation of images, either real or phantom, takes place in cortex of the human brain. The visual system occupies a proportionally larger part of the avian brain in birds than it does in mammals (Fig. 7). This size would indicate that vision and image processing are important to birds and vision is a prime candidate as an avenue to communicate the presence of an aircraft to birds.

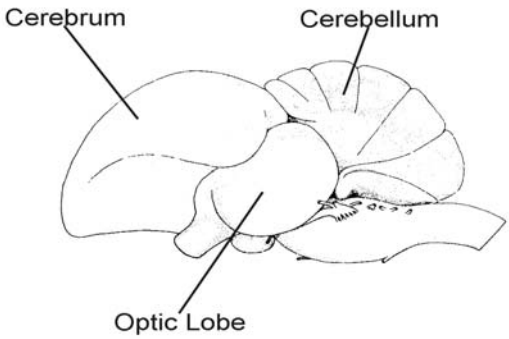

Figure 7. A generalized drawing of a pigeon brain showing the relative size of the Optic Lobe compared to the rest of the brain.

The visual acuity of raptors is at least twice that of humans and might be even higher [14, 15]. This means they can discriminate objects at a greater distance. This ability should be beneficial when trying to alert birds to the presence of aircraft but the bird also needs to determine the distance to the aircraft. Other species that have been examined have a visual acuity similar to humans. Theoretically, the visual acuity of avian binocular vision is about 40% better than that of monocular vision [15]. Consequently, the visual acuity of some avian species is hindered by the placement of their eyes laterally. The result is that while birds have an excellent field of view to the side, they have a very narrow zone of stereoscopic vision, high acuity, and depth perception in front of them [16]. Thus, it is important to attract a bird's attention in such a way that it seeks to determine the distance to the aircraft and its approach speed. Birds have two foveae in the eyes used for high visual acuity: the central foveae in the monocular visual field, the temporal foveae in the frontal binocular field [17]. The central foveae are more differentiated but whether that means the lateral vision has better resolution than the forward vision awaits further study [18].

The second sensory avenue that might be exploited to warn birds of the presence of an aircraft is hearing. Hearing is an important communication avenue for birds and probably the second most important avenue by which they detect threats. In order to use this avenue, we must know the range of frequencies to which hazardous species of birds are sensitive and the temporal and frequency resolutions. To maximize their effectiveness, the sounds that are used to disperse birds must:

1. be loud enough to be audible to the birds,

2. be within the frequency range the birds' ears can detect,

3. provide a context-relevant message such that the birds depart.

Avian ears and hearing are different from those of humans and other mammals in several ways. The first, obvious difference is that birds lack an external ear or pinna. Terrestrial mammals use the pinna and external canal to concentrate sound and increase the sensitivity of the ear. The sound travels down the auditory canal to the eardrum (tymnpanic membrane) where it produces vibrations in the fluid-filled inner ear. These vibrations are transmitted to the inner ear, where sound information becomes encoded in the nervous system by the ear ossicles (bony elements). Birds have a single ossicle, the columella, compared to three in mammals. The theoretical amplification for a single element is about 20-fold from the tympanum to the fluid of the inner ear (cochlea). Unlike the coiled mammalian cochlea, the avian cochlea is a straight or slightly curved tube whose length differs among species. The differences in length, both among avian species and between birds and mammals, probably reflect differences in the range of frequencies that the species can detect. Longer cochlea allow for more auditory receptors and better sensitivity to either a wider range of frequencies or better resolution among frequencies.

Different species of birds have the greatest sensitivity to sounds within a relatively narrow range. For most avian species this is around 1-4 kHz but some species are sensitive to lower or higher frequencies [19]. None of the avian species examined has shown sensitivity to frequencies above 20 kHz (ultrasound) [20] and generally the upper threshold is about 10 kHz [21].

Sensitivity to infrasound (below 20 Hz) has been observed in pigeons and in some of other species but not in all species tested [22, 23, 24].

In general birds are less sensitive to specific frequencies (pitches) of sound than humans [25]. Consequently, sounds must be louder for a bird to hear it than for a human. This will be important when designing auditory alerts for birds. Birds also are faced with the problem of extracting a meaningful signal from the background noise. Airport environments contain much broadband noise, making any type of communication difficult. In some cases the noise level is so great that it causes damage to the haircell receptors used for hearing by humans and birds. Such damage can affect the frequencies to which birds are sensitive and impact attempts to use auditory dispersal techniques [26].

SUMMARY

The research at the NWRC Ohio Field Station continues to be focused on ways of making airfields and their surrounding environments unattractive to birds and other wildlife, and to warn birds away from aircraft. Based on centuries of observations by scientists and on evolutionary logic, birds will do what they can to avoid being killed; dead birds no longer produce offspring. If we can develop techniques and devices to communicate to the bird that a dangerous object is approaching, the bird will get out of the way. In order to do that we need to know the limits of avian sensory perception and exploit that range of sensitivities.

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