EVALUATING AND MONITORING AVIAN HAZARDS USING COMBINED VISUAL AND RADAR TECHNIQUES

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ABSTRACT

Ecological relationships between wildlife populations and habitat are usually discerned through observations during the course of an annual cycle. Although proximate hazards, on the airport, are well defined during the evaluation process, off-airport features also can attract wildlife. Wildlife species can transit airport property traveling to and from attractive habitat attractants. During an airfield evaluation, common wildlife sampling techniques are employed to determine species, their approximate numbers, and through association an index of potentially attractive habitat. Continuous observations could provide a more complete picture but would require greater sampling effort. Radar is a tool that has demonstrated efficacy to automatically monitor wildlife at greater distances than can be achieved through traditional visual techniques. Modern systems also have the ability to record a variety of spatial and temporal variables simultaneously and processed data streams can be further analyzed. In association with GIS software, these data can be queried to provide hazard and risk mapping on the airfield and in the approach/ departure corridors, as well as the air traffic pattern. The use of radar in combination with traditional wildlife observation techniques could significantly increase the amount of information available for analyses during an evaluation. We used radar observations to document winter waterfowl movements at night (including migration departures) as well as diurnal bird movements. These movements included incursions into the approach/ departure corridors and the initial location of the waterfowl presenting the hazard. Although radar has its benefits, such as detecting wildlife at night and greater distances than can be accomplished visually, it also has its shortcomings. These include reduced sensitivity during heavy precipitation (e.g., X- and K-band radars) and the inability to identify the species of the birds detected. Radar provides an additional source of information for evaluating wildlife strike risks.

INTRODUCTION

Wildlife, especially flying wildlife, present threats to aviation. These threats are to the aircraft's structure through penetration and to its engines through ingestion. Ninety percent of bird-aircraft collisions between 1990 and 2005 occurred within 1000 m of the ground [1] and most of those are on or in the immediate vicinity of the airfield [2]. Because of the hazards birds and other wildlife present to aviation safety, the Federal Aviation Administration (FAA) has made specific recommendations regarding habitats and land use on and near airfields (see [3] for discussion). The most specific of these recommendations are contained within FAA Advisory Circular 150/5200-33A.

The price of these strikes to American air carriers within the United States is estimated to be over US$500 million and approximately US$2 billion for aviation world-wide. These costs include inspection and repair of damaged parts, time out of service, and loss of customer revenue [2]. The price does not include the loss of human lives.

The first step in evaluating the wildlife hazards at an airfield is to determine which species are present, the population size of each species, and the behavioral patterns of each species that makes it a threat to air safety. The ecology and behaviors of different species might make one a serious hazard to safety but another might be much less of a hazard. Historically, evaluating or assessing wildlife and its impacts has been problematic given the dynamic nature of wild animal populations on the landscape, of which airports are a component. Over time the wildlife profession has refined several tools and procedures with which natural resources personnel can measure wildlife populations. Many of these procedures are efficacious and provide good information with which conscientious management decisions can be enacted resulting in a safer airport environment. Although the current set of tools and procedures is good, the ability to detect wildlife at greater ranges and under varying conditions is often limited. Recently, advances in remote sensing technologies have filled some of these gaps in our abilities. The use of small mobile radar units for bird detection is a developing technology that can allow the observer to evaluate potential wildlife risks to aviation at greater distances and under varying conditions (e.g., night-time). With advances in modern computing the use of this technology is becoming easier to employ. When combined with current techniques, the potential for this technology to aid wildlife biologists in describing and ultimately understanding how wildlife interacts with airport environments is great. Our work discusses how current techniques and procedures can be coupled or enhanced through the application of radar in the airport environment.

EVALUATING WILDLIFE HAZARDS

Wildlife hazard assessments are conducted at certificated airports within guidelines set by the FAA, developed in conjunction with the APHIS Wildlife Services program, part of the U. S. Department of Agriculture [3]. Trigger events related to incidents between aircraft operations and wildlife can precipitate such an assessment. For example, observations of wildlife known to potentially cause hazardous situations, damaging wildlife strike events, or strike events causing a negative effect on flight are such triggers as outlined in the Code of Federal Regulations (i.e., Title 14, Part 139.337). A typical wildlife hazard assessment is conducted by a qualified wildlife biologist possessing experience with wildlife issues at airports. The type of hazard that bird species present is determined by several factors including the size of individual birds, the size (extent) of the flocks it forms, the altitude at which it flies, and its preferred habitat. In conducting an assessment, wildlife biologists seek to document and define these ecological relationships between wildlife and habitat present at the airport site. The ability to detect wildlife and evaluate their use at or near the airport is paramount to the successful conduct of the assessment.

Concurrently, wildlife that are utilizing habitat outside of the airport boundary also are categorized especially when those populations transit the immediate airspace or approach and departure airspace corridors (e.g., wildlife might cross a runway when traveling to and from a landfill). The FAA recognizes the importance of the areas outside of the airport boundary and provides guidance to airports and the public regarding wildlife attractants outside of airports (i.e., Advisory Circular 5200-33a). When necessary the FAA has engaged other government bodies in these efforts (e.g., the Environmental Protection Agency and landfills location near airports). The level of guidance or recommendation depends on the type of aircraft using the airfield. For instance, a buffer of 5,000 ft from the active operations area (AOA) is required for airports servicing piston-powered aircraft and 10,000 ft for airports with turbine-powered aircraft. In addition, approach and departure paths must be clear of wildlife hazards for 5 miles (Figure 1).

Currently, wildlife can be assessed in these areas outside of airports using traditional wildlife survey methods (i.e., visual and auditory techniques). However, the majority of assessment work at airports takes place within the airport boundary mainly because of logistical constraints. Even in these cases though, it is impossible to discern all hazardous situations at all locations on the airport. This is especially true when sampling efforts to assess wildlife are periodic versus continuous. Other more extreme cases such as the inability of the observer to assess bird movements at night also create disparity. In some cases, therefore, evaluations of wildlife hazards on and off airports might not adequately reflect the overall situation.

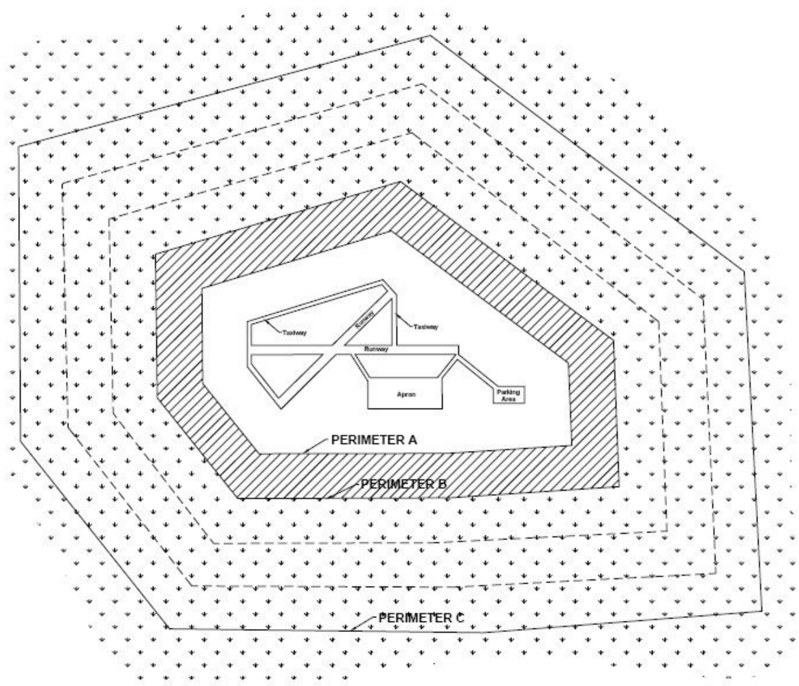

Figure 1. Airfield perimeters used to develop wildlife management guidelines. Perimeter A is for airfields having only piston-powered aircraft, perimeter B is for airfields serving turbine-powered aircraft, and perimeter C is for approach and departure corridors and traffic patterns. (Figure from FAA Advisory Circular 5200-33a.)

Remote sensing techniques can assist wildlife personnel conducting evaluations of wildlife hazards at or near airports. The use of Geographic Information Systems (GIS) technology can assist by helping to examine different assemblages of data (i.e., water, soil, different habitat resources, etc.). Personnel also can use Geographic Positioning System technology to delineate natural resources of interest during investigations (e.g., the exact location of a storm water structure). Examination of this type of data can often reveal how previously unrecognized features can act as an attractant to wildlife. Other types of remote sensing are available to personnel to determine wildlife presence in areas. For example, the use of remotely triggered cameras, night-vision optics and Forward Looking Infrared (FLIR) devices allow for the detection of previously un-seen wildlife. An analogous tool is small mobile radar units that can allow for the continuous monitoring of areas at the ground level and at varying altitudes. Similar to GIS, radar can provide a level of observation that exceeds what is capable from direct visual observation at the airport level. Radar detections of birds can be documented at altitudes or ranges not visible to the observer. These areas of detection can be on or off the airport and during times when visual techniques are limited (e.g., adverse weather, darkness).

VISUAL TECHNIQUES

Assessment of wildlife hazards within airport environments involves the identification and quantification of wildlife, especially birds, that use habitats and locations both on the airfield itself and within the landscape matrix surrounding the airport [3]. Such assessments typically involve a series of standardized surveys conducted over time (e.g., during a 1-year period). These survey methods are commonly based on time-tested methods for quantifying wildlife populations and habitat use, such as the U.S. Fish and Wildlife Service's Breeding Bird Survey [4]. During each individual survey (e.g., time-area count), an observer identifies and counts the number of wildlife (e.g., birds) visually observed or heard at pre-determined locations for a given time period (e.g., 3 minutes). Additionally, the activities (e.g., flying across runway), specific habitat types the wildlife are using (e.g., a pond), and other pertinent information are recorded by the observer. Observers often use binoculars, spotting-scopes, bird identification books, and other tools to assist in the detection and identification of wildlife. Specific survey locations, both on and off the airfield, are selected to represent important habitat types, potential wildlife attractants (e.g., landfills), and other areas and locations that might be used by wildlife hazardous to aviation. Wildlife observation data obtained from surveys are then compiled and summarized. Analyses of these data are often focused on those wildlife species that pose a threat to safe aircraft operations.

Wildlife surveys provide important information regarding wildlife hazards within or adjacent to airports. Most observed wildlife can be identified to the species level, allowing for further assessment of the risk posed by wildlife in the airport environment. For example, birds of larger body masses [5] and/or flocking species pose more risk to safe aircraft operations than smaller birds that are more solitary in their occurrence. Wildlife surveys that utilize visual techniques can be used to quantify the occurrence of wildlife hazardous to aviation within airport environments and to identify those species that exhibit behaviors that increase the risk of bird-aircraft collision (e.g., flying across or foraging near runways and taxiways). The use of habitats by hazardous wildlife, particularly those that occur on the airfield itself, can be assessed by wildlife surveys and data analyses. Once identified, habitats or locations on the airfield that are used by hazardous wildlife can be modified to reduce or eliminate their attractiveness to hazardous wildlife. Also, wildlife surveys allow for the specific evaluation of potential wildlife attractants that might influence bird movements within the airport environment. For example, a sanitary landfill located near an airport could be evaluated to determine if wildlife hazardous to aircraft, such as gulls, use the facility. Further, visual techniques could be used to determine if gulls using the landfill traveled across the airfield or within critical airspaces used by aircraft, thus increasing bird-strike risks.

Although wildlife surveys that utilize visual techniques are very useful and an important component of wildlife hazard assessments, such methods have shortcomings as well. Detection of hazardous wildlife using visual survey methods is limited to the specific area that an observer can see. Further, the effective distance that birds can be detected by the observer varies by the species and behaviors of different birds. Consequently, only a small portion of the airfield or location is sampled at a specific location during standardized surveys. Consequently, it is very important that survey points are selected to be representative of the entire airfield or airport environment. Survey methods that rely on visual detection of birds can be relatively ineffective during conditions of low light or visibility (e.g., pre-dawn hours, fog) and useless during night-time hours. Recently, new technologies, such as infrared and night-vision devices, have become available and might be useful for detecting the presence and movement of wildlife at night [6]. However, much research is needed to determine the effectiveness of these tools in airport environments.

RADAR TECHNIQUES

The ability of radar to detect and monitor birds, especially during their migrations, has been documented since the 1940s [7]. Most of the research studies on using radar to monitor bird movements were focused on nocturnal migrations. Radar is an excellent tool with which to study migration because it works as effectively at night as during the day and it can detect and track birds at great distances (e.g., up to 100 km for high-powered radars).

During the 1950s and 1960s, small X-band (3 cm wavelength) and S-band (10 cm) radar units were developed for use on fishing vessels and large recreation boats. Although these units do not have the detection abilities of the high-powered military and FAA systems, they can detect birds farther than they can be seen visually (up to 10 km). Because of their small sizes, especially the X-band units, they have been used by biologists to monitor and study movements of birds, bats, and insects since the 1970s [8]. The small physical size and power requirements make them very mobile and well-suited to installation on trailers, trucks, and vans. At remote locations, these units can be powered by small generators if electrical power is not available. These features have resulted in such units being used for a variety of situations that require monitoring the movements of birds, including on airfields. Although the equipment can be operated continuously, an operator must monitor the display and record the radar tracks that denote movements of birds. In some studies, automatic cameras have been attached to the display to record bird movements. However, such an arrangement requires that a researcher experienced in interpreting radar images analyze the records [9].

Since 2000, new software has been developed to process the radar signals and provide the results in a format that is meaningful for researchers who are not versed in the use of radars [10]. As a result of the processing capabilities of modern microcomputers, individual targets (e.g., individual birds or flocks of birds) can be tracked. Because the computer can associate successive locations to a single track, the heading (i.e., direction of movement), ground speed, and flock size (e.g., single bird/small flock versus medium or large flock) can be calculated or estimated for each individual radar track. Utilizing this information, a scientist might be able to effectively categorize the type of bird or animal that produced the radar track(s).

We provide an example of how this technology might be used to monitoring wildlife hazards in an airfield environment in Figure 2. This figure depicts radar tracks of birds passing over an airfield during the first four hours after sunset. Radar tracks of birds can be accumulated and displayed relative to the geography of the airfield. Based on their flight speeds (e.g., 100 km/h), we believe the birds presented in this image were most likely Tundra Swans (*Cygnus columbianus*). These birds winter in the general vicinity of the airfield and were begin their spring migration from the area in February. If their migratory tracks are extrapolated, it appears the birds were flying to the Chesapeake Bay, a well known staging location for Tundra Swans. Because of their size (mean body mass of 6 kg (female) or 7 kg (male); [11]) and behavior of typically traveling in large flocks, Tundra Swans present an especially serious hazard to aviation. Tundra Swans were responsible for the most serious bird-aircraft collision in the United States. This accident occurred in 1962 while a United Airlines Viscount aircraft was preparing to land at an airfield in Boston, Massachusetts. The aircraft collided with a flock of Tundra Swans, resulting in the aircraft's tail empennage being broken off. The resulting crash killed all 17 persons aboard.

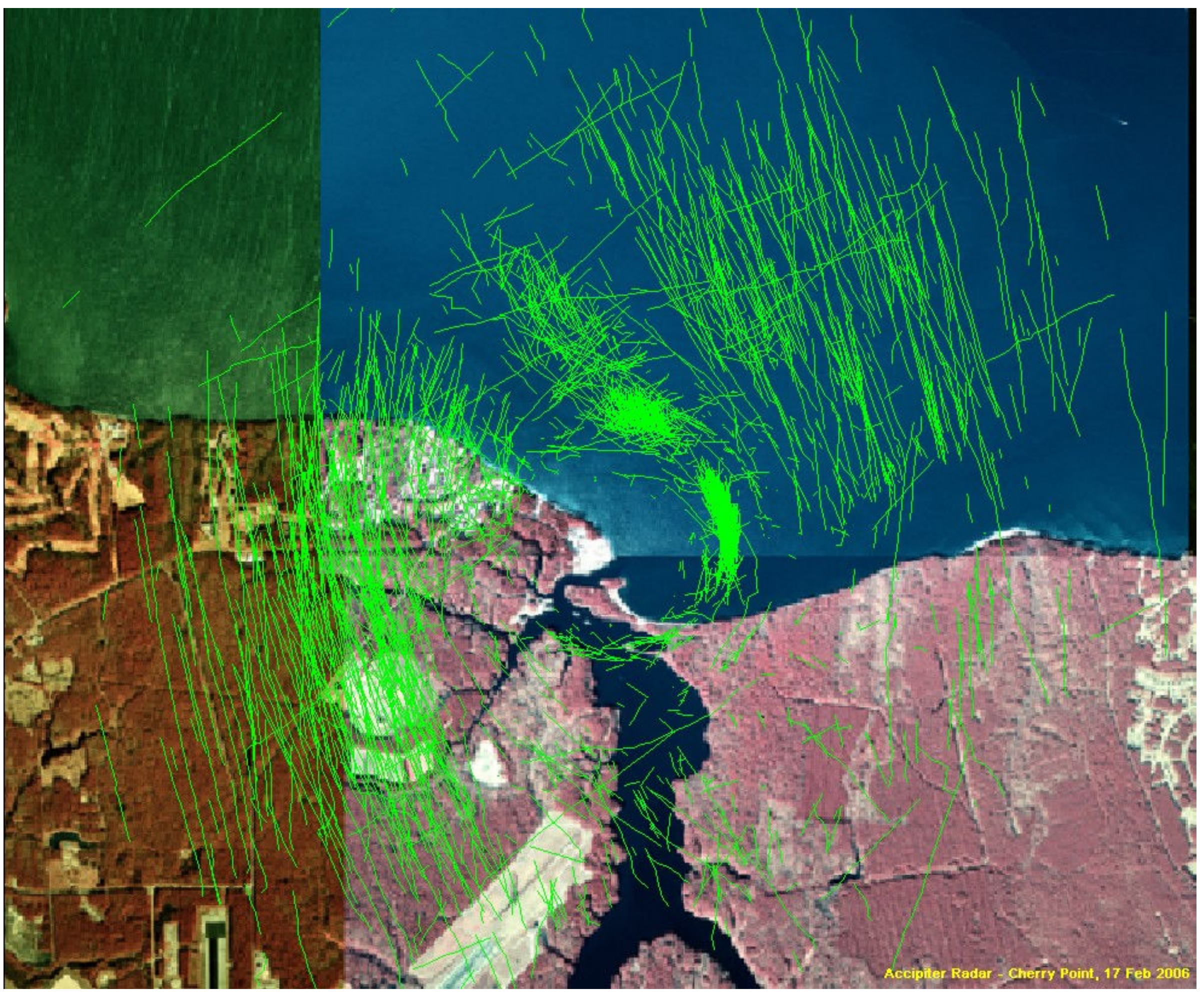

Figure 2. Accumulated radar tracks of birds during a 4-hour period at airfield in coastal North Carolina in February of 2006. The birds, believed to be Tundra Swans, were moving in a northern direction (with a mean bearing of 350°).

Two benefits of using radar to assess wildlife hazards are that this technique works equally well during the day and at night and it has the potential to detect birds at great distances (e.g., up to 10 km from the radar unit). The radar unit's computer stores the radar tracks, including details about their characteristics, so patterns of bird movements can be further analyzed at a later date. Such analyses might be especially useful for determining off-airfield attractants to birds hazardous to aviation. As an example, Figure 3 contains an illustration of many radar targets, believed to be flocks of ducks, passing over an airfield in predawn hours.

As with any tool, radar is not without its short-comings. This technology is complex and relatively expensive. Most of the large government radar systems cannot provide information on the altitude of birds and no current radar system can provide positive species identification of birds being tracked. However, based on the behavior of the birds and their flight speeds, bird radar targets can potentially be segregated into meaningful taxonomic groups (e.g., small songbirds, waterfowl).

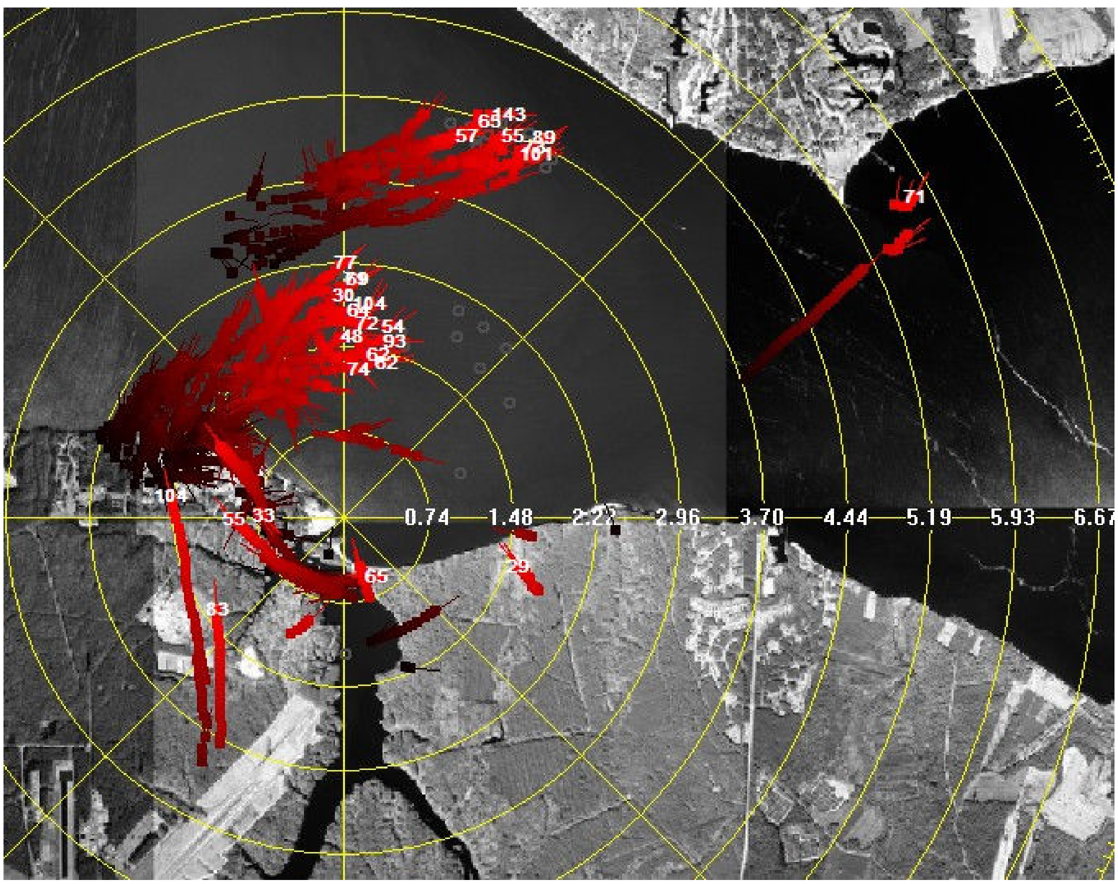

Figure 3. A radar record of birds (believed to be flocks of ducks) flying past an airfield during the hour before dawn. The birds are likely traveling from their night-time roosts to a bay to forage. The most recent location of the birds is indicated by the white numbers and the tails (red in color) show the previous 2 minutes of locations. Range ring values represent the distance from the radar (in km).

ACOUSTICAL MONITORING

An additional technique that can be used in conjunction with visual and radar methods is acoustic monitoring. Acoustic monitoring uses a set of vertically directed microphones to record the flight calls of birds passing overhead [12, 13]. Using a personal computer, the identification of flight calls can be automated and recorded with timestamp information [14]. The timestamp allows for proper correlation with simultaneous radar and/or visual observations [15]. Although not all bird species call while flying, especially during migration, acoustic monitoring could provide some information on the identity of the bird species detected by a radar or during visual surveys. Acoustic monitoring, combined with radar observations, might be especially useful during night-time hours.

CONCLUSION: INTEGRATED TECHNIQUES

Visual, acoustical, and radar techniques for assessing wildlife hazards in airport environments have benefits and shortcomings (Table 1). When two or three of these techniques are used in combination to assess wildlife hazards, they have the considerable potential to complement one another. Visual techniques can be used to quantify hazardous wildlife within airport environments, especially on the airfield itself, identify those species that exhibit behaviors that increase the risk of bird-aircraft collision (e.g., flying across runways), and identify airfield habitats attractive to hazardous wildlife. Radar can be useful for detecting bird movements during low-light and night-time hours and describe higher altitude movements; however, it cannot determine the species or the number of individuals within flocks birds. Visual techniques could provide this missing information during the day. Acoustical monitoring can provide some species identification at night. Although one could not identify all of the birds detected by a radar unit, visual techniques can be used to sample bird targets and provide important information regarding the species' composition of bird flocks utilizing the airspace over or near airfields. Furthermore, when this bird species composition and movement information is combined with landscape characteristics and habitat information, perhaps most effectively by using GIS technologies, key wildlife attractants within the landscape could be identified and evaluated for use by the bird species posing the highest risk to safe aircraft operations. Ultimately, an approach that utilizes multiple methods and techniques results in a more effective assessment of wildlife hazards within an airport environment, leading to more effective decisions and management actions to reduce the risk of wildlife-aircraft collisions and threats to human health and safety.

Table 1.
A Comparison of the Types of Information Visual, Radar, and Acoustic Techniques can Contribute to Evaluating the Hazard to Aviation Presented by Birds.

Visual	Radar	Acoustic
Species identification	Identification to taxonomic group	Species identification of calling birds
Flock numbers	Approximate extent of flock	Estimate of flock numbers
Nocturnal movements missed	Nocturnal movements observed	Some nocturnal movements detected
Distant birds missed	Birds observed to 10 km depending on size and number	Distant birds missed

REFERENCES

1. Dolbeer, Richard A., "Height Distribution of Birds Recorded by Collisions with Civil Aircraft," Journal of Wildlife Management, Vol. 70, pp. 1345-1350, 2007.
2. Cleary, Edward C., Dolbeer, Richard A., and Wright, Sandra E., "Wildlife Strikes to Civil Aircraft in the United States," Serial Report DOT/FAA/National Wildlife Strike Database-12, U.S. Department of Transportation, Federal Aviation Administration, Office of Airport Safety and Standards, Washington, DC, June, 2006.
3. Cleary, Edward C., and Dolbeer, Richard A., *Wildlife Hazard Management at Airports, Second Edition*, U.S. Department of Transportation, Federal Aviation Administration, Office of Airport Safety and Standards, Washington, DC, July 2005.
4. Droege, S., "The North American Breeding Bird Survey," Pages 1-3 in John R. Sauer and S. Droege, eds., *Survey designs and statistical methods for the estimation of avian population trends*, U. S. Fish and Wildlife Service, Biological Report, Washington, DC, Vol. 90, 1990.
5. Dolbeer, Richard A., and Eschenfelder, Paul A, "Amplified bird-strike risks related to population increases of large birds in North America," *Bird and Aviation*, Vol. 24, pp. 1-4, 2004.
6. Blackwell, Bradley F., Seamans, Thomas W., Washburn, Brian E., and Cepek, Jonathan D., "Use of infrared technologies in wildlife surveys," Proceedings of the Vertebrate Pest Conference, Vol. 22, *In press*, 2006.
7. Eastwood, Eric, *Radar Ornithology*, London, Methuen, 1967.
8. Williams, Thimothy C., Settel, J., O'Mahoney, P., and Williams, Janet M., "An ornithological radar." *American Birds,* Vol. 26, pp. 555-557, 1972.
9. Flock, Warren, "Flight Safety Aspects of Precision Radar Near Air Bases in Bird-Aircraft Collision Avoidance," Air Force Weapons Laboratory *Technical Report* No. AFWL-TR-72-25, 58 pp., 1972.
10. Nohara, Timothy J., Weber, Peter, Premji, Al, Krasnor, Carl, Gauthreaux, Sidney A., Jr., Brand, Marissa, and Key, Gerry, "Affordable Avian Radar Surveillance Systems for Natural Resource Management and BASH Applications," *Radar Conference, IEEE International*, pp. 10-15, 2005.
11. Dunning, John B., Jr., *CRC Handbook of Avian Body Masses*, Boca Raton, FL, CRC Press, 1993.

12. Evans, William R., "Monitoring avian night flight calls - the new century ahead," *Passenger Pigeon* Vol. 67, pp. 15-24, 2005.
13. Evans, William R., and Mellinger, David K., "Monitoring Grassland Birds in Nocturnal Migration," *Studies in Avian Biology* Vol. 19, pp. 219-229, 1999.
14. Mills, Harold, "Automatic Detection and Classification of Nocturnal Migrant Bird Calls," *Journal of the Acoustic Society of America,* Vol. 97, pp. 3370, 1995.
15. Farnsworth, Andrew, Gauthreaux, Sidney A., Jr., and van Blaricom, Donald. "A Comparison of Nocturnal Call Counts of Migrating Birds and Reflectivity Measurements on Doppler Radar," *Journal of Avian Biology* Vol. 35, pp. 365-369, 2004.